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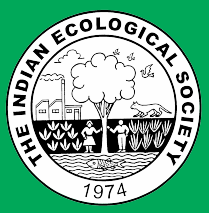

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Intercomparison of Trend Analysis using Multi Satellite Precipitation Products and Gauge Measurements

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Abstract: This study evaluates the capability of four multi-satellite precipitation products using gridded rain gauge data collected by India Meteorological Department (IMD) for the period of 2000–2018 at monthly scale with the spatial resolution (0.25° × 0.25°). The gridded precipitation datasets are compared for all districts of Andhra Pradesh region. TRMM, CHIRPS, PERSIANN, and MSWEP datasets accuracy for the districts are measured by comparing with IMD using mean absolute error (MAE), root mean square error (RMSE) and correlation coefficient (CC). To evaluate the data pattern, the Mann-Kendall (MK) test is applied, and magnitude of change is detected by Sen's Slope using all datasets for annual and seasonal time periods. The monthly Correlation Coefficient between these Satellite datasets and IMD has shown above 0.80. CHIRPS and TMPA are better comparable to gauge-based precipitation than any other datasets. The annual and monsoon trend pattern for TMPA, CHIRPS, PERSIANN and MSWEP matched with IMD data in the coastal and northwest districts. The products of TMPA and CHIRPS showed better performance relative to IMD than MSWEP and PERSIANN, thus suitable for use in hydrometeorological studies in the data-scarce area of the state.

Keywords**:** Precipitation, IMD, TRMM, CHIRPS, MSWEP, Trend analysis

Rainfall is one of the most important climatic element which helps in planning and management of water resources and it links directly to forestry, agriculture, disaster management, preparedness and its mitigation measures. Consequently, authentic rainfall data are vital for model correction, validation and prediction of various natural phenomenons. Generally, rainfall trend series is calculated by utilizing historical data, which are conventionally recorded from rain -gauge stations (Agarwal and Kumar 2020 2021). Rainfall time series for any site may be either point data or gridded data. In many parts of the world, acquiring station data is challenging due to various technical reasons and sometimes it is expensive, mainly in arid regions where precipitation is limited. Satellite rainfall products get prominent importance for global and local hydrologic studies (Xue et al 2013). Each product has its specific benefits and constraints. In India, Gauge-based precipitation has limited network in several parts of the country (e.g., Himalayas), although over some region gauges are widely distributed (Bandyopadhyay et al 2018). In India, TRMM multi satellite rainfall products were compared with gauge data and observed TMPA gave better performance than other multi satellite rainfall product (Prakash et al 2014, 2015b, 2016). TMPA rainfall products are consistent and applied for hydrological modeling with high spatial and temporal resolution. (Tawde and Singh 2015) studied TMPA 3B42 v7 rainfall products with the IMD dataset with spatial resolution of 0.5° for the Western Ghats of India. (Nair and Indu 2017) observed MSWEP precipitation product matched with IMD daily rainfall over India. (Shen et al 2020) compared the global performance of CHIRPS and CHIRP at monthly scale against the gauge based GPCC. Massari et al (2017) evaluated global performance of satellite products without gauge observations. Kumar et al (2019) estimated the weekly rainfall over India using different satellite products and rain gauge satellite merged products compared with IMD gridded data. Kumar et al (2015) compared IMD data with satellite data product with spatial resolution of 1° × 1° from 2000 to 2010. Mondal et al (2018) compared rainfall trend pattern of CMORPH, PERSIANN-CDR, MSWEP, TMPA against IMD gridded data with 0.25° × 0.25° spatial resolution at monthly scale for major river basins of India. Numerous studies evaluated trend pattern of precipitation based on point observations from rainfall station (Sonali and Kumar 2013). However, rainfall trend findings dealing with satellite-based products are comparatively limited (Kumar and Jain 2010, Rathore et al 2013). Waghaye et al (2018) studied the rainfall trend in different regions of Andhra Pradesh and Telangana using station data. Patakamuri et al (2020) evaluated rainfall homogeneity, trend and its pattern for

Anantapur, Andhra Pradesh state using station data. Man-Kendall (MK) test is used for identifying trend in many studies. Nonparametric test is considered advantageous over parametric test Goyal (2014). Valli et al (2013) identifying the Monthly, Seasonal, and Annual distributions, variations, and trends in ten AP districts using a 30-year database of monthly precipitation. Rainfall trend pattern of Andhra Pradesh evaluated using station data for various studies, but no such past studies used multi satellite precipitation product for Trend analysis. The aim of the present study is to analyze and compare the trend pattern of TMPA, CHIRPS, PERSIANN-CDR, and MSWEP rainfall products with 0.25° × 0.25° gauge based IMD data for district of Andhra Pradesh state.

MATERIAL AND METHODS

The study area, Andhra Pradesh, state of India, located between 12°41' and 19.07°N Latitude and 77° and 84°40'E Longitude (Fig. 1), the south - eastern region of subcontinent. It is surrounded by Indian state of Chhattisgarh, Orissa, Telangana in the north, Karnataka in the west, Tamil Nadu in the south. Study area covers 1,62,968 sq. km which is 4.96% of the geological area of the country. The environment of the region is usually hot and humid. During summer, the daily temperature is higher than 30 °C and even exceeding 40 °C in central part of state. During winter (October to February), the climate is cold, and this is when the state attracts most of its tourists. The temperature ranging from 13°C to 30 °C in winter. Annual precipitation of coastal region is 1000 to 1200 mm, but half of the precipitation is occurring in western region. In north eastern mountains precipitation exceed 1200 m which can be as high as 1400 mm. Maximum elevation and average elevation of Study area is 2514 m and 239 m (Fig. 2). This study analysed four types of seasonal variability, pre-monsoon (March–May), monsoon (June–September), post-monsoon (October-December), and winter (January-February).

Ground reference datasets: IMD daily gridded rainfall dataset with spatial resolution of 0.25° covering longer period of 118 years (1901-2018) is arranged in 135x129 grid points. This gridded data is made from daily rainfall events and stored using Shepard method at the National Data Centre, IMD, Pune which uses rainfall records of 6955 Rain gauge stations. Out of these rain gauges, 547 are from IMD observatory stations, 494 are under the Hydro-meteorology program, 74 from under Agriculture meteorological stations while rest are various rainfall reporting stations provided by the State Government of India (Pai et al 2014). Earlier versions of IMD data are IMD3, IMD2, IMD1 which is developed during the period 1971-2005 (6076 rain gauges), 1901-2004 (1380 rain gauges) and 1951-2007 (2140 rain gauges) with spatial resolution of 0.5° × 0.5° and 1° × 1° across India. In this study, version of data used is IMD4 which is accessible in Net CDF format and processed using Grads software. The gridded data (0.25° × 0.25°) is directly

Fig. 1. IMD grid points with 0.25 spatial resolution

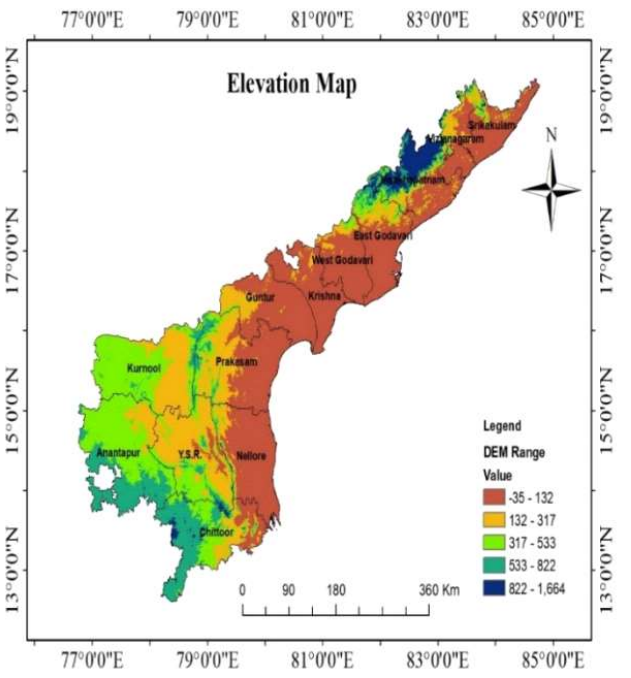

Fig. 2. Elevation map of Andhra Pradesh State

projected on District of Andhra Pradesh shapefile and the average of that gridded district data is used of the analysis. IMD monthly data is reference data for comparison of multisatellite precipitation product.

Satellite-based Precipitation Dataset

TRMM: The TRMM is considered as a Low Earth Orbit (LEO) satellite primarily used to study the physical features of tropical and sub-tropical precipitation. Two types of products are included in version 7 of TMPA, the real-time version (3B42RTV7) and the gauge-adjusted post-real-time research product (3B42V7) having spatial resolution of 0.25° × 0.25°. Data is available from 1998 to present in 3 hours duration (3B42_v7), daily (3B42RT_v7) and monthly (3B43_v7) temporal resolution. By combining the results of different multiple geostationary satellites and ground-based precipitation data, the TMPA dataset is developed (Huffman et a. 2007). In this study, Monthly(3B43_v7) Precipitation product downloaded in the Tag Image File Format (TIFF) of 0.25° × 0.25° resolution.

CHIRPS: It is a more than 35 years quasi-global (50°S - 50°N) rainfall data set, at a very high spatial resolution 0.05° × 0.05° and provides daily, Pentadal and monthly temporal outputs for the period of 1981 to present. The CHIRPS product is developed through blending USGS and U.S. Interior Department (Funk et al 2015) for trend analysis and monitoring of seasonal droughts. It relies on precipitation dependent on InfraRed (IR). Numerous studies showed the purpose of CHIRPS precipitation dataset around the globe. In the present study, the monthly CHIRPS version 2.0 from 2000 to 2018 is used. CHIRPS data were resampled from 0.05° × 0.05 to 0.25° × 0.25 to ensure homogeneity with other precipitation products.

PERSIANN-CDR: It is released by the Centre for Hydrometeorology and Remote Sensing (CHRS) at the University of California, Irvine which provides daily rainfall estimates at 0.25° for the latitude band 60°S to 60°N over the period of 1983 to present. It is produced from the PERSIANN algorithm using GridSat-B1 infrared data and adjusted using the Global Precipitation Climatology Project (GPCP) monthly product to maintain uniformity of the two datasets at 2.5-degree monthly scale throughout the entire record. Using Artificial Neural Network, the algorithm converts InfraRed IR information into rain rate. The purpose of this product is to resolve the need for a reliable, long-term, high-resolution and global precipitation dataset.

MSWEP: Multi-Source Weighted-Ensemble Precipitation (MSWEP) is historical precipitation dataset (1979–2019) with a 3-hourly temporal and 0.1° spatial resolution globally, enabling trend and drought assessment. This product considers data from the comparative merits of satellite infrared and microwave precipitation estimates, rain gauge observations and reanalysis products (Beck et al 2017a). This product is demonstrated as one of the best performers, during the recent assessment of 22 precipitation products over global scale using rain gauge and hydrological modelling (Beck et al 2017b). This data is validated using observation from nearly 70,000 gauges and hydrological modeling for 9000 catchments, with daily gauge corrections globally. Precipitation data from IMD (ground based) and TRMM, CHIRPS, PERSIANN, and MSWEP (Satellite based) are processed for thirteen districts of Andhra Pradesh from 2000 to 2018 grid wise. All data sets are up to 2018 except MSWEP which is accessible only till 2017. Resampling is done for MSWEP and CHIRPS Precipitation products at 0.25° to maintain homogeneity of all datasets.

To assess the performance of Multisatellite precipitation products with IMD gridded data, three indices are evaluated using root mean square error (RMSE), Mean Absolute Error (MAE) and correlation coefficient (CC). RMSE is used to measure average error in magnitude. Lesser values of RMSE show better fit. To evaluate the agreement between satellite-based precipitation and rain-gauge observations, CC is used. The value of the CC is from -1 to +1. The value of +1 indicates a perfect positive fit. If there is no linear correlation, CC is close to zero. The mean absolute error (MAE) is used to represent the average magnitude of the error. These assessment metrics were calculated as follows:

$$MAE = \frac{\Sigma_{i=1}^{n} \left| S_i - G_i \right|}{n} \quad (1)$$

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (S_i - G_i)^2} \quad (2)$$

$$CC = \frac{\Sigma_{i=1}^{n} (G_i - G)(S_i - S)}{\sum_{i=1}^{n} (G_i - G)^2 \sum_{I=1}^{n} (S_i - S)^2} \quad (3)$$

Here, S_i represents satellite product and G_i represents IMD Gauge based product, S and G are respective mean and n is the number of observations. The non-parametric trend analysis method, Mann–Kendall (MK) is applied using precipitation datasets for the annual and seasonal time series to detect the actual pattern of change from 2000 to 2018. Sen's Slope estimator test used to estimate the magnitude of change (Fig. 3).

RESULTS AND DISCUSSION

The MSWEP product mostly underestimates all

datasets in all districts except for Srikakulam and Vizianagaram. Anantapur, Guntur, Kurnool, Chittoor, Srikakulam, Kurnool, East Godavari and Vizianagaram, have shown similarity between TMPA and PERSIANN products while the districts of Krishna and Prakasham has no similarity between these two datasets (Fig. 4). There is less variation between TMPA, PERSIANN, and CHIRPS in districts of East Godavari, West Godavari, Visakhapatnam, Vizianagaram. In the northeast part of Andhra Pradesh, the average precipitation (Fig. 5) and standard deviation (Fig. 6) of all

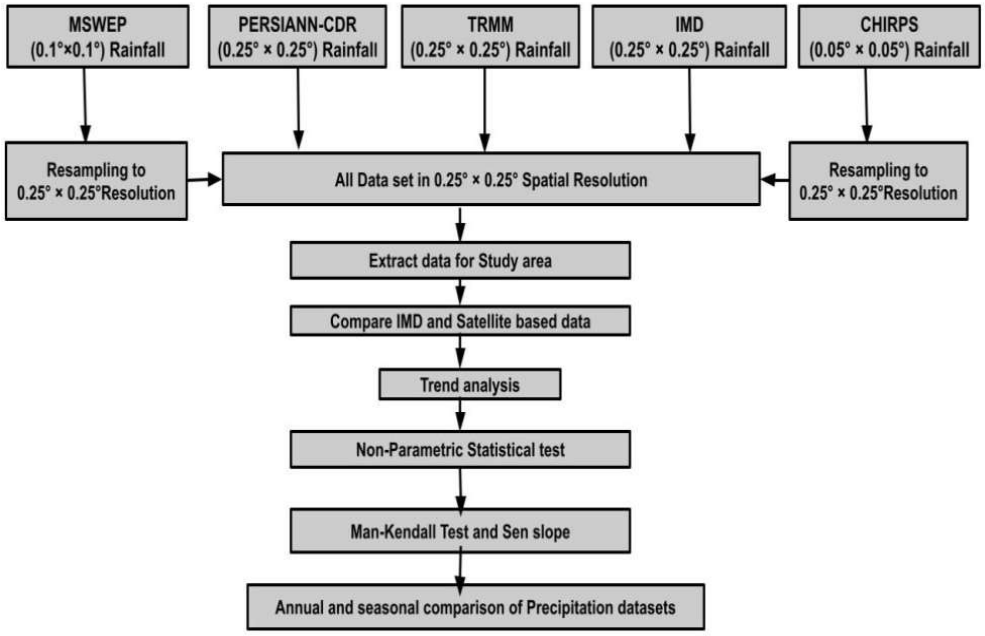

Fig. 3. Comparative study of precipitation products

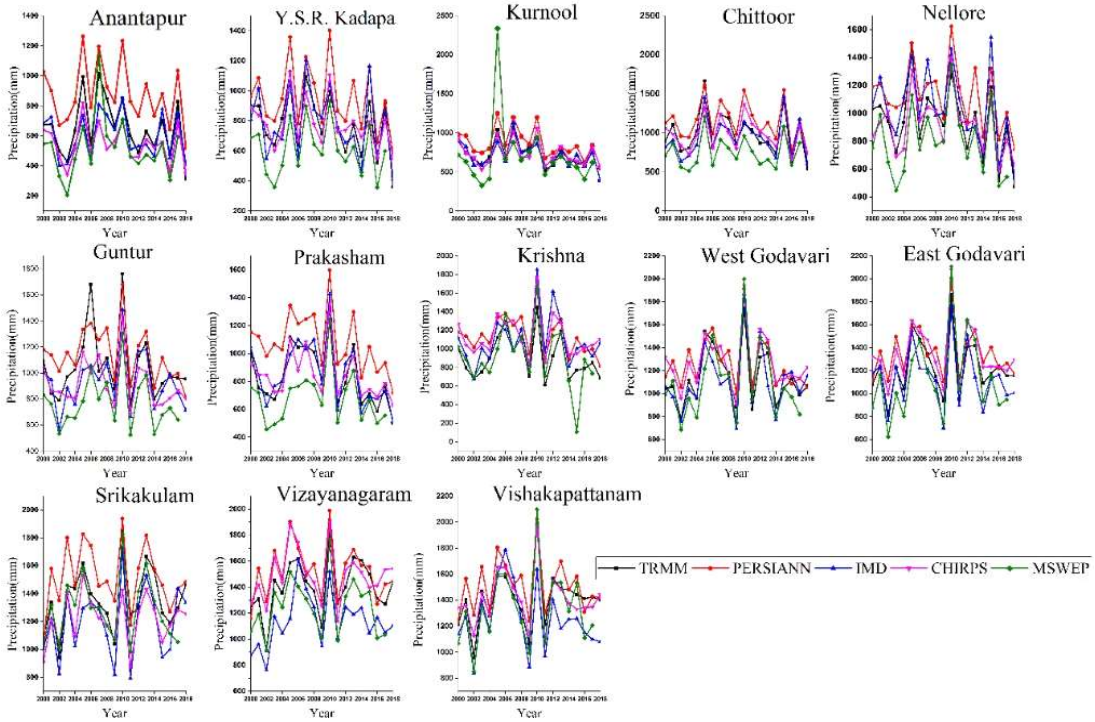

Fig. 4. Annual precipitation for all datasets district wise

datasets are high except in Anantapur, Y.S.R Kadapa, Kurnool and Chittoor. Compared to other datasets, MSWEP reported lower mean precipitation and standard deviation in most of the districts. In most of the districts, comparisons to other datasets, PERSIANN reported greater mean rainfall and standard deviation.

From June to October, all data sets showed, higher precipitation compared with the rest of the year. For almost all months except November and December, TRMM exaggerated the IMD dataset (Fig. 7). MSWEP underrated the measurements of the IMD in all the months apart from May. PERSIANN-CDR has exaggerated the measurements of the IMD for almost all months except November, December, and January. CHIRPS underrated the IMD measurements in all months except June, July, and August. High RMSE is observed around the eastern north region Figure 8.

The monthly Correlation Coefficient between TMPA, PERSIANN, CHIRPS, and IMD showed CC of above 0.80 in all districts of Andhra Pradesh (Fig. 10). Correlation coefficient of MSWEP showed the same pattern in all the Districts expect Kurnool. TRMM, MSWEP better correlated with IMD data than other datasets. High MAE values observed coastal part of the state, Srikakulam, Nellore, Prakasam, East Godavari, West Godavari, Visakhapatnam (Fig. 9). The districts with the higher RMSE and MAE are mostly located in the areas with precipitation range 1045 mm to 1170 mm.

For all datasets, the MK (Mann-Kendall) test is carried out to evaluate trend patterns and their levels of significance (Z-statistic) (Fig. 11). Annual and Monsoon, positive and negative patterns conforming with the Z-statistic values (significant or non-significant). In some districts, West Godavari, East Godavari, Visakhapatnam a positive significant trend is observed along the eastern border of the upper part of the state. In many of these districts, the pre-monsoon season showed a negative and positive non-significant precipitation trend. During the post-monsoon season, positive non -significant trend is only observed in the Kadapa and Kurnool. In the monsoon season positive significant trend is observed for West Godavari in IMD datasets while East Godavari and Visakhapatnam showing positive trend in TRMM. Major Districts of Andhra Pradesh showed non-significant Negative trend for all datasets.

Sen's slope test is done for all precipitation datasets Figure 12. The annual and monsoon magnitude of slope indicated increasing trend in the Srikakulam and Visakhapatnam in all datasets. In Rayalaseema region (Anantapur, Kurnool, YSR Kadapa and Chittoor), decreasing trend was observed in all datasets expect CHIRPS. During

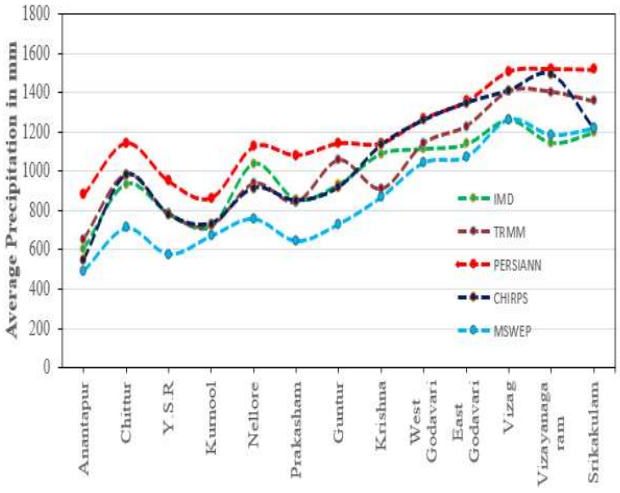

Fig. 5. Average annual precipitation of IMD, TMPA, CHIRPS, PERSIANN and MSWEP datasets

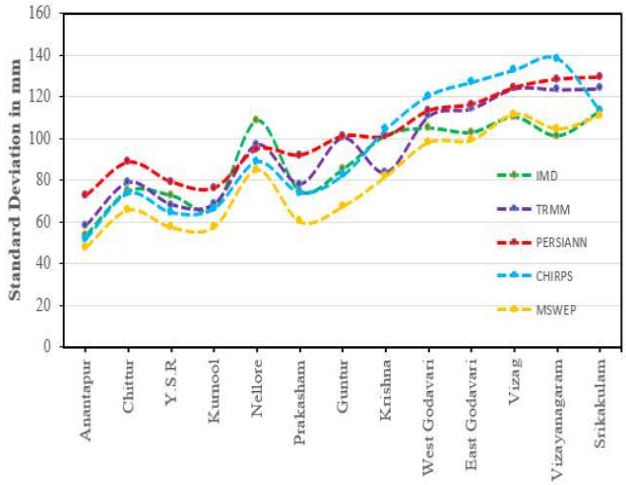

Fig. 6. Standard Deviation of annual precipitation for IMD, TMPA, CHIRPS, PERSIANN and MSWEP

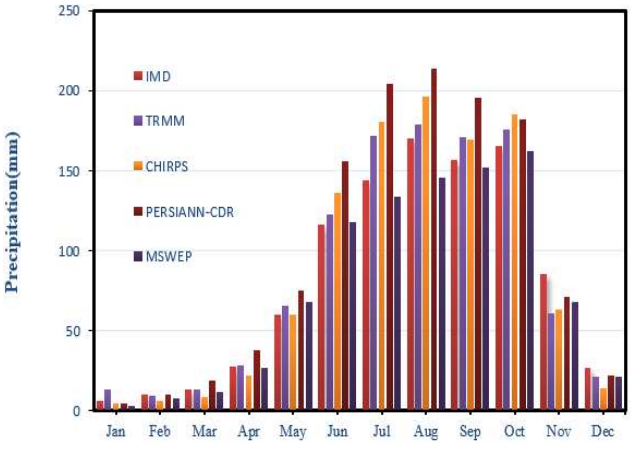

Fig. 7. Monthly average precipitation of IMD and satellite datasets (2000–2018)

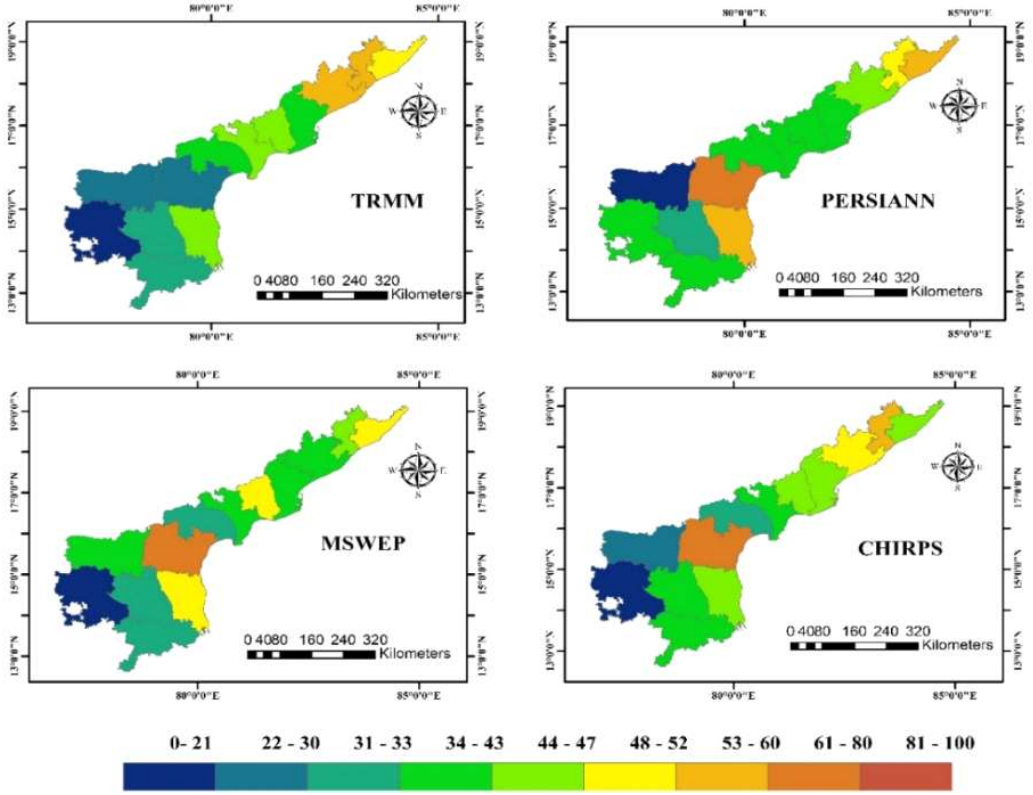

Fig. 8. Root MEAN Square Error (RMSE) between monthly IMD and satellite datasets

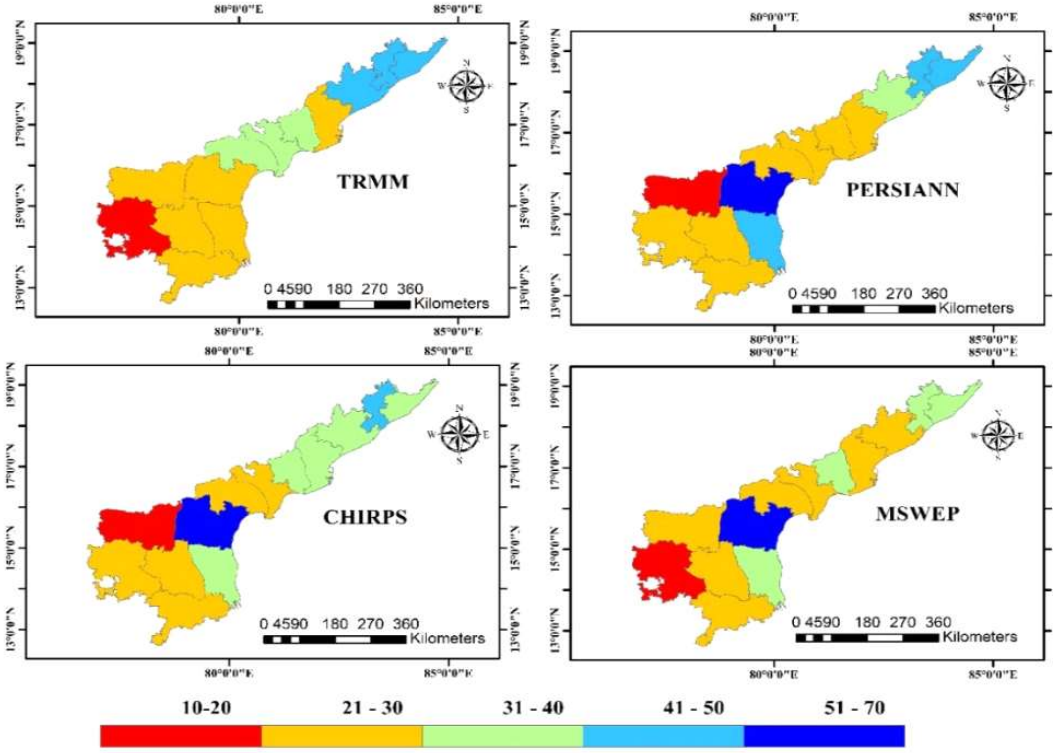

Fig. 9. Mean Absolute Error (MAE) between monthly IMD and satellite datasets

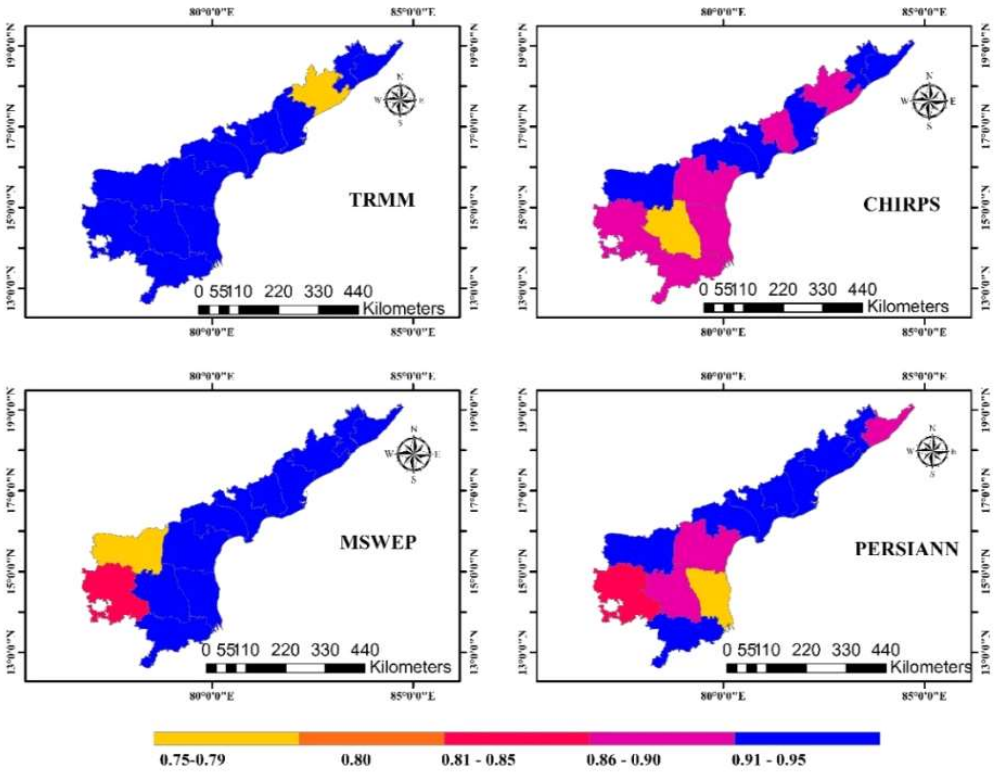

Fig. 10. Correlation Coefficient (CC) between monthly IMD and satellite datasets

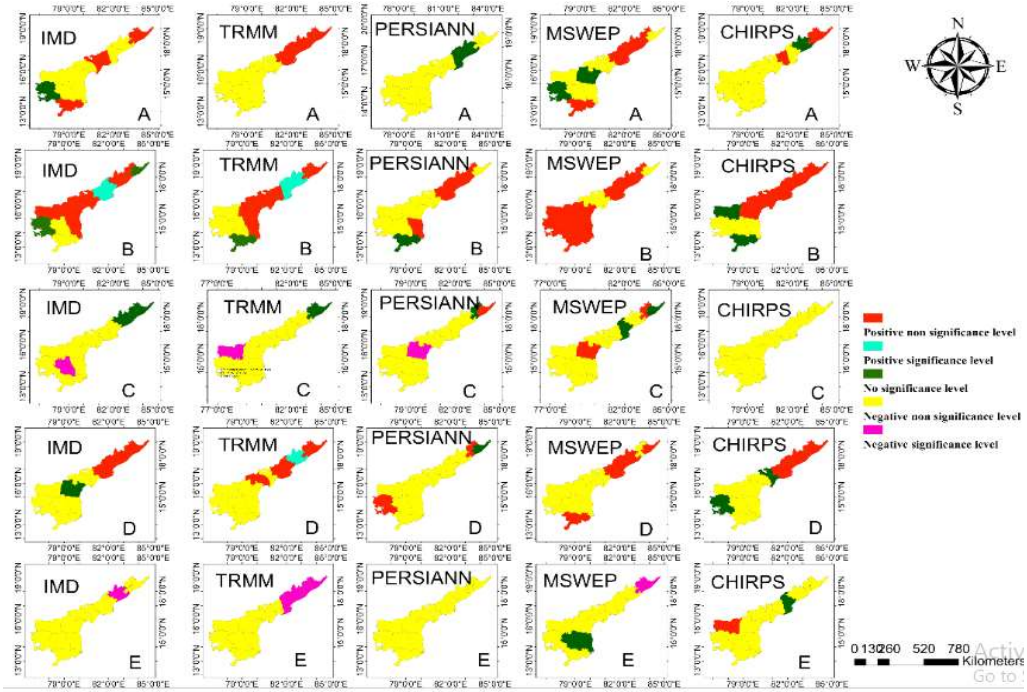

Fig. 11. Annual and seasonal Z-statistics values for satellite and IMD precipitation datasets (A=Annual, B=Monsoon, C=Post-Monsoon, D=Pre-Monsoon, E=Winter)

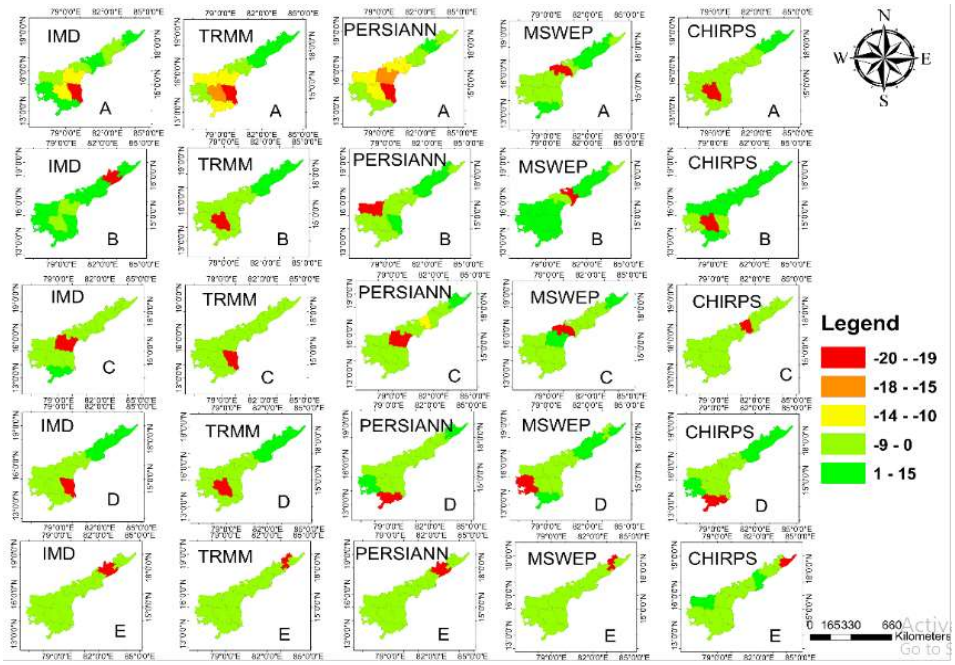

Fig. 12. Annual and seasonal Sen's Slope values for satellite and IMD Precipitation datasets (A=Annual, B=Monsoon, C=Post-Monsoon, D=Pre-Monsoon, E=Winter)

the pre-monsoon season, a similar pattern of increase and decrease in magnitude of Slope is found for IMD, TMPA, and CHIRPS datasets. During the post-monsoon and winter season, maximum areas showed decrease in magnitude of Slope for all datasets.

The reliability of satellite products with respect to ground-based data, the correlation coefficient and the root mean square error are used (Kundu et al 2017a). TMPA and IMD relationship, districts of Visakhapatnam and Krishna indicated lower CC and Visakhapatnam, Vizianagaram & Srikakulam higher RMSE which are in East Northern parts of Andhra Pradesh. The average RMSE of 40.6 mm (minimum), MAE of 24.1 mm (minimum) and CC of 0.918 (maximum) for TMPA and IMD datasets for entire A.P., implying highest relevance between these two datasets. Average RMSE of 51.7 mm (maximum), MAE of 33.6 (maximum) and CC of 0.89 (minimum), for PERSIANN for entire Andhra Pradesh indicating the lowest relevance between these two datasets. The MSWEP dataset showed lower RMSE and higher CC (48.1mm and 0.905) than the PERSIANN dataset (51.7 mm and 0.903) which is like other study done by (Mondal et al 2018). Highest similarity for annual and monsoon analysis between CHIRPS and IMD (69.23%) while PERSIANN shows minimum similarity between IMD (38.46%). The TRMM and MSWEP both gave the same percentage of matched data with IMD (about 61.5%). TRMM demonstrated better trend analysis results in the post-monsoon, pre-monsoon, winter (76.9%) and monsoon seasons (53.8%) relative to IMD. The similar trend between IMD and other datasets varied from 38.46% (MSWEP in monsoon) to 76.9% (TMPA in post-monsoon, Pre-monsoon and Winter). All datasets in coastal Andhra Pradesh generally showed an increasing trend, while the central and northern parts of Andhra Pradesh showed a decreasing trend using the MK method from 2000 to 2018.The precipitation trend indicated almost decrease in trend for districts of Andhra Pradesh.

CONCLUSION

CHIRPS and TMPA are better compared to gauge-based precipitation estimates than MSWEP for all districts of Andhra Pradesh, which is clear from higher correlation (CC), lower Mean Absolute Error (MAE) and Root Mean Square Error (RMSE). The products of TMPA and CHIRPS showed better performance relative to IMD than MSWEP and PERSIANN based on accuracy, thus suitable for use in hydrometeorological studies in the data scarce area of the state. The trend analysis implied small variations among the TRMM, CHIRPS, and MSWEP data. However, MSWEP dataset showed best similarity to IMD in annual and monsoon trend analysis. These three satellite products are more reliable for use in ungauged areas and in complex terrain where measurement of in situ precipitation is scarce. In

addition, multi-satellite precipitation products were finally reprocessed with some enhancements and published the revised version, which ultimately needs to be thoroughly tested before being implemented into any application.

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Impacts of Land Use/Land Cover on Surface Temperature and Soil Moisture in the Region of Nagavali Basin

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***Abstract*:** The land use/land cover (LULC) has the major impact on various hydro-meteorological parameters. The present study focuses on the influence of LULC changes on surface temperature and soil moisture for the Nagavali basin, India. In the present study, LULC was prepared from Landsat series of data with maximum likelihood image classification algorithm. The land surface temperature (LST) estimated from the thermal infrared band of Landsat data using radiative transfer equation. The soil moisture index estimated from the scatter data feature space of normalized difference vegetation index (NDVI) and surface temperature. The result of the study confirms the LULC has the significant impact on surface temperature and soil moisture. Land surface temperature drastically increased from the year 1990 to the year 2017. Soil moisture content calculated for each class of LULC and the results showed that the hilly and vegetative terrain has higher moisture content than low lying region.

***Keywords*:** Nagavali basin, Land use/land cover, Land surface temperature, Soil moisture index, Temperature vegetation dryness index

To study the anthropological influence on the natural environment and ecosystem, land use/land cover (LULC) provides important information about the changes in the land surface. The LULC changes impact on surface parameters include roughness, albedo, temperature, visible light radiation, precipitation, and vegetation coverage. In addition to the surface parameter, LULC transforms the typical hydrological process and its element primarily evapotranspiration, runoff, infiltration and subsurface flow (Wagner et al 2016, Mohaideen and Varija 2018). The classification of LULC can be performed using both visual interpretation and digital processing techniques with satellite remote sensing image. Individual classes of LULC contribute temperature changes. The changes in LULC depict a strong correlation with the increasing land surface temperature (LST). Thermal infrared remote sensing plays a major role to extract the LST and the information of surface thermal condition. The soil moisture aspects can be inferred well from the relation of surface thermal range and vegetation index space, which commonly used in soil moisture reversal models in recent years. Temperature vegetation dryness index (TVDI) is the dryness index generally used for assessing soil moisture and which is based on the interrelationship of vegetation indices and temperature of land estimated regional crop yield with TVDI and authors concluded that crop yield estimation from TVDI shows better than the yield estimation obtained from vegetation index monitored soil moisture based on vegetation index and surface temperature space for Southwest China from the multispectral image and concluded that TVDI has the stronger association with soil moisture at 3.9 inches. Analyzed agriculture drought based LST-VI Feature Space for Anantapur, India and they concluded that drought classification for the year 2016 shows 40percent of the area under severe and moderate drought and remaining area under normal and no drought. Estimated impacts of LULC on gross primary production (GPP) of urban vegetation for Wuhan, China and results showed that the greatest GPP loss caused where the crop land transforms to settlement and the greatest GPP gain happened due to the transformation of cropland to forest. There are plenty of researches discussing about the impact LST and NDVI on LULC. The present study analyzed TVDI and LST impact on LULC due to the limited availability of the research. In this research, soil moisture influence on each land cover studied under different temperature condition. In the present study, the main objective is to quantify the land use influence on surface temperature and soil moisture index in the region of Nagavali Basin.

MATERIAL AND METHODS

Description of study area: Nagavali basin of southern India selected as study are located between 18°16'N to 19°31'N latitude and 82°53'E to 83°55'E longitude (Fig. 1). The areal extent of the Nagavali basin is 8397 km^2. The major reservoirs are Vottigedda, Totapalli, Narayanpur, and

Madduvalasa. The study area receives an annual rainfall of about 703.4mm.

Data description: Remote sensing satellite data used to prepare LULC include the Landsat Series (OLI/TIRS, ETM+, and TM) of 30 m resolution for the years 1990, 2002, and 2017 (Table 1). Landsat TM is a multispectral sensor working in visible and infrared (IR) electromagnetic spectrum. Landsat ETM+ introduced all the features of TM with the addition of 15 m resolution panchromatic band and 60 m resolution thermal band. The Landsat TM has the thermal band of resolution 120 m. The Landsat OLI/TIRS has all the feature of TM and ETM+ with thermal band acquired at 100 m. The thermal band obtained from all the three sensors resampled to 30 m in the delivered product.

Land cover/land use classification: The LULC map generated from Landsat group of remotely sensed data using maximum likelihood image classification method (Prabu and Dar 2018).The survey of India topo sheets taken as reference data for classifying Landsat images into seven classes which are settlements, water bodies, wasteland, current fallow, cropland, forest, and plantation. The maximum likelihood algorithm operating based on the principle of Bayes theorem of decision making. The methodology for estimating the likelihood (*D*) based on the equation 1.

$$D = \ln(a_K) - [0.50\ln(|cov_K|)] - [0.5(X - X_K)T(cov_K^{-1})(X - X_K)] \quad (1)$$

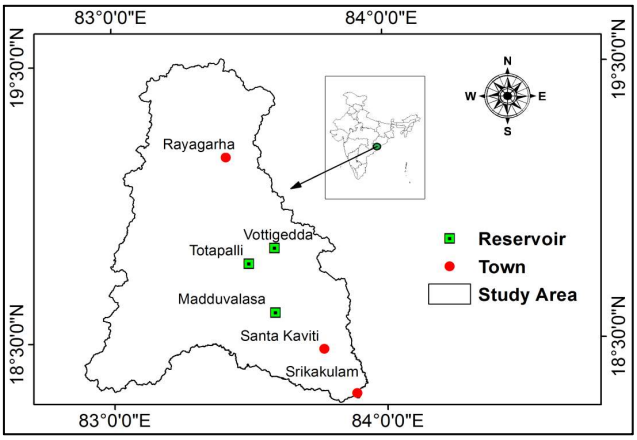

Fig. 1. Geographical setting of the study area

Where, X_K is known classes and X is unknown measurement vector coming under known classes.

The accuracy of the image classification assessed based on the overall accuracy and kappa coefficient. According to Congalton (1991) theoretical description of the image assessment methods are detailed as follow:

Overall Accuracy

$$\text{Overall Accuracy} = \frac{1}{N}\sum_{i=1}^{r} x_{ii} \quad (2)$$

Kappa Coefficient

$$\text{Kappa Coefficient} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} x x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} x x_{+i})} \quad (3)$$

where x_{ii} is the number of observations in row i and column i (the diagonal elements), r is the number of rows in the matrix, N is the number of observations, and x_{+i} and x_{i+} are the marginal totals of row r and column i respectively.

Normalized difference vegetation index (NDVI) estimation: NDVI is the threshold of vegetation which related to spectral reflectance of the Earth surface feature. The threshold value of NDVI ranges from -1 to +1 (Singh et al 2016, Vaani and Porchelvan 2017). The NDVI values scaled from minimum (bare soil) to maximum fractional vegetation cover. The NDVI defined as:

$$NDVI = \left(\frac{\lambda_{NIR} - \lambda_{RED}}{\lambda_{NIR} + \lambda_{RED}}\right) \quad (4)$$

Where λ_{NIR} and λ_{RED} represent near-infrared band (NIR) and red band from the visible spectrum respectively.

Land surface temperature quantification: Satellite data offer the possibility for estimating LST all over the places in the world with good temporal and spatial resolution. The thermal infrared (TIR) band of satellite sensor related to LST through the radiative transfer equation (Li et al 2013). Three steps involved in the calculation of LST, the initial step involves the transformation of digital number (DN) values to radiance, and the second step involves the calculation of brightness temperature. Finally, conversion of resultant temperature from the unit of Kelvin to Degree Celsius

Table 1. Data specification of the Landsat imageries

Satellite data	Spatial resolution of optical band (m)	Spatial resolution of thermal band (m)	Scene (path, row)	Time of acquisition
Landsat TM	30	120	(141, 47)	April, 1990
Landsat ETM+	30	60	(141, 47)	May, 2002
Landsat OLI/TIRS	30	100	(141, 47)	May, 2017

$$L_\lambda = \lambda_{TIR} MF + AF \quad (5)$$

$$T(\mathrm{K}) = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)} \quad (6)$$

(Chokkavarapu and Mandla 2018). It described as:

$$T(^{o}\mathrm{C}) = T(\mathrm{K}) - 273 \quad (7)$$

Where, L_λ is spectral radiance of the top of the atmosphere, λ_{TIR} is thermal infrared band of satellite image, *MF* is the multiplicative factor of thermal band, *AF* is the additive factor of thermal band, K_1 and K_2 are specific conversion constants of thermal band, *T*(K) is temperature in Kelvin, and *T*(°C) is temperature in Degree Celsius. The common factors affect the LST are (i) sensor noise and error are the strong influence on LST, (ii) due to the presence of atmosphere between the sensor and surface, affects the quality of radiance measurement in radiometer, (iii) to avoid the uncertainty in LST, analysis was done in clear sky data.

Soil moisture index: The soil moisture index is a threshold index which indicates the presence of moisture content in the soil. The soil moisture condition can estimate from the relation of temperature vegetation dryness index. TVDI provides the effective indication of land moisture and is computed based on NDVI-LST feature space. The TVDI calculation method commonly called as triangle method because the scatter of LST and NDVI is the triangular shape in feature space (Przeździecki et al 2018). Fig. 2 shows the schematic definition of soil moisture index. The line CE in Fig. 2 is dry edge and the line DE is the wet edge. The lower moisture and transpiration capacity nearer to the dry edge and the capacity of moisture and transpiration become higher at the wet edge. According to the TVDI defined as:

$$TVDI = \frac{T - T_{MIN}}{T_{MAX} - T_{MIN}} \quad (8)$$

$$T_{MAX} = a_{MAX} + b_{MAX} NDVI \quad (9)$$

$$T_{MIN} = a_{MIN} + b_{MIN} NDVI \quad (10)$$

\Where, T_{MAX} is the maximum surface temperature with the function of the dry edge at NDVI-LST feature space with linear fitting parameter a_{MAX} and b_{MAX}. T_{MIN} is the function of the wet edge at the triangular plot in feature space which represents the minimum surface temperature of each pixel with the coefficient of linear regression parameters (a_{MIN} and b_{MIN}). Figure 2 also defines the threshold value of TVDI ranges between 0 and 1. The value closer to the zero indicates moisture and the threshold value nearer to the 1 indicates dryness.

The method assumes that the LST for the given NDVI happened due to the variation in soil moisture rather than the canopy temperature, atmospheric pressure, and air temperature.

RESULTS AND DISCUSSION

The settlement cover increased from 1990 (58 km^2) to 2017 (427 km^2). The surface area of the water bodies in the basin decreased from 1990 (154 km^2) to 2002 (48 km^2). After the construction of several reservoirs in the Nagavali basin, water surface area increased in the year 2017 (305 km^2). Wasteland of the study area decreased on the year 2002 (481 km^2) from the year 1990 (877 km^2), because of growth of small shrubs in the study area on the year 2002 some part of wasteland comes under the vegetation classes. The increase in crop cover of the year 2002 confirms the wasteland and fallow land conversion. In 2017, wasteland increased to 980 km^2. The cropland of the year 1990 (2006 km^2) increased during monsoon season in the year 2002(3567 km^2) which shows satisfactory rainfall received in the basin. In 2017, the cropland area dropped to 1812 km^2. Due to infrastructural developmental activities, forest covers gradually decreasing from year 1990 (3279 km^2) to the year 2017 (2155 km^2).

The mean temperature of all land cover feature gradually increases from the years 1990 to 2017, it reveals climate change scenario (Fig. 3, 4). The forest area received lower temperature compared to another surface feature. The settlement, water bodies, wasteland, and fallow land receive the maximum and almost nearly equal range of temperature with 0.5°C variation. The temperature range of cropland and plantation is less than settlement, water bodies, wasteland, and fallow land and greater than forest cover temperature. The results of the present study prove vegetation cover receives a lesser amount of temperature compared to other surface features.

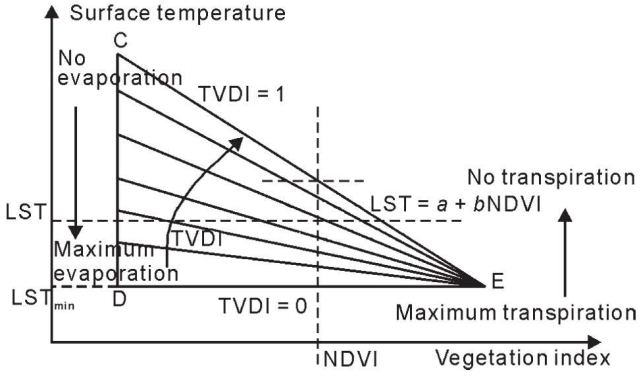

Fig. 2. Soil moisture index (CE is dry edge and the line DE is the wet edge)

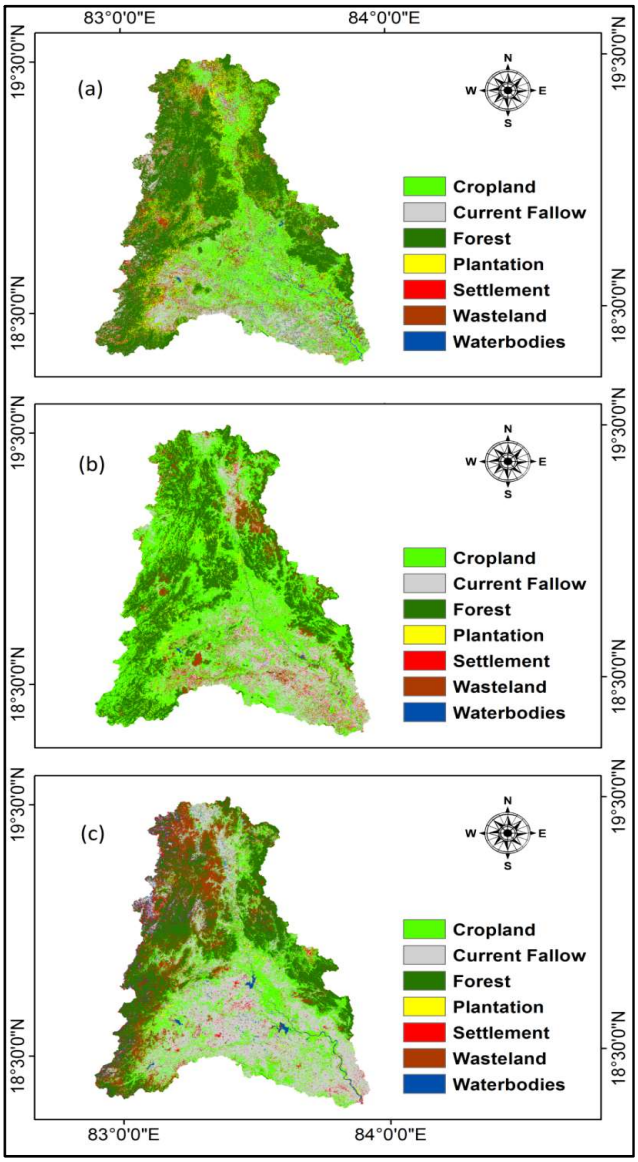

Fig. 3. LULC of the Nagavali Basin on (a) April, 1990, (b) May, 2002, and (c) May, 2017

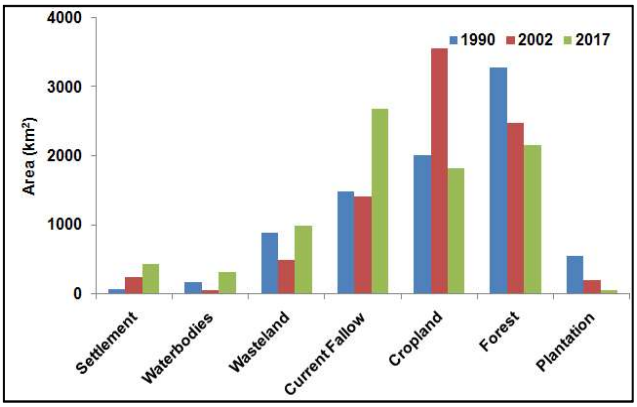

Fig. 4. Trend of LULC changes for the years 1990, 2002, and 2017

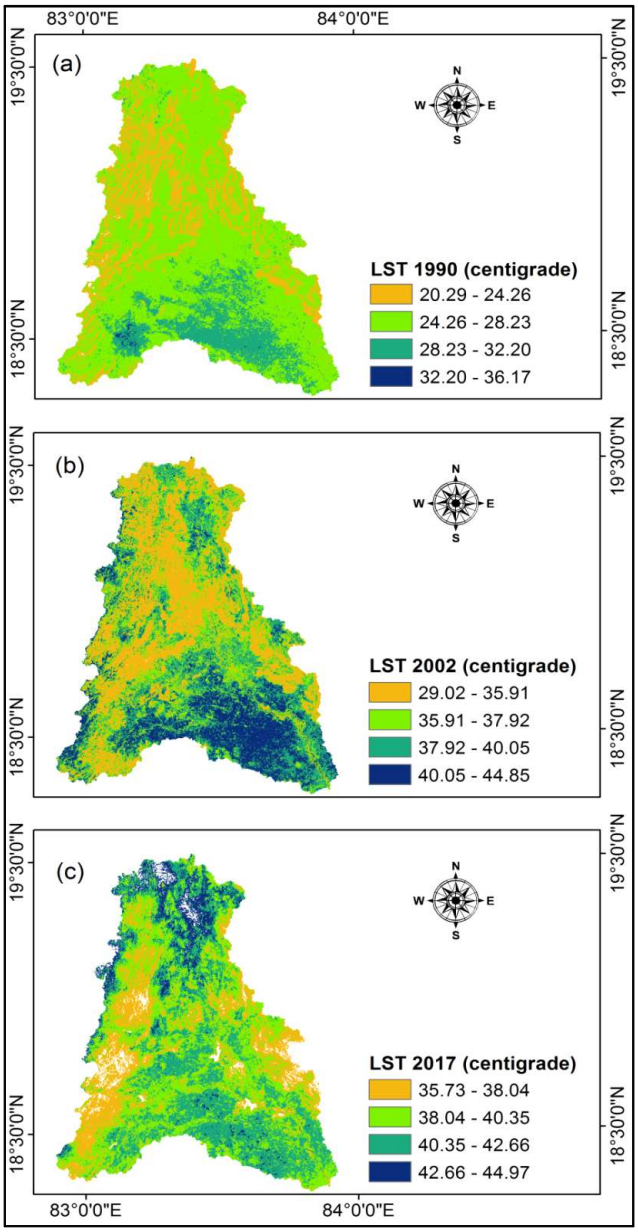

Fig. 5. LST map of the Nagavali Basin on (a) 1990, (b) 2002, and (c) 2017

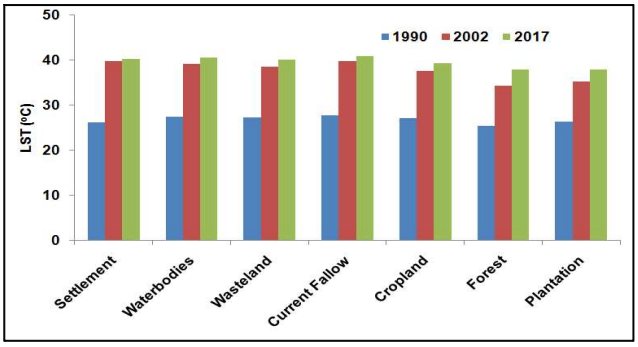

Fig. 6. Temperature changes for LULC of the years 1990, 2002, and 2017

The threshold value of the soil moisture index ranges from 0 to 1 (Fig. 7). The value close to zero and 1 indicates the presence of good and poor quantity moisture. The overall mean of soil moisture in the years 1990, 2002, and 2017 are 0.52063, 0.53881, and 0.4002, respectively. The forest area is having the presence of higher soil moisture compared to other feature. The, hilly and forest cover regions having good moisture presence compared to low lying areas.

Table 2. Assessment of accuracy for the classified images

Year	Name of the satellite image	Overall accuracy of classification (%)	Kappa statistics
1990	Landsat TM	78.37	0.7364
2002	Landsat ETM+	76.83	0.6957
2017	Landsat OLI/TIRS	79.52	0.7160

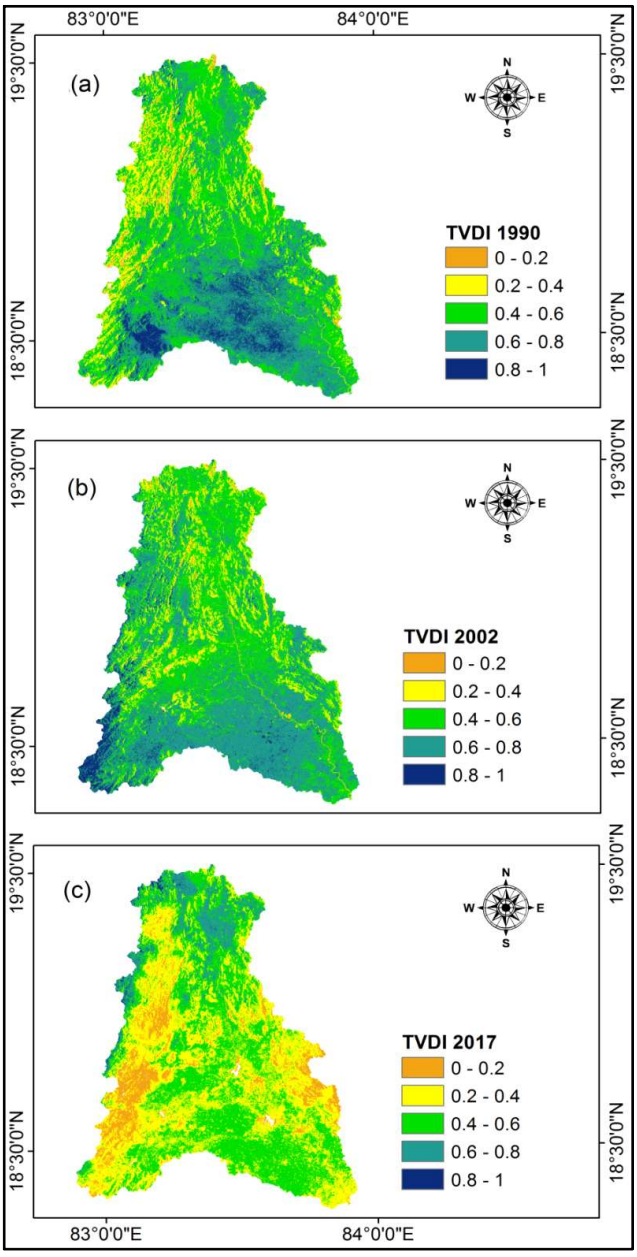

Fig. 7. Soil moisture index (TVDI) map of the Nagavali Basin on the years (a) 1990, (b) 2002, and (c) 2017

CONCLUSION

Remote sensing is a viable tool to predict climate change impact in Earth surface. The prepared LULC show the trend of surface feature changes from the year 1990 to the year 2017. The forest covers decreasing whiles the settlement increasing. The water surface area decreased from the year 1990 to the year 2002.After the construction of Jhanjavati reservoir in 2001 and Thotapalli barrage construction was in between 2003 and2015, water surface increased in 2017. The result confirms the majority of the changes in land surface happening due to anthropogenic activities. The results of the surface temperature map showed from the year 1990 to 2017 confirms the climate change scenario slowly occurred in Nagavali basin. The presence of higher soil moisture range and the lower surface temperature at vegetation feature compared to other features showed the possibility to maintain the surface temperature and soil moisture index by the mass plantation.

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Remote Sensing Planet Images Application in Mapping the Status of Tropical Forests: A Case Research in Kontum Province, Vietnam

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Abstract: This paper describes the process of creating a forest status map in Kon Tum province using Planet satellite images captured in December 2020 and the image interpretation keys belonged to 14 land cover types. With the aid of eCognition Developer software the satellite images were segmented into 30.896 objects and the forest status map was established with an accuracy of 82%, the Kappa coefficient is 0.801. The total forest area in Kon Tum is 621,356.05 hectares, including 547759.37 hectares of natural forests (88%) and 73596.68 hectares of planted forests (12%). The results of the article are good references for studies on satellite image application in forest classification, forest management and forest monitoring.

Keywords: Satellite image, Planet, stratified random, Random forest method, Cnfusion matrix

Forest ecosystems cover approximately 31% of land surface in the world, with a total forest area of approximately 4 billion hectares (United Nations 2017). Sustainable development and management of forest resources is required not only to meet the needs of present but also future generations. Meeting those needs is on the basis of close and harmonious coordination between economic growth, ensuring social progress and environmental protection (Hien 2020). Remote sensing technology and Geographic Information System (GIS) are considered very effective tools in forest resource management and protection. GIS is a supporting system for collecting, storing, retrieving, analyzing and displaying spatial and non-spatial data (Oyebade et al 2012). The application of GIS technology for forest management began in the early 1990s (Ahmad 2008). Up to now, the application of remote sensing and GIS in forest resource management and protection has been used in most countries, from Europe to Asia, America, and Africa (Kolosvary and Corbley 1998, Peddi 2010, Freddy et al 2014, Devaraj and Yarrakula 2018, Tuyen et al 2019, Oettel and Lapin 2020, Sonowal 2020).

In Vietnam, the application of remote sensing in forest classification is one of the priority tasks and is conducted regularly in many provinces, through research programs at different levels of management, including the province Kontum (eCognition 2004). Kontum is a province in the Central Highlands of Vietnam. The vegetation cover here is the typical forest ecosystem of the tropical monsoon mountainous and plateaus (Congalton and Green 1999). The Vietnamese government's forest inventory projects in Kontum province used images satellite SPOT to create status maps of the forest (Cuong et al 2021). In addition, the program "Survey, assessment and monitoring of national forest resources in the period 2016-2020" of the Vietnamese Ministry of Agriculture and Rural Development used Sentinel 2 satellite medium resolution images to establish current status maps of the forest.

Determination of forest status by remote sensing method depends on the interpretation key. The interpretation key is the concept showing the arrangement of image elements, detailed characteristics of the object forming a whole in the macro space (Karakış et al 2006, Genuer and Poggi 2020). Therefore, image resolution plays an important role in the establishment of forest maps since they specify the granularity of the selected interpretation keys. Planet satellite imagery has a medium spatial-resolution (4.7m) but has a high time-resolution due to the daily shooting cycle, provided free charge to users for learning and research purposes (Mai and Nguyen 2017). With their superior parameters, the Planet satellite imagery offers significantly higher value than the popular non-commercial satellite images commonly used for forest status mapping such as Landsat 8 (spatial

resolution of 30 m, shooting cycle 15 days) or Setinel 2 (spatial resolution of 10 m, shooting cycle of 5 days). In this research, we use satellite imagery of Planet to create a forest status map of the area in Kontum province. The results of image interpretation are to compare advantages and disadvantages of Planet images with SPOT or Setinel images.

MATERIAL AND METHODS

Research area: Kontum province is located in the North Central Highlands of Vietnam, has a border with two countries Laos and Cambodia (Fig. 1 Error: Reference source not found). The research area is located to the west and north of the Annamite mountain range (Truong Son mountain range). The terrain is mainly mountainous and plateaus, very favorable for the development of agriculture and forestry. The research territory has a tropical plateau climate with 2 distinct seasons. The rainy season starts from April to November, the dry season from December to March next year. The average annual precipitation is from 1730-1880mm. In addition, this is also the origin of major river systems such as the Se San River (formed from two rivers Po Ko and Dak Bla), Sa Thay river, Dak Rong river. The natural conditions have formed a diverse soil system, in which the soil groups are typically Acrisols, Ferrasols and Alisols (Nguyen et al. 2020). Favorable natural conditions for forestry are the basis for the diversity of forest types. The typical ecosystems for the highlands and high mountains in Kontum province include evergreen broadleaf tropical forest, mixed broadleaf and coniferous forest, coniferous forest, bamboo forest, etc. In addition, this place is also inhabited by ethnic minorities such as Bahnar, Rade, Sedang, Jeh-Tariang. The different traditions have made their cultural diversity as well as the type of agro-forestry farming (Kontum Provincial People's Committee).

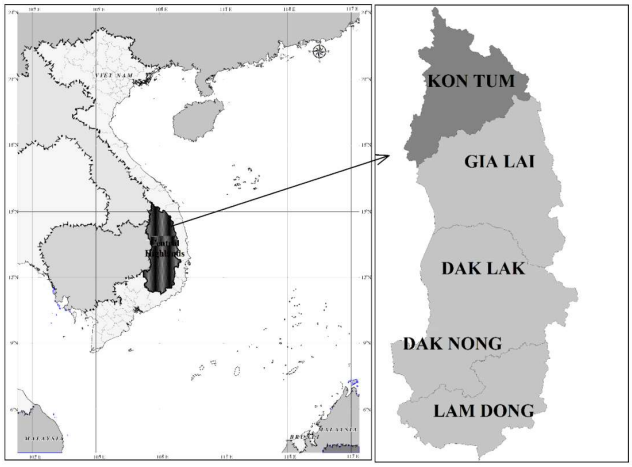

Fig. 1. Location map of Kontum province, Vietnam

Satellite image: To establish the forest status map of Kontum province, used the Planet satellite image taken in December 2020 (https://www.planet.com/products/basemap/). The geometrically calibrated satellite image with the parameters is shown in Table 1.

Software: Jalbuena (2015) used the Multiresolution algorithm to segment LiDar images based on eCognition software. In the article, eCognition Developer v9.1 is used for image segmentation and interpretation. Open-source software QGIS and ArcGis Desktop 10.4 software were used for editing and mapping forest status. These are two of the optimal GIS software for editing and creating specialized maps. In 2017, Atesoglu used Collect Earth software in identifying image interpretation key samples for research in Turkey. Collect Earth is free and open-source software that uses Google Earth and Bing Maps. This software provides high resolution satellite image data (Atesoglu et al 2017). In this research experiment, used the Collect Earth software to collect ground data from satellite images for the classification and evaluation of the reliability and accuracy of the interpretation results.

Research Methods

Image interpretation process: The process of interpreting remote sensing images for the vegetation cover of Kontum province is shown in Figure 2. In the research, a set of interpretation keys for satellite images was conducted by stratified random sampling (method Random Forest RF) in ArcGis software with a total of 1200 samples. In which 850 samples are used for image interpretation and 350 samples are used to evaluate accuracy and reliability. This set of image interpretation keys was standardized and verified in Collect Earth software to determine forest status based on the built-in high-resolution Google Earth and Bing Maps satellite imagery. For the interpretation keys that cannot determine the state, they will be synthesized and further checked during the fieldwork.

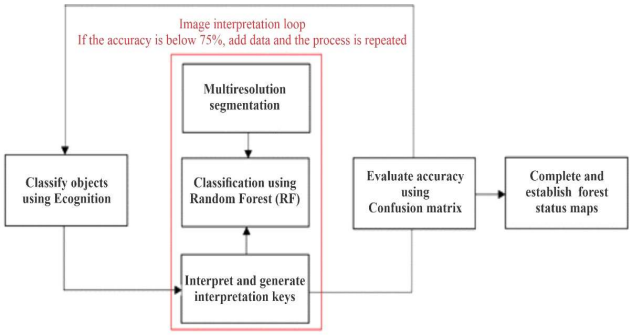

Fig. 2. Diagram of the remote sensing planet image interpretation process

A mandatory requirement when determining the status for these 1200 image interpretation key samples is that they must be independently performed by a minimum of two experts. Experts synthesize and reject distorted patterns, using only highly reliable image interpretation keys. This is a very important and decisive step to the accuracy of the interpretation process. The image interpretation key is entered into eCognition software to implement the Multiresolution segmentation algorithm. This is the algorithm proposed by Baatz and used to group areas with similar pixels and neighboring points into objects by considering uniformity criteria (Baatz and Schape 2000). Kavzoglu (2014) showed that segmentation creates objects by grouping similar spectral properties on an image. Multiresolution segmentation is a bottom up region-merging technique starting with one-pixel objects. The purpose of this technique is to divide an image into sections that are strongly correlated with the objects or areas in the image. Segment images are used to determine the position of objects and the boundaries between them (Kavzoglu and Yildiz 2014). In numerous subsequent steps, smaller image objects are merged into larger ones. Throughout this pairwise clustering process, the underlying optimization procedure minimizes the weighted heterogeneity *"nh"* of resulting image objects, where *"n"* is the size of a segment and *"h"* an arbitrary definition of heterogeneity. In each step, that pair of adjacent image objects is merged which stands for the smallest growth of the defined heterogeneity. If the smallest growth exceeds the threshold defined by the scale parameter, the process stops (eCognition 2004). Spectral or color heterogeneity is described as:

$$h = \sum_c w_c \sigma_c$$

Heterogeneity as deviation from a compact shape is described by the ratio of the de facto border length *"l"* and the square root of the number of pixels forming this image object (Karakış et al 2006):

$$h = \frac{l}{\sqrt{n}}$$

According to Genuer (2020), the determination of the state after image segmentation is done by the Random Forest (RF) method in eCognition Developer. This is a comprehensive method of machine learning for performing classification, regression, and other tasks that operate by constructing a multitude of decision trees at training time and outputting the class that is the mode of the classes (classification) or mean/average prediction (regression) of the individual trees (Genuer and Poggi 2020).

To check the results of image interpretation, a random selection method was used. Each forest state will have a minimum of 10 control points. After that, the current situation was verified by field survey and compared with interpretation results. In the case where the accuracy is less than 75%, it is necessary to re-check the procedure and the method of taking the interpretation key to improve the correct value (Mai and Nguyen 2017). This process requires constructing of confusion matrix between classification results and control samples and evaluation of Kappa coefficient (K). According to Congalton and Green (1999), this matrix is the most effective method to evaluate accuracy is to evaluate overall accuracy, user accuracy and producer accuracy. The Kappa coefficient is used as a measure of classification accuracy. These are the utility coefficients of all the elements from the confusion matrix. It is the fundamental difference between the real difference in the deviation error of the matrix and the total change indicated by the row and column (Mai and Nguyen 2017). The formula for determining the Kappa coefficient is as follows:

$$K = \frac{N \sum_{i=1}^{r} X_{ij} - \sum_{i=1}^{r} (X_{i+} - X_{+i})}{N^2 - \sum_{i=1}^{r} (X_{i+} - X_{+i})}$$

Where: r = Number of columns in the image matrix; X_{ii} =

Table 1. Parameters of the Planet satellite image taken in December 2020 for Kontum province

Image attribute	Description
Visual bands	3-band natural color (Red, Blue, Green)
Ground sample distance	4.7m x 4.7m (at reference altitude 475 km)
Pixel size (orthorectified)	3125 m
Bitdepth	8-bit
Image geometry correction	Sensor-related effects are corrected using sensor telemetry and a sensor model. Spacecraft-related effects are corrected using attitude telemetry and best available ephemeris data. Orthorectified using GCPs and fine DEMs (30 m to 90 m posting) to <10 m RMSE positional accuracy
Positional accuracy	Less than 10m RMSE
Color enhancement	Enhanced for visual use and corrected for sun angle
Image coordinates	WGS 84, zone 48N

number of pixels observed in row *i* and column *i* (on the main diagonal); X_{i+} = Total Pixel observed in row *i*; X_{+i} = total pixel observed in column *i*; N = the total number of pixels observed in the image matrix. The value of the Kappa coefficient is usually between 0 and 1. If within this range the accuracy of the classification is accepted. According to the US Geology Department, the Kappa coefficient has 3 groups of values: K>0.8: high accuracy; 0.4<K<0.8: moderate accuracy; and K<0.4: low accuracy.

RESULTS AND DISCUSSION

Interpretation keys: Based on the interpretation results on the Collect Earth software, the key samples with low reliability interpretation were excluded. Selected interpretation keys include 800 samples (eliminated 50 samples) for image interpretation and 299 samples (eliminated 51 samples) for verification (Fig. 3). According to Kavzoglu (2014) and Tran (2011), the number of key samples has met the requirements for interpretation for the area of Kontum province (Tran and Nguyen 2011, Kavzoglu and Yildiz 2014). After processing, interpretation keys were obtained for forest types including: (1) Evergreen broadleaf forest with good quality (93 samples); (2) Evergreen broadleaf forest with medium quality (104 samples); (3) Evergreen broadleaf forest with poor quality (58 samples); (4) Recovering evergreen broadleaf forest (79 samples); (5) Deciduous forest (10 samples); (6) Bamboo forest (47 samples); (7) Mixed trees and bamboo forest (73 samples); (8) Coniferous forest (33 samples); (9) Mixed broadleaf and coniferous forest (25 samples); (10) Plantation forest (85 samples); (11) Vacant land (57 samples); (12) Water surface (25 samples); (13) Residential area (18 samples); (14) Agricultural land (93 samples).

Results of evaluate the accuracy: Overall accuracy of the interpretation results reached 82% and the coefficient Kappa K = 0.801. Deviations appear much in interpretation key numbers from 1 to 4, with producer accuracy ranging from 71% to 73% (Table 2). These are the keys for evergreen broadleaf forests, which are all difficult to interpret and confuse with each other. Key numbers 9 and 14 have the highest accuracy (94% and 92% producer accuracy). Other interpretation keys (numbers 7, 8, 10, 11, 12) all have relatively high accuracy (89 – 90% producer accuracy).

Establish forest map of Kontum province: From the results of satellite image interpretation, the forest status map of Kon Tum province in 2020 was established (Fig. 4). The

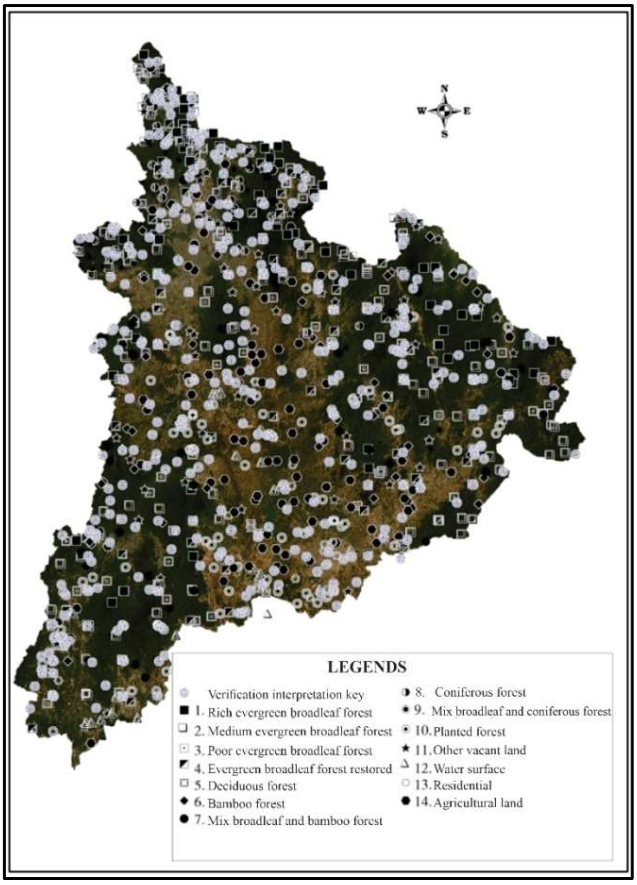

Fig. 3. Sample locations for interpretation and verification keys

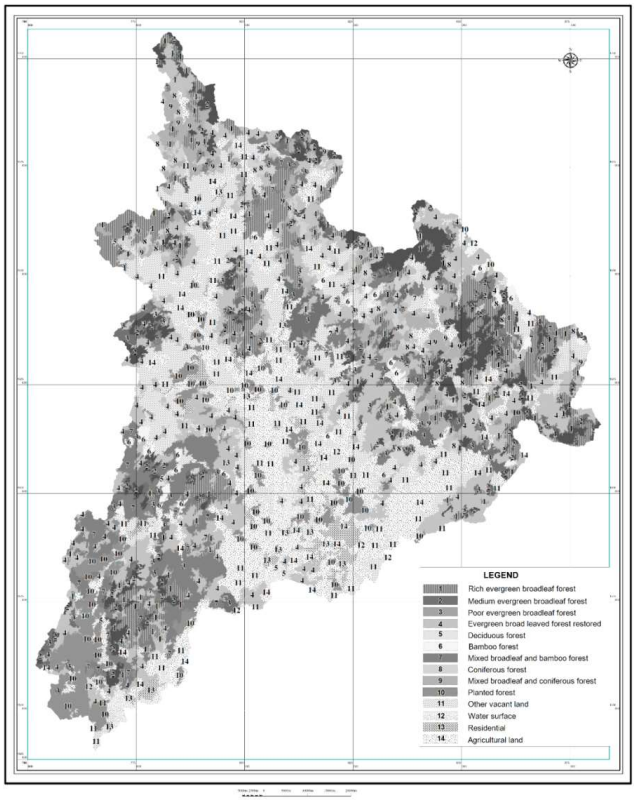

Fig. 4. Forest status map of Kontum province in 2020 established from planet remote sensing image data

vegetation cover of Kontum province has several forest types representing the plateau monsoon tropical climate: evergreen broadleaf tropical forest, deciduous forest (dipterocarp forest), coniferous forest, mixed broadleaf and bamboo forest, mixed broadleaf and coniferous forest. According to Table 3, the total area of vegetation cover including natural forest and plantation forest is 621 356.05 hectares. In which, natural forest area is 547 759.37 hectares (88%), plantation forest area is 73 596.68 hectares (12%). Of the natural forest types, evergreen broadleaf tropical forest occupies the largest area with 387472.09 hectares, over 70% of the total Kontum natural forest area. Mixed broadleaf and coniferous forests also cover a large area, with about 14% of the total natural forest area. The typical forest type for the high mountains in Kontum province is coniferous forest with an area of 30 143.05 ha, accounting for 5.5% of the total natural forest area.

To evaluate the quality of remote sensing Planet images, the results were compared with the data on the forest status map using SPOT and Sentinel 2 remote sensing images in the "Vietnam National Forest Inventory and Monitoring Program" (Fig. 5). The SPOT remote sensing image interpretation results are the official results used by the Ministry of Agriculture and Rural Development to statistic the forest area in Vietnam. The comparison results show that the deviation of remote sensing images for different forest types is small. According to Planet image, the natural forest area is about 56%, plantation forest accounts for about 8% and non-forest land is about 36%. This result is equivalent to the results of SPOT image interpretation (58%, 8% and 34%, respectively). Forest status data using remote sensing Planet image is more accurate than image Sentinel 2. For the results of forest status according to photo Sentinel 2, natural forest area is about 70%, plantation forest accounts for 3% and non-forest land about 27%. This result is much different from forest inventory data using SPOT remote sensing image. According to photo Sentinel 2, the result of natural forest area difference is 12%, plantation forest is 5% and non-forest land is 7% of total area compared to published forest inventory data.

The use of free charged remote sensing Planet image gives similar results when compared with forest inventory

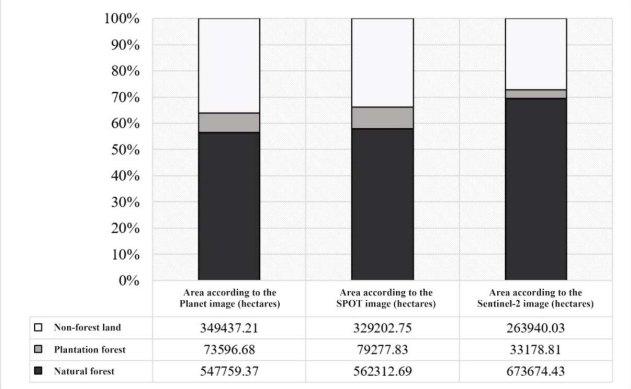

Fig. 5. Comparing forest status map data using different types of remote sensing images

Table 2. The confusion matrix between the classification results and the control key sample

	Ground truth														Evaluation			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total	Useraccuracy	Producer accuracy	Total
1	21	5													26	81%	72%	82%
2	4	20	1	1											26	77%	71%	
3	1	1	18	1											21	86%	72%	
4	2	1	3	19											25	76%	73%	
5			1	1	14	2									18	78%	78%	
6				1		12	1	1							15	80%	75%	
7				1	1	1	18	1							22	82%	90%	
8	1	1	1	1				17	1						22	77%	89%	
9					1	1	1		15		1				19	79%	94%	
10				1	1					16					18	89%	89%	
11			1		1					1	17		1		21	81%	89%	
12												17	2		19	89%	89%	
13												1	17	2	20	85%	81%	
14										1	1	1	1	23	27	85%	92%	
Total	29	28	25	26	18	16	20	19	16	18	19	19	21	25	299			

Table 3. Statistics of forest types of Kontum province based on map established from remote sensing Planet image in 2020

Interpretation key codes	Forest types	Area (hectares)	Interpretation key codes	Forest types	Area (hectares)
I	*Natural forest*	*547 759.37*	II	*Plantation forest*	*73 596.68*
1	Evergreen broadleaf forest with good quality	87 667.46	10	Plantation forest	73 596.68
2	Evergreen broadleaf forest with medium quality	73 793.95	III	*Non-forest land*	*349 437.21*
3	Evergreen broadleaf forest with poor quality	55 412.59	11	Vacant land	155 109.66
4	Recovering evergreen broadleaf forest	170 598.09	12	Water surface	14 862.45
5	Deciduous forest	2 067.18	13	Residential area	38 140.01
6	Bamboo forest	17 476.10	14	Agricultural land	141 325.09
7	Mixed broafleaf and bamboo forest	76 126.63	Total		970 793.26
8	Coniferous forest	30 143.05			
9	Mixed broadleaf and coniferous forest	34 471.33			

data using paid SPOT satellite image. This is considered a new direction in the mapping of forest status with free satellite image source, bringing high reliability in forest classification, management and protection.

CONCLUSION

In a total of 1200 interpretation keys, after removing the samples that do not meet the accuracy, the research team used 800 samples for image interpretation and 299 samples for verification. The interpretation keys for mapping forest status of Kon Tum province includes 14 types of forest statuses, of which 10 types of forest and 4 types of non-forest. After interpretation, the results of evaluating the accuracy and reliability by the confusion matrix reached the overall accuracy of 82%, the Kappa coefficient reached 0,801. All remote sensing images of the study area are divided into 30896 subjects. Based on the state of the decoding key set, these objects are classified into 14 different types of forest state with the help of eCognition Developer software based on the Random Forest classification method. The forest status map of Kon Tum province has been successfully developed with a total forest area of 621 356.05 hectares. In which natural forest area is 547 759.37 hectares (88%) and plantation forest area is 73 596.68 hectares (12%). High accuracy and K coefficient shows the feasibility and practical application of the research. The research results contribute to improving the application of remote sensing to develop forest status maps. Remote sensing Planet image is important data serving forest status mapping and assessment of forest changes over time. This is an important document in the management, conservation and development of forest resources.

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Groundwater Vulnerability Assessment by Using Drastic and God Methods

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Abstract: Vulnerability of groundwater to pollution was investigated for the optimum decision to provide the best options for stakeholders to use the suitable lands for plants and crop cover, in addition to establishing factories and industrial development areas based on the results of vulnerability maps. The aim was to choose the best method of assessment groundwater vulnerability in Teeb area, Missan province, and south of Iraq. Two models DRASTIC and GOD of vulnerability maps are analyzed using GIS techniques. DRASTIC vulnerability index (DVI) is computed as the weighted sum overlay of the seven layers. The final result of DRASTIC map ranges from 60 to 139, which represent very low to medium while the GOD vulnerability Index (GVI) is based on three parameters. GVI ranges from 0 to 1. The output of GOD map ranges from 0 to 0.6, which represent very low to high. The DRASTIC method includes three classes, for which the low class dominated most of the study area by 80.29% of the total area, while the GOD method represented four classes (very low, low, medium and high), the medium is the most prevalent in the study area with 54.12 % of the total area. Pearson correlation coefficient for DRASTIC and GOD were 73.05 and 49.79 per cent respectively. Therefore, the DRASTIC method is better for representing the vulnerability groundwater for contamination than the GOD method.

Keywords: Groundwater vulnerability, DRASTIC, GOD, GIS

The concept of the vulnerability of groundwater to contamination in its broader perspective indicates the extent to which the aquifer can be contaminated with pollutants on the earth's surface and arrival to the aquifer system (Agyemang 2017). If its arrival is easy, this indicates the high vulnerability of groundwater and on the contrary the low vulnerability indicates the difficulty of the arrival of pollutants due to the presence of natural factors provide relatively good protection. Groundwater as an important and supportive resource for surface water, which is declining due to high temperatures, increased evaporation rates in summer and reduced rainfall in winter, in addition to the policies of neighbor countries to construct dams on river sources, This in turn enhances the importance of groundwater and the ability to manage it in the best way. In recent decades, measures to protect this important resource through methods of assessing groundwater, are considered which in turn give optimal decision to decision makers on urbanization or the construction of sewage plants or agricultural land that would degrade the quality of groundwater. The assessment of groundwater vulnerabilities is carried out by Geographical Information System (GIS)-based qualitative methods, process-based methods and statistical methods. GIS-based qualitative methods include GOD, DRASTIC, SINTACS, EPIK, AVI, PI and GLA**.** In this study, qualitative methods such as DRASTIC and GOD are adopted (Ghazavi and Ebrahimi 2015). The study aim is to assess the groundwater vulnerability by choosing the best methods to be more realistic for management of the pollution of the area.

MATERIAL AND METHODS

Study area: The study area is located in the northeastern part of Missan Governorate, which constitutes an area estimated at 2450 km^2 out of the governorate's area of 16072 km^2. It represents the strategic depth of the Amara city, center of Missan Governorate. It is bordered to the north-east by the Iranian mountains, to the west by the administrative borders of Ali-Gharbi district, and to the south by Hor Al-Sanaf between longitudinal-line (47°39 11″- 47°55 ′1″) and latitude-line (32°29′ 47″- 31°58′ 16″). Mostly, the study area is characterized by its plain nature and the cultivated crops include wheat and barley based on economic return. For irrigation depends on the rainwater of wet seasons and on the wells in the dry seasons. Despite the existence of two rivers, Teeb and Duriage rivers, the receding of waters level, especially in the summer the attention must be paid to assess the vulnerability of groundwater for optimal management.

DRASTIC and GOD which are used in this study to identify the most prone area to pollution and comparison between two methods to choose the best one in real representation of the area pollution represented by the nitrate concentration (Machdar et al 2018 and Oroji 2018).

Drastic method: This method adopts seven layers, each layer represents the first letter of it, and each layer has its own

rate ranging from 1 to 10, while the weight for each layer ranges from 1 to 5 representing developed by the US Environmental Protection Agency (USEPA) by (Aller et al 1987). The DRASTIC Vulnerability Index (DVI) is obtained from the assemblage of the rate and weight for each of the seven parameters according to the following linear equation.

$$DVI=D_r \times D_w + R_r \times R_w + A_r \times A_w + S_r \times S_w + T_r \times T_w + I_r \times I_w + C_r \times C_w \quad (1)$$

Where D_r, R_r, A_r, S_r, T_r, I_r ^ C_r are rating for the depth to water table, aquifer recharge, aquifer media, the soil media, topographic (slop), vadose zone, and hydraulic conductivity. D_w, R_w, A_w, S_w, T_w, I_w ^ C_w are weights assigned to the depth to water table, aquifer recharge, aquifer media, soil media, topography, vadose zone, and hydraulic conductivity.

The required data are calculated from different sources such as field work, well logs, soil survey and geological maps and hydro-geologic reports available in Groundwater Directorate in Missan province 35 selected wells were measured by the sounder device. The depth ranged from (zero to twenty-nine meter). There groundwater recharge is calculated with WetSpass model (Salih 2020). By finding an average of the 12 input layers for each month and analyzing the resulting layer through the technique within the GIS environment. WetSpass model reduces uncertainty and reliability not only for spatial distribution of recharge but also for hydraulic conductivity and ultimately simulate the transport of pollutants. All the recharge values ranges from (zero to sixteen mm/year) which are less than 50 mm/year so it is classified as one rating.

Based on the geological map of the basin and drilling well logs to produce spatial variation of the aquifer media shows that two classes in the study area sand and gravel and shale. Twenty Soil samples are collected from the al-Teeb area randomly distributed and at a depth of 30 cm and tested by Hydrometer test. Soils are classified to three types (sand, sandy loam and loamy sand). The topography of the area refers to the slope of the surface area by per cent. Topographic map is constructed from digital elevation model (DEM) with accuracy of (30 m). Four classes of topographic map range from 0-2, 2-6, 6-12, 12-18 per cent as in Aller tables. Low slope (0-2) % is occupied most study area by (86%) as rated 10 which more potential of groundwater pollution. Remaining slopes (2-6, 6-12,12-18) are occupied low percentage of study area by (11%, 2% and 1%) respectively. Four segments of vadose zone are (sand, gravel, sand & gravel, and clay) classes. Hydraulic conductivity varies (2.19 to 12.87 m/day) as shown in Table 1, Figure 1.

God method: This method was advanced in England by (Foster 1987) is a swift estimate of groundwater vulnerability

Table 1. Parameters used in drastic

Parameters	Units	Range	Rating	Percentage	Relative weight
Depth to groundwater	m	0-1.5	10	1`	5
		1.5-4.5	9	6	
		4.5-9	7	71	
		9-15	5	18	
		15-23	3	3	
		23-29	2	1	
Net recharge	mm/year	< 50	1	100	4
Aquifer media		Sand & Gravel	8	70	3
		Shale	6	30	
Soil media	-	Sand	9	45	2
		Sandy Loam	6	3	
		Loamy Sand	7	52	
Topography	%	0-2	10	86	1
		2-6	9	11	
		6-12	5	2	
		12-18	3	1	
Impact of Vadose Zone	-	Gravel	9	1	5
		Sand&Gravel	8	6	
		Sand	7	74	
		Silt/ Clay	3	19	
Hydraulic conductivity	m/day	Less than 4	1	31	3
		4.0 -12	2	69	

as a result of its reliance on three hydrogeological parameters of any study area and represents abbreviated three characters GOD, here G represents groundwater occurrence, O lithology of unsaturated zone (overall aquifer class), and D r aquifer depth.

$$GVI = G_r \times O_r \times D_r \quad (2)$$

Where the symbol r is the rating of the three parameters mentioned above. The ratings used for the parameters range from 0 to 1 (Table 2, Fig. 2).

RESULTS AND DISCUSSION

The final vulnerability DRASTIC and GOD maps are illustrated Figure 3 and 4, respectively. DRASTIC map shows three classes ranges from very low to medium which scores ranged from 60 to 139, respectively, (Fig. 5). The final vulnerability map is obtained by the DRASTIC technique that varies from (60 to 139) (Fig. 3). About 80.29% of study area is classified under low vulnerability; the remaining 7.84 and 11.87% are under very low and moderate vulnerability respectively (Table 3). The DRASTIC parameters mean shows that the highest contribution to the vulnerability index is made by slope and soil media (mean = 10) followed by aquifer media by (mean = 7.40) and depth (mean= 6.58). Hydraulic conductivity and recharge mean of 1.69 and 1, respectively contribute lowest to the contamination of groundwater. The coefficient of variations indicates a high contribution to the variation of vulnerability index is made by hydraulic conductivity (27 %), then by vadose zone (26%) (Table 4). GOD vulnerability map depicts four classes ranges from very low to high which represents scores from 0.0 to 0.6 (Fig. 6). Medium vulnerability zone is dominated in study area occupied by 54.12% of area while the low vulnerability area was occupied by 44.32% and high vulnerability area represents the remaining percentage of study area (Table 5). The means shows that groundwater occurrence and depth to groundwater were the highest by mean of 0.8. Then over all lithology mean was 0.58. The coefficient of variations shows that groundwater occurrence is higher than other parameters by 20%, followed by overall lithology 14% and the remaining represents 8.5% depth groundwater (Table 6). There is no fixed model that meets all the requirements of the hydrological environments due to the different nature and study area. The model must therefore be adjusted to suit the needs of the study area. The choice of the right model depends on several factors, the most important of which is the availability of data, hydrological setting and the final use of the map. Nitrate concentration was used to verify the accuracy of groundwater risk map as a basis for comparison between different models where Pearson coefficient was employed for this purpose. Pearson's correlation coefficients

Table 2. Parameters used in GOD method

Parameters	Range	Rating	Percentage
Groundwater occurrence	Unconfined	1	83
	Semi-confined	0.3	16
	Confined	0.2	1
Overlaying lithology	Unconsolidated sediment	0.4	17
	Consolidates dense rocks	0.7	81
		0.8	2
Depth to groundwater (m)	<2	1	1
	2-5	0.9	21
	5-10	0.8	44
	10-20	0.7	31
	20-50	0.6	3

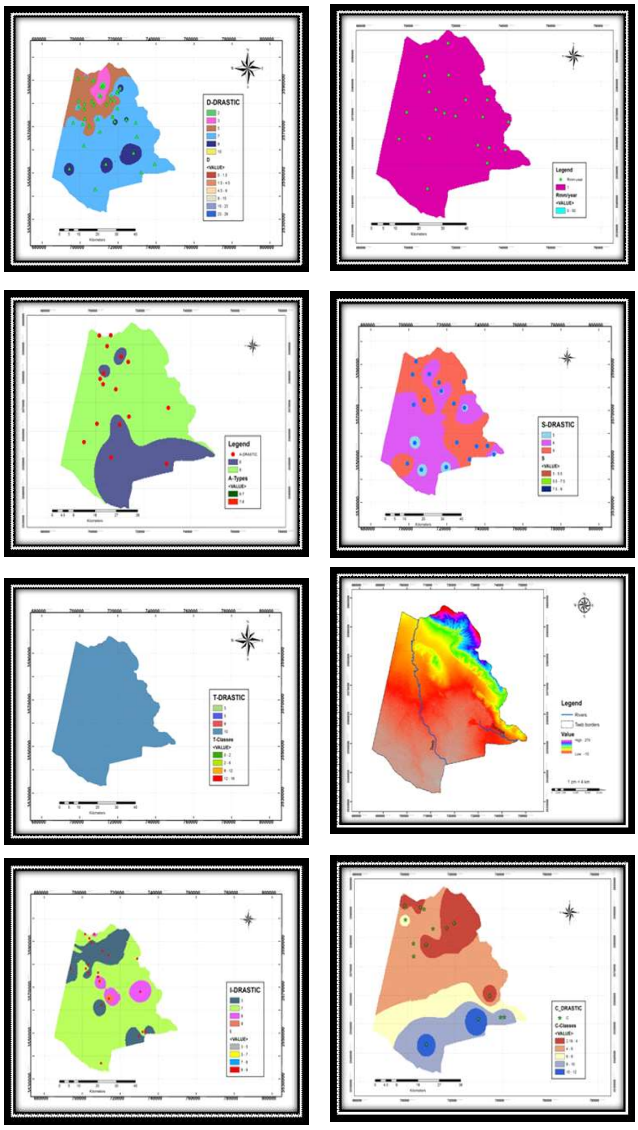

Fig. 1. The range and rating of parameters used in DRASTIC method

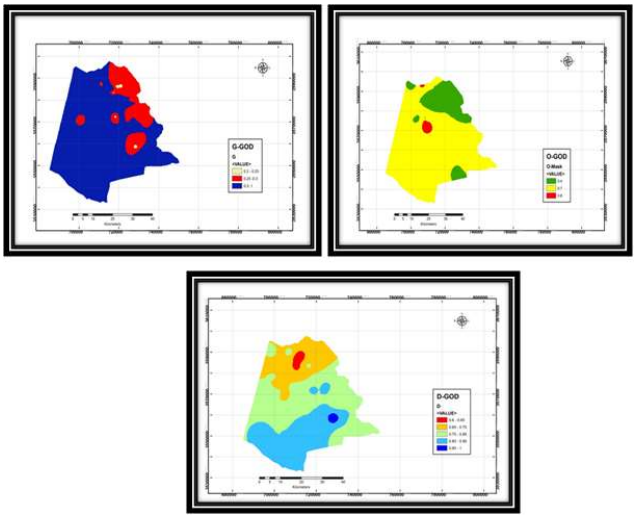

Fig. 2. Parameters of GOD methods

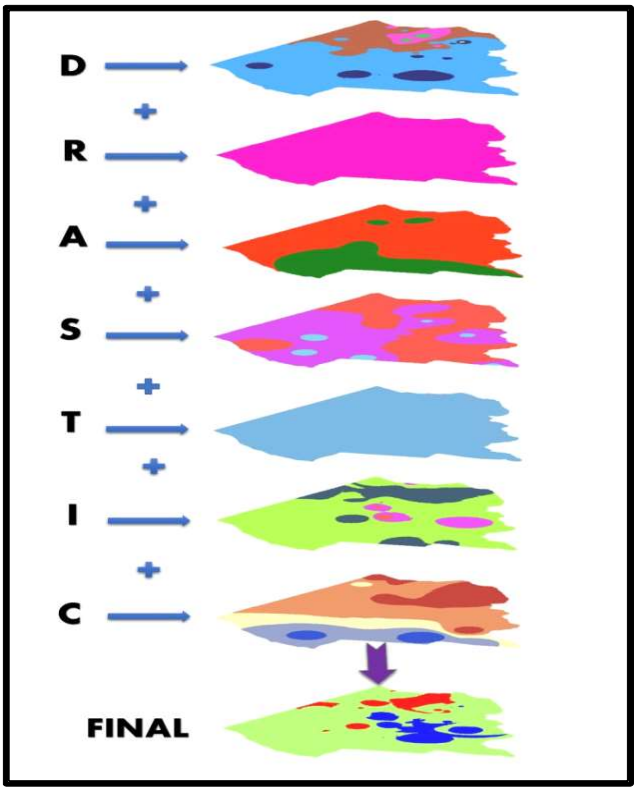

Fig. 3. DRASTIC parameters

for comparing each vulnerability map with the rate of nitrate concentration as spatial distribution map was 73.05and 49.79 per cent for DRASTIC and GOD, respectively. DRASTIC vulnerability map appears more interconnected than GOD and represented the best technique for evaluating vulnerability map in the study area which can be recommended (Fig. 7).

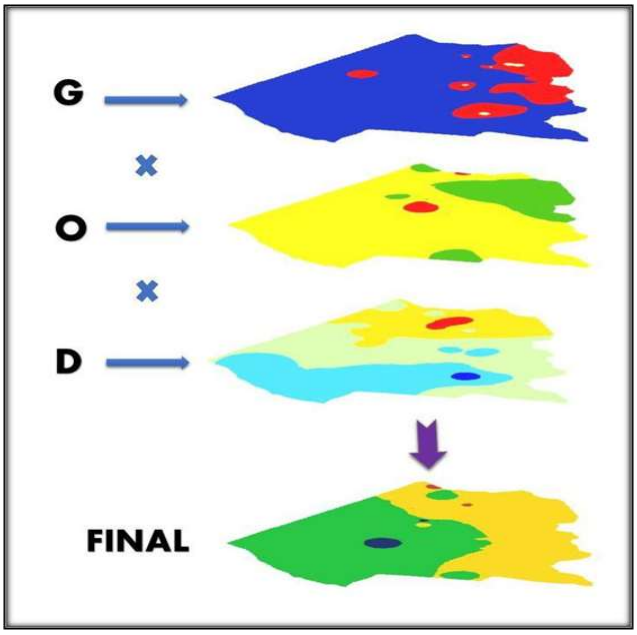

Fig. 4. GOD parameters

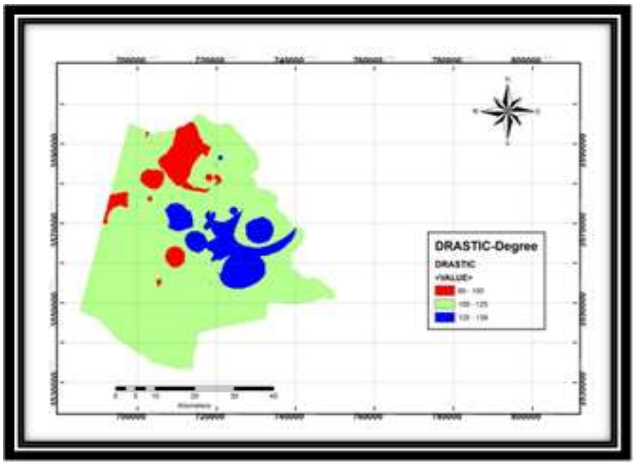

Fig. 5. DRASTIC vulnerability map

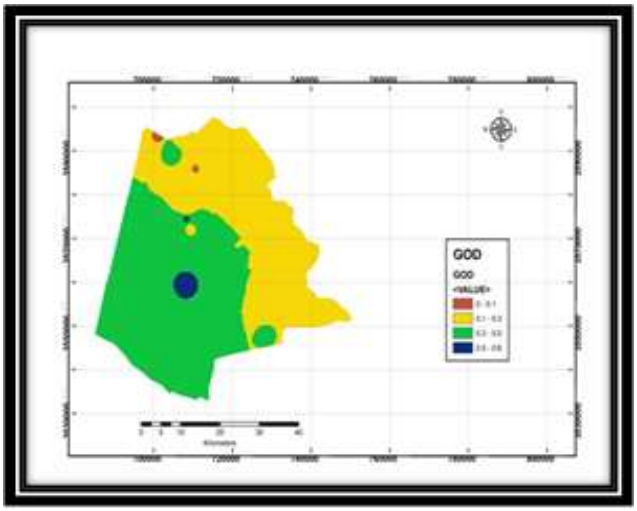

Fig. 6. GOD vulnerability map

Table 3. Percentage of each zone of DRASTIC vulnerability

Vulnerability zone	From	To	Area (Km^2)	Percent
Very low	60	100	190.17	7.84
Low	100	125	1948.5	80.29
Medium	125	139	288	11.87

Table 4. Statistical analysis of the seven parameters

Parameters	Weights	Minimum	Maximum	Mean	SD	Cv (%)
D	5	2	10	6.58	1.25	19
R	4	1	1	1	0	0
A	3	6	8	7.4	0.92	12
S	2	3	10	10	0	0
T	1	3	10	10	0	0
I	5	3	9	6.3	1.63	26
C	3	1	2	1.69	0.46	27

Table 5. Percentage of each zone of GOD vulnerability

Vulnerability zone	From	To	Area (Km^2)	Percent
Very low	00	0.1	7.21	0.29
Low	0.1	0.3	1086.18	44.32
Medium	0.3	0.5	1326.4	54.12
High	0.5	0.6	31.98	1.3

Table 6. Statistical analysis of the GOD parameters.

Parameters	Minimum	Maximum	Mean	SD	Cv
G	0.2	1	0.8	0.16	20
O	0.3	0.9	0.58	0.08	14
D	0.6	1	0.8	0.068	8.5

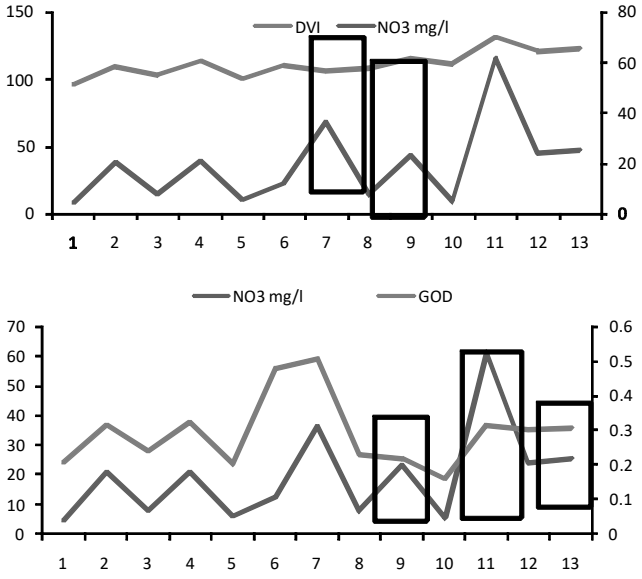

Fig. 7. Spatial variability of nitrate

CONCLUSION

DRASTIC technique that varies from 60 to 139. The area under low vulnerability was 80.29 prevent followed by 7.84 and 11.87 per cent under very low and moderate vulnerability respectively while the final vulnerability map obtained by the GOD technique t varies from 0.0 to 0.6. About 54.12% of study area is classified under moderate vulnerability, the remaining 44.32% and 1.3% are under low and very low vulnerability, respectively. Pearson's correlation coefficients for comparing each vulnerability map with the rate of Nitrate concentration as spatial distribution map as follows 73.05, 49.79 per cent for DRASTIC and GOD, respectively. So, that DRASTIC is the best technique for evaluating Vulnerability map is recommended in the study area.

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Flood Vulnerability Mapping using Frequency Ratio Model and Dempster Shafer Theory: A Case Study on Devikulam and Udumbanchola Taluks of Ldukki District, Kerala, India

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***Abstract*:** Each year floods triggered by heavy monsoon rains have displaced millions of people in India, Nepal and Bangladesh in the north and Kerala in south. Vulnerability helps us to find the degree to which the area is susceptible to flooding. In this study flood vulnerability mapping was done for Devikulam and Udumbanchola taluks of Idukki district in Kerala state. The factor taken for this study are land use, drainage density, lineament density, soil, slope, rainfall, geology and geomorphology. Thematic maps of these factors were prepared from satellite images and field data using ARCGIS 10.5. Frequency ratio model and Dempster Shafer Theory were used to map the vulnerability of flood in the taluks of Idukki district. The flood vulnerability map of the region was divided in to low, medium, high and very high vulnerable area by using both the models. The results of the models were validated using the past flood occurred locations. 24.92% of the study area falls under very high flood susceptibility region and 25.75% of the area falls under high flood susceptibility region. Frequency ratio provided 75% prediction accuracy and Dempster Shafer Theory showed higher prediction accuracy (80%). These results obtained can be used for the planning and management of the areas vulnerable to floods and prevent flood-induced damage.

Keywords: Rainfall, Slope, Soil, Flood, Remote sensing and GIS

The flood is an inevitable phenomenon which occurs over a period displacing millions of people every year. During a heavy rainfall event, the flood plain as well as its surrounding area is covered by the water which rises above the normal bed. This mainly occurs due to the rapid increase in the amount of flow discharge in a river (Ahmed 2013). Flood hazard can be classified in to primary hazards that occur due to contact with water, secondary effects that occur because of the flooding. The hazards have many aspects like structural and erosion damage, contamination of food and water, disruption of socio-economic activity, communication, loss of life and property (Ellakkia 2020). India embraces flood event during every monsoon period and suffers from irrecoverable damages. India is considered as one of the worst flood affected country. Kerala receives heavy rainfall during the monsoon which causes flooding in the local region. On 16 August 2018, kerala was severely flooded due to unusually high rainfall during the monsoon season and 35 out of 54 dams had to be opened due to heavy rainfall, flooding local low-lying areas. Over 483 people died and about a million were excavated. Idukki is one of the districts in kerala which receives high rainfall during the monsoon. Idukki received about 129.80 mm rainfall. It was estimated that 161 properties including houses were buried under landslides and 400 houses were completely destroyed. Devikulam and Udumbanchola taluks are the worst affected taluks in Idukki district.Hence assessing the probability of flooding and susceptibility of Kerala to flood hazard has become a vital part of development and planning. The purpose of this research work is to identify the flood vulnerable area in Devikulam and Udumbanchola taluks of Idukki district. In natural hazard modelling different qualitative or quantitative approaches are used. Different researchers had used different ecological modelling approaches to map the vulnerability of flood prone areas such as frequency ratio (Tehrany et al 2015), support vector machine (Tehrany et al 2018), artificial neural network (Vijay et al 2016) and fuzzy analytical hierarchy process (Pratibha et al 2018). This study aims to generate accurate flood vulnerability mapping using frequency ratio and Dempster Shafer model.

MATERIAL AND METHODS

Study area: Kerala is a southern state of Indian located in the southwestern Malabar Coast. The study areas of this research work are Devikulam and Udumbanchola taluks, Idukki District, Kerala. Both the taluks are the worst affected taluks by the flood and is located between North latitudes 9º16' 30" and 10º21'00", East longitudes 76º 38' 00" and 77º24'30". Both the taluk has a notably diverse flora and fauna. The base map for the study area is extracted from the topo sheet map obtained from Survey of India (Fig. 1).

Fig. 1. Base map of the study area

Flood inventory: A flood inventory map was created by mapping the flood location in Devikulam and Udumbanchola taluk using documentary sources and field survey and was divided in to two groups training and testing. The training set of data is used for the flood conditioning layers which were considered dependent factor. The test data set is used for the purpose of validation of the result.

Flood conditioning factors: In this study a total of eight parameters were considered for flood susceptibility mapping such as land use, geology, geomorphology, drainage density slope, soil, lineament density and rainfall intensity. The spatial data base related to these conditioning factors was compiled. After preparing the data base all the conditioning factors were transformed in to grid data base. Topographic map of high precision has direct impact on the output of the modelling (Tehrany 2015). The digital elevation model is used to obtain the conditioning factors like slope and drainage. Quantile method is used to classify these conditioning factors. The slope is finally divided into 5 classes as very low, low, medium, high and very high. Drainage density can be defined as the total length of all the streams and a river in a drainage basin divided by the total area of the drainage basin and was classified as very low, low, medium, high and very high. Geology map is generated by the data collected from Geological Survey of India. This map shows the rock formation present in the study area. The maximum area is covered by peninsular gneissic and khondalite rock and lesser by acidic rock. Lineament data was generated from LISS IV and created from SRTM DEM. The study area includes structural and geomorphic lineament. Lineament density is calculated from the extracted lineament lines and was classified using quantile method into five classes very low, low, medium, high and very high. Rainfall is the important hydrological element contributing to the flood event. The rainfall data is collected from Indian Meteorological Department Trivandrum. The records of monthly rainfall were obtained from 3 rain gauge stations namely Devikulam, Udumbanchola and Idukki. The rainfall map was prepared by using ArcGIS with 2018 rainfall data. Rainfall map is categorized into five classes very low, low, medium, high and very high. Soil map shows surface property of study area. Soil map was obtained from soil survey of India (SSI). Study area is mostly covered by clay.

The drainage lines were delineated from an accurate topographic map and was used to calculate the drainage density and is also classified using the quantile method in to five classes very low, low, medium, high and very high. Land use map of this study area is generated from LISS IV satellite image. The study area is divided into five categories such as water body, forest, agriculture, built-up and scrubland. The 62 percent of the study area is covered by agriculture and forest area. Built up area covers 21% of the study area.

Statistical Analysis

Frequency ratio model: Frequency ratio model is applied to evaluate the flood vulnerability of the study area. The spatial relationship between the past flood occurred locations and a set of flood conditioning factors is assessed using this model. The frequency ratio model for the study area is carried out as a ratio of the probability of presence or absence of flood occurrence for each conditioning factor. Ratio value greater than one indicates that there is strong relationship between the conditioning factor and the probability of occurrences of the flood and ratio value less than 1 indicates the relationship between the conditioning factor and the probability of occurrences of the flood is week (Sarkar et al 2020).

$$FR = \frac{N_i^p / N}{N_i^{fp} / N^f} \qquad (1)$$

Where, N^p_i = Number of pixels in each flood conditioning factor class

N = Total Number of all pixels in the study area

N^{fp}_i = Number of flood pixels in each flood conditioning factor class

N^f = Total number of all flood pixels in the study area.

Dempster-Shafer theory of evidence model: In the study

area, the four series of mass functions of Dempster-Shafer theory of evidence which are namely Belief (Bel), Disbelief (Dis), uncertainty (Unc) and plausibility (Pls) were calculated using the below functions. The properties of these functions are explained as below:

$$Bel(H) \leq Pls(H) \quad (2)$$

$$Pls(H) = 1 - Bel(H) \quad (3)$$

Where, H indicates the negative form of H and Belief H indicates the Disbelief function. The difference between Belief and Plausibility gives the degree of uncertainty. The clear details of the basic equations needed to establish the evidential belief mass functions and the equations are given below from equation 4 to equation 13. These equations of mass functions quantify the relationship between flood occurred locations and the factors controlling the flooding event in the study area. The algorithm of likelihood ratio function is used in this model.

If i number of conditioning factors are considered in a study area then each layer will have evidence E_i for the target proposition T_P. If E_{ij} is the evidence of the j^{th} class attribute of a particular conditioning factor then the likelihood ratio which supports the positive target proposition is given by the equation below

$$\lambda(T_p)_{Eij} = \frac{N(L \cap E_{ij})}{N(L)} \quad (4)$$
$$\frac{N(E_{ij}) - N(L \cap E_{ij})}{N(A) - N(L)}$$

Where, N (L) is the total number of flooded location, N ($L \cap E_{ij}$) is number of flooded locations occurred in E_{ij}, N (E_{ij}) is the number of pixels in E_{ij} and N (A) is the total number of pixels in the study area.

The belief function is given by the equation below.

$$Bel = \frac{\lambda(T_p)E_{ij}}{\sum \lambda(T_p)E_{ij}} \quad (5)$$

Equation 6 is used to calculate the likelihood ratio for the opposite target proposition. The disbelief function is derived from the equation 7. The equation 8 gives the disbelief function.

$$\lambda(\overline{T}_p)_{Eij} = \frac{N(L) - N(L \cap E_{ij})}{N(L)} \quad (6)$$
$$\frac{N(A) - N(L) - N(E_{ij}) + n(L \cap E_{ij})}{N(A) - N(L)}$$

$$Dis = \frac{\lambda(\overline{T}_p)E_{ij}}{\sum \lambda(\overline{T}_p)E_{ij}} \quad (7)$$

Plausibility function is calculated from the equation 8. The uncertainty function is the difference between the plausibility function and the belief function. From the equation 8 and 9 it is clear that sum of the belief, uncertainty and disbelief is equal to one. The value of belief and plausibility ranges from 0 to 1.

$$Pls = 1 - Dis \quad (8)$$

$$Unc = Pls - Bel \quad (9)$$

After calculating the four mass functions for all the conditioning factors considered the Dempster's rule of combination is used to estimate the integrated mass functions (Dempster 1968). The combination rule used in this research work to combine two conditioning factors A and B is given below

$$Bel_x = \frac{Bel_A Bel_B + Bel_A Unc_B + Bel_B Unc_A}{\beta} \quad (10)$$

$$Dis_x = \frac{Dis_A Dis_B + Dis_A Unc_B + Dis_B Unc_A}{\beta} \quad (11)$$

$$Unc_x = \frac{Unc_A Unc_B}{\beta} \quad (12)$$

$$Pls_x = Unc_x + Bel_x \quad (13)$$

X denotes each conditioning factor considered in this study. Normalization factor which is also known as the degree of conflict is represented as β. George and pal 1996 defined β as an expression used to measure the degree of conflict between the pieces of evidence. The mathematical expression of β given below

$$\beta = 1 - Bel_A Dis_B - Dis_A Bel_B \quad (14)$$

RESULT AND DISCUSSION

Frequency ratio model: The frequency ratio analysis was able to derive the relationship between the flood occurrences and the classes of each conditioning factors. Slope is cited as the most influencing factor in flood studies (Mojaddadi et al 2017, Tehrany et al 2018). The medium slope region shows high frequency ratio of 1.879, which indicates that the medium slope regions have high probability of flooding event. The very high slope region showed the lowest probability (0.697) of flooding event. Similarly, the area with medium drainage density showed high frequency ratio (2.154) indicating high probability of flood. The rainfall intensity is the important conditioning factor to predict the flooding event. In this research work area with high rainfall intensity shows the highest frequency ratio of 1.887. The area with Gravelly clay soil has high frequency ratio of 1.021 and Gravelly loam type soil showed zero probability for flooding event. Region with Charnokite rock showed highest probability for the flooding event with the frequency ratio value of 1.535 and migmatite type of geology had the lowest probability for the flooding

event with the frequency ratio of 0.624. The dissected middle plateau has the highest frequency ratio of 1.468 in the geomorphologic conditioning factor. The land use and land cover has a strong relationship with the probability of occurrence of flooding. The land with vegetation cover has the lowest frequency ratio i.e. agricultural land and scrubland has the lowest frequency ratio of 0.765 and 0.899 respectively. This proves that the vegetation cover controls the rapid flow of the water and there by decreases the potential of flooding over that area. On contrary, the barren and built up region show high frequency ratio. The built up area is mostly covered by the impervious layer and there is no possibility for infiltration which makes the region more susceptible to flooding. The flood vulnerability map generated using frequency ratio model is presented in Figure 3.

Dempster-Shafer theory of evidence model: The Dempster Shafer Theory is used to analyze the area for flood vulnerability. The accuracy of the Dempster Shafer Theory is greatly enhanced by the uniqueness of this model to predict the uncertainty using the uncertainty mass function (Evany et al 2018). From the result it is found that the factors which has high belief function value has the low disbelief function value and vice versa. The region with high belief function value and low disbelief function value has the highest probability for the occurrence of flood. The region with medium slope has high belief value of 0.301 i.e high probability for flooding event. Similarly, the area with medium drainage density showed

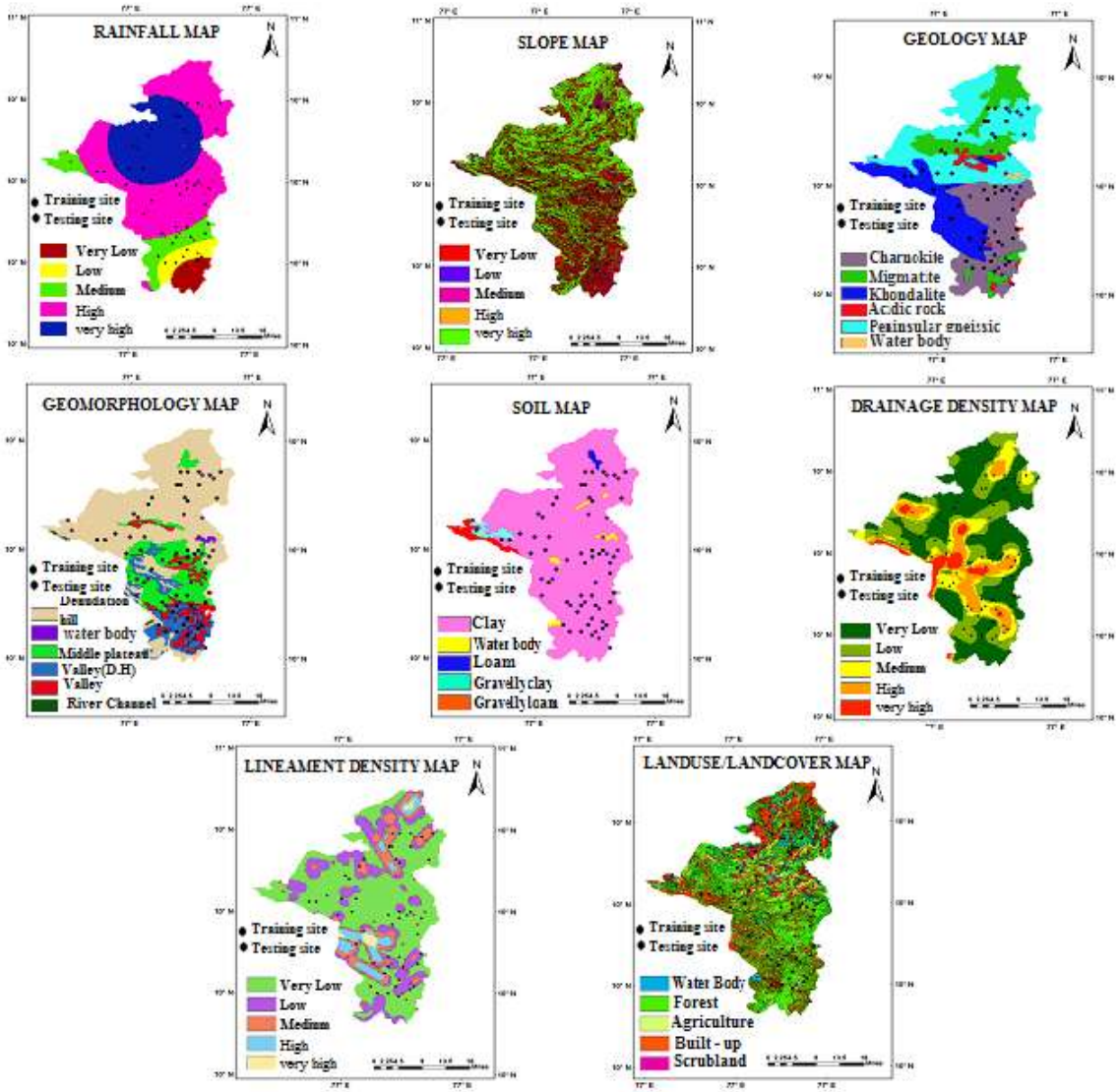

Fig. 2. Thematic layers: Rainfall map, slope map, geology map, geomorphology map, soil map, drainage density, lineament density, land-use / land-cover

Table 1. Results of FR and DS theory foreach flood conditioning factors

Category	No. of pixels	Pixel (%)	No .of flood location	Flood location (%)	Frequency ratio	Dempster shafer mass functions			
						Belief	Disbelief	Uncertainity	Plausibility
Slope									
Very low	60538	2.67	1	2	0.749	0.240	0.195	0.566	0.806
Low	158574	7.01	4	8	1.143	0.183	0.195	0.622	0.806
Medium	337449	14.90	14	28	1.879	0.301	0.167	0.532	0.833
High	667976	29.49	15	30	1.020	0.163	0.196	0.641	0.804
Very high	1039628	45.91	16	32	0.697	0.112	0.248	0.64	0.752
Drainage density									
Very low	7294	43.27	16	32	0.739	0.143	0.236	0.621	0.764
Low	4451	26.40	10	20	0.756	0.147	0.214	0.639	0.786
Medium	2348	13.93	15	30	2.154	0.419	0.160	0.421	0.84
High	2027	12.02	9	18	1.497	0.291	0.184	0.525	0.816
Very high	734	43.55	0	0	0	0	0.206	0.794	0.794
Lineament density									
Very low	23794	60.62	24	48	0.792	0.194	0.257	0.549	0.743
Low	8962	22.83	19	38	1.667	0.408	0.156	0.436	0.844
Medium	3663	9.33	6	12	1.286	0.316	0.188	0.496	0.812
High	2343	5.96	1	2	1.626	0.083	0.203	0.714	0.797
Very high	486	1.23	0	0	0	0	0.197	0.803	0.803
RainfalL									
Very low	763	4.5	2	4	0.889	0.154	0.199	0.647	0.801
Low	903	5.3	5	10	1.887	0.327	0.189	0.484	0.811
Medium	1756	10.41	6	12	1.153	0.200	0.195	0.605	0.805
High	8500	50.4	24	48	0.952	0.165	0.208	0.627	0.792
Very high	4932	29.26	13	26	0.889	0.154	0.208	0.638	0.792
Soil									
Clay	16167	94.01	48	96	1.021	0.278	0.146	0.576	0.854
Water body	231	1.34	1	2	1.538	0.419	0.214	0.367	0.786
Loam	90	0.52	0	0	0	0	0.212	0.788	0.788
Gravelly clay	317	1.84	1	2	1.087	0.303	0.214	0.482	0.786
Gravelly loam	392	2.28	0	0	0	0	0.215	0.785	0.785
Geology									
Charnockite rocks	4481	26.06	20	40	1.535	0.317	0.135	0.548	0.865
Migmatite	2752	16.01	5	10	0.624	0.129	0.178	0.693	0.822
Khondalite rocks	3255	18.93	12	24	1.268	0.262	0.156	0.582	0.844
Acidic rocks	460	2.6	1	2	0.769	0.154	0.167	0.679	0.833
Peninsular rocks	6168	35.88	12	24	0.668	0.138	0.197	0.665	0.803
Water body	73	0.4	0	0	0	0	0.167	0.833	0.833
Geomorphology									
Denudation hills	11112	64.84	25	50	0.771	0.149	0.228	0.623	0.772
Water Body	73	0.4	0	0	0	0	0.161	0.839	0.839
Dissected middle plateau	2803	16.35	12	24	1.468	0.284	0.145	0.571	0.855
Valley (denudation hill)	1803	10.52	7	14	1.331	0.258	0.154	0.588	0.846
Valley	1290	7.5	6	12	1.6	0.309	0.152	0.539	0.848
River Channel	56	0.3	0	0	0	0	0.162	0.84	0.84
Land use/Land cover									
Water Body	244435	10.37	7	14	1.35	0.202	0.190	0.608	0.81
Forest	824056	34.97	16	32	0.915	0.137	0.207	0.656	0.793
Agriculture	677294	28.74	11	22	0.765	0.115	0.217	0.668	0.783
Built-up	496598	21.07	9	18	2.854	0.434	0.206	0.666	0.794
Scrubland	113890	4.83	7	14	0.899	0.128	0.179	0.387	0.821

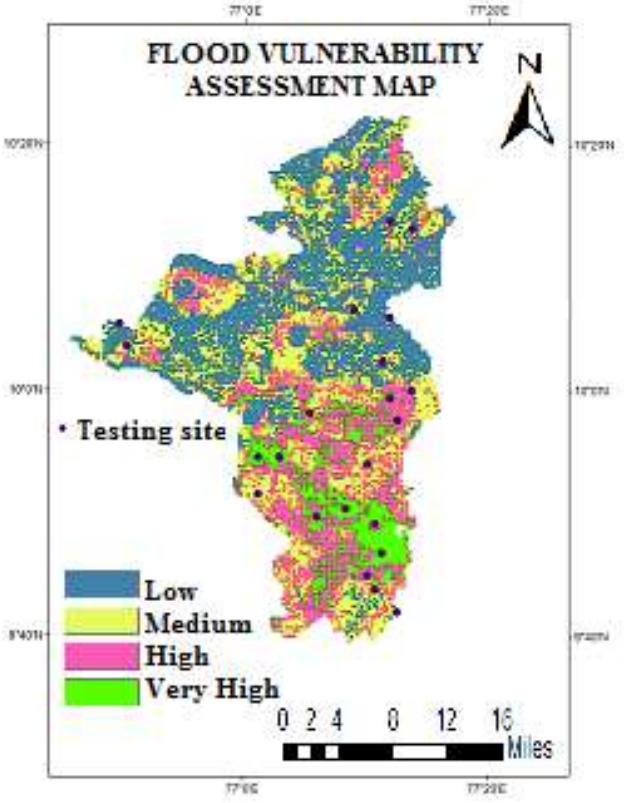

Fig. 3. Flood vulnerability assessment map derived using frequency ratio model

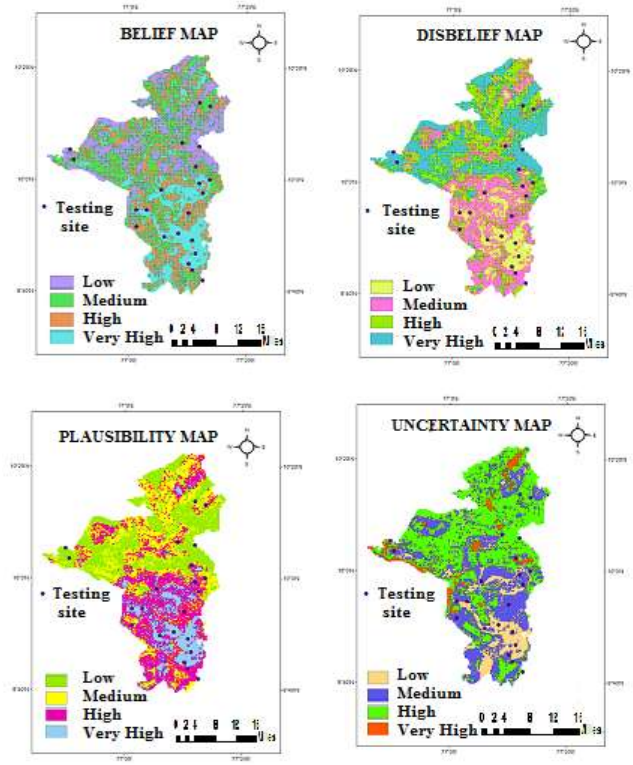

Fig. 4. Belief map, disbelief map, plausibility map and uncertainty map

high belief value of 0.419 and low disbelief value of 0.16 revealing a strong relationship between the flooding and medium drainage density. When the mass functions were calculated for the lineament density the region with low lineament density showed high belief of 0.408 and low disbelief of 0.156. This output indicates that the area with low lineament density has high probability for the occurrence of flooding event. The area with gravelly clay soil has high belief value indicating high probability for flooding event. When geology of the area was analysed, the results were similar to the frequency ration model i.e charnokite rock showed high probability for flooding event with high belief value of 0.317 and low disbelief value of 0.135. In case of land use / land cover the results were similar to frequency ratio model i.e. the agricultural land has low belief value and high disbelief indicating that land covered with vegetation is an effective method for flood mitigation. The belief function map is most appropriate map in evaluating flood vulnerability assessment. The belief values are series of continuous values that ranges from (1.62-3.144). This index predicts the probability of occurrence of flooding for the considered set of conditioning factors and it is classified into 4 classes as low, medium, high and very high using quantile method. Thus the map representing the belief mass function of the entire conditioning factors gives the flood vulnerability assessment

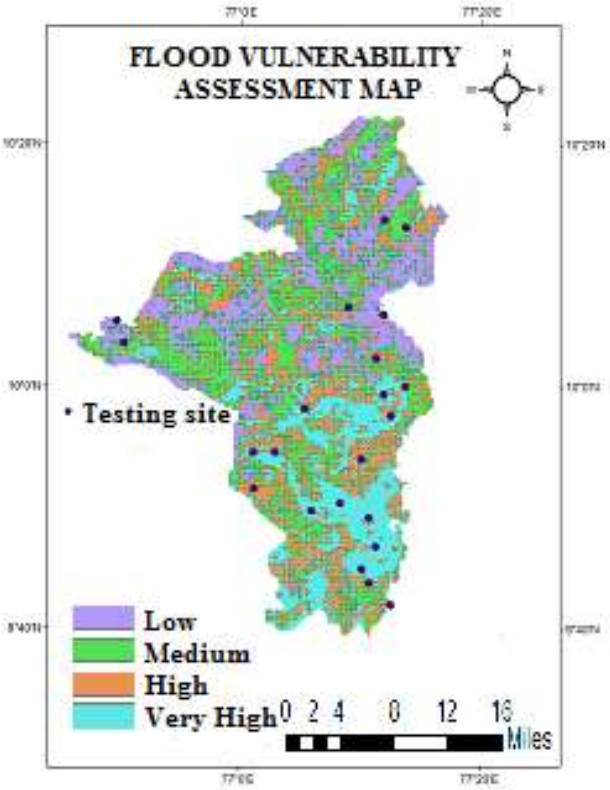

Fig. 5. Flood vulnerability assessment map derived using Dempster Shafer Theory

Table 2. Validation of flood vulnerability assessment

Flood vulnerability Index	Flood occurrence location in case of FR	Flood occurrence location in case of FR (%)	Cumulative flood occurrence (%)	Flood occurrence in case of DS	Flood occurrence location in case of DS (%)	Cumulative flood occurrence (%)
0-0.1	1	5	100	1	5	100
0.1-0.2	1	5	95	1	5	95
0.2-0.3	2	10	90	1	5	90
0.3-0.4	1	5	80	1	5	85
0.4-0.5	1	5	75	2	10	80
0.5-0.6	3	15	70	3	15	70
0.6-0.7	2	10	55	2	10	55
0.7-0.8	1	5	45	1	5	45
0.8-0.9	3	15	40	4	20	40
0.9-1.0	5	25	25	4	20	20

map. The flood vulnerability map produced using Dempster Shafer is shown in Figure 5.

Validation: Validation is an important part of the analysis to find the prediction accuracy of the models. In order to find the prediction accuracy initially the flood vulnerability index of the Frequency Ratio and Dempster shafer model are converted into values between 0 to 1 using linear Fuzzy Membership function for the purpose of comparison. After the conversion of values from 0 to 1, the values are classified into ten classes with an interval 0.1. Then validation is performed using the flood inventory map. The percentage of occurrence of flood in each class is calculation and shown in Table 3.

The cumulative percentage of flood occurrence for the vulnerability index is calculated for both the frequency ratio model and Dempster Shafer Theory model. Then the flood location data set separated for the validation purpose was overlaid on the flood susceptibility map generated using frequency ratio method and Dempster Shafer Theory model to analyze the accuracy of the results. In frequency ratio method 75 percentage of the flood locations were in the region with high susceptibility to flood. Similarly in case of Dempster Shafer Theory model 80 percentages of the flood locations were in the region with high susceptibility to flood. These results prove that the Dempster Shafer Theory is more accurate than the frequency ratio model with an accuracy rate of 80%. One of the drawbacks of the frequency ratio model is that it a bivariate statistical analysis i.e it only evaluates the impact of each class of the conditioning factors to the flooding event and it does not correlate the relationship among the factors themselves. Dempster Shafer Theory performs both the bivariate and multivariate statistical analysis at the same time. Therefore it produces high accuracies compared to the frequency ratio model. This proposed Dempster Shafer Theory is being used by the researchers in different natural hazard domains to derive the susceptibility map and provided promising results (Thimmaiah et al 2019). The flood susceptibility map provides reasonably accurate results and can be used in hydrological studies and disaster management.

CONCLUSION

Flood is one of the major disasters faced by the human society for many decades. Different strategies and methods have been followed to mitigate and control flooding. The evaluation of the flood vulnerability is a nonlinear and tough problem. Many researchers have followed different mathematical model to evaluate the flood vulnerability map. The flood vulnerability mapping was carried out for the study area using frequency ratio method and Dempster Shafer Theory. The generated results were validated to check the accuracy of the output. The frequency ratio model has an accuracy of 75% and the Dempster Shafer Theory model has 80% accuracy. The highest prediction rate was achieved using Dempster Shafer Theory, suggesting that this technique is more capable of identifying the flood vulnerable region accurately compared to the other technique. These results can be used by the disaster management authorities to formulate an effective mitigation programme for flood management in Devikulam and Udumbanchola taluks of idukki district.

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Use of Remote Sensing and GIS techniques in Monitoring of Land Use/ Land Cover Changes: Case Study of Kanaan area of Diyala Province, Central Iraq

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Abstract: This study was conducted on the floor coverings in the Kanaan area of Diyala province, central Iraq, between latitudes 44° 39' 23.47 '- 45º 02 ' 39.81" and33º 28' 29.47" – 33º 42' 37.51" an area of 993.506 km ^{2}. The field survey was based on ground observation points. Two satellite data the first for the Landsat 7 sensor ETM + (row 37 and path 168) captured on 18/4/2009 and the second satellite Landsat 8 sensor OLI_TIRS (row 37 and path 168) captured on 2/3/2019 was used. The results were classified as unsupervised on the spatial data. The result of the classification showed that 5 plant coverings, including forest and orchard trees, exploited agricultural land, unexploited agricultural land, buildings and Constructions, and barren land. They were identified and compared with land control 75 points. The classification and evaluation of the satellite data were based on the error matrix. The percentage of each category and the whole plan were 81 and 86% in 2009 and 2019 respectively. Respectively, and reached a clear deterioration of the vegetation cover by 34.53% or equivalent area of 79. 884 km^2, and an increase in the area of agricultural land by 67,895 km^2 (26.35%) during the study period.

Keywords: Vegetation degradation, Land coverings, Remote sensing, GIS

Land use change / land cover is an important factor environmental and ecological change (Sharjee et al 2016) and must differentiate between floor coverings and uses of land, the Land cover intended all natural and human phenomena that spread over a surface area, either land use means Land use manifestations arising from human activities (Mathewos and Bewuketu 2018, Ranjeet et al 2018), which necessitates the continuation of their monitoring and follow-up of their developers to develop their management and investment programs in remote sensing and geographic information systems (GIS) systems to achieve this because the data of these technologies are accurate, comprehensive, spectral and time-critical (Selassie 2018, Shivangi et al 2018, Shanmugapriya et al 2019).

Aidoo et al (2019) in Tarkwa west of Ghana detected the change in floor coverings using satellite images of the satellite Landsat 7 for the period 1991-2008 and concluded that the buildings and barren land increased by 25%, while land, dense vegetation, land scattered plants and shrubs decreased by 17, 5 and 28%, respectively. Maggie et al (2019) in Dedza in Malawi detected the change in floor coverings using satellite images of the satellite Landsat 7 for the period 1995-2015 and concluded that forests and water bodies and wetlands of agricultural land dropped significantly while the urban areas of arid land and significantly increased between 1995 and 2015. Biswajit et al (2018) monitored the change in land cover and land use in study found that urban, agricultural and forest areas are the major groups that have changed through natural and human activities. Ali and Muhammad (2016) mentioned that the remote sensing is very effective and useful tool for use in the study of covariance time for the types of floor coverings The study on floor coverings for the province of Baghdad to detect changes for the years 1976, 1990 and 2014, indicated that there is an increase of urban areas versus vegetation. Because LUCC changes are attributed to human activities as one of the main factors of local, regional and global environmental changes and LULC studies are vital in enhancing understanding and monitoring environmental change. This study aims to use remote sensing and GIS techniques to prepare land cover classification maps in the Canaan region and the amount of change in it.

MATERIAL AND METHODS

Study area: The study area was determined by field visits using the GPS Test program and compared to the coordinates of the study with the GPS (Global Positioning System), as readings matched 100%, after determining the study area, which reached an area of 993.506 km^2. The 30 random samples were selected and geographical coordinates, was adopted from two satellite images first

Landsat 7 sensor + ETM captured on April 18, 2009 (row 37, path 168) and the second Landsat 8 OLI_TIRS grade sensor (row 37 ,path 168) captured on 2/3/2019 (Fig. 1)

Processing of satellite images: Erdas Imagine V.14 to geometric correction and radiometric correction for satellite images was used, for spatial accuracy 15 m, the channels or bands (1-7) and (2-8) were combined for Landsat 7 and Landsat 8 respectively. After that, the study area was cut and using ArcMap 10.3.1 A map of the study area was prepared and as shown in (Fig. 2)

Fieldwork: For field work, a set of random control points was randomly assigned to the study area (the simplest and most widely used method for producing classification maps for floor coverings). Obtained through several visits and field surveys for the study site and using the GPS Test program by selecting 30 samples (5 samples per class) using the stratified method and each layer representing a class of floor coverings in the Kanaan area (Emad et al 2014). The sample area of 15 max 15 m according to the spatial accuracy of the satellite image, standing in the middle of the sample and take their geographical coordinates to represent the ground control points for these samples.

Land cover classification map: The satellite maps of Landsat 7 and Landsat 8 were adopted for the purpose of finding land items in the study area, relying on the Erdas Imagine V. 14 software in the unsupervised classification method. The final product of this iterative process is a set of layers that the interpreter may wish to merge together or a group of those that he wishes to divide subsequent (Dawod 2015), In this study, five varieties were obtained for different land coverings, including vegetation cover (forest and orchard trees),unexploited agricultural land, exploited agricultural land, buildings and constructions, and barren land. For better distinguish the varieties, used ArcMap 10.3.1 to filter and filter Majority (Fig. 3).

RESULTS AND DISCUSSION

Using the unsupervised Classification method, two satellite data were classified. after verification . The items were found to be identical to those in the area. These items included vegetation cover (forest trees and orchards), unexploited agricultural land, exploited agricultural land, buildings and constructions and barren land. Pixels for each category and area of coverage in Canaan after the filtration process were obtained (Table 1). There was a decline and decrease in the area of vegetation cover and unused agricultural land by 79,884 and 21,806 km^2 and 34.53, 8.59% respectively, while there was an average increase in the area of land undergrowth 8,476 km^2, and a significant increase in the area of cultivated agricultural lands, buildings and constructions 67,895 and 25,318 km^2, and 26.35 and 16.54% respectively .

Changes in the characteristics of land use and vegetation cover between 2009 and 2019 show changes of land use as well as the environmental impacts that have led to significant variation in both categories. Both categories include the same land types and land cover[vegetation cover(forest trees and orchards), unexploited agricultural land, exploited agricultural land, buildings and constructions and barren land]. The area of change in land use and plant cover during the two periods was estimated. The analysis of changes in land use, indicate that can increase the understanding of the changes occurring during the two periods. The overall change in each category of species that emerged in the region, whereas some of these varieties have changed significantly (vegetation and unexploited agricultural land) have lost part of their area while other varieties have increased their area (Table 1). The vegetation cover and the unexploited agricultural land lost 79,884 km^2 and 21,806 km^2. There was a decrease in vegetation and excessive cutting and overgrazing or poor exploited so that the areas of the rest of the varieties, especially exploited agricultural land exploited and buildings and constructions increased at the expense of the area of vegetation and unexploited agricultural land. There is deterioration in land use and the transformation of plant coverings in lower level of

Table 1. Number of pixels units for floor coverings of the study area in Canaan for each category and area

Category	2009		2019		Amount of change / km^2	Percentage change
	Number of pixels	Area km^2	Number of pixels	Area km^2		
Vegetation cover	1028144	231.332	673106	151.449	-79.884	34.53
Unexploited agricultural land	1128253	253.857	1031339	232.051	-21.806	8.59
Exploited agricultural land	1145015	257.628	1446770	325.523	67.895	26.35
Buildingsand Constructions	680259	153.058	792785	178.377	25.318	16.54
Barren lands	433907	97.629	471578	106.105	8.476	8.68
Total	4415580	993.506	4415580	993.506	0.000	

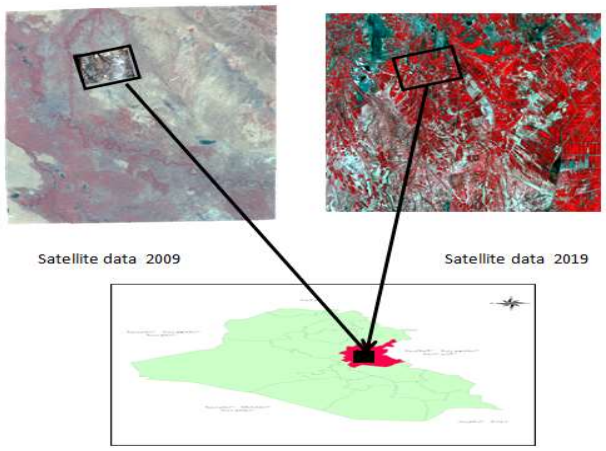

Fig. 1. Area in Canaan is part of the satellite's Landsat 7 (2009), Landsat 8 (2019) (upper Fig.) and Diyala Governorate (lower Fig.)

use , the increase in the area of exploited agricultural land due to the availability of water significantly as a result of the amount of heavy rains in the winter of 2019, which led to the farmers to use more agricultural land compared to 2009. There should be an effort to develop and by reducing unproductive land and exploiting it as arable land for other purposes (Abed El Hay et al 2016).

The loss and gain on plant cover or other items shows that there is a regular change of these two periods. The change indicates that there are two directions. The first trend: represents the development of performance or work in the exploitation of agricultural sites that can be exploited for the production of different agricultural crops and the cultivation of land and barren land to productive land. The second trend is that there was deterioration in the vegetation due to the loss of part of the area in favor of the other covers. To make sure

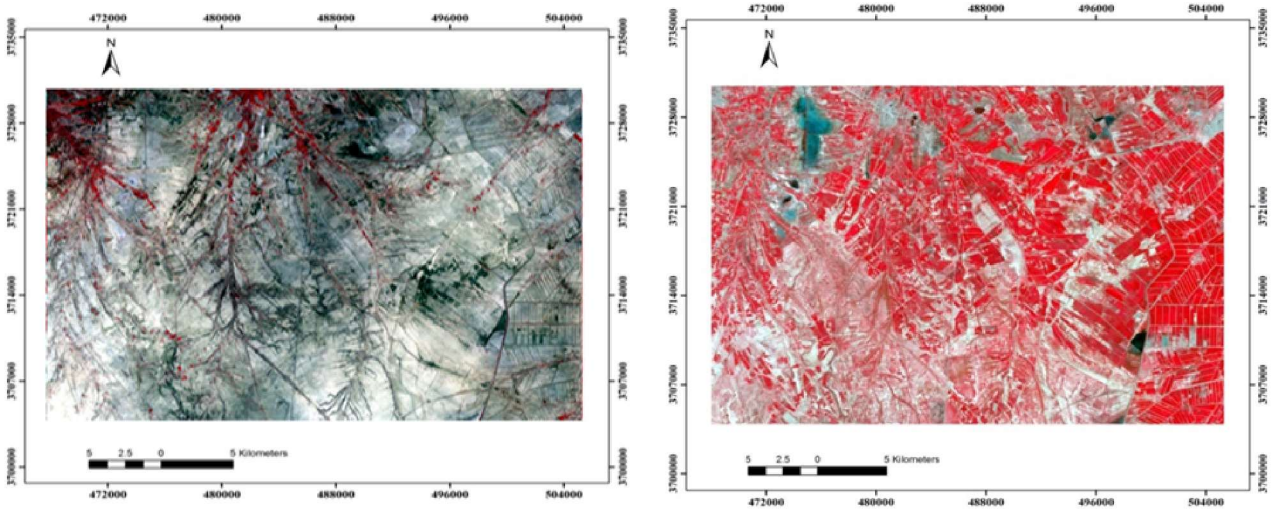

Fig. 2. Studied area in Canaan is part of the satellite A (Landsat 7 2009) and B (Landsat 8 2019)

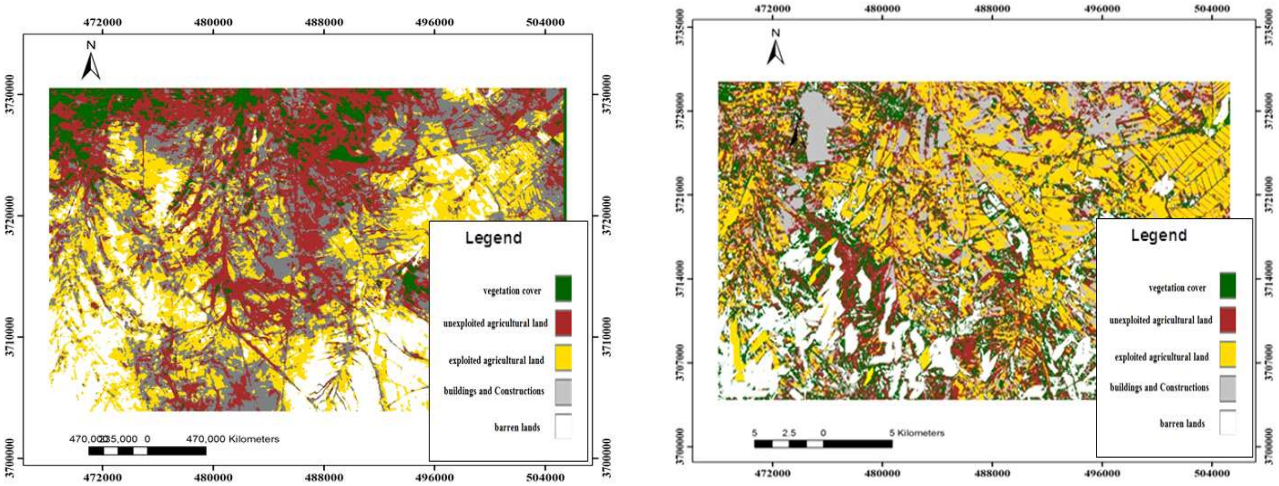

Fig. 3. Classified satellite data for land coverings in the Canaan area A (2009), B (2019)

that there were significant differences between the two study periods, used the chi-square test with calculated scale of 12.26 which is greater than the value of the scale of 3.84 (0.05 level) indicating that there are statistically significant differences between the periods.

Rating accuracy: The process of evaluating the accuracy of the classification of the elements of the different spatial statement is particularly important to the classification of vegetation covers and land classification. Through this accuracy can determine the compatibility of the classification with these covers, and the possibility of reliance on the map prepared and used in the future. The random sampling method was used to evaluate the classification accuracy of plant coverings in the Kanaan area by taking 75 (15 points per category) ground adjustment points to determine this accuracy. The accuracy of the classified data (2009 and 2019) was (81 and 86%, respectively, indicating that the overall rating accuracy of each of the above categories is good. The ratio to 2000 was high for all cultivars for vegetation (100%) and the lowest (77%) for barren land. The highest value (93%) was for the exploited agricultural lands for the 2009 and 2019, and the lowest was for the unexploited agricultural land (73%) and vegetation cover for the 2009 map The lowest (80%) or the 2019 was also for the unexploited agricultural land and vegetation cover. and is acceptable for the evaluation of Classification Accuracy (McCoy 2005). When using the Kappa statistical scale, a classification accuracy was 0.83 and 0.84 for the years 2009 and 2019, respectively, This is in agreement with Al-Nakhshabandi (2013) and Selassie 2018). To estimate the coverage of each category, the DOT GRID METHOD was used in Arc GIS V 10.3 by creating a layer of points and dropping it on the classified satellite data (Table 5)

The highest coverage for 2009 and 2019 was for agricultural land 26 and 33%, respectively, and the lowest for vegetation and barren land and this corresponds to the reality in terms of areas, but there was decline in vegetation (Table 1). This indicates a decrease in the area of vegetation cover due to over-exploitation, poor and unscientific exploitation, and the conversion of green spaces into residential lands, or cutting of the vegetation which turns barren land (Inyoman et al 2018) .There is an increase in the area of buildings and barren land is, and increase in exploited agricultural land in exchange for a decrease in unexploited agricultural land is

Table 4. Kappa 's statistical value of 2009 and 2019

Category	2009	2019
Vegetation cover	0.82	0.81
Exploited agricultural land	0.89	0.93
Unexploited agricultural land	0.80	0.79
Buildings and constructions	0.82	0.85
Barren lands	0.83	0.82
Accuracy %	0.83	0.84

Table 2. Accuracy of the classification map prepared by Landsat 2009

Category	Vegetation cover	Exploited agricultural land	Unexploited agricultural land	Buildings and constructions	Barren lands	Total
Vegetation cover	11	1	1	1	1	15
Exploited agricultural land	1	14	0	0	0	15
Unexploited agricultural land	1	0	11	2	1	15
Buildings and Constructions	1	0	2	12	0	15
Barren lands	1	0	1	0	13	15
Total	15	15	15	15	15	75
Accuracy (%)	0.73	0.93	0.73	0.80	0.86	0.81

Table 3. Accuracy of the classification map prepared by Landsat 2019

Category	Vegetation cover	Exploited agricultural land	Unexploited agricultural land	Buildings and constructions	Barren lands	Total
Vegetation cover	12	0	1	1	1	15
Exploited agricultural land	0	14	1	0	0	15
Unexploited agricultural land	1	1	12	1	0	15
Buildings and Constructions	1	0	1	13	0	15
Barren lands	1	0	0	0	14	15
Total	15	15	15	15	15	75
Accuracy (%)	0.80	0.93	0.80	0.86	0.93	0.86

Table 5. Percentage of the distribution of floor coverings for the study area in Kanaan

Category	2009		2019		Percentage change
	Number of points	Percentage	Number of points	Percentage	
Vegetation cover	69	23	45	15	-8
Exploited agricultural land	76	26	97	33	9
Unexploited agricultural land	75	26	69	23	-3
Buildings and constructions	45	15	53	18	3
Barren lands	29	10	32	11	1
Total	295	100	295	100	

not exploited and to exploit the latter and converted to exploited agricultural land by farmers because of the availability of arable water due to abundance rain in the winter season .

CONCLUSION

There was change in vegetation cover and untapped agricultural land in favor of other land coverings, deterioration of the vegetation cover by 34.53% or equivalent area of 79. 884 km2, and an increase in the area of agricultural land by 67,895 km2 by 26.35 % during the study period,. The use of remote sensing techniques and geographic information systems is very important in interpreting the results through different programs.

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Analysis of Land Surface Temperature based on NDVI in Basavana Bagewadi

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Abstract: The present study is carried out in Basavana Bagewadi taluk of Bijapur district, which is well known for experiencing fluctuations in temperature over years. Comparison of LST derived from Landsat with respect to NDVI and MODIS LST data for 12 years (2005 to 2017), is carried out in the present study. Based on the study, it is found that the region experiences hot climatic conditions during summer with the mean temperature of 40℃. Comparison of the LST obtained from Landsat and MODIS datasets experiences a variation of 5℃ to 7℃ with the considered data products. The variation experienced is due to the comparison of finer and coarser resolution products.

Keywords: Land surface temperature, NDVI, MODIS, Emissivity

One of the significant parameters which affects variety of applications such as urban climate, hydrological cycle, climate change and vegetation monitoring is, land surface temperature (LST)), which plays a crucial role in land applications and is directly related to the transportation of heat between the atmosphere and the surface (Vlassova et al 2014, Reddy et al 2019). LST is a key parameter of the earth surface as it involves in processing energy and water exchange with atmosphere (Yu et al 2014) and is the measure of the emitted heat from the features associated with the earth surface (Ramachandra et al 2012). LST is also essential for various flood studies (Vaishnavi et al 2020). Land surface temperature varies spatially due to the non-homogeneity of land cover features. The other method of predicting LST accurately is ground measurements but it is time consuming, expensive and requires large human effort (Suresh and Yarrakula 2020a, b). Remote sensing satellites with the integration of thermal infrared bands paved way for obtaining LST information at regional and global scale without having any contact with the ground (Lakshmi et al 2016). Landsat ETM+ and OLI/TIRS are built with thermal bands with a resolution of 60m (ETM+) and 100m (OLI/TIRS) (Suresh and Yarrakula 2018).Various methods have been developed for the estimation of LST since the availability of Landsat images. The methodology adopted in the present study for the estimation of LST from Landsat images is the Algorithm for Automated Mapping of Land Surface Temperature developed by USGS that utilises red band, near infrared (NIR) band and thermal infrared (TIR) bands. In Landsat 8 Thermal Infrared band 10 was used to derive LST as the TIRS band 11 is not reliable due to its larger calibration (Ramachandra et al 2012). The Present study is carried out with an objective to understand the varying temperature in Basavana Bagewadi Taluk and the study the variation of LST obtained from Landsat and MODIS datasets.

MATERIAL AND METHODS

Study area: Basavana Bagewadi Taluk, Bijapur District is located in the northern part of Karnataka state lies between 16.44ºN and 16.59ºN latitude and 75.88ºE and 75.99ºE longitude. Lying at an elevation of around 607m above mean sea level, the town receives an average annual rainfall of 685mm. The region experiences cold winter with temperature fall less than 19ºC and very hot summer with the rise in temperature over 45ºC. Figure 1 shows the geographical location of the study area.

The Survey of India (SOI) toposheets of scale 1:50000 were obtained for the study area and georeferenced. In QGIS Georeferencer platform. The base map and the taluk boundary are extracted from the georeferenced toposheets. Landsat 7 and 8 dataset are downloaded from USGS earth explorer from the year 2005 to 2017 and the data is pre-processed and layer stacked using Semi-Automatic Classification Plugin (SCP tool). Proportional vegetation is calculated with the obtained NDVI using which the land surface emissivity (LSE) is derived. The estimation of LST with Landsat 7 and Landsat 8 datasets with the combination of thermal bands. Normalized Difference Vegetation Index

(NDVI) and Land Surface Emissivity (LSE) were estimated using the visible and near infrared bands. With the obtained NDVI, LSE and thermal band, LST was estimated and the results obtained were compared with the Moderate Resolution Imaging Spectroradiometer (MODIS) data to study the efficiency of the MODIS data in Indian conditions (Table 1, Fig. 2).

Land surface temperature estimation: The radiative skin temperature of the land surface measured by using the remote sensing sensors (Lakshmi et al 2016, Suresh et al 2016).

$$LST = \frac{BT}{(1 + [\lambda * BT / \rho) * In(e)}$$

Where,

BT = Thermal Band at ºC

λ= Wavelength of Thermal Band

$$\rho = \frac{h * c}{s} = \frac{6.626 * 10^{-34} * 3 * 10^{8}}{1.38 * 10^{-23}} = 14388\ \mu mK$$

h = Plank's constant

c = Velocity of light

s = Boltzmann constant

e = Emissivity

RESULTS AND DISCUSSION

The Landsat Dataset for the study area are downloaded and re-projected to WGS84 (EPSG: 4326). DN values of the downloaded datasets are converted to spectral radiances and the NDVI is calculated using red and near infrared bands. Comparison of NDVI and LST is carried out by plotting a random of 1000 points across the study area and extracting the corresponding NDVI and LST values from 2005 to 2017. The values of the sampling points are extracted and Mean is calculated. The comparison of the mean LST and NDVI are shown in Figure 3-5.

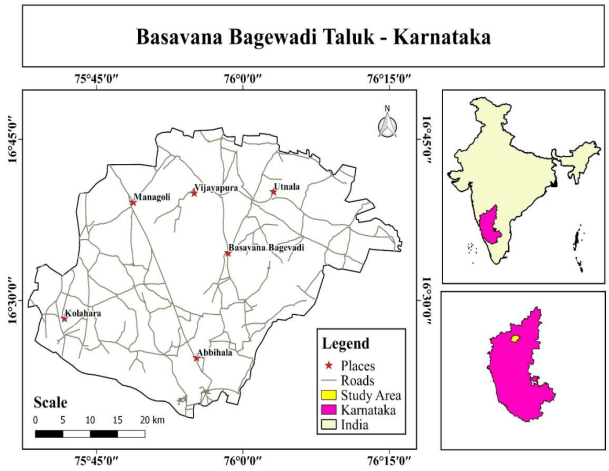

Fig. 1. Study area - Basavana Bagewadi Taluk, Bijapur district

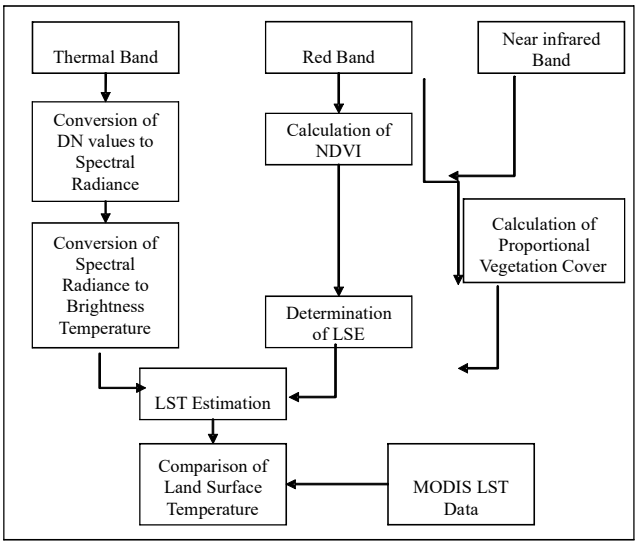

Fig. 2. Methodology adopted in the present study

Table 1. Dataset used in the present study

Year	Landsat satellite	Sensor	Resolution	Path	Row	Date
2017	Landsat-8	OLI/TIRS	30	145	49	01.05.2017
2016	Landsat-8	OLI/TIRS	30	145	49	28.04.2016
2015	Landsat-8	OLI/TIRS	30	145	49	26.04.2015
2014	Landsat-8	OLI/TIRS	30	145	49	07.04.2014
2013	Landsat-7	ETM+	30	145	49	27.03.2013
2012	Landsat-7	ETM+	30	145	49	25.04.2012
2011	Landsat-7	ETM+	30	145	49	22.03.2011
2010	Landsat-7	ETM+	30	145	49	19.03.2010
2009	Landsat-7	ETM+	30	145	49	16.03.2009
2008	Landsat-7	ETM+	30	145	49	13.03.2008
2007	Landsat-7	ETM+	30	145	49	11.03.2007
2006	Landsat-7	ETM+	30	145	49	24.03.2006
2005	Landsat-7	ETM+	30	145	49	21.03.2005

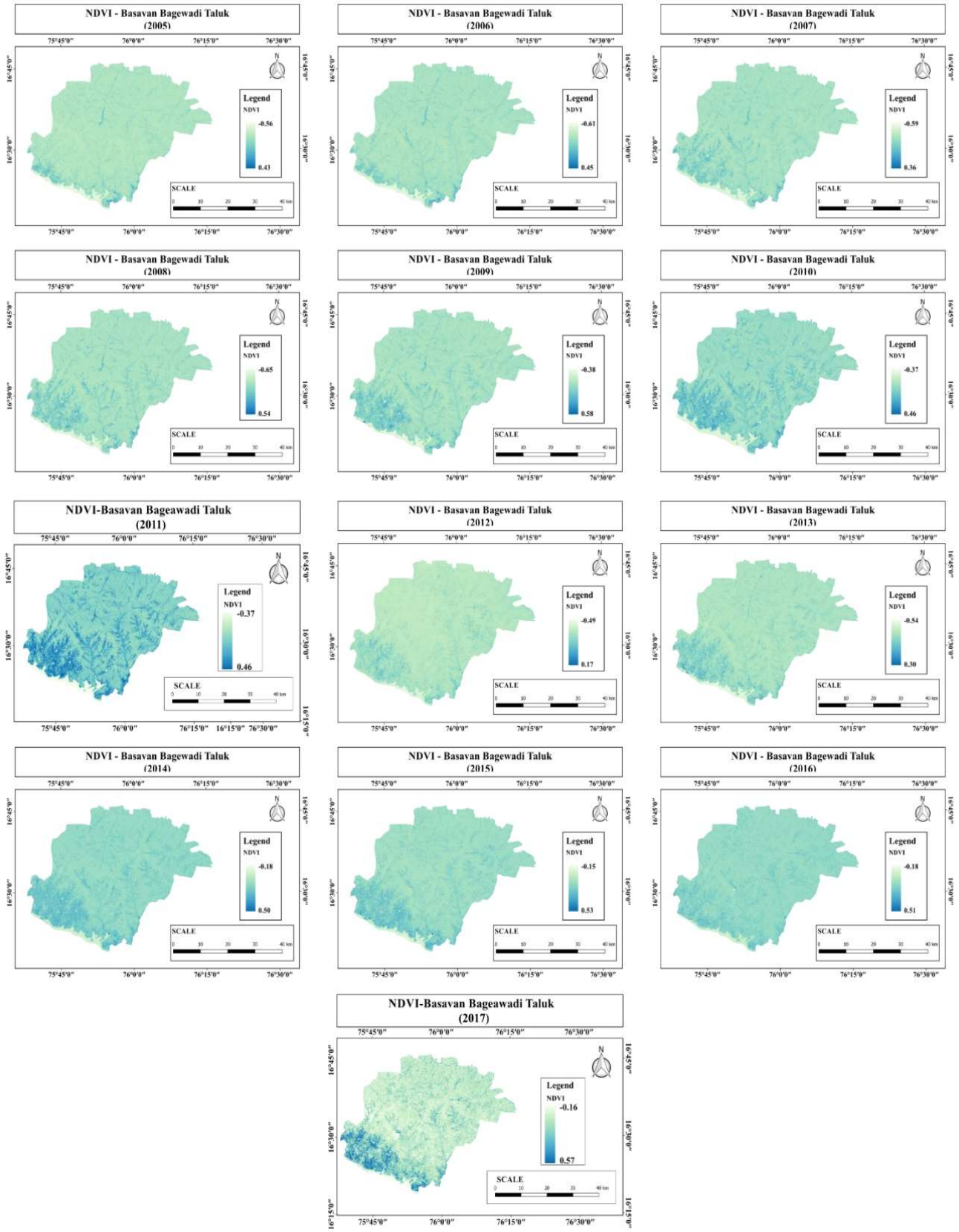

Fig. 3. NDVI map for the year 2005 to 2017

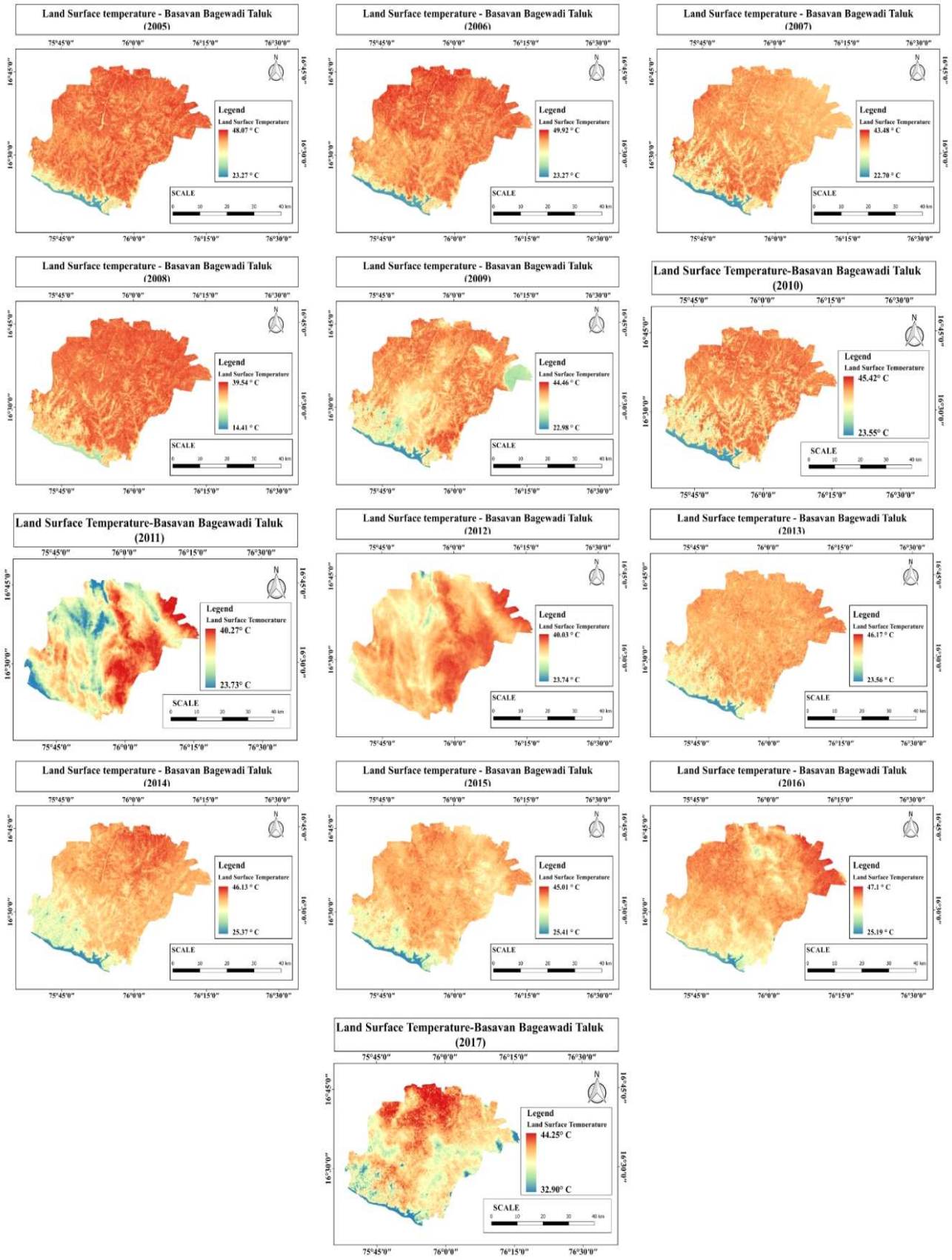

Fig. 4. LST map for the year 2005 to 2017

Based on the LST obtained from the datasets it is observed that the study area experiences a hot weather during summer which varies between 40℃ to 45℃, where a drop in the temperature of 2℃ is experienced since a peak temperature of 50℃ is experienced in 2006. NDVI values obtained for the study area clearly indicates the wide spread vegetation variation between 2005 to 2017 within the study area. NDVI values indicates an increase in the vegetation in the region since a sudden fall in the values are experienced in 2012. The presence of the perennial river Krishna supplies water for vegetation within the surrounding regions encouraging vegetation and based on the study carried out it is evident that there is a fall in the temperature from 2005 and 2017. Comparison of NDVI and LST results prove that the management of water within the taluk has improved across decades resulting in fall of temperature and increase in the vegetation.

MODIS and Landsat are the products widely used for LST studies and the MODIS data at 1km resolution is used in the present study for comparison. The MODIS data for the study area is not available for the years (2014 to 2017) due to the error in the data. A comparison of LST obtained from MODIS and Landsat was performed by plotting around 500 points randomly around the study area (based on the pixel reliability of MODIS data) and the correlation between LST from Landsat and MODIS was found. Figure 6 shows the comparison of mean LST of MODIS and Landsat from the year 2005 to 2013. The correlation and Standard deviation between the datasets are provided in Table 3. Based on the comparison between the datasets, it is clearly evident that there is a huge correlation between the MODIS and Landsat datasets for all the 500 sampling locations with the year 2012 as an exception and a linear variation of 5°C to 5°C is experienced. The variation between the MODIS and Landsat

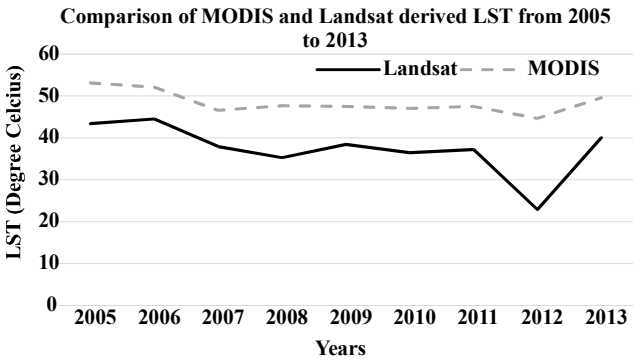

Fig. 6. Comparison of MODIS and Landsat LST from 2005 to 2013 (500 sampling points)

Table 2. Minimum and maximum values of LST and NDVI from 2005 to 2017

Date of acquisition landsat images	Land surface temperature		NDVI	
	Min (ºC)	Max (ºC)	Min	Max
01.05.2017	32.90	44.25	-0.16	0.57
28.04.2016	25.19	47.10	-0.18	0.51
26.04.2015	25.41	45.01	-0.15	0.53
07.04.2014	25.37	46.13	-0.18	0.50
27.03.2013	23.56	46.17	-0.54	0.30
25.04.2012	23.74	40.03	-0.49	0.17
22.03.2011	23.73	40.27	-0.37	0.46
19.03.2010	23.55	45.42	-0.37	0.46
16.03.2009	22.98	44.46	-0.38	0.58
13.03.2008	14.41	39.54	-0.65	0.54
11.03.2007	22.70	43.48	-0.59	0.36
24.03.2006	23.27	49.92	-0.61	0.45
21.03.2005	23.27	48.07	-0.56	0.43

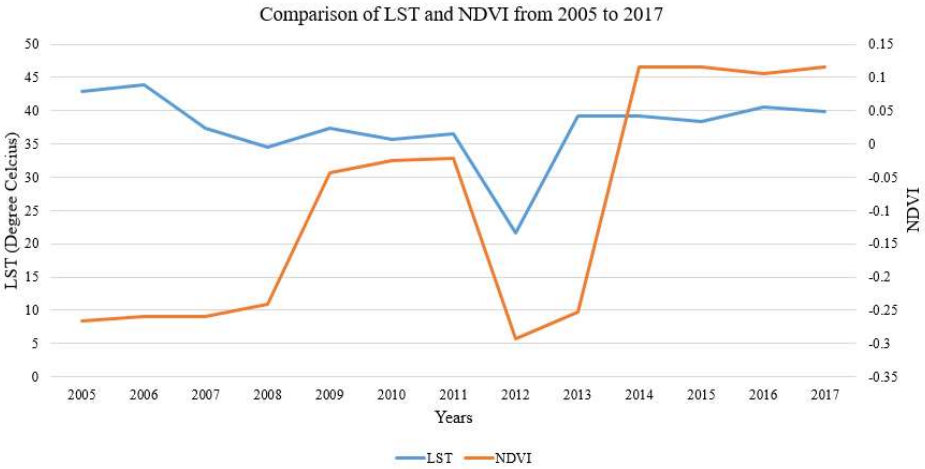

Fig. 5. Comparison of LST and NDVI from 2005 to 2017 (1000 sampling points)

Table 3. Correlation and Standard Deviation between Landsat and MODIS derived LST

	Correlation	Standard deviation
2005	0.78	5.96
2006	0.75	5.32
2007	0.71	5.15
2008	0.71	6.87
2009	0.78	5.72
2010	0.71	6.20
2011	0.74	6.02
2012	0.084	12.61
2013	0.79	5.56

derived datasets are experienced due to the processing techniques and it is suggested to use a scaling factor of 5^{O}C for the LST datasets obtained from MODIS data and use the same for analysis in the future.

CONCLUSION

The area of Basavana Bagewadi Taluk experiences an average LST of above 35ºC during summer. The temperature increases simultaneously since 2014 crossing 40ºC making the area warmer and uncomfortable for the people residing in the location. It is recommended to the Government to take necessary actions during summer to save the locality from heat waves. Management of water resources indicates the development of vegetation in the region and is also found that the LST values is constant for a decade and less compared to the highest recorded temperature of 505^{O}C. Further measures has to be taken to provide better livelihood to the farmers and to support the localities during summer season. There was a variation of around 5ºC to 7ºC the MODIS LST is not reliable in the particular study area as it has a variation of around 5ºC to 7ºC and it is recommended to consider a scaling factor over the region to utilise the MODIS datasets at larger scale.

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Assessment of Sedimentation in Maithon Reservoir using Remote Sensing and GIS

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***Abstract*:** Multipurpose reservoir plays a vital role in water resources development; at the same time sedimentation in these reservoirs causes hurdle in water resources management. In this study, reservoir capacity and sedimentation survey of Maithon reservoir was done with the help of remote sensing and GIS. The water spread area of the reservoir was calculated using per-pixel classification technique using Landsat data images between 2018 to 2019 and then capacity of reservoir was calculated using prismoidal formula at different elevation. It was observed that capacity of reservoirs was decreased to 441.93 MCM in 2019 as compared to 611.3 MCM in 1994 as reported by central water commission. Assessment revealed 6.7 MCM/year is the loss of capacity during the last 25 years; which is due to sedimentation in the reservoir. The study shows that reservoir water spread area and sediment deposited was effectively estimated using remote sensing and GIS, which may act as time saving process as compared to manual based survey in future.

Keywords: Reservoir, Sedimentation, Remote sensing, Maithon, Landsat

Conservation and management of water, is essential for sustainable development of any region. Multipurpose reservoirs are constructed across the rivers for the storage of water for different purpose like flood control, irrigation, hydropower generation, and water supply for industrial and domestic uses (Balaji and Kumar 2018). But these purposes fail due to the heavy sedimentation because of high soil erosion from the catchment of the reservoir (Kumar et al 2018, Yadav and Satyannarayana 2020), which lead to decrease in capacity and increase in water spread are which leads to flooding, high evaporation, change in water quality (Asadi et al 2017) and this all lead to great loss, by which these projects are constructed. Capacity of reservoirs is gradually reducing due to silting and hence sedimentation of reservoir is of great concern to all the water resources development projects around the world. Silting not only occurs in the dead storage but also encroaches into live storage capacity, which has long and short-range impact on the functioning of the project and economics (Schiefer et al 2013). Correct assessment of the sedimentation rate is essential for assessing useful life of the reservoir as well as optimum reservoir operation schedule. It was established that the live storage of reservoir is getting reduced due to siltation, a systematic effort has been made by various departments/organizations to evaluate the capacity of reservoirs. Faced with the high temporal and spatial variability of rainfall (Reshma et al 2018, Kumar et 2018), more than 3000 major and medium river valley projects have been constructed in India to tap the available water resources to serve various conservation purposes and to control flooding. In view of the limited availability of good storage sites because of topographical constraints, it is important that the live storage capacity of existing reservoirs be preserved as much as possible. Impact of sedimentation in multipurpose reservoir is more significant than that on others. In some of the reservoirs, the sedimentation rate is high as compared to the sedimentation rate considered at the planning stage. Many of the reservoirs in India are losing capacity at the rate of 0.2 to 1.0 percent annually. Therefore, it has become necessary that the surveys should be conducted in all the existing reservoirs for ascertaining siltation rate and their useful life. Sedimentation adversely affects planning for long term utilization of reservoir capacity for irrigation, power generation, drinking water supply and flood moderation.

There are several methods which have been used in past to determine the amount of sediment in reservoirs, such as hydrography (Furnans and Austin 2008), mathematical and computer models (Wu et al 2012, Reshma et al 2017), hydrometry (Heidarnejad et al 2006), bathymetric survey (Haregeweyn et al 2012). But, these methods are time taken and costly, which cannot be affordable by everyone. Remote sensing and GIS are the latest methods which is very helpful in solving many problems like assessment of land use and land cover change (Selvaraj and Saravanan 2019), water quality (Gurijala et al 2019, Sujatha et al 2019), soil erosion,

hypsometric analysis (Malik and Kumar 2019) Flood (Vaishnavi et al 2020, Kesanapalli et al 2018) drought (Agarwal et al 2019), Climate (Dabbakuti and Ratnam 2017), groundwater monitoring (Vinothkanna et al 2020), landslides (Chandrasekaran et al 2020) in recent year as studied by many researcher's around the world. The present study is taken with the objective of assessment of sedimentation in Maithon reservoir using remote sensing and GIS.

MATERIAL AND METHODS

Study area: Maithon Dam is built across river Barakar, the main tributary of Damodar River and it is located 48 km from Dhanbad District, the state of Jharkhand (Fig. 1) India during 1957. The reservoir is situated between lat. 23°51´01´´ N and long. 86°46´40´´ E. Dam has composite structure of earth, concrete and masonry. The reservoir water spread area at full reservoir level (FRL) is 99.55 Sq.km. The catchment area is 6391.74 sq. km. The reservoir volume is 441.64 M.m^3 (utilizable) and 1093.54 Mm^3 (gross). The reservoir is multi-purpose used for supply water for irrigation, Hydropower, domestic, industrial and for recreation facilities.

Data used: For the study Landsat_OLI8 data collected from USGS Explorer. The Landsat 8 scene size is 185-km-cross-track-by-180-km-along-track and the spacecraft altitude is about 705 km. The Landsat 8 satellite images of different dates between 2018 to 2019 was Downloaded (29-May-19, 27-Apr-19, 02-Apr-19, 17-Mar-19, 06-Feb-19, 09-Nov-18, 24-Oct-18, 01-Oct-18). The reservoir sedimentation and capacity survey reports; carried by CWC, India; were obtained from the Reservoir Operation Department, DVC, Maithon, Jharkhand and CWC Asansol, West Bengal, India.

Methodology: The changes in the water spread could be accurately estimated by analysing the areal spread of the reservoir at different elevations over a period of time using the satellite image data for per-pixel approaches have been used in this study to extract the water spread area of the reservoir. Estimated water spread areas were used in a simple volume estimation formula to compute the storage capacity of the reservoir. Water reflects most of the visible wavelengths, but the energy at the near-infrared (NIR) wavelength is almost absorbed by the water, thus providing a significant contrast between land and water in the NIR images. This contrast helps in extracting the water spread area of the reservoir. Among these procedures, the band threshold approach is a relatively easy and valid method for identifying the water body. It has also been suggested that this per-pixel based approach can give acceptable estimates of the area of the water body if the NIR band is used. Therefore, in the per-pixel based approach, the band threshold technique was adopted to extract the water pixels that correspond to various water levels of the reservoir by using ENVI 4.3 software. Water levels of the reservoir are collected for years 2018 to 2019. The maximum and minimum levels and their difference with respect to FRL and MDDL respectively for each year from 2018 to 2019 are given in Table 1. Landsat-8OLI was used with resolution of 30m has been used for the analysis (Fig. 2).

Computation of capacity and sedimentation: Traditionally the reservoir volume between two consecutive reservoir water levels was computed using the Prismoidal formula, the Simpson or the Trapezoidal formula. Of these, the trapezoidal formula has been most widely used for the computation of volume in Indian reservoirs. In this study the volume between two consecutive reservoir water levels was computed using the following trapezoidal formula:

$$V=(h/3)\ (A1+A2+\sqrt{(A1*A2)} \qquad (1)$$

Where V is the reservoir capacity between two successive elevation h1 and h2. h is the elevation difference (h1-h2), A1 and A2 are area of reservoir water spread at

Table 1. Water spread area and cumulative capacity of reservoir at different elevation

Date	Elevation (m)	WSA (Sq.km)	Cumulative capacity (MCM)	Revised capacity (MCM)
29-May-19	137.74	26.05	137.84	137.84
27-Apr-19	138.2	27.82	150.23	213.91
02-Apr-19	139.2	32.76	180.48	242.33
17-Mar-19	140.06	33.1	208.80	270.75
06-Feb-19	141.97	34.5	273.36	350.69
9-Nov-18	142.69	36.7	298.99	361.98
24-Oct-18	144.22	39.4	357.19	472.19
01-Oct-18	146.3	42.1	441.93	611.3

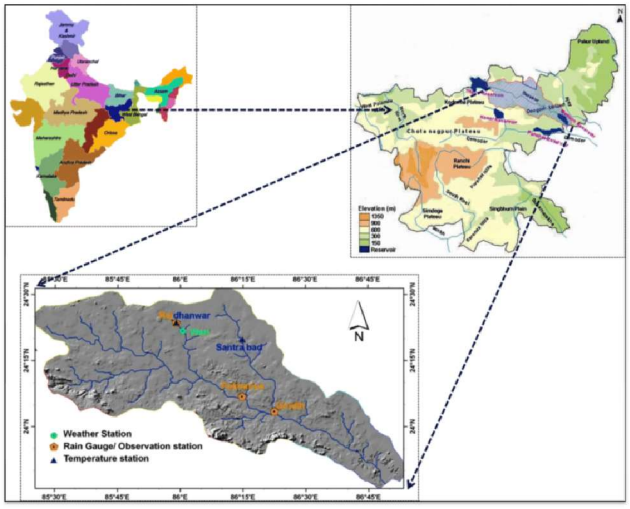

Fig. 1. Location of the maithon reservoir, Jharkhand, India

elevation at h1 and h2. The volumes computed (using equation1) between different water levels (i.e., from minimum draw down level (MDDL) to full reservoir level (FRL)) were added together to calculate the cumulative or storage capacity of the reservoir by using above formula. The difference in storage capacity between any two periods produces the amount of sedimentation deposited in the reservoir. The annual rate of sedimentation could be arrived by dividing the total amount of sediment deposited during that period.

RESULTS AND DISCUSSION

Landsat 8 data with 16-bit unsigned integer format with grey level varies from 0 to 65536. The minimum DN values of the water spread area are 198, 224, 294, 318, 408, 420, 462 and 488 for the images pertaining to the month May, April, March, February, November, and October respectively was used for the estimation of water spread area and capacity of the reservoir. The periphery of the reservoir contains low water depth and due to the presence of mixed pixels they exhibit maximum DN values. The maximum DN values used to extract the water spread area are 1116, 1330, 1488, 1504, 1512, 1515, 1526 and 1558 pertaining to the images in the chronological order. The locations of these pixels in the water spread area were also verified, and showed that the pixels with low DN were located in the deeper and central portion of the water spread area of the reservoir. The analysis of DN values of the water body show that the pixel value increases towards the periphery of the water body and the border pixels contain the maximum DN. The total number of water pixels that were extracted was multiplied by the area (30 m x 30 m) of a single pixel to compute the water spread area. The same technique was adopted to convert the extracted pixels into the water spread area in all the eight images used in this study. The Figure 3 images are the outputs arrived from ENVI 4.3 software, which is extracted water pixels from NIR band of the different water levels with corresponding water spread areas respectively. By observing the outputs in the figure, it was observed that from 2018 June to 2019 June the water spread area of the reservoir was gradually decreased due to siltation of reservoir from the last decades. It leads to reduce the storage capacity of the reservoir (Table 1). The below Figure 4 shows the variation between the original and revised capacity of the Maithon reservoir.

The reservoir capacity thus computed is 441.93 MCM at

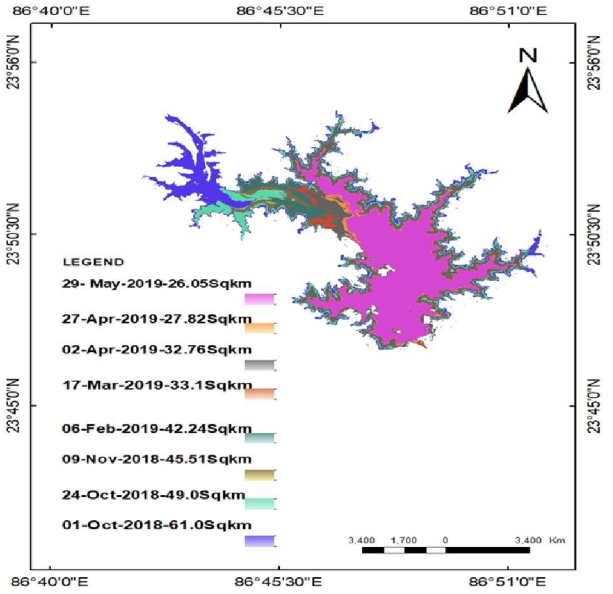

Fig. 3. Change in water spread area of the reservoir during water year 2018-2019

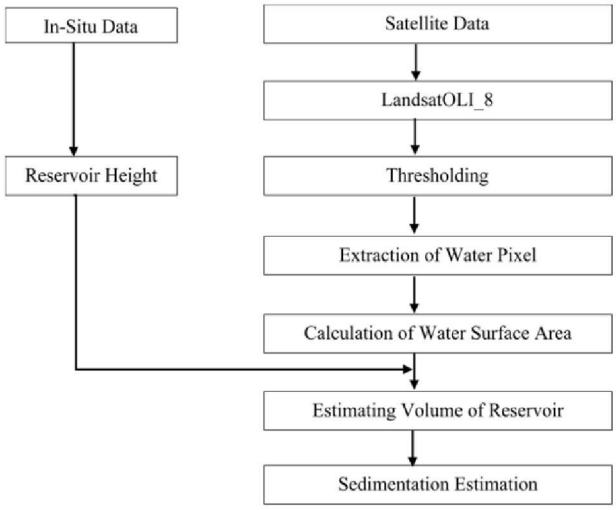

Fig. 2. Flowchart showing estimation of reservoir sedimentation

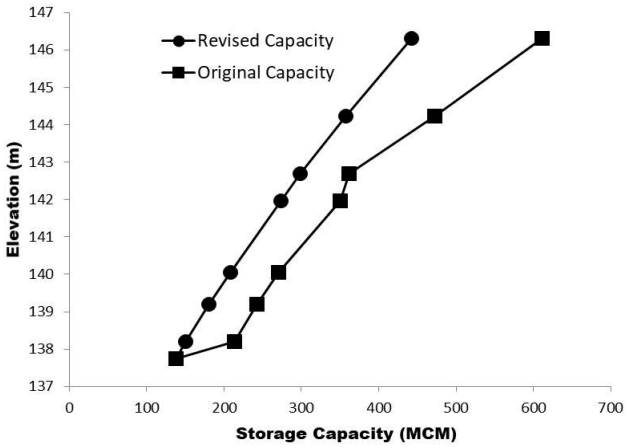

Fig. 4. Comparison of original capacity 1994 and revised capacity 2019

the elevation of 146.3 m. The capacity reported by the project authority is 611.3 MCM based on the physical survey of the reservoir 1994 (CWC, 2002). During the span of 25 years i.e., from 1993-94 to 2018-2019, it is observed that about 169.37 MCM of sediments have deposited in the reservoir, the annual rate being 6.77 MCM per year. The revised elevation capacity curve is prepared from Table 1 and compared with the curve based on the hydrographic survey of the reservoir during 1993-94, and shown in Figure 4.

CONCLUSION

Sedimentation in reservoirs is aggravated year by year due to frequent floods, soil erosion, deforestation and change in land cover pattern in the catchment. It was observed that capacity of maithon reservoir decrease in last 25 years with a rate of 6.7 MCM/year during 1994 to 2019. The storage capacity between 1994 to 2019 decreased by 27.7% with compared to the original capacity of the reservoir based on the hydrographic survey of the reservoir during 1993-94. Overall, these types studies provide real time assessment, cost and time effective estimation of the live capacity of the reservoirs.

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Prioritization of Sub-Watersheds in the Arasalar-Palavar Region using Sediment Production Rate (SPR)

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***Abstract*:** In this study, the sub watersheds of Arasalar Palavar region were prioritized based on Sediment Production Rate (SPR) evaluated using Jose and Das model. The primary Arasalar Palavar watershed region is subdivided into eight sub-watersheds such as APR1a, APR2b, APR3c, APR4d, APR5e, APR6f, APR7g and APR8h. SRTM open source data was used for delineating the streamlines over the study area. The linear aspect parameters such as form factor, circularity ratio and compactness coefficient of the watershed are used to calculate the sediment production rate. SPR value ranges from 0.00097764 to 3.009953769 ha-m/100 sq-km/year for the study area and is lesser than other watersheds, implying that the Arasalar Palavar basin is an elongated one.

Keywords: Watershed, Sediment Production Rate (SPR), Jose and Das model, SRTM

As part of a watershed management program, especially for large watersheds, it may not be possible to covenant with the entire basin using existing land treatment measures. The categorizations of particular areas or sub-watersheds in a significant watershed area are known as prioritization of watersheds. Followed by the effective watershed prioritization process, it is mandatory to organize a sub-watershed management plan for each primary sub-watershed to reduce natural and anthropogenic menaces and to conserve precious resources. Morphometric Analysis (MA) and Sediment Production Rate (SPR) are the two different methods using in the prioritization of sub-watersheds. In emerging nations, land management sustainability and water resource development are at risk from soil erosion and sediment-related issues (Maryam et al 2016). These issues result in water storage capacity loss in watersheds, damage to water reservoirs and dams, and pollution of surface waters (Ninija 2017). Therefore, appropriate watershed planning and management are needed to maintain and enhance the resource productivity, mainly through optimal land use in threatened areas. The shape of the watershed influences the rate of soil erosion and sediment production, which controls the runoff time required to focus at the outlet and the drainage configuration of a micro-watershed (Jha et al 2012). The functions of remote sensing and GIS technologies provide wide applications over water resource management plans, especially on watershed characterization and prioritization. The development of water resource technology depends on the factors such as annual rainfall, terrain, soil type, drainage, land use/land cover, and their variability playing a vital role in identifying opt places for water conservation (Ashish et al 2011).

Many studies described the prioritization of watershed over various areas elaborately. Zende et al (2018) used the grade model to determine sediment yield from the Agrani river basin using geospatial technologies. All India Soil and Land Use Survey (AISLUS) method was adopted to calculate the Sediment Yield index from 15 sub-watershed regions (Ashish et al 2011). The Game theory prioritized the watershed in Gorganroud and Qareh Sou watersheds in Golestan Province, northern Iran. The principle component analysis classified 37 independent factors into 7 components (Gajbhiye et al 2017). Aher et al (2014) used a novel Weighted Sum Analysis (WSA) technique developed for ranking of each hydrological unit concerning the weights obtained from morphometric parameters to prioritize the watershed in semi-arid regions in India. Jha et al (2012) used the Jose das model to estimate the sediment production rate concerning morphometric characteristics in the region of Umbaniun micro-watershed in Meghalaya having an area about 3951.18 ha. The satellite-derived DEM used to retrieve morphometric parameters such as bifurcation ratio, form factor, circularity ratio, elongation ratio, drainage density, stream frequency, and drainage texture sub-watershed integrating with land use/land cover, soil, and slope information to determine the sediment yield. Based on the highest to lowest morphological parameters value, the watershed ranking has been assigned accordingly (Pandey et al. 2011). Hamed Noori et al (2016), conducted a study in the region of two sub-basins of Dez Watershed, Iran. The two

models named Modified Pacific Southwest Inter-Agency Committee (MPSIAC) and Erosion Potential Method (EPM) were used to estimate the sediment yield and concluded that the EPM model performance was astonishing. Suresh et al (2004) prioritized the watershed using sediment production rate in the Tarai basin. The sediment production rate in this area varies from 2.45 to 11 ha-m/100 km^2/year. Kumar and Kumar (2011) judiciously compared the parameter results in the 'importance matrix' depend on a scale of importance intensities. An attempt to prioritize and characterize the watershed in the central west part of the Subernarekha basin made using the composite suitability index method. Sediment production Rate (SPR) and runoff estimate the morphological parameters present in the particular watershed region. The derived value of SPR and runoff rate gives the watershed the restrained quantity of sediment produced yearly with the enormous runoff occurred due to high relief and steeper slopes (Fuzal et al 2015). The Weighted Sum Analysis (WSA) and field data and remote sensing data worked together in the GIS platform to estimate soil erosion's susceptibility. The new model developed WSA-SPR prioritized the watershed into low, deficient, moderate, and high-level categories (Ajaykumar et al 2018). Singh (2017) used Snyder's synthetic unit hydrograph method to prioritize the watershed in Dangri River watershed, Panchkula District, Haryana. The resulting image from this method compared with the morphometric analysis and land use/cover analysis, and it is found from this study that Snyder's synthetic unit hydrograph is an enhanced method, as it is easier to use and fewer data exhaustive. The principal component analysis intended for the redundancy of morphometric parameters helps prioritize watersheds in the Shakkar River Catchment (Gajbhiye et al 2017). Das (2014) conducted a study in Haharo sub-catchment in the Damodar catchment of the upper Damodar valley area with 565 km^2 involving four watersheds in Jharkhand State in eastern India, derived a map that contains topographical information helps in fixing of priority of watershed. Sreenivasulu Vemu (2012), used USLE to estimate sediment yield at the river Indravati catchment outlet. Mohammad Ezz-Aldeen et al (2018) assessed the annual runoff and sediment loads of the Dokan Dam watershed using the soil and water assessment tool (SWAT) model. The objectives of this study are to prioritize Arasalar-Palavar watershed using Jose and Das model.

MATERIAL AND METHODS

Study area: "Arasalar – Palavar watershed" lies between the geographical coordinates of 11˚05′00″ N and 12˚00′00″ N latitudes and longitudes of 79˚15′00″ E and 79˚55′00″ E along the coastal region of Cauvery delta (Fig. 1). The topo sheets numbered 58M/8, 11, 12, 15, 16 and 58N/1, 5, 9, 13 were used. The Cauvery distributaries named Arasalar, Palavar, and Cauvery are covered in this study area. The Palavar river separated into the pudumanniyar and uppanar river in the area of Kabisthalam. The maximum amount of rainfall was recorded during the monsoon period from October to November. The infiltrated groundwater to the aquifers is the source of groundwater recharge. The temperature of this region varies from 35 to 40˚C in summer and 25to 35˚C in winter. Brick clays, seashells, ilmenite, and garnet sands are the major minerals found in this region. The alluvial and tertiary deposits are the highly distributed soil in this study area. The watershed data from the Institute of Remote sensing, Chennai helps in the extraction of the exact study area. SRTM DEM open source data from the USGS website was used for delineating the streamlines. ENVI 5.5 was used to retrieve the streamlines in the study area. The geometric properties of watershed like area and perimeter were derived using GIS.

Drainage system analysis of watersheds: DEM-derived streamlines of the watershed shows a dendritic drainage pattern. The drainage system network was created and validated using ArcGIS environment with SOI topographic sheets as base. Sub-watershed boundaries were digitized based on the water divide line obtained from the watershed raster layer retrieved from SRTM in the Arc Hydro toolbox of the ARC GIS environment. The methodology used for the study is shown as flowchart (Fig. 2).

Estimation of Sediment Production Rate (SPR): SPR is the volume of sediment produced per unit drainage area per unit time. In this study, the formula estimated by Jose and das (1982) was used to calculate SPR.

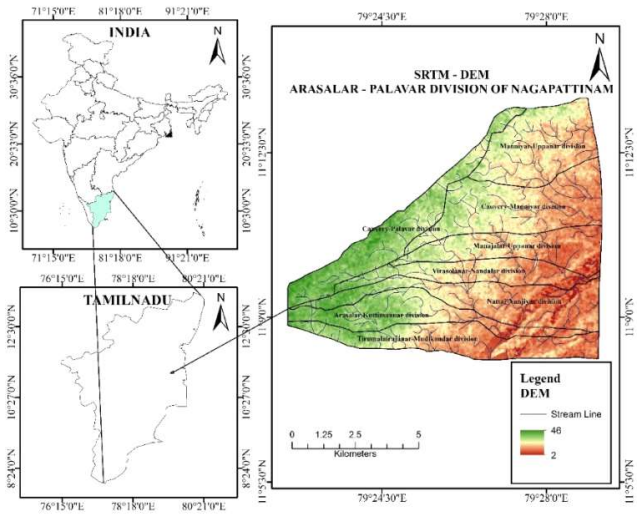

Fig. 1. Study area

$\log(SPR) = 4919.80 + 48.64 \log (100 + R_f) - 1337.77 \log (100+R_c) – 1165.65 \log (100 + C_c)$

Where, SPR = Sediment production rate, R_f = Form factor, R_c = Circularity ratio, C_c = Compactness Co-efficient

SPR model can be adopted when the land use/cover, soil, and slope information is not available. It is time saving compared to the Sediment Yield Index (SYI) and Universal Soil Loss Equation (USLE) methods that require various datasets and about giving weightage. The various geomorphic parameters and sediment production rate were estimated.

Prioritization of watershed: The erosion risk assessment factors such as linear and areal aspects called morphometric parameters are likely used to prioritize the sub-watersheds.

Form Factor (R_f): Form factor represents the shape of the basin. It is calculated as the ratio of the basin area (A) to the square of basin length (L_b). Nominal values of form factor direct a more lengthened shape of the basin, while significant values indicate its affinity to be circular (Aher et al 2014).

Circularity Ratio (R_c): The circulatory ratio is estimated as the ratio of basin's (A) area to circle area (A_c) having a circumference equal to basin's perimeter. As the basin shape approaches a circle, the circulatory ratio approaches unity.

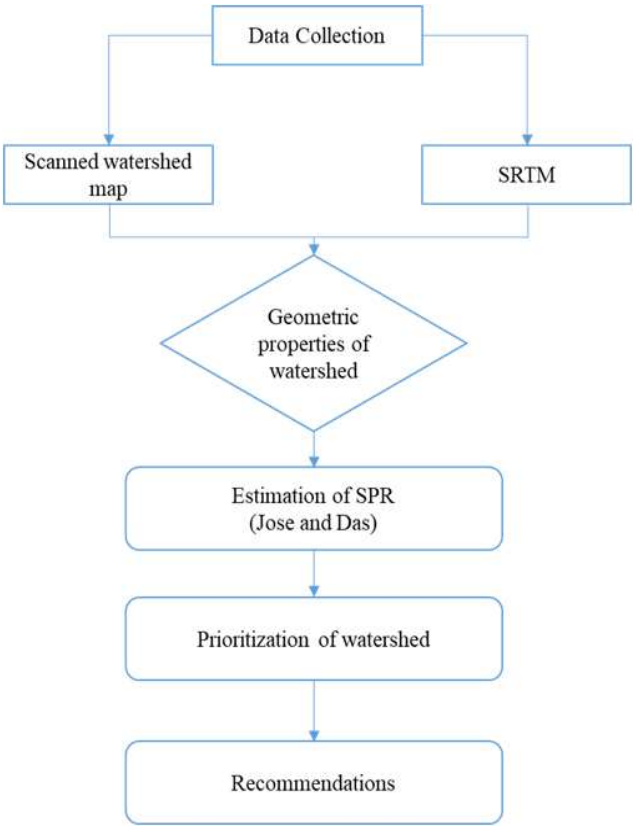

Fig. 2. Methodology

Various hydro-geological parameters like land usages, relief, and drainage patterns signify the Rc of the watershed

Compactness Co-efficient (Cc): Compactness co-efficient is calculated as the ratio between basin perimeter and perimeter of a circle to the same watershed area (Horton, 1945). It derives the relationship between actual hydrologic basins to the same circular basin having the same area as the hydrologic basin. In this study, the prioritization of all sub-watersheds in the Arasanar- Palavar was obtained by estimating the sediment production rate through linear parameters values. The sub-watershed with the minimum SPR value is specified as the highest priority.

RESULTS AND DISCUSSION

Form factor: The form factor values ranges from 0.095867 to 0.960938, with the mean value of 0.3473765.

Circularity ratio (R_c): Rc values in this watershed range from 0.1648 to 0.8094, with a mean value of 0.5218.

Compactness co-efficient (C_c): C_c values are in this sub watershed region ranges from 1.1115 to 2.4636 with a mean value of 1.4219. Figure 3 shows the graphical representation of linear aspects concerning micro level watershed.

The watershed (4B1A4) is divided into 8 sub-watersheds such as APR1a, APR2b, APR3c, APR4d, APR5e, APR6f, APR7g and APR8h (Fig. 1). For all the 8 sub-watersheds, the Sediments Production Rate (SPR) was estimated using linear aspect parameters. The calculated values of SPR ranges from 0.00097764 to 3.009953769 ha-m/100 sq-km/year. The highest value of SPR found in the Cauvery-Manniyar subwatershed and the lowest value of

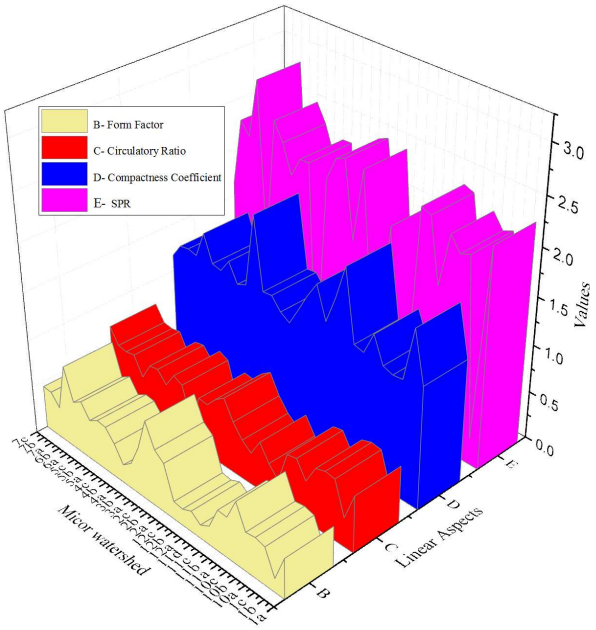

Fig. 3. Linear aspects of watershed

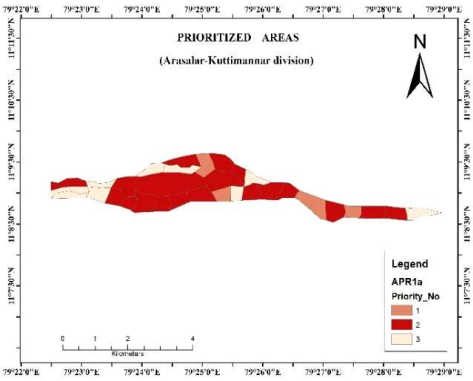

Fig. 4. Arasalar-Kuttimannar sub-watershed

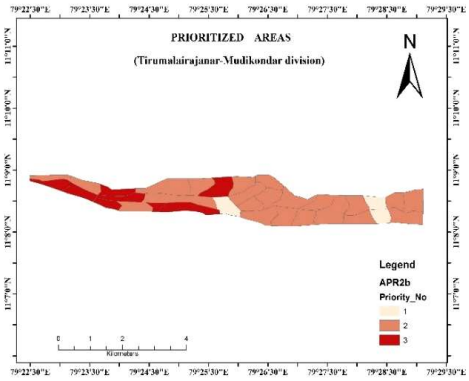

Fig. 5. Tirumalairajanar-Mudikondar division

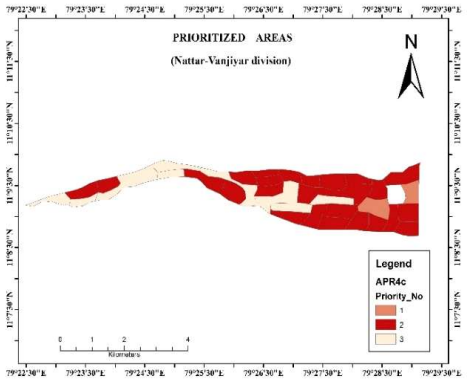

Fig. 6. Nattar-Vanjiyar division

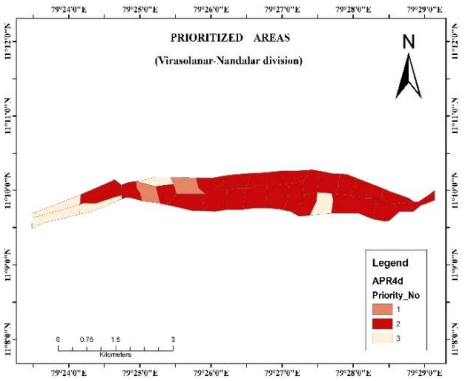

Fig. 7. Virasolanar-Nandalar division

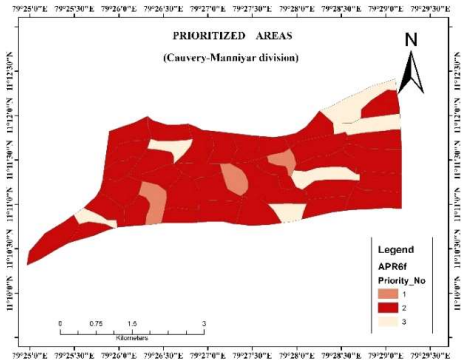

Fig. 8. Cauvery-Manniyar division

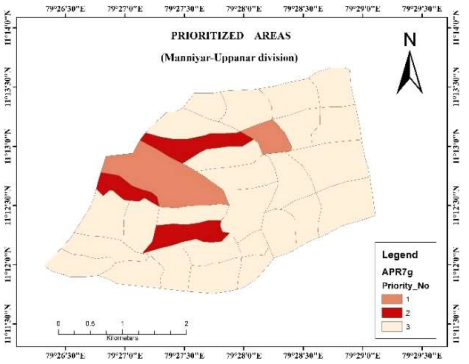

Fig. 9. Manniyar-Uppanar division

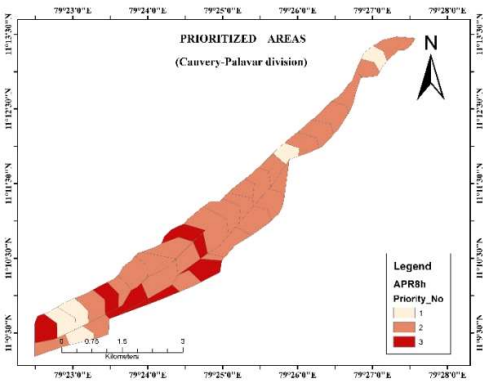

Fig. 10. Cauvery-Palavar division

Table 1. Sub watersheds and their priority at micro-level

Sub-watershed	Mini-watersheds (No)	Micro-watersheds (No)	Micro-watershed under priority 1 (No)	Micro-watershed under priority 2 (No)	Micro-watershed under priority 3 (No)
Arasalar-Kuttimannarsub-watershed (APR1a)	12	33	4	21	8
Tirumalairajanar-Mudikondar division (APR2b)	13	35	3	22	10
Nattar-Vanjiyar (APR3c)	14	43	5	23	15
Virasolanar-Nandalar division (APR4d)	11	30	2	23	5
Manajalar Uppanar (APR5e)	9	29	3	23	3
Cauvery-Manniyar division (APR6f)	15	45	3	36	6
Manniyar-Uppanar (APR7g)	12	33	2	28	3
Cauvery-Palavar (APR8h)	12	38	5	26	7

SPR found in the Tirumalairajanar-Mudikondar sub-watershed. Since the values of linear parameters are compared with other drainage basin values and found to be less, it can be concluded that the basin is elongated. The watershed having the highest sediment production rate, given lower priority. There are total 27 micro watersheds, falling in priority 1 classified as per the highest SPR which requires continuous water and soil conservation measurement. The number of micro watershed falling in priority 2 is higher than micro watershed falling in priority 1 and 2 i.e., 202 which may not require the continuos monitoring as preference given to priority 1. Total 57 micro watersheds are falling in priority 3. Based on the priority levels assigned by SPR, the gully portion could be canned with appropriate structural and vegetative measures. In accordance with the size of gullies, small and medium sized gullies selected for constructing confinement dams to store the strom runoff in order to prevent the problem of floods (Suresh et al 2004). The maps were prepared using Structural Query Language (SQL) process (Fig. 4-10). At every micro-level watershed, watershed prioritization is done based on Sediment Production Rate (SPR) model. Based on sediment production rate, the prioritization of watershed is sorted into three classes such as high SPR (priority 1), moderate SPR (priority 2) and low SPR (priority 3). The details of the sub watersheds and their priority at micro-level is shown in Table 1.

CONCLUSIONS

The study summarizes a sensible method adopted to prioritize sub-watershed using the SPR model (Jose and Das) in the Arasalar-Palavar watershed (4B1A4) region. According to the priority levels measured, the watershed adoption supported some effective structural and vegetative measures to maintain uniformity. The micro level watersheds having a higher sediment production rate would be given priority. This SPR model dominates when land use/land cover, soil, slope information of the sub watershed is not readily available in hand. Based on the prioritization level, proper conservation and engineering structures must be suggested and proposed for cropping system based on the water resources generated or sustainable use of natural resource like water, urgent need for environmental conservation, and sub watershed management surrounding communities, if necessary.

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Appraisal of Groundwater Potential Zonation Mapping in Coastal Track of Cuddalore District using Geospatial Techniques in Tamil Nadu India

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***Abstract*:** The study area covers an area of 1774 km^2, which primarily depends on groundwater due to rapid urbanization and industrialization other than agriculture and aquaculture activities in the last two decades. Hence the present study aims to isolate the groundwater potential possible zones using the geospatial techniques. Weightage index values and rank has been assigned based on the significance and water holding capacity of the individual feature through linear equation method. Remote sensing and (GIS) have been used to integrate the eight thematic layers like Lithology, geomorphology, soil, land use/land cover, lineament density, drainage density and slope of the study area for delineating the groundwater potential zone through Weightage index overlay analysis (WIOA) technique. The groundwater potential zone has been divided into five classes such as very high, high, medium, low and very low. The results were more correlated with the water level of the study region. The final map of the area was demarcated by four different zones of groundwater prospects, viz., very high, (19.38% of the area), high (44.50 % of the area), moderate (30% of the area) low (4.83% of the area), and very low (1.35% of area). The hydro geomorphological units, such as alluvial plain, low slope area, and land occupied by urbanization, are prospective zones for groundwater occurrence in the study area. The proper augmentation and management are needed through proper planning in groundwater resource development and management.

***Keywords*:** Groundwater Potential Zonation (GWPZ), Remote Sensing, GIS, WIOA, Cuddalore

In the 21st century, groundwater is an unavoidable source for agriculture, aquaculture, industries, drinking, and domestic uses in the non-rainy season, due to unexpected population growth, industrialization, and urbanization, the groundwater is under observation because of improper prediction and management (Prasad et al 2008, Saranya and Saravanan 2020). Hence, it is necessary to study the way to isolate the groundwater potential zones and its proper management of this natural resource on small scale and as well as big scale, especially the developing country like India it is necessary to isolate the potential zones with scientific methods (Magesh et al 2012, Ayyandurai et al 2016). Groundwater occurrence in our country is highly uneven due to diversified topographical, geological and climatological variations. The occurrences of groundwater are varying due to the types of aquifer such as primary aquifer (sedimentary rocks) and secondary aquifers (hard rocks) (Arkoprovo et al 2012, Lakshmi and Kumar 2018). The groundwater exploration is more in sedimentary terrains than hard rock mainly because of its needy in many ways. So, it has to be quantitative and isolate with scientific and advance techniques (Gupta et al 2018, Gebrie and Getachew 2019). Geospatial technology is a key technique for this type of study in this modern era due to more advance and error less results (Aneesh and Deka 2015). Remote sensing and GIS are an effective tool for groundwater resources studies both in quantitative and qualitative with a specific scientific method like weightage index overlay analysis (WIOA) (Selvam et al 2015, Deepa et al 2016, Ghosh et al 2016). The analysis of the study area will be in both large scale and small scale. One of the greatest advantage of using remote sensing and GIS for hydrological investigations and monitoring is its ability to generate information in spatial and temporal domain, which is very crucial for successful analysis, prediction and validation (Arivalagan et al 2014, Gnanachandrasamy et al 2018, Aggarwal et al 2019, Benjmel et al 2020, Saranya and Saravanan 2020). The present study has been attempted similar in the coastal part of Cuddalore district, Tamil Nadu, India by using all the necessary thematic layers and WIOA techniques to isolate the groundwater potential zone for necessary action like water resources management in the study area.

MATERIAL AND METHODS

Study area: The study area is located in the coastal part of Cuddalore district, Tamil Nadu, India, which is lies between the latitude of 11°12'20.67" to 11°52'48.79" N and longitude of 79°29'25.06" to 79°48'41.70" E with an area of 1772.4 km^2 (Fig. 1). Cuddalore is one of the industrial districts in the

country due to its resources and larger coastal part. The study area is exists in the east coast of India in semi-arid climatic condition. The temperature and rainfall vary with respect to monsoon and non-monsoon seasons. The 70% of the total rainfall is from the north east monsoon due to huge numbers of cyclones from Bay of Bengal, which is receives at the rate of 1446.3 mm per annum. There are four major rivers Coleroon, Vellar, Gadilam and Ponnaiyar along with backwater estuaries like Planar and Pitchavaram mangroves contains unconsolidated quaternary shallow alluvium aquifer, which is present up to 30 m below ground level (CGWB 2009). Fishing, aquaculture farms, and small-scale industries are dominant economic sources other than agriculture. The groundwater is the predominant source for the above said works along with rapid population and urbanization growth.

Methodology: The step-wise detailed methodology has been presented in Figure 2. The study area map has been prepared using survey of India topo sheet (58 M/10,11,12,14,15) with a scale of 1:50000, secondary data, and satellite images by digitizing through ArcGIS 9.3.1 software. The thematic maps such as drainage, drainage density, lineament, lineament density, geology, geomorphology, land use land cover, soil, and slope have been prepared from the source data, which is collected from the Geological Survey of India, soil survey of India, Landsat imageries and other secondary sources. Each layer is discussed in detail with respect to groundwater resources and chances. The weightage has been assigned for each layer of all the themes, which is integrated together after the weightage assigned by Weightage Index Overlay Analysis (WIOA) techniques. Each raster has been evaluated in the ArcGIS platform, which is used to predict the groundwater potential zone with more accuracy in nature. The groundwater potential zones have been classified into different zones, and the predicted zones are recommended for water resources management and artificial recharge processes.

RESULTS AND DISCUSSION

In general, the thematic layers have been discussed in detail and the weightage has been assigned for each theme of all the layers based on the groundwater holding capacity and recharge rates. Finally, the weightage has been integrated and the groundwater potential has been isolated and the necessary recommendation has been made in the medium and poor zones respectively, which has been explained in detail in the result and discussion.

Geology: The study area geology features have been generated from geology map of the Cuddalore district, which is prepared by geological survey of India, published in the year of 2001. Geological features are present up to 5 m through entire study area. The study region confined by sedimentary formations representing quaternary age and validated during field visit. Geologically it is covered eight formations such as clay, clay black, and clay with sandstone, laterite (ferricrete), sand with clay and shells, sand/clay admixture, sandy clay and silt with sand (Fig. 3). The area and percentage of each parameter have been representing in Table 1. Among eight features, three features are

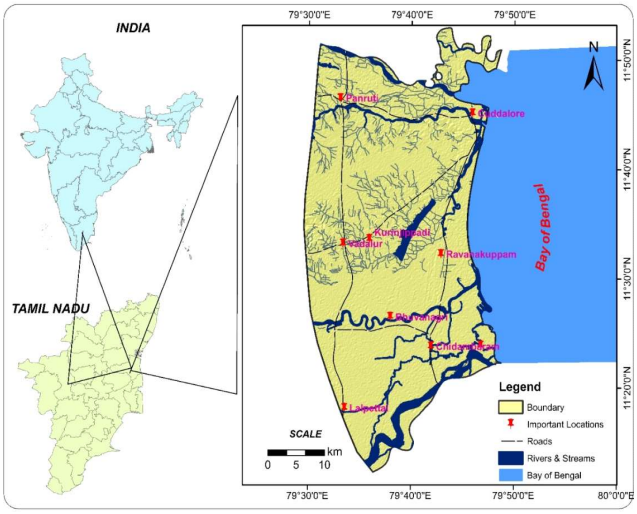

Fig. 1. Study area

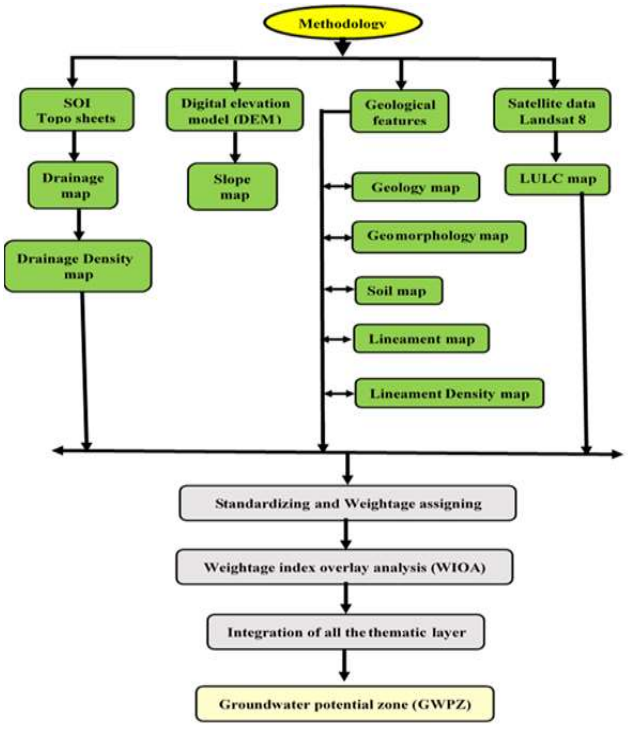

Fig. 2. Methodology

predominantly covered by such as Clay (759.7 km^2), black clay (399.2 km^2) and clay with sandstone (552.4 km^2) and other features are occurring as small patches in the predominant features such as laterite (ferricrete) (8.5 km^2), sand with clay and shells (13.93 km^2), sand/clay admixture (30.7 km^2), sandy clay (0.07 km^2) and silt with sand (7.9 km^2). Clays are observed along the south western and north western part of the study area with low top soil permeability. Black clays are noted along the coastal track of the study area and sandstone with clays are present along the Middle Western part of the study region and all formation are embedded within this geological parameter as a patch.

Geomorphology: The geomorphic features of the study area have been imported from BHUVAN - 2015 (sources: Indian Space Research Organization (ISRO) and is covered by five geomorphic features such as alluvial plain, coastal plain, flood plain, pedi plain and upland (Fig. 4). The predominant geomorphic feature is the alluvial plain observed with an area of 712.81 km^2. The alluvial plains are formed due to fluvial and river actions in the study area. The coastal plain is noted along the coastal track and which is created by sea action and covered an area of 304.27 km^2. Pedi plains are present along the Middle Western part with an area of 362.2 km^2. Uplands are observed northern part of the study domain with an Areal extant of 250.16 km^2. Flood plains are made due to flood action on the river courses, which is representing an area of 143.0 km^2.

Table 1. Details for different thematic layers

Thematic layers	Features	Area (Km^2)	Percentage
Geology	Clay	759.70	42.82
	Clay black	399.20	22.50
	Clay and sandstone	552.36	31.13
	Laterite (ferric rete)	8.50	0.47
	Sand, clay and shells	13.93	0.78
	Sand/clay admixture	30.70	1.73
	Sandy clay	0.07	0.01
	Sand and silt	7.92	0.44
Geomorphology	Alluvial plain	712.81	40.10
	Coastal plain	304.27	17.15
	Flood plain	143	8.06
	Pedi plain	362.20	20.41
	Up land	250.16	14.10
Land use /Land cover	Agricultural land	1385.86	78.12
	Built land	177.63	10.01
	Forest	5.43	0.30
	Waste land	82.02	4.62
	Water	121.17	6.83
Soil	Alfisols	746.03	41.99
	Inceptisols	218.43	12.31
	Entisols	210.99	11.89
	Vertisols	594.03	33.48
Slope	Less than 1 degree	1367.06	77.06
	1 to 5 degree	394.63	22.24
	5 to 10 degree	6.99	0.39
	10 to 15 degree	1.60	0.09
	Greater than 15 Degree	0.35	0.01
Lineament density	Less than 0.2	902.56	50.93
	0.2 to 0.5	37.07	2.09
	Greater than 0.5	832.16	46.98
Drainage density	Less than 0.5	980.34	55.52
	0.5 to 1	615.35	34.73
	Greater than 1	176.75	9.75

Land use land cover: The land use and land cover features are essential for proper planning and environmental management activities in the study area. The land use and land cover map (Fig. 5) has been created from Indian Remote Sensing Satellite P6 series (IRS- P6), Linear Imaging and Self Scanning Sensor (LISS - III) satellite data product with a resolution of 23.5m, geo-referenced in Arc GIS 10.1. LULC for the study area have been classified type I such as Agricultural land, build up land, forest, waste land and water bodies (Table 1). About 78.12% of the study area is covered by agricultural land, which includes crop land (wet and dry), plantation and fallow lands. Built up lands representing 10.01 % of the total study area is associated with cities, towns, rural settlements, villages and industrial zones. Minor features like water bodies (6.83 %), waste land (4.62 %), and forest (0.30 %). Water bodies were present throughout the study area as a lake, pond, river, channels and back waters. Waste lands are in the form of barren land and wetland.

Soil: The soil types in the study area are classified into four as per the United States Department of Agriculture (USDA) classification such as alfisols, entisols, inceptisols and vertisols (Fig. 6). Alfisols were covering major portion of the study area, which representing 746.03 km^2 of the total area (Table 1) and were rich in aluminum and distributed in the northern part of the study domain. Vertisols are occupied an area of 594.03 km^2 and represents 33.48% of the total area. The vertisols are observed along the southern part of the study area and made up of clay fragments and have wide and deep cracks during dry season and sticky during wet season. Inceptisols are noted with different rate infiltrations based on the mixing of clay content in the formation. The inceptisols are noted along the central region of the study area with an area of 218.44 km^2, which represents 12.31% of the total study area. Entisols are present along the coastal part of the study area, which is made up of sand. The entisols are covered to an area of 210.99 km^2 that representing 11.89% of the total study area.

Slope: The slope of the study area ranged from 0 to 18

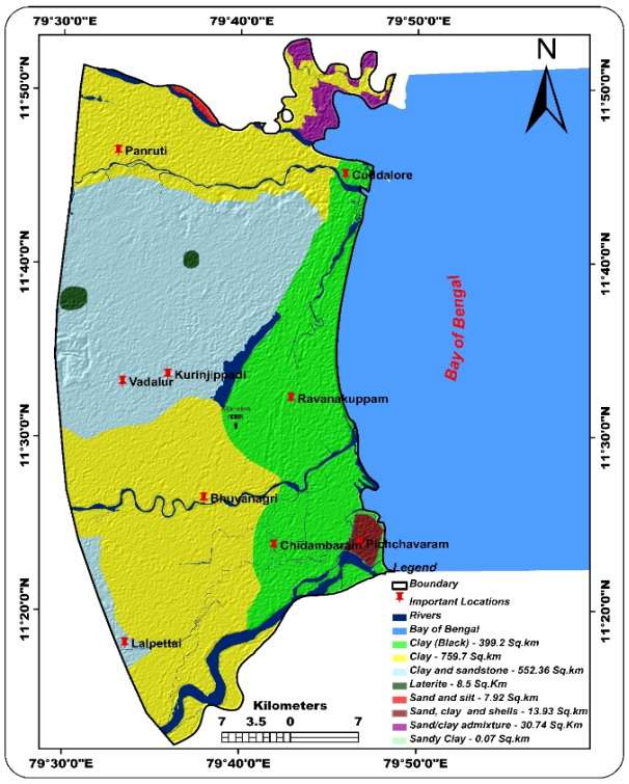

Fig. 3. Geology map of the study area

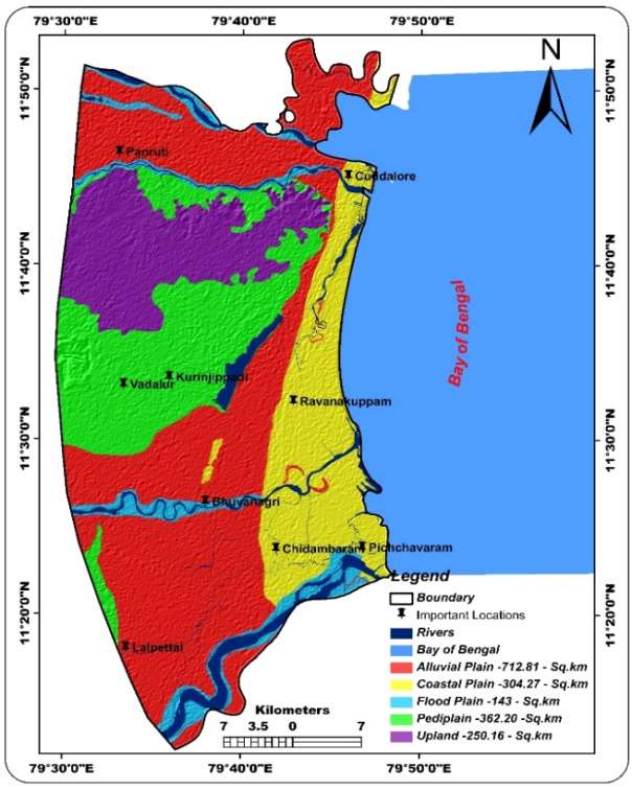

Fig. 4. Geomorphology map of the study area

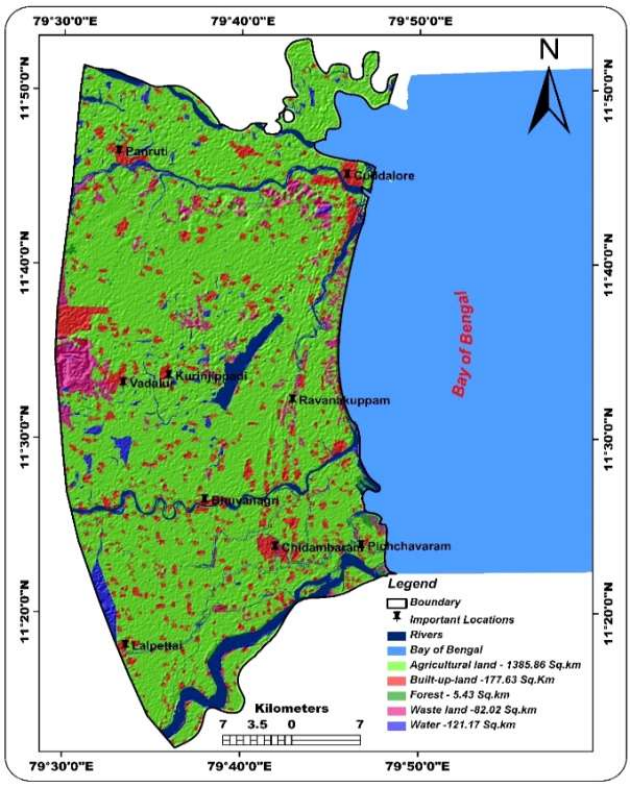

Fig. 5. Land use / Land cover map of the study area

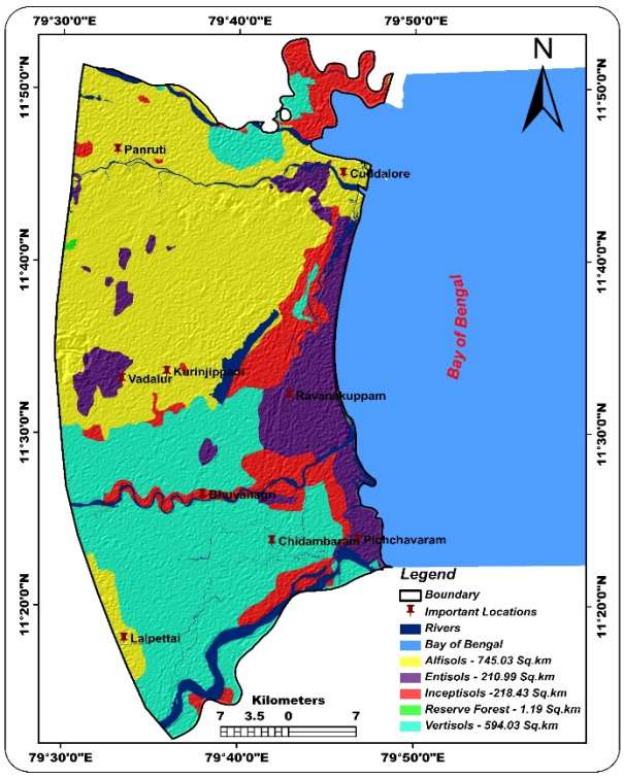

Fig. 6. Soil map of the study area

degree, which is classified into five types such as less than 1 degree, 1 to 5 degree, 5 to 10 degree, 10 to 15 degree and greater than 15 degrees. About 77% area noted the slope range is less than 1 degree (Fig. 7). The area and percentage of the slope covered area representing in Table 1.

Drainage and drainage density: The study area presents on the coastal track and crisscrossed by numerous rivers, streams, irrigational tanks and canals. Major streams like Ponnaiyar, Gadilam, Uppanar, Vellar and Coleroon were flowing in the order of north to south and all the rivers are draining from west to east (Fig. 8). The drainage density is important factor because of its impacts on lineaments, faults, joints and fractures, which play a key role in groundwater recharge, flow direction and movement. Drainage density is calculated from following equation (Horton 1932);

Drainage density = (LWS/AWS)

Where, LWS = total length of streams in watershed, AWS = area of the watershed

The estimated drainage density in the study area as drainage density (Fig. 9) is the sum of all the streams order length per unit drainage area (km km^{-2}) and is a measure of proximity of channels. The drainage density has been classified into three classes and it is varied from less than 0.5, 0.5 to 1.0 and greater than 1.0 km km^{-2} covers an area of 980.34 km^2, 615.35 km^2 and 176.75 $km^{2.}$ respectively. The moderate and higher drainage density has been noted in the northern part of the study area and the southern part of the study area represents the poor drainage density due to lesser slope and flat elevation.

Lineament and lineament density: Lineaments are defined as a long linear natural feature, which includes, zones of faults, fractures and joints etc., lineaments are rich with secondary porosity and permeability and good tank for groundwater storage. The geology map, satellite imageries and field data help to identify the lineament features in the study area (Fig. 10). Lineaments control the groundwater quantity. The length is differing from few meters to kilometers and locating in the north south and east west direction. Along the lineaments and around the lineaments are influencing the groundwater recharge. Lineament-length density (Ld); total length of all recorded lineaments divided by the area under study. The lineament density is divided into three classes such as less than 0.2, 0.2 to 0.5 and greater than 0.5 km/km^2 covers an area of 902.56 km^2, 37.67 km^2 and 832.16 km^2, respectively. The moderate and higher linear density were enhancing the groundwater recharge rate rather than low density (Fig. 11).

Weightage index overlay analysis (WIOA): The presence of groundwater in the aquifer is mainly controlled by geology (lithology), geomorphology, land use land cover, soil, slope, lineament, drainage and density. In the study area each layers depends on the different features, which is controlling the groundwater recharge and discharge rate in nature (Selvam et al 2015). The present study mainly focusing seven layers such as geology, geomorphology, land use land cover, soil, slope, drainage density and lineament density.

The rank and weightage have been assigned based on their role in the groundwater potential zones. Rank has been assigned from 1 to 4 in which, 1 indicate the good or high potential, 2 and 3 represents the moderate potential and 4 represents the poor potential in nature. The weightage for all the features assigned higher to lower (4 to 1) based on the high to low potential (Magesh et al. 2012, Prakash and Venkateswaran 2014). Higher weightage represents good potential and lower weightages represent the lower potential (Table 2). The weightage and rank have been assigned in the ArcGIS platform, all the files (geology, geomorphology, land use and land cover, soil, slope, drainage density and lineament density) were integrated in the same platform to find out the potential zone (Fig.12).

Table 2. Rank and weightage of individual parameters for groundwater potential zone

Layer	Features	Rank	Weightage Index	Total weightage
Geology	Sand and Silt	1	4	21
	Sand/Clay admixture	3	2	
	Clay	4	1	
	Clay (Black)	4	1	
	Clay and sandstone	2	3	
	Laterite	1	4	
	Sand, clay and shells	2	3	
	Sandy Clay	2	3	
Geomorphology	Alluvial plain	1	4	18
	Coastal plain	1	4	
	Flood plain	1	4	
	Pedi plain	1	4	
	Upland	3	2	
LU/LC	Agriculture land	1	4	15
	Built up land	4	1	
	Forest	2	3	
	Waste land	2	3	
	Water bodies	1	4	
Soil	Alfisols	2	3	13
	Inceptsols	1	4	
	Entisols	1	4	
	Vertisols	3	2	
Slope	Less Than 1	1	4	15
	1 to 5	2	3	
	5 to 10	2	3	
	10 to 15	2	3	
	Greater Than 15	3	2	
Lineament Density	Less Than 0.2	3	2	9
	0.2 to 0.5	2	3	
	Greater Than 0.5	1	4	
Drainage Density	Less Than 0.5	1	4	9
	0.5 to 1	2	3	
	Greater Than 1	3	2	
Sum of Weightage				100

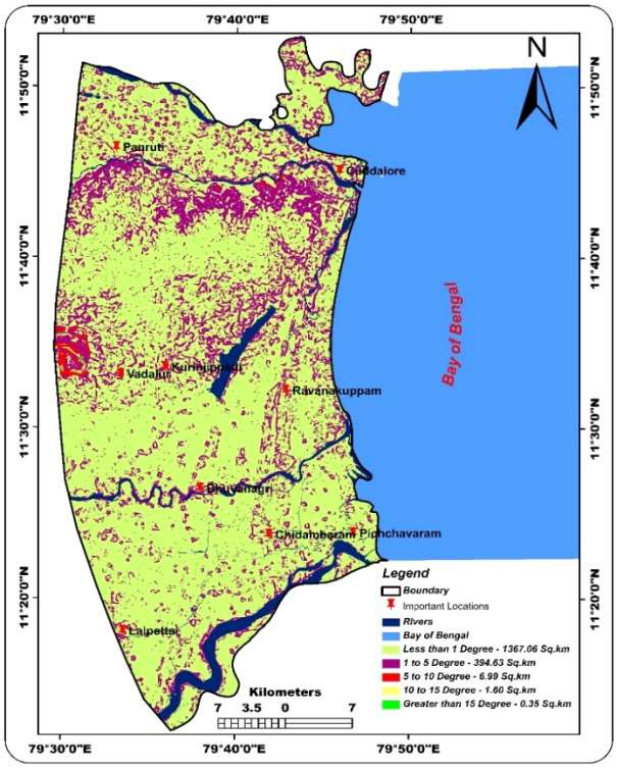

Fig. 7. Slope map of the study area

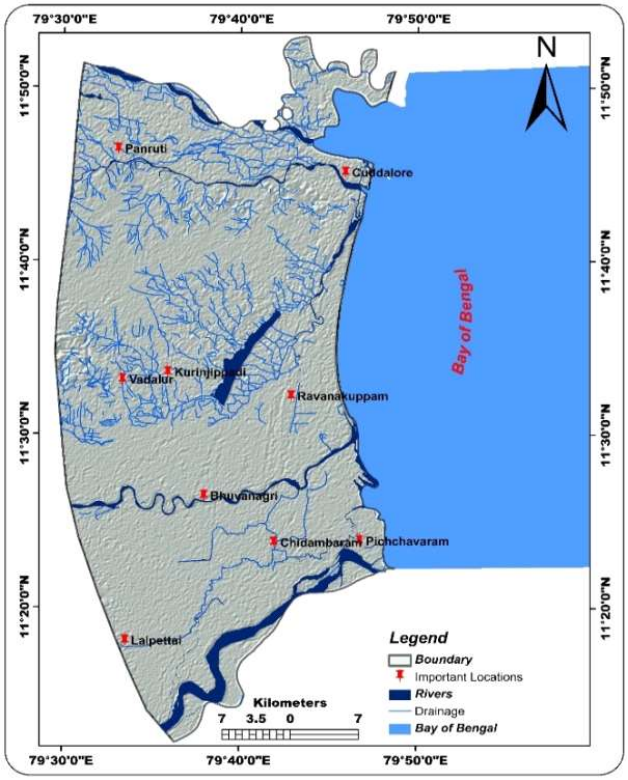

Fig. 8. Drainage map of the study area

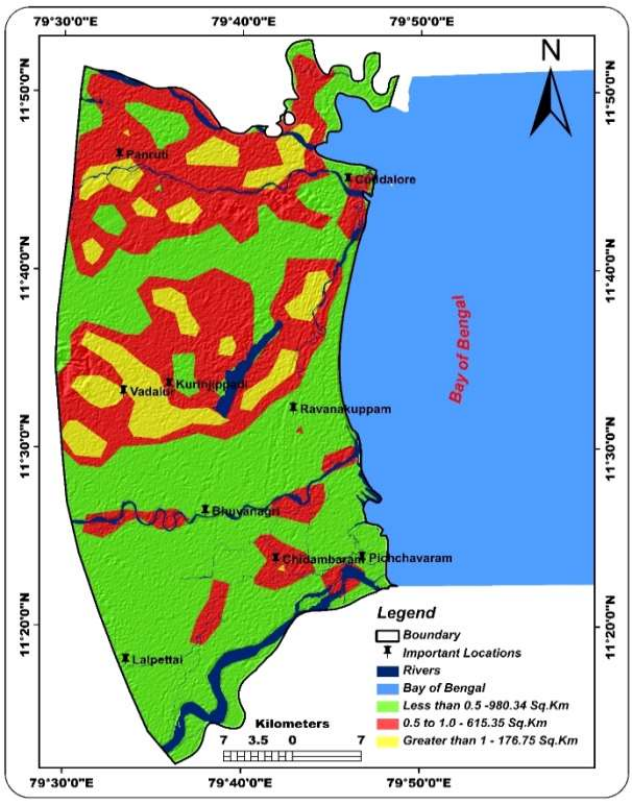

Fig. 9. Drainage density map of the study area

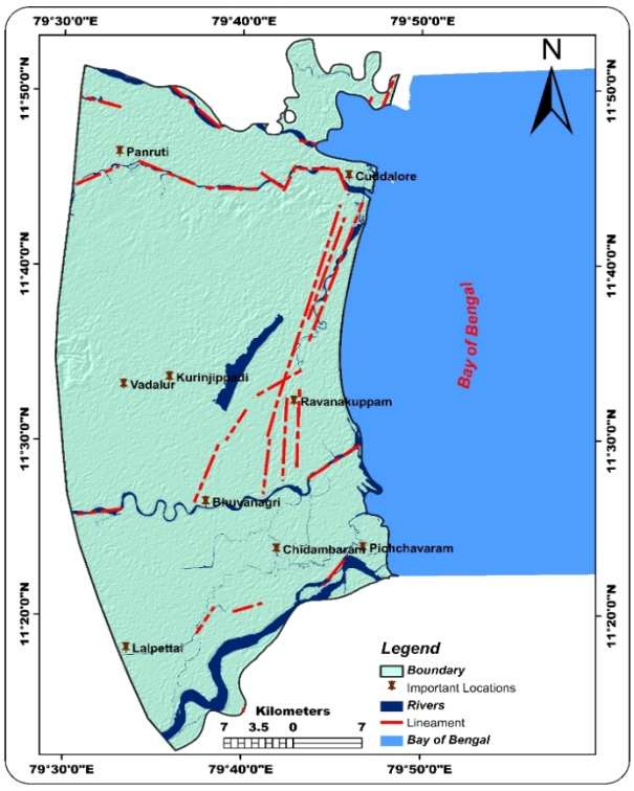

Fig. 10. Lineament map of the study area

Groundwater potential zone (GWPZ): The groundwater potential zone for the present study has been demarcated (Fig. 13). The GWPZ has been classified into five classes such as very high (343.52 km^2), high (789.60 km^2), moderate (532.24 km^2), low (85.84 km^2) and very low (23.97 km^2) (Table 3). The very high and high groundwater potential zones were representing 63.86% of the study area, which mainly contains the high weightages and 36.14% of the study area

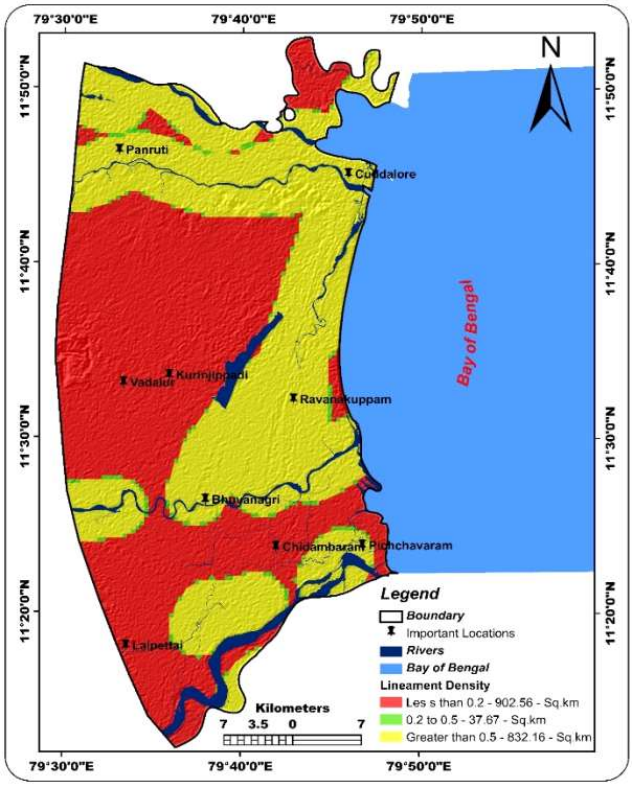

Fig. 11. Lineament density map of the study area

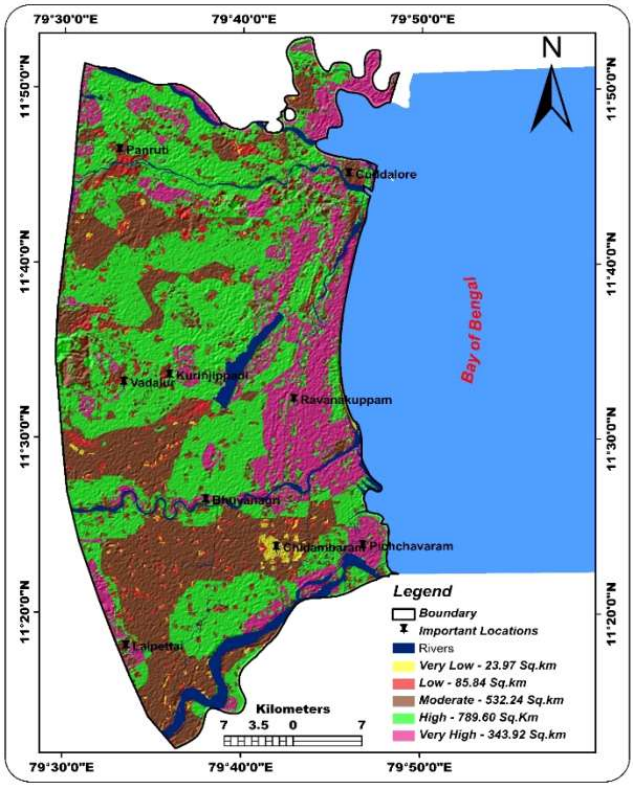

Fig. 13. Groundwater potential zone map of the study area

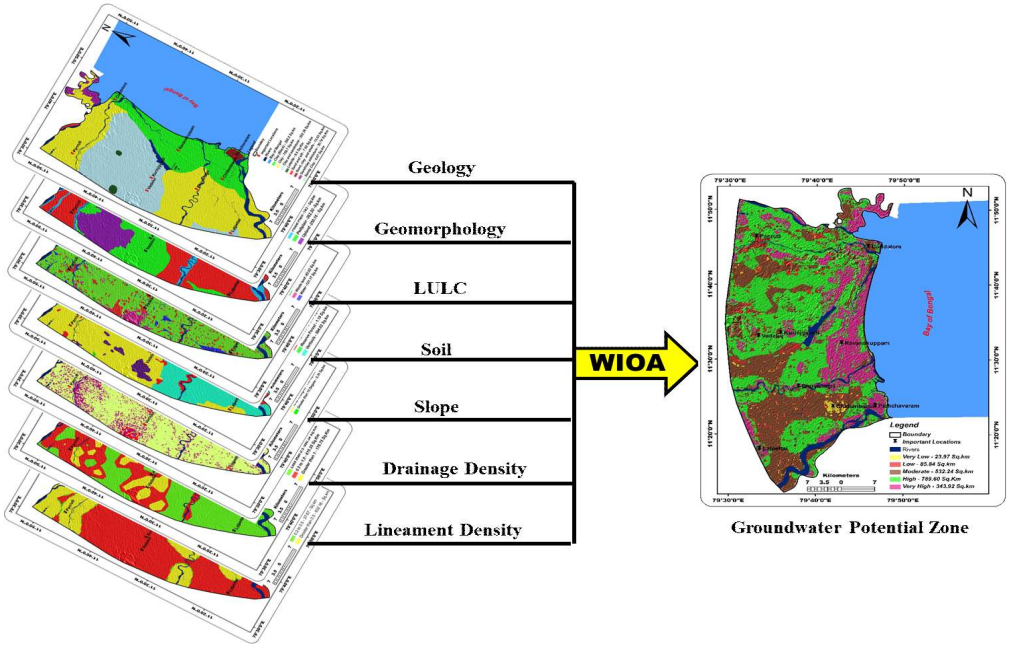

Fig. 12. Schematic representations of WIOA for GWPZ

Table 3. Categories of groundwater potential zone

Category	Area (Sq.km)	Area (%)
Very low	23.97	1.32
Low	85.84	4.82
Moderate	532.24	30.00
High	789.60	44.50
Very high	343.92	19.36

groundwater potential zones were representing moderate to very low potential zones. The groundwater potential zones were validated by field investigation in the study area, which represents shallow water level in the high and very high GWPZ and the deeper water levels were present in the moderate and low GWPZ in nature. The moderate to low groundwater potential zones are recommended for artificial recharge structures and water resources management for the enhancing of recharge to increasing the possible GWPZ and shallow water level.

CONCLUSION

The present study was attempted to isolate the groundwater potential zones in the coastal part of cuddalore district in the Tamil Nadu, India. The weightage and rank has been assigned for all the layers and the layers are integrated in the ArcGIS platform through weightage index overlay analysis techniques. The groundwater potential zones were controlled by the geology, geomorphology, land use land cover, soil, slope, lineament and drainage density features. 63.86% of the study area comes under the high to very high classes and the rest of 36.14% study area represents the moderate to low GWPZ. The water resources and management practices are recommended for the less potential zones to develop and enhance the recharge zones.

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Reproductive Phenology and Productivity Pattern of *Moghania* in Sal Forest of Gorakhpur, India

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Abstract: The congeneric species of genus *Moghania* [*M. chappar* (Benth.) Kuntze, *M. bracteata* (Roxb.) L., *M. lineata* (L.) Ktze. and *M. prostrata* Roxb.] are the common understorey associates of sal forest of Gorakhpur Forest Division, India. The main objective of the paper is to determine the phenological pattern and productivity of different congeneric species of *Moghania* facing different level of disturbance. The flowering peak is closely follows the fruiting peak. In general, peak of fruit maturation did not coincide significantly for any two species. The result shows that peak bloom of species other than *M. prostrata* overlapped to a considerable degree. Total number of seeds per plant was highest for *M. chappar*. Number of seeds and their germination was comparatively greater in experimental pot condition than in field –condition. The total as well as above ground biomass of conspecific species of *Moghania* differ significantly ($P<0.01$) among the species as evident from ANOVA test. The two species, *M. chappar* and *M. bracteata* can provide good understorey cover even in presence of considerable disturbance and thus supports the flora and fauna of the disturbed forests. A deeper understanding of reproductive phenology and productivity pattern on long term study at species level is very essential for the maintenance of ecosystem attributes in disturbed sal forest.

Keywords: Phenology, Flowering, Fruiting, Disturbance, Productivity, *Moghania*, Sal forest

Phenology includes the periodicity or timing of recurring biological activities like seed germination, leafing, flowering, fruiting, seed setting for survival and evolutionary success of many plant species. The overlapping and adjustment of phenophases of different species in nature for the efficient utilization of seed dispersal agents are important for niche differentiation in a forest ecosystem (Shukla and Ramakrishnan 1982). The phenosequence and the span of flowering and fruiting during the annual life cycle of a perennial plant is a manifestation of its adaptive strategy to the seasonal climatic condition (Sakai 2001). Several biotic and abiotic environmental conditions such as precipitation, fluctuation in temperature, pollinators and competitors have played a significant role in timing of various phenological activities (Murali and Sukumar 1994, Sundarapandian et al 2005, Gordienko and Sokolov 2009, Nanda et al 2014). The studies on reproductive phenology are not only important in understanding community attributes but also the functioning of forest ecosystem (Tesfaye et al 2011). Variations in phenophases among individuals of the same species or different species have been linked to environmental perturbations. The number of fruits produced by a plant at any one time is determined by competition for the plant resources among metabolic sinks concerned with growth maintenance and reproduction (Nakar and Jadeja 2015, Chaurasia and Shukla 2016). The reproductive phenology in sal forest is not self-regulatory and often depends on vegetative phenology and environmental constrains. Availability of resources such as light intensity and moisture content regulate the reproductive events in forest (Aravind et al 2013), which in turn determines the availability of resources for local fauna. Several studies have described the relationship between flowering and fruiting times among the species in a community and a few studies have examined this relationship among conspecific individuals (Bhat and Murali 2001, Singh and Kushwaha 2006).

Level of disturbance plays a crucial role in biomass allocation pattern. They are the important factor affecting plant growth strategies and architecture pattern of terrestrial plants worldwide (Christopher et al 2000, Bond and Midgley 2001). Sexual reproduction and asexual propagation are the two major means of regeneration in many perennials but the species of harsh environment are known to regenerate by non- seed methods (Pandey and Shukla 2019). Several studies on the biomass and allocation pattern of perennial are available (Mensah et al 2016, Pandey and Shukla 2019) and few studies have also examined the influence of disturbance regimes on the demographic and life history traits of individual species (Saha and Howe 2003, Chaturvedi et al 2011). However, study carried out by Pandey and Shukla (2018) demonstrated that under disturbance, resprouts were favoured because of their ability to persist in more competitive environment. The regional forest of Gorakhpur division is composed of different communities with a number

of leguminous and non-leguminous associates. The species -level studies on the adaptation of common woody legumes to the environment in terms of phonological periodicity is quite meager (Pandey 2000, Mauro et al 2014) and the available studies consider mostly non-leguminous woody plants. To disclose the structural organization and various resources of forest community it is essential to understand the phonological activities and productivity pattern in it. Keeping this in mind, the main objectives of the of the present study were to (i) illustrate the seasonal pattern of flowering and fruiting of genus *Moghania* in regional sal forest and (ii) effect of disturbance on aboveground and belowground productivity in congeneric *Moghania* species under different disturbance levels.

MATERIAL AND METHODS

The study was conducted in Gorakhpur Forest Division (between 27° 05′ and 27° 40′ N latitudes and 83° 30′ and 84° E longitudes at an altitude of 95 m) in eastern Uttar Pradesh, India. The division, however, consisted mostly of plantation forest of sal (*Shorea robusta* Gaertn.) planted mainly through the '*taungya system*' (Champion and Seth 1968). The climate of the region is seasonal and sub-tropical. The total average annual rainfall is about 1814 mm, 87% of which occurs during the wet summer or monsoon season (July–October). The monthly rainfall is less than 100 mm. The mean maximum temperature during wet summer, winter and dry summer is 35, 27 and 39.8°C, while the mean minimum temperature is 26, 12 and 34.8°C, respectively (Pandey and Shukla 2003).

Reproductive phenology*:* Individuals of four *Moghania* species occurring within a mature sal- dominated forest (50 ±5 yrs) were identified. The proportion of individuals undergoing reproductive activity was accounted for each species. The phonological observations were made during June 2016 to May 2017 at weekly to fortnight intervals. 40 individuals undergoing flowering, were marked for each species to observe the demography of reproductive units. The number of inflorescence stalk (peduncle) per individuals, number of flower per cm of peduncle and proportion of abortive buds, flowers and fruits were accounted. The percent fruit set and seed set and ratio of aborted vs. mature seeds were also observed. Occasionally new plants were chosen when census plant got damaged. The phenophases considered, were flowering (flower bud and full bloom) and fruiting (fruit development, ripening and fall). The span of each discrete reproductive activities were measured by marking the units upto fruit fall stage. F-test were carried out to know the level of significance of relationship between longevity of flower and fruits of different species. The fate of different reproductive unites in field conditions ware compared with that under experimental conditions in the form of pot culture.

Productivity pattern*:* The standing biomass was measured on per individual basis at the end of the active growth phase. A set of 5- replicates of different species of *Moghania* which represented different age series (from 1 to 6 year) and sequence of maturity status were excavated with their root intact. The excavated individuals were carefully washed with fine jet of water. The biomass of the harvested individuals was sorted out into their root, stem, leaf and inflorescences. The sampled individuals were dried at 80± 2ºC to constant weight. The dry weight of respective component was obtained and summed to get above ground, belowground and total biomass. The leaves and branches senescing and falling during growth, were also accounted for estimating aboveground and belowground productivity. The productivity was determined as the sum of positive changes in biomass in successive age series. The annual change in an individual biomass (ΔB) was estimated as $B_n - B_{(n-1)}$, where n, is the age in year and B in the biomass of an individual and was taken as annual biomass accumulation (Rawat and Singh 1988). Some inaccuracies were involved in the estimation of belowground production due to difficulties in the estimation of death, decay and consumption of fine roots. The above set of productivity estimation was made in stands facing high, moderate and low level of disturbances (Pandey 2000).

RESULTS AND DISCUSSION

Features of reproductive units and phenology*:* Phenophase depends on environmental conditions of the study area and are species specific (Aravind et al 2013). Extended duration flowering commonly produce fewer flowers per day as in the case of *M. bracteata* and *M. chappar*. The latter two species showed quite steady and extended flowering event. Such extended flowering has also been reported in many other understory species of tropical forests (Sundarapandian et al 2005). The different management, time of anthesis, size and colour of flower on congeneric species may reduce the competition (Mitchell et al 2009). *M. lineata* was recurrent flowerer and along with *M. prostrata* had small bright-coloured flowers with easily accessible nectar and pollen suited to be visited by the small and day active pollinator. The overlapping and displacement of flowering and fruiting phases among the woody species of the genus *Moghania* was quite variable (Fig. 1). The species started germination/ sprouting after first shower of rain in mid-June and continued extension growth, branching and leaf production until the emergence of inflorescence checked further vegetative growth. Among the different *Moghania* species, peak flowering was much earlier in prostrate than

other species. The flowering activity of *M. bracteata* and *M. chappar* was comparatively more extended and the peak flowering occurred in January and March, respectively. *M. lineata*, however, was found to be a recurrent flowerer. In addition to seasonal bloom, flower buds were also apparent at some auxillary positions on the senescing inflorescence stalk. The second peak of the flowering event in *M. lineata* synchronized with the only peak in *M. chappar*. Evidently, *M. chappar* was the last to come into bloom and continued its flowering up to May. The peak bloom of species other than *M. prostrata* overlapped to a considerable degree. The different features of reproductive units of four woody species of *Moghania* are illustrated in Table 1.

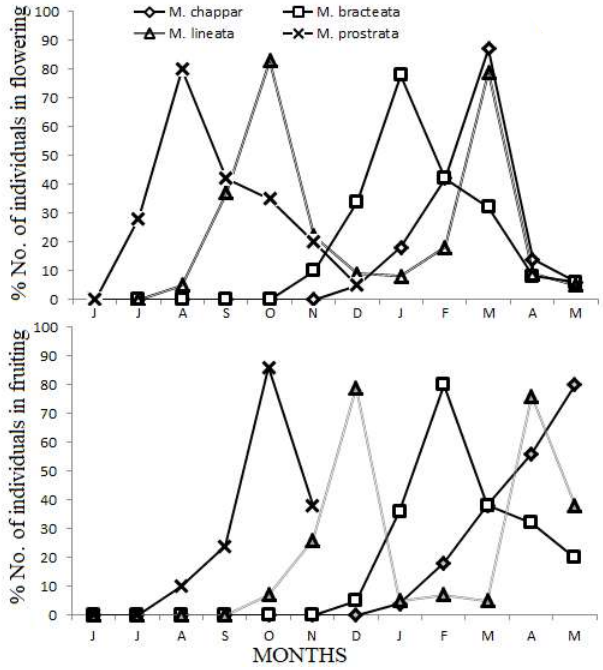

Fig. 1. Percent number of total individuals bearing flowers/ fruits in different months of the year in four shrubby species of *Moghania*

Like a few species congeners as studied by Nakar and Jadeja (2015) *M. chappar* and *lineata* shared almost the same temporal windows for reproduction. *M. prostrata* and *M. bracteata*, however, showed considerable displacement in flowering time with little overlap. However, flowering periodicity has evolved as an adaptation to an annual leafless period and the time required for the fruit to develop (Singh and Kushwaha 2006). The proximate mechanism behind the differences in flowering period involves the differences in response to seasonal rain fall and in rates of inflorescence maturation. On the other hand onset of flowering, however, has been reported to be initiated by three major physical factors of the environmental photoperiod, temperature and moisture (Sakai 2001). The event of flowering was followed by the usual process of development and maturation of fruits. In general, peak of fruit maturation did not coincide significantly for any two species. March to May was the most suitable period of fruit maturation for species other than *M. prostrata*, which had its peak fruiting during October.

Demography of reproductive units from flower bud to seed germination stages*:* Flower morphology, flower colour and nectar reward makes the species insect-pollinated a condition found also in these woody species of *Moghania*. Longevity of flowers determines the probability and the number of times a flower will be visited pollinator. Species which flower early would have invested more resources in flowers and hence have shorter flower to fruit duration (Murali and Sukumar 1994) as is the case with *M. lineata* and *M. prostrata*. Studies have reported more than one peak of flowering and fruiting in wet forest and only one peak in early wet season in seasonal dry forests (Bhat and Murali 2001). The individual flowers of *M. chappar* and *M. bracteata* showed greater longevity than that of other two

Table 1. General feature of inflorescence, flower, fruit and seed of four congeneric species of *Moghania*

Attributes	*Moghania chappar*	*Moghania bracteata*	*Moghania lineata*	*Moghania prostrata*
Inflorescence	Axillary raceme. On longer peduncle	Axillary branched raceme on shorter peduncle	Raceme, sub- sessile flowers on short peduncle	Raceme, sessile flowers packed on dense fox tail type inflorescence
Flowering pattern	Acropetal	Acropetal	Almost simultaneous	Amphipetal
Recurrence of flowering	Once, extended (Feb- Mar)	Once, extended (Jan- Feb)	Recurrent (Oct and Mar)	Once (Aug- Sept) Purple violet
Flower colour	Yellowish white	Creamy white	Pink to violet	Purplish violet
Change in flower colour	White- yellowish white light brown	Yellow- creamy white dull brown	Pink- violet- brown	Pink violet- blue- bluish yellow- yellow
Bract,shape and flower colour	Cordate, yellowish green in young, salmon brown when mature	Deeply cordate, persistent green, reddish- green when young	Minute linear scariose, dry, stiff, membranous	Membranous pubescent, gray silky out- side, deciduous, soft, brown
Pod and seeds	Brownish black with two seeds of black green shades	Brown, two seeds of black- brown colour	Glabrescent with two ovoid seeds	Pods quickly dehisces, seeds two, with brown or bluish- black shining

species. It has been argued that the longevity of individual flower affects the, total number of flowers opening at any one time which may in turn affect the level of out- crossing and the effectiveness of overall floral display in attracting pollinators (Khan et al 2005, Mitchell et al 2009). The number of reproductive units and percent abortion of flower bud, bud, flower, fruits and seed and percentage of fruit set and seed set was derived on per individual basis during the reproductive phase. The inflorescence length was maximum for *M. chappar* and minimum for *M. lineata*. The number of flowers per cm peduncle length varied greatly for different species (11.6 ± 2.6 for *M. prostrata* and between 2 to 3 for *chappar* and *bracteata*). The number of inflorescence per plant was greater for *M. chappar* followed by *M. bracteata* and *M. lineata* and lowest for *prostrata*. The number of flower buds per inflorescence was highest for *M. prostrata* (90.5 ± 18.3) and minimum for *M. bracteata* (28 ± 6.1). The percentage of flower bud aborting was maximum for *M. lineata* (32.8) and minimum for *prostrata* (23.8). The per cent number of flower aborted, was highest for *M. lineata* and lowest for *chappar*. The number of mature fruits was highest for *M. chappar* and gradually decreased from prostate, *M. bracteata* to *M. lineata,* respectively.

Synchrony in phonological event like flowering and fruiting may satiate seed predators or attract opportunistic seed dispersing animals (Freitas and Bolmgren 2008). In general, phenological results indicate that span of flowering and fruiting overlap is shorter enough to allow the species of *Moghania* to extensively share the same pollinators and seed dispersers without experiencing serious interspecific competition. Such inferences have also been drawn by a few other workers (Sundarapandian et al 2005, Aravind et al 2013). The percent fruit set was, however, minimum for *bracteata* (77.7%) and maximum for *prostrata* (86%). Fruit abortion was maximum for *M. lineata* and minimum for *M. prostrata* (16.2%). 41.2% of the total fruits of *M. bracteata* aborted at different stages. The proportion of seed set was similar for *bracteata* (50.8%) and *M. lineata* (47.8%) but was much greater for *prostrata* (83.8%). Total number of seeds per plant was highest for *chappar* (Table 2). The longevity of an individual flower or fruit widely varied for different species of *Moghania*. Flowers and fruits of *M. prostrata* were retained only for shortest period as compared to other species. The longevity of flower and of fruits was highest for *M. bracteata* and was average for *lineata* (Table 3a). Analysis of variance for the longevity of flower and of fruits within the species and between the species was significantly different even at 1% P-level (Table 3b).

Fate of reproductive units*:* There were significant differences in the fate of reproductive units between the field condition and experimental pot condition. In general, greater damage at successive reproductive stages was observed in field condition. Number of seeds and their germination was comparatively greater in experimental pot condition than in

Table 2. Demography of reproductive units of four congeneric *Moghania* species

Parameters	*M. chappar*	*M. bracteata*	*M. lineata*	*M. prostrata*
Inflorescence length (cm)	11 ± 2.3	9.0 ± 1.7	5.1 ± 1.4	7.8 ± 2.8
Flower density cm^{-1} flower stalk	2.3 ± 0.6	2.4 ± 0.4	5.9 ± 1.7	11.6 ± 2.6
No. of inflorescence $plant^{-1}$	34 ± 7.5	21.3 ± 4	9.2 ± 3.4	6.3 ± 2.1
No. of flowering buds $inflorescence^{-1}$	35.5 ± 7.5	28 ± 6.1	40.1 ± 8.4	90.5 ± 18.3
No. of flowering buds $plant^{-1}$	1200 ± 121	609 ± 97	368 ± 86	570 ± 109
No. of flowers $plant^{-1}$	860 ± 136	460 ± 88	277 ± 57	453 ± 83
No. of flowering buds aborted $plant^{-1}$	340 ± 77 (28.3 %)	149 ± 42 (24.5%)	91 ± 19 (32.8%)	117 ± 22 (23.7%)
No. of flowers aborted $plant^{-1}$	198 ± 34 (23%)	128 ± 30 (27.8%)	121 ± 37 (43.6%)	125 ± 44 (29.8%)
No. of mature fruits $plant^{-1}$	527 ± 39	258 ± 27	178 ± 16	272 ± 22
Fruit set (%)	79.6	77.7	80.5	86
No. of fruits aborted $plant^{-1}$	146 ± 17 (27.7%)	108 ± 14 (41.2%)	93 ± 9 (52.3%)	44 ± 6 (16.2%)
Seeds set (%)	72.3	50.8	47.8	83.8
Total no. of seeds $plant^{-1}$	723 ± 64	247 ± 31	153 ± 19	413 ± 56
No. of viable seeds $plant^{-1}$	610 ± 41 (84.4%)	194 ± 22 (78.5%)	97 ± 11 (63.4%)	73 ± 7 (17.7%)
No. of non- viable seeds $plant^{-1}$	113 ± 17 (15.6%)	53 ± 7 (21.5%)	56 ± 6 (36.6%)	3 ± 1 (4.1%)

field –condition. *M. prostrata* produced much greater number of seeds than other species but its germination percentage was quite low. Under experimental pot condition the percent viable seeds decreased from *chappar, bracteata, lineata* to *prostrata* respectively. The maximum seed germination, however, was observed in *M. bracteata* and minimum in *prostrata* (Fig. 2). Under field condition the crucial reproductive stage spanned from fruit to seed germination. Maximum percentage of seed set and fruit set was observed in *M. prostrata* followed by *chappar*. However, in case of *lineata* and *bracteata* the percentage of seed set was considerably higher but fruit set was very low. Fate of reproductive units is severely affected in field condition probably because of heat stress and other disturbances (Saha and Howe 2003). A considerable higher percentage of fruit set and seed set in *chappar* (as compared to *bracteata* and *lineata*) may be one of the factors responsible for its growth across much wider range. However, legume seeds are known to be highly proteinacious and often form the principal food source of several vital fauna of a forest community (Pandey 2000).

Though the aggregation pattern of bud or flower is species- specific but their density (number per cm stalk length) has been found to be affected by light intensity (Shukla and Pandey 1991). The abortion of buds, flowers and fruits have been assumed to be of various adaptive and evolutionary significance (Palupi et al 2010, Uma Shankar 2012). In general higher the life forms, greater was the abortion of buds and of flowers as compared to that of fruit.

Table 3a. Longevity of flowers (in hours) and of fruits (in day) of different congeneric species of *Moghania*

Species	Average longevity of flowers (Hours)	Average longevity of fruits (days)
M. chappar	34.5 ± 4.3	32.0 ± 5.2
M. bracteata	41.5 ± 7.2	38.0 ± 7.9
M. lineata	32.0 ± 6.0	24.0 ± 3.3
M. prostrata	19.5 ± 3.9	17.5 ± 2.7

The number of buds produced by plant is related to vigour of mother plant and climatic conditions. The number of buds is strongly correlated within populations with the number of vegetative shoots produced on the same plants during the pre-reproductive session. This suggests that plants predominantly match their resources in initial adjustment of the number of inflorescences produced (Harder and Prusinkiewicz 2013). By contrast, at the next developmental stage the number of flowers produced within each inflorescence showed little variability in control vs. field-condition. Some regulation is evident at the next two stage of development. Initiation of numerous fruits, followed by abortion of many of very flexible strategy, as the plants can compensate for uncertainties in the pollination of flowers. The early loss of fruits to predation or fluctuations in the amount of resource available for reproduction is not predictable at the time of flower initiation (Aravind et al 2013).

Productivity pattern*:* The *Moghania*, an iteroparous shrub had a large amount of below-ground biomass. This belowground storage helps them in survival during unfavourable dry summer. The abundance of such species, which can survive the hot summer in the form of underground storage may be the result of selection in significantly disturbed environment (Pandey and Shukla 2018). In general, the above ground shoot biomass grows maximum at moderate level of disturbance due to effective remains of leaf area are due to lesser competition at ground level. The total biomass showed significant difference ($P<0.01$) among disturbance level as evident from F-test (F- value was > 19 at df 2 for each congeneric species). Aboveground productivity (log value) was highest at moderate level of disturbance for species other than *prostrata,* which showed its maximum only at low disturbance. *M. chappar* had similar aboveground biomass at low or high disturbance upto 4 year plant age (Fig. 3). *M. lineata* and *bracteata* showed marked difference in aboveground productivity between the low and high level of difference. In general, the aboveground productivity increased upto 4 year irrespective of disturbance level. Belowground productivity showed no clear- cut pattern with

Table 3b. Analysis of variance (F- value) for longevity of flowers (in hours) and of longevity of fruits (in day) of different congeneric species of *Moghania*

Source of variance	Degree of freedom	Longevity of flowers		Longevity of fruits	
		Mean sum of squares	F- ratio	Mean sum of squares	F- ratio
Within the species (Between columns)	3	102	20.0*	13	0.43
Between the species (Between rows)	3	337	66.1*	316	10.36*
Residual	9	5.1		30.5	
Total	15				

*Significant at 1% P-level

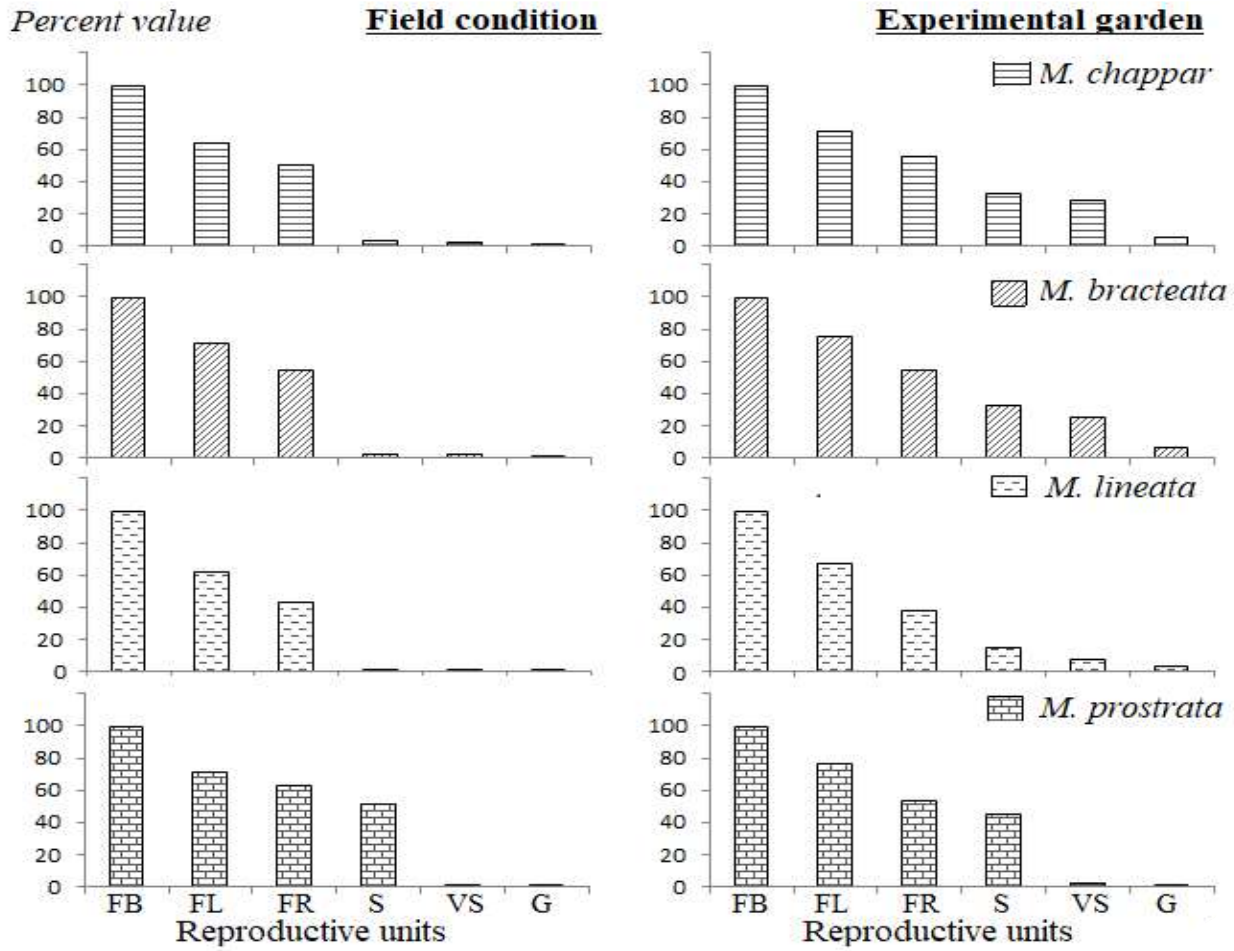

Fig. 2. Fate of reproductive units from flower bud to seed germination stage (FB, flower buds; FL, flowers; FR, fruits; S, seeds; VS, viable seeds; and G, seed germination %) under field and experimental conditions

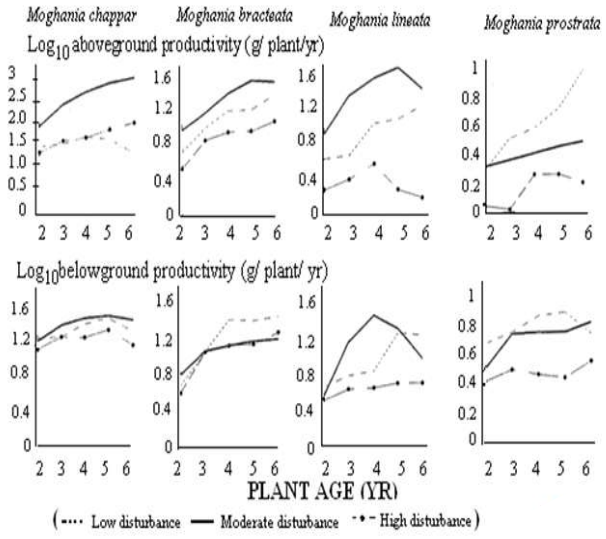

Fig. 3. Pattern of change in aboveground and belowground productivity in four *Moghania* species along the age series at three different disturbance levels

respect to degree of disturbance, but for *M. chappar* and *lineata*, it was better at moderate disturbance. The *M. breateata* and *prostrata* showed greater belowground productivity at low disturbance. High disturbance caused much lower belowground production in all the species except *M. bracteata*, for which it was better at low disturbance. Studying the productivity in terms of biomass extraction is useful in planning the proper forest management strategy and information on reproductive phenology is helpful in predicting the interaction of flora and fauna in changing stochastic environment.

CONCLUSION

Phenological behaviour of a species is its adaptation to the surrounding environment. The present study revealed that the productivity pattern and reproductive phenology of congeneric species are adaptations to the heterogeneous environment. The mechanisms behind the difference in flowering and fruiting are probably due to the local

disturbances. In general, flowering in *Moghania* was seasonal and segregated spatially as well as temporally. To understand the effect of disturbance on reproductive phenology, however, long term studies including more environmental factors are required to understand their sal forest stability.

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Impact of Different Agroforestry Systems on Depth Wise Distribution of Physico-Chemical Properties and Soil Carbon Stock in North-West India

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***Abstract*:** The present study compares the physico-chemical properties and carbon in soil under different agroforestry systems (*Populus* + wheat and *Eucalyptus* + wheat) and sole wheat mono cropping at different depths at Shahbad (Kurukshetra). 224.75±4.53 kg ha^{-1} of available nitrogen was reported in *Eucalyptus* + wheat agroforestry system, while highest soil organic carbon (1.17±0.04%), soil organic matter (2.01±0.06%) and soil organic carbon stock (29.17±0.84 Mg ha^{-1}) was reported in *Populu*s + wheat agroforestry system. Results support the hypothesis that adoption of the agroforestry system would be ecologically beneficial over sole cropping systems since adopting agroforestry practices can increase farmers profitability, marketability, and most importantly, sustainability.

***Keywords*:** Agroforestry, Agronomy, Carbon stock, *Populus*, *Eucalyptus*

A six-fold increase in the Indian population from 200 million to 1200 million has resulted in significant change in land use during 1800-2010 (Arya et al 2018, Tian et al 2014). Enormous pressure of population has led to a rapid loss of natural resources. In developing countries, drastic population growth, industrial growth, rapid deforestation, urbanization, and vehicular activities lead to increased atmospheric temperature through the tricking of a definite wavelength of energy in the atmosphere (Kumar et al 2019, Mishra et al 2013). To maintain the ecological balance and natural biogeochemical cycling, we need to explore viable options for reducing atmospheric stresses. Trees act as a sink of CO_2 by fixing carbon through photosynthesis and storage of excess carbon pools as biomass. The entire CO_2 sink/sources relation in forest, change with time as tree grows, die and degrade. The most promising management for CO_2 mitigation is reforestation, agroforestry + natural reforestation (Kumar et al 2018, Chaudhari et al 2014, Arora and Chaudhry 2014, Sharma et al 2016). Developing trees in urban areas can be a latent contributor in dropping down the concentration of CO_2 in the atmosphere by its accumulation in the form of biomass (Arya et al 2018, Giri et al 2018, Chavan 2010).

North-West India witnessed a green revolution in the 1970s by increasing the agriculture area and extensive use of fertilizers and pesticides with a mono cropping system. As a repercussion of the green revolution, the soil of this area is now facing the challenges of salt accumulation and soil degradation, which now need to be restored for sustainable growth and livelihood. Agroforestry is the intermixing of trees and shrub into the crop and/or animal yield system to create environmental, economic, and social benefits. It is a useful strategy for carbon sequestration for climate change mitigation under the CDM of the Kyoto Protocol (IPCC 2007, Nair 2007). Agroforestry may control soil erosion, act as a windbreaker, maintains and improve soil fertility, control weeds, fencing, and carbon sink in soil by their function of service (Arya et al 2018, Sarangle et al 2018, Gupta et al 2009, Nair et al 2009).

Poplar/*Eucalyptus* (Popular-wheat and/or Rice + *Eucalyptus* + wheat and /or rice) agroforestry systems have been found economically viable as well as more sustainable than other cropping rotation and monocropping system with good soil health, physicochemical properties (Arora and Chaudhry 2017, 2015, Chauhan et al 2015, Sharma et al 2016). The present study was carried out to determine the variation among the physico-chemical properties, nutrient availability, and carbon status in soil under agroforestry system of *Eucalyptus*+ wheat, *Populus*+ wheat, and sole wheat mono-cropping system.

MATERIAL AND METHODS

Site description: The study was carried out in the Shahbad town of Kurukshetra District in NW Haryana, India, which lies on the Western Bank of the river Yamuna (Fig. 1). The district is a portion of the Ganga-Indus (Indo-Gangetic) plains and

has a well-spread grid of the Western Yamuna canal. Three different land uses viz. *Eucalyptus* + wheat, Poplar + wheat, and sole wheat were sampled for analysis of soil properties.

Soil sampling: Soil samples were collected from two agroforestry and one agronomy system at three soil depths i.e., 0-20cm (surface soil), 20-40cm (subsurface soil), and 40-60cm (deep soil) using a soil auger in a zig-zag manner. During the collection of samples, the superior cover of litter was carefully wiped out; collected samples were mixed thoroughly to form a composite sample. The moist soil samples were air-dried and passed through a 2-mm sieve for the removal of plant debris and larger particles and were used for the subsequent chemical analyses.

Physicochemical analysis: Soil moisture was determined by the gravimetric method, Bulk density by soil core method (Blake and Hartage 1986). Soil pH and Electrical conductivity (soil: water, 1:2) was determined by following standard methods (Jackson 1967). Soil respiration, Available Nitrogen, Exchangeable Calcium, Magnesium, Chloride were determined by alkali absorption, Kjeldahal distillation, Versanate titration, and Argentometric methods, respectively. SOC was determined by Walkley and Black's method (Jackson 1967). Soil texture analysis was accomplished by the International Pipette Method (Baruah and Barthakur 1999).

Soil organic carbon stock calculation: The total carbon stock was calculated by following the method of Batjes (1996). The total SOC stock was calculated using the equation:

C stock in soil (Mg ha^{-1}) = C content (kg^{-1}) × BD (g cm^{-3}) × Soil depth (m)

Statistical analysis: Statistical analysis of data was computed for each parameter for the interpretation of the results.

RESULTS AND DISCUSSION

Physicochemical properties: The variations in physico-chemical properties of the soil of the three studied systems are presented in Table 1. Sole cropping land-use system of wheat recorded higher soil moisture content i.e., 26.91% while *Eucalyptus*+ wheat-based agroforestry system recorded minimum soil moisture content i.e., 13.13%. In *Eucalyptus*+ wheat based land use practice, surface soil had higher moisture content (13.46%) followed by subsurface soil. In the case of *Populus*+ wheat agroforestry system, surface soil had higher moisture content (22.06%); however, subsurface soil had the lowest moisture content (17.14%). In the sole wheat system, the highest moisture content was observed in the deep soil layer followed by surface soil. Agroforestry system of *Eucalyptus*+wheat had minimum BD (1.21 mg m^{-3}) while *Populus* +wheat based agroforestry system had maximum BD (1.33 mg m^{-3}). Bulk density increased from top to bottom with soil depth in all three systems.

Soil pH in all the three land-use systems, varied from 6.80 to 8.73. Sole wheat based agronomy system had recorded maximum pH i.e., 8.73. However, *Populus* + wheat based agroforestry land use had a minimum pH i.e., 6.80. In all the three systems, the highest soil pH was observed in the deep soil layer. EC of soil water suspension ranged from 0.15 to 0.76 dS m^{-1} with maximum EC value observed in *Populus* + wheat based agroforestry system followed by the sole wheat agronomy system and *Eucalyptus*+wheat agroforestry. The maximum value of electrical conductivity was reported in subsurface soil in all the three systems. Soil respiration or CO_2 evolution varied from 29.10 per ha day^{-1} to 107.07 per ha/day in all the land-use systems. Higher CO_2 evolution i.e., 107.07 per ha/day, was recorded in the sole wheat mono-cropping system and minimum CO_2 evolution i.e., 29.10 per ha day^{-1} was observed in *Populus* + wheat agroforestry system. The rate of soil respiration decreased down the depth in all three study sites. Available nitrogen varied from 172.48 to 224.75 kg ha^{-1} being highest in *Eucalyptus* + wheat based land-use system and lowest in *Populus* + wheat based land use practice. The available nitrogen content was observed to be decreasing down the depth of all three systems.

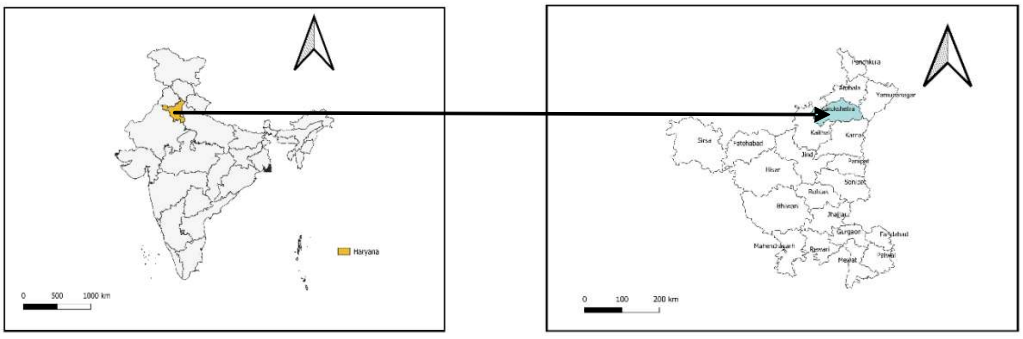

Fig. 1. Location map of the sampling site

Exchangeable cations & anions in the soil: Exchangeable calcium varied from 0.26 meq l^{-1} to 2.03 meq l^{-1}. Sole wheat based land use practice recorded maximum calcium i.e., 2.03 meq/l while *Populus*+wheat land use practice recorded minimum calcium i.e., 0.26 meq l^{-1}. The results revealed that calcium content increased down the depth all the three land-use practices under study exchangeable magnesium ranged from 1.05 to 2.81meq/l being the highest in sole wheat practice and lowest in *Populus* + wheat based agroforestry system. The magnesium content increased from top to bottom with soil depth in all the land-use practices. The chloride content in soil ranged from 1.93 to 5.87 mg l^{-1} in all three land-use systems. The highest amount of chloride content was observed in *Populus*+ wheat based agroforestry practice while the lowest amount was observed in *Eucalyptus*+ wheat based land use practice (Table 2).

Soil organic carbon (SOC): Soil organic carbon varied from 0.37% to 1.17% in the three different land-use systems. *Populus*+ wheat based agroforestry system showed a maximum SOC (1.17%) followed by *Eucalyptus*+ wheat based agroforestry system (0.72%) and sole wheat agronomy system (0.37%). In all the three systems, the SOC showed a decreasing trend down the soil depth (Fig. 2).

Soil organic matter (SOM): Soil organic matter followed the same trend as in the case of SOC. It was observed to be varying from 0.64% to 2.01%. *Populus* + wheat based agroforestry system had higher SOM i.e., 2.01%, whereas, sole wheat agronomy system had lower SOM i.e., 0.64%. The surface layer of all the three land-use practices recorded the higher soil organic matter while a deep layer of all the systems recorded lowest soil organic matter (Fig. 3).

Soil organic carbon stock: Carbon stocks varied from 9.63 Mg ha^{-1} to 29.17 Mg ha^{-1}. *Populus*+ wheat based agroforestry system had maximum soil carbon stocks (29.17 Mg ha^{-1}), and sole wheat system had minimum carbon stocks i.e., 9.63 Mg ha^{-1} (Fig. 4).

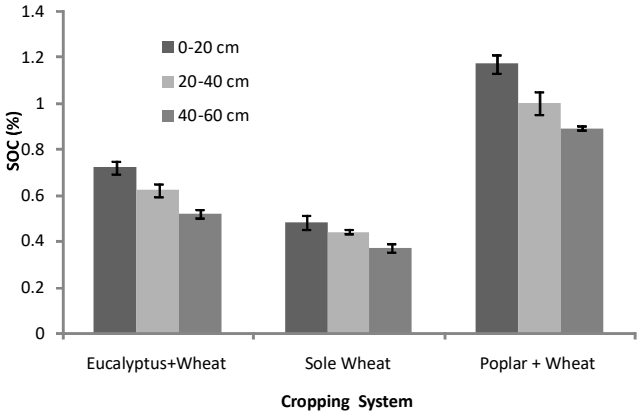

Fig. 2. Soil organic carbon (%) of different systems

Table 1. Physico-Chemical properties of the soil of different agriculture system. The values after ± represent the error

Parameters	Soil depth (cm)	Types of system		
		Eucalyptus+Wheat Agroforestry system	*Poplar+Wheat* Agroforestry system	Sole Wheat Agronomy
Moisture (%)	0-20	13.46± 0.07	22.06± 0.19	25.23± 0.40
	20-40	13.21± 0.15	17.14± 0.65	13.83± 0.17
	40-60	13.13± 0.02	17.61± 0.07	26.91± 0.37
Bulk density (mg m^{-3})	0-20	1.21± 0.01	1.25± 0.00	1.27± 0.01
	20-40	1.22± 0.01	1.29± 0.00	1.27± 0.02
	40-60	1.23± 0.01	1.33± 0.01	1.30± 0.01
Soil pH	0-20	7.39 ± 0.00	6.80± 0.10	8.36± 0.03
	20-40	7.25± 0.00	6.90± 0.00	8.33± 0.25
	40-60	7.61± 0.00	7.00± 0.00	8.73± 0.08
Electrical conductivity (dS m^{-1})	0-20	0.15± 0.00	0.50± 0.01	0.52± 0.01
	20-40	0.17± 0.00	0.76± 0.00	0.56± 0.01
	40-60	0.15± 0.00	0.65± 0.00	0.60± 0.01
Soil respiration (per ha day^{-1})	0-20	39.43± 2.45	51.43± 3.33	107.07± 1.27
	20-40	35.77± 1.42	39.50± 0.75	37.20± 2.23
	40-60	30.07± 2.54	29.10± 1.51	29.63± 1.11
Nitrogen (kg ha^{-1})	0-20	224.75± 4.53	222.13± 4.53	198.61± 11.98
	20-40	214.29± 55.07	211.68± 0.00	201.23± 4.53
	40-60	188.16± 7.84	172.48± 0.00	198.61± 22.63

Total inorganic carbon (TIC): Total inorganic carbon ranged from 0.08% to 0.17%. TIC was recorded highest in *Eucalyptus*+ wheat based agroforestry system i.e., 0.17 %, while minimum TIC has recorded in *Populus*+ wheat system i.e., 0.08%. TIC was observed to be increasing with soil depth in all the land-use practices (Fig. 5).

Aggregate associated carbon: Associated carbon with meso-aggregates varied from 0.34% to 0.58% being highest in *Populus* + wheat based land-use system and lowest in Sole Wheat based land use practice, associated carbon with micro aggregates varied from 0.55% to 0.65 % being highest in *Populus* + wheat based land-use system and lowest in *Eucalyptus* + wheat based land-use system, associated carbon with sand & silt varied from 0.67% to 0.84%, wherein highest carbon was noticed in *Populus* + wheat based land-use system and lowest in *Eucalyptus*+ wheat based land-use system and associated carbon with coarse macro aggregates varied from 0.32% to 0.52% being highest in *Populus* + wheat based land-use system and lowest in sole wheat based land-use system (Fig. 6-8)

Soil moisture content declined with depth in both agroforestry systems. The upper layer and surface layer of

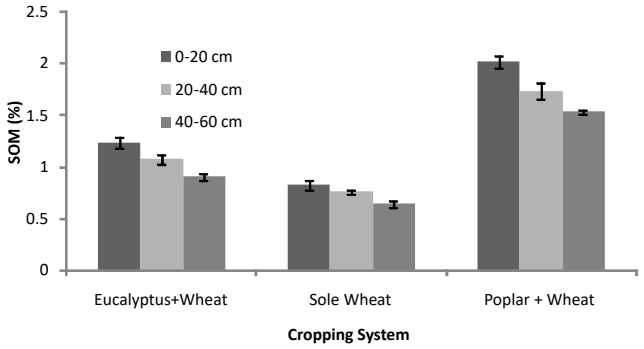

Fig. 3. Soil organic matter (%) from different systems

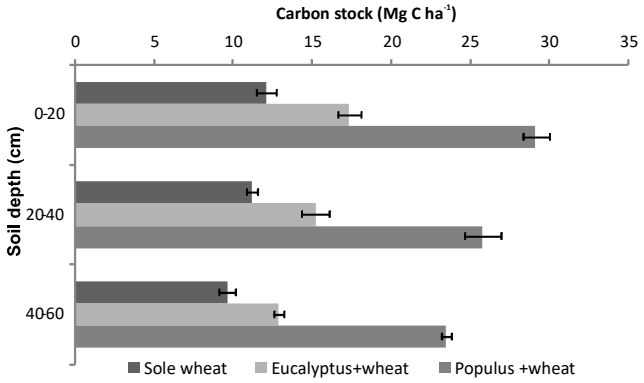

Fig. 4. Soil organic carbon stock (Mg ha^{-1}) from different systems

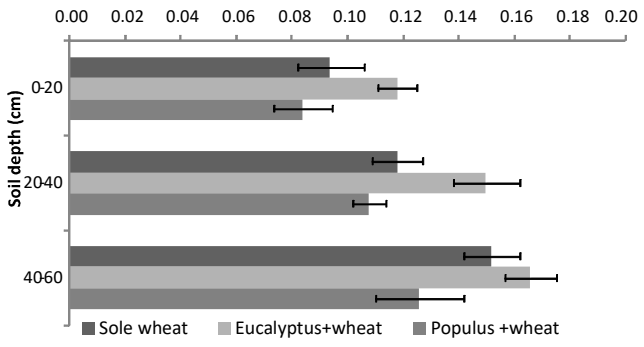

Fig. 5. Total inorganic carbon (%) of the different systems

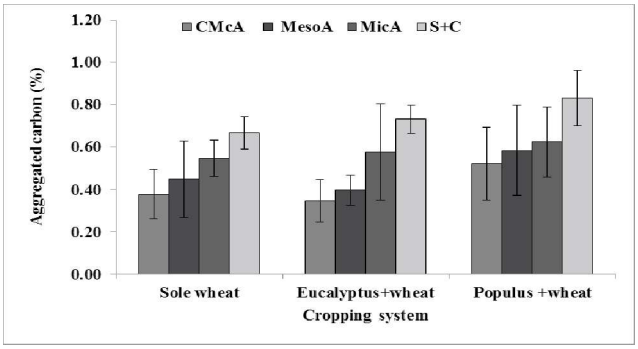

Fig. 6. Aggregate associated carbon under agroforestry and agronomy system above up to 20 cm depth

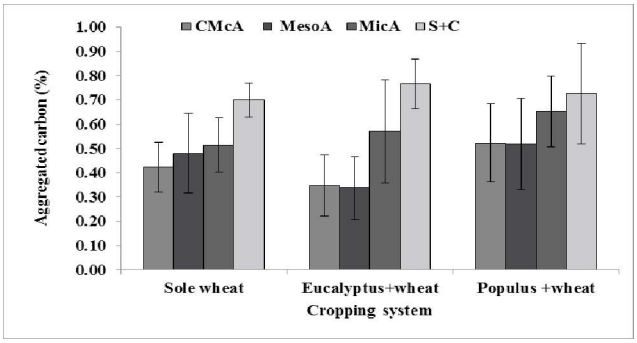

Fig. 7. Aggregate associated carbon under agroforestry and agronomy system up to 40 cm depth

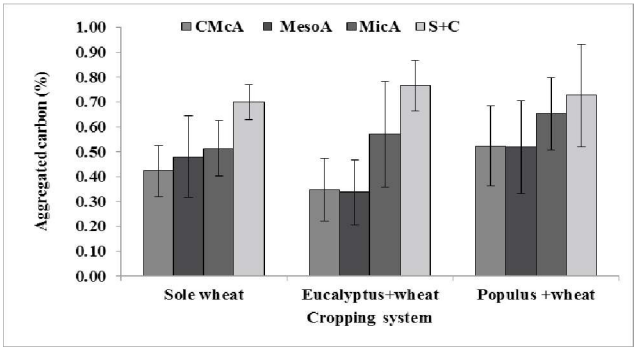

Fig. 8. Aggregate associated carbon under different land-use system above up to 60 cm depth

Table 2. Exchangeable cations and anions of the soil. The values after ± represent the error

Parameters	Soil depth (cm)	Types of system		
		Eucalyptus+Wheat Agroforestry system	*Poplar*+*Wheat* Agroforestry system	Sole Wheat Agronomy
Calcium (meq l^{-1})	0-20	0.31±0.01	0.26 ±0.02	1.21±0.01
	20-40	0.51±0.01	0.51±0.02	1.44±0.05
	40-60	0.84±0.01	0.65±0.02	2.03±0.03
Magnesium (meq l^{-1})	0-20	1.40±0.52	1.05±0.01	2.00±0.00
	20-40	1.28±0.07	1.30 ±0.00	2.23±0.02
	40-60	1.64±0.00	1.43 ±0.02	2.81±0.02
Chloride (mg l^{-1})	0-20	3.33±0.23	4.14 ±0.22	3.07±0.23
	20-40	1.93±0.12	4.67±0.23	4.15±0.22
	40-60	4.05±0.08	5.87±0.23	4.81±0.02

soil showed higher moisture content. It may be due to the reason that vegetated land uses are expected to have comparatively healthy soil characteristics that may affect both the soil infiltration and water holding capacities; however, high moisture content was noticed in the subsurface layer of soil in sole wheat agronomy system. It might be owed to leaching of irrigation water and high rate of infiltration due to absence of more vegetation, weak water holding capacity, etc. Bulk density increased from top to bottom with soil depth. The bulk density depends on several factors such as compaction, consolidation, and amount of SOC present in the soil, but it is highly correlated to the organic carbon content (Morisada et al 2004).

No consistent trends were observed in Soil pH and EC; however, a higher value of pH of the upper layer might be due to leaching and accumulation of basic ions in the deep layer of the soil profile. Production of organic acids by exudating and decomposing leaf, root, debris, and litter in soil profile may cause the lower pH agroforestry plantation compared to the sole wheat mono-cropping system. Soil respiration or CO_2 evolution was observed to be declining with soil depth in all the three land-use systems. This may be attributed to low microbial activity in deep soil (Fang and Moncrieff 2005). Various factors such as soil temperature, moisture, site productivity, soil physico-chemical properties and soil microbial communities have been reported to greatly influence the rates of soil respiration in the form of CO_2 loss (Arora and Chaudhry 2017, Chauhan et al 2018).

Available nitrogen also showed a declining trend down the soil depth in both agroforestry systems; however, the upper layer and subsurface layer of sole wheat agronomy system were noticed to have almost similar value for available nitrogen and surface layer of soil was noticed with a higher content of available nitrogen. Application of fertilizers, soil organic matter quality, temperature, and soil water availability, might have contributed to an increased level of available nitrogen in all land-use systems. Exchangeable ions were observed to increase with soil depth in all the three land-use systems. However, the surface layer of soil in *the Eucalyptus* + wheat agroforestry system noticed the lowest calcium and chloride content. A positive build-up of Exchangeable ions might be possible due to parent material.

The soil carbon viz, soil organic carbon (SOC), soil organic matter (SOM), carbon stock (CS), and total inorganic carbon was found highest in agroforestry land-use practices status, and it might be due to the more organic matter in the soil, more leaf litterfall, more decomposition than the agricultural field, whereas in the agricultural field, SOC depended on nature and types of crop, leaf foliage, and supply of inputs. Many studies have reported that tree plantations have a marked potential for carbon sequestration by improving soil structure, soil aggregation, and increasing soil carbon (Arya et al 2018, Giri et al 2018, Gupta et al 2009, Arora and Chaudhry 2015, 2014).

CONCLUSION

Soil properties are substantially altered in the soil profile by agroforestry system. Higher soil carbon dynamic build-up (soil organic carbon, soil organic matter, soil organic carbon stock) has been observed in both agroforestry systems compared to the wheat mono-cropping. Agroforestry practices have an immense potential for carbon sequestration and other multiple benefits such as soil quality indexing, biomass build-up, and environmental services of carbon elimination from the atmosphere. The agroforestry system thus can be considered as a sustainable land-use system for environmental and biological productivity by meeting the objective of sustainable development and sustainable agriculture in context of changing climate.

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Variability in Stone Characters and Early Progeny Performance of Selected *Melia dubia* Genotypes from Northern Western Ghats of India

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***Abstract*:** Variability in stone characters and early offspring performance at nursery stage was evaluated in twenty Candidate Plus Trees (CPTs) of *Melia dubia* selected from Northern Western Ghats of India. Aged drupes were gathered during February-March, 2014-15 and sown in nursery to contemplate the degree of inconstancy. Analysis of variance uncovered significant variations among the genotypes. CPTs namely NAU-9, NAU-12 and NAU-17 recorded predominance in stone morpho-metric characters, germination efficiency and early progeny performance markers under examination. Genetic variability analysis exhibited higher phenotypic coefficient of variation (PCV) with little variation to genotypic coefficient of variation (GCV) for all the characters under scrutiny whereas heritability (broad sense) ranged from 40.46 to 98.04% and genetic advancement per cent (GA%) from 6.98 to 85.81. Germination capacity of stones and seedling dry weight were the two strong heritable characters of interest which showed the higher PCV, GCV, heritability and GA% while stone length recorded lower esteems. Strong correlation among stone weight, germination capacity and seedling vigour and quality were established in this study. In addition to, twenty genotypes organized themselves in to four clusters based on similarity in characters as revealed by cluster analysis. In our examination, group III, accommodating offspring of NAU-9, NAU-12 and NAU-17 were predominant in mean stone and progeny performance characteristics. This investigation recommended the consideration of these principal genotypes for mass augmentation of quality planting material for improved farm productivity and further genetic advancement.

***Keywords*:** *Melia dubia,* Malabar neem, Variability, Stone, Progeny performance

Melia dubia, commonly known by its trade name 'Malabar Neem' is a tall and straight tree, native to moist localities and topical forests distributed in eastern Himalayas, Assam, Khasi hills and Western Ghats (Troup 1921). It goes up to 30 m in height, 9 m of clear bole and 1.2 to 1.5 m diameter at breast height. *M. dubia* has gained the recognition as a fast growing, industrially as well as medicinally important multipurpose tree species in the recent years. Wood of *M. dubia* has been proved to be a distinguished and highly suitable raw material for plywood and veneer industry industries (Uday et al 2011), paper and pulp industries (Parthiban et al 2009, 2019) and power generation plants (Sarvanan et al 2013). In addition to wood, almost every products of this species are being known equally important. Extract of bark, fruits and leaves are the source of essential oil and many compounds proven to be effective against wide range of human pathogen (Malarvannan et al 2009) and insects (Yasodha et al 2012). Leaves and fruit pulp of *M dubia* are rich source of mineral elements, crude protein, crude lipid and vitamins that serve as excellent fodder for livestock (Leela et al 2016, Sukhadiya et al 2020).

M. dubia is also considered as an model agroforestry tree with no allelopathic effects on understorey crops (Thakur et al 2017, Parmar et al 2019). Although this species has came up on Indian farms as an indigenous alternate to Eucalypts and Poplar based agroforestry but access to high quality planting stock is still constraint to farmers unlike these exotic short rotation productive crops. To bridge the gap, committed and constant efforts are being made for selection and screening of germplasm by some workers in Tamil Nadu (Kumar et al 2013), Uttarakhand (Kumar et al 2013) and Telangana (Warrier et al 2018) of Indian states but to the best of our knowledge natural germplasm available in northern most tip of Western Ghats remains untouched. Therefore, in a row, maiden efforts have been made to explore naturally growing population of Malabar Neem in the southern part of Gujarat, India (Chauhan et al 2018) and as an extension, this study being undertaken to screen the genetic variation available in locally adaptive population of *M. dubia* at nursery stage with a view to select potential germplasm for developing quality planting material and further tree breeding initiatives.

MATERIAL AND METHODS

Experimental site: Present study was undertaken in plant

nursery of College of Forestry, Navsari Agricultural University, Navsari (20° 95' N and 73° 90' E; altitude of 10 m). Experimental site experiences hot and humid tropical climate with an average annual temperature of 27°C (Max. 31°C - Min. 22°C) and rainfall of 1555 mm.

Experimental material and procedure: Ripened drupes were collected from the selected candidate plus trees (CPTs) of *M. dubia*, from different places covering three districts of South Gujarat region of Indian state which falls in Northern Western Ghats (Chauhan et al 2019) (Table 1 and Fig. 1). Collected drupes were depulped manually and dried in shade. Stones were sown in germination trays filled with sterilized sand in shade. Watering was done daily by rose can. After germination, young seedlings of different genotypes were pricked out and transplanted into poly bags of size 10 × 20 cm containing soil, sand and farm yard manure (2:1:1). Seedlings were kept under shade net, watered regularly and subsequently used for growth and biomass study.

Data collection and layout: For the evaluation of seed morphological traits, 50 stones (bony endocarp + seeds), in thrice, from each genotype were chosen. Length and width of stones were measured by using digital vernier calliper. Similarly, 50 stones were weighed and extrapolated to calculate the 100 stone weight in gram (g). Number of seeds per stone was verified by making a vertical cut to hard endocarp with the help of handy saw. Chambers either having seeds or not were counted and expressed as number of locules per stone whereas healthy seeds having compact mass were only considered to count number of seeds per drupe. Seed filling per cent was estimated by using the formula: Seed filling (%) = (Average number of seeds per stone/Average number of locules per stone) X100.

The experiment for evaluation of germination potential was laid out in Completely Randomized Design (CRD) with four replications of 100 stones in each. Emergence of plumule above the media was taken as the criteria of germination and recorded daily up to 75 days from the day of sowing. Cumulative number of germinates was used to calculate germination per cent by the formula: Germination (%) = (Number of normal seeds germinated/Number of seeds sown) X 100. For assessment of seedling growth, biomass and vigour characteristics, three replications of 5 seedlings each, were used. Monthly seedling growth observations were recorded up to six months after sowing. Shoot height was recorded from the collar region to the apex of leading shoot by using measuring tape. Root length was recorded from the collar region to the tip of main root. Collar diameter was measured with the help of digital calliper. For biomass parameters, plants were carefully uprooted and washed with water and oven dried at 80°C. Weight of dried root, stem and leaves were taken separately by using electronic top pan balance. Seedling vigour index (SVI) was calculated by the formula: SVI=Mean seedling height (cm) x Mean germination (%) (Abdul-Baki and Anderson 1973) and Seedling Quality Index (SQI) was calculated based mean growth and biomass observations i.e. SQI=Total dry weight of seedling (g)/(Final height of seedling/ Final collar diameter)

Fig. 1. Location map of seed source of *M. dubia* in Northern Western Ghats of India

Table 1. Regional details of selected Candidate Plus Trees (CPTs) of *M. dubia* in Northern Western Ghats

Tree code (Accession number)	District	Altitudinal variation
NAU-01, NAU-02, NAU-03 NAU-04, NAU-05, NAU-06, NAU-07, NAU-08, NAU-09 and NAU-10	Valsad	87-387
NAU-11, NAU-12, NAU-13, NAU-14 and NAU-15	The Dangs	127-150
NAU-16, NAU-17, NAU-18, NAU-19 and NAU-20	Narmada	340-437

+ [Final shoot + leaves dry weight / Final root dry weight (g)])(Dickson et al 1960).

Statistical analysis: The data gathered were subjected to statistical analysis following Completely Randomised Design (CRD). To understand the significance of difference among stones and progenies traits of selected genotypes, analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) was done with Web Agri Stat Package (WASP 2.0) available online. Genetic estimations, correlation matrix, path analysis and k-means clustering were worked out with the help of online statistical package OPSTAT as per Sheoran et al (1998).

RESULTS AND DISCUSSION

Stone traits and early progeny performance: Source variation studies are necessary to screen the naturally available genetic variation to select the best planting material for higher production and to select suitable genotypes for future breeding programmes (Aigbe et al 2016). The study evinced that there was significant ($P \leq 0.05$) variation among selected CPTs or genotypes for stone morphometric traits (Table 2). Stone length ranged from 24.37 to 19.02 mm, stone width from 13.25 to 10.70 mm, 100 stones weight from 228.79 to 128.77 g and seed filling per cent from 86.00 to 51.66 % among genotypes. Maximum stone length and 100 stones weight was measured in NAU-9, whereas maximum stone diameter and per cent seed filling was observed in NAU-12. The results exhibited that variation in germination per cent (38.05-15.54%) among stones of 20 CPTs (Table 2). Highest germination capacity (38.05%) was recorded in stones of NAU-12, which was at par with NAU-9 (37.00). Significant variation in early growth and biomass performance indicators (at 6 months after sowing) too, was recorded among progenies of selected CPTs (Table 2). Shoot height ranged from 115.01 to 71.39 cm, collar diameter from 9.80 to 6.50 mm, root length from 21.49 to 14.87 cm and seedling dry biomass from 19.83 to 6.76 g. Maximum shoot height and collar diameter was recorded in progeny of NAU-9, whereas highest mean root length was attained by progeny of NAU- 17 at par with NAU-7(21.49 cm). Maximum seedling dry biomass (19.83 g) was attained by progeny of NAU-12, at par with NAU-9 (19.78 g). When it comes to overall progeny performance (combining two or more important growth and biomass characters), NAU-9 recorded

Table 2. Variation in stone and progeny traits of selected CPTs of *M. dubia* in Northern Western Ghats

	Stone traits					Growth, biomass and vigour traits					
Accession No.	Stone length (mm)	Stone width (mm)	100 Stone weight (g)	Seed filling (%)	Seed germination (%)	Shoot height (cm)	Collar diameter (mm)	Root length (cm)	Dry biomass of seedling (g)	Seedling Vigour Index	Seedling Quality Index
NAU-1	21.16^{bcdefg}	11.95^{bcdef}	162.97^{fg}	71.78^{bcd}	24.87^{fgh}	94.71^{cd}	7.87^{cde}	16.64^{fghi}	10.38^{h}	2070.99^{f}	0.67^{fgh}
NAU-2	21.80^{bcde}	12.40^{abcde}	189.85^{cde}	74.22^{abc}	33.63^{cde}	80.49^{efgh}	8.63^{bc}	19.62^{bcd}	16.58^{c}	3228.59^{d}	1.37^{ab}
NAU-3	21.19^{bcdefg}	12.57^{abcd}	173.23^{efg}	74.29^{abc}	31.44^{e}	95.84^{bcd}	8.20^{bcd}	19.37^{cd}	12.02^{f}	3258.11^{d}	0.72^{fg}
NAU-4	19.02^{i}	11.22^{ef}	136.31^{i}	51.66^{f}	17.37^{j}	74.82^{fgh}	6.53^{f}	14.97^{i}	8.78^{i}	873.50^{ij}	0.69^{fg}
NAU-5	20.29^{cdefghi}	12.29^{abcde}	173.61^{efg}	60.30^{def}	26.34^{fg}	77.11^{fgh}	7.53^{def}	17.14^{fgh}	9.19^{i}	1941.32^{fg}	0.75^{ef}
NAU-6	21.95^{bc}	12.31^{abcde}	170.56^{fg}	76.71^{abc}	32.10^{de}	89.09^{de}	8.17^{bcd}	19.12^{de}	11.71^{fg}	3137.92^{d}	0.88^{e}
NAU-7	21.89^{bcd}	13.22^{ab}	195.01^{cd}	75.14^{abc}	34.74^{bcd}	83.64^{ef}	8.43^{bcd}	21.49^{a}	14.31^{e}	3448.05^{d}	1.13^{cd}
NAU-8	21.09^{bcdefgh}	11.76^{cdef}	178.37^{def}	58.60^{ef}	23.32^{hi}	76.30^{fgh}	7.00^{ef}	16.01^{ghi}	6.90^{j}	1572.71^{gh}	0.49^{ij}
NAU-9	24.37^{a}	13.21^{ab}	228.79^{a}	77.43^{abc}	37.00^{ab}	115.01^{a}	9.80^{a}	21.23^{ab}	19.78^{a}	5119.57^{a}	1.37^{ab}
NAU-10	22.03^{bc}	12.32^{abcde}	160.33^{fg}	72.83^{bc}	27.61^{f}	94.55^{cd}	8.37^{bcd}	18.40^{def}	15.47^{d}	2523.05^{e}	1.09^{d}
NAU-11	19.55^{fghi}	11.00^{f}	158.55^{gh}	60.25^{def}	15.54^{j}	81.08^{efg}	7.53^{def}	14.87^{i}	6.82^{j}	769.70^{j}	0.46^{ij}
NAU-12	22.70^{ab}	13.25^{a}	206.20^{bc}	86.00^{a}	38.05^{a}	103.76^{bc}	9.70^{a}	21.20^{ab}	19.83^{a}	4868.61^{ab}	1.50^{a}
NAU-13	19.21^{hi}	11.16^{ef}	133.86^{i}	57.34^{ef}	16.87^{j}	79.43^{fgh}	6.60^{f}	15.34^{hi}	6.14^{j}	886.33^{ij}	0.39^{j}
NAU-14	20.92^{bcdefgh}	10.70^{f}	141.82^{hi}	68.90^{cde}	26.82^{fg}	74.52^{fgh}	7.93^{cde}	17.31^{efg}	8.73^{i}	2055.68^{f}	0.75^{ef}
NAU-15	22.80^{ab}	12.90^{abc}	215.23^{ab}	82.32^{ab}	34.89^{bcd}	95.01^{cd}	8.50^{bcd}	21.13^{abc}	15.09^{de}	3986.20^{c}	1.14^{cd}
NAU-16	21.38^{bcdef}	12.38^{abcde}	160.28^{fg}	72.18^{bcd}	31.12^{e}	94.67^{cd}	8.07^{bcd}	17.35^{efg}	12.70^{f}	3103.62^{d}	0.82^{ef}
NAU-17	22.22^{b}	11.15^{ef}	203.93^{bc}	75.37^{abc}	35.96^{abc}	104.39^{b}	9.10^{ab}	22.20^{a}	18.60^{b}	4515.61^{b}	1.26^{bc}
NAU-18	20.02^{defghi}	11.91^{cdef}	167.80^{fg}	67.65^{cde}	24.48^{ghi}	92.99^{d}	8.10^{bcd}	16.91^{fgh}	10.83^{gh}	2015.58^{f}	0.74^{ef}
NAU-19	19.95^{efghi}	11.30^{def}	136.53^{i}	53.37^{f}	21.51^{i}	72.07^{gh}	7.50^{def}	16.24^{ghi}	6.76^{j}	1269.38^{hi}	0.52^{hij}
NAU-20	19.40^{ghi}	11.66^{cdef}	128.77^{i}	57.37^{ef}	18.12^{j}	71.39^{h}	6.50^{f}	16.03^{ghi}	8.18^{i}	898.03^{ij}	0.58^{ghi}

statistically highest seedling vigour index (5119.57) which was at par with NAU-12 (4868.61), whereas NAU-12 recorded maximum seedling quality index (1.50), which was on par with NAU-9 (1.37). The variability recorded in stone morphology among the individuals might be due to multiple factors. Potential genetic difference among the individuals could be one of the reasons and second may be the differences in micro-site environmental as well as edaphic factors in which the mother trees grow (Kołodziejek 2017). Role of water availability, mineral nutrition, temperature difference experienced by parents at the time of seed development and maturation, governing seed size, mass and seed fillings are well understood and archived (Gutterman 2000, Luzuriaga et al 2006). Variation amongst the genotypes for germination, growth and biomass characters are assumed to appearance of genotypic effect of parents in progeny, considering alike growing environment and inputs (Shu et al 2012). Above findings are in line with the investigations of Sehgal et al (1995) in chir pine, Loha et al (2006) in *Cordia africana,* Meena et al (2014) Chauhan et al (2018) in *Melia azedarach* and Vasav et al (2011) in *Pongamina pinnata.*

Genetic variability analysis: The genetic parameters are helpful tools for predicting amount of gain from the selection of genetic material. In the present study, phenotypic coefficient of variation was found at higher side with little variation to genotypic coefficient for all the characters studied (Table 3). Germination capacity of the stones exhibited the maximum phenotypic and genotypic coefficient of variation (46.25 and 43.89 %), followed by seedling dry weight (37.50 and 37.13%) while, the minimum was recorded for stone length (7.96 and 5.73%), respectively. Heritability (broad-sense) was maximum for seedling dry weight (98.04) followed by germination percentage (90.07), whereas, minimum heritability (broad sense) was exhibited by stone diameter, (40.46). Similarly, maximum genetic gain was observed in germination percentage (85.81%) followed by seedling dry weight (75.73) while, the minimum was recorded in stone diameter (8.49%). Revelation of higher magnitude of phenotypic coefficient of variation as compared to genetic coefficient of variation with little difference for all the characters under scrutiny demonstrated nearly equal influence of genotypic and environmental factors controlling the expression of traits. Germination percentage was found to shown higher amount of genotypic coefficient of variation, indicating that this character is considerably under the influence of genetic design of the mother tree as confirmed in *Jatropha curcus* by Ginwal et al (2005). Thus, seed germination could be reliable markers to assist early phenotypic selection. Further, in general agreement of Kaushik et al (2019), higher heritability coupled with genetic advance for traits like seedling dry weight and germination confirms that substantial amount of genetic gain could be obtained by exploiting these traits through selection and improvement.

Characters association studies: Correlation studies are important tools used to determine prevalence and relationships among variables, and to forecast events from current data and knowledge (Curtis et al 2016). Correlation matrix revealed positive inter and intra correlations among stone traits, seed germination and seedling growth and biomass characters (Table 4). Strong positive intra-correlation was detected among stone morphometric traits. Stones weight was positively correlated with stone length (r=0.652), seed filling per cent (r=0.557) and stone width (r=0.501). It indicates that, these traits are influential to decide the seed mass. Further, correlation matrix also suggested positive correlation between stone traits and germination percentage (Table 4). Germination capacity of seeds was found having strong positive significant

Table 3. Genetic estimates of stone morphometry and progeny traits in *M. dubia*

Characters	Coefficient of variation (%)		Heritability (%)	GA % of Means
	Genotypic	Phenotypic		
Stone length	5.73	7.96	51.77	8.49
Stone width	5.33	8.38	40.46	6.98
100 Stone weight	16.27	17.48	86.70	31.21
Seed filling (%)	12.71	14.57	76.01	22.82
Germination (%)	43.89	46.25	90.07	85.81
Shoot height	13.50	14.92	81.89	25.16
Collar diameter	10.64	13.39	63.19	17.43
Root length	12.68	13.98	82.25	23.69
Seedling dry weight	37.13	37.50	98.04	75.73

association with stone weight (r=0.758), length (r=0.758), and seed filling percent (r=0.732) affirming the fact that stones of CPTs carrying higher weight, length and seed filling per cent, were germinated voluminously as compared to the seeds having lower seed dimensions. Similar observations were recorded earlier in *Pongamia pinnata* by Divakara et al (2011) and Gupta et al (2016) and attributed to larger embryo and more endosperm nutrients in the heavier seeds that resulted into enhanced germination percentage (Xu et al 2014). Present investigation also revealed significant (P<0.01) positive intra and inter correlation among seedling growth and biomass parameters and with stone traits and seed germination. Data presented in table 4, illustrate the strongest positive association of collar diameter (r=0.730), root length (r=0.838), seedling dry biomass (r=0.840) and seedling vigour index (r=0.939) with germination. Among stone traits, 100 stone weight recorded strongest association with shoot height, collar diameter, and total dry biomass of seedling as well as seedling vigour and quality index (Table 5). Characters association study infers that CPTs that germinated in high quantity due to larger sized and heavy seeds have also produced vigorous and quality seedlings because of higher amount of food reserve in the cotyledons might have permitted the longer time to add these nutrients in the seedling tissues (Souza and Fagundes 2014). Significant relationship between seed mass and seedling vigour been demonstrated earlier in woody plants by Mishra et al (2014) and Palanikumaran et al (2016). Such positive correlation of germination capacity and seed mass on seedling quality and vigour pointed towards the high possibility of success in mass propagation by selecting the seed source having good seed germination capacity and dimensions.

Genetic diversity analysis: Genetic diversity analysis is a strong tool to assess the extent and pattern of variation and divergence among the genotypes to choose genetically diverse parents for inclusion in tree breeding programmes. k-means clustering analysis suggested that 20 genotypes grouped themselves in to four clusters based on similarity in characters. Cluster I and II recorded maximum number of 6 CPTs each, followed by cluster III with 3 and Cluster IV accommodate 5 genotypes (Table 5). Cluster means of stone and progeny traits exhibited wide range of variation among the clusters (Table 6). In our analysis, all the mean stone and progeny traits except stone length and width were superior in cluster III which is having progeny of NAU-9, NAU-12 and NAU-17. Inter-cluster distance were found maximum between cluster III and IV (3896.19), whereas, cluster I and IV found to be distant (1090.18) and minimum between cluster I and II (1331.32) (Table 7). Clustering pattern revealed that geographically distinct genotypes share the same clusters and trees from same geographic location clubbed in to different clusters. It infers that genetic diversity was necessarily not the geographic diversity of CPTs. Similar

Table 5. K-means clustering pattern of selected CPTs of *M. dubia*

Cluster	Number of genotypes	Candidates
I	6	NAU-1, NAU-5, NAU-8, NAU-10,NAU-14, NAU-18
II	6	NAU-2, NAU-3, NAU-6, NAU-7, NAU-15, NAU-16
III	3	NAU-9,NAU-12, NAU-17
IV	5	NAU-4, NAU-11, NAU-13, NAU-19, NAU-20

Table 4. Correlation matrix for stone and progeny traits in *M. dubia*

Traits	SL	SW	100 SWt	SF (%)	G (%)	SH	CD	RL	SDW	SVI	SQI
SL		0.584**	0.652**	0.613**	0.757**	0.584**	0.603**	0.629**	0.704**	0.775**	0.660**
SW		1	0.501**	0.472**	0.547**	0.397**	0.522**	0.522**	0.514**	0.550**	0.517**
100 SWt			1	0.557**	0.758**	0.657**	0.656**	0.763**	0.771**	0.821**	0.742**
SF (%)				1	0.732**	0.665**	0.716**	0.659**	0.702**	0.740**	0.645**
G (%)					1	0.626**	0.730**	0.838**	0.840**	0.939**	0.794**
SH						1	0.620**	0.637**	0.748**	0.777**	0.586**
CD							1	0.709**	0.776**	0.788**	0.775**
RL								1	0.834**	0.883**	0.814**
SDW									1	0.915**	0.951**
SVI										1	0.848**
SQI											1

** Significant at 1%

SL= Stone Length, SW=Stone Width, 100SWt= 100 Stone Weight, SF= Seed Filling, G= Germination, SH= Shoot Height, CD= Collar Diameter, RL= Root Length, SDW= Seedling Dry Weight, SVI= Seedling Vigour Index, SQI =Quality Index

Table 6. Cluster mean values for stone and progeny traits in accession of *M. dubia*

Cluster	SL	SW	100 SWt	SF (%)	G (%)	SH	CD	RL	SDW	SVI	QI
I	21.74	13.36	138.98	81.85	33.38	85.03	7.80	17.07	10.25	2029.89	0.75
II	21.13	12.63	184.03	75.88	32.97	89.79	8.33	19.68	13.74	3360.42	1.01
III	20.42	12.54	212.97	79.76	36.99	107.72	9.53	21.54	19.40	4834.60	1.38
IV	16.66	11.27	138.80	55.97	17.88	75.76	6.93	15.49	7.34	939.39	0.53

Table 7. Inter cluster distance in accession of *M. dubia*

Cluster No.	I	II	III	IV
I	0	1,331.32	2,805.80	1,090.98
II		0	1,474.60	2,421.64
III			0	3,896.19
IV				0

conclusions were made by Jaisankar et al (2014) and Pavithra et al (2013). Wide inter-cluster distance between cluster III and IV signify the importance of these CPTs for being chosen as potential candidates for tree breeding and hybridization programmes.

CONCLUSION

Current investigation recorded superiority of CPTs like NAU-9, NAU-12 and NAU-17 over other candidates on stone morphological qualities, progeny growth, vigour and biomass ascribes thus, recommending the inclusion of these accessions for mass production of quality planting material. Additionally, traits like stone mass, seed filling percent, germination capacity and seedling dry biomass are attention worthy for early selection of genotypes and further improvement in progeny.

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Local Forest Institution and Participation of Local Communities: A Study in Bankura (South) Forest Division in West Bengal, India

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Abstract: The local institutions like forest protection committee are working with forest department to protect forest governance under Participatory forest management. The paper attempts to construct participation index in the planning, implementation and monitoring stages across ten villages of Bankura (South) forest division of West Bengal. The paper examines whether there is any impact on change in forest area last ten years across villages. The paper also attempts to estimate the factors responsible for community participation in forest management programme at local level. This paper is based on primary data collected from 228 households in the Ranibandh range under Bankura (south) forest division of West Bengal, in the month of January, 2020. A multi stage sampling technique and questionnaire method have been used for data collection. The result of the paper shows that participation index is found to be 0.47and planning, implementation and monitoring indices are 0.478, 0.589 and 0.342respectively. There is no deforestation across ten villages in Ranibandh range on account of participation of the community. The level of participation is influenced by caste, sex, age, landholdings, monitoring and occupation. The paper has an important policy implication for sustainable forest management.

Keywords: Participation index, Planning index, Implementation index, Monitoring index, Forest protection committee, Sustainable forest management

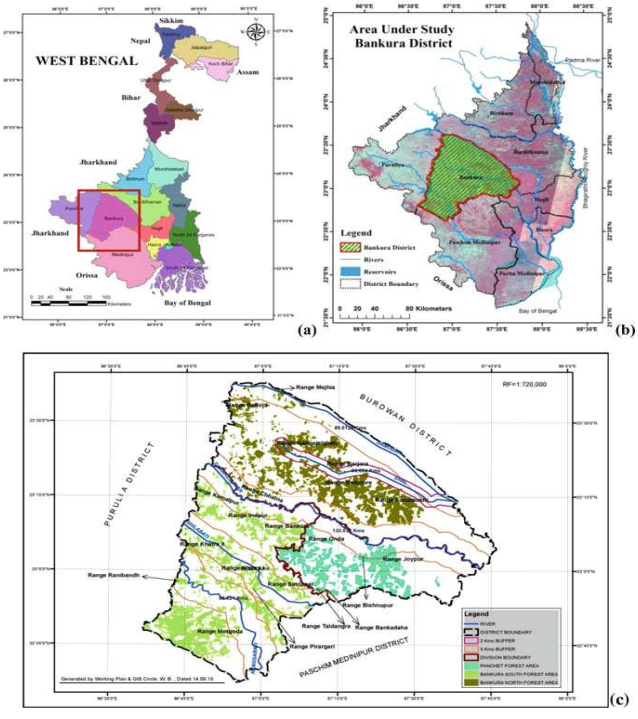
The environmental resources particularly forests play an important role in local and global context. It also plays to maintain ecological balance, soil erosion, climate change and it is also essential for development of rural economy. Forest provides various goods and services for domestic purpose as well as industrial purpose. Now-a-days forests are deteriorated gradually due to human activities. The aim of sustainable forest management is to maintain and enhance the economic, social and environmental value of all types of forest resources for the benefit of present and future generations (UN 2008, Resolution 62/98). The good quality of forest governance is necessary condition for the decrease in deforestation and long term carbon storage globally (Umemiya et al 2010). The probability of degradation of a forest declines and regeneration of forest increases with more involvement of local people or local institution (Chhatre and Agrawal 2008). A fundamental assumption is that forest user's people has given an opportunity to participate in decision-making process about forest resource management, and they properly manage and use the resources in a sustainable way (Shrestha and McManus 2008). Decentralised theory states that local people or institutions take better decision than centralised authorities because they have clear knowledge about forest resources and management (Tacconi 2007). Many developing countries have revised their forest policies. Many African and South Asian countries have merged local communities or institutions in the management of forest resources through a Participatory Forest Management (PFM) approach (Schreckenberg et al 2006). PFM is an approach to forest management where local communities are living in and around the forests together to make decisions in all forest management process like planning, implementing, monitoring and evaluation process. PFM is always for the people, of the people and by the people who lives around the forest and also other people who live far away from forest (Karki 2003).

The institutions at the local level are common Forest Management groups, Van Panchayat, Joint forest Management Committee, Traditional Village Level institutions or Village Councils and Forest Protection Committee(in West Bengal) etc. In West Bengal there are 4262 numbers of joint forest management committees having total membership of 496998.The JFMCs covering or protecting 563344.134 ha forest area in West Bengal. The SC and ST communities constitute near about 55% of members in the JFMCs (State Report, 2017-18). People participation depends on the socio-economic condition of the people around the forest and other institutional factors. The main objective of community forest programme is to get forest products for their subsistence, socio-economic development of the people and conservation of forest

resources. If people are assured that they are getting benefits from forests, they will more involve in forest protection and management activities. Accessibility is the another key factor to grow people's interest in involving or participating in forest management (Yogesh 2014).Participation of people in forest management process means planning, implementing, monitoring, decision making and evaluation of any programme. People's participation in forest management programme is a key to success local communities' development (Tadesse et al 2017). Given the above backdrop, the objectives of the paper are twofold. First is to construct community participation index of the local communities in the Bankura (South) forest Division, West Bengal. Second is to estimate the factors influencing forest participation of the local communities.

MATERIAL AND METHODS

Study area: The study has been conducted in the district of Bankura in West Bengal (Fig. 1). It is situated in south-western side of the West Bengal. Approximately 90% to 92% people live in rural areas (Census 2011). The forest divisions of Bankura district is divided into three: Bankura South, Bankura North and Panchet Division. The study is conducted in the Bankura (South) forest division which comprises of twelve (12) range offices. These offices are Bankura, Indpur, Kamalpur, Khatra, Hirbundh, Simlapal, Pirragari, Sarenga, Motgoda, Fulkushma, Ranibandh and Jhilimili. We have chosen Ranibandh range in our study on the basis of highest forest protection area. According to state forest report, Ranibandh range area comes under highest forest protection (Table 1). It is situated 60 kms to the south of Bankura town. The major component of its demography is tribal population.



Source: http://www.westbengalforest.gov.in/upload/forest_map

Fig. 1. Map of Bankura district of West Bengal, India

Data Collection: The present study, which is based on the primary data, is collected from Ranibandh range office in Bankura (south) forest division in the district of Bankura, West Bengal. A multistage sampling technique has been followed. The field survey is carried out in the month of January, 2020. We adopted a questionnaire method to collect data from head of the households. Ten JFM villages are selected under Ranibandh range purposively. After the selection of villages, 20% of households from each villages are randomly selected. Thus, total number of sample households consist of 228. The name of the villages and the name of the forest protection committees are same. The sample villages and sample households are shown in Table 2.

Analytical methods: The forest protection committees (FPCs) are the local institution at the village level under joint forest management (JFM) programme. Forest protection committee comprises of two bodies. One is executive body consists of 5-10 members and other is general body consists of all adult members of the households. All members follow the government rules but executive committee members can formulate some other rules and regulations for forest protection. Some decisions are approved in the meeting in presence of general members of the committee. Executive

Table 1. Details of range office, beat office, FPC and area under protection by FPC

Division	Range office	Beat office	No. of FPC	Protected area (ha)
Bankura (South Division)	Bankura	3	47	3230.45
	Indpur	4	63	4310.72
	Kamalpur	3	28	1670.82
	Khatra	4	104	4277.64
	Hirbundh	3	36	1922.18
	Simlapal	3	53	4238.46
	Pirragari	3	53	4004.42
	Sarenga	3	50	4648.03
	Motgoda	3	63	3032.1
	Fulkushma	3	38	3993.09
	Ranibandh	4	55	5418.94
	Jhilimili	2	24	3350.23
Total	12	38	614	44097.08

Source: Bankura forest division

committee members encourage general members to participate in the forest protection programme regularly.

Participation index: People's participation in forest protection programme is measured by the participation index. Participation index value is the average of three indices (i.e., planning index, implementation index and monitoring index). For evaluating index values of planning, implementation and monitoring, each main indicator is sub-divided into five or more indicators. Each and every household are asked to respond their views in three Likert type of scale in which Yes=1, No=2, don't know=3 is assumed on all indicators' statement (Table 3). In forest planning index, we take the responses from the households whether the households under forest protection committee at local level participate in the different planning like forest boundary demarcation, identifying forest user, participatory forest resource assessment, forest management committee election, encouraging others to participate, preparing forest management plan, developing forest management by laws and approval of forest management agreement.

For implementation index, we take the responses from the households whether the households were involved in any reforestation programme of degraded forest areas, planting any fruit trees such as Mahua and Mango, planting trees and management, any nursery establishment, beekeeping, forest fire fighting programme, attending meetings and participate in any knowledge and skill developing training. For the construction of the monitoring index, we take the

Table 2. Number of sample households

Name of the sample villages	Total number of households	No. of sample households (20% of the households)
Kamo	163	33
Makhnu	85	17
Barapatcha	50	10
Jamgeria	130	26
Dhankura	114	22
Kadmagarh	120	24
Kalabani	120	24
Bagdiha	40	08
Mitham	186	38
Mahadebsinan	130	26
Total households	1138	228

Source: Author's calculation from primary data

Table 3. Description of main and sub-indicators of participation index

Main indicator	Sub-indicator		Descriptions
Participation index	Planning index	Forest boundary demarcation	Yes=1,No=2,Don't Know=3
		Identifying forest users	
		Participatory forest resource assessment	
		Forest management committee election	
		Encouraging others to participate	
		Developing forest management by laws	
		Preparing forest management plan	
		Approval of forest management agreement	
	Implementation index	Reforestation of degraded forest areas	Yes=1,No=2,Don't Know=3
		Planting of fruit bearing trees such as mahua & mango	
		Planting trees & management	
		Nursery establishment	
		Beekeeping	
		Forest fire fighting	
		Attending meetings	
		Participations in knowledge & skill developing training	
	Monitoring index	Follow ups forest managements by law	Yes=1,No=2,Don't Know=3
		Helps forest patrols	
		Detecting of illegal activities	
		Supervise forest management plan implementation	
		Forest boundary maintenance	

Source: Author's calculation from primary data

responses from the households whether they were following up forest management by law, helping forest patrols, protection of illegal logging, supervising forest management plan implementation and helping in maintaining forest boundary.

In order to formulate the index values we need to normalize value of each indicator for each household. The normalized value lies between '0' and '1'. '0' means minimum and '1' means maximum value. This normalization procedure is followed by the methodology of Human Development Index (UNDP-2006). After normalizing procedure, we get the index value. For evaluating the index value we take the average of all indicators. Participation index is calculated as:

Participation index= 1/3[Planning index +Implementation index +Monitoring index]

Linear regression model: Linear Regression Model is used to estimate the factor responsible for participation index in the Bankura (south) forest division of West Bengal.

Model specification: In order to identify socio-economic and other determinants that influence the level of a forest user's participation at house level in participatory forest management (PFM) programme, the linear model is employed. Therefore, we specify a linear model is as follows:

$$Y_i=\alpha+\beta_1X_{1i}+\beta_2X_{2i}+\beta_3X_{3i}+\beta_4X_{4i}+\beta_5X_{5i}+\beta_6X_{6i}+\beta_7X_{7i}+\beta_8X_{8i}+\beta_9X_{9i}+\beta_{10}X_{10i}+\varepsilon_i \ldots\ldots\ldots\ldots\ldots (1)$$

Where Y_i is the Participation Index (PI) of the ith households as the dependent.

- X_{1i}= Caste of the household head (SC= 1, ST=2, OBC=3 and GEN = 4)
- X_{2i}= Sex of the household head (Male = 1, Female = 0)
- X_{3i}= Age of head of households
- X_{4i}= Occupation of the head of the households
- X_{5i}= Educational index
- X_{6i}= Distance from home to forest (in km)
- X_{7i}= Land holdings (in acres)
- X_{8i}= Monitoring Index
- X_{9i}= Cooperation of forest department
- X_{10i}= Monthly forest income as percentage of total income (in Rs)
- ε_i = random disturbance term

RESULTS AND DISCUSSION

The value of the participation, planning, implementation and monitoring indices are presented in Table 4. The value of the participation index of the households as a whole Bankura south forest division is 0.470 shown in Table 4. The value of the planning index, implementation index and monitoring index as a whole Bankura south forest division are respectively 0.478, 0.589 and 0.342 (Table 4). The positive and higher value of the indices means higher participation of the households. The value of the implementation index is highest as whole in the Bankura south forest division. The value of the participation index across ten villages is shown in the Table 5 and Figure 2. The high value of forest management committee election index (0.814) means households are more involved in choosing of forest protection committee member. The value of attending meeting is highest in implementation index (0.908). The value of reporting illegal activities are 0.833 under monitoring index. So that involvement of local communities against illegal activities is found to be highest in monitoring index (Table 4). The value of the planning, implementation and monitoring indices are shown in Table 5 and Figure 3. The value of the participation index is highest in the village Kadmagarh (0.593) followed by Dhankura (0.549), Makhnu (0.484), Kamo (0.479) and so on. The lowest participation index is in the village Kalabani (0.369). The value of planning, monitoring, and implementation indices are also low in the village Kalabani. That means participation of the villagers are very low in the village Kalabani. The value of planning index is highest in the village Dhankura (0.568) followed by Kadmagarh (0.565), Jamgeria (0.488), Kamo (0.487) and so on. The value of the implementation index is highest in the village Dhankura (0.656) followed by Kadmagarh (0.646), Kamo (0.623) and so on. The value of the monitoring index is

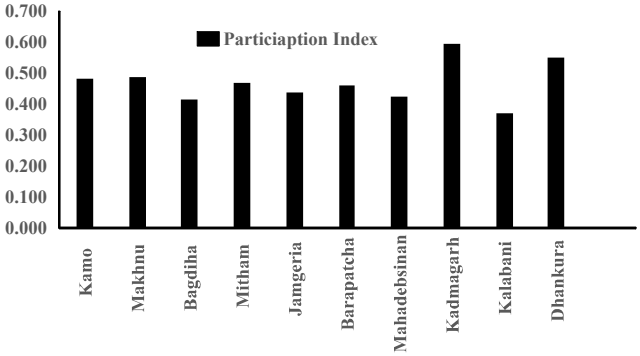


Fig. 2. Village wise participation index in Ranibandh range, Bankura (south) forest division

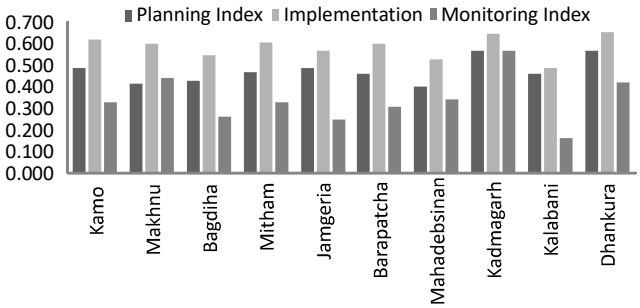


Fig. 3. Village wise planning, implementation and monitoring indices in Ranibandh range

highest in the village Kadmagarh (0.567) followed by Makhnu (0.441), Dhankura (0.423), and Mahadebsinan (0.342) and so on. The value of all indices are approximately high in the village Dhankura (Table 5).

Table 6 shows that there is no loss of forest cover across the ten villages since last 10 years (Basu 2020). Fifty per cent (50%) of the villages show a positive change in forest cover and the rest shows no changes in forest cover. This result

Table 4. Value of the main index and sub-indices

Planning index	Forest boundary demarcation	0.318
	Identifying forest users	0.450
	Participatory forest resource assessment	0.439
	Forest management committee election	0.814
	Encouraging others to Participate	0.636
	Preparing forest management plan	0.373
	Developing forest management by laws	0.404
	Approval of forest management agreement	0.395
	Planning index	0.478
Implementation index	Reforestation of degraded forest areas	0.443
	Planting of fruit bearing trees such as mahua & mango	0.669
	Planting trees & management	0.689
	Nursery establishment	0.487
	Beekeeping	0.456
	Forest fire fighting	0.779
	Attending meetings	0.908
	Participations in knowledge & skill developing training	0.283
	Implementation index	0.589
Monitoring index	Follow ups forest managements by law	0.184
	Forest patrols	0.252
	Reporting of illegal activities	0.833
	Supervise forest management plan implementation	0.167
	Forest boundary maintenance	0.272
	Monitoring index	0.342
	Participation index	0.470

Source: Author's calculation from primary data

Table 5. Value of the indices across sample villages

Village	Participation index	Planning index	Implementation index	monitoring index
Kamo	0.479 (4)	0.487 (4)	0.623 (3)	0.327 (5)
Makhnu	0.484 (3)	0.412 (9)	0.599 (6)	0.441 (2)
Bagdiha	0.413 (9)	0.430 (8)	0.547 (8)	0.263 (8)
Mitham	0.467 (5)	0.469 (5)	0.609 (4)	0.324 (6)
Jamgeria	0.435 (7)	0.488 (3)	0.567 (7)	0.250 (9)
Barapatcha	0.458 (6)	0.463 (6)	0.600 (5)	0.310 (7)
Mahadebsinan	0.422 (8)	0.397 (10)	0.526 (9)	0.342 (4)
Kadmagarh	0.593 (1)	0.565 (2)	0.646 (2)	0.567 (1)
Kalabani	0.369 (10)	0.461 (7)	0.487 (10)	0.158 (10)
Dhankura	0.549 (2)	0.568 (1)	0.656 (1)	0.423 (3)

Source: Author's calculation
Note: Figures in () indicate rank

shows that there is no deforestation because of more participation of local community in forest management (i.e., planning, implementing and monitoring) programme (Table 6).

Estimation of factors affecting participation: In order to estimate the factors that influence forest user's participation in forest management programme, we have taken linear regression model. The independent variables and their basic statistics are shown in Table 7. The dependent variable is the participation index. The Result of linear regression are given in the Table 8**.**

From the Table 8, we find that the model is overall significant as indicated by the value of F statistics. The value of F statistic is F= 164.71. Regression analysis shows that various demographic, social, economic and environmental related factor influence the level of local people's participation in joint forest management programme. Here forest user's participation is taken as the dependent variable where as social, economic, environmental factors are taken as explanatory (independent) variable like caste of households' head (SC= 1, ST= 2, GEN= 3, OTH= 4), sex of households' head (male= 1, female= 0), occupation of households' head, distance between home and forest (in km), educational index, total land holdings of the households (in acre) etc. Some other factors which also influence people's participation but are not taken into the model because of their irrelevance to our study. 88.36% of the total variation in the response or dependent variable (PI) is explained by the variation in the given all explanatory (independent) variables. On the other hand 87.82% of the total variation in the dependent variable (PI) is explained by fitted regression model (equation). It means both values of R^2 and adj R^2 is moderate. It can be concluded that all given independent variables of people's participation in forest protection and management activities are at satisfactory level. Out of the 10 independent variables tested in the regression model, six variables are proved statistically significant either at 1%, 5% or 10% probability level.

The regression result shows that there is a positive and significant relation between caste and participation of the forest users'. It implies that upper caste communities' people participate more in the joint forest management programme than the schedule and tribal communities. This means upper caste people participate more in planning, implementation and monitoring programme of forest resources which is done in collaboration with forest department. Gender of the households' head is positive and significantly associated with

Table 6. Changes of forest cover in sample villages over 10 years

Name of villages	Forest cover (ha) in 2007-08	Forest cover (ha) in 2016-17	Change of forest cover over 10 years (ha)
Kamo	100	100.23	+0.23
Makhnu	148.62	154.25	+5.63
Bagdiha	46	47	+1.00
Kalabani	223.15	297.493	+74.343
Kadmagarh	146.49	146.49	0
Dhankura	93.096	93.096	0
Mitham	139.09	139.09	0
Mahadebsinan	305.88	313	+7.12
Jamgeria	50.65	50.65	0
Barapatcha	401	401	0

Source: Basu (2020)

Table 7. Basic statistics of independent variables of Bankura (South) forest division

Variable	Mean	Standard deviation	Minimum	Maximum
Caste	0.5919662	0.3251945	0.09091	2
Sex	0.2348242	0.1330276	0	1
Age of the head of households	12.95238	6.433973	3.57143	60
Occupation of the head of households	0.5245739	0.3697685	0	2
Educational Index**	0.0589485	0.0401625	0	0.175926
Distance from home to forest	0.1003041	0.0891117	0	0.333333
Land holdings (in acres)	0.22865	0.2213052	0	1.322314
Monitoring Index	0.0905462	0.0797923	0	0.6
Cooperation	0.2443637	0.1256245	0	1
Monthly forest income as percentage of total income (in Rs)	6.938153	5.385894	0	41.86047

Source: Author's calculation

**Education index of the households is measured on the basis of UNDP methodology, where Education Index (EI) = (MYSI+EYSI)/2. MYSI is the mean years of schooling index and EYSI is the expected years of schooling index. Due to Heteroscadisity problem, we divided the regression model by total households' members. Total households' members is an explanatory variable

Table 8. Results of linear regression model of participation in Bankura (south) forest division

Independent variable	Bankura forest division		
	Coefficient	SE	t
Caste	0.0225	0.008	2.74
Sex	0.0719	0.021	3.38
Age of the head of households	0.0026	0.000	5.60
Occupation of the head of households	0.0148	0.007	2.05
Educational Index	0.0260	0.046	0.57
Distance from home to forest	0.0239	0.021	1.14
Land holdings (in acres)	0.0154	0.008	1.82
Monitoring Index	0.5484	0.030	18.22
Cooperation	-0.0119	0.024	-0.49
Monthly forest income as percentage of total income (in Rs)	-0.0003	0.000	-0.69
Constant	-0.0005	0.005	-0.10
	F(10, 217)=164.71,Prob > F=0.000, R-squared= 0.8836,Adj R-squared= 0.8782,Root MSE=0.02565		

Source: Author's calculation

the level of participation of the households. This means that male participants are more in decision making, planning and monitoring process. There is a positive and significant relation between age of households' head and level of participation. This implies that aged people are involved more in forest management programme. That means aged person or more experienced persons are mainly participate in this planning, monitoring and implementing process. There is a positive and significant relation between occupation of the households' head and level of participation. There is a positive but insignificant relation of distance from home to forest and level of participation. There is also insignificant relation between level of education and participation. There is positive and significant relation between total land holdings and level of participation of the households. Large land holders are participate more in the forest management programme. There is a positive and significant impact of monitoring on participation index shown in table 8. This means, if monitoring process such as reporting of illegal activities, supervising forest management plan implementation, following up forest management by law, forest patrolling, maintaining of forest boundaries is evaluated properly there will be a positive result in forest management programme and conservation of resources. Hence monitoring process is an important path for evaluation of participation. The participation of the households also depends upon other factors which are not taken in account. Some villagers says that committee does not involved them in this programme. Participation also depends on the occupation of the other family member in a family, number of livestock keeping and structure of the market etc.

CONCLUSIONS

The study has attempted to examine the level of people's participation in natural resource management like forests. People who are highly dependent upon forests and forest product for their livelihoods, they participate more in forest management programme. The result shows that participation of the households is measured by index value. Participation index is comprised of planning index, monitoring index and implementation index. The value of the participation index is found to be 0.470. The value of planning, implementation and monitoring indices are found to be 0.478, 0.589 and 0.342 respectively. In planning index, people's participation in forest management committee election is found to be highest (0.814). In implementation index people's participation is found to be highest in attending meetings (0.908). In monitoring index local, communities contribution is found to be highest in reporting of illegal activity (0.833) and lowest in supervising forest management plan implementation (0.167). There is no deforestation across ten villages in Ranibandh range in Bankura (south) forest division due to more participation of the local communities or forest users' communities.

The nature and level of participation is highly determined by caste, sex, age of the head of households, monitoring, total land holdings, and occupation of households. In this paper we find that local people and institutions like forest protection committee play a significant role for forest protection and management process. This study supports the change of centralized process into decentralized process. There is more involvement of forest users' communities in every stage of forest management to ensure

the better livelihood opportunities for forest dependent people or communities and sustainable forest management.

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Effect of Integrated Nutrient Management on Seedling Growth and Biomass of Sandalwood (*Santalum album* L.)

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***Abstract*:** The investigation was undertaken with *Leucaena leucocephala* as host plant and 12 INM treatments of different organic, inorganic, biofertilizers and their combinations application along with control for sandal wood growth and biomass. Among different integrated nutrient management treatments, seedling height, collar diameter, number of leaves per plant, fresh and dry weight of shoot, leaves and whole plant were recorded maximum in 1 g of NPK and vermi-compost @ 25 g seedling^{-1}. Moreover, fresh and dry weight of root and root length were registered maximum in vermi-compost @ 50 g seedling^{-1}. The seedlings without integrated nutrient treatment were poorest for all parameters under study. However, root: shoot ratio was noted maximum in vermin-compost @ 25 g seedling^{-1}.

Keywords: Sandalwood, INM, Growth, Biomass, NPK, Biofertilizers, Vermicompost

Santalum album (Sandalwood) is considered in India to be a practical agroforestry species. Among the sixteen species of the economically important genus *Santalum*, *Santalum album* L. or Indian Sandalwood is highly prized for its scented heartwood. The heartwood yields oil which is commercially known as East Indian Sandalwood oil. The oil is also used in indigenous medicine, while the wood is used in the religious rituals of Hindus, Buddhists and Muslims. It is sometimes grown as an ornamental and as a low branching windbreak, while its leaves provide green manure. Sandalwood plants can live autographically (without parasitizing a host) up to maximum of one year and for subsequent growth an intimate association with roots of a host plant through haustoria is essential (Radomiljac 1998). Artificial regeneration is achieved by dibbling seeds in pits, sowing on mounds and trenching around mother trees for wounding the roots for inducing root sucker production. Planting of nursery raised, vegetatively multiplied and tissue culture raised seedlings are also in practice (Rai and Kulkarni 1986). However, because it is very slow growing, taking up to 40 years to develop its heartwood fully, the tree has been overexploited and has become endangered in the wild. It is desirable not to clean-weed all-round the Sandalwood seedlings, as the roots form haustorial connections with adjoining weed growth. Integrated Nutrient Management (INM) system aims at achieving efficient use of chemical fertilizers in conjunction with organic manures. It also maintains the soil fertility for sustaining increased crop productivity through optimizing all possible sources, organic and inorganic, of plant nutrients required for crop growth and quality in an integrated manner, appropriate to each cropping system and farming situation in its ecological, social and economic possibilities (Roy 1986). Seedlings are not growing well during its seedling growth because of lack of proper nutrition to it. There is a need of providing the appropriate nutrition to the seedlings of Sandalwood in the nursery. There are so many sources of nutrients in integrated nutrient management and from that best integrated nutrient application we can find from this experiment. For this reasons, this experiment was designed to check the best nutrient for *S. album* seedling.

MATERIAL AND METHODS

The present investigation was carried out at Net House Complex, College of Forestry (ACHF), Navsari Agricultural University, Navsari during year 2018-19. The experiment comprised of twelve different combinations of organic, inorganic and biofertilizers along with control (Table 1). All polybags were filled with soil, sand and FYM in the ratio of 1:1:1. Seeds of Sandalwood were treated with 500 ppm GA_3 for 24 hours. After GA_3 treatment seeds were sown in sand bed. After good germination of seed in sand bed, averaged heighted plants were selected for seedling growth experiment. Then seedlings of Sandalwood (*Santalum album* L.) were transplanted in to different nutrients treated polythene bags. Leucaena (*Leucaena leucocephala*) was used as a common host plant. The bio-fertilizer like Phosphobacteria and *Azospirillium* was inoculated in polybags as per the treatments. Vermicompost powdered thoroughly and applied in polybags as per the treatments. NPK applied through chemical fertilizer as per treatments.

The observations were recorded for growth and biomass of sandalwood seedlings. Five plants randomly selected for taking observations of every treatment in all the three repetitions and the observation were recorded at monthly interval for seedling height, collar diameter and number of leaves/plant, while other parameters *viz.* root length, fresh and dry weight of leaves, shoot and root, root: shoot ratio were recorded after 6 months. The different parameters were subjected to the statistical analysis by using variance technique as described by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

The findings of research revealed that application of various INM treatment combinations on Sandalwood seedling at nursery stage significantly increased the growth parameters (seedling height, collar diameter, number of leaves and root length), fresh and dry biomass and root: shoot ratio. A constant increased in all parameters and variation among different treatments was observed during study period (30 to 180 days after transplanting).

Growth parameters: During growing period (from 30 to 180 days) all monthly observed parameters (seedling height, collar diameter and number of leaves) found increased in 1.0 g of NPK + Vermicompost @ 25 g seedling^{-1}. Among all INM treatments at the end of experiment, application of 1.0 g of NPK + Vermicompost @ 25 g seedling^{-1}recorded highest seedling height (28.47 cm), collar diameter (3.26 cm) and number of leaves (16.27) (Table 2). This might be due to prompt release of nutrients by the application of inorganic fertilizers (NPK) and thereafter slow and continuous release of nutrients by vermicompost, these together also ensures in increase in release of micronutrients. Nitrogen plays an important role in increasing the seedling height as it plays direct role in formation of proteins. It is also an integral part of chlorophyll, which is primary absorber of light energy needed for photosynthesis. This might have led to increased production of photosynthesis and its distribution into root and shoot portion resulting in higher plant height and collar diameter. Korwar et al (2005) reported that the growth of Aonla increased by the various source of nutrients such as organic and inorganic source of nutrients. Similar results were also reported by Lamani et al (2001), Sumbli and Koppad (2013), Mishra and Channabasappa, (2013), Somashekar and Channabasappa, (2015), Atik et al (2015). For number of leaves similar result was found by Manikanta et al (2016) in *Simarouba glauca.*

Maximum root length (21.45 cm) was recorded in Vermicompost @ 50 g / seedling (Table 2). The probable reason for this might be more porosity offered by higher proportion of vermicompost as compared to other treatments. This result is supported by Biradar et al (1988). Vijayanathan et al (2005), who reported maximum root length with application of vermicompost at 100 g seedling^{-1} in *Pongamia pinnata* seedlings.

Fresh and dry biomass: Biomass parameters such as fresh and dry weight of leaves, shoot, root, and whole plant were

Table 1. Treatment details

Treatment	Treatment details
T_0	Soil : Sand : FYM (1:1:1)
T_1	1.0 g of NPK seedling^{-1}
T_2	2.0 g of NPK seedling^{-1}
T_3	Vermicompost @ 25 g seedling^{-1}
T_4	Vermicompost @ 50 g seedling^{-1}
T_5	Azospirillum @ 5 g seedling^{-1}
T_6	Azospirillum @ 10 g seedling^{-1}
T_7	Phosphobacteria@ 5 g seedling^{-1}
T_8	Phosphobacteria@ 10 g seedling^{-1}
T_9	Azospirillum @ 5 g seedling^{-1} + Phosphobacteria@ 5 g seedling^{-1}
T_{10}	1.0 g of NPK seedling^{-1} + Vermicompost @ 25 g seedling^{-1}
T_{11}	Vermicompost @ 25 g seedling^{-1} + Azospirillum @ 5 g seedling^{-1}
T_{12}	Vermicompost @ 25 g seedling^{-1}+ Phosphobacteria@ 5 g seedling^{-1}

Table 2. Effect of integrated nutrient management on growth parameters of *Santalum album* L. seedlings at 180 DAT

Treatments	Seedling height (cm)	Collar diameter (mm)	Number of leaves	Root length (cm)
T_0	22.80	2.39	9.53	16.93
T_1	28.20	3.20	15.10	18.43
T_2	28.23	3.24	16.00	18.97
T_3	26.53	2.99	14.07	21.36
T_4	26.60	3.02	14.13	21.45
T_5	23.13	2.71	11.00	19.18
T_6	23.27	2.85	11.40	19.43
T_7	24.87	2.90	12.07	19.84
T_8	26.07	2.91	12.27	20.13
T_9	26.27	2.98	13.40	20.25
T_{10}	28.47	3.26	16.27	20.33
T_{11}	27.80	3.09	14.27	20.53
T_{12}	28.00	3.11	14.33	20.95
S. Em.±	0.691	0.087	0.32	0.394
CD (p=0.05)	1.97	0.24	0.93	1.12
CV %	4.57	5.08	4.24	3.44

Table 3. Effect of integrated nutrient management on fresh and dry biomass of *Santalum album* L. seedlings at 180 DAT

Treatments	Fresh weight (g)				Dry weight (g)			
	Leaves	Shoot	Root	Whole plant	Leaves	Shoot	Root	Whole plant
T_0	3.00	0.58	0.41	3.98	0.39	0.25	0.11	0.75
T_1	4.14	1.05	0.50	5.69	0.71	0.53	0.18	1.42
T_2	4.24	1.08	0.52	5.84	0.73	0.54	0.20	1.47
T_3	3.66	0.83	0.81	5.30	0.60	0.39	0.34	1.33
T_4	3.80	0.85	0.85	5.50	0.64	0.43	0.35	1.43
T_5	3.10	0.60	0.53	4.23	0.45	0.27	0.21	0.92
T_6	3.13	0.66	0.55	4.34	0.48	0.30	0.22	1.00
T_7	3.34	0.69	0.60	4.63	0.49	0.34	0.23	1.06
T_8	3.43	0.73	0.65	4.80	0.52	0.41	0.25	1.18
T_9	3.48	0.82	0.69	4.99	0.56	0.42	0.27	1.25
T_{10}	4.32	1.15	0.71	6.18	0.75	0.55	0.31	1.61
T_{11}	3.92	0.90	0.74	5.56	0.66	0.41	0.32	1.39
T_{12}	4.03	0.97	0.79	5.79	0.69	0.48	0.33	1.50
S. Em.+	0.054	0.028	0.019	0.058	0.010	0.013	0.008	0.018
CD (p=0.05)	0.15	0.08	0.05	0.16	0.02	0.03	0.02	0.05
CV %	2.56	5.83	5.33	1.97	2.98	5.70	5.45	2.57

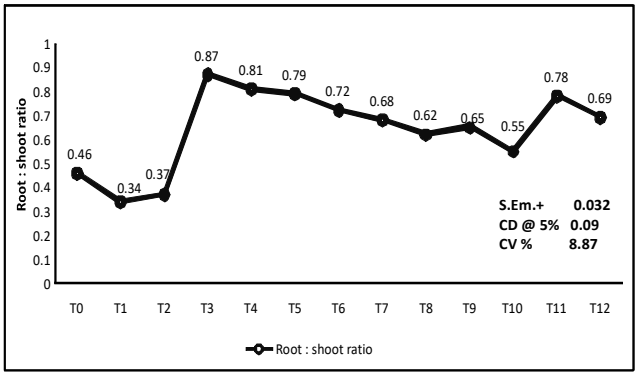

Fig. 1. Effect of integrated nutrient management on root: shoot ratio of *Santalum album* L. seedlings

recorded at 180 DAP. Maximum fresh weight of leaves (4.32 g), shoot (1.15 g) and whole plant (6.18 g) as well as dry weight of leaves (0.75 g), shoot (0.55 g) and whole plant (1.61g) were observed in 25 g Vermicompost along with 1g NPK (Table 3). This might be due to application of NPK fertilizers. Nitrogen application might have influenced chlorophyll formation in the plants, which lead to improve the photosynthetic activity which resulted in vigorous vegetative growth and ultimately development of plant. The similar results were also found by Huda et al (2007) and Khamis et al (2015). The highest fresh weight (0.85 g) and dry weight (0.35 g) of root were found in treatment having Vermicompost @ 50g (Table 3). The probable reason for this might be more porosity offered by higher proportion of vermicompost which ultimately increased aeration and finally growth of root as compared to other treatments. The same result was also recorded by Sujata and Manjappa (2014).

Root: shoot ratio: Maximum root-shoot ratio (0.87) was recorded in treatment having Vermicompost at 25 g seedling^{-1} whereas minimum root: shoot ratio was noted in treatment of 1.0 g of NPK / Seedling (Fig. 1). This result was supported by Ashraf et al (2017).

CONCLUSION

From the forgoing investigation, it is concluded that among different integrated nutrient treatments to Sandalwood seedlings, 1.0 g of NPK + Vermicompost @ 25 g seedling^{-1} significantly influenced seedling height, collar diameter, number of leaves per plant, fresh and dry weight of shoot, leaves and whole plant. The next best integrated nutrient treatments were 2.0 g of NPK / seedling, 1.0 g of NPK / seedling, Vermicompost @ 25 g seedling^{-1} + Phosphobacteria@ 5 g/seedling and Vermicompost @ 25 g seedling^{-1} + Azospirillum @ 5 g/seedling.

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Effect of Different Growing Media on the Performance of Teak (*Tectona grandis* Linn.) Stump in Nursery

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Abstract: A study was undertaken to analyse the effect of different growing media using soil, sand, FYM, sawdust and vermicompost in different proportion to optimize the sprouting and growth of behaviour of teak (*Tectona grandis* Linn.) stump in nursery condition. Stumps of 13 - 18 mm collar diameter, 2.5 cm shoot and 12.5 cm root were selected and raised in the polybags of 6" x 12" in size containing fifteen combinations of growing media under nursery condition for 150 days. Experiment revealed that vermicompost: sand: soil (1:1:1), sawdust: soil: vermicompost (1:1:1) and soil: sand: FYM (1:1:1) showed 100% sprouting indicating better sprouting possibility than solo media like FYM (96%), sawdust (95.67%) and sand (95%). Both the collar diameter and height was highest (14.47 mm and 107.91 cm) in vermicompost: sand: soil (1:1:1), which was strongly at par with vermicompost: sand (1:1) (14.04 mm and 105.42 cm), whereas the lowest collar diameter (7.53 mm) and height (53.55 cm) was recorded in sawdust and sawdust: soil (1:1), respectively. At the end of 150 days of growth, sturdiness quotient in each and every growing media except sawdust: soil: FYM (1:1:1) was cross the limit (6.0) signalling that further the growth of seedlings in the container lead to risk on survival and growth in the field.

Keywords: *Tectona grandis,* Stump, Growing media, Sprouting, Collar diameter

Teak (*Tectona grandis* Linn.) is one of the most important tree species of tropical regions and distributed from the longitudes of 73° E to 104° 30' E (Troup 1921, Mahaphol 1954). It is indigenous in both peninsulas of India, in north-eastern drier parts of Java and in other islands of Indian Archipelago (Brandis 1906). Its natural habitat lies between 10°N and 25°N latitudes with altitudinal range up to 1300 m above sea level on the Indian subcontinent and in South East Asia, especially in India, Burma, Thailand, Cambodia, Vietnam and Indonesia. It is accounted as the most highly-valued hardwood due to the dimensional stability, quality, attractiveness, workability and durability of its heartwood (Bishop 1999 and Bermejo et al 2003). It is one of the most widely grown hardwood timber species in the globe, increasing subsequently from 2.25 million ha to 6.0 million hectares (Ball et al 1999, Bhat and Hwan 2004). It is preferably grown in the areas having at mean annual temperature varies from 14º-36ºC and annual rainfall ranges from 600 to 4000 mm, but mostly prefer contrasting dry and wet seasons with a wide range of climatic and edaphic conditions (Orwa et al 2009). It prefers to grow in deep, fertile, well-drained soil with a degree of neutral to slightly alkaline pH (Luna 1996).

Teak plants are generally raised either by seeds or stumps or vegetative means as grafting, layering and branch cutting. Teak plant raised from stump has been adopted as a standard practice since 1932 because of its high success in adaptability (Champion and Pant 1932) in comparison to the other methods. Stump refers to root- shoot cutting of the seedling. Quick sprouting ability and vigorous growth of teak stump may encourage the rapid restoration of forest cover in the gaps after timber extraction or cyclone damage (Bellingham et al 1994, Riswan and Kartwawinata 1991). The growth behaviour of seedlings is an important parameter to ascertain its superiority for its successful establishment in any plantation programme which depends upon its genetic make up of parent trees well as environment particularly edaphic and climatic condition. Rapid early growth of seedlings in nursery enables them for early establishment in field. Application of mineral nutrition during establishment of seedlings may increase their growth rate (Ruaysoongnern et al 1984). To get better seedlings for achieving higher productivity, seedlings are either to be fertilized or raised with using proper growing media in nursery. This practice is now quite common for nursery man because the healthy seedlings usually develop sturdy root system and grow successfully after transplanting. Also it takes shorter time than the actual length of time required for trees to attain plantable size (Stockeler 1960). Though, a number of works on the growth performance of forest seedlings with the application of different growing media or potting mixtures in nursery have been carried out by different workers as Guleria (2006), Mhango et al (2008), Sondarva et al (2017) and Vidyasagaran and Kumar (2017). But the effect of growing

media on growth performance of stump has not been fully studied. Thus, the present study is emphasized on the application of easily available different growing media for raising quality seedlings of teak through stumps in the nursery.

MATERIAL AND METHODS

Study area: The present investigation was carried out in the central nursery of the Department of Forestry, Uttar Banga Krishi Viswavidyalaya in 2019-2020. The site was located at 26°23'47.8"N latitude and 89°23'16.2"E longitude. The climate was mostly dominated by humid subtropical over the region and soil was alluvial sandy loam with acidic in nature.

Media and stump preparation: Stumps of 13-18 mm collar diameter, 2.5 cm shoot and 12.5 cm root were selected and raised in the polybags of 6" x 12" in size containing different growing media under nursery condition for propagation. The growing media used were nursery soil, farm yard manure (FYM), vermicompost and saw dust in different proportion. The nursery soils were collected 2-3 weeks before conducting the experiment. Then the soils were air-dried and sieved to remove stones, pellets and other foreign materials. The polybags were filled with soil, FYM, vermicompost and saw dust mixture in different ratio.

Experimental layout: The present study was carried out using complete randomized design with 15 treatments in three replications and fifty stumps were taken in each replication. The experimental designs were, T_1: Sand; T_2: Soil; T_3: FYM; T_4: Soil: Sand (1:1); T_5: Sand: FYM (1:1); T_6: Soil: FYM (1:1); T_7: Sand: Soil: FYM (1:1:1); T_8: Sand: Soil: FYM (1:2:1); T_9: Sawdust; T_{10}: Sawdust: Soil (1:1); T_{11}: Sawdust: Soil: FYM (1:1:1); T_{12}: Sawdust: Soil: Vermicompost (1:1:1); T_{13}: Vermicompost; T_{14}: Vermicompost: Sand (1:1) and T_{15}: Vermicompost: Sand: Soil (1:1:1). Seedlings were weeded and irrigated as and when required. At the end of 30 days, data on sprouting percentage and time taken for complete sprouting were recorded, where the observations on growth attributes of seedlings i.e. collar diameter, shoot height and Sturdiness Quotient (S.Q.) as per Thomson (1985) were assessed at monthly interval up to the age of five months of the seedlings.

RESULTS AND DISCUSSION

Sprouting: The results pertaining to sprouting percentage and time taken for completion of sprouting are presented in Table 1. The mean sprouting percentage and time taken for completion of sprouting in the different growing media was significantly different ($p < 0.05$). Irrespective of the growing media, the sprouting of teak stumps was varied between 93.33 to 100% with an average value of 97.40%. Highest sprouting (100%) was occurred in media of vermicompost: sand: soil (1:1:1), soil: sand: FYM (1:1:1) and sawdust: soil: vermicompost (1:1:1) whereas the sole vermicompost (T_{13}) showed the lowest (93.33%) sprouting followed by soil (94.33%), which may be due to more compactness and binding property with highest Ca content in vermicompost and acidic nature of soil (Nurhidayati et al 2017). In case of solo growing media, FYM had recorded highest (96%) sprouting followed by sawdust (95.67%) and sand (95%), which was quite similar with studies in *Terminalia bellirica* for the FYM (Bali et al 2013). Sood and Ram (2019) assessed that soil: sand: vermicompost (1:1:1) was showed significantly higher germination than that of soil: sand: FYM (1:1:1) in *Oroxylum indicum*. This result is closely agreement with the findings of Billah et al (2015) and Khadijah et al (2020).

Table 1. Effect of growing media on sprouting and time for completion of sprouting

Treatments	Sprouting (%)	Time taken for complete sprouting (days)
T_1: Sand	95.00^{cde}	16.67^{abcd}
T_2: Soil	94.33^{de}	17.67^{ab}
T_3: FYM	96.00^{bcde}	13.67^{defg}
T_4: Soil: Sand (1:1)	98.00^{abc}	15.67^{abcdef}
T_5: Sand: FYM (1:1)	98.67^{ab}	16.00^{abcdef}
T_6: Soil: FYM (1:1)	97.33^{abcd}	17.33^{ab}
T_7: Sand: Soil: FYM (1:1:1)	100.00^{a}	15.00^{bcdefg}
T_8: Sand: Soil: FYM (1:2:1)	98.67^{ab}	13.33^{efg}
T_9: Sawdust	95.67^{bcde}	18.67^{a}
T_{10}: Sawdust: Soil (1:1)	98.00^{abc}	16.33^{abcde}
T_{11}: Sawdust: Soil: FYM (1:1:1)	98.67^{ab}	14.00^{cdefg}
T_{12}: Sawdust: Soil: Vermicompost (1:1:1)	100.00^{a}	12.00^{g}
T_{13}: Vermicompost	93.33^{e}	17.33^{ab}
T_{14}: Vermicompost: Sand (1:1)	97.33^{abcd}	17.00^{abc}
T_{15}: Vermicompost: Sand: Soil (1:1:1)	100.00^{a}	13.00^{fg}
Mean	97.40	15.58
SEm±	1.26	1.13
CD (p=0.05)	3.64	3.25

The longest time span (18.67 days) for complete sprouting was recorded in sawdust followed by soil (17.67 days) which was strongly at par the same value of 17.33 days in both vermicompost and soil: FYM (1:1), whereas, the shortest time span (12 days) was exhibited in T_{12}: sawdust: soil: vermicompost (1:1:1). The growing media as vermicompost: sand: soil (1:1:1), FYM, sand: soil: FYM (1:2:1) and sawdust: soil: FYM (1:1:1) with respect to the

number of days taken for complete sprouting was not significantly different with each other. This study is strong agreement with Bharadwaj (2014) in *Carrica papaya.* The higher N content in vermicompost may readily available in composite mixture than sole media which influenced the germination period (Lazcano 2010).

Growth parameter: The collar diameter and height growth of teak seedlings was significantly different ($p < 0.05$) among the different growing media treatments (Table 2). Both the collar diameter and height showed an increasing trend throughout the study period. After 30days, the highest (4.20 mm) collar diameter growth was recorded in sole FYM (T_3), which was strongly at par with 4.09, 4.08 and 4.02 mm in soil: FYM (1:1), vermicompost: sand (1:1) and sole soil (T_2), respectively and the lowest (2.96 mm) was showed in sole sawdust (T_9) at par with 3.01, 3.06, 3.11 and 3.19 mm in sawdust: soil (1:1), vermicompost, sawdust: soil: FYM (1:1:1) and sand, respectively. The treatment, vermicompost: sand: soil (1:1:1) was recorded the highest collar diameter in 60, 90, 120 and 150 days respectively, whereas the lowest (3.82 and 5.94 mm) had in sawdust at 60 and 90 days of growth and T_{10}: sawdust: soil (1:1) showed the lowest (6.88 and 7.53 mm) at the end of 120 and 150 days growth, respectively among the different media compositions. Height growth was ranged from 10.25 to 22.63 cm, 12.77 to 31.55 cm, 16.23 to 42.41 cm, 24.59 to 55.06 cm and 53.55 to 107.91 cm at 30, 60, 90, 120 and 150 days of growth, respectively. The height growth was found to be highest in vermicompost: sand: soil (1:1:1) in all growth period whereas the sole growing media sawdust (T_9)pronounced lowest height growth except 30 and 90 days of growth of seedling which was found in T_{10}: sawdust: soil (1:1). Among the treatments, Vermicompost and FYM were the best performing as sole growing media in both collar diameter and height, while sawdust and sand was the worst ones. Overall, the composite potting mixture performed better than the sole media. The media vermicompost: sand: soil (1:1:1) was statistically superior to all other growing media with highest increment in height and collar diameter which well in line with Sood and Ram (2019) in *Oroxylum indicum*. In one hand, vermicompost was not only improved the soil health but also promoted plant growth and seed germination as well (Shafique et al 2021) because of higher microbial load (Emperor and Kumar 2015) while sawdust was recorded lowest seedling growth in height and root collar diameter in seedlings (Ashiono 2017) due to slow rate of decomposition and temporary depression in nitrogen release tendency (Garner 2014).

Sturdiness quotient: At 30 days of growth, the sturdiness

Table 2. Effect of different growing media on collar diameter and height growth of teak seedlings

Treatments	30 days		60 days		90 days		120 days		150 days	
	Collar diameter (mm)	Height (cm)	Collar diameter (mm)	Height (cm)	Collar diameter (mm)	Height (cm)	Collar diameter (mm)	Height (cm)	Collar diameter (mm)	Height (cm)
T_1: Sand	3.19^{ef}	12.52^{h}	4.43^{f}	19.13^{f}	6.44^{efg}	21.06^{hi}	7.49^{de}	30.83^{gh}	8.54^{def}	61.83^{g}
T_2: Soil	4.02^{a}	17.20^{f}	5.73^{cd}	26.84^{cd}	8.41^{bcd}	31.48^{def}	8.66^{de}	42.13^{de}	10.79^{cd}	91.13^{cd}
T_3: FYM	4.20^{a}	19.40^{cd}	6.00^{c}	29.76^{ab}	9.07^{ab}	38.82^{a}	11.20^{ab}	49.56^{abc}	13.96^{a}	101.02^{ab}
T_4: Soil: Sand (1:1)	3.28^{de}	15.42^{g}	4.58^{ef}	22.35^{e}	6.58^{efg}	26.45^{fg}	8.58^{de}	35.39^{fg}	10.57^{cde}	78.62^{ef}
T_5: Sand: FYM (1:1)	3.79^{b}	17.22^{f}	5.45^{d}	26.01^{d}	7.68^{cde}	35.58^{bcd}	8.82^{cd}	48.20^{bcd}	10.97^{bcd}	95.41^{bc}
T_6: Soil: FYM (1:1)	4.09^{a}	19.16^{cd}	5.85^{cd}	28.81^{bc}	8.77^{abc}	37.08^{bc}	10.90^{b}	48.81^{abc}	13.95^{a}	100.16^{ab}
T_7: Sand: Soil: FYM (1:1:1)	3.70^{bc}	20.79^{b}	6.51^{ab}	31.16^{ab}	8.76^{abc}	38.88^{ab}	11.22^{ab}	53.75^{ab}	13.55^{ab}	102.81^{ab}
T_8: Sand: Soil: FYM (1:2:1)	3.55^{cd}	17.66^{ef}	5.74^{cd}	28.92^{bc}	7.29^{def}	37.08^{bc}	10.69^{bc}	45.74^{cd}	12.41^{abc}	85.74^{de}
T_9: Sawdust	2.96^{f}	10.79^{ij}	3.82^{g}	12.77^{h}	5.94^{g}	17.35^{i}	6.94^{de}	24.59^{i}	7.93^{ef}	53.55^{g}
T_{10}: Sawdust: Soil (1:1)	3.01^{ef}	10.25^{j}	3.92^{g}	13.71^{h}	6.24^{fg}	16.23^{i}	6.88^{e}	25.41^{hi}	7.53^{f}	55.41^{g}
T_{11}: Sawdust: Soil: FYM (1:1:1)	3.11^{ef}	11.33^{ij}	4.57^{ef}	16.40^{g}	7.53^{cdef}	24.99^{gh}	10.90^{b}	39.11^{ef}	12.88^{abc}	74.11^{f}
T_{12}: Sawdust: Soil: Vermicompost (1:1:1)	3.98^{ab}	11.67^{hi}	4.89^{e}	16.69^{g}	7.62^{cde}	29.38^{efg}	8.71^{cde}	34.98^{fg}	10.54^{cde}	75.62^{f}
T_{13}: Vermicompost	3.06^{ef}	18.44^{de}	6.08^{bc}	29.96^{ab}	9.30^{ab}	32.96^{cde}	12.33^{ab}	45.63^{cde}	14.33^{a}	103.40^{ab}
T_{14}: Vermicompost: Sand (1:1)	4.08^{a}	19.97^{bc}	5.83^{cd}	30.85^{ab}	9.05^{ab}	39.39^{ab}	11.21^{ab}	53.76^{ab}	14.04^{a}	105.42^{a}
T_{15}: Vermicompost: Sand: Soil (1:1:1)	3.78^{bc}	22.63^{a}	6.61^{a}	31.55^{a}	9.99^{a}	42.41^{a}	12.94^{a}	55.06^{a}	14.47^{a}	107.91^{a}
SEm±	0.10	0.38	0.15	0.82	0.45	1.71	0.66	2.26	0.94	3.00
CD (p=0.05)	0.28	1.08	0.44	2.38	1.31	4.93	1.90	6.54	2.72	8.66

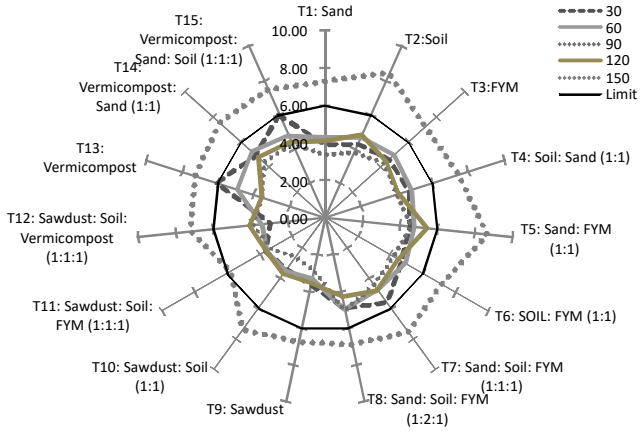

Fig. 1. Sturdiness quotient of teak seedling in different growing media

quotient was higher (6.00) in vermicompost and vermicompost: sand: soil (1:1:1) followed by 5.62 in soil: sand: FYM (1:1:1) indicating optimum height growth in the seedlings (Fig. 1). But later stage up to 120 days all the plants grow were below the limit of 6.00, indicating more diameter growth and better survival in extreme conditions. At the end of 150 days of sowing plants raised in each and every media except sawdust: soil: FYM (1:1:1) was cross the limit simultaneously and put a signal that further growth in container lead to risk on survival and growth in the field condition. Sturdiness quotient above six was an indication of physiological imbalance inducing tall spindly seedlings while in reverse there was difficulty in seedling establishment (Jaenicke 1999). Compost growing media was produced seedlings with significantly higher sturdiness quotient as compared to both soil and sand due to the effect of organic carbon and nitrogen availability of the media (Kihara 2002).

CONCLUSION

The sprouting of teak stumps were varied between 93.33 to 100% with 12 to 18.67 days for complete germination. Vermicompost: sand: soil (1:1:1) and sawdust: soil: vermicompost (1:1:1) showed highest sprouting (100%) as well as shortest time span for completion of sprouting. Though, soil: sand: FYM (1:1:1) had 100% sprouting percentage but it took more time than soil: sand: FYM (1:2:1) for completion of sprouting. The result obtained from composite media mixture showed highest sprouting and less sprouting period significantly in comparison to solo media. All the vermicompost combinations specially T_{15}: vermicompost: sand: soil (1:1:1) along with sand: soil: FYM (1:1:1) gave the best seedling growth (collar diameter and height) while all the potting mix with sawdust (T_9) gave significantly poor results. In sole media, vermicompost (T_{13}) and FYM (T_3) were the best performing while sawdust (T_9) and sand (T_1) were the poor performing media for seedling growth. Irrespective of growing media, seedlings of 120 days gave optimum result with adequate physiological balance and assurance for better survival as per the sturdiness quotient.

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Assessment of Tree Species Composition and Diversity of Core and Buffer Zones in Pualreng Wildlife Sanctuary, Mizoram, India

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Abstract: This study aims to scrutinize tree species composition and diversity in the tropical forest of Pualreng Wildlife Sanctuary which was evaluated by randomly laying 60 quadrats (10m x 10m) each in the core and buffer zones. Total of 109 tree species (≥5 cm dbh) belonging to 41 families were recorded in the study area where Fabaceae family accounts for the highest number of species followed by Malvaceae and Lauraceae. In the Buffer Zone, 71 species belonging to 63 genera and 32 families were documented while in Core zone, 94 species belonging to 77 genera and 40 families were recorded. Shannon-Weiner's Species Diversity Index (H' = 4.2) and Margalef's Index for Species Richness (R = 12.38) indicate higher values in the Core Zone but the Simpson's dominance index value (D = 0.02) was low. Pielou's Evenness Index (E = 0.6862) was slightly higher in buffer zone. Results obtained revealed high biodiversity in the study area. The study provides data for the management of protected areas and shows the potential of in situ method in the conservation of preserved areas.

Keywords: Composition, Diversity, Buffer zone, Core zone

Biodiversity refers to the degree of variations of all life forms along with their distribution patterns and comprises all living species of plants, animals, microorganisms, and the ecosystems on which they occur (Uno et al 2001). The patterns of distribution and ecomorph of a species can well be delineated by observing various ecological attributes in which the instructions can be used for proper framing and management for global anthropogeny and ecological catastrophe (Nayak and Sahoo 2020). Tropical forests account for about 52% of the global total forest, therefore in terms of biodiversity, they exhibit the highest diversities. Tropical forests provide many ecosystem services such as upholding habitats for plants and animals; play a key role in sustainable development and climate change (Anbarashan and Parthasarathy 2013). Deterioration of forests mainly on account of anthropogenic activities had led to critical losses in biodiversity (Sodhi et al 2009). Numerical studies on vegetation are of paramount importance to comprehend ecosystem dynamics as it recounts the vegetation in terms of floristic composition and diversity. The constant monitoring of diversity should be prolonged for conserving species and habitat diversity since tree species are dominant life forms (Attua and Pabi 2013). An important step made towards conserving tropical forests is the formation of strictly protected core zones, where species and their habitats are secured (Bruner et al 2001), and the surrounding as buffer zones where mild impact forest use intensity is assumed. This method can strengthen the conservation value of protected areas while providing some forest products for the fringing villages (DeFries et al 2005). The state of Mizoram has 8 wildlife sanctuaries and 2 national parks comprising a total of 1240.75 sq. km area i.e. 5.9% of the total geographical area of the state. It is located in the north-eastern region of India which is characterized by high rainfall and provides beneficial conditions for vegetation. Mizoram occurs in the Indo-Burma biodiversity hotspot having a great number of endemic species which are under serious threat. Forests within Mizoram suffer from deforestation due to extensive anthropogenic disturbances such as collection of timber, livelihood dependency of forest-dwelling populations and jhum cultivation to support the increasing population. So far, no research has been conducted to identify and evaluate the diversity of trees in this sanctuary, hence this study aims to first acknowledge tree species composition in the study area, then identify and compare tree species diversity between buffer and core zones.

MATERIAL AND METHODS

The study was conducted in the tropical forest of Pualreng Wildlife Sanctuary located in Kolasib district of Mizoram which lies between 24° 6'35"-24° 14'16'21"' North Latitude and 92°50' 17.6" -92°54'2.64" East longitude. It covers an area of 50 sq. km. which contains a rich ecosystem of flora and fauna. The altitude ranges from 260 m to 750 m and the fringing villages include N. Hlimen, Thingthelh, Bukpui, Palsang, Zohmun and N. Khawdungsei. The climatic

condition is very mild and pleasant, during summer the temperature ranges between 20°C-30°C and in winter it ranges between 10°C-20°C having a mean annual rainfall of 2000 mm-3900 mm (Sharma et al 2013). Activities such as logging, hunting and gathering of non-timber forest products (NTFPs) are prohibited in core zone. However, during fieldwork, some signs of logging and collecting of NTFPs were observed. Agriculture through jhum cultivation (slash-and-burn) is the main economic activity of the fringing villages. As a result, much vegetation in the buffer zones was degraded by the local individuals due to the expanding agricultural lands led by an increase in population.

The composition and diversity of the tree species in the study area were assessed by random sampling method in each zone. The quadrat size was set at 10m x 10m for all the plots. A total of 120 quadrats were laid, 60 quadrats in each conservation zone. All individual trees having a diameter ≥5 cm at breast height were identified, measured and recorded. Tree species were identified in their local or commercial name at the species level with the help of local people who are experienced in the vegetation of the region. These trees were later confirmed with herbarium present in the Mizoram University and herbarium of the Botanical Survey of India (BSI), Eastern circle, Shillong and counter checked using various regional floras (Kanjilal et al 1934-1940, Lalramnghinglova 2003, Sawmliana 2009, Singh et al 2002). Unidentified tree species were collected and identified with the help of experts at Mizoram University. The core and buffer zones were identified and shown in Figure 1. Diversity indices can be utilized to gain information about the community structure along with the rarity or commonness of species. Comparison of indices between two types of habitats can be done through these diversity indices (Kent and Coker 1992). Species diversity and indices were determined following the works of Misra (1968), Mueller-Dombois and Ellenberg (1974).

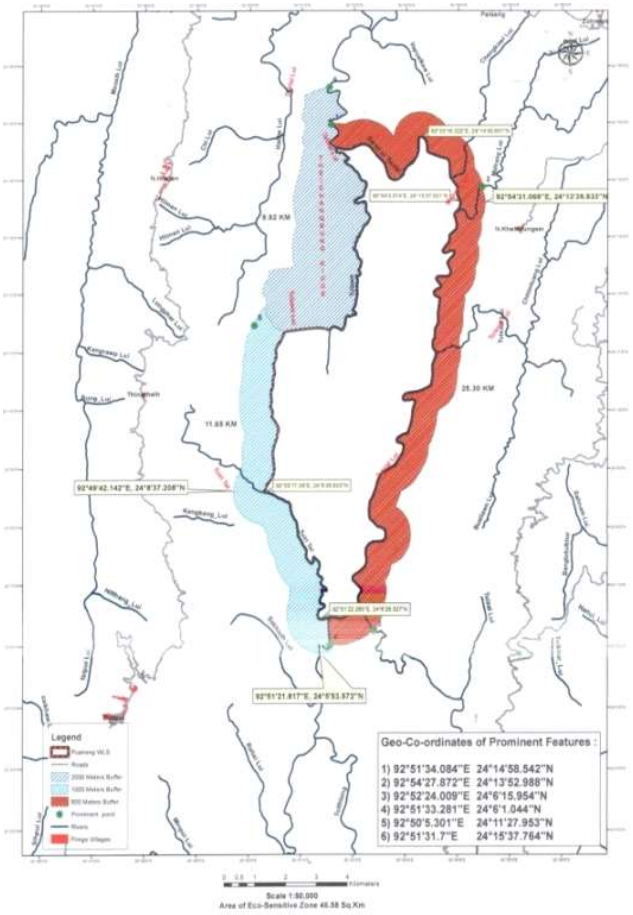

Fig. 1. Core and buffer zones of Pualreng wildlife sanctuary

RESULTS AND DISCUSSION

Floristic composition: In the study area, a total of 109 tree species belonging to 41 families were identified. Fabaceae was the most dominant family with 11 species, followed by Malvaceae and Lauraceae with 7 species each. In core zone, 94 species of trees were documented belonging to 77 genera and 40 families while in buffer zone, 71 species of trees belonging to 63 genera and 32 families were identified. The number of species in core zone is comparable to Phawngpui National Park, Mizoram (84 species) (Malsawmsanga and Lalramnghinglova 2011) while buffer zone is more comparable to Hollongapar Gibbon Wildlife Sanctuary, Assam (75 tree species) (Sarkar and Devi 2014). However, number of species present in both zones is significantly lower than those reported by Sailo (2013) at Lengteng wildlife sanctuary, Mizoram having 128 species and 127 species at Nongkhyllem wildlife sanctuary, Meghalaya by Thapa et al (2011). In both zones, Fabaceae with 8 species each was the most dominant family followed by Lauraceae (7 species) in core zone and Lauraceae, Malvaceae, Meliaceae and Rubiaceae (5 species each) in buffer zone. Tree species composition was much higher in core zone as compared to buffer zone which indicated the importance and beneficial effect of area enclosure on tree species composition. Kibret (2008) observed species diversity may be depleted in buffer zones as compared to core zones since less protection is provided for tree species in buffer zones so they are more vulnerable to disturbance by animals or humans. This suggests that individuals in buffer zones are harvested by local residents for firewood, house construction, or clearing for agricultural lands.

Species diversity, evenness and richness: The diversity was higher in core zone (4.2) as compared to buffer zone (3.9). Diversity index tends to be higher in tropical forests

Table 1. Floristic composition of core and buffer zones

Core Zone		Buffer Zone	
Name of species	Family	Name of species	Family
Acer laevigatum Wall.	Sapindaceae	*Acrocarpus fraxinifolius* Arn.	Fabaceae
Albizia chinensis (Osbeck) Merr.	Fabaceae	*Aglaia edulis* (Rox.) Wall.	Meliaceae
Albizia procera (Roxb.) Benth.	Fabaceae	*Albizia procera* (Roxb.) Benth.	Fabaceae
Alseodaphne petiolaris (Meisn.) Hook. fil.	Lauraceae	*Alseodaphne petiolaris* (Meisn.) Hook. fil.	Lauraceae
Anthocephalus chinensis (Roxb.) Miq.	Rubiaceae	*Anogeissus acuminate* (Roxb. ex DC.) Wall. ex Guill. and Perr.	Combretaceae
Aporosa octandra (Buch.-Ham. Ex D.Don) Vickery	Phyllanthaceae	*Anthocephalus chinensis* (Roxb.) Miq.	Rubiaceae
Ardisia polycephala Wall. Ex A.DC.	Primulaceae	*Aporosa octandra* (Buch.-Ham. Ex D. Don) Vickery	Phyllanthaceae
Artocarpus chama Buch.-Ham.	Moraceae	*Ardisia polycephala* Wall. Ex A.DC.	Primulaceae
Artocarpus lacucha Roxb.	Moraceae	*Baccaurea ramiflora* Lour.	Phyllanthaceae
Baccaurea ramiflora Lour.	Phyllanthaceae	*Bauhinia variegate* L.	Fabaceae
Bauhinia variegate L.	Fabaceae	*Bischofia javanica* Blume	Phyllanthaceae
Bischofia javanica Blume	Phyllanthaceae	*Bombax ceiba* L.	Malvaceae
Bombax ceiba L.	Malvaceae	*Calliandra umbrosa* (Wall.) Benth.	Fabaceae
Bombax insigne Wall.	Malvaceae	*Callicarpa arborea* Roxb.	Lamiaceae
Callicarpa arborea Roxb.	Lamiaceae	*Canarium strictum* Roxb.	Burseraceae
Calophyllum polyanthum Wall. ex Choisy	Calophyllaceae	*Carallia brachiate* (Lour.) Merr.	Rhizophoraceae
Canarium strictum Roxb.	Burseraceae	*Cassia javanica* L.	Fabaceae
Carallia brachiate (Lour.) Merr.	Rhizophoraceae	*Castanopsis indica* (Roxb. ex Lindl.)	Fagaceae
Cassia javanica L.	Fabaceae	*Castanopsis lanceifolia* (Oerst.)	Fagaceae
Castanopsis indica (Roxb. ex Lindl.)	Fagaceae	*Celtis australis* L.	Cannabaceae
Castanopsis lanceifolia (Oerst.)	Fagaceae	*Chrysophyllum lanceolatum* (Blume) A.DC.	Sapotaceae
Castanopsis tribuloides (Sm.) A.DC.	Fagaceae	*Chukrasia velutina* (M. Roemer) King	Meliaceae
Celtis australis L.	Cannabaceae	*Cinnamomum tamala* (Buch.-Ham.)	Lauraceae
Chukrasia velutina (M. Roemer) King	Meliaceae	*Colona floribunda* (Kurz) Craib	Malvaceae
Cinnamomum tamala (Buch.-Ham.)	Lauraceae	*Cordia dichotoma* G. Forst.	Cordiaceae
Cordia dichotoma G. Forst.	Cordiaceae	*Diospyros malabarica* (Desr.) Kostel.	Ebenaceae
Derris robusta (DC.)Benth.	Fabaceae	*Diospyros stricta* Hort. ex Loudon	Ebenaceae
Diospyros lanceifolia Roxb.	Ebenaceae	*Duabanga grandiflora* (Roxb. ex DC.) Walp.	Lythraceae
Diospyros stricta Hort. ex Loudon	Ebenaceae	*Dysoxylum binectariferum* Hiern.	Meliaceae
Drimycarpus racemosus (Roxb.) Hook.fil.	Anacardiaceae	*Dysoxylum gobara* (Buch.-Ham.) Merr.	Meliaceae
Duabanga grandiflora (Roxb. ex DC.) Walp.	Lythraceae	*Emblica officinalis* L.	Phyllanthaceae
Dysoxylum gobara (Buch.-Ham.) Merr.	Meliaceae	*Erythrina stricta* Roxb.	Fabaceae
Elaeocarpus lanceifolius Roxb.	Elaeocarpaceae	*Ficus retusa* L.	Moraceae
Emblica officinalis L.	Phyllanthaceae	*Flacourtia jangomas* (Lour.) Rauesch.	Salicaceae
Erythrina stricta Roxb.	Fabaceae	*Garcinia anomala* Planch. and Triana	Clusiaceae
Ficus benjamina L.	Moraceae	*Garcinia pedunculata* Roxb.	Clusiaceae
Ficus racemosa L.	Moraceae	*Garuga floribunda* (King ex W. Smith) Kalkman	Burseraceae
Flacourtia jangomas (Lour.) Rauesch.	Salicaceae	*Garuga pinnata* Roxb.	Burseraceae
Garcinia anomala Planch. and Triana	Clusiaceae	*Gmelina arborea* Roxb.	Lamiaceae
Garcinia sopsopia (Buch.-Ham.) Mabb.	Clusiaceae	*Helicia robusta* (Roxb.) R. Br. ex Wall.	Proteaceae
Garcinia xanthochymus Hook. f.	Clusiaceae	*Heritiera papilio* Bedd.	Malvaceae
Garuga pinnata Roxb.	Burseraceae	*Hibiscus macrophyllus* Roxb. ex Hornem.	Malvaceae
Glochidion khasicum (Müll.Arg.) Hook.f.	Phyllanthaceae	*Holigarna longifolia* Buch.-Ham. ex Roxb.	Anacardiaceae
Gmelina arborea Roxb.	Lamiaceae	*Hydnocarpus kurzii* (King) Warb.	Achariaceae
Gmelina oblongifolia Roxb.	Lamiaceae	*Litsea cubeba* (Lour.) Pers.	Lauraceae
Helicia excels (Roxb.) Blume	Proteaceae	*Litsea monopetala* (Roxb. ex Baker) Pers.	Lauraceae
Helicia robusta (Roxb.) R. Br. ex Wall.	Proteaceae	*Macaranga denticulate* (Blume) Müll.Arg.	Euphorbiaceae
Heritiera papilio Bedd.	Malvaceae	*Macaranga indica* Wight	Euphorbiaceae
Holigarna longifolia Buch.-Ham. ex Roxb.	Anacardiaceae	*Mesua ferrea* L.	Calophyllaceae
Hydnocarpus kurzii (King) Warb.	Achariaceae	*Michelia champaca* L.	Magnoliaceae

Cont...

Table 1. Floristic composition of core and buffer zones

Core Zone		Buffer Zone	
Name of species	Family	Name of species	Family
Knema erratica (Hook.fil. and Thomson) J. Sinclair	Myristicaceae	*Michelia oblonga* Wall. ex Hook.f. and Thomson	Magnoliaceae
Lithocarpus elegans (Blume) Hatus. ex Soepadmo	Fagaceae	*Mitragyna diversifolia* (Wall. ex G.Don) Havil.	Rubiaceae
Litsea cubeba (Lour.) Pers.	Lauraceae	*Neonauclea purpurea* (Roxb.) Merr.	Rubiaceae
Litsea monopetala (Roxb. ex Baker) Pers.	Lauraceae	*Nyssa javanica* (Blume) Wangerin	Nyssaceae
Macaranga denticulate (Blume) Müll.Arg.	Euphorbiaceae	*Ostodes paniculata* Blume	Euphorbiaceae
Macaranga indica Wight	Euphorbiaceae	*Palaquium polyanthum* (Wall. ex G.Don) Baill.	Sapotaceae
Machilus japonica Siebold and Zucc.	Lauraceae	*Parkia timoriana* (DC.)Merr.	Fabaceae
Macropanax dispermus (Blume) Kuntze	Araliaceae	*Persea minutiflora* Kosterm.	Lauraceae
Magnolia hodgsonii (Hook.f. and Thomson) H.Keng	Magnoliaceae	*Polyalthia jenkinsii* (Hook. f. and Thomson)	Annonaceae
Mesua ferrea L.	Calophyllaceae	*Protium serratum* (Wall. ex Colebr.) Engl.	Burseraceae
Michelia champaca L.	Magnoliaceae	*Pterospermum acerifolium* (L.) Willd.	Malvaceae
Michelia oblonga Wall. ex Hook.f. and Thomson	Magnoliaceae	*Randia wallichii* Hook. f.	Rubiaceae
Mitragyna diversifolia (Wall. ex G.Don) Havil.	Rubiaceae	*Sapium baccatum* Roxb.	Euphorbiaceae
Nyssa javanica (Blume) Wangerin	Nyssaceae	*Saraca asoca* (Roxb.) Willd.	Fabaceae
Oroxylum indicum (L.) Benth. ex Kurz	Bignoniaceae	*Schima wallichii* (DC.) Korth.	Theaceae
Ostodes paniculata Blume	Euphorbiaceae	*Spondias pinnata* (L.f.) Kurz.	Anacardiaceae
Parkia timoriana (DC.)Merr.	Fabaceae	*Syzygium cumini* (L.) Skeels	Myrtaceae
Persea minutiflora Kosterm.	Lauraceae	*Tetrameles nudiflora* R. Br.	Tetramelaceae
Phoebe attenuate (Nees) Nees	Lauraceae	*Toona ciliata* M. Roem.	Meliaceae
Podocarpus neriifolius D.Don	Podocarpaceae	*Wendlandia grandis* (Hook.f.) Cowan	Rubiaceae
Polyalthia jenkinsii (Hook. f. and Thomson)	Annonaceae	*Zanthoxylum rhetsa* (Roxb.) DC.	Rutaceae
Protium serratum (Wall. ex Colebr.) Engl.	Burseraceae		
Prunus ceylanica (Wight) Miq.	Rosaceae		
Pterospermum acerifolium (L.) Willd.	Malvaceae		
Randia wallichii Hook. f.	Rubiaceae		
Sapium baccatum Roxb.	Euphorbiaceae		
Saurauia punduana Wall.	Actinidiaceae		
Schima wallichii (DC.) Korth.	Theaceae		
Sophora wightii Baker	Fabaceae		
Spondias pinnata (L.f.) Kurz.	Anacardiaceae		
Sterculia villosa Roxb.	Malvaceae		
Stereospermum colais (Buch.-Ham. ex Dillwyn) Mabb.	Bignoniaceae		
Stereospermum neuranthum Kurz.	Bignoniaceae		
Syzygium cumini (L.) Skeels	Myrtaceae		
Terminalia crenulata Roth	Combretaceae		
Terminalia myriocarpa Van Heurck and Müll. Arg.	Combretaceae		
Tetrameles nudiflora R. Br.	Tetramelaceae		
Toona ciliata M. Roem.	Meliaceae		
Ulmus lanceifolia Roxb.	Ulmaceae		
Vitex heterophylla L.	Lamiaceae		
Vitex peduncularis Wall. ex Schauer	Lamiaceae		
Walsura robusta Roxb.	Meliaceae		
Wendlandia grandis (Hook.f.) Cowan	Rubiaceae		
Zanthoxylum rhetsa (Roxb.) DC.	Rutaceae		

where it has been reported to vary from 3.6 to 5.4 for tree species (Knight 1975). The diversity index of both zones points towards the higher range reported for tropical forests of the Indian sub-continent having a range of 0.67-4.86 (Kumar et al 2010, Panda et al 2013). In Indian forests, diversity index (H') ranges between 0.83-4.1 (Vishalakshi 1995) so the value of diversity index in both zones indicates high diversity of tree species in the study areas. However, diversity index of both zones was lower than those recorded by Giriraji et al (2008) in the tropical forest of Western Ghats but higher than those indices recorded earlier workers (Sundarapandian and Swamy 2000, Rao et al 2011,

Table 2. Diversity indices estimated for core and buffer zone of the study area

Diversity Indices	Core Zone	Buffer Zone	Overall
H'	4.2	3.9	4.3
E	0.6814	0.6862	0.6518
D	0.02	0.03	0.02
R	12.38	10	13.53
Number of species	94	71	109

H' = Shannon-Weiner diversity index; E = Pielou's evenness index; D = Simpson's dominance index; R = Margalef's index of species richness

Malsawmsanga 2011). It is more comparable to that of the tropical moist forest of Reiek (Devi et al 2018). A lower value of Simpson's dominance index was observed in the core zone (0.02) than the buffer zone (0.03). The tropical forests of India reported Simpson's index in the range of 0.03-0.92 (Bhuyan et al 2003, Nath et al 2005, Devi and Yadava 2006, Deb and Sundriyal 2011, Kushwaha and Nandy 2012) so the dominance index of the study area tends towards the lower range reported for other tropical forests.

Pielou's evenness index revealed that species were more uniformly distributed in buffer zone (E = 0.6862) as compared to core zone with a value of 0.6814. This showed that there was little difference between the two zones suggesting an even distribution of species in the study area. Evenness index of the study is comparable to 0.584 - 0.898 reported from tropical mountain cloud forest in Yunnan, South Western China by Shi and Zhu (2009). Margalef's index of species richness is higher in core zone (12.38) compared to the buffer zone (10.0). The values are comparable to 9 -19 recorded by Bhatt and Bankoti (2016) and fall within the range of 4.3 – 14.73 as reported by Sagar and Singh (2004).

CONCLUSION

The study exhibits that the forests of Pualreng wildlife sanctuary are rich in terms of floristic composition where a total of 109 tree species were identified in the study area in which 94 species of trees occur in core zone and seventy one species of trees were identified in the buffer zone. The lower values of diversity indices are observed in the buffer zone due to the increasing anthropogenic pressure such as logging, collection of NTFPs and jhum cultivation for agricultural lands. Many rare and endangered species of trees were identified within the study area however due to higher frequency of disturbances in buffer zone these rare species are under more stress which could lead to a reduction of such rare species. The present study will provide primary information for better management plans and monitoring of tree species in the future.

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Climate Change and Habitat Adaptability of *Madhuca longifolia* (J. Koenig ex L.) J.F. Macbr.: An Endangered Tree Species of High Socio-Economic Significance to Tribal Community of Eastern India

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Abstract**:** *M. longifolia* (J. Koenig ex L.) J.F. Macbr., also known as Mahua, is facing issues of gradual depletion and poor regeneration due to overexploitation and climate change. Present study highlights the distribution of suitable habitats of *M. longifolia* under the varying climatic conditions in eastern India using Maxent. At present about ~ 29,550.29 Km^2 area possesses suitable habitat for the distribution of *M. longifolia* in the eastern region, with prominent distribution in Jharkhand comprising ~ 72% of total suitable area followed by Chhattisgarh with ~ 17 % area. The future projections for the year 2050 indicated an increase in suitable habitat area in the range of ~1.2- 2.7% with southward shifting but the pattern of distribution is getting confined to a narrower geographical range as compared to the existing extent. Variable Bio_3 (isothermality) followed by elevation was the major predictor variable in limiting the distribution of *M. longifolia* for the present as well as future climatic scenario. The outcome of the study provides an insight on suitable habitats of *M. longifolia* and promotion and conservation strategies on predicted areas shall enable better growth scenario and contribute towards socioeconomic upliftment of tribal communities in the region.

Keywords**:** Climate change, Habitat, *M. longifolia*, Maxent, Tribal community

The 27 percent of total population of India, depend on non-timber forest products (NTFPs) for subsistence and livelihood support with an annual turnover of about Rs.60000 Million Rupees (Bhattacharya and Hayat 2009, Malhotra and Bhattacharya 2010).One of the major NTFP tree species of eastern India, *Madhuca longifolia* **(**J. Koenig ex L.) J.F. Macbr., belongs to *Sapotaceae* family and generally referred to as the butternut tree or Mahua (Ramadan et al 2006) is widely distributed in India, Sri Lanka and Nepal under dry tropical and subtropical climatic conditions (Saluja et al 2011). It is an important multipurpose tree species that provides livelihood support to tribal populations and is widely used by them in various ceremonies and festivals (Bisht et al 2018). The branches of *M. longifolia* are symbolized and regarded as the witness of the marriage in tribal communities (Kala, 2011). The plant possesses antibacterial, analgesic, antidiabetic, anticarcinogenic, wound healing, Nephro and hepatoprotective properties (Devi and Sangeetha 2016). *M. longifolia* flowers, fruits and leaves are edible (Fern 2014) and oil extracted from its seed is used for the manufacture of soaps and candles and is a remedy for seed pests and diseases (Orwa et al 2009). In ChotaNagpur plateau, *Shorea robusta* seeds boiled with *M. longifolia* flowers used as a substitute for grain staples by the tribals (Sunita et al 2013). The nectar produced by *M. longifolia* flowers is an excellent and valuable source of feeding for honey bees in the periods of scarcity (Singh and Upadhyay 2008). The forests, especially NTFPs have been overexploited to the various demands of the growing population, in this process the distribution and population of several plant species have been reduced to such an extent that if conservation interventions are not taken, some of these may face extinction. The extremely poor regeneration of *M. longifolia* in natural forests, burning of forest floor, sometime cutting of bark of old trees to facilitate collection of *M. longifolia* flower during summer in the natural forest are several examples prevailing destructive harvesting practices (Mishra and Teki 2007). Such unsustainable practices coupled with overexploitation and degrading habitats are major factors leading to reduced resources of this important tree species and has been put in endangered category by the IUCN (Gopi et al 2018). Further, the climate change has also impacted the distribution range of species (Gomez-Ruiz and Lacher Jr 2019) and has necessitated the need to understand the habitat adaptability response of species with reference to varying climatic conditions. Habitat suitability models have emerged as one of major tools to study the habitat distribution pattern of various species due to varying climatic conditions and have been attempted by many research groups (Edenius and Mikusiński 2006). Numerous studies undertaken using habitat suitability modelling tools, suggests that the climate change has emerged as one of the major factors leading to

shifts in habitats of various species (Mishra et al 2021, Weiskopf et al 2020), depleted resources (Singh and Singh 2012), altered forest composition (Keenan 2015) and compromised ecosystems (Bellard et al 2012).

The present study is an important endeavor to assess the response of *M. longifolia* to varying climatic conditions across varied agro-climatic zones of eastern India using Maxent. The study was taken up with the objectives to assess the present distribution range of *M. longifolia* in eastern India , investigate the species response to climate change by 2050 and examine the change in potential suitable habitats of *M. longifolia* due to the climate change.

MATERIAL AND METHODS

Study area: The study area lies between 17° 46' 56.49" N to 27° 31' 17.88" N and 80° 14' 39.27" E to 89° 52' 27.11" E encompassing major states of eastern region including Chhattisgarh, Bihar, Jharkhand, West Bengal and Odisha. The total geographic area of the present study is 553526 Sq Km, Odisha cover largest area of the study that is 155707 Sq Km, followed by Chhattisgarh (135194 Km^2), Bihar (94163 Km^2), West Bengal (88752 Km^2) and Jharkhand (79714 Km^2). The study area is mostly tribal dominated and the major population of the area depends on forests to meet livelihood support in their day to day life.

Occurrence data: The occurrence data was collected through a field survey and also from GBIF (Global Biodiversity Information Facility) web site (https://www.gbif.org/). The field survey to Chhattisgarh, Bihar, Jharkhand and Odisha was conducted during the year 2018-19 across all seasons for the collection of occurrence data of *M. longifolia*.

Environmental data: In the present study we used 19 Bioclimatic variable layers acquired from the Worldclim site (www.worldclim.org) at a spatial resolution of 30 arc seconds (~1 × 1 km resolution) (Fick and Hijmans 2017). Aspect and slope layers were derived from Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) acquired from USGS (https://earthexplorer.usgs.gov).The soil layer for the study area was derived from FAO soil maps (http://www.fao.org/geonetwork/srv). Different climate layers for the year 2050, representing RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5 (Navarro-Racines et al 2020) were acquired from Climate Change, Agriculture and Food Security data portal (www.ccafs_climate.org) and used GCM model IPSL-CM5A-LR (Dufresne et al 2013). These RCP datasets are statistically downscaled for regional studies using Delta method (Van Vuuren et al 2011).

Model training and evaluation: The Maxent 3.4.1 version (Phillips et al 2021) was employed for the analysis of the most probable distribution area of *M. longifolia.* Maxent due to its robustness and accuracy is preferred and applied by various research groups to study the impact of climate change on species habitat (Qin et al 2017, Gebrewahid et al 2020, Ghosh et al 2021, Rawat et al 2020, Dasari et al 2020). The species occurrence file in .csv format, along with bioclimatic and geographical data layers in ASCII format were entered in Maxent. The training and test data were set at a ratio of 75:25 and background dataset points were set to 10,000 with 10 replicates.

Model performance: The species distribution map of *M. longifolia* was modelled for the present as well as for the year 2050 under different RCP scenarios, *i.e.,* RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5. The model performance and accuracy analysis are as under:

Receiver operating curve (ROC) analysis: The area under receiver operating characteristics curve (AUC/ROC) determines the efficiency of the model and ROC curve value close to 1 suggests excellent performance (Hajian-Tilaki 2013). The average test AUC under the present climatic scenario (2020), was 0.858 (Fig. 2a). For future scenario, depending upon RCP, AUC ranges between ~ 0.83-0.88 (Fig. 2 (b-e))

Jackknife test: Jackknife test deduce the most significant contributor variable (Fig. 3 (a-e)) and the test indicates that bioclimatic variable Bio_3 followed by elevation contributing most in the model fitting for the current climatic conditions as well as for the year 2050 across all the RCPs.

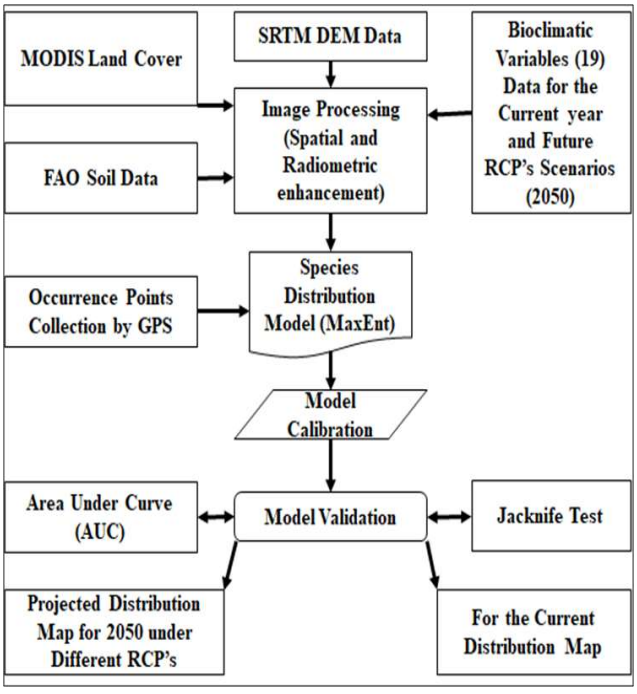

Fig. 1. Process flow diagram of the study

RESULTS AND DISCUSSION

Projected habitat suitability maps of *M. longifolia:* The most probable suitable habitat area of *M. longifolia* for the year 2020 and 2050 under different RCP scenarios is displayed through Figure 4(a-e). The area distribution statistics show that the suitable habitat area will increase by 2050 across all RCPs with maximum expansion to ~35000 Km^2 in suitability range under RCP 8.5 as compared to present calculated area ~ 29550.29 Km^2 (Fig. 5). The current distribution pattern show wide distribution of *M. longifolia* in the region, with dominance in the state of Jharkhand ~21627.39 Km^2, followed by Chhattisgarh ~5102.07 Km^2 and to some extent in West Bengal ~1469.67 Km^2. The projections for the year 2050 exhibited traits of clumped increase in suitable habitat confined to Jharkhand, Chhattisgarh and Odisha, where the suitable habitat area may increase maximum up to ~26219.54 Km^2, ~6880.91 Km^2 and ~1885.80 Km^2 respectively. In contrast, the study exhibited three to four times decrease in suitable habitat areas for West Bengal and Bihar and it may reduce to ~228.58 Km^2 and ~202.21 Km^2 as compared to present statistics of ~1469.67 Km^2 and ~793.44 Km^2 respectively.

The results for the year 2020 exhibits that the distribution of *M. longifolia* is mostly dominated in the state of Jharkhand which is having about ~73% of total suitable habitat area followed by Chhattisgarh with about ~17% area. Study

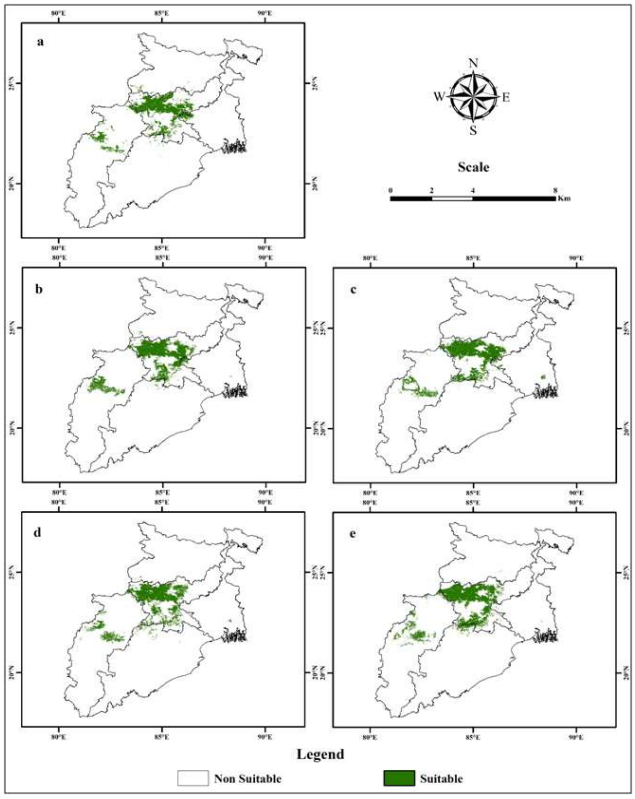

Fig. 4. Habitat suitability map of ***M. longifolia*** in eastern India for the year (a) 2020 and (b-e) 2050 under RCP 2.6, 4.5, 6.0 and 8.5

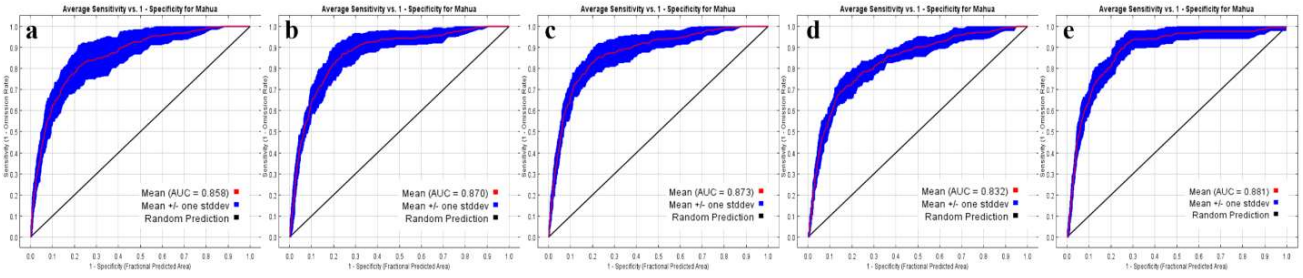

Fig. 2. AUC Curve for the year Fig (a) 2020 and Fig (b-e) 2050 under different RCPs *i.e.* 2.6, 4.5, 6.0 and 8.5

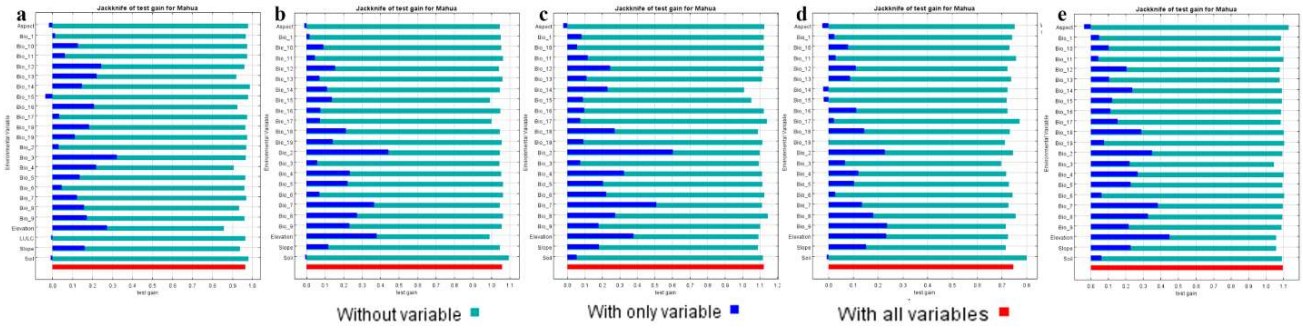

Fig. 3. Jackknife test gain result on AUC for the year Fig (a) 2020 and Fig (b-e) 2050 for different RCP Scenario *i.e.* 2.6, 4.5, 6.0 and 8.5

Table 1. Projected suitable habitat area (in Km^2) of *M. longifolia* for the year 2020 and 2050 under different RCPs

Year	Scenario	Bihar	CG	Jharkhand	Odisha	West Bengal
2020	Current	793.44	5102.07	21627.39	507.72	1469.67
2050	RCP 2.6	231.51	6189.30	23624.55	687.21	1052.80
	RCP 4.5	202.21	5384.87	24796.76	492.33	1274.05
	RCP 6.0	405.15	5873.53	23993.06	1282.84	228.58
	RCP 8.5	248.36	6880.91	26219.54	1885.80	397.09

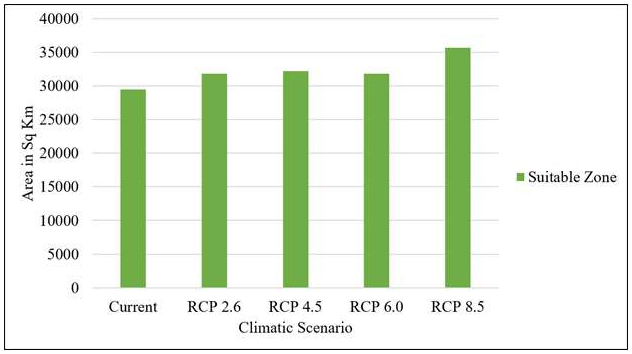

Fig. 5. Projected distribution of suitable habitats of *M. longifolia* in eastern India for 2020 and 2050 under different RCPs

revealed that at present only ~1.72 % of suitable habitat area exists in Odisha. Field surveys revealed wide distribution of *M. longifolia* exists in forest landscape with associated species like *Shorea robusta, Terminalia bellirica, Boswellia serrata* and *Lagerstroemia parviflora.* The distribution was also found along road side as well as private lands. The observation was in agreement with earlier report that *M. longifolia* trees can be found in natural landscape, revenue, under private land holding class (Mishra and Padhan, 2013).

The predictor variable study showed that Bioclimatic variable Bio_3 (isothermality) followed by variable elevation was the most significant contributor variable in limiting the distribution of *M. longifolia* for the year 2020 as well as for 2050 across all RCPs except for RCP 8.5, where elevation was the major contributing factor followed by Bio_3. The outcome of the study revealed that the elevation zone upto 1200 m was more congenial to the suitable habitats for *M. longifolia* in the study area and field surveys also confirmed this pattern of occurrence. This supports one of the earlier studies that reported the distribution of *M. longifolia* upto 1200-1800 m in the marginal areas of arid tropical and subtropical forests of India (Orwa et al 2009). The projections for the year 2050 indicated further expansion in suitable habitat area in the region with overall gain in the range of ~1.2 - 2.7%. The state wise analysis for the year 2050 exhibited an increase in suitable habitat areas in Jharkhand, CG and Odisha across all RCPs but in contrast the area is projected to be decreasing in Bihar and West Bengal. The pattern suggested that by 2050 although the overall suitable habitat area of *M. longifolia* is increasing in the region but this increase is getting confined to a comparatively narrow geographical range as compared to existing geographical extent. The study exhibits contraction in spatial extent of distribution with distribution area getting confined from northern and eastern part with southward shifting of the habitat. This is in sync with a study that reported southward shifting of *B. Monosperma* by 2050 due to the climate change (Tiwari et al 2021). A study carried out in eastern US to assess response of habitat distribution of 125 number of tree species to climate change showed that the habitat range for most of the species were shifting towards the north east, but some of the species including *Acer pensylvanicum L., Prunus pensylvanica and Sorbus americana* showed southward shifting (Iverson et al 2019). The projected shift in habitat endorses the fact that in future, the species habitats would shift due to the climate change (Tiwari et al 2021, Rajpoot et al 2020). The study showed decrease in suitable habitat areas particularly in the state of West Bengal and Bihar in future. Thus conservation interventions of *M. longiolia* in these states need to be initiated on priority basis.

M. longifolia carries great medicinal, edible as well as cultural significance for the tribal community living in the region but due to the economical value of its seeds and flowers is under anthropogenic stress (Hegde et al 2018). A single tree of *M. longifolia*, contributes to about Rs 1500/- annually from its flowers and seeds (Kohli 2018). Considering the socio-economic importance of this species and its ecological adaptability characteristics, the promotion strategy in the wasteland, community land and as agroforestry practices can be adopted. Many parts of the region particularly Chhattisgarh and Odisha face severe drought issues and *M. longifolia* being a drought resistance species (Bisht et al 2018) can be a good option in such areas. The increased resource base of *M. longifolia* and other similar multipurpose tree species having edible and medicinal significance shall also support promotion of small scale industries, enabling employment opportunities to the marginal population living in this region as well as help to

address the issue of large scale migration of labours from this part for employment.

A well defined strategy to promote mixed plantation of *M. longifloia* and other similar native species shall support the balance in uniform distribution of natives across varied geographical extent, providing much needed support towards increased forest cover, livelihood support to the marginal population living in the vicinity of forests as well as shelter to a wide category of faunal community.

CONCLUSION

The present study highlights the distribution and habitat adaptability characteristics of *M. longifolia* in eastern region under the varying climatic conditions. The outcome of the study revealed prominent distribution of *M. longifoia* exists in Jharkhand, CG and West Bengal. The future projections for the year 2050 indicated a decrease in geographical extent from the northern and eastern part of the study area with a southward shift of the suitable habitat. Study indicated that in future the distribution range of *M. longifolia* is getting confined to a narrower range due to the climate change as compared to the existing distribution extent. A well planned conservation strategy in vulnerable states and promotion in the line of suitable habitat zones as predicted by the study shall support the optimum growth and increase in the resources of *M. longifolia* in the region. Further, the promotion of small scale industries based on *M. longifolia* and other similar NTFP tree species need to be encouraged to promote socio-economic upliftment of marginal tribal communities, strengthen rural economy and enable better employment opportunities in the eastern region of the country.

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Quantitative Analysis of Elements in Some Efficacious Medicinal Plants by Using ICPMS and IRMS Method

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Abstract: Determination of chemical composition and element profile of medicinal plants used as pharmaceutical agents and herbal products is very important for understanding their beneficial and therapeutic value. The study aims to carry out a Quantitative elemental analysis of leaves of five efficacious medicinal plants of Bhilai in Chhattisgarh, India by using Inductively Coupled Plasma Mass Spectrometry (ICPMS) and Isotope Ratio Mass Spectrometry (IRMS) methods. The elements found in the dried leaf samples of *Clitoria ternatea,Calotropis gigantea, Mentha Arvensis, Aegle marmelos* and *Catharanthus roseus* were Fe, Co, Cu Cr, Mn, Zn, Se, Mo, As, Cd, Ni and Pb. To verify the precision of the proposed spectrophotometric techniques, standard reference material is used. The Pearson Correlation analysis method is used for the interpretation of the elements analysed. The investigation results confirm that the leaves of selected medicinal plants as a potential source of twelve elements, that are essential for the nutrition and health of human beings. The results obtained in this study will be useful for herbal medicine, alternative medicine and herbal products to ensure the standard.

Keywords: Elemental analysis, Herbal medicine, ICP-MS, IRMS, Medicinal plant, Pearson correlation

Medicinal plants play a vital role in promoting and maintaining a healthy life. The application of medicinal plants from ancient times may be reasoned for the emergence of modern medicine (Esther et al 2020). Herbal medicines are used for maintaining good health, preventing diseases and cure ailments. The therapeutic value of these medicinal plants is due to the chemical constituents in them that develop a specific physiological action in human beings (Mishra et al 2018). The use of plant-based medicines to prevent and cure many human ailments is enhancing day by day around the world because of high effectiveness, easy availability, low cost and negligible toxicity as side effects and proving to be a good alternate for synthetic chemotherapeutic agents (Rani et al 2016). Elements show significant function in the production of the phytochemicals found in medicinal plants which accounts for their medicinal value and toxic nature. For better metabolic growth and good health, the human body needs both metallic and non-metallic elements within certain permitted levels. Natural food fulfils the nutritional requirements of the body. It is taken in the form of fruits, roots, seeds, nuts, and leaves provided by plants which are consumed as a major dietary source for both trace and essential elements (Ngigi and Muraguri 2019). The quantitative analysis of various elements present in plants and their concentrations is important as it determines the pharmacological properties and effectiveness of the medicinal plants used in treating various ailments and in the production of herbal drugs. *Clitoria ternatea* known as 'Aprajita or Butterfly Pea' is a medicinal plant of the family Fabaceae commonly used in Ayurveda medicines. It has been used as a sedative agent, memory enhancer, antidepressant, anticonvulsant, anti-stress, tranquillizing and anxiolytic for centuries (Md. Bakhtiar et al 2017). *Calotropis gigantea* is a commonly seen weed plant known as 'giant milk' belongs to the family Asclepiadaceae and is known for its various therapeutic properties and used in the treatment of disorders such as bronchial asthma, rheumatoid arthritis, diabetes mellitus and nervous disorders(Dhivya and Manimegalai 2016). *Mentha arvensis* Linn belongs to the family Lamiaceae and is an edible and aromatic herb commonly found throughout the year. Mentha shows antimicrobial, antiviral, anti-allergic, anti-inflammatory, anti-cancer and insecticidal activity and extensively used in pharmaceutical, cosmetic and flavouring industries(Md Nauman and Saleem 2016). *Aegle marmelos* an indigenous plant that belongs to the family Rutaceae, commonly known as 'bael' and is used in curing cardiac disorders, dysentery, diarrhoea, fever, inflammation, diabetes and pain. The pharmacological properties of the plant leaf include antipyretic, antioxidant, anticancer, anti-hyperglycemic, anti-inflammatory and analgesic properties (Jadhav et al 2017). *Catharanthus roseus* is an evergreen shrub commonly called Madagascar periwinkle. It belongs to Apocynaceae family and shows anti-cancer properties due to the presence of

alkaloids such as vincristine and vinblastine. The different parts of the plant are used for treating various ailments like corns, eczema, psoriasis, sores, epilepsy, dermatitis, ringworm, malaria, tumours and used as an antidiabetic, antihypertensive and antioxidant and for curing Alzheimer's disease (Aziz et al 2016).

Many studies have been carried out to explore the action of organic components in medicinal plants. The awareness of the effects of essential and trace elements in the cure of various diseases has less noted. In addition to phytochemicals, macro and trace elements in medicinal plants also play a vital role in the prevention of various diseases, in physiological activities and as cofactors in the metabolism of enzymes in human beings. The excess or insufficiency of these elements is also responsible for toxicity in plants (Jyothsna et al 2020). Thus, the present study focus on the estimation of elements in the selected plant leaves by ICP-MS and IRMS spectroscopic methods to determine the concentration of major and trace elements present in the five selected medicinal plants which are used for the cure and prevention of various ailments.

MATERIAL AND METHODS

Preparation of sample: The leaves of selected five plants (Fig. 1) were collected in May from the Bhilai region in Chhattisgarh, India. The list of selected medicinal plants used for elemental analysis and their medicinal use is illustrated in (Table 1). The leaves were cleaned thoroughly in tap water and distilled water, dried in the shade at room temperature and then ground in a grinder to make a fine powder. The leaf powder sieved using a standard sieve and a grain size of less than 100 µm was used for further determinations. All apparatus and glassware were cleaned thoroughly with 10% nitric acid and rinsed with double distilled water.

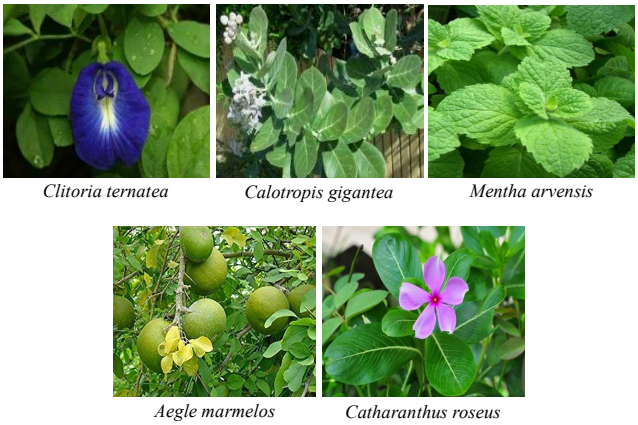

Fig. 1. Medicinal plants analysed for essential and trace elements

Instrumentation: Inductively coupled plasma mass spectrometry (ICP-MS) has emerged as a new and powerful technique for isotope and element analysis as it comprises plasma, a high-temperature ionization source (8000 K) quadruple mass spectrometer (MS) analyser, the sensitive rapid scanning detector and an exclusive interface. In a single analysis, elements can be measured in concentration terms from ppb to ppm-level. The advantages of ICP-MS includes broad linear range, extreme sensitivity, minor elemental interference, requires only minimal sample size, lower detection limits and it provides fast and automated multi-elemental analyses with negligible interference of chemical components contained in the sample or on the individual element recoveries (Jianquan et al 2006).The ICP-MS system, an Agilent 7500 cx model, Tokyo, Japan, was applied for simultaneous multi-element detection is used in the present study. The operating conditions of the ICP-MS instrument are illustrated in (Table 2). The stable isotope carbon ratios (13C/12C) of the five selected plant samples

Table 1. Medicinal plants used for elemental analysis and their medicinal use

Botanical name	Family name	Common name	Medicinal use
Clitoria ternatea	Fabaceae	Butterfly pea	Used to treat various disorders such as body aches, common cold, cough, asthma, infections, urogenital disorders, eradication of intestinal worms (anthelmintic) and as an antidote to animal stings
Calotropis gigantea	Asclepiadaceae	Giant milkweed, crown flower	Used to cure disorders such as diabetes mellitus, rheumatoid arthritis, bronchial asthma and nervous disorders
Mentha Arvensis	Lamiaceae	Mint	Used as a medicinal herb to treat belly ache, chest pains, Fever, diabetes, constipation, skin infections and Urinary disease
Aegle marmelos	Rutaceae	Stone apple, Bael	Used in treating diarrhoea, dysentery, stomach ache, thyroid-related disorders, as a cardiac stimulant, anaemia, fractures, swollen joints, typhoid, coma, colitis, bleeding sores, and cramps
Catharanthus roseus	Apocyanaceae	Madagascar periwinkle	Used in the treatment of lymphocytic cancer, Wilkins's cancer, reticulum cell tumour, Hodgkin's disease, biliary disorders, jaundice, dysentery, diabetes and diarrhoea

were measured using a mass spectrometer, Delta V Plus IRMS isotope ratio mass spectrometer (Thermo Electron Corporation, Germany) interphase with a combustion device, Flash EA 1112 via TC/EA gas control unit (Thermo Finnegan, Germany).

Determination of element concentration with ICP-MS: The di-acid digestion method was used for the elemental analysis. 300 mg of dried, leaf powder of each plant sample was taken in a 100 ml volumetric flask and mixed with the acid mixture [(3:1 mixtures of nitric acid (HNO_3) and hydrogen peroxide (H_2O_2)]. The mixture heated at a higher temperature till the volume reduced to almost 3 ml. The mixture is kept for cooling then added 20 ml of distilled water and filtered through Whatman No. 41. The above mixture was then, taken for the determination of elements by using an ICP- MS spectrophotometer.

Determination of carbon isotope ratio by IRMS: The stable isotope carbon ratios (13C/12C) of the five selected plant samples were measured using a Delta V Plus IRMS isotope ratio mass spectrometer (Thermo Electron Corporation, Germany) interphase with a combustion device, Flash EA 1112 via TC/EA gas control unit (Thermo Finnegan, Germany). To determine the δ13C, samples of the dry leaves were weighed and then encapsulated samples were first combusted in an oxidation tube and the sample is then placed in a chamber in which reduction is carried out where nitrous oxides are converted into nitrogen and excess oxygen is also removed. Each sample was analysed three times.

RESULT AND DISCUSSION

Quantitative analysis of elements in five selected medicinal plants: Using ICPMS, twelve elements present in five selected medicinal plant leaves were determined and the mean elemental concentrations of iron (Fe), cobalt (Co), copper (Cu), chromium (Cr), manganese (Mn), zinc (Zn), selenium (Se), molybdenum (Mo), arsenic (As), cadmium (Cd), nickel (Ni) and lead (Pb) were measured.The validity of the method is tested by using standard reference material. The result reveals that the elemental concentrations of plant leaves detected by the ICPMS method follows the standard approved values. The mean concentrations (in ppm) of elements found in five selected medicinal plant leaves are shown in (Table 3). The elements detected and their concentrations (ppm) are shown respectively in (Fig. 2).

Elemental Analysis

Iron (Fe): The concentration of iron was found to be in the highest concentration in *Mentha arvensis* (83.88 ppm) followed by *C. gigantea* with 10.3 ppm and least in *A. marmelos* (2.095 ppm). The permissible amount of iron in the diet is 10-60 mg per day. The deficiency of iron may result in risks like anemia, depression, poor immunity and problems in adverse pregnancy whereas a high dose of iron in the diet may aggravate the risk of cancer in the colorectal and liver (Pingale et al 2017).

Copper (Cu): The mean concentration of copper in selected plants was maximum in *C. roseus* (0.259 ppm) and lowest in *A. armelos* having (0.0153) ppm. The permitted intake of copper in the diet is 1.5 to 3.0 mg per day in an adult. The lack of a proper amount of copper in diet may result in Meknes syndrome, neutropenia condition and weakened growth, particularly in children. When copper is taken in excess it may cause neurological problems such as Alzheimer's disease, Wilson's disease, discolouration of hair and skin (Pingale et al 2017).

Table 2. Operating conditions of ICP-MS

Parameters	Specifications
Nebulizer	Glass concentric
RF generator	1,550 W
Carrier gas	0.90 L min^{-1}
Makeup gas flow rate	0.23 L min^{-1}
Spray chamber temperature	2 °C
Cones	Ni
Uptake time	20 sec
Stabilization time	60 sec
Helium flow rate	5 mL min^{-1}
KED	2V
Sample depth	8.0 mm
Integration time[sec]	0.1 sec $point^{-1}$
Number of replicates	3

Table 3. Mean elemental concentration (in ppm) in the selected medicinal plants

Plant	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Mo	Cd	Pb
Clitoria ternatea	0.011	0.119	3.838	0.0014	0.0056	0.0759	0.2092	0.0093	0.0155	0.085	0.0004	0.01
Calotropis gigantea	0.0289	0.894	10.3	0.0067	0.0203	0.0934	0.6471	0.0073	0.0197	0.148	0.0011	0.007
Mentha arvensis	0.0345	4.371	83.88	0.1703	0.0814	0.0463	0.8931	0.06	0.0589	0.344	0.0011	0.01
Aegle marmelos	0.0094	11.34	2.095	0.0223	0.0173	0.0153	0.2321	0.0018	0.0362	0.068	0.0004	0.013
Catharanthus roseus	0.0132	0.184	3.534	0.0035	0.0088	0.2593	0.3707	0.0024	0.0029	0.055	0.0005	0.015

Manganese (Mn)*:* The concentration of Mn is considerably high in *A. marmelos* (11.34 ppm) followed by *M. arvensis* (4.84 ppm) and lowest in *C. ternatea* (0.0119 ppm). Manganese is very important for the metabolism of carbohydrates and protein, in blood coagulation and the treatment of diabetes. The inadequate intake of Mn results in cardiovascular diseases, skeletal ailments and effects in a male and female reproductive system whereas its higher dosage may lead to adverse effects on the brain and lungs, cause neurological problems such as Parkinson's disease (Jyothsna et al 2020).

Nickel (Ni): In the present investigation, less than 1 ppm Ni concentration was in all the samples of leaves. *C. ernatea* leaves contain the lowest Ni concentration (0.0056 ppm) and the highest concentration was of *Mentha arvensis* (0.0814 ppm).The permissible limit for Ni is given to be 1.63 mg/kg (WHO 2007) in edible plants. However, for medicinal plants, no such limits were given. Nickel is essential in insulin production, skin and healthy bone. The health problems like high blood pressure, cardiovascular problems, neurological problems and lung cancer is increased due to high exposure to Nickel. The deficiency of Nickel may cause the liver disorder. The absorption of Nickel in the body is very low hence induced toxicity by Nickel in the human body is rare(Varhan et al 2019).

Cobalt (Co): In the human body, cobalt is required in a trace amount. The mean concentration of cobalt in all selected plant leaves was less than 1ppm. *M. arvensis* contain the highest amount of 0.173 ppm and the lowest was in *C. ternatea* (0.0014 ppm). *C.gigantea, A. marmelos and C. roseus* contained only a trace amount of cobalt. Generally, Cobalt is used for the treatment of various cancers and also used in patients having anemia. If given in a higher dose may increase the risk of coronary diseases. The permissible limit for Cd in edible plants is 200 µg/kg, as reported by the World Health Organization (Varhan et al 2019). The Cd levels of all selected five samples were found to be below the stated WHO limits.

Zinc (Zn): Zinc content in the plant leaves analyzed ranged from 0.2-0.8 ppm. Leaves of *Mentha arvensis* shows the highest Zn (0.089 ppm) and lowest was in *C. ternatea* (0.209 ppm). The zinc levels of all selected sample were below the permissible limits of 27.40 mg/kg. Zinc is a significant part of insulin in the body and it is known to enhance the activity of insulin in diabetic people. It enhances the immune response in the body. The lack of Zn may result in health problems such

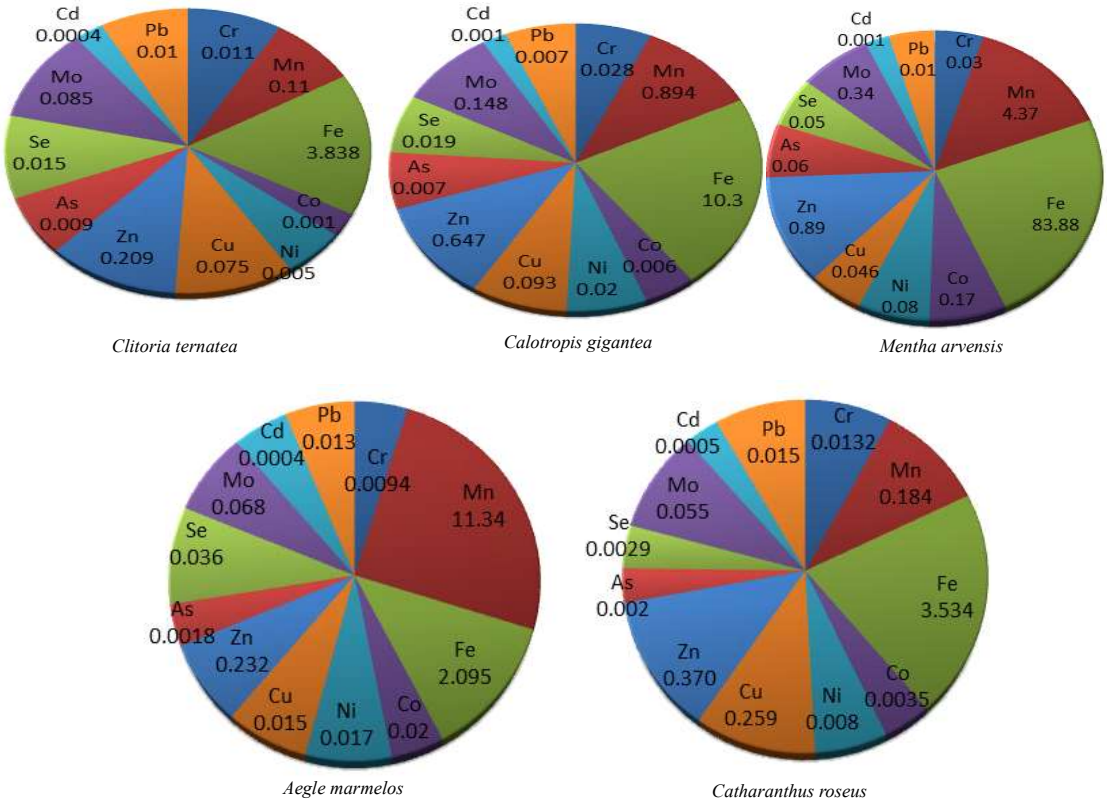

Fig. 2. Concentration of elements (ppm) in selected plants leaves

as reduction of growth, loss of hair, skin rash and night blindness (Pingale et al 2017).

Chromium (Cr): Chromium content in the plant leaves samples varied from 0.011 to 0.0345 in *C. ternatea, Calotropis gigantean and M.arvensis,* respectively. Chromium is used in curing ailments such as hypercholesterolemia and diabetes mellitus. The trivalent chromium (Cr 3+) is essential for human metabolism but the (Cr6+) is reported to have toxic effects on human beings. The deficiency of Cr may lead to disorders like diabetes, hyperglycemia and atherosclerosis. The human body requires chromium in a very trace amount. It causes damages to the kidney, lung and liver if taken for a long duration (Zhang et al 2013).

Molybdenum (Mo): The amount of molybdenum in the five selected medicinal plant leaves ranged from 0.055 -0.344 ppm being maximum in *Mentha* and least in *C. roseus*. It is observed that Mo is present in these selected plant leaves in trace amounts. Molybdenum is considered a significant element in diet that is required for the synthesis of amino acids. If taken 10-15 mg/day for a long time, may lead to an enhanced concentration of uric acid in the blood. Intake of meals with a high dose of molybdenum content may result in lower-limb Osteoporosis (Anal and Chase 2016).

Lead (Pb): The permissible limit given by WHO, 2007 for lead is (10 mg/kg).The levels of lead in all the selected plant leaf samples were below the permitted limits. Lead is a highly toxic heavy environmental metal pollutant. Even a minimum amount of lead in the human body causes various health damages and can affect the central nervous, cardiovascular and especially the immune systems

Ca**dmium (Cd):** In the present investigation, the content of cadmium is found to be a very negligible amount, in all five selected samples. The content of cadmium in all five plant species is lower than the permissible level of heavy elements as a daily intake. The concentration of Cd was 0.0004 ppm in *C.ternatea* and *A. marmelos*, 0.0011 ppm in *C. gigantea*, *and M. arvensis* and 0.0005 ppm in *C. roseus* respectively. Cd is known to be toxic and reported as a high-risk factor to public health in general. Cadmium in food has inherent toxicity and accumulation in the food chain. The reported permitted level as stated by WHO for cadmium is 0.2 to 0.81 ppm. The accumulation of Cadmium in flora and fauna has been observed to be with a half-life of around 25-30 years (Giuseppe et al 2020).

Selenium (Se): In mammals, selenium provides several significant physiological actions like fertility, metabolism of thyroid hormone and the immune system (Nikolay et al 2021).It possesses anti-inflammatory, antioxidant and immunological properties. Se deficiency contributes to heart diseases. The requirement of Se for an adult is 0.02-0.2 mg/day (Frontasyeva et al 2014)**.**The selenium concentration in selected plant samples analyzed was in traces.

Arsenic (As): Studies show that globally people are exposed to arsenic toxicity by environmental factors of about 0.33 ppb to 2500 ppb concentration (Eva et al 2020).The accumulation of arsenic in cell, tissues and inhibit the metabolic activities of the cellular enzyme. High intake of As ingestion is found to cause health problems such as cancer, cardiac problems, diabetes mellitus, cerebrovascular disease and circulatory problems(Alam et al 2019).In the present investigation, the content of Arsenic is found to be a very negligible amount, in all the five selected medicinal plants. The content of As in all the plant species was less than permitted daily intake of a heavy element.

Correlations: In the present study, Pearson correlation analysis was applied for 12 elements detected in five selected medicinal plants and the relationship between these plants is determined (Table 4). According to statistical analysis principles, if the value of correlation coefficient, r is near (+1) or (-1), then it indicates a high level of a relationship between two variables, if r=0 means no relationship between them and if correlation coefficient, $r > 0.7$ they are strongly correlated. The correlation between two different parameters is moderate if the value of r is between 0.5 and 0.7.The variables increase and decrease simultaneously and show a direct relationship if the correlations are positive. The significant strong positive correlation coefficients were between MP1 and MP2(r= 0.998), MP1 and MP3 (r= 0.999) and between MP1 and MP5 (r=0.997), whereas very low correlation is found between MP1 and MP4 .The MP2 and MP1, MP2 and MP3, MP2 and MP5 show significant and high correlations and less significant correlation coefficient was between MP2 and MP4.The correlation coefficients between MP3 were positive for MP1 MP2 and MP5). There was significant strong and positive correlation between MP5 and the rest MP1, MP2 and MP3. Results showed moderate positive correlation coefficients between MP4 and MP1, MP2, MP3 and MP5. (MP1= *C. ternatea*, MP2= *C. gigantea*, MP3= *M. arvensis*, MP4= *A. marmelos*, MP5= *C. roseus*). The strong positive correlation among the samples indicates that they are closely associated and reveals that the existence or non-existence of one element affects to a greater extent the other and thus suggest their origin and characteristic properties.

IRMS Analysis: Isotope Ratio Mass Spectrometry (IRMS) is an advanced spectroscopic technique using stable isotopes to get information about the chemical, biological and geographical origins of substances. The source of an organic

Table 4. Correlation analysis of plant samples

		MP1	MP2	MP3	MP4	MP5
Plant	Pearson Correlation	1	0.998**	0.999**	0.112	0.997**
Clitoria ternatea	Sig. (2-tailed)		0.000	0.000	0.730	0.000
	N	12	12	12	12	12
	Pearson Correlation	0.998**	1	0.998**	0.169	0.996**
Calotropis gigantea	Sig. (2-tailed)	0.000		0.000	0.599	0.000
	N	12	12	12	12	12
	Pearson Correlation	0.999**	0.998**	1	0.141	0.994**
Mentha arvensis	Sig. (2-tailed)	0.000	0.000		0.662	0.000
	N	12	12	12	12	12
	Pearson Correlation	0.112	0.169	0.141	1	0.124
Aegle marmelos	Sig. (2-tailed)	0.730	0.599	0.662		0.702
	N	12	12	12	12	12
	Pearson Correlation	0.997**	0.996**	0.994**	0.124	1
Catharanthus roseus	Sig. (2-tailed)	0.000	0.000	0.000	0.702	
	N	12	12	12	12	12

**Correlation is significant at the 0.01 level

Table 5. Analysis of carbon isotope ratios of samples by IRMS

	Weight	d 13C/12C	CID	Avg	SD
Clitoria ternatea	110	-30.919	20.2916	20.30443	0.382612
	118	-30.946	20.31726		
	114	-30.236	19.6421		
Calotropis gigantea	147	-30.05	19.46507	19.23508	0.407514
	97	-29.567	19.00508		
	118	-29.197	18.65241		
Mentha arvensis	145	-29.037	18.49982	18.5127	0.846355
	155	-29.064	18.52557		
	106	-27.516	17.04694		
Aegle marmelos	134	-27.471	17.00389	16.91585	0.091327
	155	-27.287	16.82782		
	150	-27.335	16.87376		
Catharanthus roseus	155	-27.387	16.92352	16.90916	0.059228
	108	-27.357	16.89481		
	160	-27.268	16.80963		

substance can be determined from the relative stable isotopic abundances of the elements from which the substance is comprised. This method is generally used to measure the isotopic ratios of elements such as carbon, hydrogen, oxygen, sulphur, and nitrogen. The stable isotope ratio of a particular substance is expressed as a ratio relative to an internationally accepted reference standard. The stable isotope ratios (13C/12C) are given in the delta (δ) notation and calculated against the international standard.

The following formula is used for calculation:

$$\delta\ ^{13}C = \left(\frac{R\ sample}{R\ standard} - 1\right) \times 100$$

Where R_{sample} is the isotope ratio of the sample and $R_{standard}$ is the isotope ratio of the international standard. The values of delta are expressed in units “per mil” .If δ value is positive it means that the sample contains more of the heavy isotope than the standard value whereas a negative value of δ reveals that the sample contains less heavy isotope than the standards. In the present study, it is found that all the five selected medicinal plant samples show negative δ values indicating a less heavy isotope than the standard (Table 5).

CONCLUSION

The present investigation concludes that the selected

five medicinal plants contain twelve essential elements such as Fe, Co, Cu Cr, Mn, Zn, Se, Mo, As, Cd, Ni and Pb required by the human body to sustain good health. Among the essential trace elements detected, Mentha arvenesis leaves has the highest concentration of Fe with 83.3ppm followed by 10.3 ppm in *Calotropis gigantea* and 4.37ppm in *Aegle marmelos* whereas Mn was highest in Aegle marmelos leaves with 11.3 ppm and 4.37 ppm in Mentha arvensis. These results indicate that these plants are rich source of essential trace element. Cadmium (Cd) and Lead (Pb) has a negligible concentration in all plants. The essential elements and trace elements found in the analysed medicinal plants are within the permissible limits given by FAO & WHO. Toxic element measurements were found to be below the permissible level. The plant to plant correlation with the elemental concentration done with Pearson correlation coefficient values that are significant at 0.01 levels was evaluated. MP1, MP2, MP3, and MP5 are strongly positively correlated with each other. While MP4 shows moderate correlations with other plant samples. The conclusion of the correlation coefficient studied in this study might be a useful evaluation tool for medicinal plant breeders when functioning for a particular character. The carbon isotope ratio values measured by IRMS technique for selected medicinal plants in the present investigation will be very helpful to find the essential elements and adulterants in crude drug. Thus the elemental fingerprint of plants generated by ICPMS and IRMS in the current investigation can be applied for the identification and quality control of herbal dosage prepared from these plants. The results of present study confirm that selected plant leaves are very good sources of twelve vital elements which can be used as a safer drug and a promising source of alternative medicines.

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Asiatic Black Bear (*Ursus thibetanus*) Activity Pattern and Human-Black Bear Conflict in the Nanda Devi Biosphere Reserve, Western Himalaya, India

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***Abstract*:** Asiatic black bear (*Ursus thibetanus*)-human conflicts and its activity in buffer and transition zone of Nanda Devi Biosphere Reserve (NDBR), Uttarakhand, India was assessed, based on semi-structured interviews with villagers during 2016-2018. The 65% of villagers depended on forest products and 80% crop depredation was by black bear agricultural field situated near to bear habitat. The three types of black bear-human conflicts recorded from NDBR were crop depredation, livestock depredation and attacks on humans. From these crop depredations (80%), most of the crop depredations were on maize (91%) in agricultural crops and apple (88%) in orchard crop. Maximum observations were recorded for prematurity stage (69.23 %) and followed by maturity stage (23.08 %). A total of 82 cases of attacks by black bear on livestock were reported, of these, 57 (49 on cattle and 8 on sheep/goat) were killed in the night shelters, 16 were killed in the forest while grazing. The 24 attacks were on humans, out of them mauling was 87% and rest were killed and maximum attacks were in autumn season (62.50%), dawn and dusk time (58.33%), in agricultural fields (58.33%), on head and face (37.50%) of body. The improvement in traditional crop protection measures, improvement in night shelters and proper disposal of home waste material and regular monitoring of high conflict zone with wildlife management team is recommended. These protection measures will improve problem with black bears and to get in local villagers support for black bear conservation.

***Keywords*:** Asiatic black bear, Conflict, Livestock depredation, Management, Protection

Conflict between Asiatic black bears (*Ursus thibetanus*) and humans span a diverse array of geographic and human demographic contexts. Bears typically compete with humans directly for food, space, cover and security. Human food has been reported throughout their range as the most attractive leading to bear–human conflict (Bargali et al 2005, Fredriksson 2005, Smith et al 2005, Mordo et al 2008, Yadav et al 2009). Throughout the range of Asiatic black bear conflict with humans occurs in the Indian Himalayas (Stubblefield and Shrestha 2007, Honda et al 2009). In Asia black bear receives more public attention than some other large mammals, due to its conflicts occurs frequently with villagers living close to black bear habitat (Liu et al 2011). Asiatic black bears are very good in memories, can locate seasonally available cultivated crops in and around their habitats. Agricultural crops and orchards provide nutritious food for bears. If once bears identify crops, which are rich source of energy, they visit regularly to depredate the same agricultural field or orchard (Hashimoto et al 2003).

In the Himalayan landscape Asiatic black bear–human conflict has been reported in the past too, but in the recent years severity of such conflicts have increased (Sathyakumar and Choudhury 2007). Main reasons behind these conflicts may be due to disturbance of bear habitats and changes in land use pattern, such as expansion of agricultural field or orchards and encroachment, as well as increased human development activities and increasing human population surrounding bear habitats (Sathyakumar and Choudhury 2007). Black bears are also known to depredate on livestock, leading to economic losses to local communities and attack on humans (Charoo et al 2011). Therefore, if species legally protected, damages to agricultural fields, livestock or property, people think that they are at a disadvantage against these species and they prefer illegal ways of dealing with these problems (Wani 2014). As human population increasing and extending towards wildlife habitats, so natural territory of wildlife is displaced. The overlapping population density of wild animals and humans increasing their interaction with each other, it results increase in physical conflict. Degradation of habitat, lack of food resources, trade of bear body parts and increased conflict with humans (Bargali 2003, Bargali et al 2005) are among the main reasons posing serious threat to the bear population in the country as well as in their entire distribution range. Bear

populations usually require large habitat for their survival and usually compete directly with humans for resources such as security, food, space and cover. Almost all bears may depredate or injure livestock, depredate agricultural or horticultural crops and directly competes with humans (Chauhan 2004). Some traditional methods used by people to threat black bear to reduce crop depredation and cattle lifting by black bears in NDBR includes crackers, drumming on empty metal canister, use of guard dogs, burning of red chilies, barbed wire fencing and golliwogs. Black bear-human conflict occurs in NDBR but there has been no investigation on this till date. Therefore, we investigated the magnitude of black bear-human conflict in NDBR.

MATERIAL AND METHODS

Study area: The study was conducted in the Nanda Devi Biosphere Reserve (NDBR), lies between 30° 05'-31° 02'N Latitude, 79° 12'-80° 19'E Longitude, located in the state of Uttarakhand, India, falls in the biogeographically classified zone, 2B (Rodgers et al 2000). The reserve is spread over Chamoli district in Garhwal region and Bageshwar and Pithoragarh districts in Kumaun region of the Uttarakhand State. The NDBR with an area of 6020.43 km^2 is comprised of two core zones i.e., Nanda Devi National Park, 630 km^2; Valley of Flowers National Park, 87.5 km^2; surrounded by a buffer and a transition zone. Both the core zones have been recognized as World Heritage Site by UNESCO. Human habitations are absent inside the core zones but buffer zone having 47 and transition zone having 33 villages with six villages in the immediate after of the core zones. Settlements (small townships and villages), agricultural land (terrace farms), orchards, plantation and developmental areas or human modified landscapes are available in the region. Most of the flora and fauna in the NDBR is native and endemic.

Methodology

Informal interviews using semi-structured questionnaires were carried out in the villages located in the buffer zone and transition zone of NDBR since September 2016 to July 2018. Interviews with villagers were mostly based on interaction basis; however, all the information was recorded in the pre-designed formats. In each village, by adopting participatory rural appraisal (PRA) techniques (Charoo et al 2011) and stratified sampling of households was adopted by compiling census data of village households. Based on economic status of households, the government of India has classified into 2 groups: below poverty line (BPL) and above poverty line (APL) - families have less than and more than 1.5 lakh INR annual incomes (Department of Food, Civil Supplies & Consumer Affairs, Government of Uttarakhand 2019). In villages adjoining NDBR landscape, families in APL or BPL are in equal proportions. Five families (households) were sampled in each village, 3 from group exceeded 50% of the population in that village (Charoo et al 2011).

The information on black bear encounters with villagers (number, place and time), cropping pattern, crop depredation, livestock depredation, attacks on humans, protection measures and forest dependency (fuel wood/fodder collection and livestock grazing) was recorded from each family interviewed. The presence of black bear in the crop fields were verified with the help of forest officials and villagers. Field investigations (direct and indirect observation) were also conducted for recording crop depredation (n = 78) on different growth stages, livestock depredation and human casualties. The black bear-human conflicts were categorized in three categories as crop depredation, attacks on humans and livestock depredation. The data on crop depredation sites (crop type, part eaten, stage of the crop and month) and approximate distance (<500 m to >1000 m) from the nearest bear habitat and altitude (<2000 m to > 3000 m) were recorded. Data of black bear attacks on humans, that includes month, time and location as reported by the victim, family members of the victim or a witness were recorded. For livestock depredation cases, location, time and month were recorded.

RESULTS AND DISCUSSION

A total of 157 respondents were interviewed in Nanda Devi Biosphere Reserve. About 65% of respondents recorded the dependence on forest products and about 52% were below poverty line. Black bear-human conflicts were recorded most intense near to bear habitats (Fig. 5) and in the altitudinal range between 2000-2500 m (Fig. 1 & 6). The most conflict cases were recorded between human and black bear from the months of March to December (Table 1).

Crop depredation: In NDBR region, villagers were producing seasonal crops such as *Zea mays, Vigna unguiculata, Eleusine coracana, Phaseolus vulgaris, Solanum tuberosum, Cucumis sativus, Cucurbita pepo,* etc. and fruits like *Malus pumila, Juglans regia, Prunus armeniaca, Prunus persica, Prunus domestica, Morus* spp., etc. About 80 percent villagers living near black bear habitats were more prone to crop depredation by black bear. Most of the crop depredations were on maize (91%) in agricultural crops and apple (88%) in orchard crop (Fig. 2). The crop depredation was observed at germination, flowering, prematurity and maturity stages of plants. During field survey crop depredation mainly recorded at prematurity stage (69.23 %) and followed by maturity stage (23.08 %). The crop depredation by black bear was maximum at prematurity

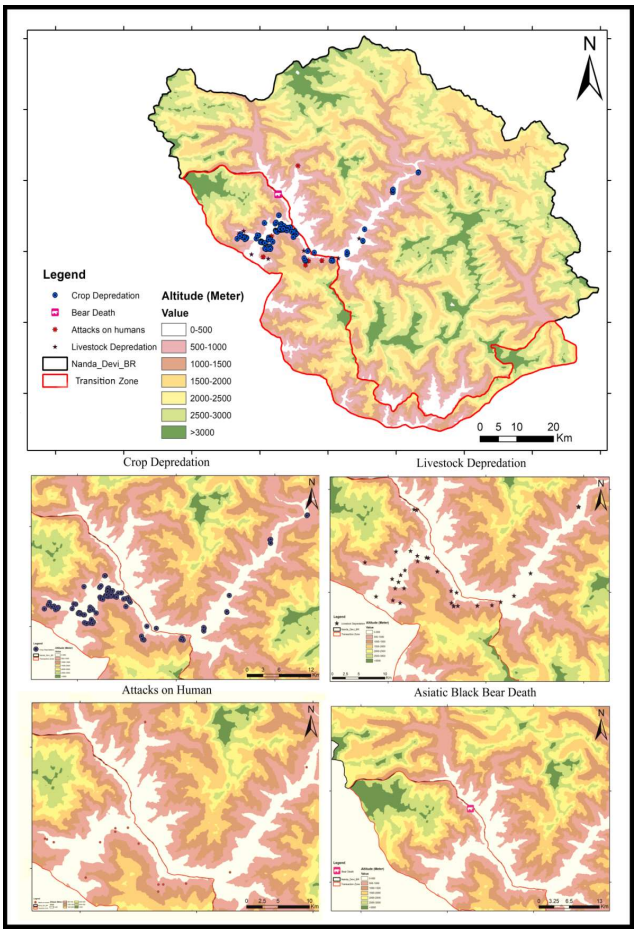

Fig. 1. Study area (NDBR) with activity and conflict details

stage (84.08 %) and followed by maturity stage (68.79 %) as villagers said. Results showed similar trend to field observations as well as people's perception with commonly depredated crops by black bear (agricultural crop - maize, frenchbean, cowpea, potato, finger millet, cucumber and pumpkin; orchard crops - apple, walnut, apricot, peach, plum and mulberry) (Fig. 2 & 3). There was no crop depredation at germination stage during field observations.

Crop depredation by black bear recorded maximum in the morning time (86.62 %) and followed by night time (71.34 %) (Fig. 4). Agricultural fields closer to black bear habitats were more prone to depredation than those further away.

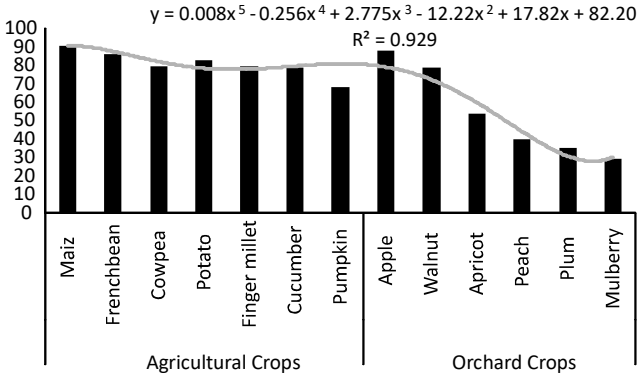

Fig. 2. Crop depredation by Asiatic black bear (*Ursus thibetanus*) in NDBR (n = 157) since 2016 to 2018; polynomial line: trend line

Table 1. Asiatic black bear crop depredation and livestock depredation in different months and seasons in NDBR, India, as reported by respondents (n = 157)

Seasons	Months	Crop depredation (%)		Livestock depredation (%)			
		Monthly incidence	Seasonal incidence	Monthly incidence	Incidence		Seasonal incidence (%)
					Cattle	Goat/Sheep	
Winter	December	7.64	7.64	7.64	7.64	-	7.64
	January	0		-	-	-	
	February	0		-	-	-	
Spring	March	2.55	7.01	2.55	1.27	1.27	6.37
	April	4.46		3.82	3.18	0.64	
Summer	May	5.73	40.76	3.18	2.55	-	15.29
	June	7.64		4.46	2.55	1.27	
	July	11.46		5.73	2.55	0.64	
	August	15.92		4.46	3.18	2.55	
Autumn	September	20.38	44.59	5.10	5.10	-	22.93
	October	14.01		6.37	7.01	0.64	
	November	10.19		8.92	10.19	-	
	Mean±SD	13.08±9.97	39.25±32.14	6.83±4.84	5.92±4.93	0.92±1.24	13.06±7.67

Maximum crop depredation (60 %) in agricultural fields occurs close proximity to the black bear < 500 m from the habitat (Fig. 5). Crop depredation by altitudes ranges from less than 2000 m to more than 3000 m. Maximum crop depredation (56 %) recorded between 2000-2500 m altitudes and followed by between 2500-3000 m altitudes (35 %) (Fig. 1 & 6).

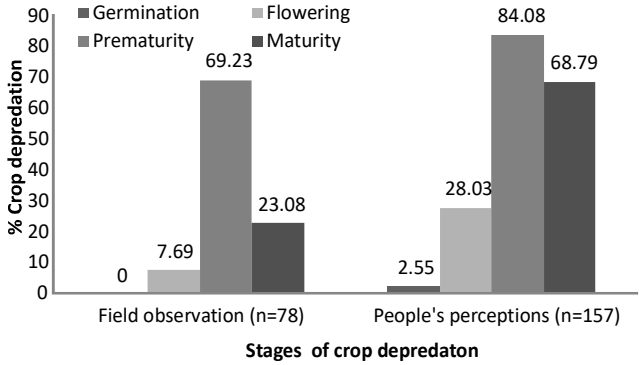

Fig. 3. Stages of crop depredation by Asiatic black bear (*Ursus thibetanus*) in NDBR between 2016-2018

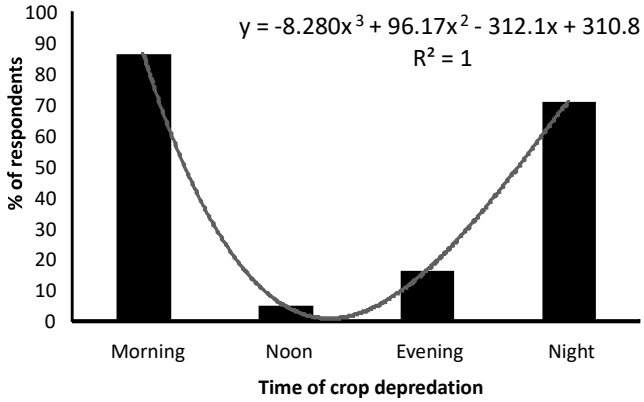

Fig. 4. People's perception (n=157) about time of crop depredation by black bear in NDBR; polynomial line: trend line

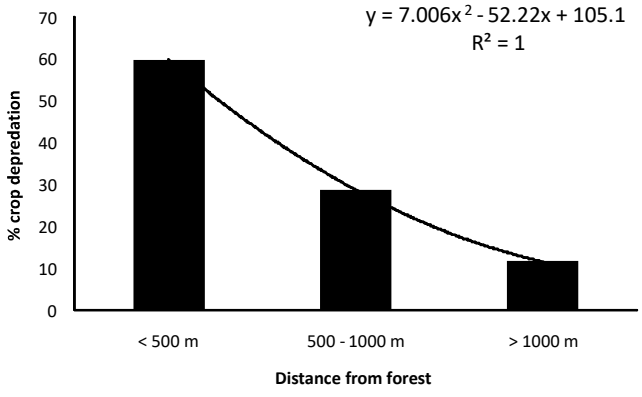

Fig. 5. Asiatic black bear crop depredation–human conflict by distance from forest in NDBR India, as reported by respondents to a survey (n = 157); polynomial line: trend line

Autumn season had the maximum number of crop depredation cases (44.59 %) followed by summer, winter, and spring (Table 1). The maximum cases of crop depredations (62 %) occurred in July, August, September and October. During November, there were few cases of crop depredation (10.19 %) and the cases declined as autumn progressed, with only 7.64 % of cases reported in December (winter) (Table1). The villagers were using protection measures for against the black bear conflict or crop depredation. The most commonly used measure to repel black bear was use of fire crackers (84.71 %) followed by drumming on empty metal canisters, use of barbed wire fencing, golliwogs, guard dogs and burning of red chilies with cow dung (Fig. 7).

Livestock depredation: A total of 82 attacks by black bear on livestock were reported during the study period since August, 2016 to July, 2018. Of these, 57 (49 cattle and 8 sheep/goat) were killed in the livestock night shelters, 16 were killed in the forest while grazing and others in villages or fields. The livestock depredation occurred maximum in the November month (8.92%) of the year and autumn season (22.93%) (Table 1 & Fig. 8). The attacks on livestock recorded maximum for cows (24.39%), on hump portion (46.34%) it might be due to availability of fat content in the hump and during pregnancy (34.15%) (Yadav et al. 2018; Yadav et al 2019)(Table 2).

Table 2. Attack on livestock by Asiatic black bear in NDBR, India, as reported by respondents to a survey (n = 82)

Attacks on livestock		Attacks on livestock (%)
Body parts of attacks	Head	7.32
	Neck	32.93
	Stomach	13.41
	Hump	46.34
	Mean±SD	20.50±14.71
Attacks on animals	Cow	51.22
	Bull	24.39
	Buffalo Female	10.98
	Goat/Sheep	13.41
	Mean±SD	20.5±15.11
Stage of attacks	Calf	14.63
	During pregnancy	34.15
	After birth	24.39
	Normal	26.83
	Mean±SD	20.5±6.61

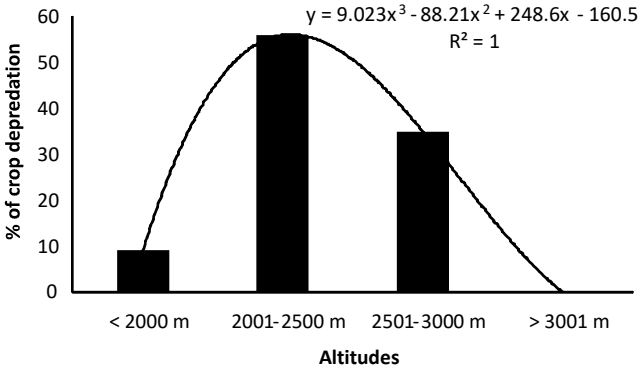

Fig. 6. Asiatic black bear crop depredation–human conflict by altitudes in NDBR India, as reported by respondents to a survey (n = 157); polynomial line: trend line

Attacks on humans: Asiatic black bear attacks on humans were occurred from March to December. There were 24 attacks on humans, out of them 87% mauling and rest killing (13%) occurred during study period. Most of the attacks were recorded on male (62%) and followed by female (38%). Maximum attacks were occurred during autumn season (62.50%), followed by summer and winter (16.67%) and spring season (4.17%) (Fig. 9). The higher attacks were in dawn and dusk time (58.33%), followed by in night time and during day time. Most attacks (58.33%) were occurred when people working in agricultural fields and villages, followed by in the forest, near to water sources and near to den site of black bear.

Attacks on different body parts of humans were also

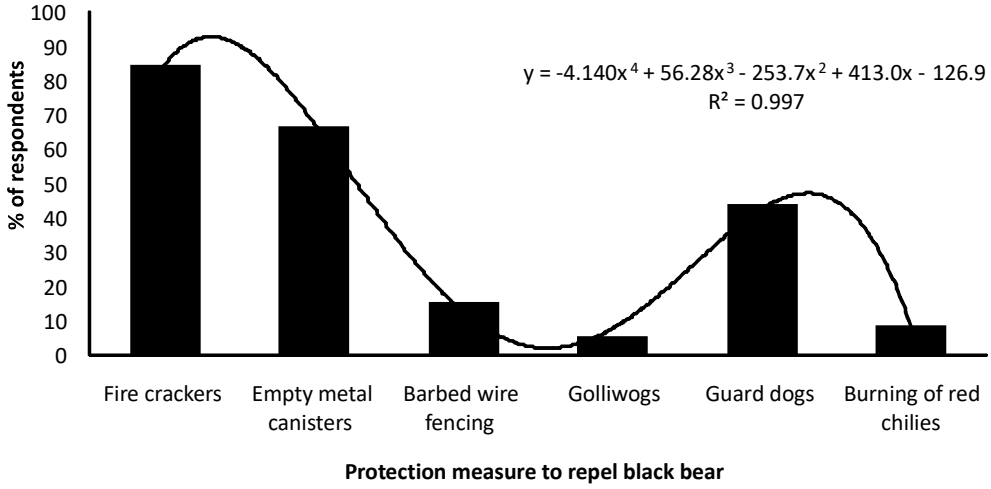

Fig. 7. Protection measures used by villagers to repel black bear in NDBR, India, as reported by respondents to a survey (n = 157); polynomial line: trend line

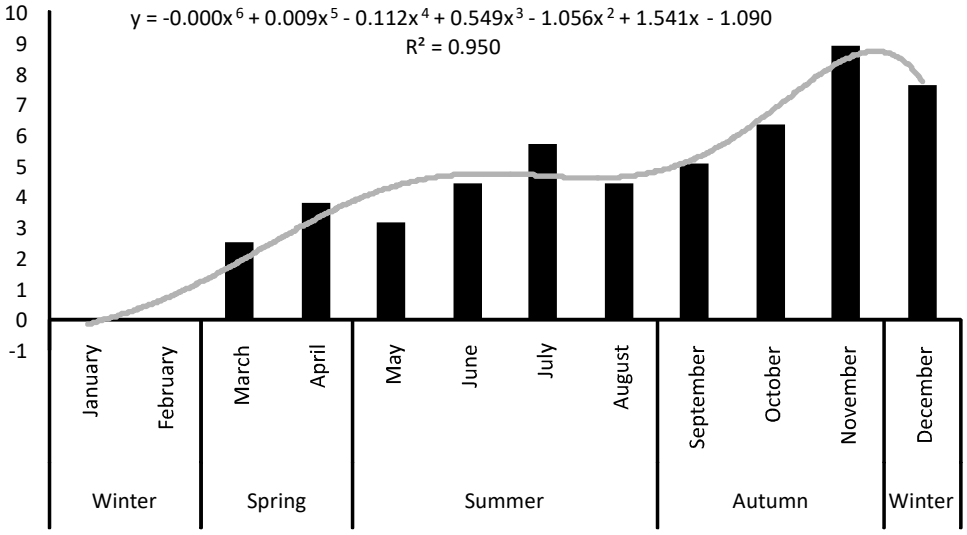

Fig. 8. Livestock depredation by Asiatic black bear in different months and seasons in NDBR, India, as reported by respondents to a survey (n = 157), polynomial line: trend line

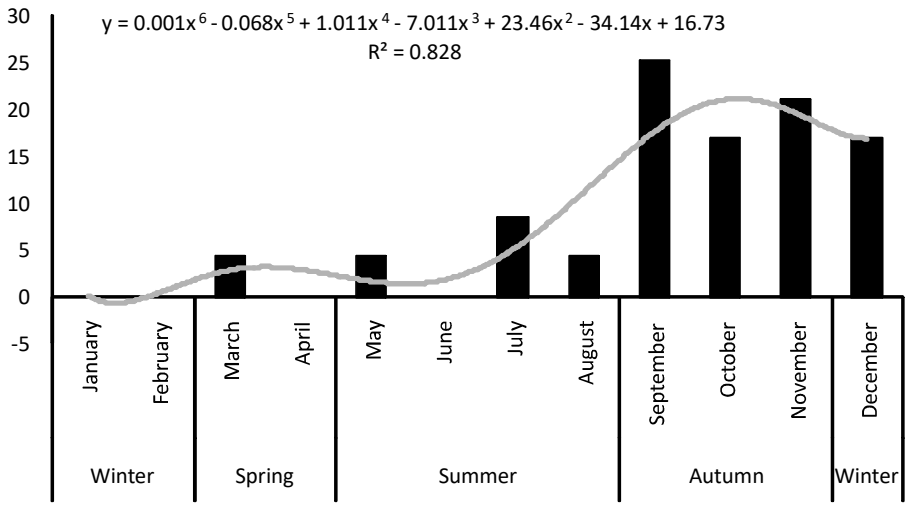

Fig. 9. Human casualties due to Asiatic black bear attacks in different months and seasons in NDBR, India, as reported during survey (n = 24), polynomial line: trend line

recorded. Maximum attacks were on head and face (37.50%), followed by stomach and back, chest and arms, and least on hips and legs, (Table 3). Black bear attacks on humans are the most serious trouble of all the types of black bear-human conflicts. The periods of black bear-human conflict correspond to the periods of increased intensive human activity: mostly cultivation of crops occurred between May to December, and increases human movement in summer and autumn probably made humans vulnerable to bear attacks (Charoo et al 2011). During interviews, villagers claimed that black bears were more active in crop field during dawn and dusk, resulted more fatalities between these hours (58.33%) (Table 3). A remarkable factor contributing to this condition is the growth of human population and expanding development of habitat along the wild land, urban interface.

Black bear-human conflicts have been reported to be increasing in the recent past years. For example, in Uttarakhand, black bears accounted for 28.5% of 540 attacks on humans by large carnivores between 1991 and 2001. Of these attacks, 9% resulted in a human fatality (Chauhan 2004). The high levels of conflicts between black bears and humans have been reported at the interface of wild and developed areas, under such circumstances humans are expected to be at more risk (Honda et al 2009). Charoo (2009) also stated that, most of the incidents were reported with villagers living at the edge of forests. The incidences of conflicts between humans-black bears have increased because fragmentation of bear habitats and transformation of forested areas to farmland has increased (Charoo et al 2011). The continuous presence of humans in black bear habitats might have also increased the incidences of conflicts in forests area. Main reason of human–black bear conflicts is competition for food resources and space (Trent 2010, Charoo et al 2011). Conflict increasing between humans and bears due to fragmentation of bears habitats with adjacent human habitations and croplands or orchards (Bargali et al 2005).

About 80 percent villages that were living near black bear habitats were more prone to crop depredation by black bear in NDBR. Agricultural fields surrounding to forest area accidentally attracts bear with nutritious food. Black bear locates seasonally available cultivated crops around its habitat; they have an excellent memory (Wani 2014). Recently changes in agricultural practices near to these high-density bear habitats from low crops to orchards changes aggregate the problem of crop depredation, causes to big economic losses for farmers (Choudhury et al 2008). Livestock depredation by black bears is not uncommon and may become a serious problem. Black bears are known to depredate on livestock in night shelters or during grazing in its habitat (Charoo et al 2011, Yadav et al 2009, 2018, Yadav 2020). Such encounters happen because of the habit of villagers to store harvested honey & fruits in their cattle shed. Economically losses in the form of livestock depredation or crop depredation results in retaliatory killing of bears and therefore has serious implications for bear conservation. During study period death of a black bear was reported due to feeding on poisonous food material in Pandukeshwar beat of NDBR . Attraction of bears for human food sources are a secondary effect of attacks on humans (Yadav et al 2020). Black bear attacks on humans are the most serious trouble of all the types of black bear-human conflicts. The periods of black bear-human conflict correspond to the periods of

Table 3. Asiatic black bear attacks on humans in NDBR, India, as reported during survey (n = 24)

Attacks on humans (n=24)		Attacks on humans (%)
Seasons of attacks	Spring	4.17
	Summer	16.67
	Autumn	62.50
	Winter	16.67
	Mean±SD	6±6.16
Time of attacks	Dawn & dusk	58.33
	Night	29.17
	Day	12.50
	Mean±SD	8±5.57
Place of attacks	Near to den	8.33
	Crop fields and villages	58.33
	Near to water source	12.50
	In the forest	20.83
	Mean±SD	6±5.48
Body parts of attacks	Head & face	37.50
	Chest & arms	20.83
	Stomach & back	25.00
	Hips & legs	16.67
	Mean±SD	6±2.16

increased intensive human activity: mostly cultivation of crops occurred between May to December, and increases human movement in summer and autumn probably made humans vulnerable to bear attacks (Charoo et al 2011). During interviews, villagers claimed that black bears were more active in crop field during dawn and dusk, resulted more fatalities between these hours. A remarkable factor contributing to this condition is the growth of human population and expanding development of habitat along the wild land, urban interface.

CONCLUSIONS

The study indicates that the urgency of management of black bear-human conflict in the NDBR. A fully equipped, well trained and motivated conflict management team comprised of wildlife staff, veterinarian and staff of related departments should be constituted. Human home waste is the main reason of attraction of black bear towards villages, so proper disposal techniques for waste material should be adopted. Simultaneously plantation of fruiting plant in the bear habitat should be required so that bear attraction towards agricultural field may reduce. Maximum livestock depredation incidences were recorded at night shelters in villages, we recommend to villagers for strengthening of doors, windows and other weaker portions of the shelters to reduce loss from depredation by black bears. Findings of the study shows that attacks of black bear on humans might be reduced through extension campaign that make villagers aware that they are mainly vulnerable to attacks of black bear when they are alone during dawn and dusk in the agricultural field and forest; that they could reduce the risk of attacks by black bear by giving safe passage to black bears they encounter and when they are alone should never try to scare off black bear. We suggested villagers to watch their agricultural field with proper lighting and cooperatively using crackers and drumming on empty metal canisters without harming the black bear to reduce the loss.

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Assessment of Arsenic Induced Oxidative Damage and Modulation of Antioxidant Defence System in Tomato

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***Abstract*:** Arsenic (As) is proved to be phytotoxic for growth and development of plants. After uptake by plants causes cell membrane damage, inhibition cellular functions, oxidative damage, and even cell death. As exposure results in the generation of ROS (reactive oxygen species) such as superoxide radical, hydroxyl radical and hydrogen peroxide which can directly damage proteins, amino acids and nucleic acids. It can also cause peroxidation of membrane lipids. Being a strong oxidizing agent, ROS induces oxidative stress which results degradation of biomolecules and finally cell death. To cope with oxidative stress plants induce their antioxidant defence system which leads to the synthesis of enzymatic and non-enzymatic antioxidants such as superoxide dismutase (SOD), catalase (CAT) and glutathione-S-transferase (GST), ascorbate (AsA) and glutathione (GSH). In addition, phytohormones also play important role to inhibit oxidative stress-induced cell death. Increased concentrations of phytohormones were observed in response to treatment. It has been concluded that the induction of oxidative stress is the main process underlying As phytotoxicity. The present investigation portrays a general idea about phytotoxic effect of As in terms of oxidative damage and its regulation in tomato plants.

***Keywords*:** Antioxidants, Arsenic, Oxidative stress, Phytohormones, Phytotoxicity

Arsenic (As) is a non-essential and toxic metalloid for all life forms including plants (Armendariz et al 2016, Afzal et al 2018). In nature As exists in both organic and inorganic forms, out of which the latter is predominantly present in the environment, particularly as arsenite (As III) and arsenate (As V) (Armendariz et al 2016). Arsenate is a chemical analogue of phosphate, so it is absorbed through high affinity phosphate uptake systems, whereas, As (III) is taken up via aquaglyceroporins (Chandrakar et al 2016). Arsenite is 100-fold more toxic than Arsenate, due to its strong affinity towards -SH groups of proteins leading to disturbance of structure and functions, which ultimately results in death of plants. As phytotoxicity may assess by observing several morphological symptoms such as wilting of leaves, inhibition of root and shoot length, leaf chlorosis and necrosis, violate leaf color decrease or complete loss of root hairs, damage to epidermal cells and cortex (Singh et al 2007), degradation of thylakoid membranes (Li et al 2006) and finally cell death. As phytotoxicity leads to oxidative stress which is induced by overproduction of reactive oxygen species (ROS), such as, superoxide anion (O_2^{-}), hydroxyl radical ($OH^{\cdot}$) and hydrogen peroxide (H_2O_2), resulting in oxidative damage imposing array of irreparable injuries to the plants (Flora 2011, Kaur et al 2012, Syu et al 2019). The ROS can react and deteriorate/damage all sorts of cellular macromolecules like lipids, carbohydrates, proteins and nucleic acids (Parkhey et al 2014a, Gaba et al 2018). Moreover, lipid peroxidation can also be initiated enzymatically by lipoxygenase (LOX) as a result of oxidative stress and is believed to be a critical factor for inhibition of growth and development in plants exposed to heavy metals (Mostofa and Fujita 2013). In order to combat against oxidative burst (excessive production of ROS) and to protect the cells from oxidative damage, plant cells possess a complex network of defence system, which includes both enzymatic and non-enzymatic components (Chandra and Keshavkant 2016, Chandrakar et al 2016, Kumar and Trivedi 2018, Wang et al 2020). The enzymatic component comprises superoxide dismutase (SOD), catalase (CAT), guaiacol peroxidase (POD) and ascorbate peroxidase (APX) (Dong et al 2014). Non-enzymatic component includes low molecular weight anti-oxidants, such as, α-tocopherol, proline, ascorbate, glutathione and phenolic compounds (Raza et al 2014, Singh et al 2015b). The very first line of defence for the detoxification of cellular ROS is made by SOD antioxidative enzyme (Keshavkant and Naithani 2001). SOD is one of the metalloenzymes that convert two $O_2^{\cdot -}$ radicals into H_2O_2 and O_2 (Keshavkant and Naithani 2001). CAT and POD catalyzes the breakdown of H_2O_2 (Chandra and Keshavkant 2016). Although, CAT is apparently absent in the chloroplasts, H_2O_2 may be detoxified in a reaction catalyzed by an ascorbate-specific peroxidase through the ascorbate-glutathione cycle (Chandrakar et al 2016). Phytohormones salicylic acid (SA) and ethylene have been considerably recognized as signal molecules involved in plant's defense

mechanisms by modulating both physiological and biochemical processes (Odjegba 2012, Dong et al 2015). SA enhances accumulation of proline thereby minimizes phytotoxic effects of abiotic stressors (Mostofa and Fujita 2013). Previous researches demonstrated that protection of plants from oxidative damage by SA is intimately linked with an enhanced antioxidant defence system (Parkhey et al 2014b). In the light of above information, the present study was carried out to probe As-induced oxidative deterioration/damage and its regulation by modulation of antioxidant defence system in a well-known model plant, tomato.

MATERIALS AND METHODS

Plant material and growth conditions: The tomato seeds were obtained from Indian Institute of Vegetable Research (IIVR), Varanasi for proposed experiments. Tomato plants were grown in controlled greenhouse condition of 14 h light and 10 h dark at 27 ± 0.5°C.

Hydroponic culture development: The tomato seeds were germinated in Petri dishes containing moist blotting paper in a growth chamber under controlled condition. The seedlings were then placed in a container of 2 L capacity having Knop's medium prepared by 6 mmol L^{-1} KNO_3, 4 mmol L^{-1} KH_2PO_4, 500 µmol L^{-1} $MgSO_4.7H_2O$, 500 µmol L^{-1} $Na_3C_6H_5O_7.2H_2O$, 100 µmol L^{-1} $FeCl_3$, 1 mmol L^{-1} $CaCl_2.2H_2O$, 50 µmol L^{-1} H_3BO_3, 10 µmol L^{-1} $MnCl_2.4H_2O$, 0.9 µmol L^{-1} $ZnSO_4.7H_2O$, 2 µmol L^{-1} $NaMoO_4.2H_2O$, 0.4 µmol L^{-1} $CuSO_4.5H_2O$, and 0.2 µmol L^{-1} $CoCl_2.6H_2O$ at pH 5.5-5.8. pH of the solution was adjusted using 1N NaOH and 1N HCL. After 3-4 weeks, the tomato plants were ready to use for As treatment to assess expected outcomes.

As treatment to tomato plants: Treatment of As was given directly to the roots of hydroponically grown tomato plants in triplicate manner. Different arsenic concentrations were prepared by using $NaAsO_2$ (sodium arsenite). Tomato plants were treated with various concentrations of As and plants without arsenic treatment were kept as control. To assess the phytotoxic effect of As the plants were harvested at 0, 12, 24, 36, 48, 72 and 96 h after treatment and cut at the root-shoot junction. The roots and shoots were washed, weighed, and dried at 65 °C to a constant weight for estimation of As accumulation.

Determination of ROS generation: The following methods were used to assess the phytotoxic effect of As on the ROS generation in tomato leaf tissues.

DAB staining to detect H_2O_2 accumulation : For DAB staining, As-treated leaves were cut with razor blade 1 cm above the base of the petiole and immediately placed in a beaker containing 1 mg/ml 3,3′-diaminobenzidine hydrochloric acid (DAB-HCl), at pH 5.6 followed by their incubation in a humid growth chamber for 8 h in dark condition. The leaves were adjusted in vertical position with 5 mm of the basal part dipped into the DAB solution. After proper uptake of DAB stain, the leaves were cleared in boiling solution of 96% ethanol, and examined under microscope. Accumulation of H_2O_2 was visualized as a reddish-brown coloration in leaf tissue.

Estimation of H_2O_2 level: Production of H_2O_2 was estimated as per the method of Sagisaka (1976). The treated and control plant leaf tissues were ground in a cold solution of 5% trichloroacetic acid (TCA) by using mortar and pestle and centrifuged at 17,000g for 10 min at 0°C. According to this method a reaction mixture was prepared by using 1.6 ml of supernatant, 0.4 ml of 50% TCA, 0.4 ml of ferrous ammonium sulphate, and 0.2 ml of potassium thiocyanate. The absorbance was estimated spectrophotometrically at 480 nm after 15 min of incubation. The amount of H_2O_2 was measured by plotting a calibration curve prepared with known concentrations of H_2O_2.

Estimation of lipid peroxidation: Lipid peroxidation was estimated by measuring the amount of malondialdehyde (MDA) according to the method of Heath and Packer (1968). The treated and control leaves were cut into small pieces and ground with pestle and motor after the addition of 1 ml of 0.1% cold TCA. The samples were then centrifuged at 10,000g for 20 min at room temperature. A reaction mixture was prepared by adding 1 ml supernatant, 1 ml 20% TCA containing 0.5% thiobarbituric acid and 0.01 ml 4% butylated hydroxyl toluene solution in ethanol into a new tube and incubated at 96°C for 35 min. The tubes were then placed on ice bath for 5 min followed by centrifugation at 10,000g for 5 min. Finally, absorbance of the supernatant was noted at 532 nm and corrected for non-specific turbidity by subtracting the absorbance recorded at 600 nm. The MDA concentration was calculated with the help of its molar extinction coefficient (156 mmol L^{-1} $cm^{-1)}$ which was expressed as µM/g FW.

Production of phytohormones: The following methods were used to assess the production of phytohormones in the tomato plant tissues under arsenic treatment condition.

Ethylene production assay: For ethylene production the method of Lund et al (1998) was followed. The treated and control leaves of tomato plants were excised and placed in test tubes for 1/2h to allow the escape of wound ethylene. After this, the tubes were sealed for 2 h for the collection of gaseous sample. Analysis of ethylene content was done on gas chromatograph (Model CP-3800 GC, Varian, Inc. CA, USA) equipped with flame ionization detector (FID) and a column (CP-Pora PLOT Q, 25 m × 0.32 mm) packed with fused silica. One ml gas sample was injected into the GC

column using a Hamilton gastight syringe (Model: 701 RN) for the measurement of ethylene content. The temperature of the column, injector and detector were adjusted at 110°C, 130°C and 130°C, respectively. Nitrogen gas at a flow rate of 30 ml/min was set as the carrier in the column. The ethylene production was quantified by comparing with standard curve prepared by using standard ethylene gas (SSG, Alltech Asso. Inc., USA).

Salicylic acid production assay: Production of SA was measured by following method of Gil and Martínez-Merino (2007) as SA reacts with ferric chloride to form coloured (blue or violet) complexes. To determine SA content, 0.2 g leaf tissues (control and treated) were homogenized with mortar and pestle in 2 ml of distilled water. The homogenate was then centrifuged well at 10000g for 15 min. In a fresh tube, 2 ml of the supernatant was added to 1 ml of 0.1% aqueous solution of $FeCl_3$. The colour (blue/violet) development is the indication of the presence of salicylic acid. Then absorbance of the sample solution was recorded spectrophotometrically at 540 nm. Concentration of the SA in the solution was calculated by comparing with standard curve.

Assessment of antioxidative enzyme activities : For the determination of antioxidative enzyme activities, the leaves were homogenized (1:5 w/v) in 1 M NaCl in 50 mM potassium phosphate buffer (pH 7.0) containing 1% polyvinyl pyrrolidone (PVP) and 1 mM EDTA. For the assay of Ascorbate peroxidase activity (APX), leaf extracts were prepared in the same medium containing 1 mM sodium ascorbate. After centrifugation of homogenate, the supernatant was used as an enzyme extract to assay superoxide dismutase (SOD), catalase (CAT), APX, and peroxidase (POX) activities.

Protein content: The protein content was estimated by the method of Bradford (1976), with standard curves prepared with the help of bovine serum albumin (Sigma).

Superoxide dismutase (SOD) activity: Assay of SOD activity was done spectrometrically according to the method of Beauchamp and Fridovich (1971) which based on the inhibition of the photochemical reduction of NBT. An assay mixture was prepared by adding 50 mM potassium phosphate buffer (pH 7.8), 13 mM L-methionine, 75 µM NBT, 0.1 mM EDTA, 2 µM riboflavin and enzyme extract. At last riboflavin was added and the reaction was started by placing the tubes under two 15 W fluorescent lamps. The reaction was terminated by removal from the light source after 10 min. Non-illuminated and illuminated tubes without enzyme extract served as control. The absorbance was recorded at 560 nm. The volume of enzyme extract corresponding to 50% inhibition of the reaction was considered as one unit of enzyme activity for the calculation of SOD activity.

Catalase (CAT) activity: Assay of CAT activity was performed spectrophotometrically as per the method of Dhindsa et al (1981). The assay mixture contained 50 mM potassium phosphate buffer (pH 7.0), 15 mM H_2O_2 and enzyme extract. The decomposition of H_2O_2 (absorbance coefficient of 45.2/mM cm) was measured at 240 nm at 25°C.

Ascorbate peroxidase (APX) activity: Assay of APX activity was based on the oxidation of ascorbate to dehydroascorbate at 265 nm (an absorbance coefficient of 13.7/mM cm) according to the method of Nakano and Asada (1981). The assay mixture was prepared by adding 50 mM potassium phosphate buffer (pH 7.0), 0.25 mM sodium ascorbate, 25 µM H_2O_2 and enzyme extract. Reaction was started by addition of H_2O_2. The rates were corrected for the non-enzymatic oxidation of ascorbate by the inclusion of reaction mixture without enzyme extract.

Peroxidase (POX) activity: Assay of POX activity was performed as per the modified method of Manoranjan and Dinabandhu (1976). POX was determined by measuring the oxidation of 4 mM guaiacol at 470 nm ($\varepsilon = 22.6\ mM^{-1}\ cm^{-1}$) in 50 mM potassium phosphate buffer (pH 6.5), following addition of 1 mM H_2O_2. The oxidation of guaiacol was calculated by the increase of absorbance of 470 nm. The increase in A_{470} produced by H_2O_2 breakdown was noted per min. The activity of POX was expressed as enzyme unit (U)/mg protein, where 1 U of POX activity was defined as an increase of 0.01 in the readings per minute.

Experimental design and statistical analyses of data: The experimental was in completely randomized block design. All the experiments were carried out in triplicates and were repeated two times. Statistical analysis was done using Duncan's Multiple Range Test (Duncan 1955).

RESULTS AND DISCUSSION

As-induced cell death in tomato root: After 96 h of As treatment significant amount of cell death was observed this was increased with increasing concentration of As (Fig. 1). The maximum cell death was induced by 5 ppm of As concentration as assessed by Evans blue staining method. At 7 ppm As also showed similar amount of cell death. Hence, the 5 ppm concentration of As was selected for further experiments to assess its phytotoxicity in tomato plant parts. Similar phytotoxic concentration of arsenic was used by Mishra et al (2011) to induce oxidative stress and modulation of antioxidant defence system in rice seedlings (Mishra and Dubey 2006). Cao et al (2004) also reported that greater As concentration in plants causes greater oxidative stress.

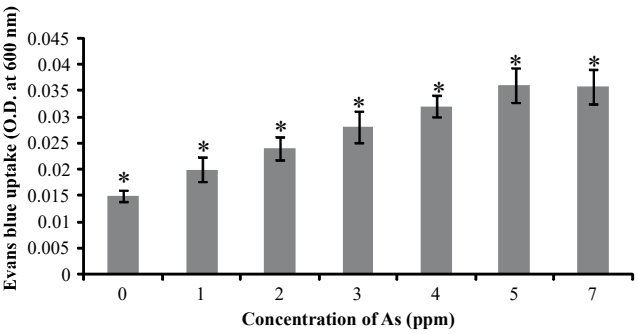
As-induced oxidative burst (H_2O_2 production) Tomato leaves treated with As showed enhanced H_2O_2 production. The increase in H_2O_2 generation was time-dependent. The

level of H_2O_2 started to increase gradually after arsenic exposure that reached to maximum at 72 h and then declined (Fig. 2). Low basal level of H_2O_2 was observed in control leaves. Enhanced level of H_2O_2 in As-treated tomato leaves showed prevalence of ROS in tomato plants under exposure to As. Similar results were reported by Hartey-Whitaker et al (2001) and Srivastava and Sharma (2013).

Effect of As on membrane lipid peroxidation: The level of MDA, the final decomposition product of lipid peroxidation in the leaves of tomato plants treated with As, was significantly different in all samplings as compared to the control leaves (Fig. 3). MDA accumulation in leaves was increased gradually up to 48 h after As exposure and then declined. The result suggests that As-induced production of ROS which leads to increased lipid peroxidation.

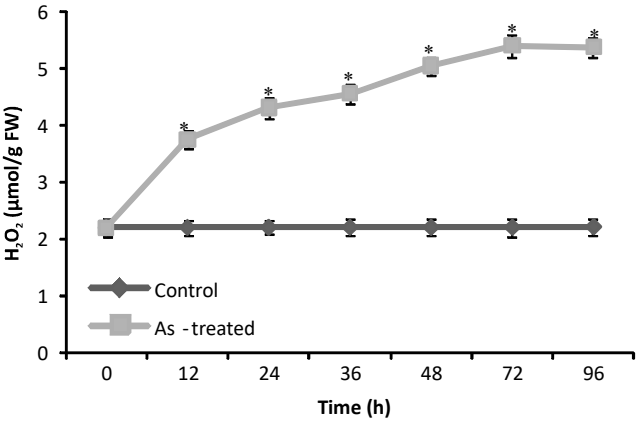
Effect of As on phytohormone production: Production of some phytohormones such as ethylene and SA was investigated following the treatment of As to the leaves of hydroponically grown tomato plants. The significant increase in ethylene evolution was measured after As treatment in comparison to control leaves. As triggered ethylene production in tomato leaves after exposure. Initially, ethylene evolution was slower but increased rapidly after As exposure and reached at peak at 24 h, then decreased afterword (Fig. 4 A). SA is a major phenylpropanoid compound whose synthesis is triggered by various stressors. In this study, SA production started to increase after As treatment which reached to maximum at 24 h and declined thereafter (Fig. 4 B). These phytohormones (ethylene and SA) play an important role in the process of cell death after As treatment (Lund et al 1998).

Induction of antioxidative enzymes after As exposure: The significant increase in SOD activity was observed after As treatment as compared to control. SOD activity increased after As exposure in the leaf tissue up to 48 h and declined thereafter (Fig. 5A). Result shows that increased SOD activity acts as first line of defence which catalysed the dismutation of superoxide radicals to H_2O_2 (Qureshi et al 2005, Diwan et al 2008). CAT activity in the leaves of As-treated plants increased gradually and reached at peak after 48 h of treatment (Fig. 5B). However, it was less significantly higher in comparison to control at all the samplings. It was observed that CAT activity did not participate actively in H_2O_2 reduction. Similar pattern has been reported earlier in response to other heavy metals stresses (Wu et al 2003, Diwan et al 2007). APX activity As treated leaf tissue was significantly higher as compared to control throughout all samplings (Fig. 5C). Increase in APX activity suggested a role of APX in the detoxification of H_2O_2 and its up-regulation under As-induced oxidative stress as established earlier with reference to other heavy metals (Qureshi et al 2005, Israr et al 2006, Diwan et al 2008). Significant increase in POX



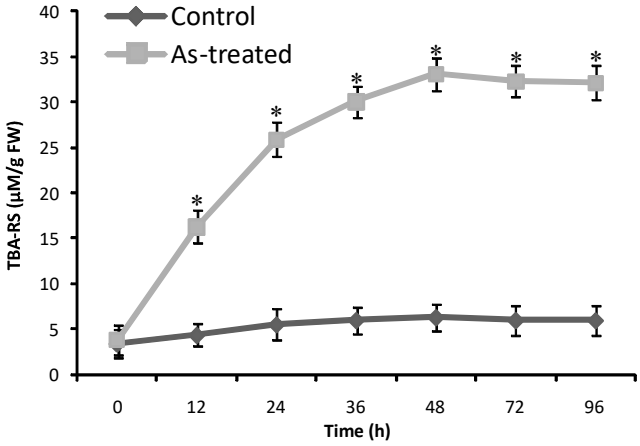
Mean ± standard error. * indicates that values are significantly different (p<0.05)

Fig. 1. Cell death in the leaves of tomato plant treated with various concentrations of As after 96 h (O.D., Optical density)



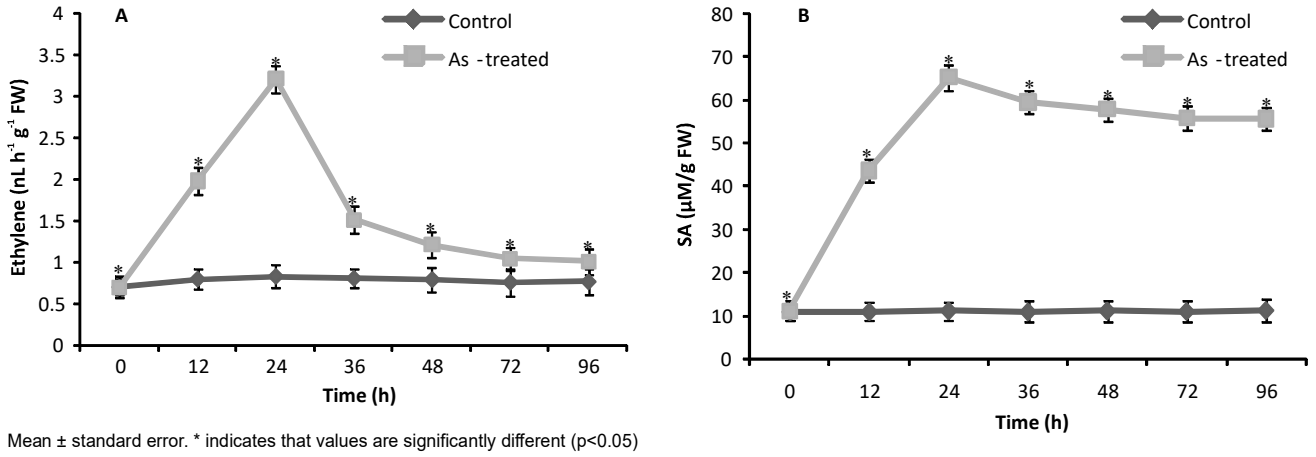
Mean ± standard error. * indicates that values are significantly different (p<0.05)

Fig. 2. H_2O_2 production in the roots of tomato plants treated with As



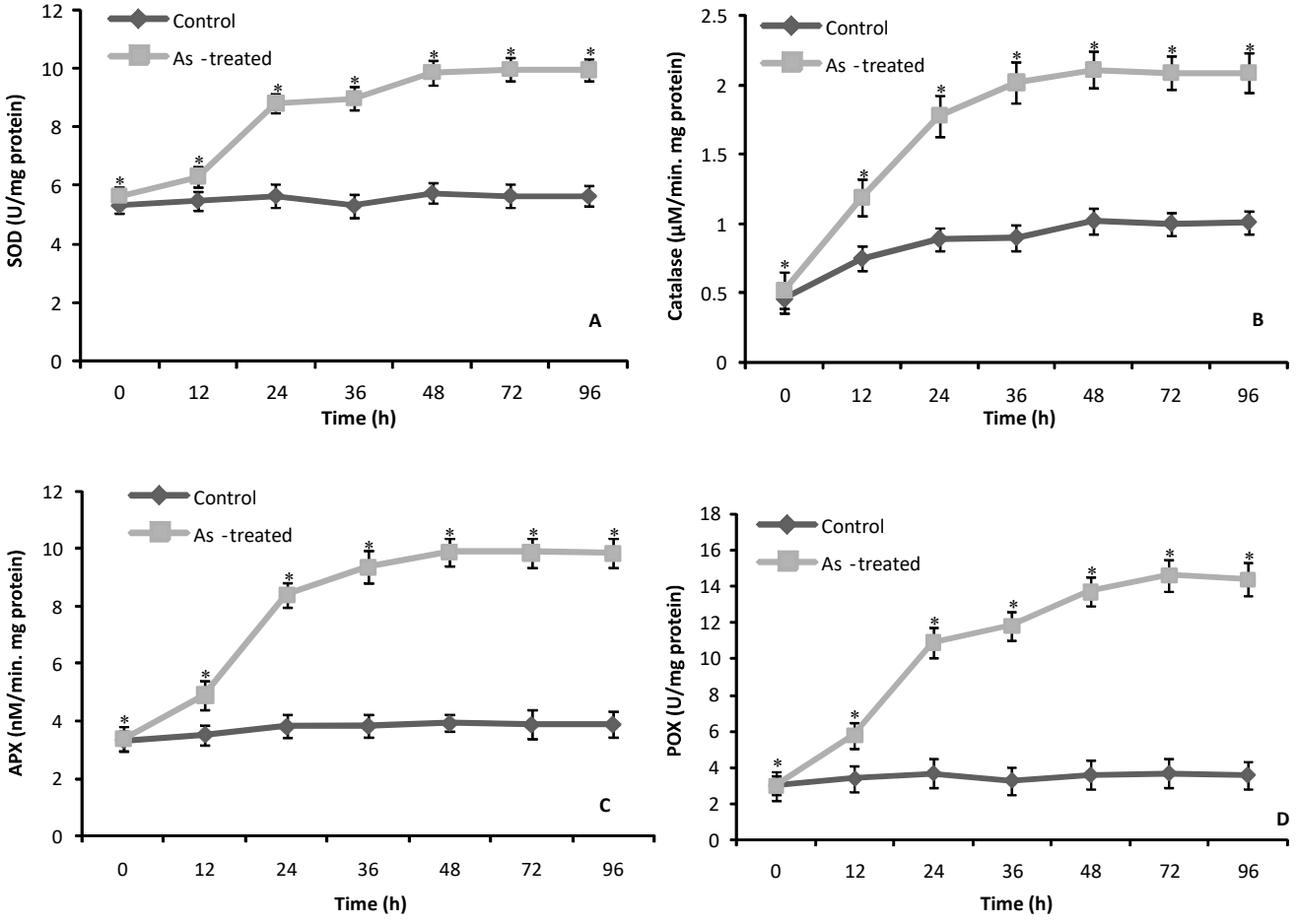
Mean ± standard error. * indicates that values are significantly different (p<0.05)

Fig. 3. Lipid peroxidation in the roots of tomato plants treated with As



Mean ± standard error. * indicates that values are significantly different (p<0.05)

Fig. 4. Effect of As treatment on phytohormone production in tomato roots. **(A)** Ethylene production in the roots of tomato plant treated with As, and **(B)** SA production in the roots of tomato plant treated with As.



Mean ± standard error. * indicates that values are significantly different (p<0.05)

Fig. 5. Activities of antioxidative enzymes in the roots of tomato plant treated with As. **(A)** Effect of As treatment on enzymatic activity of SOD in tomato roots, **(B)** Effect of As treatment on enzymatic activity of CAT in tomato roots, **(C)** Effect of As treatment on enzymatic activity of APX in tomato roots,**(D)** Effect of As treatment on enzymatic activity of POX in tomato roots.

activity was measured in As-treated leaf tissue. POX activity was assayed with guaiacol. Its activity increased gradually up to 2 or 3 days after As exposure as compared to control (Fig. 5D). Plant peroxidases exist in a variety of isoforms that use different electron donors and may play different functions. Enhanced activity of POX enzyme on As exposure suggests their protective role under As phytotoxicity. (Probst et al 2009, Talukdar 2012b).

CONCLUSION

As-induced phytotoxicity was evident with inhibition plant growth and development. As exposure resulted an enormous oxidative burst in leaf tissues of tomato plants. The oxidative burst i.e. generation of large quantities of ROS like hydrogen peroxide is one of the earliest responses of plant cells under heavy metal stress. Overproduction of ROS imposed an oxidative stress in plant cells which resulted oxidative damage of membrane lipid. Thus, As-induced oxidative burst is evident from increased lipid peroxidation. To cope with As toxicity plants developed a cellular strategy involving activation of antioxidative defence system. Results demonstrate that evolution of some phytohormones viz. ethylene and SA provokes oxidative burst, while ROS stimulates their production. In this way these signalling molecules induce each other's production, thus amplifying the initial signal, ultimately resulting in to plant cell death. In the present study, a concomitant enhancement in ROS production, the down regulation of the antioxidant enzyme activities and increased lipid peroxidation were crucial for the onset of cell death in tomato plants which proved phytotoxic nature of As metalloid.

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Screening Blackgram (*Vigna mungo* (L.) Hepper) Varieties for Shade Tolerance in Coconut Gardens of Southern Laterites of Kerala

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Abstract: A field experiment was conducted to examine the prospects of blackgram cultivation in coconut garden as an intercrop during *Rabi* 2019. Twelve promising blackgram varieties with three cultures were evaluated for their yield performance and shade tolerance in coconut garden with palms aged above 40 years experiencing a light intensity between 40-46.5 Klux. Results of the study revealed that the performance varied significantly with respect to yield attributes and yield among the varieties and cultures. Sumanjana and culture 4.6.1 flowered much early compared to other varieties (34 days) and higher number of pods per plant was in DBGV-5 (23.67) which was on par with Sumanjana, VBN - 6, VBN - 5 and CO - 6. The variety DBGV-5 recorded superior yield attributes and yield (1183.33 kg ha^{-1}) followed by VBN - 5 (916.67 kg ha^{-1}) and Sumanjana (906.67 kg ha^{-1}) under shaded situations in coconut garden. The study identified DBGV - 5, Sumanjana and VBN - 5 as promising varieties for intercropping in partially shaded situation in coconut garden with superior yield attributes.

Keywords: Blackgram, Coconut garden, Partial shade, Varieties, Yield attributes

Blackgram [*Vigna mungo* (L.) Hepper] is an important crop among the premier pulse crops and considered as third important pulse crop in India, covering an area of 5.03 million ha accounting for 17.32 per cent of the total acreage, and constitutes only 14.12 per cent of the total pulse production of the country. In Kerala, blackgram is mainly cultivated under rainfed condition in rice fallows during summer season, fit well in intercropping, crop rotation and crop mixture and can be included in any cropping system practiced in the tropics. In Kerala, coconut gardens account for 7.9 lakhs ha with a production of 5473 million tonnes and offer an opportunity for expanding its cultivation as inter crop. In ccoconut plantations of above 40 years, light transmission increases about 50 per cent which makes growing of intercrops possible in the interspaces. The active root zone of coconut is confined only to 25 per cent of the available land area. So, the interspaces in coconut garden can be effectively utilized for growing blackgram. To obtain maximum yield under low light, selection of suitable varieties plays an important role in intercropping. Different varieties respond differently to shading stress in terms of morpho-physiology as well as yield (Pooja et al 2021). Since horizontal expansion of cultivation of pulses is not possible during any of the seasons, increase in pulses production can be achieved by intercropping. Growing short duration pulses in the coconut garden has numerous advantages like utilization of available space in between coconut palms, additional income to the farmers, enhancing the soil fertility and ensuring food and nutritional security. Being a favourable short duration pulse crop, blackgram survives better in all seasons either as sole, intercrop or catch crop. The present study was undertaken to evaluate the performance of blackgram varieties for yield and shade tolerance in partially shaded situation in coconut garden in the southern laterites of Kerala.

MATERIAL AND METHODS

The field experiment was carried out in *Rabi* season of 2019 with cropping period extending from October to January at College of Agriculture, Vellayani, Kerala, India located at 8° 25' 46" N latitude, 76°59' 24" E longitude and altitude of 29 m above the mean sea level. The region enjoys a humid tropical climate experiencing temperature of 26.9 to 42.2°C and relative humidity of 89%. A total of 244.5 mm rainfall was received in 105 days with an average weekly evaporation of 33.89 mm during the cropping period. Seeds of 12 promising blackgram varieties along with 3 cultures were collected from different research stations of South India and evaluated for their yield performance and shade tolerance in coconut garden experiencing a light intensity between 40-46.5 Klux. The varieties were, Sumanjana, DU -1, DBGV - 5, VBN - 5, VBN - 6, VBN - 8, Rashmi, CO - 6, TAU - 1, TAU - 2, Blackgold and AKU - 15 (Table 1). The three cultures tested were 4.5.8

(T-9 x Rusami), 4.5.18 (T-9 x Rusami) and 4.6.1 (T-9 x Rusami). Coconut garden in the farm with palms above 40 years age planted at a spacing of 7.6m x 7.6m was selected for screening the varieties. The plots were laid out in randomized block design replicated thrice. From the base of the palm, two-meter radius was left to avoid interruption from coconut roots so that growth and development of intercrop was unaffected. Hence in between two coconut palms, 3.6 m space was utilized for sowing blackgram. Land in between the palms was thoroughly ploughed, micro plots of 1.5 m^2 were taken and applied lime @ 250 kg ha^{-1}. The shade level in coconut garden was assessed using light meter and ranged from 40-46.5 klux which was 58.5-65% less solar irradiance than that of open conditions. Photo-synthetically active radiation (PAR) was also measured at monthly interval which ranged from 4.41 to 10.01 µmoles m^{-2}. Well decomposed farmyard manure was incorporated at the rate of 20 t ha^{-1} as basal dose. The recommended nutrients (20:30:30 kg N: P_2O_5: K_2O ha^{-1}) was given through urea, rock phosphate and muriate of potash (KAU, 2016). Half the dose of N, full P and K were given as basal and the remaining half dose of N was given as two foliar spray at 15 and 30 days after sowing (DAS). Two weedings were done at 15 and 30 DAS with irrigation provided on alternate days. All the varieties reached maturity within a range of 80-100 days. A total of three pickings were taken and the observations of sample plants were recorded. Comparative yield percentage was based on the yield potential under open condition for each variety.

RESULTS AND DISCSSION

Assessment of yield attributes and yield under shaded condition: There was significant difference among the varieties and cultures tested with respect to days to 50% flowering, number of pods per plant, 100 seed weight and seed yield. The variety Sumanjana and the culture 4.6.1 flowered much early compared to other varieties with 34 days to reach 50% flowering. The variety DBGV - 5 which reached 50% flowering at 36 DAS was on par with Sumanjana and culture 4.6.1. TAU - 2 took the maximum number of days (43.33) to reach 50% flowering and was on par with VBN- 5, VBN -6, DU -1 and Rashmi. Among all the varieties and cultures tested, DBGV - 5 produced the highest number of pods per plant (23.67) and on par with Sumanjana, VBN - 5, VBN - 6 and CO - 6 under shade. Varietal difference did not show a remarkable influence on length of pod and number of seeds per pod. However, 100 seed weight was an important yield determining character of each variety and culture. The culture 4.6.1 produced bold seeds with the highest 100 seed weight (5.06) and was at par with DBGV - 5, DU - 1,

Table 1. Characteristics of blackgram varieties used for screening for shade tolerance

Variety	Selection/Parentage	Year of release	Duration (days)	Yield (kg ha^{-1})	Remarks	Seed source
TAU 1	T 9 x UM 196	1985	65-70	1000-1200	Bold seed, fast growth	PDKV, Akola
TAU 2	T 9 x U 196	1993	70	1000	Purplish black pods, seeds bold	PDKV, Akola
Sumanjana	Pure line selection from Co Bg9	2000	75	933	Suited to summer rice fallows of Thiruvananthapuram	COH, Vellanikkara, Thrissur
AKU 15	TAU 1 x Pant U 31	2006	65-83	1000-1200	Kharif, tolerant to powdery mildew	PDKV, Akola
VBN 5	CO 4 x PDU 102	2007	65-70	836	Hairy pods, 100 grain weight - 4 g, moderately resistant to yellow mosaic virus	NPRC, Vamban, TNAU
DU 1	TAU 1 x 169	2008	75-80	1000-1200	Suited to paddy fallows, tolerant to stem fly	UAS Dharwad
CO 6	DU 2 x VB 20	2010	60-65	733	Moderately resistant to yellow mosaic virus	COA, Vellayani
Rashmi	LBG 17 x UG 201		80-85	1000	Hairy pods, protein 20-25%	UAS, Bangalore
VBN 6	VBN 1 x UK 17	2011	65-70	850	Hairy pods, synchronized pod maturity, moderately resistant to yellow mosaic virus	NPRC, Vamban, TNAU
DBGV 5	TAU 1 x LBG 20	2012	82-85	1200	Moderately resistant to yellow mosaic virus	UAS Dharwad
VBN 8	VBN 3 / VBN 04-008	2016	65-75	900	Non shattering, synchronous maturity, protein content - 21.9 %, arabinose content - 7.5%	NPRC, Vamban, TNAU
Blackgold	AKU- 10 -1	2016	70-75	1000-1100	Tolerant to powdery mildew	PDKV, Akola

Table 2. Effect of treatments (varieties and cultures) on yield attributes

Treatments (variety)	Days to 50% flowering	Number of pods plant^{-1}	Average length of pod (cm)	Number of seeds per pod	100 seed weight	Seed yield per plant (g)	Seed yield kg ha^{-1}
Sumanjana	34.33	20.55	4.34	6.67	4.13	4.40	906.67
DU -1	41.67	16.65	4.48	7.10	4.70	3.19	583.33
DBGV - 5	36.33	23.67	4.41	6.54	5.01	5.44	1183.33
Culture 4.6.1	34.33	17.75	4.39	6.44	5.06	3.84	756.67
Culture 4.5.8	38.00	12.70	4.33	6.50	3.85	2.16	310.00
Culture 4.5.18	43.00	17.30	4.22	7.11	4.02	3.39	636.67
VBN - 6	42.33	20.45	4.58	7.33	4.29	4.20	853.33
VBN - 8	39.67	14.65	4.35	6.89	3.93	4.06	816.67
VBN - 5	42.67	22.00	4.36	6.66	4.46	4.44	916.67
TAU - 2	43.33	18.40	4.48	6.67	4.587	3.53	673.33
Rashmi	43.00	20.80	4.45	7.00	4.497	3.59	690.00
CO - 6	37.67	22.55	4.54	7.00	4.403	4.03	863.33
Blackgold	38.67	16.83	4.48	6.93	4.96	3.88	766.67
TAU - 1	38.33	17.16	4.48	6.67	4.887	4.03	806.67
AKU - 15	36.67	17.67	4.29	7.12	4.837	4.24	806.67
CD (p=0.05)	2.15	4.92	NS	NS	0.422	0.78	209.520

Table 3. Effect of correlation of yield attributes and yield

Particulars	Days to 50% flowering	Number of pods per plant	Average length of pod	Number of seeds per pod	100 seed weight	Sees yield per plant	Seed yield
Days to 50% flowering	1						
Number of pods per plant	0.0215	1					
Average length of pod	0.087	0.159	1				
Number of seeds per pod	0.350*	0.180	0.133	1			
100 seed weight	0.171	0.157	0.068	0.264	1		
Seed yield per plant	-0.245	0.510**	0.150	-0.132	0.232	1	
Seed yield	-0.245	0.519**	0.149	-0.131	0.232	0.998**	1

*Significant at 1% **Significant at 5%

Blackgold, TAU - 1 and AKU - 15 under coconut garden.

The observation on seed yield per plant was highest in DBGV-2 (5.44 g) followed by VBN 5 (4.44 g) and Sumanjana (4.40 g). This might be due to the highest number of pods per plant produced by the respective varieties (Table 2). DBGV - 5 with a seed yield of 1183.33 kg ha^{-1} was superior to rest (Table 2) followed by VBN - 5 (916.67 kg ha^{-1}) and Sumanjana (906.67 kg ha^{-1}). Higher number of pods per plant (23.67) in DBGV-5 attributed to the highest seed yield of the variety. Higher yield obtained from Sumanjana could be related to its suitability to Thiruvananthapuram, Kerala condition (KAU 2016). Interestingly, yield of VBN-5 was higher than the yield under open condition (109.65%) while that of DBGV-5 and Sumanjana were 98.61 and 97.18 percentage of the average yield recorded under open field conditions. The better performance of these varieties in coconut garden could largely be connected to its efficiency in capturing the solar radiation (55%) not intercepted by the canopy. This indicate that light intensity levels in the interspaces in coconut gardens was sufficient to drive photosynthesis and related physiological processes in shade tolerant varieties. The number of pods per plant and seed yield were highly correlated with a correlation coefficient of 0.519 indicating a significant positive association between seed yield with pods per plant and 100 seed weight (Table 3) and in line with the results of Sohel et al (2016) and Sushmitharaj et al (2018). However, days to 50% flowering and seed yield showed negative correlation of -0.245 which implied that, early flowering promotes better flowering and pod formation thereby higher yield. Similar observations were made by Hemalatha et al (2017) in blackgram.

CONCLUSION

Among the varieties and cultures tested for yield and

shade tolerance in coconut gardens with 40-46.5 klux light intensity, the study identified DBGV - 5, Sumanjana and VBN - 5 as the most performing ones. DBGV - 5 recorded the highest seed yield (1183.33 kg ha^{-1}) in shaded condition prevailed in coconut garden followed by VBN - 5 and Sumanjana, confirming its capacity to perform better under the shade levels in Southern lateritic soils of Kerala. Considering the yield performance, DBGV - 5, VBN -5 and Sumanjana could be recommended as the suitable varieties for inter cropping in shaded situations of coconut garden above 40 years of age.

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Effect of Injecting Soils with Lime and Gypsum by Sawdust Extract and the Wetting and Drying Cycles on Physical Properties and Phosphorous Behavior in the Soil

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Abstract: A laboratory study was conducted on undisturbed soil samples taken from a depth of 0-12 cm, collected from different desert areas in lime and gypsum percentages, devoid of agricultural use in the western Anbar Governorate. The organic extract of sawdust (EOM) was added at 10% of the extract equivalent to the percentage of dry organic matter from the dry soil weight for all samples of the study soil. Nine wetting and drying cycles were performed with a 3-day incubation of samples after each wetting and drying cycle. There was significant increase in the mean weighted diameter (MWD) at fast wetting (flood) by increasing the percentage of gypsum. The significant increase in gypsum soil was by 8.02% compared to calcareous soil, and the presence of a significant increase in the mean weighted diameter at slow wetting by increasing the lime percentage. Further significant increase in calcareous soil by 15.20 and 10.77%, respectively, compared to soils with a close percentage of lime and gypsum and gypsum soil. The wetting cycles as well as the succession of wetting and drying cycles had a significant effect on decreasing the dispersion ratio, as the highest decrease ratio was 45.88% in the ninth cycle compared to the first cycle. Moreover there was no significant effect of lime and gypsum on the amount of available phosphorus by adding 10% of sawdust extract.

Keywords: Available phosphorus, Calcareous soil, Gypsum soil, Soil structure

A large part of the Iraqi land suffers from the problem of deterioration and low percentage of organic matter as a result of weak vegetation cover due to the prevailing climatic conditions such as high temperature and lack of rainfall. Soil high level of salinity, as a result of irrigation with poor quality water and not using water properly. Therefore, it is necessary to add organic matter to the soil to improve its properties in general and to reduce the deterioration of the Iraqi soil structure. The presence of organic matter in the soil is a major factor affecting soil properties. Humic substances in the soil improve its structure and increasing its stability of aggregates by connecting soil particles, improving its porosity. The, distributing water and air increasing the soil's ability to retain moisture and providing suitable conditions for the growth of the roots, thus increasing nutrient absorption by the roots. Furthermore, organic matter has an effective role in covering soil particles and reducing rapid wetting due to its containment of hydrophobic substances such as humates. In addition, organic materials can provide some nutrients such as nitrogen, carbon, and phosphorus and contribute to increasing the biological activity in the soil better than industrial fertilizers. The organic acids work to dissolve some compounds inside the soil and releasing most of the nutrients. However, this research aims to identify the effect of wetting and drying cycles with 10% sawdust extract injection to soil samples with different lime and gypsum ratios on the stability of aggregates and some physical and chemical properties.

MATERIAL AND METHODS

Sawdust was collected from several carpentry factories in Ramadi city, Anbar Governorate, sieved through 0.5 mm sieve to obtain very fine sawdust to increase the speed of s decomposition. The 70 kg of fine sawdust was subjected to the process of aerobic decomposition by placing the sawdust in a pile on polyethylene pieces, then, 2% nitrogen was added to the sawdust in the form of N (46% urea) (Sarheed 2013). The compost was mixed with sawdust, moistened with water by a drizzle, and then covered with polyethylene in order to raise temperature and to provide suitable conditions for decomposition by the microorganisms. Furthermore, the pile was flipping manually and moistened every 3 days until the original sawdust becomes difficult to identify. The temperature of the pile was measured continuously, the temperature was decreased from 65 to 45 ° C, and this decrease was considered as a sign to ending the decomposition process. However, the decomposition period lasted 4 months and the decomposing material was spread to air dry for 4 days. Undisturbed soil samples were collected from different desert areas devoid of agricultural use located to the west of the Anbar governorate in which a previous study was conducted (Al-Nuaymy et al 2013), by using

cylinders made of PVC, with a diameter of 10 cm and a height of 12 cm. These cylinders were folded at one end to facilitate the process of entering the soil by using a hydraulic press, after the cylinder was implanted and was raised from the soil, then the soil is removed from the tip of the cylinder that was implanted in the soil by a sharp tool. In addition, the cylinder is covered on both sides by caps. After that, the cylinders were placed in plastic boxes with inflexible walls, and then the gaps between the cylinders were filled by foam. The samples analysed for physical and chemical properties (Table 1). The soil samples were wetted with the capillary action by placing the cylinders on a sand column of 0.5 mm particle size and the column length 20 cm above the water surface. The water column was fixed with a Macloren bottle, where the wetting process continued to the point of saturation (about 16 hours). The samples treated with organic matter extract were left to lose their water until they reached a lower level of the field capacity, and the amount of required extract solution was estimated to be added to the soil by injection. The extract of organic matter was injected in an amount equivalent to the amount of the organic matter in the soils, and all treatments were incubated at a temperature of 22 ° C for three days (Smucker et al 2007).

Then, the cylinders were removed and placed on the ground horizontally to be air-dried for three days. Three replicates were prepared for all soil treatments for analyzed where the soil cylinders are cut from opposite sides in half lengthwise by melting the plastic with a knife heated to a high temperature. Besides, the sample is placed on sieves 9.5, 4, and 2 mm with their natural moisture after air-drying and are sifted and air-dried at a laboratory temperature of 25°C1 and prepared for analysis. The Mean weighted diameter (MWD) was estimated by taking 25 g from soil aggregates on the 4 mm sieve and passersby through a 9.5 mm sieve to estimate the MWD (Yoder 1936) and modified (Van Bavel 1950) using a wet sieving device manufactured according to the specifications of the device mentioned (Kemper et al 1986) and consisting of five sieves in the order 0.25-0.5-1-2-4-9.5 mm. The samples are wetted in two technique, the first is to flooding the soil suddenly for 5 minutes, then turn the device on for 10 minutes, and then transfer the soil quantitatively to boxes made of aluminum of known weight and place in an oven at a temperature of 105°C. The samples were exposed to water vapor by placing a sieve with a hole of 4 mm diameter above a cylindrical water tank in the second technique. The tank height was 210 mm and its diameter is 180 mm, two-thirds of it was filled with water, after which the sieve was covered. The same diameter as the sieve with a hole in the middle of a diameter of 50 mm, a cylinder height of 10 cm is placed on it to insert soil aggregates and calculate MWD from the equation below

$$MWD = \sum_{i=1}^{n} wi\,\overline{x}i \ldots\ldots 1$$

Finally, the dispersion ratio was estimated, by taking 10 g of soil passing through a 2 mm sieve, then it is placed in a volumetric cylinder with a capacity of one liter and then completing the volume to a liter with distilled water. The shaking the contents of the cylinder was done by using the plunger and leaving the suspension for some time, and then the volume of soil aggregates was calculated using Stokes' law. The process is repeated by taking 10 g of soil passing through a 2 mm sieve, then, an analysis of particle sizes was performed, by removing the organic matter using (H_2O_2), removing the salts using distilled water, and dispersing the soil aggregates using the dispersion solution, then the dispersion ratio was calculated according to the following equation

$$DR = \frac{\text{\% Silt + clay (without remove)}}{\text{\% Silt + clay (with remove)}} \qquad (2)$$

Where

Silt (%)+ clay (w) are the percentage of clay and silt in distilled water without adding a dispersion solution.

Silt (%)+ clay (g) is the percentage of clay and silt with the addition of the dispersion solution.

RESULTS AND DISCUSSION

Effect of lime and gypsum in the soil with the addition of 10% of the extract equivalent of sawdust in the MWDf at the fast wetting: The wetting and drying cycles increased significantly the MWDf, and the increase ranged between 10% for the second cycle and 41.81% for the ninth cycle compared to the first cycle (Table 2). Further, the mean weighted diameter increased gradually ranged between 3.21% for the third cycle and 26.83% for the ninth cycle compared to the second cycle. There was also a significant increase in MWDf and ranged between 4.76 and 18.64% from the fourth to the ninth cycle, respectively, compared to the fourth cycle. Likewise, the ninth cycle had a significant effect in MWDf, with increasing percentages of 18.55, 21.04, and 15.73 compared to the fifth, sixth, and seventh cycle, respectively. It is also evident that MWDf decreased insignificantly in the eighth cycle compared to the seventh session, as the decrease percentage reached 2.48. The increase in MWDf is attributed to the effect of humic acids resulting from the decomposition of sawdust. These acids bind the soil particles to each other upon drying while allowing the aggregates to expand when they absorb water again in the next wetting process. As well as, the incubation

period, growth, and reproduction of microorganisms at each wetting and drying cycle. There was a significant difference between the soil types in MWDf by the method of fast wetting (Fig. 1b). Gypsum soil (lime less than 15% and gypsum more than 25%) showed the highest increase in the mean weighted diameter, with an increase of 8.02% over calcareous soils (lime more than 25% and gypsum less than 15%). The increase in MWDf at gypsum soil is due to the role of organic acids in covering gypsum grains preventing water from reaching and reducing their solubility during the wetting period. Further, the role of acids resulting from the decomposition of organic matter increases the binding between gypsum granules. There was a significant effect of the interaction between the wetting and drying cycles and the soil types with different gypsum and lime percentages (Table 2). However, the gypsum soils and soils with converging lime and gypsum percentage showed an increase in MWDf in the fast wetting method with increasing wetting and drying cycles until the ninth cycle. There was a great difference in the response of the (MWD) with the wetting cycles in different types of soils with different lime and gypsum percentage. Similarly, the highest (MWD) was in the gypsum soil at the ninth cycle with an increase of 73.35 and 45.33% compared to the first and second cycle respectively, while calcareous soils (lime more than 25% and gypsum less than 15%) recorded the lowest (MWD) in the eighth cycle, with a decrease of 24.70%. The reason for an increase in the gypsum soil is due to the presence of calcium sulfate that changes the microbial activity by changing the level of soil acidity and releasing calcium ions during the wetting process, which leads to the formation of complex compounds (clay - calcium - organic matter). Besides, the deficiency is due to the calcium ion shared between calcium carbonate and calcium sulfate, which had a negative effect on MWDf. The addition of organic acids increased the (MWD) significantly. Moreover, the interaction between organic components and carbonates present in calcareous soils leads to the formation of organic carbon bonds (Kartani et al 2011).

The wetting and drying cycles at slow wetting has a significant effect on the (MWD), as the (MWD) increased by two percentages of 16.78 and 6.83% in the eighth and ninth cycle, respectively, compared to the first cycle (Table 3).

Table 1. Physical and chemical characteristics of the study soil, as FG_1 represents calcareous soils, BG_2 represents soils with converging lime and gypsum percentage, and CG_3 represents gypsum soil

Sample	Silt (g kg^{-1})	Clay (g kg^{-1})	Sand (g kg^{-1})	Texture	Elect conduct. ds m^{-1}	Bulk density Mg kg^{-1}	pH	Gypsum (g kg^{-1})	Lime (g kg^{-1})	Organic matter in soil aggregates (g kg^{-1})
FG_1	40.7	48.7	10.6	Silty clay loam	7.3	1.37	8.12	19.9	61.52	5.5
BG_2	57.3	8.9	33.8		4.8	1.34	7.62	21.8	34.37	10.7
CG_3	30.6	10.9	58.6		14.33	1.33	7.96	56.8	12.64	3.4

Table 2. Effect of different percentages of lime and gypsum in the soil when adding 10% of the extract equivalent of sawdust in (MWD) at the fast wetting by water vapor

Soil type	1	2	3	4	5	6	7	8	9	Average soil type
Lime	0.5113	0.5804	0.5408	0.5679	06103	0.4541	0.5318	0.3850	0.5785	0.5289
Lime and Gypsum	0.4754	0.4793	0.5350	0.53551	0.5583	0.5612	0.5646	0.5878	0.6903	0.5541
Gypsum	0.4139	0.4937	0.5273	0.5353	0.5071	0.6259	0.6198	0.7010	0.7175	0.5713
Average soil type	0.4669	0.5178	0.5344	0.5461	0.5585	0.547	0.5721	0.5579	0.6621	
L.S.D (p=0.05)	Soil type = 0.06203				Interaction = 0.10744			DW cycle = 0.03581		

Table 3. Effect of the difference in lime and gypsum percentage in the soil and the DW cycles when adding 10% of the extract equivalent of sawdust on the MWD (mm) by the slow wetting

DW cycle Soil type	1	2	3	4	5	6	7	8	9	Average soil type
Lime	4.1720	4.1420	4.0230	4.0540	3.594	3.2370	2.9320	4.2990	3.0470	3.7220
Lime and gypsum	2.9370	3.2290	3.2250	3.2390	3.0220	2.8470	3.4420	3.4630	3.6720	3.2310
Gypsum	2.9940	3.0780	3.0690	3.1380	3.0850	3.4200	3.3470	4.0380	4.0740	3.3600
Average soil type	3.3680	3.483	3.4390	3.4770	3.2340	3.1680	3.2400	3.9330	3.5980	
L.S.D	Soil type = 0.3128				Interaction = 0.9385			DW cycle = 0.5419		

Though the values were not significantly affected in the other wetting and drying cycles compared to the first cycle, and it was also evident that the (MWD) decreased insignificantly in the fifth, sixth, and seventh cycles compared to the second cycle, as the decrease percentage reached 7.15, 9.94 and 6.98%, respectively. The eighth cycle had a significant effect on the (MWD), with an increasing percentage of 21.61, 24.15, and 21.39%, compared to the fifth, sixth, and seventh cycle, respectively. As for the rest of the cycles from the second to the seventh and the ninth cycle, it did not have a significant effect, and the reason for this increase in the (MWD) is attributed to the positive and effective role of the wetting and drying cycles in the formation of soil aggregates. As well as, an increasing its stability with the addition of organic matter, as the wetting and drying cycles increase the organic carbon, and maintain it inside the soil aggregates, increase the activity of microorganisms. Likewise, the formation of secretions and fungal hyphae, which positively affect the soil aggregates because of its action as a bonding material between soil particles (Rahman et al 2017, 2018). There was significant difference in the (MWD) at slow wetting for the soil samples and significant decrease of 15.20 and 10.77% in soils was observed with converging lime and gypsum percentage and gypsum soils in order compared to calcareous soils. There was no significant difference between soils with converging lime and gypsum percentage and gypsum soils, and the reason for the decrease may be the increase in positive charges resulting from the increase of calcium ions Ca^{+2} more than the negative charges on the clay particles, which leads to less aggregation between soil particles (Tayel et al 2010). The increase in the (MWD) in slow wetting by steam compared to fast wetting by flood may be due to the homogeneity of wetting distribution of the samples at wetting by steam by capillary action. The water steam will condense in the pores of soil aggregates at approximately the same time. There was no difference in the expansion and swelling of the soil aggregate parts during wetting, while allowing the gradual exit of air. The absence of air explosions inside the aggregates, which leads to the absence of breakage of the aggregates during wetting and the constant distribution of the aggregates and the strong soil aggregates is not affected, as opposed to fast wetting (Al-Nuaymy and Al-Hadithi 2014, Carrizo et al 2015). The significant effect of interaction within the first cycle was observed as soils with converging lime and gypsum percentage and gypsum soils, recorded a decrease of 36.78 and 34.17%, respectively, compared to calcareous soil. Moreover, the ninth session also had a significant effect, as gypsum soil recorded a percentage of an increase of 33.70 compared to calcareous soils, while there was no significant difference when soils with converging lime and gypsum percentage and gypsum soils. The reason for this increase in calcareous soils is attributed to the increase in the binding between mineral components of the soil and calcium ions resulting from calcium carbonate due to the action of acids in the soil solution, which leads to an increase in the formation of aggregates. The microorganisms secretions also play significant role in increasing the binding of soil particles. In gypsum soils is due to the formation of bonds resulting from microbial activity due to the availability of appropriate conditions during the incubation period along with the role of organic acids (humic and fulvic) in the organic extract by interacting with the calcium ions a^{+2} already present in the soil and resulted from calcium sulfate, which contributes to increasing the MWD (Norambuena et al 2014).

The succession of the wetting and drying cycles had a significant effect on the dispersion ratios, as the decrease in the dispersion ratio for the third to ninth cycles reached 3.35, 17.46, 20.55, 12.82, 35.88 38.98, 45.88%, respectively, compared to the first cycle (Table 4). The decrease is due to an increase in binding factors and an increase in organic carbon, which led to an increase in the stability of aggregates with an increase in MWD (Table 2) as a result of adding organic extract and increasing microbial activities (Han et al 2010). There was significant increase in the dispersion ratio for soils with a converging lime and gypsum percentage and gypsum soils compared to calcareous soils (14.02 and 8.54%, respectively), which was due to the decrease in the

Table 4. Effect of the difference in lime and gypsum percentage in the soil and DW cycles when adding 10% of the extract equivalent of sawdust on the dispersion ratio (%)

DW cycle Soil type	1	2	3	4	5	6	7	8	9	Average soil type
Lime	0.5904	0.5473	0.5427	0.4520	0.4220	0.4997	0.43285	0.3786	0.3110	0.4635
Lime and Gypsum	0.6408	0.5893	0.5637	0.4867	0.4900	0.3150	0.4867	0.5107	0.3737	0.5285
Gypsum	0.6465	0.6977	0.6663	0.5750	0.5450	0.4843	0.3327	0.2720	0.3080	0.5031
Average soil type	0.6259	0.6114	0.5909	0.5046	0.4857	0.5330	0.4159	0.3875	0.3309	
L.S.D	Soil type = 0.04502				Interaction = 0.13505			DW cycle = 0.0.7797		

MWD. This can also be due the role of acids in increasing the acidity of the soil and decomposition of calcium carbonate, which is highly soluble in acids and low solubility in water, which leads to breaking the bonds and dispersing the soil particles, as the lime bind the fine soil parts. The increase is can also be attributed to the large role of indirect calcium carbonate in stabilizing organic carbon in calcareous soils through its direct role in stabilizing soil aggregates through the binding of calcium ions with organic carbon, preventing consumption and increasing protection by microbes. The decrease may be because calcium carbonate increases the biological activity and activates its role in the mineralization process of the organic matter, which leads to the loss of Co_2, a decrease in the organic carbon accumulation, and consequently the instability of aggregates (Paradelo et al 2015). There was significant effect of the interaction, as it showed a gradual decrease in the dispersion ratio from the second to the fifth cycle and for all types of soils. The significant difference in the decreasing values of the dispersion ratio from the sixth to the ninth cycle with different soil type was observed as the gypsum soil recorded the highest decrease percentage in the eighth cycle (57.93%), while soils with converging lime and gypsum percentage recorded the lowest decrease percentage in the sixth cycle (2.58%). This is due to improved soil structure and increased stability of aggregates (Table 4). Han (1995) pointed out by explaining the reason for the decrease in the interaction of calcium ions with negatively charged humic acids during the succession of wetting and drying processes that form complexes that may contribute to reducing the dispersion of particles. The establishment of a strong correlation between the soil particles, as well as the succession of wetting and drying processes that transfer the binding agents from points within the soil and its deposition on the contacts between soil particles, depending on the organic matter, soil type and the amount of biomass was observed (Albalasmeh et al 2014).

There was no significant effect of the wetting and drying cycles in available phosphorus (Table 5) except for the third and fifth cycles. There was significant increase for phosphorus for the fifth cycle by 105% compared to the third cycle. However, the amount of available phosphorus decreased by 121 and 81.00% for the sixth and eighth cycles, respectively, compared to the fifth cycles, where the reason for phosphorus deficiency is attributed to the fixation of available phosphorus within the microbial cells after re-wetting (Yevdokimov et al 2016). The increase or decrease in available phosphorous after each wetting cycle may be due to the difference in the microbes type prevailing in the soil, bacteria or fungi, or both, and the size microbes formed in the soil at each wetting and drying cycle (Dinh et al 2017). The amount of available phosphorus increased significantly by 85.68% for gypsum soil, in the first cycle, compared to a calcareous soil (Table 5). Besides, the amount of available phosphorus increased significantly by 46.77% at gypsum soil, compared to soils with converging lime and gypsum percentage. There was no significant difference between soils with converging lime and gypsum percentage and calcareous soils, as the second, fourth, fifth, and sixth wetting cycles affected at gypsum soil compared to a calcareous soil. However, the increase in the amount of available phosphorous may be due to the binding the available phosphorous by releasing high amounts of (soil organic matter) SOM resulting from Humic acids, which is complex with the resulting Ca_2 and thus reducing the phosphorous binding energy in the soil (Tolanur et al 2003). There was significant increase in the amount of available phosphorus in calcareous soils in the second, fourth and fifth wetting and drying cycles by 85.6, 85.83 and 80%, respectively, compared to the first cycle (Table 5). The significant decrease was observed for phosphorus and percentage ranged between 61.89-90.32 from the third to the ninth cycle compared to the second cycle, except for the fourth and fifth cycles. It was also evident that there was a significant increase in the fourth and fifth cycles by a percentage of 90.41 and 86.47, respectively, compared to the third cycle. There was a decrease in the amount of available

Table 5. Effect of the difference in lime and gypsum percentage in the soil and the DW cycles when adding 10% of the extract equivalent of sawdust on the available phosphorous (mg per kg soil)

DW cycle Soil type	1	2	3	4	5	6	7	8	9	Average soil type
Lime	71	496	48	501	355	189	161	188	119	236
Lime and Gypsum	264	30	265	276	438	253	171	115	291	234
Gypsum	496	352	230	48	324	62	490	310	294	290
Average soil type	277	293	181	275	372	168	274	205	238	
L.S.D	Soil type = 91.8				Interaction =275.5				DW cycle = 159.1	

phosphorous for the sixth, seventh and ninth wetting cycles by percentages reached 62.27, 67.86, and 76.24, respectively, compared to the fourth cycle. The last five wetting cycles had no significant effect and the deficiency of available phosphorus in calcareous soils is due to the occurrence of some adsorption, sedimentation. The stabilization reactions was due to the high degree of reaction that changes the state of phosphorous in the soil from available to stabilize, which reduces the readiness of phosphorus in the soil. The addition of sawdust solution improves the ability of soil to retain water and reduces its ability to release available elements (Zhang et al 2020), while the increase is due to the killing and accumulation of microbial cell as a result of soil compaction that destroys the microorganisms inside the soil during the drying process. The re-decomposition during the wetting process, transformed the organic phosphorus into available phosphorus in the soil (Khan et al 2019). The soils with converging lime and gypsum percentage indicated no significant effect except for the second and fifth cycles, as there was significant increase in the amount of available phosphorus for the fifth cycle by 93.15% compared to the second cycle. The amount of available phosphorus decreased by 73.74% for the eighth cycle compared to the fifth cycle. There was a significant decrease in the amount of available phosphorus in the gypsum soil for the fourth and sixth cycles of 90.32 and 87.5% compared to the first cycle, and the same two cycles decreased by 86.36 and 82.38% compared to the second cycle. Despite the amount of available phosphorus for the fifth and seventh cycles increased by 85.18 and 90.20% compared to the fourth cycle and the amount of available phosphorus for the seventh cycle increased by 87.34% compared to the sixth cycle. For the third, fifth, seventh, eighth, and ninth wetting cycles did not significantly affect, and the increase is due to role of organic acids in regulating the degree of reaction of the gypsum soil reducing the sedimentation. In addition to the adsorption processes that occur to phosphorous in the soil as a result of gathering out the exchange sites in soil colloids, and their effective role in the increasing biological activity. Besides their contribution to the production of the phosphatase enzyme, which works to dissolving phosphorous-containing compounds in the soil and increase the available phosphorus (Shafi and Sharif 2019).

Scanning electron microscope analysis of soil: The calcareous soils at the fourth cycle, showed the presence of light-colored soil aggregates that may be due to the presence of microorganisms (Fig. 1 FD_4). The repeated wetting and drying cycles from the appropriate conditions of water and food increased the percentage of oxygen necessary for its growth (Dorner et al 2012). However, the picture BD_4 represents the treatment of soils with converging lime and gypsum percentage for the fourth cycle. There is a wide convexity in the form of big aggregates with smooth edges whose structure appears in the form of mass and lamellar, with clear and large gaps between the aggregates. The CD_4 represents the treatment of gypsum soil for the fourth cycle and indicate that there are many aggregates of uniform shape, the gradient in size, with a lamellar and granular structure, with smooth edges and few clear pores. The FD_8, Fig. 2, represents the treatment of calcareous soils at the eighth wetting and drying cycle, where the aggregates had a mass structure and the pores were more clearly compared to the picture FD_4 respectively, and it was also observed that there was more clear granularity with different sizes. The BD_8 also represent the treatment of soils with converging lime and gypsum percentage for the eighth cycle, in which the presence of granularity appears in a small number. Also the presence of fungi aggregate is widely observed as white color (Alnuaymy and Al-Alousi 2016). The Fig 2, CD_8, represents the treatment of gypsum soil in the eighth cycle, the presence of large granules with the growth of fungi on

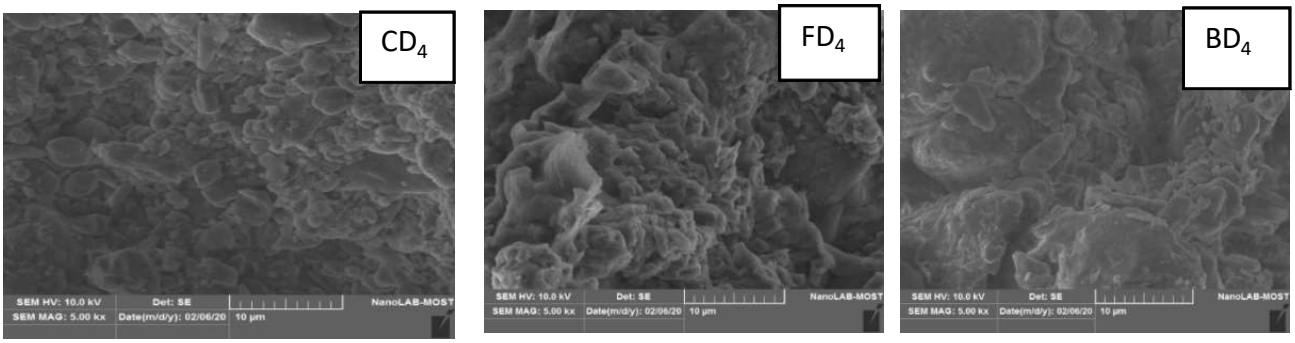

Fig. 1. Images taken with a fine-scanning electron microscope of soil samples treated in the equivalent of 10% of the equivalent extract of sawdust after the end of second wetting and drying cycle, as FD_4 represents calcareous soil treatment, BD_4 soil treatment of converging lime and gypsum percentage and CD_4 gypsum soil treatment

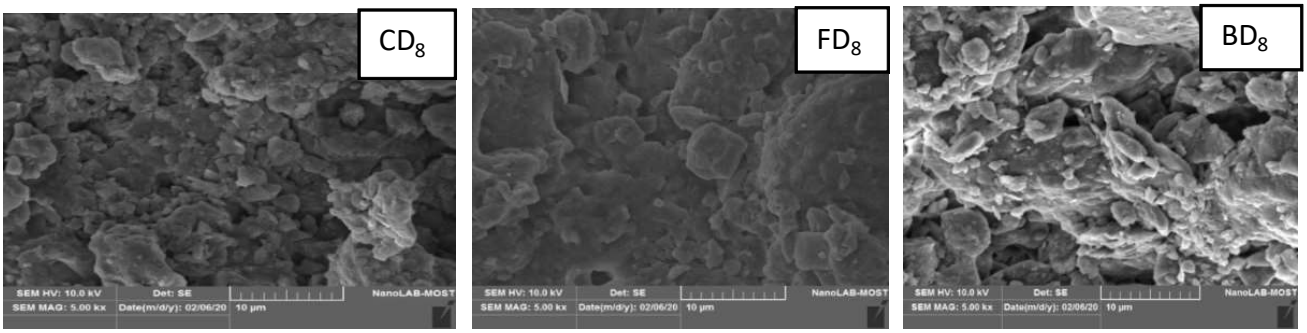

Fig. 2. Images taken with a micro-scanning electron microscope of soil samples treated in the equivalent of 10% of the equivalent extract of sawdust after the end of the eighth wetting and drying cycle, as FD 8 represents calcareous soil treatment, BD 8 soil with converting lime and gypsum percentage treatment and CD 8 gypsum soil treatment

some aggregates and the presence of a large number of pores more clearly. This may be to the high MWD. The increase in aggregates formation is attributed to the role of wetting and drying cycles on the transfer and spread of binder materials such as secretions resulting from a biological activity from inside the soil, Besides sedimentation between contact points for soil particles where colloidal substances act as an effective adhesive to connect between soil particles. Further, the role of the incubation period and the availability of appropriate conditions of water, food, air and the addition of organic matter, as well as the presence of a high percentage of calcium carbonate originally in the soil have led to encouraging the growth of fungi and microbial groups and the formation of stable aggregations. Finally, it was also found that the type of soil and the type and quantity of organic matter has an effect on the formation of aggregates, and this was observed through accurate imaging of the studied samples using an environmental scanning electron microscope (ESEM) (Albalasmeh et al 2014).

CONCLUSION

The sawdust extract played a positive role in improving the MWD of gypsum soils more than calcareous soils. Besides, the wetting and drying cycles had the clear effect of increasing the MWD upon fast wetting (flood) and reducing the dispersion ratio of both types of gypsum and lime soils, and it increased the formation of soil aggregates and the formation of fungus. The sequence of wetting cycles was positively improved with the addition of 10% of the equivalent extract of sawdust. The increase in the number of wetting cycles has increased the levels of available phosphorus in the soil. for The phosphorous contents differ with types of soils in their ability to release available phosphorous according to the different number of wetting cycles, and that gypsum soils are abler to increase content of available phosphorus, starting from the first wetting cycle upwards.

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Analysis of Physical Composition and Nutrient Content of Decomposed Municipal Solid Waste in Fonko Town of Analemo District, Southern Ethiopia

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Abstract: The aim of the present study was to determine the physical composition and status of major nutrient content in the solid waste for waste management practices. Ten randomly collected municipal solid waste samples (10 kilograms) were mixed together and to get a composite sample and then it was spread on a polythene sheet and sorted into different categories for the analysis of physical components in the municipal solid waste. For physic -chemical, major nutrient content, and heavy metal analysis, one kilogram of randomly collected decomposed solid waste was collected from a bottom layer in the dumping site. The physical composition in the solid waste revealed the presence of food, ash, yard, paper, plastic, glasses, and metal waste. Among the identified physical composition of municipal solid waste showed the highest proposition of food waste (43.07%) followed by ash content (16.9%) and paper waste (15.5%). Therefore, the municipal solid waste contains more percentage of bio-degradable waste (85.71%). The electrical conductivity (EC) was 1.58 ds/m, pH is 6.23, and moisture content was 46.44% inthe municipal solid waste. The major nutrient content analysis revealed the presence of a sufficient quantity of organic carbon, total nitrogen, phosphorus, and potassium in the municipal solid waste. The heavy metal in the study area indicated the presence of copper, zinc, iron, manganese, lead, chromium, and nickel. Among the selected heavy metals iron showed the highest quantity in the study area next to zinc and copper. The analysis of physico-chemical and major nutrient content in the municipal solid waste indicates that favorable conditions as well as good source of nutrients for which can be used as organic fertilizer or soil alteration to the composting process.

Keywords: Physical composition, Nutrient content, Municipal solid waste, Fonko town

Solid waste is a serious environmental problem in both developing and underdeveloped countries. Inadequate management of solid waste leads to problems that impair human and animal health and ultimately result in economic, environmental, and biological losses (Ramachandra et al 2018).An efficient system for MSW management requires a good knowledge of the characterization of solid wastes to be disposed of. The recoverable matter, as well as selection and functioning of collection and transportation equipment, energy transformation, mostly related to the physical composition of solid wastes and design of proper disposal methods (Rishi Rana et al 2018). Most of developing countries have newly started refining their municipal solid waste management practices. The physical composition includes food and drink cans, plastic containers, scrap metal, and plastic bags. Depending on the characteristic threats connected with its physical and chemical properties, solid waste can be categorized as either hazardous or non-hazardous. Hazardous (harmful) waste possesses potential threats to the environment. Substances such as toxic, infectious, and corrosive are classified as hazardous. Those wastes do not possess hazardous characteristics considered as non-hazardous wastes and are not harmful to people and the environment. Rapid population growth and expanding urbanization have caused a drastic increase in municipal solid waste generation and the variety of waste composition (Ramachandra et al 2018). Municipal solid waste (MSW) consists of all types of solid waste generated by households and commercial establishments and collected usually by local government bodies (Jasir Mushtaq et al 2020) Established countries are able to accomplish the several types of waste to an acceptable level, opposing to developing nations like Ethiopia which are still harassed to deal with the problem of proper management of solid wastes. Moreover, the current proportion of urbanization municipal solid waste assortment, transportation, and dumping has been a major problem of municipalities in most of the Ethiopian cities significant amount of research work has been conducted on solid waste management in Ethiopia (Abiot et al 2012, Feleke 2015). For sustainable management of this waste, it is very important to know the physical and chemical composition of the waste for the waste management practices. Therefore, the present study was carried out to determine the Physical composition, physic-

chemical, and major nutrient content in the municipal solid waste.

MATERIAL AND METHODS

Study area: Fanko is one of the capital towns of the Analemo District in the Hadiya Zone of the Southern, Nations, Nationalities, and Peoples' Region of Ethiopia. It is located between 70 15' 47" to 80 08' 32" North latitude and 37041'55" to 380 18' 25" East longitude and it is bordered on the southwest by Lemo *woreda*, on the north by the Silte zone, and on the southeast by Shashogo woreda. The study area is situated at about 130 km northwest of the regional town Hawassa and 230 km from Addis Ababa, to through the asphalt road from Addis Ababa to the Hosanna town that passes via towns of, Wolait Sodo, Arbminch, Ethiopia.

Collection of municipal solid waste for physical composite: Ten sample sites were selected from the bottom layer (decomposed) of the municipal solid waste dumping site in the study area and were mixed together and to get a composite sample. The composite sample was dried on the polythene sheath and was subjected to further analysis.

Physico chemical composition of decomposed municipal solid waste: Fifty grams of fresh compost samples of food and yard waste were weighed and dried at 105°C for 24hr. After this sample was removed from the oven and cooled indesiccators for 30min and weighed. The percentage moisture was calculated. For the pH estimation 10 grams of the sample was placed in a flask; to this 500 ml, distilled water was added and stirred for 3 to 5minutes. The mixtures were allowed to settle for 5 minutes and pH was measured by using a pH meter with a glass electrode (Philippe and Culot 2009).The Electrical conductivity of a 1:1 aqueous extract was measured and the reading was corrected to conductivity at 25ºC sample saturation with chemical method (Rhoades 1996).

Nutrient content in decomposed municipal solid waste: Total nitrogen content was analyzed using the Kjeldahl digestion (Hogarh 2012) and total organic carbon content in the samples by Walkley and Black (1934). Total phosphorus in compost samples requires conversion of insoluble phosphates to soluble forms by digestion with a mixture of nitric acid and sulphuric acid. The total potassium and phosphorus contents in compost are estimated by conversion of insoluble potassium/phosphorus to soluble forms by digestion with a mixture of nitric acid and sulphuric acid. The potassium content in the solution was estimated with a flame photometer (Hogarh 2012) and phosphorus by spectrophotometer.

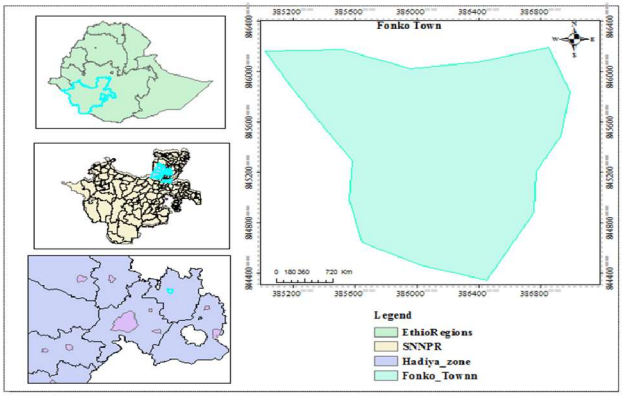

Fig. 1. Location map of Fonko town

RESULTS AND DISCUSSION

Physical composition of municipal solid waste: The physical composition of the municipal solid waste from different sources was identified (Table 1). The major dominant sources of municipal solid waste in the study area were residential, commercial and institutional area. The physical composition revealed the presence of food, ash, yard, paper, plastic, glasses, and metal waste. The food waste showed the highest percentage (50.8%) in the residential areas followed by commercial and institutional areas. However, ash content was not observed in the institutional area. In addition to this more yard waste (11.7%) was observed in the residential areas. In high proposition paper waste (34.3%) was observed in the institutional area and least (2.3%) in a residential area. Moreover, plastic glass and metal waste were observed more in the institutional areas followed by commercial.

Among the identified physical composition of municipal solid waste showed the highest proposition of food waste (43.07%) followed by ash content (16.9%) and paper waste (15.5%). The municipal solid waste contains more percentage of bio-degradable waste (85.71%). The inorganic fraction accounts for 14.30 %. This indicates that the

Table 1. Physical composition of municipal solid waste from different sources

Composition	Residential (%)	Commercial (%)	Institutional (%)	Average (%)
Food	50.8	47.21	31.2	43.07
Ash	26.7	24	-	16.9
Yard	11.7	9	10	10.23
Paper	2.3	9.89	34.3	15.5
Plastic	3.5	4.5	14	7.33
Glasses	1.5	2.6	4.2	2.77
Metal	1.5	1.2	4	2.23
Others	2	1.6	2.3	1.97
Total	100	100	100	100

composition of organic waste was dominated by food waste (mixed). It mainly includes leftover food residue, vegetable waste, leaves, and decayed vegetables, The finding was similar to study conducted in Hosanna town in Ethiopia (Endalu and Habtamu 2014) and Numan town in Nigeria (Abubakar et al 2018).

Physico chemical characterization of decomposed municipal solid waste: The average moisture content in the study areas was 46.44%. The large quantity of moisture in the garbage is mainly contributed by cooked waste material. The results were somewhat similar to that reported by Jasir Mushtaq et al (2020) and recommend a moisture range of 45-65%. The moisture content of the wastes was very important for degradation rate, landfills, and leachate quality was determined. The specific physicochemical properties and biological material being composted to contribute to the optimum moisture content. Compost with low moisture content (<35%) may be too dry and dusty and irritating when handled. Compost with too high moisture content (>65%) can become too clumpy and difficult to transport which will limit its chances of being advertised as a quality product. The pH value of municipal solid waste in Fonko town was 6.23. In comparison to another finding, there was not as much variation in the pH content of the samples. Rawat et al (2013) observed pH values of the composite 5.5-8.5. The pH level was an important parameter in the composting process. It affects microbial activities during composting microbial activities become limited when the pH was outside the optimal range (Chen et al. 2015). The electrical conductivity (EC) was 1.58 ds/m in municipal solid waste. The EC indicates the total salt content of compost reflecting the quality of compost to be used as a fertilizer (Awasthi et al 2014). The electrical conductivity of compost was dependent on the amount of the soluble salts present in it, the lower EC of the MSW decreased the concentration of salt present in the food waste as a result of degradation of organic matter that results in the release of bases and nutrient content. High salinity levels (when suspended solids concentrations are greater than 10-15) can be toxic to plants (Giacomo Luigi et al 2019)

Nutrient content in decomposed municipal solid waste: The total organic carbon of MSW samples was 38.2% (Gautam et al 2010) also observed high concentration of carbon in MSW (38%), The total nitrogen content in the study area of the MSW was 1.29% Abebe (2015). This finding also observed 0.7 to 1.8 % of the nitrogen in MSW compost may contain N on a dry weight basis. The concentration and availability of nitrogen in compost were very important to assess when considering its agronomic value. Nitrogen was an essential nutrient for successful plant production. The phosphorous concentration of compost samples was 5587.93 ppm. This finding was comparable to the other in Ethio-highland and ZK farms (Abebe 2015). Phosphorous was also an important nutrient for plant growth. The higher the content of the phosphorus in compost and this indicated the greater fertilizer value of the compost in the study area. As the levels of these elements were generally higher, application rates might be required when they are to be used for soil fertilization (Hogarh 2012). The total Potassium was 7034.90 ppm. Potassium was highly soluble in the wastes was one of the macronutrients that were required by plants in large amount for growth and development. Potassium in its available form in compost exists as K_2O (Sudharsan 2013). Therefore, potassium was leached easily. The insoluble potassium salts can be solubilized by the decomposition of the wastes (Rawat et al 2013). Moreover, Vidyasagaran and Vikas Kumar (2017) reported that use of municipal garbage for the growth nursery plant showed the highest growth parameters. This indicates that municipal solid waste contain good source of nutrient content for plant growth and development.

Heavy metal content in decomposed municipal solid waste: Heavy metals such as copper, zinc, iron, manganese, lead, chromium, and nickel were analyzed (Table 4). Among the selected heavy metals zinc was maximum followed by copper and iron highest quantity in the study area next to zinc and copper. The least quantity of heavy metal was manganese and nickel.

Anjanapriya and Lalitha (2016) observed that concentrations of heavy metals such as copper, zinc, iron, manganese, lead, chromium, and nickel in decompose municipal solid waste did not exceed the limits when compared with Indian and USEPA standard. The presence of lead (Pb), cadmium (Cd), copper (Cu), and nickel (Ni) is

Table 2. Physico chemical composition of decomposed municipal solid waste

Parameters	Average value
Moisture content	46.44 %
pH value	6.23
Electrical conductivity	1.58 ds/m

Table 3. Major nutrient composition of decomposed municipal solid waste

Parameters	Average value
Organic Carbon (%)	38.2
Total nitrogen (%)	1.29
Phosphorous ppm	5587.93
Potassium ppm	7034.90

Table 4. Heavy metal composition of decomposed municipal solid waste

Parameters	Average value
Copper (ppm)	195
Zinc (ppm)	160
Iron (g kg^{-1})	530
Manganese (ppm)	23
Lead (ppm)	25
Chromium (ppm)	40
Nickel (ppm)	12

potentially toxic to plants and animals and get accumulated in the food chain. Zinc (Zn) is a necessary micronutrient for plants but at a high level is phytotoxic and might reduce the fertility of the land. In addition to this, Omer et al (2021) reported that presence of more concentration of heavy metal nearby solid waste dumping site water sample. Therefore, continuous dumping of wastes can disturb natural soil physical, chemical, and biological characteristics, pollute groundwater, and causes a hazardous impact on human health.

CONCLUSIONS

The physical composition of municipal solid waste showed the major component of the wastes was organic or biodegradable waste which accounts for about 85.7% of the average value within 7 days, which was an easily degradable and relatively very low concentration of toxic materials. Organic waste was dominated by food waste. The inorganic fraction accounts for 14.3 %. Physicochemical properties of municipal solid waste were analyzed, moisture content, pH and electrical conductivity showed the value of 46.44, 6.23, and 1.58ds/m respectively. The major nutrient content revealed the presence of a sufficient quantity of organic carbon, total nitrogen, phosphorus, and potassium. This study also exposed the presence of heavy metals such as copper, zinc, iron, manganese, lead, chromium, and nickel. Among this highest value was observed for iron followed by zinc and copper. The analysis of physico-chemical and major nutrient content in the municipal solid waste indicates that good sources of nutrients for which can be used as organic fertilizer or soil alteration to the composting process.

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Influence of Agronomic Management Practices on Rhizosphere Microbial Biodiversity in Coleus [*Plectranthus rotundifolius* (Poir.) J.K. Morton]

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***Abstract*:** An investigation was conducted at, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala to assess the influence of method of planting, nutrient management practice with consortium biofertilizer (INM) and growth promoters in coleus on the diversity of microbiome population in rhizosphere. The experiment was laid out in split plot design with five main plots and six subplot treatments, replicated four times. The main plot treatments included five methods of planting and six sub plot treatments involving combinations of two nutrient management practice and three growth promoter. The population of microbes (*Azospirillum lipoferum*, *Azotobactor chroococcum*, *Bacillus megaterium, Bacillus sporothermodurans*, fungi and actinomycetes) among the methods of planting were higher in raised beds planted at a closer spacing (30 cm x 15 cm) and the crop management practice of manuring with 60:30:120 kg NPK ha^{-1} + PGPR Mix 1 @ 2 per cent, irrespective of the growth promoter applied. Highest counts were recorded for bacteria and, the genera *Bacillus sporothermodurans* was most prominent. The interaction effect of main plot and subplot treatments revealed higher population of microorganisms in bed planting with closer spacing, nutrient management practice of 60:30:120 kg NPK ha^{-1} + PGPR Mix 1 and irrespective of the growth promoter.

***Keywords*:** Coleus, Growth promoters, Planting method, Microbes, Nutrient management, Rhizhosphere

Rhizosphere is a dynamic system controlled by the combined effects of soil properties, plants characteristics and the interactions of plant roots with microorganisms and the surrounding soil (Bowen and Rovira 1999). Soil properties, especially the biological properties in the rhizosphere soil, are markedly different from the bulk soil. Plant roots secrete a wide range of organic compounds in the rhizospheric region which act as food source for microbial communities to increase microorganism density and other activities in the rhizospheric region compared to bulk soil (Kushwaha et al 2020). This assumes significance in crop production as the rhizospheric microbial activities to a large extent govern root growth, nutrient uptake, mobilisation and performance of the crop. Schmidt et al (2019) observed that the crop rhizosphere microbial communities are greatly influenced by crop management practices. The rhizosphere has a unique biophysical and biogeochemical environment shaped by plant roots in their interdependent and dynamic interaction with soil microbial communities (Canto et al 2020). Coleus [*Plectranthus rotundifolius* (Poir.) J.K. Morton] is cultivated in many parts of the world for its edible tubers. The proper agronomic management practices including land preparation, optimum planting time, crop geometry, plant population, nutrient and weed management paly significant role in higher productivity (Kabir et al 2004, John et al 2016, Nedunchezhiyan et al 2018). The importance of microbial activity in soil governing the nutrient availability and favourable soil properties influencing crop growth and yields have also been documented (Nedunchezhiyan et al 2018). Nevertheless, research works on the influence of the management practices on the rhizospheric microbial diversity that would have contributed to the better yields have been less explored. Schmidt et al (2019) mentioned that agricultural management practices such as fertilization and tillage shape microbial communities in bulk soil, but little is known about how these practices affect the rhizospheric composition. Inoculation with rhizobacteria apparently caused changes in the microflora colonizing the roots and stolons, which in turn brought about a better growth and yield and would have immense significance in a crop like coleus as this is a tuber crop and the economic part, roots. In this background, the paper attempts to assess the microbial diversity in the rhizosphere soil in coleus raised under different agronomic management practices in the southern laterites of Kerala, India.

MATERIAL AND METHODS

The field experiment was conducted at College of Agriculture, Vellayani, and Thiruvanathpuram, Kerala, India located at 8.5° N latitude and 76.9° E longitude and 29 m above mean sea level (MSL), during October 2019 to February 2020. The soil of the experimental site was sandy

clay loam with an acidic pH (6.05) and high in organic carbon (1.05%). The photo insensitive coleus variety, Suphala released from Kerala Agricultural University was used for the study. The experiment was laid out in split plot design with five methods of planting as main plots and six combinations of nutrient management practices (two) and growth promoters (three) as subplot treatments with four replications. The main plot treatment, method of planting included, m_1: bed method (30 cm x 15 cm), m_2: bed method (30 cm x 30 cm), m_3: ridge method (30 cm x 15 cm), m_4: ridge method (30 cm x 30 cm), m_5: mound method (30 cm x 30 cm). Nutrient management practices n_1: 60:30:120 kg NPK ha^{-1} + PGPR Mix 1; n_2: 60:30:120 kg NPK ha^{-1}) and growth promoters g_1: humic acid @ 5 g L^{-1}; g_2: benzyl adenine @ 50 mg L^{-1}; g_3: water spray, in combination comprised the subplot treatments. The land was ploughed with cultivator followed by rotavator and field was uniformly manured with recommended dose of farm yard manure @ 10 t ha^{-1}. Healthy vine cuttings of size 10-15 cm were planted in the spacings fixed as per treatments. Half the dose of nitrogen (N) and potassium (K) and full dose of phosphorus (P) were given basally and remaining quantity of N and K at 45 days after planting (DAP). The chemical sources used were urea (46 % N), rock phosphate (20 % P_2O_5) and muriate of potash (60 % K_2O). The biofertilizer, PGPR Mix 1 (N fixers, *Azospirillum lipoferum*, *Azotobactor chroococcum*, P solubiliser, *Bacillus megaterium* and K solubiliser, *B. sporothermodurans*) developed in the Department of Agricultural Microbiology, College of Agriculture, Vellayani was mixed with FYM @ 2 per cent, and 5g of the mixture was applied per plant thrice, at the time of planting, 30 DAP and 60 DAP in n_1. Humic acid (Shiviproducts all purose organic humic acid) @ 5 g L^{-1}, benzyl adenine (Alfa Aesar™) @ 50 mg L^{-1} and irrigation water with a spray volume of 500 L ha^{-1} were used as g_1, g_2 and g_3 treatments respectively. All cultural operations were done as per the package of practices recommendation (KAU 2016) and the crop was harvested when the top portion started drying (140 DAP). Rhizosphere soil samples were collected after uprooting the tubers. The bulk soil from the tubers were shaken and the adhering soil were taken as rhizosphere soil samples. These were used for the enumeration of microorganisms afresh, adopting the serial dilution agar plate method. The different microorganisms were also isolated using the media by adopting the standard procedures (Johnson and Curl 1972) (Table 1). A dilution of 10^6 was used for *B. sporothermodurans,* and 10^5 for *Azotobacter* and actinomycetes, 10^4 for *Azospirillum, B. megaterium* and fungi, and the counts were expressed in cfu g^{-1} of soil.

Table 1. Media used for isolation and initial microbial population of the experimental site

Organism	Media	Count (cfu g^{-1} soil)
A. lipoferum	Nitrogen Free Bromothymol Blue (NFB) medium	1.5×10^4
A.chroococcum	Jenson's medium	1×10^5
B. megaterium	Pikovaskaya's medium	1×10^4
B. sporothermodurans	Nutrient Agar medium	1×10^6
Fungi	Rose Bengal agar medium	3×10^4
Actinomycetes	Kenknights medium	2×10^5

RESULTS AND DISCUSSION

Effect of methods of planting (M): The bed method with planting at closer spacing, 30 cm x 15 cm (m_1) recorded significantly higher population for all the microbes assessed, bacteria, fungi and actinomycetes. Manipulation of the soil to form beds, ridges and mounds loosens the soil and improves the porosity and this has a strong impact on soil microbial community. The soil pores define regions with high microbial activity related to carbon turnover and sequestration (Canto et al 2020). Further, raised bed planting optimizes water holding capacity and conductivity of soil solutions, increasing bacterial counts via enhanced aeration/porosity of soil (Hemmat and Eskandari 2004, Patino-Zúniga et al 2009). Zhang et al (2012) also observed higher population of bacteria, fungi and actinomycetes in raised bed planting which is supported by the improved physical properties associated with formation of raised beds. The counts were lower with wider spacing of 30 cm x 30 cm in the modified methods of planting compared to the closer spacing. This may be attributed to the higher plant population and root density that arise with closer spacing. Plant roots play an active role in designing the soil and rhizospheric environment (Costa et al 2006, Haichar et al 2012) and the root surface area determines the extension of the rhizosphere effect (Dotaniya and Meena 2015). The roots release a variety of organic compounds that are responsible for enhancing microorganism population in rhizosphere zone due to increased availability of carbon (C) for food and energy (Aira et al 2010). As these root exudates represent an easily degradable nutrient source for microorganisms allowing rapid proliferation, larger the root volume higher will be the microbial population. Arguably this would be the plausible reason for the higher counts observed in closer spacing. The population of bacteria was maximum followed by actinomycetes and fungi. Dotaniya and Meena (2015) reported that the rhizosphere effect is higher for bacteria > fungi > actinomycetes > protozoa. Among the different species of bacteria enumerated, population of *B.*

sporothermodurans was highest in ridge planting (m_3) with a spacing of 30 x 15 cm (2.75 x 10^6) and on par with bed method with the same spacing (2.67 x 10^6). The populations of *A. lipoferum* (7.25 x 10^4 cfu g^{-1} soil) and *B. megaterium* (4.88 x 10^4 cfu g^{-1} soil) were superior in bed method of planting with lower spacing (m_1) followed by ridge planting (m_3) with a spacing of 30 x 15 cm. Ridge and mound methods with planting at 30 cm x 30 cm spacing (m_4 and m_5 respectively) recorded lower populations of *Azospirillum* and were on par whereas the lowest count of *B. megaterium* was enumerated in the ridge method with spacing of 30 cm x 30 cm. The similar trend of higher counts of in bed and ridge method of planting with lower spacing of 30 cm x 15 cm were recorded for *A. chroococcum,* the population being 5.50 x 10^5 and 5.75 x 10^5 cfu g^{-1} soil in m_1 and m_3 respectively. Fungal (13.08 x 10^4 cfu g^{-1} soil) and actinomycete (6.9 x 10^5 cfu g^{-1} soil) populations were significantly the highest in bed method of planting with lower spacing of 30 cm x 15 cm (m_1) followed by ridge planting with a spacing of 30 cm x 15 cm (m_3) in the case of fungi. The lowest counts of fungi and actinomycetes were recorded in m_4, ridge method (30 cm x 30 cm). The variations in specific species also followed the same trend as the total counts, confirming that the closer spacing was primarily responsible for the increased counts.

Effect of nutrient management and growth promoter (N x G): The combination of nutrient management and growth promoter registered significant influence on microbial population. Irrespective of the growth promoters, all the treatments which involved an integrated nutrient (INM) package, 60:30:120 kg NPK ha^{-1} + biofertilizer, PGPR Mix 1 recorded the highest population of all microbes enumerated under study. The results corroborate the findings of Vijendrakumar et al (2014) and Gopi et al (2020). Vijendrakumar et al (2014) observed that dual and triple inoculation of biofertilizers resulted in maximum counts in soil with respect to both beneficial and general microflora. The lowest population of microbes was recorded in plots without PGPR mix 1. It is apparent that the N fixers, P and K solubilisers in the consortium biofertilizer augmented the microbiome in the rhizosphere. In addition the better nutrient availability, uptake and hence the growth and photosynthetic efficiency with INM would resulted in proliferated root growth, exudation of organic substances that enhanced microbial activities. Photosynthates are comprised mainly of carbon compounds, electrons, protons, water, and inorganic ions, which all enter the rhizosphere as root exudates (Olanrewaju et al 2019). .

Interaction effect of methods of planting, nutrient management and growth promoter (M x N x G): The interaction effect of methods of planting and combination of nutrient management and growth promoter on the count of microbial population was significant. The population of *Azospirillum* (9.50 x 10^4 cfu g^{-1} soil) was highest in combination, bed method (30 cm x 15 cm) + 60:30:120 kg NPK ha^{-1} + PGPR Mix 1 and benzyl adenine spray ($m_1n_1g_{2)}$ and on par with $m_1n_1g_1$ and $m_1n_1g_3$ (9.25x10^4 cfu g^{-1} soil). The

Table 2. Effect of methods of planting and combination of nutrient management and growth promoter on microbial count (cfu g^{-1} soil)

Treatment	*A. lipoferum* (10^4)	*A. chroococcum* (10^5)	*B. megaterium* (10^4)	*B. sporothermodurans* (10^6)	Fungi (10^4)	Actinomycetes (10^5)
Methods of planting						
m_1	7.25	5.50	4.88	2.67	13.08	6.92
m_2	3.83	4.33	2.83	2.04	9.33	4.17
m_3	5.62	5.75	3.88	2.75	10.46	4.21
m_4	2.79	3.42	1.71	1.54	4.83	3.25
m_5	2.96	2.38	2.25	1.75	9.38	4.17
CD (p=0.05)	0.33	0.38	0.28	0.46	0.39	0.37
Nutrient management x growth promoter						
n_1g_1	5.55	5.60	4.5	2.75	12.65	4.95
n_1g_2	5.75	5.70	4.65	2.70	12.85	5.15
n_1g_3	5.50	5.45	4.45	2.70	12.75	4.90
n_2g_1	3.35	2.85	1.6	1.65	6.00	4.05
n_2g_2	3.45	3.10	1.75	1.55	6.20	4.15
n_2g_3	3.35	2.95	1.7	1.55	6.05	4.05
CD (p=0.05)	0.28	0.32	0.34	0.30	0.42	0.52

closer spacing, INM and foliar spray (growth promoter/ water spray) recorded higher counts of *Azotobatcter* in both bed and ridge method of planting. The values ranged between 7.25 to 7.50 x 10^5 cfu g^{-1} soil. The *Bacillus* sp. *B. megaterium* and *B. sporothermodurans* also recorded similar trends indicating the superiority of closer spacing, INM and foliar spray in enhancing beneficial bacteria in the root zone. The highest counts of fungi (16.5 x 10^4 cfu g^{-1} soil) were combination $m_1n_1g_3$ which was on par with $m_1n_1g_1$ and $m_1n_1g_2$. In actinomycetes, $m_1n_2g_3$ recorded the highest count of 7.25 x 10^5 cfu g^{-1} soil, but was on par with the treatments comprising of bed method of planting with lesser spacing (30 cm x 15 cm), irrespective nutrient and growth promoter along with $m_5n_1g_2$. The higher microbial counts in bed method of planting (30 cm x 15 cm) with 60:30:120 kg NPK ha^{-1} + PGPR Mix 1 is a reflection of the individual effects in combination. The favourable environment for root and canopy spread would have enhanced the rhizodeposits and created a niche for microbial activity. The microbes help plants to grow and function more effectively by increasing plant pathogen

Table 3. Interaction effect of methods of planting and combination of nutrient management and growth promoter on microbial count (cfu g^{-1} of soil)

Treatments	*A. lipoferum* (10^4)	*A.chroococcum* (10^5)	*B. megaterium* (10^4)	*B. sporothermodurans* (10^6)	Fungi (10^4)	Actinomycetes (10^5)
$m_1n_1g_1$	9.25	7.50	6.25	3.50	16.25	6.50
$m_1n_1g_2$	9.50	7.50	6.50	3.75	16.25	7.00
$m_1n_1g_3$	9.25	7.25	6.25	3.75	16.50	6.75
$m_1n_2g_1$	5.25	3.50	3.25	1.75	9.75	7.00
$m_1n_2g_2$	5.25	3.75	3.50	1.50	10.00	7.00
$m_1n_2g_3$	5.00	3.50	3.50	1.75	9.75	7.25
$m_2n_1g_1$	5.25	5.50	4.25	2.75	11.25	5.25
$m_2n_1g_2$	5.50	5.75	4.50	2.75	11.50	4.50
$m_2n_1g_3$	5.25	5.25	4.25	2.50	11.25	4.50
$m_2n_2g_1$	2.25	3.00	1.25	1.50	7.25	3.75
$m_2n_2g_2$	2.50	3.25	1.50	1.25	7.50	3.50
$m_2n_2g_3$	2.25	3.25	1.25	1.50	7.25	3.50
$m_3n_1g_1$	6.00	7.25	6.25	3.25	15.25	4.25
$m_3n_1g_2$	6.25	7.50	6.50	3.25	15.50	4.50
$m_3n_1g_3$	6.00	7.25	6.25	3.00	15.25	4.25
$m_3n_2g_1$	5.25	4.00	1.25	2.25	5.50	4.00
$m_3n_2g_2$	5.00	4.25	1.50	2.50	5.75	4.25
$m_3n_2g_3$	5.25	4.25	1.50	2.25	5.50	4.00
$m_4n_1g_1$	3.50	4.50	2.25	2.00	6.25	3.00
$m_4n_1g_2$	3.50	4.75	2.50	1.75	6.50	3.50
$m_4n_1g_3$	3.25	4.25	2.25	2.00	6.25	3.25
$m_4n_2g_1$	2.00	2.25	1.00	1.25	3.25	3.25
$m_4n_2g_2$	2.25	2.50	1.25	1.25	3.50	3.25
$m_4n_2g_3$	2.25	2.25	1.00	1.00	3.25	3.25
$m_5n_1g_1$	3.75	3.25	3.50	2.25	14.25	5.75
$m_5n_1g_2$	4.00	3.00	3.25	2.00	14.50	6.25
$m_5n_1g_3$	3.75	3.25	3.25	2.25	14.50	5.75
$m_5n_2g_1$	2.00	1.50	1.25	1.50	4.25	2.25
$m_5n_2g_2$	2.25	1.75	1.00	1.25	4.25	2.75
$m_5n_2g_3$	2.00	1.50	1.25	1.25	4.50	2.25
CD (p=0.05)	**0.63**	**0.74**	**0.77**	**0.69**	**0.96**	**1.18**

resistance, retain more water, take up and utilize more nutrients and, in general, increase their growth (Olanrewaju et al 2019). The microbiota vary with the root exudates and other rhizodeposits secreted by plants (Moe 2013). C_3 and C_4 plants show variations in the types of exudates released into the rhizosphere, with C_3 plants are reported to exude more carbohydrates and organic carbons (Nabais et al 2011) and C_4 plants, higher numbers of organic acids and amino acids compared to C_3 plants. Coleus is a C_3 plant and microbes that have affinity for the mannose, maltose, and ribose sugars are more prominent in its rhizosphere. Augmentation with PGPR Mix I contributed to the increased microbial activity in the rhizosphere. The mutualistic relation the co-exists in the soil-plant- microbe interface regulates and induces responses in the rhizosphere which ultimately governs organic matter decomposition, nutrient acquisition, biotic and abiotic stress tolerance in the crop plants.

CONCLUSIONS

The agronomic management practice for a favourable rhizosphere manipulation in coleus would include a land preparation of raised beds with planting at a spacing of 30 cm x 15 cm, manuring with the nutrient dose of 60:30:120 kg NPK ha^{-1} + PGPR Mix 1 @ 2% with 5 g per plant and irrespective of growth promoter spray.

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Influence of Organic Formulations as Foliar Sprays on Yield Attributing Traits of Onion (*Allium cepa* L.)

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Abstract: The present investigations with five promising onion varieties of Haryana region were selected viz. Pusa Riddhi, Pusa Madhavi, NHRDF Red, Pusa Red and AGLR were conducted for yield potential. Three organic formulations were applied as pre- harvest spray viz., neem based formulation (Besara), Panchgavya, *Trichoderma viride* (bio shield) and Control (water). Organic formulations sprayed as foliar application at the interval of fifteen days on pre-harvest gave better results in yield and yield attributing characters of onion as compared to control condition. Panchgavya applications resulted in maximum plant height, number of leaves, bulb diameter and bulb weight irresptives of onion varieties. Among the onion varieties Pusa Riddhi exhibited maximum plant height, number of leaves, bulb diameter and bulb weight. Minimum response was in onion varieties treated with *Trichoderma viride.*

***Keywords*:** Onion, Organic formulations, Varieties, Yield attributes

Onion (*Allium cepa* L.) is one of the oldest bulbous crops known to mankind and consumed worldwide in various cooked and raw forms. It is one of the most important commercial horticultural vegetable crops and is of global commercial importance. It is grown in almost all part of the world and believed to be originated in central Asia (Kukanoor 2005). India ranks second in the production of onions next to china and contribute about 19.25% of total world production (FAO 2018).The other leading onion producing countries apart from china and India are United States of America, Turkey and Pakistan. In the year 2017-18, India exported about 1588985 MT of fresh onion to the world amounting to 479.32 million USD. The major export destination included Bangladesh, Sri Lanka, Malaysia, UAE and Nepal (APEDA 2018). It is also reported that productivity of India (14.35 t ha^{-1}) is 5 times less compared to Republic of Korea (66.16 t ha^{-1}), 4 times less than USA (56.13 t ha^{-1}), Spain (55.21 t ha^{-1}), Netherland (51.64 t ha^{-1}) and Myanmar (46.64 t ha^{-1}) (Chengappa et al 2012). The conventional methods of fertilization and application of inorganic chemicals have helped in both i.e. the bulb yield and the bulb quality. But, in India the routine management practice appear to be incapable of maintaining yield over the long period. The steady reduction of soil fertility and occurrence of several nutrient deficiencies in onion field has led to the reduced onion production (Sharma et al 2003).

In past few years, organic agriculture is getting hold of movement in India (Gopal 2015) due to individual as well as group efforts to protect environment and contamination of farm produce from use of chemical fertilizers and pesticides. Since, Onion is a bulbous crop and is capable of scavenging heavy metals from soil or contaminated irrigation water, applied chemicals etc., poses severe health hazard. It is really crucial to develop ecological and eco-friendly noble agricultural practices through organic resources based on scientific facts so that safe and hygienic production of onion crop could be achieved (Worthington 1998, Kannaiyan 2000). During the past ten years a gradual shift in affinity towards organically grown produce has been noticed and as a result of which demand of organically grown onion has also been seen increasing (Naik et al 2014). Presently, India is ranked 10th among the countries in terms of area under organic certification. India produced approximately 1.24 million MT of certified organic products in all varieties of foods (APEDA 2018). Since, State of Haryana is among top 10 leading onion producing states of the country, an attempt was made through this study to evaluate quality of five major promising onion varieties of Haryana region (Pusa Riddhi, Pusa Madhavi, NHRDF Red, Pusa Red and AGLR) and effect of different organic formulations (applied as foliar sprays during growth period) on quality and yield.

MATERIAL AND METHODS

Present investigation conducted at National Institute of Food Technology Entrepreneurship and Management (NIFTEM), Sonepat, Haryana during *Rabi* seasons of 2014-

16. Seedlings of five indigenous varieties of onion obtained from regional station IARI, Karnal, Haryana (Pusa Riddhi, Pusa Madhavi) and from regional station National Horticulture Research and Development Foundation (NHRDF), Karnal, Haryana (NHRDF Red, Pusa Red and AGLR) were used as experimental materials. The field experiment was conducted in randomized block design (RBD) with three replications. The seedlings were planted in plot size of 10 m x 4 m. with plant to plant spacing of 10 cm and row to row spacing 15 cm.

Four different treatments *viz.* Neem based formulation (Besara) @20 ml L^{-1}, Panchgavya @100ml L^{-1}, *Trichoderma viride* (Bio Shield) @50g L^{-1} and untreated control were subjected in form of foliar spray to all the varieties in replicated mode. The organic formulations mentioned as above were applied at four different intervals of times as pre-harvest foliar sprays using hand sprayer. First spray applied at 30 days to transplanting and subsequently remaining three sprays given at 15 days interval (45, 60 and 75 days). The dosage of respective organic formulation to be applied was finalized as suggested by (Compant et al. 2019).

RESULTS AND DISCUSSION

Plant height: There was significant difference in plant height of different onion cultivars due to application of organic formulation and different onion varieties. Pusa Riddhi exhibited maximum plant followed by Pusa Red. The application of panchgavya had significant impact on plant height on all varieties. The maximum plant height was in Pusa Riddhi (45.85cm) followed by Pusa Red and NHRDF Red. The least impact on plant height of onion varieties was observed with the application of *Trichoderma viride*. All onion varieties were responsive towards application of panchgavya and neem based formulation and recorded significant increase in plant height as compared to control. The increase on plant height due to application of panchgavya was also reported by Kumar and Neeraj (2015) in onion and Kumar et al (2020) in legume. The increase of plant height may be due to better nutrient uptake and metabolization efficiency resulting in increased cell division and enhancement of cell size.

Number of leaves per plant: The results showed that irrespective of treatments, among various onion varieties the maximum number of leaves per plant was observed in Pusa Riddhi (14.52) on overall mean basis (Table 1). Maximum number of leaves among varieties applied with panchgavya. Pusa Riddhi exhibited highest number of leaves (17.06) followed by Pusa Red which was significantly higher as compared to other treatments. Even under control condition, maximum number of leaves per plant was recorded in Pusa Riddhi (13.17) followed by Pusa Red (12.23), which were higher and statistically significant as compared to number of leaves in AGLR (6.30). No major difference was observed in onion varieties applied with *T. viride* and control. The application of neem based formulation was second best treatment as compared to *Trichoderma viride* and control. Similar results regarding more number of leaves per plant were recorded by Selvaraj (2003) and Choudhary et al (2017) while working with panchgavya and neem based formulations.

Bulb diameter: The results in Table 2 irrespective of treatments, on overall mean basis showed that Pusa Riddhi had highest bulb diameter (45.71mm) followed by Pusa Red (42.50mm), NHRDF red (41.32mm). The smallest bulbs were observed in AGLR (38.29mm). Even under control condition, maximum bulb diameter was recorded in Pusa Riddhi (44.50mm) followed by Pusa Red (41.80mm). Among various treatments applied, on over all mean basis, the maximum bulb diameter (irrespective of varieties) was observed in onion bulbs treated with panchgavya (43.38mm).

This was slightly higher as compared to other treatments

Table 1. Impact of foliar spray of organic formulations on plant height (cm) and number of leaves plant^{-1}* of selected onion varieties

Treatments [A]	Plant height (cm) of onion varieties [B]					
	Pusa Madhavi	Pusa Riddhi	Pusa Red	NHRDF Red	AG LR	Mean
Control	40.80 (10.30)	44.38 (13.17)	42.33 (12.23)	41.36 (8.09)	40.50 (6.30)	41.87 (10.02)
Neem based formulation	41.54 (11.42)	46.10 (14.43)	44.17 (13.14)	42.34 (9.09)	41.09 (7.79)	43.05 (11.18)
Panchgavya	42.40 (13.45)	48.36 (17.06)	45.25 (14.81)	43.09 (10.30)	42.92 (8.38)	44.41 (12.80)
Trichoderma viride	40.84 (10.36)	44.58 (13.14)	42.45 (12.53)	41.52 (8.14)	40.62 (6.46)	42.00 (10.13)
Mean	41.40 (11.39)	45.85 (14.52)	43.55 (13.18)	42.08 (8.90)	41.29 (7.23)	
CD (p=0.05)	Treatments [A]		Varieties [B]		Interaction [A x B]	
	0.02 (0.01)		0.01 (0.01)		0.02 (0.03)	

*No. of leaves plant^{-1} in parentheses

Table 2. Impact of foliar spray of organic formulations on Bulb diameter (mm) and bulb weight* (g) of selected onion varieties

Treatments [A]	Bulb diameter (mm) of onion varieties [B]					
	Pusa Madhavi	Pusa Riddhi	Pusa Red	NHRDF Red	AG LR	Mean
Control	39.89 (86.33)	44.50 (89.34)	41.80 (87.87)	40.85 (80.54)	37.65 (72.17)	40.94 (83.27)
Neem based formulation	40.09 (87.46)	45.46 (90.77)	42.17 (87.67)	41.06 (81.21)	37.84 (72.15)	41.32 (83.91)
Panchgavya	41.86 (88.60)	48.15 (92.34)	44.07 (89.15)	42.51 (88.67)	39.90 (73.60)	43.38 (86.47)
Trichoderma viride	39.95 (86.51)	44.72 (89.22)	41.96 (87.29)	40.84 (80.76)	37.76 (72.30)	41.05 (83.21)
Mean	40.45 (87.23)	45.71 (90.42)	42.50 (88.00)	41.32 (82.80)	38.29 (72.65)	
CD (p=0.05)	Treatments [A]		Varieties [B]		Interaction [A x B]	
	0.02 (0.38)		0.02 (0.53)		0.05 (0.86)	

*bulb weight in parentheses

and control. The least bulb diameter irrespective of treatments was observed in control (40.94mm). Among various varieties, maximum bulb diameter was observed with panchgavya application in Pusa Riddhi (48.15mm) followed by Neem extract (45.46mm), which more than control (44.50mm). Similarly, in Pusa Red, application of panchgavya gave maximum diameter (44.07mm) followed by application of Neem based formulation (42.17mm), which was more than control (41.80mm). The least impact on bulb diameter of onion bulb was observed with application of *Trichoderma viride* in all the varieties which was more or less same as that of control. The results are in accordance with the finding of Kondappa et al (2009) and Manna et al (2016) in chilli with different organic formulations.

Bulb weight: There was increase in bulb weight as a result of application of various organic formulations as compared to control (Table 2). Maximum bulb weight was recorded with application of panchgavya. Irrespective of treatments, Pusa Riddhi had maximum mean bulb weight (90.42gm) on overall mean basis followed by in Pusa Red (88.00gm), Pusa Madhavi (87.23gm). The minimum bulb weight was observed in AGLR (72.65gm). The maximum bulb weight was observed in all the selected onion varieties as result of panchgavya application, however, the maximum bulb weight was recorded in Pusa Riddhi (92.34gm) followed by 89.15gm in Pusa Red. Pusa Madhavi, NHRDF Red showed similar weight with panchgavya application (i.e. 88.60gm and 88.67gm, respectively). The results obtained with the application of panchgavya in all the varieties were higher and differences were statistically significant as compared to control and *Trichoderma viride* application. The results also showed that there was about 10% increase in bulb weight in NHRDF Red (88.67gm) with panchgavya application as compared to control (80.54gm). Similar finding on increase in weight of onion bulb have also been reported by other researchers working with onion (Boyhan et al 2001, Meena 2017).

CONCLUSION

Pusa Riddhi had maximum overall mean value for plant height, number of leaves per plant, bulb diameter and bulb weight and appeared as the best performing variety under the given organic treatment. Among numerous treatments applied, irrespective of varieties, Panchgavya exhibited better growth as compared to other treatments including control for all the attributing characters under study. On contrary, irrespective of genotypes *Trichoderma viride* showed minimum response towards all the characters studied.

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Influence of Foliar Application of Nano-Zinc and Iron Fertilizers on Growth and Yield of Bell Pepper (*Capsicum annuum* L.)

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Abstract: A field experiment in the autumn 2019 was conducted to investigate the combined effect of foliar spraying with nano zinc and iron fertilizers on growth and yield of bell 0, 1.5, 3, and 4.5 g. The spraying with nano-Fe and nano-zinc at 3 g l^{-1} resulted in significant increase in plant height, the number of branches, leaf area, dry weight, leaf content of chlorophyll, nitrogen, phosphorus, and potassium, number of fruits, fruit weight and total yield. The iron and zinc nano at 3 g l^{-1} + 3 g l^{-1} had significant effect on all the above traits. Nano-fertilizers as a foliar application enhanced the growth and yield of bell pepper with a higher uptake of nutrients.

Keywords: Bell pepper, Micronutrient, Nano fertilizers, Fe and Zn

Pepper is cultivated in Iraq with the traditional method at the beginning of spring under field conditions and the protected method at the beginning of autumn. Fertility can improve by adding organic and inorganic fertilizers to the soil. Nanotechnology improves soil fertility and crop production while minimizing environmental impact. Improving food security and environmental sustainability in agricultural systems requires an integrated approach to managing soil fertility, ensuring that crop production is minimizing the depletion of nutrient stocks in the soil. Using nanotechnologies in agriculture helps to improve soil fertility practices, supporting the intensification of crop production and the conservation of natural resources. Soil fertility can by improved through nano fertilizers that add organic matter to the soil, which leads to improved soil structure and contributes to creating healthy and fertile soils, or by spraying foliar fertilizers, to compensate for the losses resulting from plant uptake and other processes of the crops through improved nutrient use (Ziogas et al 2020). Using foliar nutrients is a complementary method of soil fertilization, which addresses the shortage of one of the important nutrients for plant growth (Singh et al 2017). The most important objectives of agricultural policy are to improve production and increase the number of agricultural products, in order to meet the needs of the ever-growing population. Among these technologies, nanotechnology has the potential to revolutionize agricultural systems, biomedicine, environmental engineering, safety, security, and energy conversion (Taran et al 2021, Kaphle et al 2018). The aim of this research was to determine the effect of foliar application of two types of iron and zinc nano fertilizers and their effect on the indicators of vegetative growth and yield of bell pepper.

MATERIAL AND METHODS

The experiments were conducted in a non-heated plastic house at Al-Mussaib Technical College during the autumn 2019to observe the effect of foliar spraying with nano zinc and iron fertilizers on growth and yield of bell pepper (Yolo Wonder cultivar). The study included two factors, first factor included four concentrations of iron nano fertilizer (0, 1.5, 3, and 4.5 g l^{-1}) and the second factor included four concentrations of the zinc nano fertilizer (0, 1.5, 3, and 4.5 g l^{-1}). The spraying was done five times at 20 days interval. Control treatment was sprayed with water only. The spraying was done in the morning and until the complete wetness for the plants, which is preceded by irrigation of the seedlings before one day .The irrigation prior to spraying reduces the concentration of the solutes in the leaf cells because of the water entering and increasing the swelling, thus opening the stone which increases the permeability of the spraying solution ions to the leaf cells (Schjoerring et al 2019). The recommended cultivation practices were followed as per the vegetable production guide, 2013. The experimental design was randomized complete block design with three replicates test. All statistical tests were performed with the program R 2.15.0 (Team RC 2017). The mineral fertilizer was added with an average of 250 kg ha^{1} of ammonium sulfate and 150 kg ha^{1} of triple superphosphate in two batches during the vegetative and flowering stage. Random samples were collected from the soil field of the Bell pepper from three areas with a depth of 0-30 cm. The samples were mixed well and analyzed to determine the physicochemical traits according to standard methods (Jackson 1958) (Table 1).

After completion of the experiment, the data on various

parameter was recorded from six plants which included plant height and stem height was measured to the apical meristem, number of branches per plant, leaf area, dry weight of plants (dried at 70-75 °C in an electric oven and until the weight is stable), number of fruits and fruit weight, and total yield of plant . Nitrogen in leaves was estimated using macro or micro Kjeldahl technique method (Jackson 1958), phosphorus by using the acid, ammonium oxalate extraction method (Olsen and Sommers 1982) and potassium by using a Flame photometer. Vitamin C content was estimated with the method of Horwitz et al (1970).

RESULTS AND DISCUSSION

Plant height (cm) and number of branches: The plant height and the number of fruit branches differ significantly in different treatments. Maximum plant height and number of fruit branches (105.85 cm and 6.43 branches, respectively) were in nano solution of iron and zinc at a concentration of 3 ml l^{-1}, compared to the control (81.43 cm and 3.7 branches, respectively) (Table 2). The spraying of the zinc nano at different levels led to a significant increase in these two traits (110.9 cm and 6.9 branches, respectively). The lowest average for these two traits was in control. There was no significant differences between the two factors (3 g l^{-1}) and (4.5 g l^{-1}) for both elements and both traits. The interaction treatment (spraying fertilizers at a level of 3 g l^{-1} Fe + 3 g l^{-1} Zn) resulted in the maximum plant height and the number of branches (. The lowest average of these two traits was in control.

Table 1. Physical and chemical traits of the soil used in the experiment

Traits	Value	Unit
Electrical conductivity	2.7	ds.S^{-1}
pH	7.1	--
Organic matter	9.5	g kg^{-1} soil
Interchangeable capacity	16.92	Cmol.kg^{-1} soil
Calcium carbonate	18.3	g kg^{-1} soil
Nitrogen	23.5	Cmol.kg^{-1} soil
Phosphorus	4.9	
Potassium	67.9	
Apparent density	1.42	µg m^{-3}
Sand	601.6	g kg^{-1} soil
Silt	241.3	
Clay	157.1	
Soil texture	Loamy sand soil	

Leaf area and the dry weight of the plant: There were significant differences between the spraying levels for the iron Nano on leaf area and the dry weight, with spraying at 3 g l^{-1} . The average number of leaves in the seedling and the leaf area were 25.48 dm^2 and 108.9 g, respectively compared to the control treatment (spraying with add water) (19.05 dm^2 and 92.23 g, respectively) (Table 3). Spraying with the nano zinc at different levels led to a significant increase in leaf area and the dry weight (24.33 dm^2, 112.72 g), compared to the control treatment. With the addition of nano zinc at 3 and 4.5 g l^{-1} there is no difference between them in both traits. The interaction between the two factors had a significant effect on the increase in the average leaf area and dry weight. The e spraying t with a mixture of the two fertilizers (nano iron 3 g l^{-1} + nano zinc 3 g l^{-1}) gave maximum leaf area and the dry weight (26.3 dm^2 and 121.2 g, respectively).

Phosphorus and potassium content in leaves (%): The differences were significant between the spraying levels of the nano iron solution on phosphorus and potassium in the leaves (%) and spraying treatment at 3g l^{-1} gave the highest phosphorus and potassium in the leaves o (0.67, 1.99%, respectively) as compared to the control (0.51, 1.44%, respectively) (Table 4). The spraying with the nano zinc fertilizer at 3 g ^{1} resulted in increase in the percentage of phosphorus in the leaves (0.66%) and spray nano zinc fertilizer at 4.5 g L^{-1} was significant in the t content of

Table 2. Effect of foliar application of nano fertilizer on plant height and number of branches

Fe (g l^{-1})	Plant length (cm)				Average	Number of fruit branches per plant				Average
	Zinc (mg l^{-1})					Zinc (mg l^{-1})				
	0	1.5	3	4.5		0	1.5	3	4.5	
0	53.7	77.2	98.5	96.3	81.34	2.8	3.5	4.6	3.9	3.7
1.5	79.4	89.5	101.6	97.4	91.98	4.7	5.0	6.2	5.5	5.35
3	102.3	106.9	110.9	103.3	105.85	5.9	6.3	6.9	6.6	6.43
4.5	97.5	101.9	106.2	105.5	102.93	4.5	5.5	6.4	6.8	5.80
Average	83.23	93.88	104.45	100.63		4.48	5.08	6.03	5.7	
LSD (0.05)	Fe 7.48	Zn 7.48	Interaction 13.56			Fe 0.41	Zn 0.41	Interaction 0.76		

potassium with highest averages of 1.89% as compared to the control . The interaction between the two factors had a significant effect on the increase in the average leaves' content from the phosphorus and potassium. The interaction of spraying with a mixture of the two fertilizers (3 g l^{-1} Fe + 3 g l^{-1} Zn) gave the highest average of leaves content from the phosphorus and potassium (0.70, 2.27%, respectively).

Number of fruits and weight: There were significant differences between the spraying levels for the iron nano for the number of fruits per plant and the average weight of fruit at a concentration of 3 g l^{-1} (32.36, 99.73g, respectively) compared to the control (27.4 fruits, 84.63 g respectively). Spraying zinc Nano fertilizer at 3 g l^{-1} led to a significant number of fruits per plant (Table 5). The interaction between the two factors had a significant effect on the increase in the average number of fruits per plant and the average weight of fruit. The interaction treatment spraying with iron nano at a level of 3 g l^{-1} and zinc nano at level 3 g l^{-1} (35.6 fruits and

Table 3. Effect of foliar application of nano fertilizer on a leaf area and dry weight of total plant

Fe (g l^{-1})	Leaf area (dm^2)				Average	Dry weight for the total vegetative (g)				Average
	Zinc (mg l^{-1})					Zinc (mg l^{-1})				
	0	1.5	3	4.5		0	1.5	3	4.5	
0	17.4	18.6	19.7	20.5	19.05	76.7	92.9	95.9	96.4	90.55
1.5	21.6	22.8	25.6	23.9	23.48	85.9	90.0	115.7	111.8	100.85
3	24.8	25.4	26.3	25.4	25.48	96.3	98.6	121.2	119.5	108.9
4.5	22.7	24.2	25.7	25.1	24.43	95.3	97.8	118.1	109.8	105.25
Average	21.63	22.75	24.33	23.72		88.55	94.83	112.72	109.37	
LSD (0.05)	Fe 1.08	Zn 1.08	Interaction 1.76			Fe 7.68	Zn 7.68	Interaction 14.22		

Table 4. Effect of foliar application of nano fertilizer on phosphorus and potassium content in leaves

Fe (g l^{-1})	Phosphorus (%)				Average	Potassium (%)				Average
	Zinc (mg l^{-1})					Zinc (mg l^{-1})				
	0	1.5	3	4.5		0	1.5	3	4.5	
0	0.38	0.47	0.60	0.62	0.51	1.32	1.39	1.47	1.60	1.44
1.5	0.50	0.61	0.66	0.63	0.60	1.39	1.46	1.68	1.64	1.53
3	0.63	0.69	0.70	0.68	0.67	1.73	1.83	2.27	2.15	1.99
4.5	0.65	0.66	0.68	0.67	0.66	1.59	1.70	2.17	2.16	1.90
Average	0.53	0.60	0.66	0.64		1.50	1.59	1.88	1.89	
LSD (0.05)	Fe 0.04	Zn 0.04	Interaction 0.07			Fe 0.28	Zn 0.28	Interaction 0.52		

Table 5. Effect of foliar application of nano fertilizer on fruit number and fruit weight

Fe (g l^{-1})	Number of fruits per plant				Average	Fruit weight (g)				Average
	Zinc (mg l^{-1})					Zinc (mg l^{-1})				
	0	1.5	3	4.5		0	1.5	3	4.5	
0	23.8	27.5	29.8	28.5	27.4	78.6	82.2	88.3	89.4	84.63
1.5	26.3	28.8	32.9	31.4	29.85	80.6	85.6	90.2	91.2	86.9
3	28.9	32.4	35.6	33.6	32.63	89.4	94.2	109.5	105.8	99.73
4.5	29.5	30.2	33.2	34.0	31.73	90.6	93.3	107.7	106.7	99.58
Average	27.13	29.73	32.88	31.88		84.80	88.83	98.93	98.28	
LSD (0.05)	Fe 1.07	Zn 1.07	Interaction 1.75			Fe 7.62	Zn 7.62	Interaction 14.20		

109.5 g, respectively) had a significant difference.

Plant yield and vitamin C: The differences were significant between the spraying levels for the iron and zinc nano solution in the total yield and vitamin C The spraying treatment of iron nano at 3 ml l^{-1} gave the highest average of the total yield and vitamin C (3.03 kg, 15.34 mg kg^{-1}**)** compared to the control (2.11 kg $plant^{-1}$, 13.11mg kg^{-1}) (Table 6). The addition of spraying of zinc nano at different levels resulted in significant increase in yield and vitamin C (3.05 kg per plant, 14.5 mg per kg). The lowest average for these traits was at the treatment without spraying with the two fertilizers.

Total sugars and carotenoids: There were significant differences between the spraying levels for the iron nano for the total sugars and carotenoids at a concentration of 3 g l^{-1} (5.36%, 9.47 mg kg^{-1}, respectively) as compared to the control (4.60%, 5.13 mg kg^{-1}, respectively). Spraying zinc nano fertilizer at 3 g l^{-1}) led to a significant increase of the total sugars and carotenoids (Table 7). The addition of spraying of zinc Nano at different levels led to a significant increase in these two traits above (The lowest average for these two traits was in without spraying with the two fertilizers. The interaction between the two factors had a significant effect on the increase in the average of total sugars and the carotenoids.

These factors (spraying with the two types of Nano fertilizers (iron and zinc) affected significantly all indicators of vegetative and flowering growth. The level of spraying 3 g l^{-1}) for the two fertilizers sequentially significantly excelled in plant height, the number of branches, leaf area, dry weight, leaf content of chlorophyll, percentage of nitrogen, phosphorus, and potassium in the leaves. This reason may be because of iron is a necessary element for plant growth and development (Rui et al 2016). Iron also contributes many of bio-processes including the production of amino acids, metabolism, and enzymes that help to increase cellular divisions and increase the activity of enzymes against the process of oxidation and this leads to the organization of plant growth and the promotion of activity, which reflects the increase in the indicators of vegetative growth of the plant. Foliar application of nano iron resulted in a significant improvement in growth and yield, which might be attributed to increased photosynthetic activity and increased production and accumulation of carbohydrates. It contributes to the promotion of energy transfer and metabolism and increased cell division, These results were positively reflected with the increase in plant height averages, the number of branches, leaf area, and concentration of phosphorus and potassium in leaf tissue and fruits and were observed by many authors (Jadczak et al 2010, Nair et al 2011, Zaki et al 2013).The increase in the number of fruit branches with use foliar fertilization leaf with iron nano can be an attribute that the iron component reduces the auxins that promote the growth of the apical growth and

Table 6. Effect of nano fertilizer in the average of the total plant yield and vitamin C

Fe (g l^{-1})	Total yield (kg $plant^{-1}$)				Average	Vitamin C (mg kg^{-1})				Average
	Zinc (mg l^{-1})					Zinc (mg l^{-1})				
	0	1.5	3	4.5		0	1.5	3	4.5	
0	1.63	1.99	2.28	2.56	2.11	12.73	13.15	13.36	13.21	13.11
1.5	2.01	2.18	2.99	2.70	2.47	13.24	13.45	14.24	13.85	13.69
3	2.39	2.89	3.58	3.27	3.03	14.92	15.34	15.72	15.39	15.34
4.5	2.44	2.72	3.35	3.31	2.96	13.33	13.52	14.71	13.82	13.84
Average	2.11	2.44	3.05	2.96		13.55	13.86	14.5	14.06	
LSD (0.05)	Fe 0.23	Zn 0.23	Interaction 0.42			Fe 0.88	Zn 0.88	Interaction 1.11		

Table 7. Effect of the nano fertilizer on the total sugars and carotenoids

Fe (g l^{-1})	Total yield (kg $plant^{-1}$)				Average	Vitamin C (mg kg^{-1})				Average
	Zinc (mg l^{-1})					Zinc (mg l^{-1})				
	0	1.5	3	4.5		0	1.5	3	4.5	
0	4.50	4.55	4.74	4.63	4.60	4.74	4.76	5.11	5.92	5.13
1.5	4.59	4.95	5.19	5.09	4.95	5.26	5.33	6.98	6.72	6.07
3	4.97	5.16	5.89	5.41	5.36	8.54	9.24	10.58	9.51	9.47
4.5	4.91	4.92	5.67	5.33	5.21	7.03	7.12	8.44	7.45	7.51
Average	4.74	4.89	5.37	5.11		6.39	6.61	7.77	7.4	
LSD (0.05)	Fe 0.26	Zn 0.26	Interaction 0.49			Fe 0.92	Zn 0.92	Interaction 1.24		

therefore plant tends from more fruit branches. Nechitailo et al (2018) observed similar results on growth indices of bell pepper. The significant effect of zinc nano in the indicators of the vegetative growth can also be attributed to in the amino's formation acid tryptophan and formation of the growth regulator IAA, which affects the increase of cell division and promotes the activity of cell membranes and division and many of the biological reactions (Guo et al 2011). The significant increase in the number of fruits and their weight and total yield because of the spraying of the two types of Nano which may be attributed to the role of nano-nutrients (Fe and Zinc) in the synthesis and activation of many enzymes necessary for the Bio-processes in the plant and control the hormonal balance of the plant and this is the increase in the indicators of vegetative growth (Zhao et al 2019).

CONCLUSION

This study unraveled the factors affecting the response of Bell pepper to nano foliar application. The iron and zinc nano fertilizers had a significant effect on the indicators of growth and yield of Bell pepper. However, the iron nano fertilizer alone or combined with the addition of zinc nano fertilizers at the stages of growth could be useful in improving vegetative growth, quality and yield of bell pepper.

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Assessment of Physico-chemical Parameters and Water Quality Index of Bhavanisagar Reservoir, Tamil Nadu

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***Abstract*:** The present study employs the technique of WQI to provide the overall quality of water. The evaluation of physico-chemical parameters values were within or below permissible limits which was also confirmed by WQI indicated that the water of the reservoir was oligotrophic in nature and an ideal source for drinking and irrigation purposes. The adequate nutritional load of the water would suffice a balanced growth of micro and macro organisms and provides a well-balanced and sustained aquatic ecosystem.

***Keywords*:** Water quality, Quality assessment, WQI, Physico-chemical parameters, Bhavanisagar reservoir

Dynamic function of an ecosystem is determined by the water availability of the region. About 3/4th of the world's total surface is covered by water in which 1.2% is surface water which is used for human consumption. In India, monsoon prevails from June – September, which is mainly fed by Southwest and Northeast monsoon with average rainfall of 4000 billion cubic meters from which only 18% can be used for conventional purposes (Panda 2011). This sudden influx of periodic water supply to the system causes a change which may result in flood. Reservoirs are artificial catchment built across perennial or long season stream for multi – variant purpose i.e. man – made surface impoundment impeding water flow, for irrigation, fisheries, flood control and hydro – electric power supply. According to the area covered the reservoirs are classified as small, medium and large. India has 19,370 reservoirs consisting of 3,153,366 ha area of the region, out of which Tamil Nadu accounts for holding large number of small reservoirs. The inflow and outflow of the water to the reservoirs alters the reservoir ecosystem from natural ecosystem which is a distinct feature of reservoir. The surface flow of rainwater obstructed by the reservoir, act as a source of potable water after various treatments. The variation of reservoir ecosystem from the natural environment alters hydrological properties, deviating from the natural environment may be compatible or incompatible depends on the quality of water determining parameters. The quality must be checked to prevent deterioration of water availability for the human consumption. Rapid industrialization and urbanization results in deterioration of the water quality making the water unfit for human consumption and domestic purposes. Periodic assessment of the analytical parameters is essential for protection, preservation and utilization of water resources. In a water quality study, analytical parameters vary according to the purpose of study and function of water body (Sawant et al 2013). Physical and chemical parameters are the quality determinants of a water body. Water Quality Index (WQI) is a suitable method to assess the quality of surface water, through determining the relative weight of analytical parameters in terms of concentration (Tyagi et al 2013, Bora et al 2017). The present study gives a detailed analysis of physico-chemical parameters to assess the water quality and WQI is calculated.

MATERIAL AND METHODS

Study area: Bhavanisagar Dam located at latitude 11°28' N and longitude 77°06' E, is constructed below the confluence of River Moyer and River Bhavani of Tamil Nadu. The reservoir is built 280.2 m above the Mean Sea Level (MSL). The height of the reservoir is about 40 meters (120ft) and the capacity is about 32.8 TMC (Thousand Million Cubic). Heavy rainfall in the study area is during low-pressure depressions and cyclones during the northeast monsoon period. The dam is fed by both Southwest and Northeast monsoon. The amount of rainfall is about 621mm (458 mm during monsoon and 163mm during in non-monsoon months) and the higher is towards coast.

Sampling method: Water samples were collected on fortnight intervals from June 2019 - October 2019. Surface sampling were done at two sampling points of latitude and longitude 11°28'14"N 77°06'52"E named as S1 and 11°28'15"N 77°06'49"E named as S2. Sterilized polyethylene bottles of one litre capacity were used for collecting samples. Three samples for each sampling point were taken for

concordance and the average is calculated. Dissolved oxygen, pH and temperature were carried out at the collection site, other parameters and heavy metals were analysed in laboratory using the standard procedure given by Bureau of Indian Standards (BIS) (IS 3025-42 1992) (IS 3025-34 1998) (IS 3025-41 1992) (IS 3025-47 1994) (IS 3025-49 1994) (IS 3025-52 2003). Standard limits were set in reference with WHO and BIS.

WQI assessment: Weighted arithmetic water quality index (WAWQI) method was employed to determine the WQI. Commonly used 10 water quality parameters were considered to determine the quality of water. The water quality rating as per WAWQI method is given in Table 1. The calculation of WQI was made by using the following equation:

$$WQI = \sum Q_i W_i / \sum W_i$$

The quality rating scale (Q_i) for each parameter is calculated by using this expression

$$Q_i = 100[(V_i - V_o / S_i - V_o)]$$

Where,

V_i is estimated concentration of ith parameter in the analysed water

Table 1. Water quality rating as per WAWQI method

WQI value	Rating of water quality	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very poor water quality	D
Above 100	Unsuitable for drinking purpose	E

V_o is the ideal value of this parameter in pure water

V_o = 0 (except pH = 7.0 and Dissolved Oxygen = 14.6 mg/l)

S_i is recommended standard value of ith parameter.

The unit weight (W_i) for each water quality parameter is calculated by using the following formula:

$$W_i = K/S_i$$

Where,

K = proportionality constant and can be also calculated by using the following equation:

$$K = 1/\sum(1/S_i)$$

RESULTS AND DISCUSSION

The water quality was assessed considering the physico- chemical parameters and overall rating was given by Weighted Arithmetic Water Quality Indices (WAWQI) are tabulated in Table 2 & 3.

Physical parameters: The pH in water samples ranges from 8.1-8.6 indicate the alkaline nature of water. But the basic nature increased and fluctuated from 8.3-8.7 from August till October due to the influence of rain water by the dilution of the chemical parameters. The temperature range was from 28°C to 29°C. The color variation during the study period was significant, the transition from transparent to greenish color occurred during September and October signifies an elevated amount of chlorophyll content due to the increase in primary producers of water due to nutrient input from rains (Pires et al 2017).

Chemical parameters: Total dissolved solids were maximum

Table 2. Estimated physico-chemical parameters of water sample from June - October, 2019

Parameters (mg l^{-1})	June	July	August	September	October	Permissible limits (mg l^{-1})	
						BIS	WHO
pH	8.1±0.1	8.2±0.1	8.6±0.1	8.5±0.1	8.5±0.1	6.5-8.5	6.5 - 9.5
Temperature	28±1.8	29.2±0.9	28±1.4	29.5±0.5	29.2±0.9	-	-
Total dissolved solids	48.2±5.7	78.6±5.8	62.2±13.0	45.7±2.7	44.5±1.4	500-2000	500 - 1000
Total suspended solids	0.2±0.08	0.7±0.2	0.3±0.1	0.1±0.05	0.1±0.09	-	-
Total solids	49.7±2.0	50±6.7	62.9±18.0	54.5±4.0	50.2±2.0	-	-
Chloride	17.5±3.0	23.6±5.0	16.8±3.3	21.3±4.9	15±3.0	250	200
Total alkalinity	35±15.0	46±7.5	41.2±16.0	25±7.0	37.5±11.0	200	100
DO	3.3±0.1	3.7±0.3	3.6±0.1	5.0±0.7	4±0.5	4 -6	4 - 6
Sulphate	2.3±2.0	4.8±0.6	2.0±2.3	0	0	200	250
Total hardness	32.5±10.0	34±12.0	35±5.7	31.2±8.5	35±9.0	200	500
Sodium	0.1±0.0	0.09±0.1	0.3±0.3	0	0	180	200
Calcium	7.8±1.0	6.0±3.0	8.3±5.0	5.5±1.9	10±4	75	75
Magnesium	6.5±1.0	7.7±2.2	2.2±0.2	4.1±0.2	0	30	50
Nitrate			BDL			45	50
Phosphorus			BDL			-	-

during July and August but the TDS levels remained constant during June, September and October. The variation was due to dilution of water in reservoir by rain water. The average range of TDS was from 44.5 mg l^{-1}-78.6 mg l^{-1}. A corresponding increase in Total suspended solids were observed with increase TDS by 0.7 mg l^{-1} during July. The highest value of both parameters signifies the inflow of water fed by monsoon. The maximum value of alkalinity was recorded during July with an average range of 25 mg l^{-1}- 47 mg l^{-1}. The high value may indicate the process of weathering in the reservoir during high temperature. The above phenomenon was observed by Singh et al (2005) at Gomathi River, India. The DO ranged from 3.3 mg l^{-1}- 5.0 mg l^{-1}. The highest value corresponds to the increase in the oxygen production in post – monsoon period. The increase in DO during September was due to the easy exchange of air between the atmosphere and water surface. The lowest value of 3.3mg/l was observed during June due to the effects of high temperature. The concentration of calcium and the magnesium ions present in the form of Mg^{2+} and Ca^{2+} in water determines the total hardness. The total hardness was between 32.5 mg l^{-1} and 35 mg l^{-1}. Similar results were observed by Ramteke (2013) in Savithri reservoir, Maharashtra. The values obtained from the analysis for the total hardness indicates that the water is soft and lies between the ranges of 0 mg l^{-1} -75 mg l^{-1}. The average range of magnesium was between 6.5 mg l^{-1} and 7.7 mg l^{-1}. The magnesium was either very low or in BDL. Chloride constitutes the salt taste of water. The highest and lowest values of chloride were observed in S1 during July and October was 28.6 mg l^{-1} and 10.6 mg l^{-1}, respectively are less than the permissible limits indicating the soft nature of water (Asok et al 2014). The concentration of heavy metals was in Below Detectable Level (BDL) which indicates that the water is free from pollutants and suitable for irrigation and for drinking purposes. Similar studies were made by Semy et al (2019) at Tsurang River, Nagaland; Rahmanian et al (2015) at State of Perek, Malaysia and Abhishek et al (2020) at Rohtak, Haryana.

The estimated values of physico-chemical parameters were lower than permissible limits, indicate a very less nutritional load – a characteristic feature of Oligotrophic water. Walker et al (2007) in a special report entitled "Nutrients in Lakes and Reservoir" states: The oligotrophic water supports a very limited source for the survival of biological components where one or more macronutrients (Nitrogen, Phosphorus and Carbon) are absent and enhances water quality for drinking and irrigation purposes. Moreover, reservoir exhibits very low variability in its parameters and nutritional load due to its dynamic nature. The movement of water from higher gradient to lower gradient (Reservoir) limits the flow of nutrients to the lower gradient and hence a less nutritional load is obtained from the watershed areas. Anthropogenic activities and domestic wastes can induce certain organic, inorganic substances and heavy metals to the water which might contribute to the nutrient availability and when released in excess leads to eutrophication and pollution of the water. Data generated from our study depicts that the DO level of the Bhavanisagar reservoir and BDL of phosphorus supports the oligotrophic nature of water also the absence of eutrophication and BDL of heavy metals indicates the water is suitable for human consumption and irrigation.

WQI is commonly used for the detection and evaluation of water pollution. WQI were determined for the two samples during the study period by considering 9 parameters. According to the water quality rating status the value at the two sampling stations were between the range of 0-25. This indicates that overall water quality during the time period of

Table 3. WQI rating for sampling months - June – October, 2019

Parameters	Common weighing factor	Quality rating for sampling months				
		Jun	July	August	September	October
pH	0.0359	220.0	240.0	320.0	300.0	300.0
TDS	0.0005	9.6	15.7	12.4	9.1	8.9
TA	0.0022	29.2	38.5	34.3	20.8	31.3
TH	0.0009	10.8	11.3	11.7	10.4	11.7
NO_3	0.0060	-	-	-	-	-
Cl	0.0011	7.0	9.4	6.7	8.5	6.0
Fe	0.8981	-	-	-	-	-
SO_4	0.0013	1.2	2.4	1.0	-	-
DO	0.0539	117.7	113.5	114.6	99.5	110.4
WQI		14.3	14.8	17.7	16.2	16.8

June-October was suitable for drinking and irrigation. The quality status though deteriorated during the month of August, September and October the range was within the level of excellent. The variation was due to influence of rainfall over water.

CONCLUSION

Bhavanisagar reservoir is a catchment of flood waters from the watershed areas that are not frequently accessed by humans. Hence, anthropogenic intervention, domestic wastes and other chemical effluents are absent or very less due to which the nutritional content is checked. The lower nutrition load signifies the oligotrophic nature of water, sustains a stable aquatic ecosystem which do not lead to algal bloom and eutrophication. The physico-chemical assessment and WQI method used to determine the quality of water indicates that the water quality is excellent for the consumption and for the purpose of irrigation. As the water in the reservoir is used for drinking and irrigation purposes the values are ideal for the both purposes.

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Analysis of Nitrate Contamination of Water in Deeg District - Bharatpur (Rajasthan), India

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Abstract: The occurrence of high nitrate levels in groundwater has to be recognized as a threat to humans and animals. In the present investigation, an attempt has been made to understand the nitrate toxicity and evaluation of seasonal changes in the concentration of nitrate in town Deeg (Bharatpur). A comparison with ISI standard shows that all the samples of ground water (hand pump and well) exhibit nitrate content very much higher in all seasons. Nitrate was minimum in post-monsoon somewhat higher in pre-monsoon and highest in monsoon season. The water was severely polluted and unfit for human consumption for drinking and bathing at all location in all seasons. In hand pump water of Kaman road high nitrate (376.97ppm) was recorded as compared to other samples during monsoon season. All instances of nitrate pollution are related to anthropogenic sources can be managed to reduce or eliminate nitrogen inputs and for protecting groundwater resources.

Keyword: Town Deeg, Nitrate, Seasonal variation, Ground water

Water quality is affected by a wide range of natural and human influences and most important of the natural influences are geological, hydrological and climatic. Although water may be available in adequate quantities, its unsuitable quality limits the uses. Although the natural ecosystem is in harmony with natural water quality, any significant changes in water quality will usually due to disruptive influence of ecosystem. Water pollution can be analysed by the changes in physical, chemical and biological properties like colour, organic/inorganic contents and microbial load (Kumari et al 2008). The source of this waste could be raw sewage, chemicals, trash, or fertilizer. Water pollution has severe consequences, since less than 3% of the earth contains water that is potable or safe for drinking. When a source of drinking water becomes contaminated with untreated sewage can spread diseases through the water like *Giardiasis*, a diarrheal disease caused by a parasitic protozoa, *Giardia lamblia* (Kumari et al 2008).Water pollution also occurs when water is contaminated with fertilizer (nitrified and phosphoralized). These added nutrients in the water can cause eutrophication which promotes excessive growth of algae and aquatic plants. Water pollution is also due to trash and chemicals that are dumped into a body of water.

The groundwater quality deterioration can be attributed broadly to two mechanisms, anthropogenic and geogenic during the last two decades, nitrate (NO3) contamination in groundwater has become serious issue. Nitrate, nitrite (NO2), ammonia (NH3), and organically bound forms of nitrogen (Org-N) are of concern for water resource management around the globe. Ground water is the major source of water supply for urban and rural areas. The evaluation of ground water quantity and quality is very important since the physical and chemical characteristics of ground water determine its suitability for agricultural, industrial and domestic uses (Singh 2016, 2019). Although degradation of water quality is almost invariably the result of human activities. Certain natural phenomena can result in water quality falling below that required for particular purposes. Natural events such as torrential rainfall and hurricanes lead to excessive erosion and landslides, which in turn increase the content of suspended material in affected rivers and lakes. Seasonal overturn of the water in some lakes can bring water with little or no dissolved oxygen to the surface. Such natural events may be frequent or occasional. Permanent natural conditions in some areas may make water unfit for drinking or for specific uses, such as irrigation. Common examples of this are the salination of surface waters through evaporation in arid and semi–arid regions and the high salt content of some ground waters under certain geological conditions (Omezuruike et al 2008). Safe drinking water is the basic need of the people. The residents of town Deeg do not totally depend on ground and PHED water supply scheme, for drinking purpose they fetch water from the wells and hand pumps at some places situated sometimes at far off places is being used for drinking purpose without any treatment. The main objective of the present investigations is to assess and identify the quality of well,

hand pump, pond and PHED supply water with the reference of nitrate.

MATERIAL AND METHODS

Collection of water samples: The samples were collected during pre-monsoon (February to May), monsoon (June to September) and post-monsoon season (October to January). Four samples from Hand pump, well, PHED and pond water from study areas (Nagar road, Goverdhan road, Jal mahal and Kaman road) were collected. Samples were analyzed by standard methods (APHA 2005, WHO 2011) and compared ISI standards (2012). pH and turbidity were determined on spot by portable water analyzer kit model no. METZ–302M while the other parameters were determined in the laboratory within 24 hours of sampling. Nitrate was measured by phenoldisulfonic acid method (rubbing method) using spectrophotometer.

RESULTS AND DISCUSSION

The concentration of NO_3 ranged in between 6.60 to 376.97 ppm. Content of nitrate has been observed in the present study show higher values in hand pump and well water and within the permissible limit in ponds and PHED supply water in all area and seasons as prescribed by ISI (45

Table 1. Nitrate (NO_3^-) of water of town Deeg (Bharatpur) Rajasthan (mg L^{-1})

Area	Type of water	Pre monsoon season	Monsoon season	Post monsoon season
Nagar Road (A)	Hand pump	219.00± 0.06	246 ± 0.99	125.5 ± 0.98
Goverdhan Road (B)	Well	209.00± 0.02	233± 0.98	142.65 ± 0.07
	PHED supply	25.6 ± 0.05	43 ± 0.48	44.5 ± 0.07
	Pond	7.6 ± 0.05	28.34 ± 0.63	22.46 ± 0.38
	Hand pump (W_1)	210 ± 0.04	241 ± 0.98	115.25 ± 0.38
	Well (W_2)	210.06 ± 0.05	233 ± 0.88	82.67 ± 0.07
	PHED supply (W_3)	47 ± 0.05	85 ± 0.13	40.75 ± 0.39
Jal Mahal (C)	Pond (W_4)	6.6 ± 0.05	43 ± 0.23	42.62 ± 0.20
Kaman Road (D)	Hand pump (W_1)	209 ± 0.06	225 ± 0.14	115.25 ± 0.04
	Well (W_2)	217 ± 0.04	248 ± 0.98	125.25 ± 0.38
	PHED supply (W_3)	25.6 ± 0.06	35.9 ± 0.07	12.65 ± 0.07
	Pond (W_4)	6.7 ± 0.05	27.9 ± 0.08	35.5 ± 0.07
	Hand pump (W_1)	220 ± 0.04	376.97 ± 0.08	325.75 ± 0.48
	Well (W_2)	212.02 ± 0.03	247 ± 0.38	142.65 ± 0.07
	PHED supply (W_3)	26.7 ± 0.06	49.5 ± 0.34	45.25± 0.08
Area	Pond (W_4)	44 ± 0.05	39 ± 0.36	42.62± 0.49
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	Well (W_2)	212.02 ± 0.03	247 ± 0.38	142.65 ± 0.07

(Mean ± S.E)
Permissible limits: Min.: 45.00 mg l^{-1}

ppm) (Table 1).

Pre-monsoon season: All the samples of ground water (hand pump and well) exhibit nitrate content moderate higher as compared to ISI standards in pre-monsoon season.

Monsoon season: Water samples of hand pump and well exhibit nitrate content very much higher as compared to ISI standards in monsoon season. Alarming positions with regards to nitrate value (376.97 ppm) in the hand pump water of Kaman road as compared to other samples during monsoon season. Nitrate in PHED water supply water was also moderately high in Goverdhan area of present study.

Post-monsoon season: All the samples of ground water (hand pump and well) exhibit nitrate content very much higher and PHED water supply water was also moderately high in Goverdhan area as compared to ISI standards in post-monsoon season except pond water. Chandrashekar et al (2005) observed that nitrate was minimum in post-monsoon sand higher in pre-monsoon and highest in monsoon season.

The high levels of nitrate in the ground water in monsoon season in the present study may be due to the deposition of organic matter of human and animal waste, industrial effluents, manure from livestock, seepage of sewage through drainage system and deposition of municipal and domestic waste around the water resources. Some ground water naturally have high nitrate and further become more contaminated by percolation of runoff and wastes into the aquifer (Kalyani et al 2018, Nasseem and Shive 2019). Batheja et al (2009) observed high nitrate in water as a result of leguminous crops. The ability of NO_3 to enter well water depends on the type of soil and bedrock present and on the depth and construction of the well. If there is excessive rainfall or over irrigation, nitrate will be leached below the plants root zone and may eventually reach ground water. In the soil bacteria convert various forms of nitrogen to nitrate. Nitrate is highly leachable and readily moves with water through the soil profile because of the low capacity of soil to retain nitrate which leads to an increase in nitrate content in ground water (Abhishek et al 2020, Kannan et al 2005). NO_3 in ground water may result from naturally occurring sources of nitrogen (Sairendri et al 2019, Ragunath and Sunder 2018). Further, in the nearby areas of town Deeg there are croplands, where a very rich crop of mustard every year forms the major part of livelihood of the people of that area. Since, mustard is a leguminous plant (fix nitrogen into nitrate), the possibility of high nitrate due to this leguminaceae crop cannot be ruled out (Batheja et al 2009).

The elevated levels of nitrate in ground water have also been reported by earlier workers (Garg et al 2008, Kumar et al 2008, Gupta and Singh 2009). The decreased value of nitrate in pre and post-monsoon may be attributed to the biological utilization and absorption of nitrate into the sediment (Rajaram et al 2005, Tatwat and Chandel 2007).

CONCLUSIONS

The ground water of town Deeg contain very high amount of nitrate which renders the water unsuitable for drinking purpose. All the samples of ground water (hand pump and well) exhibit very much high nitrate content. However, an alarming position with regards to nitrate value (376.97 ppm) in hand pump water of Kaman road observed. The ground water of town Deeg contain very high amount of nitrate which renders the water unsuitable for drinking purpose.

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Nutrient Release Pattern in Soil Incubated with Fly Ash, Inorganic Fertilizers and Organic Manures

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Abstract: An incubation experiment was conducted to assess the nutrient release pattern in soil added with fly ash, inorganic fertilizers and organic manures. The fly ash was procured from Mettur thermal power station. The pH of fly ash was neutral to slightly alkaline and contains nutrients such as P, K, Ca, Mg, Fe, Mn, Zn and Cu. Since it was poor in nitrogen and organic carbon content, organic manures were added as supplement. Fly ash applied as a basal dose @ 20 t ha^{-1} with three manures *viz.,* farm yard manure (FYM @ 12.5 t ha^{-1}), green leaf manure (GLM @ 6.25 t ha^{-1}) and humic acid (HA @ 37.5 litres ha^{-1}). Period of the incubation study was for two months. Destructive soil sample from each set of container was taken for analysis at weekly intervals and analyzed for pH, electrical conductivity (EC) and available macro nutrients (N P K). No change in the pH, EC, N, P and K were recorded during the first three weeks. There was no significant change in pH and EC after the third week of incubation. Prominent changes were recorded at 6th week of incubation study with respect to soil available nitrogen and phosphorus, and for soil available K noticeable changes were observed at 4th week of incubation. Maximum release of NPK was in the soil treated with fly ash @ 20 t ha^{-1} and GLM @ 6.25 t ha^{-1} along with recommended dose of fertilizers (RDF). The available macro nutrients released during the period were found to be statistically significant.

Keywords: Soil incubation, Fly ash, FYM, GLM, HA, pH, EC, Available macro nutrients

Fly ash is a noncombustible mineral matter in coal, which is thermally altered as it goes through the combustion process and is a fine powdered waste that contains partially or completely burnt or unburnt particles of carbon released as a byproduct from coal based thermal power stations (Gautama et al 2012). The total quantity of fly ash generated during 2019-20 was 256 million tonnes and it was expected to reach 400 million tonnes at the end of 2030. About 40,000 ha of land are required for the construction of ash ponds for dumping 250 million tonnes of fly ash (Dived and Jain 2014). Indian coals, though low in sulfur, contain higher amount of ash (about 35-45 %), hence the fly ash generated in huge quantities from the thermal power plants. Many technologies have been developed for gainful utilization and safe management of fly ash. Fly ash was moved from “hazardous industrial waste” to “waste material” category during the year 2000 and during November 2009, it became a saleable commodity (Jambhulkar et al 2018, Senapathi 2011). Use of fly ash in agriculture provides a feasible alternative for its safe disposal to improve the soil environment and enhances the crop productivity (Rao et al 2020, Gond et al 2013). Fly-ash has great potentiality in agriculture due to its efficacy in modification of soil health and crop performance. The high concentration of nutrient elements (P, K, Na, Zn, Ca, Mg and Fe) in fly-ash increases the yield of many agricultural crops (Ahmaruzzaman 2010). But compared to other sectors, the use of fly-ash in agriculture is limited. Fly ash is being utilized in many sectors namely cement industries, brick making, road and building construction and agriculture. Compared to other sectors utilization of fly ash in agriculture was only 2 per cent (Basu et al 2009, Kishor et al 2010). Fly ash is an amorphous ferro-alumino-silicate mineral that contains essential nutrient elements required for plant growth except nitrogen and organic carbon (Tiwari et al 2016). However, a proper management strategy has to be developed to abate the land pollution from the dumping of fly ash. Hence, with the view of effective use of fly ash in agriculture, the present experiment was initiated to study the nutrient release from fly ash with the combined addition of organic manures.

MATERIAL AND METHODS

Laboratory incubation study was conducted in silt loam soil to assess the nutrient releasing pattern of N, P, K from native and applied sources *viz.,* fly ash, farm yard manure FYM, green leaf manure (GLM) and humic acid (HA). The experiment was conducted with two factor completely randomized factorial design with three replications. Factor A comprised of fly ash (FA) @20 t ha^{-1} applied along with

organic manures namely., - farm yard manure (FYM), humic acid (HA) and green leaf manure (GLM - *Glyricidia* was added). The main plot treatments were: M_0 - FA alone; M_1 - FA + FYM (12.5 t ha^{-1}); M_2 - Fly ash + HA (15 liters ac^{-1}) and M_3 - Fly ash + GLM (@ 6.25 t ha^{-1}). Factor B comprised of fertilizer treatments as listed: S_0 - No Fertilizer; S_1 - 100 % RDF (100:50:50) kg NPK + $ZnSO_4$ @ 25 kg ha^{-1}+ $FeSO_4$ @ 50 kg ha^{-1}); S_2 - NP + $ZnSO_4$ + $FeSO_4$; S_3 - NP + 50% K + $ZnSO_4$ + $FeSO_4$; S_4 - NPK + $ZnSO_4$; S_5 - NPK + $FeSO_4$; S_6 - NPK.

Preparation of soil medium: The soil was collected from the Field no. 9E of KVK, Tirur. Polythene containers each with a capacity of 100 ml were used for conducting incubation study. Totally 840 numbers were used for entire experiment.

Application of fly ash, FYM, GLM and humic acid: Fly ash @ 20 t ha^{-1} was added to the total quantity of soil and mixed thoroughly. After mixing, the soil was separated into four equal parts, for one part humic acid was added, for the second FYM was applied, GLM was added to the third part and the fourth part was kept as control. Required quantity of water was added to maintain the soil moisture at field capacity throughout the period of incubation (2 months).

Soil analysis for releasing pattern of nutrients: Each one of the four sets of soil treated with fly ash and other organics was filled in 10 sets of containers, each set consists of 84 numbers (7 treatments and 3 replications). Destructive sample from each set of container was utilized for analysis at weekly intervals. Samples were estimated for pH, EC and available N, P, K as per the standard procedures.

RESULTS AND DISCUSSION

Characteristics of fly ash: Fly ash was analysed for total N, P, K, micro nutrients and heavy metal content. The total N content of the fly ash was very low (0.04%). The total P and K content in fly ash were (0.22%) and (0.51%) was comparatively high among three macro nutrients. DTPA extractable micro nutrients *viz.,* Zn, Fe, Cu and Mn recorded as 6.8, 17.0, 1.5 and 1.3 mg kg^{-1}, respectively. The heavy metal content, Cr, P b and Cd was recorded as 2.1, 2.6 and 1.1 mg kg^{-1}, respectively.

Initial characteristics of soil: The composite soil collected from field was slightly alkaline in reaction and non saline. The textural analysis revealed that it is silty clay loam in nature. The physical properties *viz.,* bulk density, particle density, porosity and water holding capacity were 1.35 (Mg m^{-3}), 2.64 (Mg m^{-3}), 47.3 per cent and 40.1 per cent, respectively. The organic carbon status was medium and the exchange reactions of soil in respect of cations were 13.4 cmol (p^+) kg^{-1}. Available nutrient status of soil with respect to N, P and K showed high K, medium P and low N.

Nutrient composition of the manures: FYM recorded 0.97 per cent of N, 0.58 per cent of P and 0.72 per cent of K. GLM (Glyricidia) was recorded high K (4.6%) followed by N (2.76 %) and P (0.28 %), NPK content in HA were 3.5, 1.5 and 2.1 per cent, respectively.

Change in soil reaction (pH): Initial pH of the soil ranged from 8.0 to 8.4. During the I^{ST} two weeks, no change in the pH was observed. After 30 days the pH starts declining up to 7.9. The fall in pH was more in fly ash + GLM than in fly ash alone treatment. As the incubation prolonged to 60 days the pH had fallen to the initial pH level (Table 1). The pH of soil has slightly increased with the addition of fly ash. This may be attributed to the reaction of CaO present in the fly ash with soil water and atmospheric CO_2 as the incubation was conducted in an open system. Similar results were reported by (Dash

Table 1. Effect of fly ash, manures and fertilizers on soil reaction at different periods of incubation

Treatments	Initial					IVth week					IXth week				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
F_0	8.2	8.2	8.1	8.4	8.23	8.0	8.0	8.0	7.9	7.98	8.2	8.2	8.1	8.3	8.20
F_1	8.3	8.4	8.4	8.3	8.35	8.1	8.1	8.2	8.1	8.13	8.2	8.3	8.2	8.3	8.25
F_2	8.4	8.4	8.4	8.2	8.35	8.0	8.0	8.2	8.1	8.08	8.3	8.1	8.1	8.2	8.18
F_3	8.3	8.3	8.2	8.3	8.28	8.0	7.9	7.9	8.2	8.00	8.2	8.3	8.2	8.2	8.23
F_4	8.3	8.3	8.2	8.2	8.25	8.0	7.8	7.9	8.1	7.95	8.2	8.1	8.1	8.1	8.13
F_5	8.2	8.2	8.0	8.1	8.13	7.9	7.8	8.1	8.1	7.98	8.1	8.1	8.0	8.1	8.08
F_6	8.1	8.1	8.1	8.1	8.10	7.8	7.8	7.9	8.0	7.88	8.1	8.0	8.1	8.1	8.08
Mean	8.26	8.27	8.20	8.23	8.24	7.97	7.91	8.03	8.07	8.00	8.19	8.16	8.11	8.18	8.16
CD (P = 0.05															
M			0.06					0.0					0.05		
F			0.08					0.09					0.0		
M×S			0.17					0.18					NS		

and Sahoo 2017, Jambhulkar et al 2018). The degree of change in soil pH upon the addition of fly ash generally depends on the pH of fly ash and soil, buffering capacity of soil and the amount of CaO, MgO, and Al_2SiO_5 present in fly ash (Truter et al 2005, Schonegger et al 2018). Fly ash might contain considerable amounts of silicate minerals such as mullet, which in principle can take up H^+ and helps to neutralize the pH through the formation of silisic acid. Thus, dissolving even a small quantity of silicate minerals with fly ash application would broadly increase the soil pH (Jankowski et al 2006, Panda and Biswal 2018). The decline and stability could be ascribed to the formation of stable carbonates of Ca and Mg (Table 1d). The atmospheric CO_2 in the absence of organic manures and CO_2 evolved from the decomposing organic manures would have facilitated the formation of stable carbonates and thus resulting in the stability of pH with time (Sahu et al 2017, Yakubu et al 2018). The magnitude of reduction in the pH was more in fly ash and organic manure incubated soils. The results indicated that fly ash by virtue of the presence of Ca, Mg and Na oxides would raise the pH of the soil (Ribeiro et al 2018). Adding fly ash with manures to a highly buffered soil might not affect the soil pH very much.

Change in soil salinity (EC): The initial values of EC in the fly ash, manure and fertilizers treated soil ranged from 0.51 to 0.66 dS m^{-1} (Table 2). Significant increase in the soil salinity was with the application of fly ash along with organic manures. During the initial week of incubation study, changes in the soil salinity were recorded were small. In the 4th week of incubation period, the EC increased from 0.58 to 0.72 dS m^{-1} (Table 2). Thereafter, a gradual decrease in the pH was recorded in the proceeding weeks and it became stable at the end of the incubation period. At the end of the incubation period the EC was 0.50 to 0.66 dS m^{-1}. Increase in the soil salinity with the addition of fly ash may be attributed to the dissolution of salts from fly ash and added manures. This dissolution of salts might raise the ionic concentration in the soil solution. The results were in accordance with the findings of Prita and Alka (2012). Since fly ash is rich in soluble salts, its soil application might tend to increase soil EC (Tsadilas et al 2002), which could be undesirable. However, in some cases, the soil EC was decreased due to fly ash application (Sinha and Gupta 2005). The decrease in soil EC in these cases were attributed to the precipitation of the soluble compounds in the ash amended soils. In general, it could be said that fly ash application to soils is not likely to increase EC to harmful levels for most agricultural crops, unless fly ash is applied in excessive amounts (Sahu et al 2007).

Release and availability of nitrogen in soil: Initially the available N content of fly ash alone, fly ash + FYM, fly ash + HA and fly ash + GLM treated soil were 116.2, 131.7, 122 and 134.3 mg kg^{-1}, respectively (Table 3). Addition of fly ash, manures and fertilizers showed an increase in the status of available N content at 6th week of incubation period. The available N content of 119, 136.8, 125.5 and 143.2 mg kg^{-1} was recorded in fly ash alone, fly ash + FYM, fly ash + HA and fly ash + GLM, respectively on 6th week (Table 3). After that decline in the status of soil available N was observed (Table 3a-3d). Though there was a decline in the available soil N status as the period of incubation proceeded, the effect of fly ash and organic manures on increasing available N content in the treated soil was found to be statistically significant. Fly ash is a poor source of N. Combined application of fly ash

Table 2. Effect of fly ash, manures and fertilizers on electrical conductivity (dS m^{-1}) at different periods of incubation

Treatments	Initial					IVth week					IXth week				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
F_0	0.51	0.50	0.50	0.52	0.50	0.62	0.52	0.51	0.55	0.55	0.52	0.50	0.50	0.55	0.52
F_1	0.61	0.51	0.49	0.59	0.55	0.65	0.56	0.56	0.61	0.59	0.60	0.52	0.51	0.60	0.56
F_2	0.62	0.61	0.56	0.66	0.61	0.66	0.64	0.61	0.66	0.64	0.62	0.62	0.61	0.66	0.63
F_3	0.67	0.68	0.59	0.64	0.65	0.71	0.72	0.61	0.66	0.67	0.61	0.67	0.60	0.65	0.63
F_4	0.56	0.62	0.61	0.49	0.57	0.59	0.66	0.61	0.55	0.60	0.55	0.63	0.63	0.52	0.58
F_5	0.60	0.58	0.59	0.55	0.58	0.64	0.61	0.60	0.58	0.61	0.60	0.61	0.61	0.55	0.59
F_6	0.58	0.60	0.57	0.60	0.59	0.61	0.62	0.59	0.58	0.60	0.60	0.60	0.61	0.60	0.60
Mean	0.59	0.58	0.55	0.58	0.58	0.64	0.62	0.58	0.60	0.61	0.58	0.59	0.58	0.59	0.58
CD (P = 0.05)															
M			0.01					0.01					0.007		
F			0.01					0.01					0.02		
M×S			0.03					0.02					NS		

with manures and fertilizers increased the nitrogen availability in soil. The sole addition of fly ash with poor N and C contents might not be a good source to improve soil fertility with respect to available N (Sajwan et al 2003). Conjoint addition of fly ash and organics can be recommended to provide the necessary nutrients, moisture, aeration, energy and conducive C: N ratio and this could facilitate better biotic activities and release of available N. The fly ash combined with GLM and RDF showed better results in improving the nitrogen content of soil compared to the other treatment combinations. Similar results were reported by Ondrasek et al (2021).

Release and availability of phosphorus in soil : Soil treated with fly ash alone, fly ash + FYM, fly ash + HA and fly ash + GLM recorded the initial available P as 10.7, 11.7, 11.2 and 12.2 mg kg^{-1}, respectively (Table 4). Increasing pattern in available P was recorded on 6th week of incubation. After 6th week of incubation period, the fly ash, organic manure and fertilizer treated soil showed decline in the P availability as the period of incubation advanced. At the end of the period the P content was recorded as 11.5, 13.1, 1.5 and 13.2 mg kg^{-1} (Table 4). However the effect of fly ash and organic manures on increasing available P in the treated soils was found to be statistically significant, as compared to the initial available P status. Conjoint application of fly ash and organics had marked influence on P availability. The synergistic effect of combined addition and the contribution of P from the organic sources might have resulted in the marked enhancement of P

Table 3. Effect of fly ash, manures and fertilizers on $KMnO_4$ N (mg kg^{-1}) release at different periods of incubation

Treatments	Initial					IVth week					IXth week				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
F_0	112.6	129.3	120.0	131.0	123.2	114.0	136.6	123.0	138.3	128.0	113.3	136.3	125.3	136.0	127.7
F_1	119.3	133.6	123.0	137.6	128.4	121.0	139.0	126.3	146.3	133.1	123.0	139.3	127.6	144.3	133.5
F_2	118.0	133.0	123.6	136.6	127.8	123.3	138.3	127.3	144.3	133.3	123.3	138.0	127.6	142.3	132.8
F_3	117.3	132.3	123.6	135.6	127.2	120.0	136.3	126.3	145.0	131.9	121.0	137.0	126.6	143.2	132.0
F_4	116.3	131.6	121.3	134.0	125.8	118.0	134.6	126.0	143.3	130.5	120.0	137.0	126.6	142..0	131.2
F_5	115.6	131.3	121.3	133.3	125.4	118.3	135.0	124.0	143.0	130.0	119.3	137.3	125.0	141.3	130.7
F_6	114.6	130.6	121.3	132.3	124.7	118.6	138	125.6	142.3	131.1	119.6	136.3	125.3	140.3	130.4
Mean	116.2	131.7	122.0	134.3	126.1	119.0	136.8	125.5	143.2	131.1	119.9	137.3	123.6	135.7	131.2
CD (P = 0.05)															
M			0.45					0.66					0.56		
F			0.60					0.87					0.74		
M×S			1.21					1.74					NS		

Table 4. Effect of fly ash, manures and fertilizers on NaHCO3 extractable P (mg kg^{-1}) release at different periods of incubation

Treatments	Initial					IVth week					IXth week				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
F_0	10.4	11.5	11.1	12.0	11.2	11.1	12.8	12.4	13.3	12.4	11.0	12.0	12.1	13.0	12.0
F_1	10.9	11.9	11.4	12.4	11.6	11.9	13.8	13.0	13.9	13.1	11.7	13.5	12.8	13.4	12.9
F_2	10.7	11.9	11.3	12.3	11.6	11.8	13.6	13.0	13.8	13.0	11.7	13.5	12.8	13.4	12.8
F_3	10.8	11.7	11.3	12.3	11.5	11.8	13.5	12.8	13.7	12.9	11.7	13.3	12.6	13.3	12.7
F_4	10.7	11.7	11.3	12.2	11.5	11.6	13.4	12.7	13.7	12.8	11.6	13.3	12.4	13.2	12.6
F_5	10.7	11.7	11.2	12.2	11.4	11.5	13.5	12.7	13.7	12.8	11.4	13.1	12.4	13.2	12.5
F_6	10.5	11.7	11.2	12.1	11.4	11.5	13.0	12.6	13.6	12.6	11.2	12.9	12.3	13.1	12.3
Mean	10.7	11.7	11.2	12.2	11.5	11.6	13.4	12.7	13.7	12.8	11.5	13.1	12.5	13.2	12.6
CD (P = 0.05)															
M			0.04					0.08					0.06		
F			0.05					0.11					0.07		
M×S			NS					23					0.15		

Table 5. Effect of fly ash, manures and fertilizers on NH_4OAc extractable K (mg kg^{-1}) release at different periods of incubation

Treatments	Initial					IVth week					IXth week				
	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean	M_0	M_1	M_2	M_3	Mean
F_0	175.0	189.3	183.3	186.1	183.4	182.3	195.6	192.0	188.4	189.6	179.6	193.6	190.3	188.6	188.0
F_1	183.3	194.6	188.6	210.0	194.1	191.0	206.0	203.6	214.6	203.8	185.3	202.0	197.3	212.6	199.3
F_2	182.6	191.0	186.3	205.3	191.3	185.0	196.3	193.0	206.4	195.2	184.0	199.0	192.6	205.6	195.3
F_3	181.6	194.3	187.3	207.1	192.6	189.0	202.0	199.3	212.6	200.7	185.3	200.0	194.6	210.8	197.7
F_4	179.6	193.0	186.3	202.1	190.3	188.3	199.0	196.3	204.3	197.0	184.0	198.3	192.6	200.7	193.9
F_5	179.0	192.3	186.0	203.4	190.2	186.0	199.3	196.0	201.4	195.7	183.3	197.3	192.3	200.5	193.4
F_6	178.3	190.6	184.6	193.4	186.7	186.3	197.6	195.6	194.1	193.4	182.0	195.3	191.0	190.1	189.6
Mean	179.9	192.1	186	201.1	189.8	186.8	199.4	196.5	203.1	196.5	183.3	19.9	191.3	201.3	193.9
CD (P = 0.05)															
M			0.7					0.8					0.5		
F			0.9					1.0					0.7		
M×S			1.9					2.1					NS		

availability in the soils (Ondrasek et al 2021). The increased P availability was in the highest order with the combined addition of organics with fly ash at 20 t ha^{-1} indicating higher levels of fly ash would result in higher p availability whatever may be the soil type. The organic acids would have hastened the solubility of fly ash P and thus adding more to the available P pool (Schonegger et al 2018, Hong et al 2018, Sharma and Kalra 2005). Increase in P release during the study was noticed from 15th day onwards and it reached to the maximum on 45th day of incubation. The availability tends to decline after 45 days and it might be attributed to the reversion of available P into soluble form. Results clearly showed that fly ash either as such or in combination with organic manures could improve the P availability of the soil. The results were corroborated with the earlier findings of Seshadri et al (2013).

Release and availability of potassium in soil: Regarding K availability, the initial soil available K status was recorded as 179.9, 192.1, 186 and 206.2 mg kg^{-1} in fly ash alone, fly ash + FYM, fly ash + HA and fly ash + GLM treated soil respectively (Table 5). Available K content did not show any changes during the first four weeks, the increase in the K was observed at 4th week (Table 5). Application of fly ash + GLM recorded the highest K content of 211.9 mg kg^{-1} and the least was registered in the fly ash alone treated soil (186.8 mg kg^{-1}). The availability of K was found to increase with the manurial addition along with fly ash. The availability was reduced significantly as the period of incubation advanced 60 days (Table 5). With respect to the interaction effect of fly ash, manures and fertilizers the highest K content was recorded in fly ash + GLM and RDF on 4th week. At the end of the incubation period the K content was decline to 183.3, 197.9, 193 and 211 mg kg^{-1} in fly ash alone, fly ash + FYM, fly ash + HA and fly ash + GLM treated soil respectively. Addition of fly ash enhanced the available K content in soil. Application of organics along with fly ash added good amount of K to soil. As the incubation period advanced, decline in the K content was observed and the reduction could due to the mobilization of Ca from the added sources which might have affected the release of K (Ashfaque and Inam 2019). This trend explains the possible fixation of K in the soils, when the concentration of K increased due to the additive effect of fly ash and organics. Khan and Khan (1996) reported the highest available K in soil treated with fly ash within 15 days of incubation and thereafter a decline up to 5th week was noticed. Those changes might be attributed to the dynamic nature of K-fixation and release as pointed out by Sarwar et al *(*2008).

CONCLUSION

The present study reveals that soil reaction and electrical conductivity did not show any negative impact in soil with the addition of the fly ash. Available nutrient release was high in the soil treated with fly ash @ 20 t ha^{-1} and GLM @ 6.25 t ha^{-1} along with RDF. With respect to available NPK content, the nutrient release was observed up to 40 days for N, P and 30 days for K in the incubation experiment. When these findings are taken to the field crop, it will enhance the nutrient content and uptake besides improving the post-harvest soil nutrients status.

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Evaluation of the Efficiency of the Northern Project for the Water Purification and Transport, in Al-Dour City, Salahaldin, Iraq

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***Abstract*:** The study was conducted to evaluate the efficiency of the northern project for water purification and transport in Al-Dour City, based on the of physical tests and chemical analyses in addition to pollution Indicators Water Quality Index (WQI), and Heavy Metal Pollution Index (HPI). Water samples were collected from four sites: Tigris River water (Intakes), sedimentation basins, after passing through the filtration unit, and house water. Laboratory work included the physiochemical properties of water: EC, TDS, TH, Tur., Alk and pH. It also included chemical analyses for samples: Cations (Ca, Mg, Na, and K), Anions (SO_4, HCO_3,Cl, and NO_3) and Heavy Metals, such as: Fe, Co, Zn, Cu, Mn, Cd, and Pb. Accuracy of chemical analyses were calculated using the Ionic Balance Equation. The results of the analyses were compared with the limits and specifications proposed by the Iraqi standard (IQS), World Health Organization (WHO), and Canadian Specifications. The concentrations of the major Ions (Cations and Anions) were within the permissible limits, while the Heavy Metals were within the permissible limits except Iron and Cadmium. Water Quality Index **(**WQI), it was found that the water quality was not acceptable for drinking in River, and Filtrations basin, and was very poor in Sedimentation basin, and poor in Houses. Heavy Metal Pollution Index (HPI), was low in River and Sedimentation basin and medium in Filtrations basin and Houses. In general, the efficiency of the project was acceptable, but required chemical treatments to remove heavy metals, suspended contaminated sediments, and impurities in addition to the disposal of unacceptable turbidity.

***Keywords*:** Al-Dour, Heavy metals, Standard specification, Pollution indicators

Fresh water is vital to life and yet it is a finite resource and of all the water on earth, just 3% is fresh water, (Souilmi and Tahraoui 2021). Many water resources are polluted due to variable reasons. The United Nations reports that the use of contaminated water leads to the death of a child every eight seconds (Montana et al 2013). Water quality depends mainly on the physical and chemical properties and determines the suitability of use of this water. Accordingly, water standards have been developed for the purpose of determining their suitability for different uses, (WHO 2011). The constant variability in the chemical composition of river water is very important for water purification and distribution for different uses. The quality of raw water treatment varies as much as the quality of water sources, which leads to the use of scientific and practical methods to reducing and minimizing the impact of pollutants that may exist in an unacceptable proportions and thus control pollution, therefore, interest in studies related to the evaluation of the water efficiency purification projects relationship with human life. The aim of study was to evaluate the efficiency by assessing the water quality before entering the first station comparing with international and local standards to determine their suitability for human drinking.

Study area: The study area is located in Al-Dour City, Salauldin Governorate, Iraq, that longitude (43º 46" 21`) E and latitude (34º 29" 43`) N, it represents the northern water purification project (Fig. 1).

Detailed description of the project: The project is 70 meters away from Tigris River, it was established in 1978. Project area about 15000 m^2, and design capacity 500 m^3 $hour^{-1}$. The project consists of the following units (Fig. 2).

Intake*:* It is located on the Tigris River to draw water with special pumps and delivered it to sediment basin.

Main pumps*:* The four main pumps, two of them are to draw water from the river to the project and two are working to push the water into the city, and operates a maximum capacity 500 m^3 $hour^{-1}$.

Pipelines: Parallel lines of diameter 12 inches, to transport raw water from the intake to the sedimentation basins, filtrations basins, and final tank.

Sediments basin: This units contain two circular basins inside the project, each consisting of three basins, in this station, chlorine is added (primary chlorination).

Filtrations basin: This include four the sand filters type and add chlorine to the water (final chlorination).

Final tank*:* It is the main tank for storing treated water and is located inside the project then the water is pumped to the network. Finally, treated water from the final tank is

transported by lines of 30 cm diameter pipes to the city.

MATERIAL AND METHODS

The necessary water samples were taken before and after treatment from four stations: Intake (Tigris River water), sedimentation basins, after passing through the filtration unit, and then from house water. Physiochemical test, total dissolved solids, pH, electrical conductivity, turbidity and total hardness, of water samples was collected from the project and analyzed at, Department of Chemical Engineering, and of Central laboratory, in Tikrit University. Chemical analysis, included: Cations: sodium (Na^{+}), potassium (K^{+}), calcium (Ca^{++}), and magnesium (Mg^{++}), and Anions such as chloride (Cl^{-}), sulfate ($SO_4^{=}$), bicarbonates (HCO_3^{-}) and nitrate (NO_3^{-}), and heavy metals (Fe, Co, Zn, Cu, Mn, Cd, and Pb). Accuracy (A) was calculated to show the accuracy of chemical analysis using Ionic balance equation (Hem 1985).

$$E\% = (\Sigma r.\ Cat - \Sigma r.\ Ani / r.\ Cat + \Sigma r.\ Ani) * 100$$

$$A = 100 - E\%$$

Where:

E%: Percentage of error.

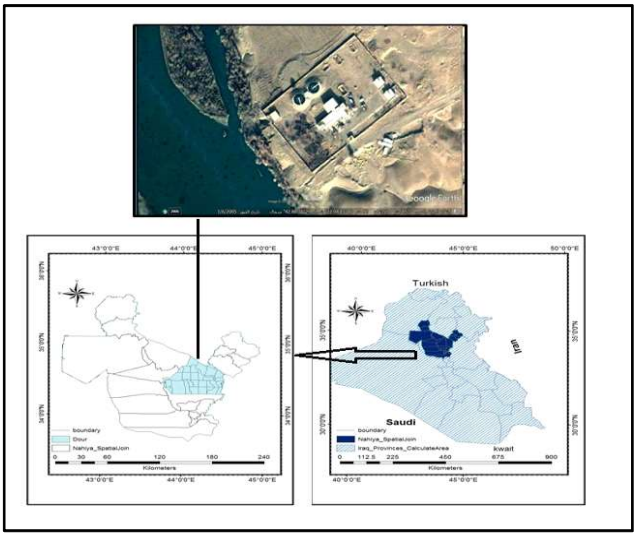

Fig. 1. Location map of the study area

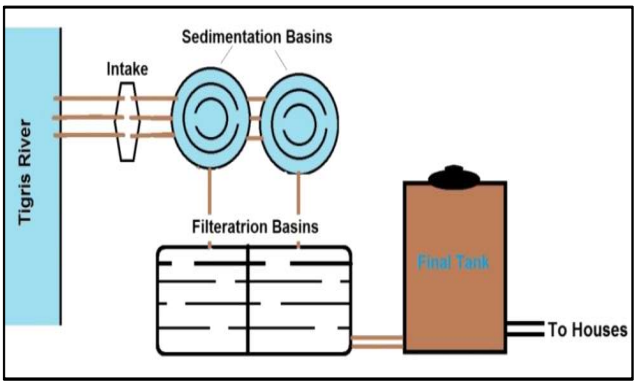

Fig. 2. Main project units

Σ r. Cat: Total concentrations of Cations in units epm.

Σ r. Ani: Total concentrations of Anions in units epm.

Where concentrations of ions in epm.

The international and local specifications and parameters of human drinking (IQS 2009, WHO 2017, Canada 2017), were used to determine the suitability of water and thus evaluate the efficiency of the project.

Pollution indicators were used as the final criterion in evaluating the efficiency of the project work. pollution indicators were:

1. Water quality index (WQI): calculated by equations of Cristina et al (2014).

2. Heavy metal pollution index (HPI): calculated by equations of Ameh and Akpah (2011).

RESULTS AND DISCUSSION

Physical tests: The results of the physical tests are shown in Table 3.

Electrical conductivity (EC): The variation of conductivity gives important information about the evolution of water quality. The EC in the stations of was in range of 489-500 µ.s/cm (Fig. 3). Accordingly Detay classification, water samples are classified as having moderately mineralized water (Table 1).

Total dissolved solid (TDS): TDS concentrations are varied, determined by the geological structure, the different solubility of rock materials, and the time it takes for water to come into contact with the rocks. TDS values ranged between 267-312 ppm, (Fig. 3). According on Todd 2005 and Klimentove 1983 classification the station water was Fresh water (Table 2).

Total Hardness (TH): In the Stations, TH ranged between 220 to 277 ppm (Fig. 3). Hard type based on Boyd classification of Boyd 2000.

Turbidity (Tur): In the Project stations of the Turbidity ranged between 6.71-15 NTU.

Alkalinity (Alk): The main source of carbon dioxide that produces alkalinity in water is the CO_2 gas fraction of the atmosphere, or the atmospheric gases present in the dirt (Towfik and Hammadi 2020). Alk values showed a range of 134- 162 ppm.

pH: In most of standards pH must be between 6.5 to 8.5. In the stations the pH value was 7.3 to 7.7. The pH is affected by several factors, including temperature, the presence of calcium carbonate and plants, as the photosynthesis process reduces the amount of carbon dioxide and causes an increase in pH.

Temperature (T): It was between 34 to 39 Cº. Water temperature directly touches many of its physiochemical characteristics..

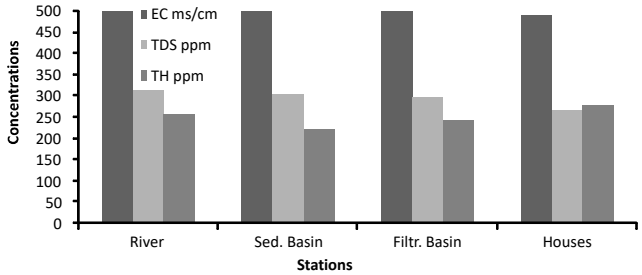

Fig. 3. Concentrations of EC, TDS, and TH in the stations

Table 1. Relation between EC and mineralization (Detay 1997)

EC (µS cm^{-1})	Mineralization
<100	Very weakly mineralized water (granite terrains)
100-200	Weakly mineralized water
200-400	Slightly mineralized water (limestone terrains)
400-600	Moderately mineralized water
600-1000	Highly mineralized water
>1000	Excessively mineralized water range

Table 2. Todd and Klimentove water classification

Water class	Todd, 2005	Klimentove, 1983
Super	-	200
Fresh Water	<1000	200 – 1000
Slightly saline	1000 – 3000	1000 – 3000
Brackish Water	3000 – 10000	3000 – 10000
Saline Water	10000-35000	10000 – 35000
Brine	> 35000	> 35000

Table 3. Physiochemical properties of water samples

Stations	EC µ.s cm^{-1}	TDS ppm	T.H ppm	Tur NTU	Alk ppm	pH	T C°
River	500	312	257	14.60	162	7.7	34
Sedimentation Basin	496	302	220	7.45	147	7.6	37
Filtration Basin	497	297	243	15	134	7.6	34
Houses	489	267	277	6.71	159	7.3	39

Chemical Analyses

Cations: The results of Cations are shown in Table 4 and Figure 4.

Calcium (Ca^{+2}): The concentrations varied between 80 to 95 ppm. Calcium was dominant cation which separately accounted for of the total cations. The relatively high values of Calcium in the study area are attributed to the presence of dissolution of some sedimentary minerals, such as calcite, dolomite, anhydrite, and gypsum. Most Calcium in surface water comes from streams flowing over limestone, gypsum, and other calcium-containing rocks and minerals. Evaporates rocks containing gypsum and anhydrite are also most important sources of calcium soluble in water

Magnesium (Mg^{+2}): Mg value was between 2.5 and 18.7 ppm.

Sodium (Na^{+}): Sodium values of the study area varied from 5.65 to16.7 ppm.

Potassium (K^{+}): Rivers generally contains about 2-10 ppm potassium. Potassium is highly soluble, therefore it is not easily removed from water except by ion exchange (Filippin et al 2008). The concentrations varied between 6.1 to 8.22 ppm.

Anions: The results of Anions are shown in Table 4 and Figure 5.

Sulfate (SO_4^{-2}): Sulfate concentration in the water samples of the study area ranged between 16.8 to 28.6 ppm. Sedimentary rocks such as gypsum and anhydrite represent an important source of sulfate (Todd 2005). Other sources for sulfate include agricultural and industrial activities (Obiefuna and Sheriff 2011).

Bicarbonate (HCO_3^{-}): Its concentrations ranged between 94.77 to 101.25 ppm, which is within the permissible limits. The little increase in HCO_3^{-} can be attributed to the effect of CO_2 in the atmosphere and in soil and carbonate rock solutions. In addition, the process of respiration and decay of plants after their death, CO_2 is released.

Chloride (Cl-): The Chloride concentration in the stations

Table 4. Chemical analyses (cations, anions) of water samples

Stations	Units	Cations				Anions				Accuracy %
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$SO_4^{=}$	HCO_3^{-}	Cl^{-}	NO_3^{-}	
River	ppm	95	4.65	15	8.22	22.5	98.45	138	4.54	97%
	epm	4.47	0.38	0.65	0.20	0.47	1.61	3.89	0.07	
Sedimentation Basin	ppm	83	3.01	16.7	8	28.6	94.77	112	3.5	98%
	epm	4.14	0.25	0.73	0.20	0.60	1.55	3.16	0.06	
Filtration Basin	ppm	93	2.5	5.65	6.25	16.8	101.25	92	4.99	95%
	epm	4.64	0.21	0.25	0.15	0.35	1.66	2.60	0.08	
Houses	ppm	80	18.7	7.18	6.1	19.7	97.32	120	6.52	96%
	epm	3.99	1.54	0.31	0.15	0.41	1.60	3.39	0.1	

was between 92 to 138 ppm. High concentration of Cl^-, because chloride content is increased in water by evaporation and salts chloride has high solubility, such as Halite. Thus, the falling rain (even if a few) dissolves chloride salts and increases water content. Cl^- with HCO_3^- were dominant Anions which separately accounted for of the total Anions.

Nitrate (NO_3^{-1}): Nitrate value ranged 3.5 to 6.5 ppm, which is within the permissible limits. In general, nitrate is a very small percentage in the Tigris River water.

Heavy metals: The concentrations of Heavy metals were found for the water samples: Fe, Co, Zn, Cu, Mn, Cd, and Pb, Figure 6, and Table 5. Most of the concentrations were within its acceptable limits except Fe and Cd.

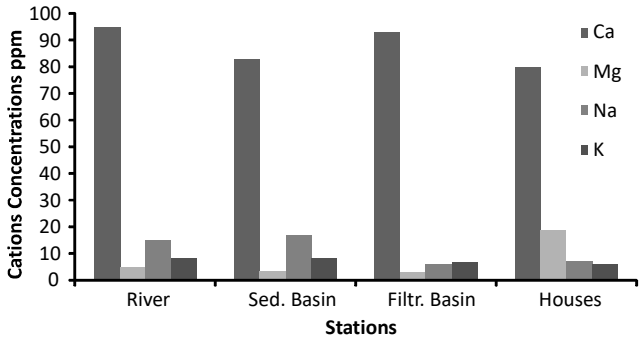

Fig. 4. Concentrations of cations in the stations

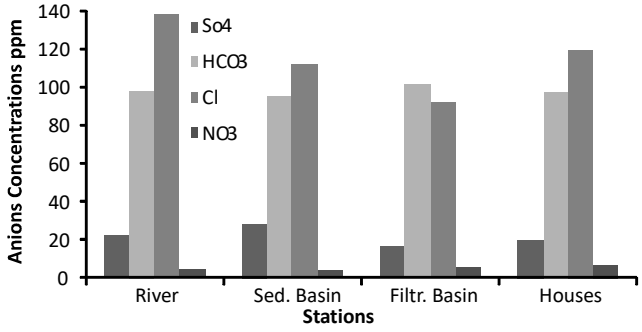

Fig. 5. Concentrations of anions in the stations

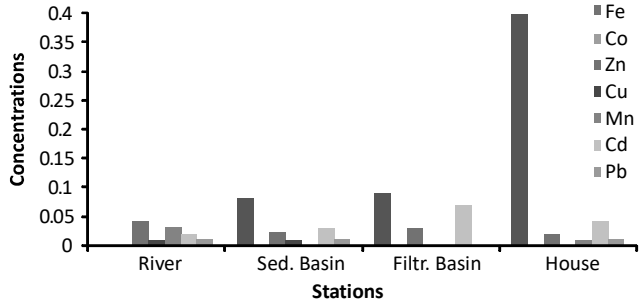

Fig. 6. Concentrations of heavy metals in the stations

The potential contamination of river waters with Heavy metals is very harmful due to their non-biodegradable nature, long biological half-lives and their potential to

Table 5. Heavy metals concentrations (ppm) of water stations

Station	Fe	Co	Zn	Cu	Mn	Cd	Pb
River	0. 21	0.001	0.04	0.008	0.031	0.02	0.01
Sedimentation Basin	0.08	Nil	0.021	0.007	0.002	0.03	0.011
Filtration Basin	0.09	Nil	0.029	0.002	0.002	0.07	0.001
House	0.41	0.002	0.02	Nil	0.007	0.04	0.01

Table 6. Standards (international and local) for drinking water

Types	Parameters (ppm)	WHO 2017	Canada 2017	IQS 2009
Physio-chemical	TDS	600	500	1000
	pH	8.5	6.5-8.5	6.5- 8.5
	T.H.	500	500	500
	Tur. (NTU)	5	--	5
Cations	Ca^{++}	100	--	150
	^{++}Mg	125	--	100
	Na^+	200	200	200
	K^+	12*	--	--
Anions	$SO_4^=$	250	≤ 500	400
	HCO_3	350*	--	--
	Cl^-	250	250	350
	NO_3^-	50	45	50
Heavy metals	Cu^{2+}	2	1	1
	Pb^{2+}	0.01	0.01	0.01
	Fe^{2+}	0.3*	≤ 0.3	0.3
	Zn^{2+}	3	≤ 5	3
	Cd^{2+}	0.003	0.005	0.003
	CO^{2+}	0.002	--	--
	Pb	0.01	0.01	0.01

* WHO 2006

Table 7. Water quality index (WQI) in the project stations

Name of stations	Water Quality Index (WQI)
River	155.947
Sedimentation Basin	91.012
Filtration Basin	154.281
Houses	71.030
Not acceptable for drinking, Very Poor type, Poor type	

* Classification of water Quality Index (WQI) (Brown et al 1972): If WQI>25 Excellent type, 26-50 Good type, 51-75 Poor type, 76-100 Very Poor type, and <100 Not acceptable for drinking

Table 8. Heavy Metal Pollution Index (HPI) in the four water samples

Name of stations	Heavy Metal Pollution Index (HPI)
River	8.4715
Sedimentation Basin	11.9155
Filtration Basin	24.349
Houses	19.4575
Low pollution, Medium pollution	

* Classification of Heavy Metal Pollution Index (HPI) (Tiwari et al 2015): If HPI >15 Low pollution, 15-30 Medium pollution, and <30 High pollution

accumulate in different body part, (Khanna et al 2011). The natural sources of Heavy metals are the weathering of the rocks and soil. Pollution of the natural environment by heavy metals is a universal problem because these metals are indestructible and most of them have toxic effects on living organisms, when permissible concentration levels are exceeded (Mmolawa et al 2011).

After comparing physiochemical and chemical analysis results, (Table 3, 4) with the international and local specifications (Table 6), and all parameters were within the permissible limits except the turbidity was more than 5 NTU. From Comparing the results of the heavy elements most of them were within the permissible limits except for increase of Iron (Fe), and Cadmium (Cd). The concentration of iron was within the permissible limits in the first three stations and exceeded the limit after the arrival of water from the project to the houses, and this indicates that there is corrosion in the water transmission network.

Pollution Indicators

Water quality index (**WQI):** The Water Quality Index for the water samples of the project was classified based on the Brown classification which depends on the physicochemical properties of water, and water quality was not acceptable for drinking in River, and Filtration basin, and very poor in Sedimentation basin, and poor in Houses (Table 7).

Heavy metal pollution index (HPI): This indicator was calculated based on the classification of Tiwari et al 2015. The pollution level was low in the River, and Sedimentation basin, and it was Medium pollution level in Filtration basin and Houses (Table 8).

CONCLUSIONS

Based on the analyses results, it was found that raw water (Tigris River water) is generally good for treatment and processing of water suitable for human use. After comparing the physiochemical test results with international and local standards and specifications, it was found that within the permissible limits except Turbidity. The chemical analyses results (Cations and Anions) were all within the permissible limits for human drinking. From Comparing the results of the Heavy Metals concentrations with the specifications, it was found that most of the elements were within the permissible limits except for a noticeable increase of Iron (Fe), and Cadmium (Cd). Iron increased content and the crossing of the permissible limit at the fourth station (water houses) reflects the inefficiency of the water pipeline network. Water Quality Index (WQI) it was found that the water quality was not acceptable for drinking in River, and Filtration basin, and was very poor in Sedimentation basin, and poor in Houses. Heavy Metal Pollution Index (HPI), was low in River, and Sedimentation basin, and Medium pollution level in Filtration basin and Houses. In general, this study showed acceptable efficiency of the project to filter and treat water except the turbidity and increase of Iron and Cadmium. We recommend, attention to the chemical unit treatment in the project and to provide the plant with integrated units and devices for the purpose of avoiding the increase of heavy metals and suspended contaminated sediments. In addition to the use of anti- corrosion pipes and tanks to improve the water transport and storage network to maintain water quality. Finally, a periodic cleaning of water treatment basins and tanks for the purpose of getting rid of turbidity and contaminated sediments.

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Study on Bioaccumulation and Translocation of Trace Metals by, *Eichhornia crassipes* and *Pistia stratiotes* from Selected Fresh Water Ecosystems of Goa

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***Abstract*:** Aquatic species show different capacities for metal uptake and can accumulate trace metals in roots, stems and/or leaves thereby improving the lake ecosystems. Present study compares the trace metal bioaccumulation and translocation capabilities of two aquatic macrophytes viz. *Eichhornia crassipes,* and *Pistia stratiotes* from selected fresh water bodies of Goa. Trace metals from water were extracted using APDC (ammonium pyrorolidene dithio carbamate) and MIBK (methyl isobutyl ketone). Root and shoot samples of selected macrophytes were digested using nitric acid and were aspirated for detection of trace metals using Atomic Absorption Spectrophotometer. Metal concentration in water except Zinc, exceeded the drinking water limits prescribed by WHO. Lotus lake was more contaminated as compared to Curtorim lake as far as trace metal concentration is concerned. Aquatic macrophytes showed absorption of trace metals in the following order for *E. crassipes* - Fe>Cu>Mn>Zn>Ni>Pb and for *P. stratiotes* – Cu>Mn>Fe> Zn>Pb>Ni. Absorbed metals were accumulated and translocated in the plant body. Differences in bioaccumulation and translocation factor (BAF and TF) indicate the preferential accumulation/uptake and translocation of metals due to morphological and anatomical peculiarities of selected species. Both aquatic plants have rapid growth rate, high biomass yield, show uptake of a large amount of trace metals, the ability to transport metals in aboveground parts of plants is high, so also the mechanism to tolerate metal toxicity is very high. Environmental factors like pH, solar radiation and nutrient availability greatly influence phytoremediation potential and growth of these plants. BAF and TF were higher than 1 in most of the metals analyzed in case of both the species thus proving to be highly potential for phytoremediation of aquatic bodies contaminated with trace metals.

Keywords: Trace metals, Phytoremediation, Bioaccumulation and translocation factor, *Eichhornia crassipes, Pistia stratiotes*

Aquatic ecosystems are heavily influenced by human activity over the years. Many industrial and mining processes cause trace metal pollution, which contaminate fresh water systems and become a hazard to human health **(**Delbari and Kulkarni 2013, Kumar and Balamurugan 2018, Mohanakavitha et al 2019**)**. Colonization of macrophytes on water or sediments polluted with trace metals and their role in transportation of metals is very important. Submerged, emergent and free-floating aquatic macrophytes are known to accumulate and bioconcentrate trace metals from the water, producing an internal concentration several fold greater than their surroundings (Lu et al 2010). Many of the aquatic macrophytes are potential scavengers of trace metals from water (Ugya et al 2015). The present investigation was planned and executed to understand the potential of macrophytes *E. crassipes* and *P. stratiotes* as a biological filter of the aquatic environment.

MATERIAL AND METHODS

Study has been carried by selecting two water bodies from South Goa district in viz; Lotus and Curtorim Lakes. Lotus lake is situated between 15.2°N Latitude and 73.9°E Longitude at Benaulim in Salcete taluka. The lake is polluted and has abundant growth of aquatic weeds. Curtorim Lake is situated between 15.2°N Latitude and 74.0°E Longitude at Curtorim in Salcete taluka. Lake is a source of irrigation for paddy crop (Fig. 1). Water and plant samples were collected during pre-monsoon, monsoon and post Monsoon seasons. Trace metals *viz.,* Fe, Mn, Cu, Ni, Zn and Pb were analyzed from water and aquatic plants using standard protocols.

Sample collection, preparation and analysis: Sterile plastic containers (washed with detergent, later with 1:1 nitric acid and rinsed with deionized water) of one litre capacity were used sample collection. Samples were acidified by adding few drops of concentrated HNO_3. After transportation to laboratory it was filtered using 0.45 microns pore (Millipore) filter. From this 500 ml of water sample was taken in 1000 ml separating funnel and pH was adjusted to 4-5 with dilute NH_3. Trace metals from water were extracted using APDC (ammonium pyrorolidene dithio carbamate) and MIBK (methyl isobutyl ketone) (APHA, 2012). Ten ml of APDC and 15 ml MIBK was added to sample and mixture was shaken for two minutes. The two phases were allowed to separate after 15-30 minutes. Upper organic layer was drained into 100ml

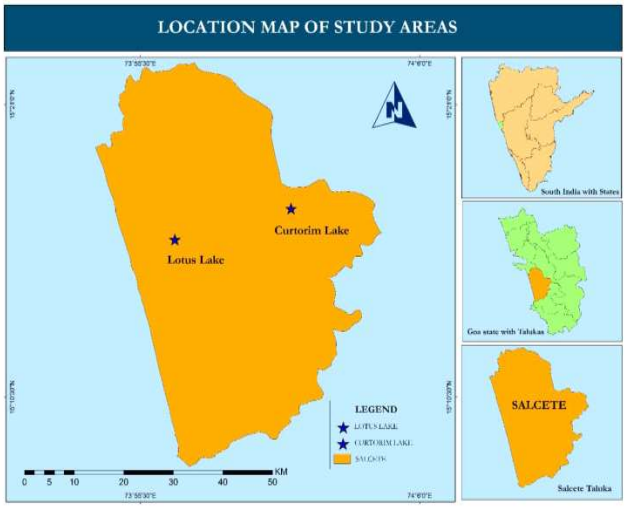

Fig. 1. Location of study sites

separating funnel (ensuring that MIBK extract was free from water sample). The procedure was continued by adding 5 ml APDC and 10 ml MIBK to water sample and the contents were transferred in a separating funnel. The contents were shaken again for 2 minutes and both the extracts were combined. Aquatic plants were handpicked from the habitat that is Lotus and Curtorim Lakes and washed with lake water carefully. For estimation of trace metals, roots and shoots of *E. crassipes* and *P. stratiotes* were separated, washed in distilled water and dried at 70°C in hot air oven for 48 hours. Dried samples were homogenized and ground to yield fine powder. Nitric acid digestion method was followed for extraction of trace metals from plants (Zheljazkov and Nielson 1996). One gram of powdered sample was taken to which 10 ml of concentrated HNO_3 was added. The sample was heated for 45 minutes at 90°C, and then the temperature was increased to 150°C at which the sample was boiled for at least 8 hours until a clear solution was obtained. Concentrated HNO_3 (5 ml) was added thrice to the sample. Digestion was carried out until the volume was reduced to 1 ml. After cooling, 5 ml of 1% HNO_3 was added to the sample. The solution was filtered using Whatman No. 42 filter paper and transferred to a 25 ml volumetric flask by adding milique water. The digested sample solutions were aspirated for trace metals using Atomic Absorption Spectrophotometer after ensuring the technicalities as per standard procedures (APHA, 2012). Average values of three replicates were taken for all detections. The BAF and TF were calculated as follows:

BAF= Metal concentration in plant tissue / Metal concentration in water (Klavins et al 1998).

TF= Metal concentration in root / Metal concentration in shoot (Wu and Sun 1998).

RESULTS AND DISCUSSION

There were significant differences in the trace metal concentration in both the water bodies. Aquatic plants always develop extensive root and shoot system which help them to accumulate contaminants in their body. The metal concentration in water and plants is depicted in Table 1 and 2. The concentration of analyzed metals in water was compared with the drinking water limits prescribed by WHO 2008 (Table 2).

Iron content in water ranged from 0.42 to 8.61 ppm. It exceeding the WHO (2008) drinking water limit. Iron concentration in plants ranged from 0.37 to 12.36 ppm. *E. crassipes* roots showed more accumulation compared to *P. stratiotes* roots while it ranged from 0.04 to 4.29 ppm, in shoots of *E. crassipies.* Total concentration of Fe was higher in *E. crassipes*. Manganese in water ranged from 0.004 to 0.60 ppm which exceeded WHO drinking water limit. It was higher in Curtorim Lake than in lowest at Lotus Lake. Manganese concentration ranged from, 0.37 to 2.65 ppm in root and from 0.02 to 0.34 ppm in shoots. The highest concentration was in *P. stratiotes*. Copper concentration in water varied from 0.014 to 1.72 ppm, which was more than the WHO limit for drinking water and ranged from 0.01 to 3.06 ppm in roots while it varied from BDL to 0.40 ppm in the shoots. Highest concentration of Cu was in *P. stratiotes* followed by *E. crassipes*. Nickel concentration in water varied from BDL to 1.40 ppm exceeding the WHO limit and ranged from BDL to 1.10 ppm in roots and from BDL to 0.06 ppm in shoots. Highest concentration of Ni was in *E. crassipes.* Zinc in water ranged from BDL to 2.52 ppm. However the concentration was lower than WHO limit. It ranged from 0.01 to 1.31 ppm in the roots while it varied from BDL to 0.71 ppm, in shoots. Highest Zn concentration was in *E. crassipes* and *P. stratiotes*. Lead in water ranged from BDL to 0.32 ppm which was higher than WHO drinking water limit. Lead concentration BDL to 0.74 ppm in roots and BDL to 0.51 ppm in shoots and *highest* was in *E. crassipes*. Metal concentration in selected macrophytes was in the following order for *E. crassipes* – Fe>Cu>Mn>Zn>Ni>Pb and for *P. stratiotes* – Cu>Mn>Fe> Zn>Pb>Ni

Earlier workers suggested that *E. crassipes* and *P. stratiotes* are hyper accumulators and can be applied for the remediation of surface waters (Jindal and Kauri 2000, Syed et al 2010, Qin Lu et al 2011, Ndeda and Manohar 2014). Because *E. crassipes* and *P. stratiotes* have quick growth rate, high biomass yield, they uptake of a large amount of trace metals. The ability to transport metals in aboveground parts of plant is high, so also the mechanism to tolerate metal toxicity is very high. Environmental factors like pH, solar radiation and nutrient availability greatly influence

phytoremediation potential and growth of the plant.

Bioaccumulation and translocation factor (BAF): The absorption of metals depends upon the degree and extent of exposure of the water body to anthropogenic activities, size of the water body, amount of rainfall, life cycle of an exposed plant species, besides light intensity, oxygen and even the age of the sampled plant from that particular sampling point (Siriwan et al 2006). Bioaccumulation factor for analyzed metals was: Fe - *Eichhornia* > *Pistia;* Mn - *Eichhornia* > *Pistia;* Cu - *Pistia* > *Eichhornia;* Ni - *Eichhornia* > *Pistia;* Zn - *Pistia* > *Eichhornia;* Pb - *Eichhornia* **>** *Pistia.* Both aquatic plants growing in the study area exhibited variations in trace metal concentrations due to their internal tolerance mechanism and internal detoxification. Metal uptake was more during dry season compared to monsoon. Temperature and pH played an important role in the metal up-take and can be attributed to elevated temperatures in dry season that enhances evapo-transpiration which transports metals at a faster rate from the soil solution to root, steam and leaf. Low water pH during dry season increased metal bioavailability in hydrophytes. Both the aquatic plants showed difference in translocation of accumulated metals. TF for analyzed metals was in following order**:**

Fe - *Pistia* > *Eichhornia;* Mn - *Eichhornia* >*Pistia;* Cu - *Eichhornia* > *Pistia; Ni* - *Pistia* > *Eichhornia;* Zn - *Eichhornia* > *Pistia*; Pb - *Eichhornia* > *Pistia*

Active transport of trace metals in free-floating aquatic plants occurs from the roots, from where metals are transferred to other parts of the plant body. Passive transport is associated with plant body and pollution medium. In passive transport, heavy metals mainly accumulate in upper parts of the plant body. *E. crassipes* and *P. stratiotes* are the most frequently used free-floating plants for the remediation of trace metals (Tabinda et al 2018). *E. crassipes* has the advanced tendency of remediating different pollutants like organic material, trace metals and removal of nutrients. *P. stratiotes* possesses extraordinary tolerance for extensive range of pH and temperature. Extension and proliferation of water lettuce occured with the production of daughter plants and also produced seeds which remained present in water and their germination occured during the wet seasons because of which it is an excellent contender for the phytoremediation (Forni et al 2006). Yanquan et al (2005) reported that when the TF value is greater than 1, the plants are considered as *accumulator species* whereas when TF value is less than 1 the plants are considered as *excluder species*. Akinbile and Yusoff (2012) observed differences in TF values thereby indicating the preferential accumulation/

Table 1. Concentration of trace metals in water in Lotus Lake and phytoaccumulation by *Eichhornia crassipes*

Metal	Pre - monsoon			Monsoon			Post - monsoon		
	Water	*Eichhornia* (Root)	*Eichhornia* (Shoot)	Water	*Eichhornia* (Root)	*Eichhornia* (Shoot)	Water	*Eichhornia* (Root)	*Eichhornia* (Shoot)
Fe	1.03	7.32	0.37	1.35	1.19	0.16	8.61	12.36	4.29
Mn	0.22	0.43	0.30	0.22	1.22	0.09	0.004	1.40	0.02
Cu	BDL	0.01	BDL	1.72	0.20	0.01	0.014	2.25	0.31
Ni	BDL	BDL	BDL	1.32	0.29	0.05	BDL	1.10	0.06
Zn	BDL	0.01	BDL	2.52	1.00	0.30	1.69	1.31	0.49
Pb	0.27	0.41	0.01	0.32	0.05	0.02	BDL	0.74	0.51

Legend : BDL = below detectable level; Fe - Iron, Mn - Manganese, Cu - Copper, Ni -Nickel, Zn - Zinc, Pb – Lead; units -ppm
All values are mean of three readings

Table 2. Trace metal concentration (water) in Curtorim Lake and phytoaccumulation by *Pistia stratiotes*

Metal	Pre - monsoon			Monsoon			Post - monsoon			Maximum permissible limit in water (WHO, 2008) (mg l^{-1})
	Water	*Pistia* (Root)	*Pistia* (Shoot)	Water	*Pistia* (Root)	*Pistia* (Shoot)	Water	*Pistia* (Root)	*Pistia* (Shoot)	
Fe	0.42	0.37	0.04	3.10	1.04	0.59	3.31	2.01	1.26	0.30
Mn	BDL	0.92	0.34	0.40	0.37	0.06	0.60	2.65	1.06	0.10
Cu	BDL	3.06	0.40	1.47	2.45	0.10	0.018	0.08	0.01	0.05
Ni	BDL	0.04	0.01	1.40	BDL	BDL	BDL	BDL	BDL	0.05
Zn	0.65	0.49	0.30	0.90	0.31	0.16	0.26	0.25	0.04	5.00
Pb	0.21	0.10	0.02	0.20	BDL	BDL	BDL	BDL	BDL	0.05

See Table 1 for details

Table 3. Bioaccumulation and translocation factor of selected macrophytes

Metal	*Eichhornia crassipes*		*Pistia stratiotes*	
	BAF	TF	BAF	TF
Fe	2.33	2.88	0.77	1.59
Mn	7.86	1.43	5.40	2.50
Cu	4.12	7.25	5.22	7.65
Ni	1.14	5.80	0.03	4.00
Zn	0.73	1.40	0.85	1.63
Pb	2.94	1.45	2.48	5.00

uptake and it translocation of metals due to morphological and anatomical peculiarities of the species and also influences of elevated temperature enhancing evapotranspiration and low pH during dry season.

CONCLUSION

Fresh water bodies provide number of environmental benefits like replenishing ground water; preserve biodiversity, opportunities for recreation and tourism, source of irrigation, supply water for drinking purpose, besides others. Present study revealed that with exception of zinc; the concentration of all other trace metals exceeded the drinking water limits prescribed by WHO (2008). Lotus lake was more contaminated as compared to Curtorim lake as far as trace metal concentration is concerned. In a small state like Goa, discharge of nutrient loads into fresh water bodies has increased resulting in the degradation of fresh water bodies. In order to restore the lakes and to mitigate bad conditions phytoremediation technique can be effectively used. The selected macrophytes showed bioaccumulation and translocation of analyzed metals. Maximum absorption was observed in roots compared to shoots in both the macrophytes. Both BAF and TF were higher than 1 in selected metal accumulator species and thus proves to be useful potential for phytoremediation of metal polluted aquatic bodies.

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Site Suitability Analysis for Development of Decentralized Solid Waste Processing unit for Coimbatore City, South India

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Abstract: The decentralized solid waste management will provide a comprehensive solution to the waste management challenges due to improper segregation of recyclable waste, unavailability of infrastructure to handle huge amount of waste generation. The Coimbatore city is one of the developing cities in Tamilnadu which produces about 1000 tons of municipal solid waste per day with 60% of wet waste and 40% of dry waste processed at one processing unit site at Vellalore, Coimbatore city. In this research the suitable site for solid waste processing unit for north zone region of Coimbatore is found by using GIS tool and weighted overlay analysis. Primary thematic layers were considered weights are assigned and analysed by weighted overlay analysis. The results are justified and screened under categories as highly suitable, high to moderately suitable, moderately suitable, poorly suitable and not suitable. It is found that 2 sqkm is highly suitable and 10 sqkm is high to moderately suitable for solid waste processing unit. The suitability map shows the availability of land for solid waste processing unit.

Keywords: Site suitability, Weighted overlay analysis, Solid waste management, Decentralized processing unit, North zone

The urban development and industrialization in a city is for well being of the society and people but the solid waste management should also compete along with the development of country in order to improve the living standard and quality of life of population. The solid waste disposal management is influenced by many factors like financial environmental and political consideration (Central public health and environmental engineering organization, June 2018). Many research have identified factors influencing the elements of waste management system. Site selection for solid waste disposal involves in depth investigation with respect to many parameter like population, land use land cover, drainage density, soil type, slope factor and many. The time taken by each type of waste for degrading varies according to the individual characteristics of each waste. The decentralized waste management system can rely on more effective recycle, reuse and recover operations (City Report on Coimbatore solid waste management project under JNNURM,2013). Land suitability analysis can be done for different purpose like agricultural suitability, sewage treatment plant ,urban development and dump yard location in which the agricultural land suitability analysis has a profitable impact to the public (Tran Thi Tuyen et al 2019). GIS combined with various techniques weightage modeling, AHP and MCDA gives a concrete output for suitability analysis. Weighted overlay analysis is more suitable for landslide analysis and zonation hazard land were detected using weightage modeling (Chandrasekaran et al 2019). In hierarchy of solid waste management system the landfill is the least preferred option in order to decrease the dumping of waste. The effective decentralized processing unit can no doubt reduce the unscientific dumping of waste in landfill.

Enormous literature on decentralized solid waste management by different approach is being analysed in other cities (Shoukr Quarani et al 2018.) Design and study for composting process site can help to reduce the major organic waste produced by public (Satty 2008). The selection of site for solid waste processing unit by traditional means with available disaggregated data may end in unscientific and poor output hence using GIS tool helps to resolve the decision making issue and can suggest suitable site for installing solid waste processing unit. In the present research the Coimbatore city is taken as study area to arrive suitable site for installing decentralized solid waste processing unit.

MATERIAL AND METHODS

The study area lies in the geographic latitude and longitude of 11º01'06''N and 76º58'21''E respectively. The present population of the city is approximately 13 lakhs For administrative purpose the Coimbatore city is divided into five zones North Zone, South Zone, East Zone, West Zone and Central Zone. For the present study north zone of Coimbatore is analyzed for development of processing unit for solid waste.

In the present study, an attempt is made to identify the

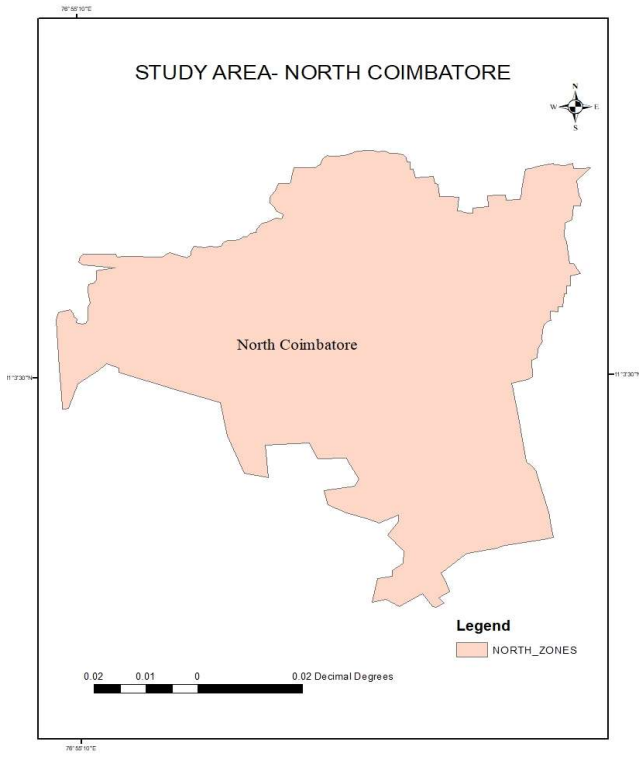

Fig. 1. Study area

suitable land for development of decentralized processing unit, for achieving this research eleven predominant factors are considered they are land use, geomorphology, geology, soil, lineament density, groundwater depth, distance from water bodies, road density, distance from railway track, slope (degree) and drainage density. The essential base map prepared from India toposheet. IRS P6 LISS III image to get land use, geomorphology, and lineament and water body extraction.

The SRTM DEM 90 m resolution satellite data utilized for preparation of slope map. Geological features and soil information are prepared from GIS 1998 and Soil survey of India map respectively. Ground water depth is measured from field at 43 spots and ground water levels also referred from previous research papers. Distance measurement is done by buffer tool the distance from water bodies and distance from railway track are prepared using buffer tool. The road information digitized from toposheet and road density map generated using ArcGIS tool. The railway track information also gathered from toposheet. The drainage line digitized from India toposheet and drainage density was generated from ArcGIS tool.

Land use: The land use was prepared with five major classification namely agriculture, commercial educational, industrial and residential use. The ranking is given according to the most preferable and least preferable land use. The agricultural land cannot be used for the processing unit plant since it is more sensitive to ecological system. The ranking is done according to the land use and overall score weightage for land use criteria is 14.

Geomorphology: The present map is classified into seven major classifications as structural hills, pediplain weathered, pediment buried, bazada, colluvial fan, flood plain, inselberg complex in which structural hills are least preferred due to hilly terrain. The flood plain is nearer to the river flow and the region is more prompt to flood. Therefore the buried pediment is more suitable due to its infiltration feature and the ranking is done accordingly the overall score weightage for geomorphology criteria is 10.

Geology: In present study the geology of the study area is classified as granite, granitoid gneiss, hornblende biotite gneiss, quartz vein, sand and silt, sandstone and shale, and ultrabasic rocks. The preferable and essential feature of earth is permeable accordingly the presence of sand and silt is given priority in ranking and the overall score weightage for geology criteria is 12.

Soil: The study area has different soil types namely Alfisols, Entisols, Inceptisols, Vertosols,and reserve forest, vertisols category is more suitable for the treatment unit next to vertisols inceptisols,can also accepted as preferable option Ranking is done according to the importance the particular feature and their influence. The overall score weightage for soil criteria is 9.

Lineament: The study area with less lineament density is most preferable for the installation of processing unit .Lineament density of range 0-0.20 km km^{-2} is most preferable and ranked as 1 for this present study. The overall score weightage for lineament criteria is 9.

Groundwater depth: The study area is classified into five categories in ranges varies from 4m to 16m.The site can be chosen based on the depth of ground water level maximum depth is preferred for disposal site. The ranking is done with high ground water depth as 1, because the below ground level increases the proximity to contamination decreases. The overall score weightage for ground water depth criteria is 10.

Distance from water bodies: Therefore the ranking is done for five classification which ranges from 250m to 1000m and the rank 1 is given for greater than 1000m value and which is most preferred zone for installation of processing unit. The overall score weightage for distance from water bodies is 12.

Road density: According to the guidelines and recommendation of MSW rules the low road density zones are most preferable for the solid waste disposal and processing unit. The ranks are assigned with most preferred rank 1 for least road density and rank 5 for high road density.

The overall score weightage for road density is 5.

Slope: Therefore the design of a sanitary engineer will be effective if the slope is flat or gentle. The slope map is prepared with SRTM DEM 90M resolution satellite depth and slope map is classified into five categories as 0 to 0.99,0.99-4.28,4.28-11.28,11.28-20.71,20.71-36.56 the lower slope values is given as rank 1 and the steeper slope values is given as rank 1 and the steeper slope value is given as higher rank. Since the steeper slope are less preferred. The overall score weightage for slope criteria is 7.

Distances from railway track: The allocation of site for solid waste processing unit influences the solid waste management of whole city. Hence it is necessary to consider the development as a part of town planning. For any town planning development activities it is compulsory to study the existing location of other infrastructure of city, in this list the railway track is also major factor to be considered for allocating the location for solid waste processing unit. The solid waste guidelines says that the railway track should be away from 500m hence the higher rank is given for the greater distance to arrive the suitable land. The overall score weightage for distance from railway track criteria is 6.

Drainage density: The drainage density of the area is represented in unit Km km^2, which is the key to calculate the surface run off and the low density reflects lesser surface run off. The site for solid waste processing unit should have lesser drainage density because hindrance of surface run off may lead to flood in that region. Hence the area with lesser density is most suitable for installing solid waste processing unit therefore the ranking is done as per preference level. The drainage density is classified under five ranges 0-0.35, 0.99-1.67, 0.35-0.99, 1.67-2.80, 2.80-4.82 and ranking done accordingly. The overall score weightage for drainage density criteria is 6.

Weighted overlay analyses: The weighted overlay analysis was performed on a GIS platform to identify the suitable location for solid waste processing unit. The prepared various thematic maps such as land use, geomorphology, geology, soil, lineament, groundwater table, water bodies, road, railway track, slope and drainage were used for weighted overlay analysis. Based upon the importance of the each feature ranks and weight has been assigned (Table 1). In a weighted overlay analysis, as per ARC GIS weighted overlay tool the evaluation scale represents the range of suitability the value at one of scale represent one extreme of suitability the value at other end represent other extreme. The weight assigned ranges from 5 to 15 and ranks assigned ranges from 1 to 5. Weighted overlay analysis is performed to identify the suitable site in north zone of Coimbatore city.

Thematic maps: The thematic maps of eleven selected

Table 1. Weighted overlay analysis parameters and weights

Parameter	Class	Rank	Weight
Land use	Agricultural use	3	14
	Commercial use	4	
	Educational use	1	
	Industrial use	2	
	Residential use	2	
Geomorphology	Structural Hills	4	10
	Pediplain Weathered	1	
	Pediment buried	1	
	Bazada	5	
	Colluvial fan	2	
	Flood Plain	2	
	Inselberg Complex	4	
Geology	Granite	4	12
	Granitoid gneiss	4	
	Hornblende biotite gneiss	4	
	Quartz vein	5	
	Sand and silt	1	
	Sandstone and shale	1	
	Ultrabasic rocks	3	
Soil	Alfisols	4	9
	Entisols	3	
	Inceptisols	2	
	Vertisols	1	
	Reserve Forest	5	
Lineament	0-0.20 km/sq.km	5	9
	0.20-0.57	4	
	0.57-0.94	3	
	0.94-1.52	2	
	1.52-2.65	1	
Ground water depth	4.29-7.46	5	10
	7.46-8.84	4	
	8.94-10.11	3	
	10.11-11.73	2	
	11.73-16.09	1	
Distance from water bodies	> 1000 m	1	12
	750-1000 m	2	
	500-750 m	3	
	250-500 m	4	
	< 250 m	5	
Road Density	0-.0.88 km/sq.km	1	5
	0.88-2.50	2	
	2.50-4.75	3	
	4.75-8.41	4	
	8.41-13.37	5	

Cont...

criteria are created for the present study analysis in which the land use map, geomorphology map, groundwater depth map and slope map are shown below. Likewise other maps are prepared and analysis is done to arrive suitability map for north zone of Coimbatore city.

Table 1. Weighted overlay analysis parameters and weights

Parameter	Class	Rank	Weight
Distance from railway track	> 1000 m	1	6
	750-1000 m	2	
	500-750 m	3	
	250-500 m	4	
	< 250 m	5	
Slope	0-0.99	1	7
	0.99-4.28	2	
	4.28-11.28	3	
	11.28-20.71	4	
	20.71-36.56	5	
Drainage Density	0-0.35 km/sq.km	1	6
	0.99-1.67	2	
	0.35-0.99	3	
	1.67-2.80	4	
	2.80-4.82	5	

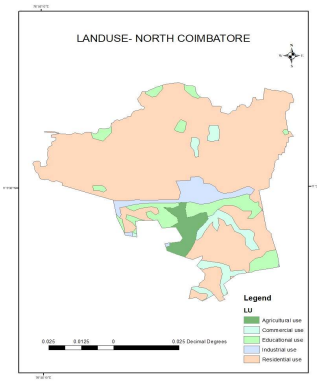

Fig. 2. Land use map

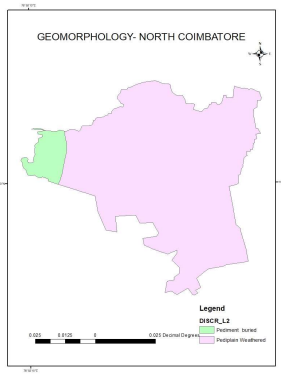

Fig. 3. Geomorphology map

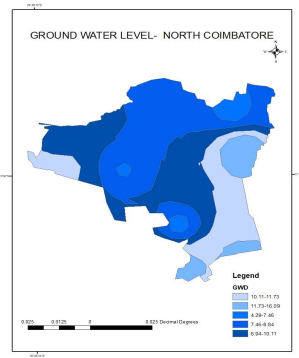

Fig. 4. Ground water depth map

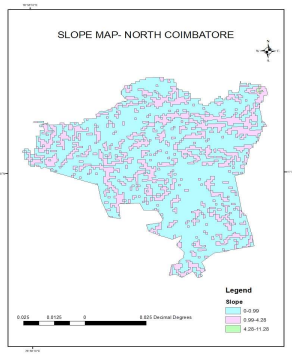

Fig. 5. Slope map

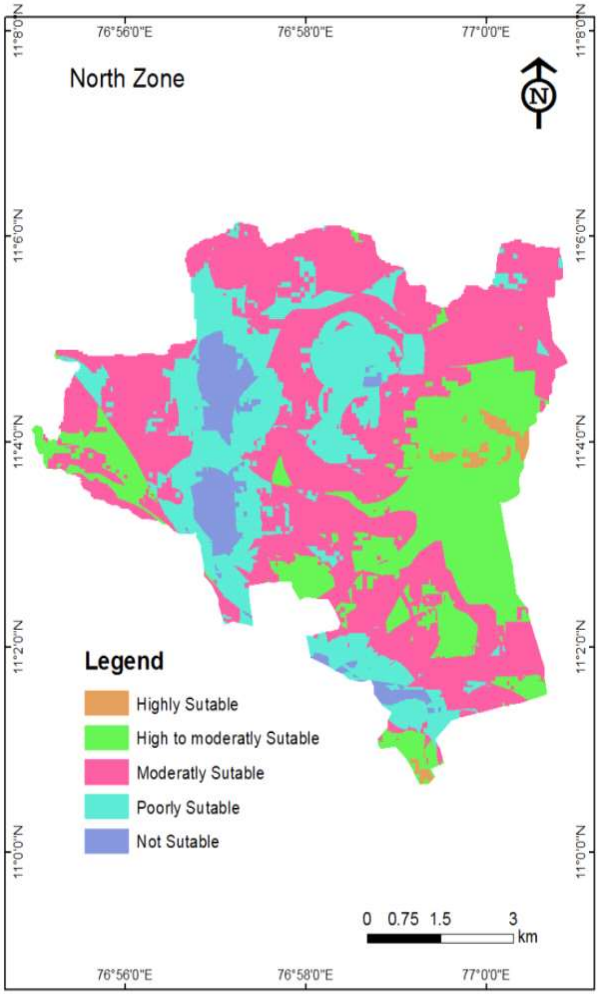

Fig. 6. Site suitability map for North Zone

Table 2. Site suitability analysis output for processing unit for north zone

Criteria	Area in Sq Km	% Area
Highly suitable	2	3.80
High to moderately suitable	10	18.90
Moderately suitable	24	45.30
Poorly suitable	12	22.64
Not suitable	5	9.43

Table 3. Processing unit design

Title	Dimension (m)	Area (Sqm)
Composting yard	131 X 57	7467
Vehicle zone	57 X 69	3933
Screening machine	43 X 69	2967
Baling	131 X 22	2882
Shredder	131 X 21	2751
Total area (In Sqm)	20000 Sqm	

RESULTS AND DISCUSSION

The site suitability map of decentralized processing unit for north zone of Coimbatore city was obtained by using Arc view GIS Software (Fig. 6).The parameters considered are land use, geomorphology, geology, soil, lineatment, ground water depth, distance from water bodies, road network density, slope, railway tract and drainage density. Ranking are given according to highly suitable, high to moderately suitable, moderately suitable and not suitable. The weights of the parameter ranges from 5 to 14.Using weighted overlay analysis and GIS the suitability map is arrived and it reveals that 2 km^2 of land is highly suitable, 10 km^2 high to moderately suitable, 24 km^2 of land is moderately suitable, 12 sqkm of land is poorly suitable, and 5 km^2 of land is not suitable area for the decentralized solid waste processing unit.

The theoretical design of processing unit with all essential Process arrived and it is found that 20000sqm area is required for the processing unit, which shows that the land availability is sufficient for the processing unit (Table 3).

CONCLUSIONS

The integrated weighted overlay analysis of eleven thematic layers suggested 2 sq km of area is more suitable, 10 sqkm of area is high to moderately suitable, for installing decentralized solid waste processing unit.

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Analysis of Groundwater Quality of Haridwar Region by Application of Nemerow Pollution Index Method

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***Abstract*:** The study was done for determining the pollution contributing parameters in the groundwater quality of water in Haridwar district. The physico-chemical parameters were taken into consideration and based on the study, 10.53% of the water samples were clean, 84.21% under slightly polluted and 5.26% under moderately polluted. The parameters total dissolved solid, total hardness and electrical conductivity exceeds the permissible limits as per guidelines given by Bureau of Indian Standard (BIS), World Health Organisation (WHO) and Indian Council of Medical Research (ICMR). The pollution index of the area ranged between 0.99 to 4.32. In Bahadrabad, Bhagwanpur and Laksar block, proper waste water sewage management should be taken in order to limit the contagion of contaminant with the ground water.

***Keywords*:** Water quality, Physio-chemical parameter, Nemerrow comprehensive pollution index

Ground water quality monitoring is an effort to generate information on chemical composition of water on a regional scale and the assessment of the suitability of water for various purposes, through representative sampling in different hydro geological units (Abbasnia et al 2019). The quality of surface water and the groundwater is a major concern in India. In the upper reaches, water quality is fit for human consumption, agricultural use but as one goes towards the lower reaches the quality goes on decreasing (Al-Omran et al 2015, Tiwari and Nayak 2002). The overexploitation of surface water and dumping of pollutants into the source put pressure on the groundwater resources and necessary to preserve groundwater resources from pollution. Earlier studies indicated that the water of the river Ganga is polluted due to industrial effluents, religious activities, and agricultural waste (Mishra 2010, Sharma et al 2014). Inorganic waste such as heavy metals contributes a lot to degradation because of its diligent nature (Rai et al 2010, Giri and Singh 2014), to manage the demand for water for domestic, agricultural, and industrial use preventive measures must be taken to ensure the suitability of the resources. The purpose of the study was to scrutinize the physio-chemical properties of the shallow groundwater of Haridwar district to quantify the extent of pollution and to identify the parameter(s) responsible for the pollution.

MATERIAL AND METHODS

Study area and data collection: Haridwar district lies in the south-western part of Uttrakhand state. The water samples was collected over the Haridwar district & block-wise details of sampling location are given in Table 1 and collected samples was sealed to prevent them from contamination and were carried to Laboratory for Physio-chemical analysis. The parameters such as color, odor, taste, and pH were tested at the time of sampling and by pocket digital pH meter while the others such as electrical conductivity, total dissolved solids, total hardness, alkalinity, nitrate, turbidity, magnesium, calcium, and chloride was analyzed by titration method, Spectrophotometer and flame photometry (APHA 1985).

Water quality: For determining the water quality of Haridwar district, the examined data were judged against different standards given by different agencies such as BIS (BIS 2012), WHO (WHO 2004- 2011) and ICMR (ICMR1975). For determining the water quality index, the weighted index method (Brown et al 1970, Parmar and Parmar 2010, Adimalla and Qian 2019) was used and the calculation was done using the following equation:

$$WQI = \frac{\sum_{r=1}^{n} Q_r \times W_r}{\sum_{r=1}^{n} W_r} \times 100 \quad (1)$$

Where, WQI=Water Quality Index, Q_r= Water Quality Rating. W_r= Relative Weight of r^{th} parameter.

$$Q_r = \frac{(U_a - U_i)}{(S_i - U_i)} \times 100 \quad (2)$$

Where, U_a= Lab tested value, U_i= Ideal pure water (0 for all parameters except 7 for pH and 14.6mg/l for DO) and S_i= Standard permissible value.

$$W_r = \frac{k}{S_n} \quad (3)$$

k= proportionality constant, which can determine by using:

$$k = \frac{1}{\left[\frac{1}{S_1} + \frac{1}{S_2} + \ldots\ldots\ldots + \frac{1}{S_n}\right]} \quad (4)$$

Table 1. Distribution of sampling locations in different blocks

Name of block	Location(s)	Longitude	Latitude
Bahadrabad	Khedki	78.03	29.92
	Bahadrabad	78.06	29.92
	Kankhal-d	78.12	29.93
	Kisanpur	78.13	29.88
	Shahpur	78.14	29.80
	Chandighat Bridge	78.16	29.95
	Kangri (Shyampur)	78.18	29.90
	Sajanpur Pili	78.19	29.85
	Gaindi Khanta	78.25	29.79
	Ahmadpur Chidiya	78.28	29.75
Roorkee	Iqbalpur-d	77.8	29.88
	Nanheda	77.81	29.89
	Puhana	77.84	29.92
	Imlikhera	77.90	29.93
	Jhanjheri (Landhora)	77.93	29.81
	Kaliyar	77.94	29.92
	Dhanauri	77.95	29.94
	Jainpur (Belada)	77.96	29.89
	Jamalpur-Daulatpur	77.98	29.94
Narsan	Sahranpur Road	77.76	29.81
	Gurukul Road	77.78	29.80
	Jataul	77.79	29.79
	Sadholi	77.79	29.77
	Ramnagar	77.8	29.73
	Tikola Kalan	77.81	29.71
	Narsan	77.85	29.7
	Dhayanki	77.85	29.73
	Manglour	77.87	29.79
	Jhabreda-1d	77.74	29.82
	Jhabreda-2	77.77	29.81
Bhagwanpur	Rahmatpur Flavada	77.74	29.82
	Sirchandi	77.76	29.94
	Chudiala-d	77.78	29.92
	Chanchak	77.78	29.95
	Bhagwanpur Road	77.79	29.96
	Raipur	77.8	29.95
Laksar	Rasulpur Bakkal	77.99	29.78
	Laksar	78.03	29.76
Khanpur	Nil		

The standard permissible values and unit weight of the parameters by different agencies are listed in Table 2.

Nemerow pollution index: Nemerow's pollution index is an index that gives quick results based on the status of water and concept was given by Nemerow and Sumitomo in 1970 and is used for determining the pollution index as described below in eq. 5:

$$P_r = \frac{(C_i)}{(L_i)} \times 100 \quad (5)$$

Where, P_i= Nemerow's pollution index of the i^{th} parameter; C_i= Concentration of the i^{th} parameter; and L_i= Allowable limit of the i^{th} parameter.

The value for Nemerow's pollution index (NPI) was unit less as the units of both the parameters were the same. If the value of NPI exceeds 1, it signifies the presence of impurities in water (Dawood 2017 and Jie 2012). For determining the Nemerow comprehensive Pollution Index, the following relationship was used as shown in eq. 6:

$$P = \sqrt{\frac{\left(\frac{1}{n}\sum_{i=1}^{n} P_i\right)^2 + \left[(P_i)_{Max}\right]^2}{2}} \quad (6)$$

Where,

P=Nemerow comprehensive pollution index, N= Total number of water quality parameters, P_i= Nemerow's pollution index of the i^{th} parameter and $(P_i)_{max}$ = maximum value of pollution index.

According to the Nemerow comprehensive Pollution Index, the classification of water based on its quality is given in Table 3.

RESULTS AND DISCUSSION

Physio-chemical parameters: Total Hardness, electrical conductivity and alkalinity were beyond the permissible limit

Table 2. Standard values and unit weight of the parameters

Parameters	Standard values (S_n)	Unit weight (W)
pH	6.5-8.5	0.2190
Electrical conductivity	300	0.317
Total dissolved solid	500	0.0037
Nitrate	45	0.0412
Total hardness	300	0.0062
Calcium	75	0.025
Magnesium	30	0.061
Chloride	250	0.0074
Alkalinity	120	0.0155

given by different standard agencies such as ICMR, WHO & BIS (Table 2).

Nemerow pollution index: None of the samples lies under

Table 3. Classification of water-based on Nemerow comprehensive Pollution Index

Nemerow's comprehensive pollution index (P)	Water class
<0.80	Clean
0.80-2.50	Slightly polluted
2.50-4.25	Moderately polluted
4.25-7.20	Heavily polluted
>7.20	Seriously polluted

Table 4. Descriptive statistical analysis of groundwater sample data

Parameters	Mean	Std. Dev
Color	-	-
Odorphy	-	-
Taste	-	-
pH	7.50	0.32
Electrical conductivity	591.8	244.43
Total dissolved solid	310.81	141.65
Turbidity	2.43	1.57
Nitrate	1.44	4.24
Sodium	35.01	21.83
Alkalinity	366.12	136.43
Total hardness	525.5	286.71
Chloride	41.41	24.89
Calcium	65.95	17.53
Magnesium	27.15	8.73

Table 5. Nemerrow comprehensive pollution index

Block's name	Location (s)	Nemerow pollution index												
		pH	EC	TDS	Alkalinity	Cl	TH	Mg	Ca	Nitrate	Turbidi	Avg.	Max.	P
Bahadrabad	Khedki	0.91	0.82	0.33	1.00	0.10	1.40	0.50	0.29	0.01	0.40	0.58	1.40	1.07
	Bahadrabad	0.98	0.71	0.29	0.98	0.09	1.30	0.31	0.24	0.01	0.20	0.51	1.30	0.99
	Kankhal-d	0.99	0.69	0.28	0.90	0.08	1.45	0.33	0.20	0.01	0.40	0.53	1.45	1.09
	Kisanpur	0.93	3.85	1.56	1.48	0.37	3.22	0.42	0.69	0.01	1.00	1.35	3.85	2.89
	Shahpur	0.89	2.66	1.07	1.45	0.19	1.65	0.69	0.48	0.08	0.24	0.93	2.66	1.99
	Chandighat Bridge	0.93	1.25	0.51	1.28	0.11	1.35	0.31	0.25	0.01	0.60	0.66	1.35	1.06
	Kangri (Shyampur)	0.90	1.63	0.70	1.65	0.11	6.00	0.33	0.25	0.02	0.28	1.18	6.00	4.32
	Sajanpur Pili	0.99	2.82	1.16	2.45	0.23	0.95	0.59	0.35	0.01	0.20	0.97	2.82	2.1
	Gaindi Khanta	0.98	1.88	0.76	2.23	0.13	1.00	0.36	0.33	0.01	0.32	0.80	2.23	1.67
	Ahmadpur Chidiya	0.99	1.57	0.63	1.83	0.09	1.65	0.75	0.40	0.03	0.60	0.85	1.83	1.42
Roorkee	Iqbalpur-d	0.90	2.30	0.93	2.28	0.14	2.85	0.29	0.55	0.01	0.38	1.06	2.85	2.15
	Nanheda	0.93	1.35	0.55	1.60	0.09	3.50	0.80	0.55	0.01	0.20	0.96	3.50	2.57
	Puhana	0.89	1.52	0.61	1.63	0.09	2.60	0.45	0.58	0.01	0.54	0.89	2.60	1.94
	Imlikhera	1.01	1.33	0.54	1.73	0.11	1.88	0.29	0.36	0.04	0.40	0.77	1.88	1.43
	Jhanjheri (Landhora)	0.96	1.41	0.57	1.55	0.09	4.30	0.66	0.94	0.01	0.28	1.08	4.30	3.13
	Kaliyar	0.95	1.89	0.76	2.00	0.12	1.20	0.53	0.59	0.01	0.46	0.85	2.00	1.54
	Dhanauri	0.91	1.51	0.62	2.55	0.31	2.00	0.65	0.32	0.01	0.30	0.92	2.55	1.92
	Jainpur (Belada)	0.90	1.77	0.71	2.03	0.09	4.27	0.51	0.44	0.01	1.36	1.21	4.27	3.14
	Jamalpur-Daulatpur	0.89	2.35	0.96	2.70	0.15	1.20	0.55	0.21	0.01	0.60	0.96	2.70	2.03
Narsan	Sahranpur Road	0.93	2.17	0.98	2.00	0.11	2.15	0.37	0.76	0.03	0.20	0.97	2.17	1.68
	Gurukul Road	0.90	2.55	1.03	2.30	0.24	1.90	0.42	0.53	0.00	0.20	1.01	2.55	1.94
	Jataul	0.98	0.70	0.29	0.65	0.14	1.80	0.70	0.45	0.14	1.46	0.72	1.80	1.37
	Sadholi	0.90	1.51	0.61	1.38	0.12	2.88	0.48	0.38	0.23	0.34	0.86	2.88	2.12
	Ramnagar	0.89	1.41	0.57	1.38	0.12	1.80	0.80	0.58	0.21	0.36	0.79	1.80	1.39
	Tikola Kalan	0.99	1.20	0.49	1.25	0.09	5.00	0.45	0.41	0.11	0.32	1.02	5.00	3.61
	Narsan	0.90	2.74	1.11	1.40	0.34	3.20	0.55	0.62	0.38	0.50	1.17	3.20	2.41
	Dhayanki	0.91	1.95	0.79	1.68	0.22	2.00	1.26	0.44	0.01	0.32	0.96	2.00	1.57
	Manglour	0.90	2.45	0.99	2.58	0.15	2.25	0.74	0.52	0.01	0.80	1.14	2.58	1.99
	Jhabreda-1d	0.90	1.64	0.66	1.50	0.12	3.35	0.42	0.68	0.47	0.60	1.03	3.35	2.48
	Jhabreda-2	0.93	3.91	1.58	3.15	0.56	3.20	0.41	0.59	0.47	0.60	1.54	3.91	2.97
Bhagwanpur	Rahmatpur Flavada	0.98	2.93	1.18	2.68	0.35	2.30	0.62	0.48	0.01	1.38	1.29	2.93	2.26
	Sirchandi	0.96	1.69	0.71	1.75	0.15	1.75	0.42	0.42	0.01	0.20	0.81	1.75	1.36
	Chudiala-d	0.91	3.03	1.24	3.63	0.11	3.40	0.70	0.48	0.01	0.80	1.43	3.63	2.76
	Chanchak	0.91	1.55	0.63	2.18	0.13	3.75	1.06	0.57	0.01	0.20	1.10	3.75	2.76
	Bhagwanpur Road	1.01	2.06	0.82	2.38	0.11	1.60	0.54	0.43	0.02	0.60	0.96	2.38	1.81
	Raipur	0.99	1.15	0.47	1.60	0.54	3.15	0.91	0.40	0.01	1.00	1.02	3.15	2.34
Laksar	Rasulpur Bakkal	0.96	2.32	0.93	2.75	0.19	4.30	0.45	0.59	0.01	0.32	1.28	4.30	3.17
	Laksar	0.98	2.36	0.96	2.38	0.17	2.15	0.76	0.80	0.07	1.40	1.20	2.38	1.88

P< 0.80, which indicates the quality of water ranged from slightly polluted to heavily polluted. Water quality of river Ganga of Haridwar district was suitable for domestic and irrigation purpose except for the rainy season due to rise in the concentration of EC and TDS (Joshi et al 2009, Chauhan and Singh 2010, Bhuiyan et al 2015). In Roorkee, Laksar, and Bhagwanpur block, pollution was high due the level of concentration of the pollution contributing parameters are

Table 6. Pollution contributing parameters

Block's name	Location(s)	Pollution contributing parameters (NPI Values)
Bahadrabad	Khedki	Alkalinity (1.0), TH (1.40)
	Bahadrabad	TH (1.30)
	Kankhal-d	TH (1.45)
	Kisanpur	EC (3.85), TDS (1.56) Alkalinity (1.48), TH (3.22)
	Shahpur	EC (2.66), TDS (1.07), Alkalinity (1.45), TH (1.65)
	Chandighat Bridge	EC (1.25), Alkalinity (1.28), TH (1.35)
	Kangri (Shyampur)	EC (1.63), Alkalinity (1.65), TH (6.0)
	Sajanpur Pili	EC (2.82), TDS (1.16), Alkalinity (2.45)
	Gaindi Khanta	EC (1.88), Alkalinity (2.23), TH (1.0)
	Ahmadpur Chidiya	EC (1.57), Alkalinity (1.83), TH (1.65)
Roorkee	Iqbalpur-d	EC (2.30), Alkalinity (2.25), TH (2.85)
	Nanheda	EC (1.35), Alkalinity (1.60), TH (3.50)
	Puhana	EC (1.52), Alkalinity (1.63), TH (2.60)
	Imlikhera	pH (1.01), EC (1.33), Alkalinity (1.73), TH (1.88)
	Jhanjheri (Landhora)	EC (1.41), Alkalinity (1.55), TH (4.30)
	Kaliyar	EC (1.89), Alkalinity (2.0), TH (1.20)
	Dhanauri	EC (1.51), Alkalinity (2.55), TH (2.0)
	Jainpur (Belada)	EC (1.77), Alkalinity (2.03), TH (4.27)
	Jamalpur-Daulatpur	EC (2.35), Alkalinity (2.70), TH (1.20)
Narsan	Sahranpur Road	EC (2.17), Alkalinity (2.00), TH (2.15)
	Gurukul Road	EC (2.55), TDS (1.03), Alkalinity (2.30), TH (1.90)
	Jataul	TH (1.80)
	Sadholi	EC (1.51), Alkalinity (1.38), TH (2.88)
	Ramnagar	EC (1.41), Alkalinity (1.38), TH (1.80)
	Tikola Kalan	EC (1.20), Alkalinity (1.25), TH (5.0)
	Narsan	EC (2.74), TDS (1.11), Alkalinity (1.40), TH (3.20)
	Dhayanki	EC (1.95), Alkalinity (1.68), TH (2.00)
	Manglour	EC (2.45), Alkalinity (2.58), TH (2.25)
	Jhabreda-1d	EC (1.64), Alkalinity (1.50), TH (3.35)
	Jhabreda-2	EC (3.91), Alkalinity (1.58), TH (3.20)
Bhagwanpur	Rahmatpur Flavada	EC (2.93), TDS (1.18), Alkalinity (2.68), TH (2.30)
	Sirchandi	EC (1.69), Alkalinity (1.75), TH (1.75)
	Chudiala-d	EC (3.03), TDS (1.24), Alkalinity (3.63), TH (3.40)
	Chanchak	EC (1.55), Alkalinity (2.18), TH (3.75), Mg (1.06), Turbidity (1.10)
	Bhagwanpur Road	pH (1.01), EC (2.06), Alkalinity (2.38), TH (1.60)
	Raipur	EC (1.15), Alkalinity (1.60), TH (3.15), Turbidity (1.0)
Laksar	Rasulpur Bakkal	EC (2.32), Alkalinity (2.75), TH (4.30)
	Laksar	EC (2.36), Alkalinity (2.38), TH (2.15)
Khanpur	Nil	

Table 7. Classification of water-based on Nemerow comprehensive pollution index

Water class	Nemerow comprehensive pollution index	Percent samples
Clean	<0.80	10.53
Slightly polluted	0.80-2.50	84.21
Moderately polluted	2.50-4.25	5.26
Heavily polluted	4.25-7.20	-
Seriously polluted	> 7.20	-
Total		100.00

also high leading to anthropogenic contribution to the groundwater (Table 5).

Based on the Nemerrow comprehensive pollution index value the pollution contributing parameters to the areaswere EC, TDS, Alkalinity and TH (Table 6). This is because of the shallow aquifer getting contaminated mainly due to urban and agricultural waste water. The areas i.e. Chandighat Bridge, Kankhal-d, Bahadrabad, Khedki, Imlikhera, Raipur, Naheda, Jatual and Tikola Kalan were less polluted areas. The entry of industrial effluents from the Bhagwanpur and Lasar block should be restricted to the river flow in order to have a proper management in the groundwater quality in the district

The data partially indicates that the main parameters that are contributing to the pollution in the groundwater were EC, Alkalinity, Total Hardness, and TDS (Table 5). This is because the shallow aquifer getting contaminated mainly due to urban and agricultural wastewater. Only 10.53, 84.21 and 5.26% of the water samples were clean, slightly pollutedand moderately polluted. The Bhagwanpur block and some parts of Narsan blocks are highly polluted. The Bahadrabad block of the Haridwar district was the lowest polluted area. The sources of pollution in these areas were effluent from industries, agricultural chemicals, and fertilizers that drains out by agricultural runoffcand sewage waste (Semwal and Jangwan 2009, Caliman et al 2011).

CONCLUSIONS

The greater deviation in the concentration of alkalinity, electrical conductivity and total hardness were observed by comparing with the standard values recommended by different agencies which obviously explained the aptness of intake of water. The negative value for alkalinity electrical conductivity and total hardness were recorded which means parameters crossed the permissible limits leading to deterioration of groundwater quality. The results of Numerow Comprehensive Pollution Index also indicated that 10.53% samples were under clean category and 84.21% of samples come under slightly polluted category. For enhancing the better groundwater quality in the study area, the results suggested that the use of fertilizer and crop manure in the fields should be reduced. The discharge of industrial effluents into waterways should regulate properly. Thus, water can be consumed for drinking and also for irrigation purposes before taking proper treatment for the pollutants.

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Ichthyofaunal Migration Causes Realized Niche Amplification Leading to Habitat Adaptation and Speciation in Rivers of Bengal Delta

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Abstract: Investigations of thirteen rivers of Southern Bengal delta- India, reveal that high precipitation years create functionally significant interconnections among them to facilitate average ichthyofaunal population rise by 22 %, biodiversity amplification (richness, equitability, diversity indices by 28.29%, 12%, 15.41% respectively and decrease in concentration of dominance by 50%), along with intensified inter-riverine fish migration, than the low precipitation years. Annual average rainfall explains 88% variability in fish count rise within a polynomial relationship, and average rise amounts to 34% across the rivers. In low rainfall years, many migrated species disappear indicating their incapability to reproduce in other habitat conditions. Species depletion percentage ranges from 6.4 to 34.9 across the rivers, with an average depletion of 8%. Species number also differs between high and low precipitation years in each river. Some rivers act as sources and some as sinks for these migrated species. They survive temporarily in sinks, but reproduce only in sources ensuring temporary availability in rivers beyond their ecological amplitude. Such recurring phenomena may have led to habitat adaptations and diversification. High rainfall years trigger realized niche expansion beyond fundamental niche in some ichthyofaunal populations through flood induced river interconnectivity and habitat homogeneity during intense monsoon.

Keywords: Ecotype, Fish-diversity, Habitat-adaptation, Interconnected- Rivers, Migration

Variations induced by natural heterogeneity create bio-diversified ecosystems and such variations across and within populations of coexisting species affect regional diversity pattern (Pereira et al 2018). Diversity pattern is a dynamic component of fish communities and the latter's structure and functions are comprised of both migrant and resident species in a river. This can be an important reference to assess and restore the ecological integrity of that river (Schmutz et al 2000). Ecological integrity in lotic functions can be maintained through spatially and temporally coordinated, dynamic life supporting mechanisms (Roy 2011) and other survival strategies. However, aquatic ecosystem's integrity is imperiled due to anthropogenic activities for which many perennial rivers have shifted to intermittent conditions (Datry et al 2011, Oliveira et al 2018). This corresponds to retrogression of the river-water and its aquatic communities. Aquatic ecosystems however, tend to restore stability through many ways. An important way is community succession (Hershkovitz and Gasith 2013) mediated through migration and adaptation. This can be facilitated by extra influx of water as spatial, seasonal, and intra plus inter-riverine migrations of invader species are facilitated by increasing homogeneity among rivers during monsoonal flooding (Thomaz et al 2007). Stability is also brought through configurative alterations in the composition of fish communities relating to niche apportionments avoiding any biodiversity loss (Soares et al 2017). Hypothesis tested here is whether intensified monsoonal rainfall and drought periods influence the fish species distribution through niche manipulation in the network of fresh water lotic and associated lentic ecosystems of Bengal delta.

MATERIAL AND METHODS

Study area: The study sites are within geographical co-ordinates of 22°18´ to 24°10´N latitude and 86°32´ to 89°09´ E longitude, in the lower Ganga delta of West Bengal in India, supporting a large tract of deciduous Sal (*Shorea robusta*) dominating forests, habitations, industries, mines, agricultural lands on a mixed terrain of lateritic soil in western part of Bengal delta and alluvial in the eastern Gangetic plane (Fig. 1).

Seasonal climate persists such as rainy (mid June to September), winter (November to February) and summer (April to Mid June). October and March demarcate transition periods between rainy and winter and winter and summer

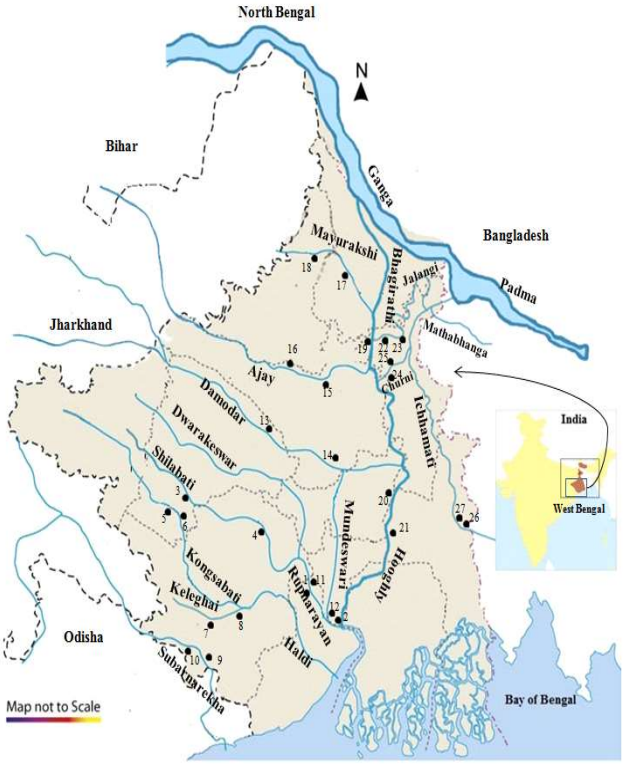

Fig. 1. Study sites on lower Gangetic Bengal delta. Ghatal (1), Gadiara(2), Mukutmanipur (3), Khirpai (4), Ranibandh (5), Khatra (6), Dudhkundi (7), Mahisadal (8), Shyamsundarpur (9), Gopiballavpur (10), Kolaghat(11), Deulti (12), Birbhanpur(13), Amta(14), Ketugram(15), Kenduli(16), Suri(17), Sundarpur(18), Nabadwip(19), Bandel(20), Panihati (21), Krishnanagar (22), Tehatta(23), Ranaghat (24), Birnagar (25), Hasnabad(26), Basirhat(27). Modified from Google-Map

seasons respectively. Annually seven to eight months are dry. Remaining months are wet due to South West monsoonal precipitation. Rainy season encounters about 76 per cent of annual precipitation creating recurring flood. The average rainfall is around 1420 to 1425 mm per year. Mean maximum temperature is below 22°C in December and January and rises to about 28°C in February, 34°C in March, and 38°C in April- May.

Riverine system of lower Ganga delta: Thirteen principal rivers of the lower Ganga river basin (23371 sq km) in the state of West Bengal (Fig. 1) have been investigated within freshwater zone characterized by less than 0.05 % of dissolved salts (Cavin 2017). These rivers include Bhagirathi/ Hooghly (R1), Ajay (R2), Mayurakshi (R3), Jalangi (R4), Churni (R5), Ichhamati (R6), Damodar (R7), Darakeswar (R8), Shilabati (R9), Rupnarayan (R10), Kongsabati (R11), Keleghai (R12), Subarnarekha (R13).

Sampling: Twenty-seven fish landing regions (two landing regions per river), (Fig. 1) were selected one each by and large at upstream and downstream, except Hooghly/Bhagirathi where three landing regions were sampled for being the central and the largest river. A single sample (*n*) was the addition of total catches by a group of 7 fishermen in two replicates in one morning only up to 3 PM, made from an area of 100 m^2 (a single quadrate) within the aquatic body. Altogether five samples per season were taken into consideration at each landing region for fish counts (means ten quadrats). It means ten samples were added up per season for two landing zones of each river for three seasons indicating thirty samples (sixty quadrats) annually (winter, summer and rainy) for each river. There were 45 samples for 3 landing regions in case of Hooghly. Quadrates were also placed on river associated lentic bodies and agricultural lands during flood and inundation. Fish were subject to identification. Worth mentioning that accurate sampling was difficult in Hooghly and many other lotic continuums in a condition of ever-present spatial and temporal variations in water quality and consequent habitat quality induced heterogenous clustering of Ichthyofauna (Aarts and Nienhuis 2003, Souilmi and Tahraoui, 2021). Depth could also be excessive at many places.

1450 mm was considered as the midpoint of average annual precipitation (calculated from 15 years data from different locations). Years with rainfall below this average were marked 'Below Average Annual Precipitation' (BAAP), (altogether 6 years) and years with rainfall above this average were marked 'Above Average Annual Precipitation' (AAAP), (altogether 6 years) to provide a logical representation of the data. 3 years data had been discarded as the average rainfall values were close to annual average, either at higher or lower (within ± 20 mm S.E.) side.

Diversity analysis: Diversity indices were calculated consulting Roy (2003), Fedor and Zvarikova (2019). Standard indices such as Equitability Index, Concentration of Dominance, Index of Diversity and Species Richness Index, were calculated as follows:

Equitability Index (Es)

$$Es = \frac{\log S}{\log n_i - \log n_s}$$

S = Number of species;

n_i =Number of individuals of the most abundant species.

n_s= Number of individuals of the least abundant species.

Concentration of dominance (Cd)

$$Cd = \sum_{n_i=1}^{s} \left(\frac{n_i}{N} \right)^2$$

n_i = Proportion of individuals of the i^{th} species measured as number of individuals of each species in all quadrats.

N= Total number of individuals of all species.

Index of diversity (D)

$$D = \frac{N(N-1)}{\sum n_i(n_i-1)}$$

N = Total number of individuals of all species.

n_i = Total number of individuals of each species in all quadrats.

Species richness index (d)

$$d = \frac{S-1}{\log N}$$

S = Number of species.

N = Number of individuals of all species.

Indices have been represented as relative per cent values to compare AAAP (Above Average Annual Precipitation) and BAAP (Below Average Annual Precipitation) effects. Models have also been obtained by fitting these indices in polynomial equations. Dominance Diversity curves (species importance curve/ DD curve) were drawn in accordance with Roy, 2003. DD curves were represented as log values of annual average fish count of each species (Total average fish count for 6 AAAP years and 6 BAAP years plotted separately for each river per 30 × 100 m^2 quadrate) on *Y* axis of a semi logarithmic scale with each species arranged on *X* axis in an order of most to least abundance.

Statistical analysis: Shapiro-Wilk Normality test and Polynomial modeling were conducted using Past 3.14 statistical software, Graph Pad Prism 5 Statistical Software and Microsoft Excel 7.

RESULTS AND DISCUSSION

Fish population and number of species: Out of 137 fish species recorded, 36 species are common to all rivers in both AAAP and BAAP years and 101 species are uncommon. In many rivers they have never appeared in samples and in some of the rivers they are available in AAAP years only (Table 2). However, increase in number of species in AAAP years has been variable. Average numbers of species available in each river in AAAP and BAAP years are given in Figure 2. Subarnarekha (R 13) has a maximum of 125 species in AAAP years and a minimum number of 117 species in BAAP years and is highest among all rivers. Ajay (R2), with lowest number of species among all rivers, has a maximum number of 64 species in AAAP years and 47 species in BAAP years (Fig. 2). The difference in number of fish species in AAAP and BAAP years was significant. However, the same difference due to sites (rivers) were insignificant and this indicates that no conclusion should be drawn regarding the exact number of species in any specific river as there is high degree of mixing during flood, heterogeneous clustering and habitat specific adaptations etc. This is further supported by the non-correlated polynomial relationships between average population of

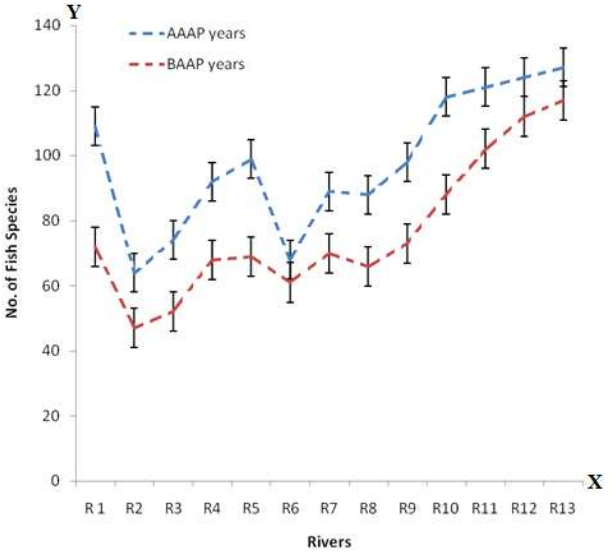

Fig. 2. Average no. of fish species (Mean ± Data error.) in AAAP and BAAP years (*Y*) available in each river arranged on *X* axis as R1, R2, R3 and so on. Values are joined along the sites by fragmented lines to represent treatments only; otherwise *X* axis represents static values of each river. Data are dynamic along *Y* axis only

Table 1. River wise ichthyofaunal dominance- diversity indices, expressed as relative percentage for AAAP & BAAP years

Diversity indices	Years	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13
Equitability index: Es	AAAP	53.16	50.88	50.88	52.51	69.34	51.55	53.47	53.42	50.81	53.52	50.64	52.91	52.79
	BAAP	46.84	49.12	49.12	47.49	30.66	48.45	46.53	46.58	49.19	46.48	49.36	47.09	47.21
Concentration of dominance: Cd	AAAP	50.00	50.00	50.00	50.00	42.86	50.00	33.33	40.00	50.00	50.00	40.00	50.00	50.00
	BAAP	50.00	50.00	50.00	50.00	57.14	50.00	66.67	60.00	50.00	50.00	60.00	50.00	50.00
Index of diversity: D	AAAP	50.26	50.51	53.36	50.02	51.36	52.61	50.44	52.96	52.08	51.46	50.61	50.77	51.22
	BAAP	49.74	49.49	46.64	49.98	48.64	47.39	49.56	47.04	47.92	48.54	49.39	49.23	48.78
Species richness index: d	AAAP	57.85	52.41	51.92	55.41	52.13	52.13	51.66	52.38	55.79	58.63	59.47	59.61	60.49
	BAAP	42.15	47.59	48.08	44.59	47.87	47.87	48.34	47.62	44.21	41.37	40.53	40.39	39.51

Table 2. River-wise availability of 101 fish species in samples ('+' = species present in both AAAP and BAAP years' samples; '●' = species appeared in AAAP years only)

Fish species	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13
Ailia coila	+	+	+	+	+	●			●	+	+	+	+
Anguilla bengalensis bengalensis	+			+	+	+	+		●	+	+	+	+
Aorichthys seenghala	+	●	+	+	+	+	●	●	●	+	+	+	+
Aplocheilus panchax	●	●	●	●	+	+	+	+	+	●	+	+	+
Apocryptes macrolepis													+
A.s cantoris											+	+	●
Arius platystomus										●	●	+	+
Badis badis	+			●	●	●			●	●	+	+	+
Bagarius bagarius	●			+	+	+	+	+	+	●	+	+	+
B.s yarrelli	+			+		●					+	+	+
Barbonymus gonionotus	●			●		●							
Barilius barila	●			●			+	+	+	●	●	●	
B.us bendelisis							●	●	+	●	●	+	+
Botia birdi								●	●		+	+	+
Botialo hachata	●						+	●	+	●	+	+	+
Chagunius chagunio									●	●	+	+	+
Channa marulius	+	●	●	●	●	●	+	+	+	+	+	+	+
C. gachua	+			●	●	●	+	+	+	+	+	+	+
Chanda nama				+	●	●	+	+	+	+	+	+	+
C.a (*Psedoambassis /Parambassis*) *ranga*	●	●	●	●	●	●	+	+	+	+	+	+	+
Chela laubuca	+	+	+	+	+	●	+	●	●	+	+	+	+
Cirrhinus reba	+			+	+	+	+	+	+	+	+	+	+
Clupiso magarua	+			+	+	+				●	●	●	+
Colisa fasciata	●	●	●	+	●	●	+	+	+	●	●	+	+
C.sa lalia	●		●	●	●	●	+	+	+	●	●	+	+
Coiliarama carati	+				●			●	●	+	+	+	+
Corica soborna	+			+	+	+			●	●	●		
Crossocheilus latiuslatius	+	●	●				+	●	+	+	+	+	+
Ctenopharyngodon idella	+	+	+	+	+	+				+	+	+	+
Cynoglossus lingua				+	+	+	+	+	+	+	+	+	+
C.us puncticeps	●							●	●	+	+	+	+
Danio rerio				●			+	+	+	+			
Devarioa equipinnatus				+	+	+				+	+	+	+
Devario devario	●	+	+				+	+	+	+	+	+	+
Eleotris fusca	●									+	+	+	+
Eleutheronematetra dactylum	+											●	+
Erethistes pussillus								●				+	+
Escualosa thoracata	●									●	+	●	●
Esomus danricus	+	+	+	+	+	+	+	●	+	+	+	+	+
Eutropiichthys vacha	+			+	+	+				●	+	+	+
Gambusia affinis	●	+	●				+			●			
Garra mullya									●	●	+	+	

Cont...

Table 2. River-wise availability of 101 fish species in samples ('+' = species present in both AAAP and BAAP years' samples; '●' = species appeared in AAAP years only)

Fish species	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13
Gagata cenia	+			●	●	●			+	+	+	+	+
Gonialo samanmina	+	●	●	+	+	●	●	●	+	+	+	●	●
Gudusia chapra	●				●	+	+	+	+	+	+	+	+
Hara hara	●									+	+	+	+
Labeo angra						●					●	●	+
L. boga	+	+	+	+	+	+							
L. dero	●			●	●	●	+	+	+	+	+	+	+
L. gonius	●			+	+	+	●	+		+	+	+	+
Lates calcarifer	●	+	+	+	+	●		●	●	+	+	+	+
Lepidocephalus guntea				+	+	+		●	+	+	+	+	+
Liza parsia											+		+
L.a tade	●							●	+	+	+	+	+
Macrognathus aculeatus	+	+	+	+	●	●	+	+	+	+	+	+	+
M. aral	●			●	+	●				●	+	+	+
M. armatus	+	+	●	+	●	●	+	+	+	+	+	+	+
Monopterus cuchia	●			●	●	●				●	●	+	+
Mugil cephalus	+				●	●				●	+	+	+
Mystus cavasius	+	●	+	●	●		+	+	+	●		+	+
M.us gulio	+	●	●	+	+	●		●	●	●	●	●	●
Nandus nandus	+	●	●	+	+	●	+	+	+	+	●	+	+
Gogangra viridescens					●	+						+	+
Nibea soldado													+
Neotropius atherinoides						●						+	+
Odontamblyo pusrubicundus	●										+		●
Ompokbi maculatus					+	●				●	●	+	+
Ompok pabda				+	+	+				+	+	+	+
O. pabo	●			+	+	+				+	●	+	+
Oryzias melanostigma												+	+
Osteobrama cotio	+	●	●	+	+	+	●	+	●	●	+	+	+
Otolithoides biauritus	●									●	+	+	+
Puntius saranas arana			●	●	+	●	●			+			
P. phutunio	●	●	●	●	●	+	+	+	+	+	+	+	+
P. conchonius	●			●	●	+	+	+	+	+	+	+	+
Pama pama	●										+	+	+
Pangasius pangasius	●	●	●	+	+	+	+	+	+	+	+	+	+
Panna microdon	●											●	+
Parambassis lala						●			●	●	+	+	+
Pisodonophis boro	●									●	●	●	+
Plotosus canius						●							
Polycanthus fasciatus	●								●	+	+	+	+
Polynemus paradiseus	+			+	+	+			●	+	+	+	+
Prionobutis koilomatodon												+	

Cont...

Table 2. River-wise availability of 101 fish species in samples ('+' = species present in both AAAP and BAAP years' samples; '●' = species appeared in AAAP years only)

Fish species	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13
Pseudeutropius atherinoides	●		●	●	●	●			●		●		+
Pseudapocryptes elongatus	●									+	+	+	●
Rhino mugilcorsula	+			●	+	+	+	+	+	●			
Rita rita	+	+	+	●	+	●	+	+	+	+	+	+	+
Salmosto mabacaila	+	●	●	+	●	●	+	+	+	●	●		
S. maphulophulo		●	●				+	●	●	+	+	+	+
Securico lagora	+	●	+	+	+	●	●	●	●	+	+	+	+
Setipinna phasa	+			+	+	+				+	+	+	●
S.a taty	●										●	●	●
Sillaginopsis panijus	+											●	+
Tenulosa ilisha	●			●	+	+				+	●	+	+
Teraponjar bua	●											●	+
Tetraodon cutcutia	●					+	+	+	+	+	+	+	+
T. fluviatilis	●					+	+	+	+	+	+	+	+
Thryssaha miltonii													+
Trichogaster fasciata	+	●	●	+	+	+	+	+	+	+	+	+	+
T.r labiosa											●	+	+

ichthyofauna in 30 X 100 m^2 area per year in each river (*X*) and maximum number of available fish species in each river (*Y*) in both AAAP and BAAP years (Fig. 3). A large portion of Ichhamati (R6) flows through Bangladesh; data collected from this river in West Bengal however, do not represent the holistic diversity status of the river.

Figure 4 shows that AAAP years show significantly greater fish counts in almost all rivers. Average rise in annual fish count values across the rivers was 22 per cent from BAAP to AAAP years, with a minimum of 8 per cent in Rupnarayan to a maximum of 34 per cent in Hooghly River. '*Pooled t test*' of significance revealed that average fish counts of AAAP and BAAP years in each of the thirteen rivers were statistically different ($p < 0.01$ to 0.05).

Fish diversity observations: Dominance diversity curves (Fig. 5 a, b) indicate that species dominance increases during BAAP years whereas species equitability is enhanced in AAAP years (as represented by Steeper DD curves in BAAP years) in almost all rivers. Curve shows that maximum number of species available in a single river is 117 in BAAP years and this value is 125 in AAAP years. Higher average indices values encountered across all rivers in terms of equitability, diversity and richness are 1.12, 36.62, and 17.23 respectively during the AAAP years compared to 0.95, 31.73 and 13.43 respectively in BAAP years. There is a simultaneous higher average concentration of dominance index in BAAP years (0.03) than AAAP years (0.02). This

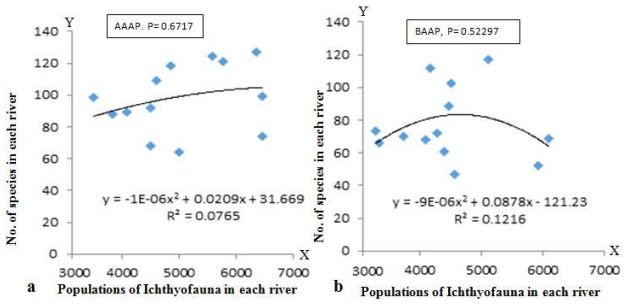

Fig. 3. Polynomial relationships between populations (average fish counts per 30 *X* 100 m^2 y^{-1}) of ichthyofauna in each river (*X*) and the maximum number of available species in each river (*Y*) in a year in AAAP (a) and BAAP (b) years

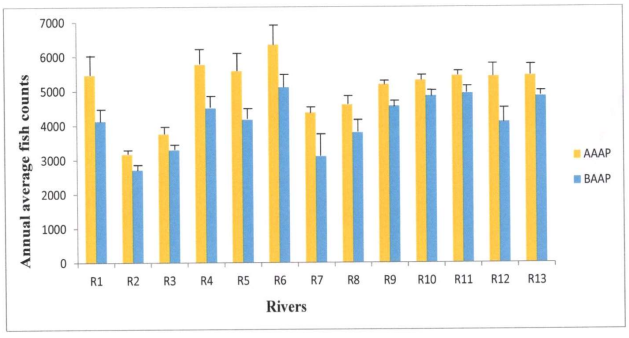

Fig. 4. Six year's annual average fish counts (±1S.E.) separately for 'AAAP' & 'BAAP' years in 30 X 100 m^2 area

phenomenon is supported by the negative polynomial relationships (Fig. 6 a, b) between the index of diversity (*X*) and the index of dominance (*Y*) in both AAAP and BAAP years across all rivers. Increased intensity of dominance indicates implosion of overall diversity, and this is more intensified in BAAP years as the relationship is significant but the same relationship is insignificant in AAAP years indicating nullification of species dominance effect due to increased habitat homogeneity. Species richness index (*Y*) has significant positive polynomial relationship with the index of diversity (*X*) (Fig 7a, b), in both AAAP ($r = 0.957$) and BAAP ($r = 0.985$) years, indicating that species richness increases irrespective of equitability with the amplification of ichthyofaunal diversity, as the same relationships between the index of diversity and equitability have been insignificant. Coefficient of determination (r^2) indicates that overall ichthyofaunal diversity explains 91 and 97 per cent variability in the species richness in AAAP and BAAP years respectively (Fig. 7a, b).

Rainfall and ichthyofaunal population: Fish counts from all rivers representing populations corresponding to annual average precipitations per 30 X 100 m^2 area per year have been put to Shapiro- Wilk Normality test, to reveal that in both AAAP ($w = 0.95$,) and BAAP ($w = 0.90$) years distributions of ichthyofaunal populations never significantly deviate from Normal Distributions and consequently the pooled up values for both the treatments have been analysed through polynomial regression equation (Fig. 8). A significant positive polynomial relationship ($r = 0.938$) between annual average rainfall (*X*) and log values of total fish counts per year (*Y*) indicate a significant rise in fish population across all the rivers with the increase in rainfall. An overall significant 88 per cent of the variations in fish population can be attributed to variations in the quantity of precipitations as reflected by the coefficient of determination (r^2). Remaining 12 per cent variations can be considered due to other reasons.

Population and diversity amplification during high monsoon years: Significantly greater fish counts during AAAP years than the BAAP years (Fig. 4) (average rise by 22%) indicate higher population due to more conducive homogeneous habitat condition. Fish population counts, diversity etc. have increased in all lotic bodies with the

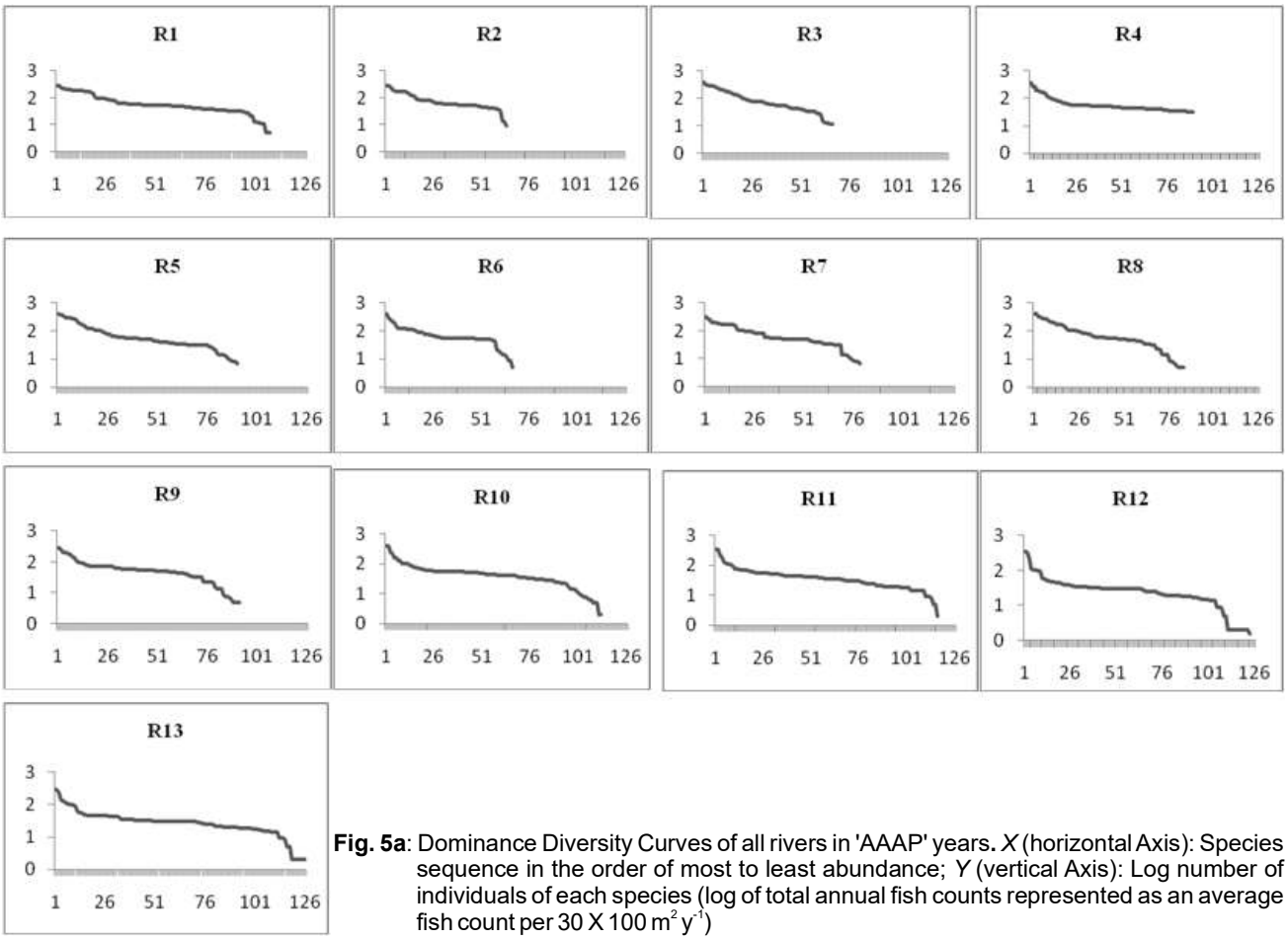

Fig. 5a: Dominance Diversity Curves of all rivers in 'AAAP' years. *X* (horizontal Axis): Species sequence in the order of most to least abundance; *Y* (vertical Axis): Log number of individuals of each species (log of total annual fish counts represented as an average fish count per 30 X 100 $m^2 y^{-1}$)

increase in precipitation. Average values for species richness index, equitability index and diversity index have amplified by 28.29, 12, 15.41 per cents respectively, whereas index of concentration of dominance has decreased by more or less, 50 per cent from BAAP to AAAP years across the rivers. Variations in the turnover of aquatic community composition between wet and dry years are influenced by the variations in intensity of hydrological perturbations (Hershkovitz and Gasith 2013). The annual average rainfall has an influence over 88 per cent variability in fish counts across the rivers during study period without considering AAAP and BAAP treatments (Fig. 8). All these signify that monsoon is the triggering factor to rejuvenate both, ichthyofaunal diversity and populations in all lotic systems.

Rivers turn into biodiversity sources and sinks: Some species have appeared in samples from many of the rivers in high monsoonal rainfall years only (AAAP years) (Table 2, Fig. 2), although these species appeared in many other rivers

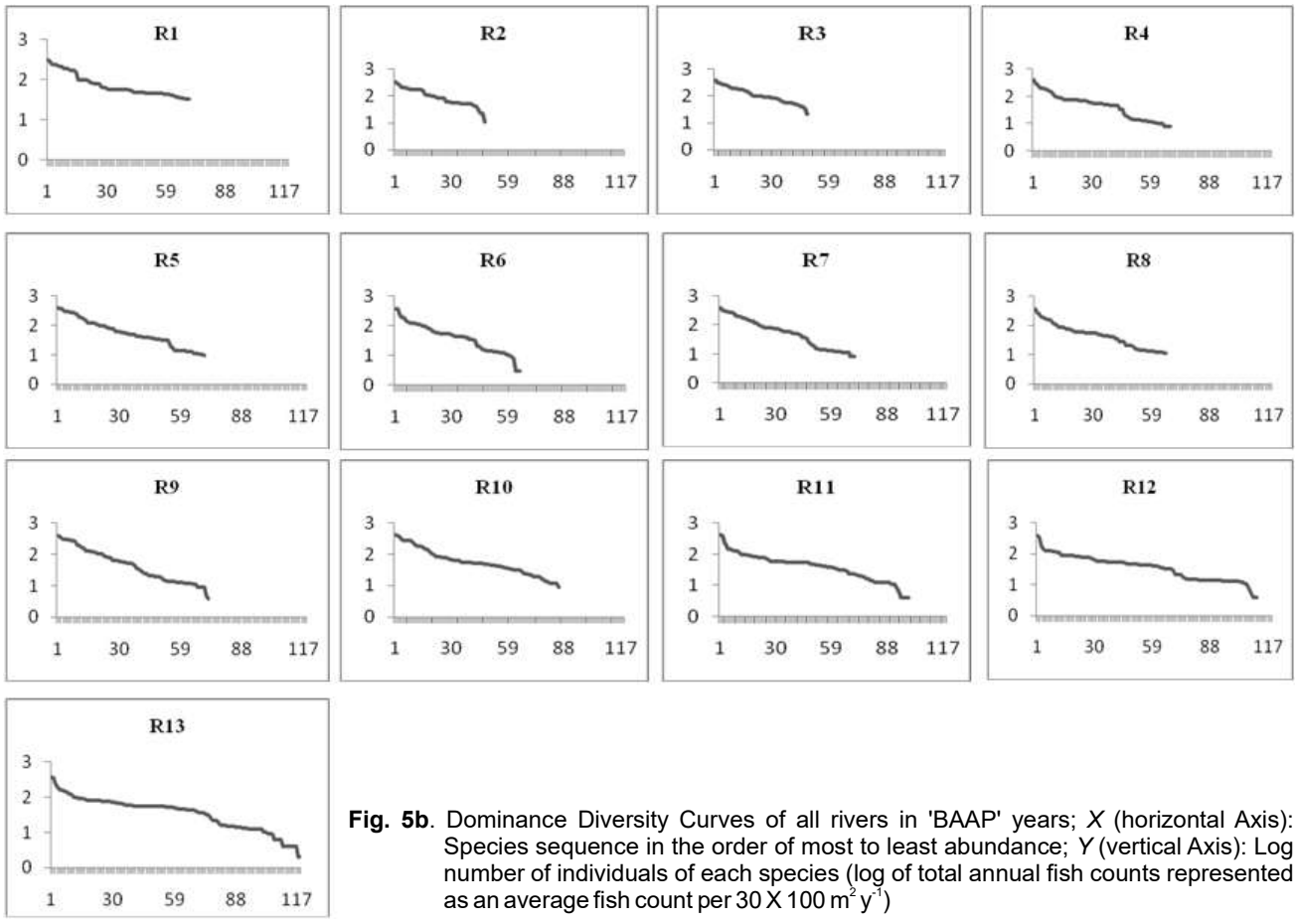

Fig. 5b. Dominance Diversity Curves of all rivers in 'BAAP' years; *X* (horizontal Axis): Species sequence in the order of most to least abundance; *Y* (vertical Axis): Log number of individuals of each species (log of total annual fish counts represented as an average fish count per 30 X 100 m^2 y^{-1})

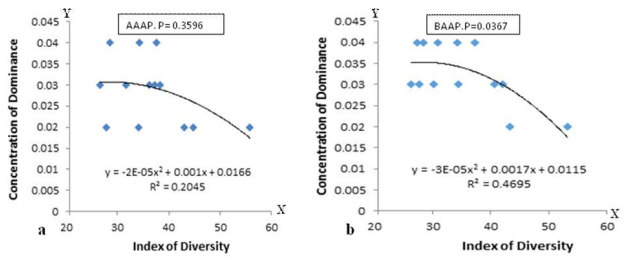

Fig. 6a, b: Negative significantly correlated polynomial relationships between the index of diversity (*X*) and concentration of dominance (*Y*) in both AAAP (a) and BAAP (b) years

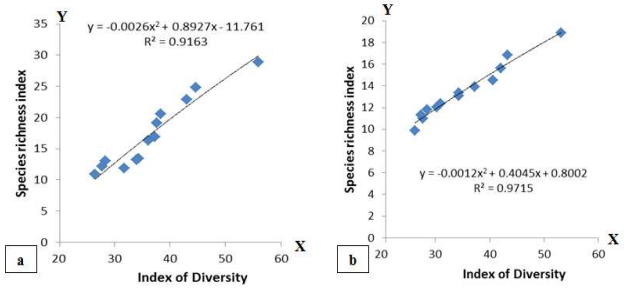

Fig. 7a, b: Polynomial relationship between the index of diversity (*X*) and species richness index (*Y*), across the rivers in AAAP (a) and BAAP (b) years

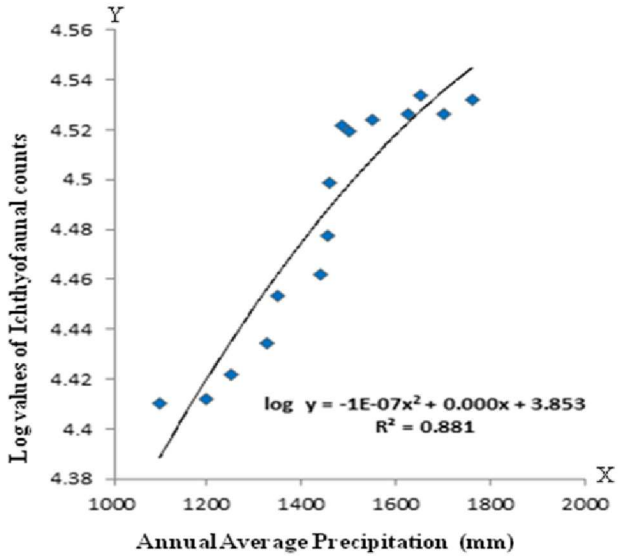

Fig. 8. Polynomial relationship between the annual rainfalls represented in mm

throughout the study period in all the years (both AAAP and BAAP). High average monsoonal precipitation mediated recurring floods at variable intensity determine ichthyofaunal compositions of rivers through rejuvenating interconnections and easy migration routes among them essential to conserve biodiversity (Datry et al 2011, Arthington 2012, Oliveira et al 2018). Floods increase similarity among aquatic habitats (Thomaz et al 2007) explaining increase in dissimilarity during low rainfall years among rivers. Many of these migrated species seldom reproduce in the migrated rivers. They disappear during dry years as well as in dry seasons within a year, when rivers are not functionally interconnected. The degree of disappearance of number of species has ranged from 6.4 per cent to 34.9 per cent across the rivers during BAAP years, with an average depletion of 8 per cent (Fig 2), indicating that in some rivers the percentage of disappearance is very high. Repeated appearances and disappearances of species within a complex of co-existing ichthyofaunal taxa, may have led to habitat adaptations as new ecotypes or varieties and subsequently new species. This observation is supported as the index of diversity explains a significant 91 (AAAP) and 97 (BAAP) per cent variability in species richness index (Fig. 7a, b), irrespective of any significant influence on species equitability index. Repeated changes in overall fish diversity and richness without affecting equitability indicate that many species are yet to establish permanently in these repeatedly retrogressive rivers supporting vulnerable fish communities. This also suggests for spontaneous phenotypic and genotypic variations in fish species in face of high instability and vulnerability during low monsoonal years as evidenced by co-existing137 species with multiple subspecies, varieties belonging to 91 genera. Phenotypic plasticity, standing genetic variations and newly derived mutations have been the prime adaptive potentials of freshwater fish with limited dispersal abilities to avoid extinctions due to natural stresses (Smith et al 2013). Transitions between discrete freshwater habitats, ecological transitions within habitats, extrinsic abiotic and intrinsic autecological constraints have profound influence on speciation and fish bio-diversification.

High rainfall triggers niche expansion in fish populations mediated through migration. Realized niche of many migrated fish species transcends their own fundamental niche (found in both originating and recipient rivers but seldom reproduce in recipient rivers) to temporarily survive beyond their ecological amplitude. Carmona et al (2016) describe that as a probabilistic hyper-volume niche can be an important parameter to quantify functional diversity components of an ecosystem.

CONCLUSIONS

Availability of a number of fish varieties in different rivers is mediated through reversible explosion and implosion of their niche spaces triggered by monsoonal rainfall. Existing aquatic communities oscillate between pre-climax and post-climax states depending on concentrations of monsoonal rainfall. High monsoonal precipitation with additional water supply rejuvenates connections between rivers and triggers amplification of ichthyofaunal population (represented by fish counts) and improvement of diversity parameters through reproduction, and inter-riverine migration. Constrained niche of migrated fish species in some rivers appears to amplify beyond their fundamental niche due to migration. Recurring appearances and disappearances of migrating species due to aquatic constraints in long term may have led to the formation of existing high fish diversity through habitat adaptations.

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Feeding Habits of an Endemic Bagrid Catfish, *Mystus oculatus* from Western Ghats of India

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Abstract: The diet composition and feeding ecology of a bagrid freshwater cat fish, *Mystus oculatus*, endemic to the Western Ghats region of South India was studied from October 2018 to September 2019. The gut contents of 363 specimens with a total length ranging from 56 to 129 mm were collected from Chalakudy river of Kerala. The mean relative length of gut (RLG) recorded was 0.32. Lowest feeding intensity and GaSI was noticed during the breeding season while highest feeding activity during pre-spawning months. Index of relative importance showed that crustaceans (37.97%) were the most preferred food item in the gut followed by insects (13.97%), fish body parts and scales (11.77%) and rotifers (10.6%). The results of the gut content analysis revealed that the species exhibits a carnivorous and euryphagous feeding habit. The present investigation provides a clear idea about the role of this endemic species in the Chalakudy river food web.

Keywords: *Mystus oculatus*, Bagrid cat fish, Feeding ecology, Carnivorous

Mystus oculatus commonly known as Malabar mystus is a bagrid freshwater catfish endemic to the Western Ghats biodiversity hotspot of India (Froese and Pauly 2019, Suryavamshi and Shivanna 2020). The species is reported from lowland rivers, wetlands and estuaries of Kerala as well as Tamil Nadu (Raghavan and Ali 2011). *M. oculatus* prefers pool and riffle habitats with gravelly or sandy bottom (Kurup 2005). The species is used as food fish by local fishers for their daily diet and recently the fish has entered in to ornamental fish trade (Haniffa 2009). Population of *M. oculatus* has declined due to various threats like sand mining, pollution from domestic and industrial waste, eutrophication, destructive fishing practices and reclamation of wetlands (Raghavan and Ali 2011).

Food web exploration is one of the most prime areas in community structure research (Prasad and Ali 2008). The environment plays an important role in deciding the nature of food of an organism and fishes are highly adaptable in their feeding habits (Manorama and Ramanujam 2017). The bagrid catfishes under genus *Mystus* constitute a very important fish group having highly nutritional significance. Dietary habit of some species of *Mystus* cat fishes has been characterised as omnivorous (Begum et al 2008, Mitu and Alam 2016) or carnivorous (Gupta and Banerjee 2014, Chattopadhyay et al 2014). However, no studies exist informing the diet composition of *Mystus oculatus* from natural waters. Hence, aim of the present study was to investigate the feeding intensity, gastrosomatic index, index of relative importance, relative length of gut of *M. oculatus* which will be helpful and in planning required steps for conservation of this endemic species in its natural habitats.

MATERIAL AND METHODS

Study are: Chalakudy River is the fifth longest river (144 km) of Kerala originates from the Anamalai hills of Western Ghats mountain ranges- a global biodiversity hotspot of India. The major tributaries of the river are Parambikulam, Kuriarkutti, Sholayar, Karappara and Anakkayam. The river drains through the highland, midland and lowland areas and its merges with the Periyar river at Elanthikara before draining to Arabian Sea. The total drainage area of the river is 1704 km² out of this 1404 km² lies in Kerala and the rest 300 km² in Tamil Nadu.

Sample collection: A total of 363 samples were collected at monthly intervals between October 2018 to September 2019 using seine nets (5-8 mm) and gill nets (15-25 mm) from Chalakudy River of state Kerala, India. Collected fishes were cleaned and wiped out for further analysis. The specimens were measured for total length (TL) to the nearest 0.1 cm using a vernier caliper and body weight (BW) to the nearest 0.1 g using an electronic balance. The size of the specimens varied from 56 to 129 mm of TL and 2.88 to 18.24 g in BW. To investigate the feeding habits, the guts of the sampled fish were dissected out and preserved in 10% formalin solution to prevent further breakdown of the gut contents. The total length, weight and fullness of the guts were recorded. The gut

contents of fishes were further analyzed in the laboratory and each food item was identified to the lowest taxonomic level using stereomicroscope.

Feeding intensity: The intensity of feeding was recorded based on the state of distension of gut and the amount of food contained therein. The guts were visually categorized as empty, poor ($^1/_4$ full), medium ($^1/_2$ full), good ($^3/_4$ full) and heavy (full) stomachs depending upon the degree of fulness and the amount of food contained in them. Feeding intensity (FI) was then calculated from: $FI = 100N_FN_T^{-1}$, where N_F is the number of specimens with full stomachs and N_T is the total number of specimens examined (Sreeraj et al 2006).

Gastrosomatic index (GaSI): The gastrosomatic index (GaSI) was calculated to investigate monthly variation in feeding intensity following Singh et al (2018).

GaSI = (Weight of the gut/Total weight of the fish) × 100.

Relative length of gut (RLG): Relative length of gut (RLG), *i.e.*, the ratio between gut length and body length and was calculated following Al-Hussaini (1949).

RLG = Total Length of the gut/Total length of the fish

Index of relative importance (IRI) Feeding habits were determined by using Index of relative importance (IRI) (Pinkas et al 1971, Hyslop 1980) (1) the frequency of occurrence (%*F*), (2) the numerical percentage (%*N*), (3) the volumetric percentage (%*V*),

Indices were calculated for each stomach as follows:

$\%N = N_i/N_{total} \times 100$

N_i is the number of prey *i* (th), N_{total} is the total number of prey items

$\%V = V_i/V_{total} \times 100$

V_i is the mass of prey *i* (th), and V_{total} is the volume of prey items

$\%F = A_i/N \times 100$

A_i is the number of fish with prey *i* (th) in their stomach, *N* is the total number of fish with stomach contents

$IRI = (\%N + \%V) \times \%F$

IRI was converted into a percentage and expressed as % IRI.

RESULTS AND DISCUSSION

Feeding intensity: The highest percentage of full stomachs was during April (53.12%) and lowest in June (12.12%) (Fig. 1). Among the 363 guts observed, 114 (31.4%) fishes were recorded with full stomachs. Poor feeding activity was reported in breeding season (May-September) of *M. oculatus* and high feeding during post and pre- spawning periods (October-April) (Dominic 2014). The low feeding activity during spawning season may be that body cavity would be occupied with fully developed gonads, limiting the space in the stomach for intake of food (Sh et al 2020). The fish feeds more voraciously because of higher energy demand associated with gonad development during the spawning stage. Seasonal variations in the feeding intensity in fishes are influenced not only by the maturation of gonads but also reduced availability of prey items in the environment (Ghanbarzadesh et al 2014).

Gastro-somatic index (GaSI): The minimum and maximum GaSI values were noticed during June (1.8) and February (3.25) respectively (Fig. 2). High feeding activity was noticed in November to April, while low feeding activity was observed during May-September. The low feeding activity during the spawning season may be attributed to completely developed gonads, permitting limited space in the abdominal cavity for intake of food. The intensity in food intake was increased after spawning and the reason is that fishes need more food and energy for their growth and development. Similar kind of observation on low GaSI value during the breeding season has been observed earlier in other cat fishes like *Mystus tengara* (Gupta and Banerjee 2014).

Relative length of gut (RLG): The observed average relative gut length (RLG) value in *M. oculatus* was very low (0.32) confirming the species as highly carnivorous in feeding habit. Structure of alimentary canal and intestine morphology of fishes has a direct bearing on the nature of food consumed by the fish (Karachle and Stergiou 2010). The gut length of herbivorous fishes is larger than that of omnivorous and

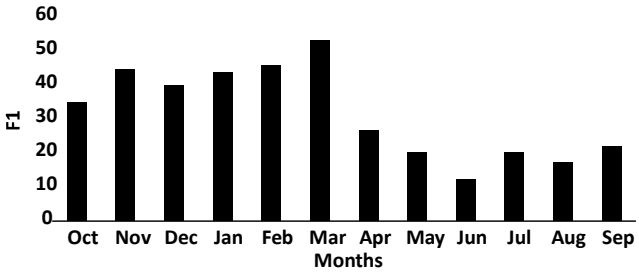

Fig. 1. Monthly variation in feeding intensity of *M. oculatus* from Chalakudy River based on proportion of individuals with full stomachs

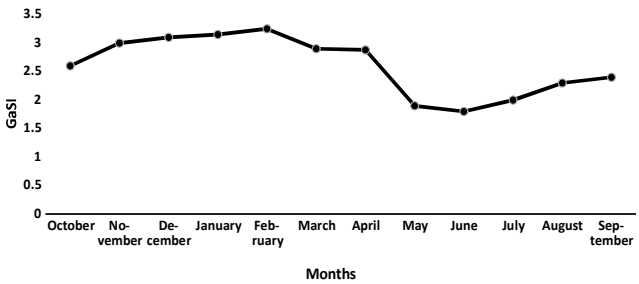

Fig. 2. Monthly variation in GaSI of *M. oculatus* from Chalakudy river

Table 1. Index of relative importance of food items in *M. oculatus* from Chalakudy river

Food items	October	November	December	January	February	March	April	May	June	July	August	September
Crustaceans	35.64	40.85	38.84	38.99	44.87	43.15	41.22	41.70	34.96	32.89	29.87	32.66
Insects	16.57	17.58	16.35	15.82	12.52	13.43	12.31	11.91	11.40	13.03	12.60	14.15
Fish body parts and scales	9.84	9.35	9.09	9.70	13.04	15.98	15.84	16.43	12.79	9.37	10.09	9.71
Rotifers	13.65	11.23	11.58	10.36	8.13	7.80	7.14	6.74	10.54	13.16	13.25	13.61
Mollusks	3.09	3.53	3.58	3.13	2.12	2.28	3.31	3.25	5.22	5.67	6.28	6.40
Plant matter	3.91	4.67	5.68	5.60	4.69	3.60	5.06	5.96	6.52	6.18	6.98	4.91
Bacillariophyceae	5.69	3.74	4.54	4.82	3.98	2.32	3.86	3.79	5.21	5.94	5.23	4.32
Chlorophyceae	3.17	2.58	3.18	3.53	3.24	2.50	3.27	3.85	4.62	6.61	6.68	6.11
Annelids	2.76	1.78	2.56	2.91	1.48	1.96	1.92	2.53	3.52	3.12	4.27	3.65
Mud and miscellaneous items	5.69	4.67	4.60	5.15	5.92	6.99	6.07	3.85	5.22	4.02	4.75	4.48

carnivorous fishes (Padmakumar et al 2009). Dasgupta (2004) reported that average RLG of 0.70 for carnivorous fishes, 1.37 for omnivorous, 3.70 for planktivorous and 4.77 for herbivorous fishes.

Index of relative importance (IRI): Gut content analysis revealed that crustaceans were the most abundant prey group among the food classes with IRI of 37.97 per cent followed by insects (13.97%), fish body parts and scales (11.77%) and rotifers (10.6%). Highest percentage composition of crustaceans was recorded (Table 1) in February (44.87%) and the lowest during August (29.87%). Percentage composition of insects was highest in November (17.58%) and lowest in June (11.4%). The occurrence of fish parts and scales was observed all-round the year with maximum value during the month of March (15.98%) and minimum value in December (9.09%). Percentage of rotifers was recorded high during October (13.65%) and low in May (6.74%). Environment and season plays an important role in the distribution of food organism in different habitats of tropical regions and such differences in the availability of prey items in the habitats are reflected in diet composition of fishes (Mukherjee et al 2016, Bhakta et al 2019). In rainy seasons, runoff transport organic matter and other nutrients in to the river, which enrich these environments (Konan et al 2014).

Scales, gills and bone parts of juveniles of small fishes could be identified as important fish parts in the guts of *M. oculatus*. Scale eating is a common habit among other species of cat fishes in tropical fresh water habitats. presence of fish scales and crustaceans in the stomach of *M. oculatus* may be related to the differential digestive property of specific prey items. Crustaceans and fish scales and gills resist digestion and are reported to be identifiable in fish guts over a long period when compared to many other food items (Raja and Perumal 2018). The presence of sand in the stomachs examined is probably due to accidental ingestion when taking from the food from river bed but may also contribute the grinding and digestion of food items. The sub terminal mouth of the fish assists benthophagic feeding nature in *M. oculatus*.

The present study revealed that species is categorized as a carnivorous feeder as the gut contains more than 80% of animal matter. The carnivorous feeding nature was also reported in other *Mystus* species like, *M. cavasius* (Krishna Rao 2007), *M. vittatus* (Chattopadhyay et al 2014), *M. armatus* (Gupta and Banerjee 2014) and *M. gulio* (Sabbir et al 2017). *M. oculatus* fed a wide range of prey items ranging from planktons to invertebrates and hence could be called as euryphagous feeder as already reported in other bagrid cat fishes like *Hemibagrus punctatus*, *Mystus gulio* and *M. tengra* (Gupta and Banerjee 2014, Karna et al 2016, Raja and Perumal 2018). The pharyngeal teeth of some catfishes have specialized in structure which will help for feeding on live prey such as crustaceans, insects, fishes, rotifers etc (Inasu et al 1997). The present study agrees greatly with the above report as *M. oculatus* feed mainly on these live organisms.

CONCLUSION

Mystus oculatus exhibited a carnivorous and euryphagous feeding habit. Crustaceans (37.97%) were the most preferred food followed by insects (13.97%), fish body parts and scales (11.77%) and rotifers (10.6%). Lowest feeding intensity was during the breeding season (May-September) while highest feeding activity was recorded during pre-spawning months (October-April). The intensity in food intake was increased after spawning as fishes need more food and energy for their growth and development during this period. Presence of fish scales, bones and crustaceans in the stomach of *M. oculatus* may be related to

the differential digestion of specific prey items. The sub terminal mouth of the fish assists benthophagic feeding nature. The study helps to understand the trophic role of fish in relation to other fish species in this ecosystem.

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Screening and Biochemical Characterization of PHB Producing Bacterium Isolated from Marine Sample

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Abstract: The increasing importance of the non-degradable plastics has emerged as one of the major concerns. For this, research is being ventured from the existing reserve to produce bio plastics on the basis of biodegradability properties. A thermoplastic is both biodegradable and environmental friendly, as well as biocompatible is Poly-hydroxy butyrate. Present study focused on identification of potential polyhydroxybutyrate producing bacterial strains from marine soil sample collected from Bapatla, Guntur District. Ten bacterial isolates were identified through Sudan Black staining, out of which RR25 observed to be potential for PHB production. Biochemical characterization was performed for preliminary identification of isolate and was *Bacillus* sp. Biopolymer obtained from the isolate was characterized by FTIR and DSC. The biopolymer compared with standard and identified as polyhydroxtbutyratye.

Keywords: Biopolymer, *Bacillus* sp, Polyhydroxtbutyratye, FT-IR, DSC

Sustainability, environmental concerns and green chemistry in the coming years will played a vital role in developing the next generation of materials, products and processes. There has been a steady decline in the petroleum assets and landfill space due to the tenacity of different plastics in the environment. Enormous amounts of waste, which is difficult to decompose, and greenhouse gases are generated by both the production and after life remediation of plastics, which cause various kinds of health hazard problems in humans (Chen et al 2012, Vijetha et al 2020, Raviteja et al 2020). Plastic is naturally resistant to degradation due to the molecular size which is up to 1, 50,000 dalton. In order to displace this ever increasing waste o plastic, a potential material could be bioplastic, which can be equally utilized in all applications and its degradability with time is the major merit of bioplastic over synthetic plastic. Bioplastics, in some cases are non-immunogenic in nature and this can be utilized for designing medical implants and devices. The physico-chemical properties of bioplastics are similar to that of synthetic polymers, with an added advantage of being degradable under normal environmental conditions. A lot of interest for scientists and researchers has been created by biodegradable polymers such as PLA (polylactic acid), PHA (polyhyrdoxyalkanoates), PHB (Polyhydroxtbutyratye) and cellophane. PHAs can be purified from bacteria, which have the ability to accumulate bioplastics under stress conditions in these forms (Chen 2009). PHA is normally produced as a polymer containing 103-104 monomers. This accumulates in the bacterial inclusion size of 0.2-0.5 µm in diameter. Depending upon the various groups and their position on the main chain, PHA consists of different classes and has approximately 150 different constituents (Loo et al 2007).The current study involved screening of bacteria that produce PHB and the characterization of PHB which is produced for the quality.

MATERIAL AND METHODS

Sample collection*:* Soil samples were collected from Bapatla, Guntur district (Costal Region of Andhra Pradesh) with *GPS* coordinates of 15° 53' 47.8392'' N and 80° 27' 37.5624'' E. The samples were stored in sterile plastic bags at 4°C and were transferred to laboratory.

Isolation of PHB producing bacteria: One gram of costal soil sample was collected and pure colonies of bacterial isolates were obtained by serial dilution pour plate technique on nutrient agar medium using L shaped spreader. All the petriplate were incubated at 37°C for 24-48 hours and bacterial colonies with unique characteristic features were maintained as pure cultures on agar slants and preserved at 4°C.

Morphological analysis of bacterial isolates: Pure bacterial colonies were characterized for colour, form, elevation, margin etc. Bacterial isolates were morphologically analysed on the basis of staining and cell morphology using microscope. The staining of isolate was done and analysed for the cell size, arrangement, form, shape and pattern of the isolated strain. Methylene blue was used as simple staining dye as per standard procedure.. The

isolates were further screened for PHB accumulation by Sudan black B staining with standard procedure.

PHB extraction from bacterial isolates: PHB extraction from bacterial isolates was carried by centrifugation of10 mL of bacterial culture (10000 rpm/15 min.) and pellet was digested with sodium solution at 37°C for 1 hrs. The mixture was further centrifuged at 5000 rpm for 15 min and washed with distilled phosphate buffer saline, water, acetone and methanol respectively. After washing, the pellet was dissolved in 5 ml of boiling chloroform and kept for complete evaporation to obtain PHB crystal. The sample was identified by Polyhydroxtbutyratye assay

Characterization of PHB: The extracted PHB was characterized by FTIR and DSC analysis.

FTIR analysis: FTIR transmits infrared radiation between 10,000 and 100cm^{-1}, which receive and pass through such radiation. The radiation absorbed is converted into rotating or vibrational energy by the sample. The received image on the sensor generally shows a profile of the sample, from 4000 $cm^{-1}$to 400 cm^{-1}. 1mg of the PHB sample and 10mg of spectral pure anhydrous potassium bromide crystal was formed into pellet for IR analysis.

DSC analysis*:* The crystallization temperature (Tc), melting temperature (Tm), and glass transition temperature (Tg) were determined by using Differential Scanning Calorimeter. Extracted Biopolymer sample was encapsulated in aluminium crucible and heated in a temperature range from -50°C to 400°C at the rate of 10°C/min. Melting temperature was recorded at the peak of the melting endotherm (Kulkarni et al 2010).

RESULTS AND DISCUSSION

Isolation and screening of PHB producing colonies: Out of 30 bacterial isolates screened for PHB production, 10 isolates screened positive after preliminary screening. Bacterial isolates that appeared bluish white under UV were selected as potential PHB producers. Among the 10 isolates which were subjected to secondary screening isolate RR25 was highly potential for PHB production (Table 1) and was selected for further studies. Andhra Pradesh has a vast coastal region of 1000kms, Bapatla, Guntur district was explored for collecting marine soil sample. In this *Bacillus* sp. RR25 strain which was isolated successfully is highly potential for PHB production (Fig. 1).

Screening of isolate RR25 by Sudan Black B: Bacterial isolate RR25 screened positive to Sudan Black B (0.3 gm in 100ml of 70% ethanol) as shown in Figure 2 when observed under Olympus microscope at 100x.

PHB assay by Law and Slepecky method: The bacterial isolates viz., RR03, RR05, RR06, RR08, RR12, RR15, RR16, RR18, RR25 and RR28 showed considerable amount of PHB accumulation as shown in Table 1. The bacterial isolate RR25 was considered for further studies as it produced maximum yield of PHB. PHB assay using concentrated $H_2SO_4$is based upon quantitative conversion of PHB to crotonic acid under boiling conditions (Fig. 3).

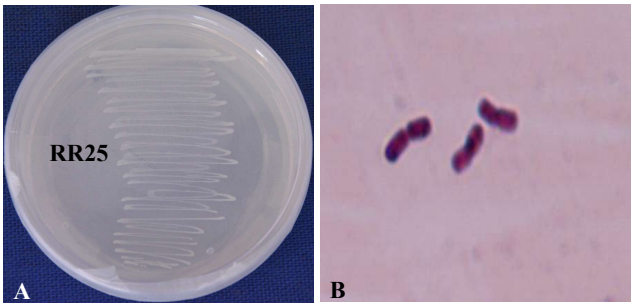

Fig. 1. PHB producing positive colony a) pure colony of RR25 b) Gram staining

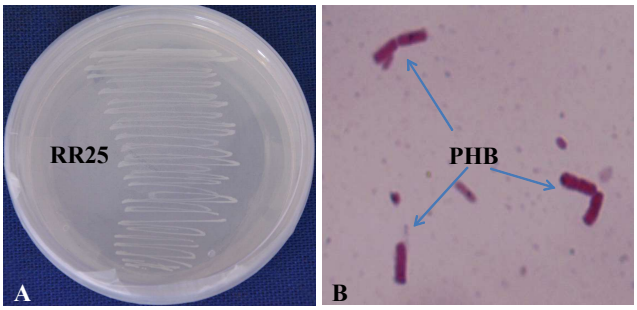

Fig. 2. PHB positive Colony a) bacterial isolate RR25 b) Sudan Black B staining

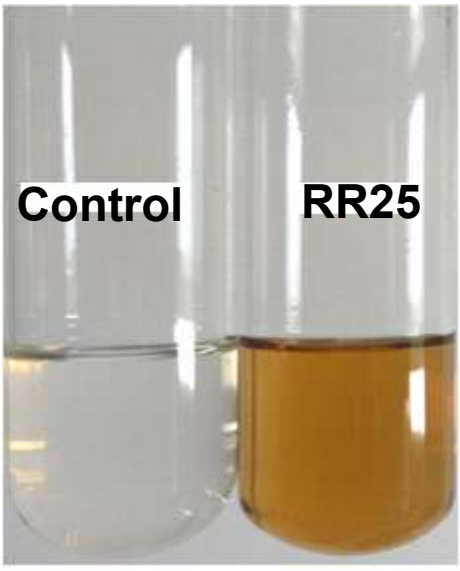

Fig. 3. PHB assay of bacterial isolate RR25 by Law and Slepecky method

Extraction of PHB: Extraction of PHB was done by the modified method of Senthil and Prabakharan. Crude PHB was extracted in centrifuge tubes as a pellet and was dried using hot air woven. Earlier researchers reported the accumulation of PHB granules by a large number of gram positive and gram negative bacterial species (Verlinden et al 2007, Reddy et al 2017, 2018, 2019a, b, Ranganadha et al 2020)

PHB characterization: FT-IR analysis: FTIR spectrum of Bacillus sp RR25 revealed the absorption peaks at 3400cm^{-1} , 3294 cm^{-1} and 3198 cm^{-1} (Fig. 4) denote terminal hydroxyl group (-OH). The absorption band at 3027 cm^{-1}represents methylene group. The absorption bands at 3027, 1594 and 1510 cm^{-1}denote the –C≡C–, –C=C–and N–O asymmetric stretch respectively. The absorption bands at 1438 cm^{-1} and 1398 cm^{-1} denoteC–O ester bond, CH vibrations of–CH_2 and–CH_3 functional groups. The absorption bands at 1238, 1072 and 500-1000 cm^{-1} represents C=O ester group, C–O stretch and OH group. The FT-IR spectral results of biopolymer isolated from Bacillus sp RR25correlated with findings of Silverstein et al (2005) and Tripathi et al (2011).

DSC analysis: The differential scanning calorimetry thermo grams revealed the characteristic or DSC which indicated that the melting temperature Tm of PHB biopolymer is 160°C which was close to melting temperature Tm (175 °C) of the standard PHB(Lee et al 2002) with an increasing temperature range from 50 °C to 450 °C as shown in Figure 5.

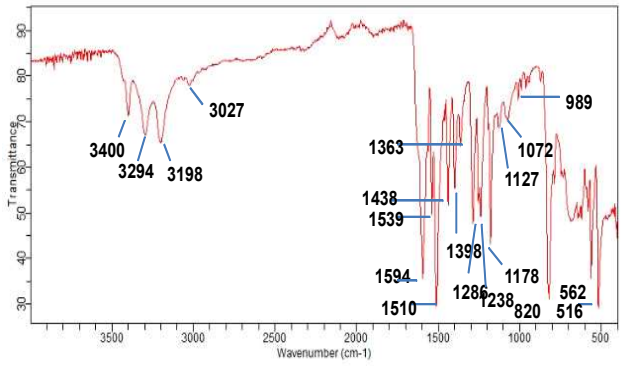

Fig. 4. FTIR spectrum of powered PHB from *Bacillus* sp. RR25

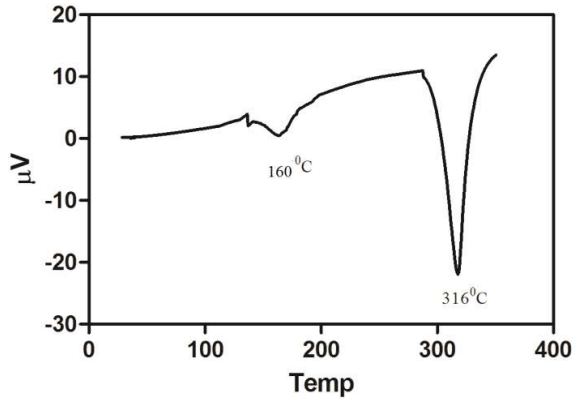

Fig. 5. DSC analysis of powered PHB from *Bacillus* sp RR25

Table 1. PHB yield from isolated bacterial colonies

Bacterial isolate	PHB Yield (g L^{-1})
RR03	0. 89
RR05	0.81
RR06	0.62
RR08	0.59
RR12	0.53
RR15	0.48
RR16	0.68
RR18	0.78
RR25	0.91
RR28	0.40

CONCLUSION

The different bacterial colonies were isolated and screened from soil for the production of Polyhydroxtbutyratye. The isolate Bacillus sp. RR25 producing greater amount of PHB was studied. The biopolymer produced by Bacillus sp. RR25 was characterized by FTIR. DSC studies revealed the melting temperature Tm of biopolymer as 160°C which was close to standard PHB.

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Micro Comparative Study on Diversity of Ants Species (Hymenoptera: Formicidae) in Goa

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***Abstract*:** The study examined the diversity and density of ant species of Carmel College campus, Nuvem, Salcete Goa, as there was no adequate information relating to ant faunal diversity of this region, from July 2006 to April 2007. The ants were collected using various standard methods. The result showed that a total of 9202 individuals were collected from the study area. The sampled specimens represented 37 species belonging to 20 genera and six subfamilies. The most diverse subfamily in relation to species was Myrmicinae with 12 species, followed by subfamily Formicinae with eleven, Ponerinae with seven and Pseudomyrmicinae with four species. Less diversity was found in subfamily Dorylinae with just two species and Dolichoderinae with only one species. In the generic trend, eight genera were in subfamily Myrmicinae while five in Formicinae, four in Ponerinae and just one genus each in Dolichoderinae, Dorylinae and Pseudomyrmicinae. This study has yielded valuable information of ant diversity in this region as well as on the campus of Carmel College of Arts, Science and Commerce for Women. An effort was made to compare the findings of this study with that of a similar study conducted almost ten years later (2015-2016) in the same study area. The results showed a remarkable difference with four subfamilies, 13 genera and 17 species.

***Keywords*:** Diversity, Density, Undisturbed areas, Disturbed areas, Formicidae

There is a steadfast curiosity in the number of species in native communities, because they are the necessary units of biodiversity. Many studies report on change in species richness but the interest of conservation biologists is to examine whether species richness changes with extensive use of land, history or degree of landscape fragmentation, change in topography and whether richness changes over time. There are numerous reasons for selecting ants as a survey taxon in research studies. Ants along with other invertebrate taxa are included in biodiversity studies because of their great diversity and quick response to even a minor environmental change. In most of the terrestrial ecosystems ants are a noticeable presence, and they are among the most frequently studied terrestrial invertebrates. They are mostly scavengers and predators, and have large impact on soil formation, seed predation and its dispersal, and invertebrate community structure (Lach et al 2010, Del Toro et al 2012, Guénard 2013). They are predominantly good candidates for observing community changes that may occur due to climate change or fragmentation of habitats. They add up to a cumulative 15-25% total terrestrial animal biomass (Schultz and McGlynn 2000, Krushelnycky et al 2005). The success of ants in many different environments is credited to their social organization and capacity to adapt to nearly any habitat, procure food resources and defend them (Keller and Gordon 2009). Due to the mutualistic behavior of ants with both flora and other fauna, they are considered as efficient biological and ecological indicators and are one of the nine projected indicators of the ecosystem (Underwood and Fisher 2006). Presence of ants is observed at all levels of the terrestrial food webs (Pfeiffer et al 2013). Nearly 12,500 of an estimated 22,000 ant species have been described (Bolton et al 2006, Philip 2007). Formicidae contains 21 subfamilies and 283 genera and about 12,500 living ant species. India has known ant fauna of 828 species in 100 genera and 10 subfamilies. About 66 species belonging to 32 genera have been reported from Goa which includes Daman and Diu (Bharti et al 2016). Ants act as ecosystem engineers and are efficient decomposers and thus play an important role in soil fertility and nutrient cycling. Considering the importance of ants in ecological communities, the present investigation was undertaken to fill in the lacuna in the existing knowledge of ant diversity in the state of Goa.

MATERIAL AND METHODS

Study area: The field work was conducted on the campus of Carmel College of Arts, Science and Commerce for Women, Nuvem, Salcete Goa, covering 14.16 ha of land. It is situated in Nuvem village (Lat. N 15° 18' 42.5772", Long. E 73° 56' 41.2764"), a suburban area, which is located three kilometers away from Margao city. This region is a biologically diverse and productive habitat of native flora and fauna because of its pristine nature and most of the area being undisturbed as it is a private property. This study was

conducted from July 2006 to April 2007 and survey included undisturbed and disturbed areas that covered study sites like various transects of the hill top and scrub areas that are hardly visited (undisturbed areas) (Fig. 1) and vehicle parking areas, roadside, botanical garden, library which are frequently visited (disturbed areas) (Fig. 2).

Habitat characterization: The campus, with an area of 14.16 ha, has a diverse biota. Predominant vegetation of the campus is scrub jungle mixed with cashew, mango, acacia, eucalyptus and wild deciduous trees. The hilltop has scrub mixed with grassy patches. The built-up area has more ornamental shrubs and also includes trees like *Peltophorum pterocarpus* and *Koelreuteria paniculata*. The ground layer is rich in seasonal herbaceous flora especially during the monsoon. The most dominant angiosperm families in the campus are Acanthaceae, Apocynaceae, Asteraceae, Araceae, Euphorbiaceae, Fabaceae, Poaceae, Rubiaceae and Verbenaceae.

Ant sampling method: Ant sampling was done from July 2006 to April 2007. Five different standard ant sampling collection methods were employed in the collection of ants: a) hand collection b) pitfall trap method, c) Tullgren funnel method, d) bait method and e) beat sheet method. Ants were mostly collected during daytime. Field information (date, time, habitat and locality) was recorded at the time of collection. The collected ants were brought to the laboratory of the Department of Zoology, Carmel College for identification, labeling and preservation.

Fig. 1. Undisturbed areas of the campus

Fig. 2. Disturbed areas of the campus

Hand collection (all-out search) method: Larger, slow moving ants were either hand-picked or picked up with the fine brush dipped in 70% alcohol (ethanol) then dropped into a collecting bottle containing 70% alcohol. Collections were also made from soil nests, foraging columns and ants found on trees.

Pitfall trap method: A small container three-quarters full of water containing detergent was placed in a hole in the ground with the rim of the container level with the surface. Ants that fell into the container were collected after 24 hours. They were transferred to collecting bottles containing 70% alcohol and later washed in saline to remove dust particles and other debris, then plain water to remove the excess saline. Cleaned ants were placed into containers with 70% alcohol for preservation.

Tullgren funnel method: Leaf litter from shady areas was collected in polythene bags and carried to the laboratory. The litter was then placed in the mouth of a broad funnel with a 40-watt bulb for heat and light. Ants moving downward fell into a beaker containing 70% alcohol.

Bait method: Baits such as honey, coconut pieces, sugar, jaggery and cooked rice were used to attract ants. The baits were on the ground, tree trunks, shrubs, and other likely places. Ants attracted to these baits were immediately collected and preserved in 70% alcohol.

Beat sheet method: An open umbrella was placed upside down under a tree and the low-hanging branches of the tree above the open umbrella were gently shaken. Ants that fell into the open umbrella were either hand-picked or collected with a brush dipped in 70% alcohol and preserved in vials of 70% alcohol.

Identification: Ant specimens that were dry-mounted were studied and identified directly under a stereozoom LABOMED CZM4 and MOTIC B SERIES B1 220 ASC microscopes. Smaller ants were temporarily mounted on microscope slides of 1mm thickness, in a drop of glycerin and then identified. Specimens were identified to subfamily using the identification keys given by Narendra and Kumar (2006). The species were identified with keys in Bingham (1903), Bolton (1995), Plowes and Patrock (2000), Bolton et al. 2006, Chavan and Patkar 2014 and AntWeb (2020). After identification, cross checking was done with the images available at http://www.antbase.net/index.html. Identifications were further confirmed with keys in Hölldobler and Wilson (1990). Diversity Indices as such as Shannon Weaver, Simpson's Index and Evenness were calculated using PAST statistical software Version 2.7. A reference collection was maintained in the Zoology Museum of Carmel

College of Arts, Science and Commerce for Women, Nuvem, Salcette Goa.

Labeling: Permanently preserved specimens were labeled with identification and data labels. The data labels include information about the date and time of collection, name of the collector, the habitat and the locality.

Mounting and dry preservation: After identification, ants were removed from the alcohol and dried in a petri dish with the help of a light source. Before mounting, specimens were relaxed by remoistening them in xylene to soften the tissues in order to facilitate the adherence of the specimen onto the paper. And body parts of taxonomic significance were repositioned.

Wet preservation: Ants not dry-mounted on points were preserved species wise in separate vials of 70% alcohol. All vials had labels containing complete field information (locality, date and time of collection, name of the collector, habitat) and specimen identity.

RESULTS AND DISCUSSION:

Six subfamilies of ant fauna have been reported from Goa that includes Daman and Diu namely Dolichoderinae, Dorylinae, Formicinae, Myrmicinae, Ponerinae and Pseudomyrmicinae. In this study ant species were recorded from six subfamilies that included 37 species and 20 genera (Table 1). Species distribution among the subfamilies was more even. The distribution of species in the subfamilies showed a dominance of Myrmicinae with 12 species (32.5%) followed by Formicinae, Ponerinae, Pseudomyrmicinae, Dorylinae and Dolichoderinae (Table 2). In the generic trend, subfamily Myrmicinae showed dominance of eight (40%) genera, followed by Formicinae five (25%), Ponerinae four (20%). The remaining three subfamilies were recorded with only one genus each (5%) (Table 2). A total of 32 (86.48%) and 24 (64.86%) ant species were identified from the undisturbed and disturbed areas respectively (Tables 3 and 4). Of the 37 ant species, 19 (51.35%) species were present in both the study areas undisturbed as well as disturbed, while 13 (35.13%) species were exclusively in the undisturbed areas and only five (13.51%) species were exclusively found in the disturbed areas (Tables 3 and 4).

Species *Tapinoma melanocephalum*, *Camponotus irritans, Camponotus radiatus*, *Pheidole grayi* and *Pheidole sharpi* were not reported from the undisturbed areas while *Cerapachys aitkenii, Cerapachys biroi, Aphaenogaster beccarii, Aphaenogaster feae, Meranoplus bicolor, Bothroponera henryi, Bothroponera sulcata, Diacamma ceylonense, D. rugosum* and the *Tetraponera* species were absent from the disturbed areas (Tables 3 and 4). The total number of ants collected from the undisturbed areas (4766)

Table 1. Checklist of ants collected from Carmel College campus

Biological name	Common name
Dolichoderinae	
Tapinoma melanocephalum (Fabricius, 1793)	Odour Ant (Ghost Ant)
Dorylinae	
Cerapachys aitkenii (Forel,1900)	Red Cannibal Ant
C. biroi (Forel, 1907)	Ant-raiding Ant
Formicinae	
Anoplolepis gracilipes (Smith, 1857)	Yellow Crazy Ant
Camponotus angusticollis (Jerdon, 1851)	Long Neck Sugar Ant
C. compressus (Fabricius, 1878)	Common Godzilla Ant
C. irritans (Smith, 1857)	Giant Honey Ant
C. parius (Emery, 1889)	
C. radiatus (Forel, 1892)	Carpenter Ant
C. sericeus (Fabricius, 1798)	Golden Black Ant
Oecophylla smaragdina (Fabricius, 1775)	Weaver Ant
Paratrechina longicornis (Latreille, 1802)	Black Crazy Ant
Polyrhachis exercita (Emery, 1889)	
P. illaudata (Walker, 1859)	
Myrmicinae	
Aphaenogaster beccarii (Emery, 1887)	Long-legged Hunchback Ant
A. feae (Emery, 1889)	
Crematogaster rothneyi (Mayr, 1879)	Common Acrobat Ant
C. subnuda (Mayr, 1879)	Common Broad Acrobat Ant
Meranoplus bicolor (Guerin-Meneville, 1844)	Shield Ant
Monomorium atomum (Forel, 1902)	
M. pharaonis (Linnaeus, 1758)	Pharao's Ant
Myrmicaria brunnea (Saunders, 1842)	Short-legged Hunchback Ant
Pheidole grayi (Forel, 1902)	
P. sharpi (Forel, 1902)	
Solenopsis geminata (Fabricius, 1804)	Common Red Fire Ant
Tetramorium wroughtonii (Forel, 1902)	
Ponerinae	
Bothroponera henryi (Donisthorpe, 1942)	
B. sulcata (Mayr, 1867)	
Diacammaceylonense (Emery, 1897)	Queenless Ant
D. rugosum (Le Guillou, 1842)	Lesser Striated Bispinous Ant
Leptogenys diminuta (Smith, 1857)	
L. processionalis (Jerdon, 1851)	Procession Ant
Odontomachus haematodus (Linnaeus, 1758)	Greater Trap-jaw Ant
Pseudomyrmicinae	
Tetraponera aitkenii (Forel, 1902)	Slender Ants
T. allaborans (Walker, 1859)	Polished Leaf-border Ant
T. nigra (Jerdon, 1851)	
T. rufonigra (Jerdon, 1851)	Arboreal Bicolored Ant
Total Subfamilies - 06	Genus - 20 Species - 37

Table 2. Total number and percentage of genera and species per subfamily

Subfamily	Genera	Percentage	Species	Percentage
Dolichoderinae	01	5	01	2.7
Dorylinae	01	5	02	5
Formicinae	05	25	11	29.7
Myrmicinae	08	40	12	32.5
Ponerinae	04	20	07	18.9
Pseudomyrmicinae	01	5	04	10.8
Total	20		37	

Table 3. Distribution of the presence of the ant species in the two study areas

Biological name	Study areas	
	Undisturbed	Disturbed
Dolichoderinae		
Tapinoma melanocephalum		+
Dorylinae		
Cerapachys aitkenii	+	
C. biroi	+	
Formicinae		
Anoplolepis gracilipes	+	+
Camponotus angusticollis	+	+
C. compressus	+	+
C. irritans		+
C. parius	+	+
C. radiatus		+
C. sericeus	+	+
Oecophylla smaragdina	+	+
Paratrechina longicornis	+	+
Polyrhachis exercita	+	+
P. illaudata	+	+
Myrmicinae		
Aphaenogaster beccarii	+	
A. feae	+	
Crematogaster rothneyi	+	+
C. subnuda	+	+
Meranoplus bicolor	+	
Monomorium atomum	+	+
M. pharaonis	+	+
Myrmicaria brunnea	+	+
Pheidole grayi		+
P. sharpi		+
Solenopsis geminata	+	+
Tetramorium wroughtonii	+	+
Ponerinae		
Bothroponera henryi	+	
B. sulcata	+	
Diacammaceylonense	+	
D. rugosum	+	
Leptogenys diminuta	+	+
L. processionalis	+	+
Odontomachus haematodus	+	+
Pseudomyrmicinae		
Tetraponera aitkenii	+	
T. allaborans	+	
T. nigra	+	
T. rufonigra	+	

Table 4. Presence and percentage of the distribution of ant species in the two study areas

Study areas	Species present	Percentage
Undisturbed areas	32	86.48
Disturbed areas	24	64.86
Common –Undisturbed areas & disturbed areas)	19	51.35
Only in undisturbed areas	13	35.13
Only in disturbed areas	05	13.51

was more compared to the disturbed areas (4436) (Tables 5 and 7). In undisturbed areas, subfamily Myrmicinae was more speciose (10 species) and the least was subfamily Dorylinae with only two species whereas in the disturbed areas it was subfamily Formicinae that was more diverse with eleven species and the least was Dolichoderinae with just one (Table 9). In undisturbed areas subfamily Dolichoderinae was absent while in disturbed areas subfamilies Dorylinae and Pseudomyrmicinae were not represented (Table 9). In undisturbed areas, subfamily Formicinae recorded maximum number of individuals (2360), followed by subfamily Myrmicinae, Ponerinae, Dorylinae and minimum was in subfamily Pseudomyrmicinae (148) (Tables 5 and 6). The monthly variation of the ant subfamilies in the undisturbed areas is represented in Table 5. Subfamily Dolichoderinae was not represented in the undisturbed areas.

In the disturbed areas, the same trend was observed with subfamily Formicinae representing the maximum number of individuals (2485) followed by subfamily Myrmicinae (1633) and the least were observed in subfamily Ponerinae (156). Subfamily Dolichoderinae was represented with 162 species in the disturbed areas while no individuals were recorded in subfamilies Dorylinae and Pseudomyrmicinae in the disturbed areas (Tables 7 and 8). The three abundant species in the undisturbed areas were from subfamily Formicinae, *Anoplolepis gracilipes* (406), *Oecophylla smaragdina* (336) and *Camponotus compressus* (292) while in the disturbed areas, the abundant species were also from the subfamily Formicinae, *Anoplolepis gracilipes* (391), *Oecophylla smaragdina* (369) and *Camponotus radiates* (314) (Table 5 and 7). Overall the subfamily Formicinae had the maximum number of ant species (4845) in the college campus in both the undisturbed and disturbed areas (Table 7). Of the 11 species recorded in this subfamily, *Anoplolepis gracilipes* is the commonest in the college campus both in the undisturbed areas (406) and in the disturbed areas (391) with a total of 797.

Altogether total number of species recorded in the study sites was 37 where 32 (86.48%) species were found in the

Table 5. Total number of ants collected from the undisturbed areas month wise from July 2006 to April 2007

Species	Undisturbed study areas (JULY 2006 – APRIL 2007)										Total A
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	
Dolichoderinae											
Tapinoma melanocephalum	-	-	-	-	-	-	-	-	-	-	-
Dorylinae											
Cerapachys aitkenii	-	08	11	11	13	12	13	15	15	16	114
Cerapachys biroi	04	08	10	11	10	13	12	14	14	16	112
Total A	04	16	21	22	23	25	25	29	29	32	226
Formicinae											
Anoplolepis gracilipes	16	26	28	30	35	37	49	57	60	68	406
Camponotus angusticollis	-	-	20	24	30	37	37	40	41	44	273
Camponotus compressus	-	15	21	27	27	35	39	41	42	45	292
Camponotus irritans	-	-	-	-	-	-	-	-	-	-	-
Camponotus parius	-	12	17	22	24	26	31	33	36	38	239
Camponotus radiatus	-	-	-	-	-	-	-	-	-	-	-
Camponotus sericeus	-	-	-	19	24	27	33	35	39	42	219
Oecophylla smaragdina	-	09	13	20	28	37	45	59	63	62	336
Paratrechina longicornis	06	11	16	21	27	32	35	39	42	44	273
Polyrhachis exercita	-	-	07	10	14	15	20	23	27	34	150
Polyrhachis illaudata	-	-	09	09	15	22	27	28	30	32	172
Total B	22	73	131	182	224	268	316	355	380	409	2360
Myrmicinae											
Aphaenogaster beccarii	-	-	04	05	06	05	06	06	07	07	46
Aphaenogaster feae	-	-	-	04	05	07	07	06	06	07	42
Crematogaster rothneyi	03	05	05	10	12	15	15	21	25	28	139
Crematogaster subnuda	04	04	04	09	09	11	15	17	21	25	119
Meranoplus bicolor	-	-	-	05	08	12	14	17	22	27	105
Monomorium atomum	07	11	10	11	12	12	18	21	26	30	158
Monomorium pharaonis	06	09	12	13	15	18	21	24	26	29	173
Myrmicaria brunnea	-	-	05	09	12	12	13	15	15	13	94
Pheidole grayi	-	-	-	-	-	-	-	-	-	-	-
Pheidole sharpi	-	-	-	-	-	-	-	-	-	-	-
Solenopsis geminata	-	09	13	16	20	23	28	33	37	41	220
Tetramorium wroughtonii	04	10	10	14	17	17	17	19	21	24	153
Total C	24	48	63	96	116	132	154	179	206	231	1249
Ponerinae											
Bothroponera henryi	-	09	12	25	28	32	15	15	10	05	151
Bothroponera sulcata	-	-	05	11	20	29	25	21	14	08	133
Diacammaceylonense	05	07	07	13	16	23	29	31	33	30	194
Diacamma rugosum	07	11	09	15	21	24	26	26	30	27	196
Leptogenys diminuta	-	-	03	03	07	10	11	09	-	-	43
Leptogenys processionalis	-	-	02	02	08	07	11	09	-	-	39
Odontomachus haematodus	-	-	-	03	05	08	08	03	-	-	27
Total D	12	27	38	72	105	133	125	114	87	70	783
Pseudomyrmicinae											
Tetraponera aitkenii	-	-	04	04	03	02	02	01	-	-	16
Tetraponera allaborans	-	-	12	10	10	07	04	02	-	-	45
Tetraponera nigra	-	-	-	09	06	06	05	02	02	-	30
Tetraponera rufonigra	-	-	12	12	10	09	07	05	02	-	57
Total E			28	35	29	24	18	10	04		148
GRAND TOTAL = (A+B+C+D+E) = 226+2360+1249+783+148											4766

Table 6. Total number of ants per subfamily in undisturbed areas

Undusturbed areas	
Subfamilies	Total number of ants
Dolichoderinae	0
Dorylinae	226
Formicinae	2360
Myrmicinae	1249
Ponerinae	783
Pseudomyrmicinae	148
Total	4766

undisturbed areas and 24 (64.86%) were recorded in the disturbed areas (Table 4). In the undisturbed areas subfamilies Dorylinae, Ponerinae and Pseudomyrmicinae were represented 100% and subfamily Dolichoderinae was not represented at all while in the disturbed areas subfamilies Dolichoderinae and Formicinae were represented 100% while Dorylinae and Pseudomyrmicinae were not represented at all (Table 9). *Camponotus* Mayr, 1861 was represented by six species, of which *C. compressus* (292 individuals) and *C. angusticollis* (273 individuals) in the undisturbed areas and *C. irritans* (217) and *C. sericeus* (216) in the disturbed areas were remarkably found in most of the sites with maximum number (Tables 5 & 7). Individuals of *Oecophylla smaragdina* (336 & 369) in the undisturbed and disturbed areas respectively, a species with arboreal nests, was dominant on tree trunks. *Anoplolepis gracilipes* (406 &391) in the undisturbed and disturbed areas respectively were especially abundant in cool, moist places under leaf litter at the base of the trees. Species *Camponotus* Mayr 1861, *Oecophylla* Fabricius 1775, *Anoplolepis* Smith 1857, *Myrmicaria* Saunders1842, *Solenopsis* Fabricius 1804, *Monomorium* Linnaeus,1758, *Diacamma* Le Guillou, 1842, *Pachycondyla* donisthorpe 1942 and *Leptogenys* Jerdon, 1851 were found throughout the study period and recorded from most of the study sites of the undisturbed and disturbed areas (Table 5 and 7).

Shannon-Wiener diversity index value (H') for undisturbed areas (3.25) was slightly higher than that of disturbed areas (3.03). Value of Simpson's index (D) for undisturbed areas was 0.044 while for disturbed areas is 0.053. Evenness values were more or less the same for both the areas, undisturbed (0.94) and disturbed (0.95). Species richness and abundance from both the areas were significantly different (Table 10). An attempt was made to compare the findings of this study and a study conducted almost ten years later in the same campus and in the same study sites with the same parameters. A remarkable difference was observed in the results. The study of 2015-2016 resulted in documenting and identifying four subfamilies, with 13 genera and 15 species in the undisturbed areas and seven genera and ten species in the disturbed. A few species were unidentified. The study of 2006-2007 had recorded six subfamilies with 18 genera and 32 species in the undisturbed areas and 14 genera and 24 species in the disturbed areas. Subfamilies Dolichoderinae and Dorylinae and genera Pheidole were not represented in 2015-2016 study (Table 11 & 12). Ants can be effectively used as indicator species as they respond to any alteration in the surrounding environment. They can also be effectively used to study landscape disturbance and species diversity (Paknia and Pfeiffer 2011). Thus, understanding the impact of habitat loss on myrmecofaunal diversity and density is a necessity. The collection and documentation of ants can give a good insight into the regional diversity and can be used in developing a regional checklist or an reference collection of an educational institution. It can also be considered as a document of faunal representation and any variation or decline in numbers can be taken as an indicator of an environment undergoing alteration as a result of human activity or natural forces. The species richness, diversity and density were less in the disturbed areas as compared to the undisturbed during both the study periods. This could be due to habitat destruction and increase in disturbance by various anthropogenic activities. Related studies on diversity of ants, butterflies and birds have shown that species richness and density decreases with increase in habitat disturbance (Ingalhallikar et al. 2000-2001, Kunte 2000-2001, Pachpor and Ghodke 2000-2001). Many studies have recorded that habitat degradation; disturbance and fragmentation have damaging impact on ant diversity and abundance where undisturbed areas or forests have higher species richness than those in the disturbed habitats (Watt et al 2002).

The undisturbed areas of the campus had abundant and diverse vegetation and hence showed a greater diversity of ant species than the disturbed areas where vegetation was not dense. During 2006-2007, the campus had more diversity and density of ant species than when it was conducted in 2016-2017 in both the undisturbed and disturbed areas. The undisturbed areas had various types of trees and plants in 2006-2007 which were felled for construction and campus expansion along with concrete pavers over the years. The plantation of acacia trees in the undisturbed areas during the gap of ten years of the study periods could be the cause of decrease in species richness and abundance during the study period of 2015-2016. Thus habitat variables such as dense canopy cover of foliage and abundant litter content in the soil can provide a suitable habitation for ants. This is

Table 7. Total number of ants collected from the disturbed areas month wise from July 2006 to April 2007

Species	Disturbed study area (JULY 2006 – APRIL 2007)										Total B	Total A+B
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR		
Dolichoderinae												
Tapinoma melanocephalum -		06	10	15	15	21	24	23	23	25	162	
Total A		06	10	15	15	21	24	23	23	25	162	162
Dorylinae												
Cerapachys aitkenii	-	-	-	-	-	-	-	-	-	-	-	
Cerapachys biroi	-	-	-	-	-	-	-	-	-	-	-	
Total B	-	-	-	-	-	-	-	-	-	-	-	226
Formicinae												
Anoplolepis gracilipes	07	12	19	29	35	43	48	55	67	76	391	
Camponotus angusticollis	-	03	07	07	09	12	12	11	11	10	82	
Camponotus compressus	10	13	15	17	20	22	25	25	23	23	193	
Camponotus irritans	05	09	12	17	23	26	29	31	32	33	217	
Camponotus parius	-	04	08	11	14	17	21	21	27	25	148	
Camponotus radiatus	11	14	19	23	28	33	37	42	52	55	314	
Camponotus sericeus	-	10	10	15	16	22	28	34	38	43	216	
Oecophylla smaragdina	07	11	17	27	33	41	46	51	63	73	369	
Paratrechina longicornis	-	10	15	21	27	32	37	37	31	29	239	
Polyrhachis exercita	03	09	11	11	15	16	22	24	25	25	161	
Polyrhachis illaudata	03	07	12	15	17	17	21	22	21	20	155	
Total C	46	102	145	193	237	281	326	353	390	412	2485	4845
Myrmicinae												
Aphaenogaster beccarii	-	-	-	-	-	-	-	-	-	-	-	
Aphaenogaster feae	-	-	-	-	-	-	-	-	-	-	-	
Crematogaster rothneyi	07	11	15	22	27	32	36	41	42	44	277	
Crematogaster subnuda	05	12	17	25	31	34	39	42	44	41	290	
Meranoplus bicolor	-	-	-	-	-	-	-	-	-	-	-	
Monomorium atomum	-	06	10	15	13	25	27	31	33	33	193	
Monomorium pharaonis	-	07	12	14	17	20	23	27	30	29	179	
Myrmicaria brunnea	-	-	-	02	05	03	07	08	09	09	43	
Pheidole grayi	02	05	09	12	14	17	13	10	07	07	96	
Pheidole sharpi	02	27	07	10	15	19	16	14	12	09	131	
Solenopsis geminata	-	04	13	27	31	37	39	40	41	43	275	
Tetramorium wroughtonii	-	-	09	13	17	21	25	23	21	20	149	
Total D	16	72	92	140	170	208	225	236	239	235	1633	2882
Ponerinae												
Bothroponera henryi	-	-	-	-	-	-	-	-	-	-	-	
Bothroponera sulcata	-	-	-	-	-	-	-	-	-	-	-	
Diacammaceylonense	-	-	-	-	-	-	-	-	-	-	-	
Diacamma rugosum	-	-	-	-	-	-	-	-	-	-	-	
Leptogenys diminuta	-	-	-	04	07	09	11	08	06	04	49	
Leptogenys processionalis	-	-	-	03	07	10	08	07	05	04	44	
Odontomachus haematodus	-	-	-	-	10	12	15	11	09	06	63	
Total E	-	-	-	07	24	31	34	26	20	14	156	939
Pseudomyrmicinae												
Tetraponera aitkenii	-	-	-	-	-	-	-	-	-	-	-	
Tetraponera allaborans	-	-	-	-	-	-	-	-	-	-	-	
Tetraponera nigra	-	-	-	-	-	-	-	-	-	-	-	
Tetraponera rufonigra	-	-	-	-	-	-	-	-	-	-	-	
Total F	-	-	-	-	-	-	-	-	-	-	-	148
GRAND TOTAL = (A+C+D+E) = 162+2485 +1633+156											4436	9202

because habitat complexity and heterogeneity was high in the undisturbed areas as compared to disturbed areas. Habitat intricacy provides hiding, nesting and foraging grounds to the many species of ants. Bharti et al (2016) reported that the most species ant genus is *Camponotus* with 83 named species which is one tenth of the total known Indian species. In this study too Camponotus was represented with six species. Similarly, in terms of species richness, the subfamily Myrmicinae is the most species in India which was also the findings in this study with 12 species. The distribution and diversity of ants can be credited to biotic or abiotic factors, human impacts or habitat structure which was also found in this study where with more human intervention and impact over the years on the natural habitat there was decline in the species richness and abundance during the study period of 2016-2017 (Armbrecht et al 2004, Philpott et al 2010, Wittman et al 2010). The diversity and density of arboreal ants can be directly connected to the presence, quality and quantity of resources available from the trees, such as extrafloral nectaries and presence of trophobiont arthropods along with other nitrogen-rich sources (Yanoviak and Kaspari 2000, Schoereder et al 2010). This was also observed in the present study in undisturbed areas with more dense vegetation which had more species than the disturbed areas.

Table 8. Total number of ants per subfamily in disturbed areas

Subfamilies	Total number of ants
Dolichoderinae	162
Dorylinae	0
Formicinae	2485
Myrmicinae	1633
Ponerinae	156
Pseudomyrmicinae	0
Total	4436

The decline observed in the ant species richness clearly states that habitat destruction does play a major role in species decrease in number and diversity. Overall relative abundance of Myrmicinae from disturbed sites was more because species of Myrmicinae might have high possibility to adjust to fluctuating environmental conditions and also found in different types of habitats worldwide. Andersen (2000) classified subfamily Myrmicinae as generalized Myrmecinae (GM) among the functional groups. Savitha et al (2008) also recorded similar results.

CONCLUSION

Study conducted on the ant diversity on the campus in 2015-2016 by D'Sa et al. (2015-2016) reports only four subfamilies which is a clear indication of decrease in the ant fauna. The rich diversity and density of the ant species documented in the study conducted in 2006-2007 may be

Table 10. Abundance, Species richness, Simpson's Index, Shannon Weaver diversity and Evenness of the species of the subfamilies in undisturbed and disturbed areas

Subfamily	Study site	
	Undisturbed	Disturbed
Dolichoderinae	0 (0)	1 (162)
Dorylinae	2 (226)	0 (0)
Formicinae	9 (2360)	11 (2485)
Myrmicinae	10 (1249)	9 (1633)
Ponerinae	7 (783)	3 (939)
Pseudomyrmicinae	4 (148)	0 (0)
Abundance	4766	4436
Species Richness	32	24
Simpson's Index	0.0442	0.0531
Shannon Weaver diversity	3.2520	3.0342
Evenness	0.9383	0.9547

Figures in the bracket indicate abundance of ants

Table 9. Total number of ants per subfamily in undisturbed and disturbed areas

Subfamily	Total number of species	Ant species present in the study areas			
		Undisturbed	Percentage	Disturbed	Percentage
Dolichoderinae	01	0	0	01	100
Dorylinae	02	02	100	0	0
Formicinae	11	09	81.81	11	100
Myrmicinae	12	10	83.33	09	75
Ponerinae	07	07	100	03	42.85
Pseudomyrmicinae	04	04	100	0	0
Total	37	32	86.48	24	64.86

Table 11. Ant species recorded in the subfamilies in 2006–2007 and 2015–2016 in the undisturbed and disturbed areas

Subfamily	Biological name	Undisturbed areas		Disturbed areas	
		2006-2007	2015-2016	2006-2007	2015-2016
Dolichoderinae	*Tapinoma melanocephalum*	-	-	+	-
Dorylinae	*Cerapachys aitkenii*	+	-	-	-
	C. biroi	+	-	-	-
Formicinae	*Anoplolepis gracilipes*	+	+	+	+
	Camponotus angusticollis	+	+	+	+
	C. compressus	+	+	+	+
	C. irritans	-	-	+	+
	C. parius	+	-	+	-
	C. radiatus	-	-	+	+
	C. sericeus	+	-	+	-
	Oecophylla smaragdina	+	+	+	+
	Paratrechina longicornis	+	+	+	+
	Polyrhachis exercita	+	-	+	-
	P. illaudata	+	-	+	-
Myrmicinae	*Aphaenogaster beccarii*	+	+	-	-
	A. feae	+	-	-	-
	Crematogaster rothneyi	+	-	+	-
	C. subnuda	+	-	+	-
	Meranoplus bicolor	+	+	-	-
	Monomorium atomum	+	-	+	-
	M. pharaonis	+	-	+	-
	Myrmicaria brunnea	+	+	+	+
	Pheidole grayi	-	-	+	-
	P. sharpi	-	-	+	-
	Solenopsis geminata	+	+	+	-
	Tetramorium wroughtonii	+	-	+	-
Ponerinae	*Bothroponera henryi*	+	+	-	-
	B. sulcata	+	-	-	-
	Diacammaceylonense	+	-	-	-
	D. rugosum	+	+	-	-
	Leptogenys diminuta	+	-	+	-
	L. processionalis	+	+	+	+
	Odontomachus haematodus	+	+	+	+
Pseudomyrmicinae	*Tetraponera aitkenii*	+	-	-	-
	T. allaborans	+	+	-	-
	T. nigra	+	-	-	-
	T.rufonigra	+	+	-	-
Total		32	15	24	10

+ = present; - = absent

Table 12. Number of genera and species recorded in the subfamilies in 2006–2007 and 2015–2016 in the undisturbed and disturbed areas

Subfamilies	Total number of genera				Total number of species			
	2006-2007		2015-2016		2006-2007		2015-2016	
	U. A.	D. A.	U. A.	D. A.	U. A.	D.A.	U. A.	D. A.
Dolichoderinae	0	01	0	0	0	01	0	0
Dorylinae	01	0	0	0	02	0	0	0
Formicinae	05	05	04	04	09	11	05	07
Myrmicinae	07	06	04	01	10	09	04	01
Ponerinae	04	02	04	02	07	03	04	02
Pseudomyrmicinae	01	0	01	0	04	0	02	0
Total	18	14	13	07	32	24	15	10

U.A. = Undisturbed Areas D.A. = Disturbed Areas

because of satisfactory nesting sites, dense and varied vegetation and along with availability of food as well as high foraging capacity on the Carmel College campus. The major findings of both the studies is the species *Odontomachus haematodus*, typically referred to as 'Greater Trap-Jaw Ant' belonging to the morphologically primitive subfamily Ponerinae. This ant has the second fastest moving and effective predatory appendages (Patek et al 2006) in the animal Kingdom after the dracula ant (*Mystrium camillae*). A local to South America is now by far the most frequent species in the rural regions nesting in decaying logs and branches at the ground. The same were the finding in this study as Carmel College campus comes under rural areas and most of it is undisturbed. Investigation of ant species on the Carmel College campus clearly indicates the richness of ant fauna in the village and in turn in the state. The study had recorded 37 species belonging to 20 genera and six subfamilies in 2006-2007. Subfamily Myrmicinae was dominant in genera as well as species. This study will yield valuable information of ant diversity to fill in the lacuna of invertebrate fauna in the state of Goa.

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Comparison of Terrestrial Beetles in Cultivated and Natural Ecosystem of Semi-Arid Region of Morocco

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***Abstract*:** The present study highlights the presence of terrestrial beetles in three locations of the semi-arid region of northeastern Morocco, more precisely the geographical area of Sidi Kacem. The objective is to establish an inventory of beetles species residing in cultivated and natural areas of the region. Sight hunting, trapping and Mowing of herbaceous vegetation are three methods used to collect the different species. The results obtained revealed the presence of 1443 specimens, divided into 53 species belonging to 14 families. The specific richness, abundance, and Shannon index of beetles species were significantly higher along the undisturbed area, while the cultivated area has a lower population density reflecting the stability of the former biotope.

***Keywords*:** Natural Steppe area, Cultivated zone, Coleoptera, diversity

The study of terrestrial beetles has long been the subject of several research to improve the biodiversity of this particular group of insects. For North Africa (Morocco, Algeria, Tunisia & Triplotitania) there are a number of published studies on beetles (Gaubil 1849, Chevrolat 1861, Bedel 1895, Peyerimhoff 1927, 1933). Similarly, specific catalogs for Tunisia were created (Normad 1935). Generally, in Morocco, beetles are relatively well known (Escalera1914, Antoine 1955 -1962, Kocher 1956-1963). These insects constitute a group of species that has an important agronomic role (Haloti et al 2006). However, studies on beetles in the arid and semi-arid region of Morocco are still limited, with an exception of a few studies conducted by earlier workers .(Chavanon et al 1995, Zitouni and Chavanon 1996 2000 2005, Arahou 2008, Hajji Hour et al 2011, Bouraada et al 2015, Castro-Arrazola 2018). In the region of Sidi Kacem revealed the presence of Coprophagous Scarabidae (Haloti et al 2006). The region is subject to an imbalance due to the massive use of fertilizers and pesticides by farmers to protect crops, which consequently affects the presence and diversity of insects (Dakkak et al 2016). The beetles of Northern Africa agroecosystems are poorly known (Dajoz2002). In Morocco, no information is available concerning beetles composition in cultivated areas. The objective of the present study is to contribute to a deeper knowledge of the beetle population in the agroecosystems of the Sidi Kacem region, especially carabid beetles which are excellent bioindicators, and compare beetles assemblages between both areas. Thus, to assess the beetle assemblages, several indices were calculated for a natural area along with two cultivated areas, including abundance (N), diversity of the Shannon-Weiner index H and equitability E.

MATERIAL AND METHODS

Study area: The Sidi Kacem region is in northeastern Morocco at an altitude of 142m, longitude 4°90'E and latitude 34°03'N respectively. The region is characterized by a semi-arid climate with an average annual precipitation of 76mm, an average annual temperature of 17.31 °C and an average annual humidity of 77% (MERRA-2 2016). The zonal soil is a silty clay soil covering about 75% of the study area (FAO/UNESCO 2003).

In present studies, 3 stations were selected (Fig.1) in based primarily for their differences in vegetation cover and these also represents the most dominant crops in the region.

Station 1: 34°12'35.5"N - 5°42'31.8"E. Located at the south-east of the entrance of the town of Sidi Kacem, 2 km from

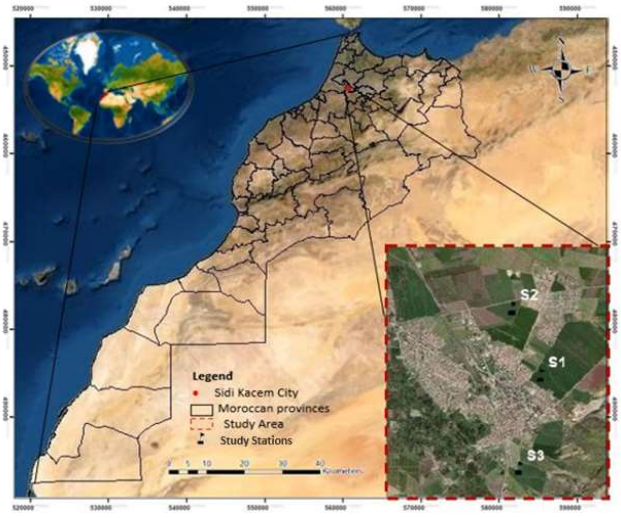

Fig. 1. Geographic location of study area and stations of Sidi Kacem

station 2 and 3 km from station 3. It is classified as field of beans (*Vicia faba*) (Fabaceae).

Station 2: 34°14'41.5"N - 5°42'14.9"E. Located 2 km from Station 1 and 6 km from station 3; it is classified as a soft wheat (*Triticum aestivum*) (Poaceae) field.

Station 3: 34°13'50.5"N -5°42'14.7"E. This is a natural steppe. The dominant plant species are: *Nicotiana glauca* (Solanaceae), *Ferula communis* (Apiaceae),*Cynara humilis* L (Asteraceae), and *Ammi visnaga* (Apiaceae).

Methodology: Beetles were sampled using sweep nets, pitfall traps, and direct observation of the study area. Samples were collected twice a month, resulting in 24 samples for 2019. The effectiveness of this method has been demonstrated by earlier workers (Southwood 1968, Greenslade 1973, Benkhellil 1991, Porcelli and Pizza2007). The captured specimens were collected, labeled and identified with a maximum magnification of x35 and several identification keys such as: French carabid fauna (Jeannel 1941, 1942), Moroccan carabid beetles (Antoine 1955 to 1962), Scarabaeidae: Fauna of North Africa (Baraud1985). For validation Antoine's collection at the Scientific Institute of Rabat (Morocco) and the National Museum of Natural History of Paris (France) were consulted. The collected data were transferred to MS Excel for further statistical validation.

Data Analysis: To determine biodiversity, various ecological indices and statistical analyses were used. The description and evaluation is based on 2 variables specific richness and abundance (Grall and Hily 2003). Twoindexes were used to characterize the structure of beetle stand, The Shannon diversity index (H) and evenness indices (E).

Specific richness: The total richness of a biocenosis corresponds to the totality of the species that make it up (Ramade 2003).

Relative abundance (AR%): Relative abundance is the percentage of individuals of a species (ni) in relation to the total number of individuals (N) as mentioned in eq.1.(Frontier 1983).

$AR = ni / N \times 100$ (eq.1)

Shannon-Weaver Diversity (H'): This index is considered to be the best way to reflect diversity (Blondel et al 1973). According to Dajoz (2008), Shannon's diversity index (H') is expressed as mentioned in eq.2.

$H' = - \sum qi \log2 qi$ (eq.2).

H': diversity index expressed in bit units

qi: relative frequency of species i in relation to individuals in the stand as a whole

Log2: logarithm based on 2.

Equitability index (E): Equitability or evenness index (E) is the relationship between diversity H' and maximum diversity H' max as mentioned in eq.3 (Blondel, 1975).

$E = H' / H'max$ (eq.3)

E: is the regularity index

H': is the Shannon diversity index expressed in bits

H' max: is the index of the maximum diversity expressed in bit.

RESULTS AND DISCUSSION

Differences between the cultivated and the natural area: The total number of individuals collected during the 24 sampling campaigns are 1443 specimens divided into 53 species belonging to 14 families. 765 specimens belonging to 39 species were captured in natural area (station 3), the cultivated area (station 1 and 2), out of which 243 specimens belongs to 23 species and 435 specimens belong to 34 species respectfully (Fig. 2). Magagula (2003), observed that the diversity is higher in natural habitats than cultivation

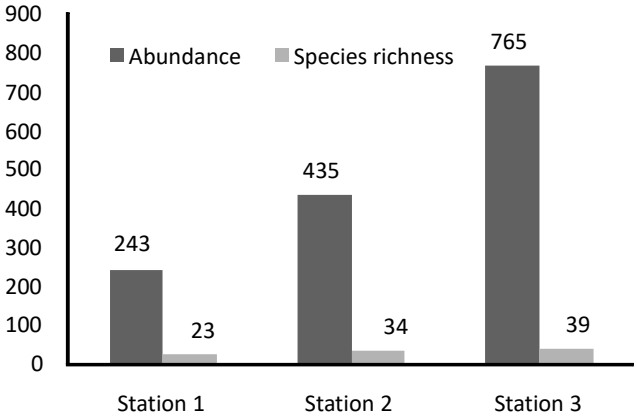

Fig. 2. Abundance and species richness caught at each station

areas which is consistent with results mentioned before.

The most abundant beetles in the natural area are mainly*Dasytes terminalis, Pterostichus globosus, Silpha tristis and Pachychila salzmanni* whereas in the cultivated area, the dominant species are *Rhagonycha fulva, Cantharis coronata, Oedemera simplex* and *Thanatophilus sinuatus* (Table1) and Carabidae was dominating species. This is probably related partially to the texture of the soil that affects the richness of species and the abundance of specimens. Dajoz (2002) also observed that the ground beetle, are abundant fin silty or clay soils. The comparison between the two biotopes revealed differences in the beetle fauna which could be related to the soil humidity conditions and density of vegetation. The richness and stability of this population may vary due to agricultural activities (Benton et al 2003, Burkle et al 2013). As a result, in cultivated area (1 and 2), there is a significant reduction in stands presumably to the methods used in agriculture during this season (harvesting, stubble burning, and plowing). These negative traits affect species diversity (Foley et al 2005). In addition to the use of pesticides which has an intensively negative effect on soil organisms reducing both their abundance and diversity (Degtjarenko 2016). Serrano et al *(*2005) also concluded that agricultural practices can cause disturbances in beetle assemblages. The density of vegetation, the availability of habitats, and food resources in the area play a major role in these abundances (Barbosa et al 2002).

Composition of the coleoptera fauna: The results show a strong dominance of the Carabidae family (40.12%), followed by the Tenebrionidae (23.63%) and, Silphidae (12.61%). The other families didn't exceed by 6% when compared to rest.

Station 3 with 39 species has the highest species richness. Carabidae are dominant with 22 species (46% specimens). They are followed by Tenebrionidae 2 species (21% specimens) and finally, Silphidae 2 species (14% specimens). Other families had negligible concentration of specimens

Station 2 comes in 2nd place along with 34 species. The principal families are Carabidae, Tenebrionidae, Silphidae and Cantharidae with 16 species (34% specimens), 2 species (22% specimens), 1 species (13% specimens) and finally 2 species (12% specimens).

Station 1 has been the lowest with only 23 species. Carabidae dominate with 11 species (38% specimens). They are followed by Tenebrionidae 2 species (33% specimens) and Cantharidae 2 species (8% specimens).

The species which have a wide distribution are: *Pterostichus globosus* (Quensel 1806) dominates with (20.93% specimens), followed by *Pachychila salzmanni* (Solier 1835) (19.96%), *Thanatophilus sinuatus* (Fabricius 1775) (6.86%) and *Silpha tristis* ((Illiger 1798) (5.75%). This dominance may be partially related to the period of activity of these species which is associated with their reproductive cycle that allows them to be active for two or three seasons in the year.The number and diversity of beetles are also strongly related to the density of the vegetation cover and the climatic conditions (Magura et al 2001, Standberg et al 2005). According to Cardwell et al (1994),mentioned thathigher density of vegetation means a longer period of soil humidity which favors a great abundance of beetles.

Monthly variations of abundance and species richness at the 3 stations: Insects depend mostly on the temperature of their living environment to perform all their vital biological functions such as feeding, reproduction, movement and growth (Faurie et al 2003). These physiological constraints related to temperature force them to be active during certain times of the year and become inactive during others. The number of beetle species varies between 8 and 30 (Table 2). The highest wasis in May with 30 species and the lowest in September & October with 8 species only. The results were obtained represent that spring has the highest number with 591 specimens (approximately 56% of the total) and consecutively represents the most favorable period for beetles; while on the contrary, autumn is the worst period with 157 specimens d (13% of the total) The total monthly abundance varies over time. It fluctuates between 44 specimens in September and 229 specimens in May. During the study period, the highest abundance occurs in spring (March, April & May). The strongest species distribution was observed in the spring (April & May) and start of summer (June). These values are probably related to the high presence of certain species such as *Pterostichus globosus* (Quensel 1806)*, Cantharis coronate* (Gyllenhal 1808), *Coccinellase ptempunctata* (Linnaeus 1758), *Pachychila salzmanni* (Solier 1835)*,* and *Silpha tristis* (Illiger 1778). Spring can even be the time period of emergence for these species. From July temperature reached 40° C with the result the abundance and the specific richness are beginning to decline. This is due to anthropogenic activity during the summer (harvest season) and the decrease in plant density during the summer season. This loss of vegetation leads to changes in the hygrothermal conditions of the soil leading to the disappearance of several families of beetles that otherwise prefer humidity (Petremand 2015).

The lowest abundances appear in autumn (September-October), then numbers gradually increase from November (Fig. 3). This variation is probably due to the emergence of certain species like *Calathus circumseptus* (Germar 1823). The lowest values of beetles occur from late summer

Table 1. Abundance of species caught at each station

Families	Species	Stations					
		Station 3		Station 2		Station 1	
		N	AR (%)	N	AR (%)	N	AR (%)
Malachiidae	*Malachius lusitanicus* (Erichson 1840)	2	0.26	4	0.92	0	0.00
	*Charopus rotundatus (*Erichson 1840)	2	0.26	6	1.38	0	0.00
Meloidae	*Lagorina sericea* (Waltl 1835)	1	0.13	0	0.00	0	0.00
Dasytidae	*Psilothrix viridicoerulae* (Geoffroy 1785)	10	1.31	4	0.92	0	0.00
	Dasytes terminalis (Jacquelin du Val 1863)	60	7.84	3	0.69	0	0.00
	Lobonyx aeneus (Fabricius 1787)	0	0.00	10	2.30	0	0.00
Staphylinidae	*Philonthus laminatus* (Creutzer 1799)	1	0.13	0	0.00	0	0.00
	Ocypus olens (Muller 1764)	0	0.00	1	0.23	0	0.00
Carabidae	*Calathus circumseptus* (Germar 1823)	8	1.05	7	1.61	5	2.06
	Scybalicus oblongiusculus (Dejean 1829)	33	4.31	6	1.38	13	5.35
	Pterostichus globosus (Quensel 1806)	171	22.35	82	18.85	49	20.16
	Pterostichus elongatus (Duftschmid 1812)	9	1.18	7	1.61	0	0.00
	Chlaenius chrysocephalus (Rossi 1790)	5	0.65	0	0.00	4	1.65
	Chlaenius cyaneus (Brullé 1835)	1	0.13	0	0.00	0	0.00
	Licinus punctatulus (Fabricius 1792)	9	1.18	0	0.00	2	0.82
	Brachinus immaculicornis (Dejean 1826)	16	2.09	0	0.00	0	0.00
	Brachinus efflans (Dejean 1830)	19	2.48	0	0.00	0	0.00
	Brachinus angustatus (Dejean 1831)	21	2.75	8	1.84	0	0.00
	Brachinus crepitans (Linnaeus 1758)	21	2.75	5	1.15	0	0.00
	Siagona rufipes (Fabricius 1792)	6	0.78	0	0.00	0	0.00
	Laemostenus complanatus (Dejean 1828)	0	0.00	1	0.23	0	0.00
	Parophonus hispanus (Rambur 1838)	2	0.26	0	0.00	0	0.00
	Poecilus decipiens (Waltl 1835)	0	0.00	2	0.46	0	0.00
	Carabus rugosus rugosus (Fabricius 1775)	0	0.00	1	0.23	1	0.41
	Graniger cordicollis (Audinet Serville 1821)	3	0.39	3	0.69	2	0.82
	Chlaeniellus olivieri (Crotch 1871)	1	0.13	0	0.00	0	0.00
	Scarites terricola pacifus (Bonelli 1813)	4	0.52	4	0.92	7	2.88
	Dixus clypeatus (Rossi 1790)	0	0.00	2	0.46	0	0.00
	Dixus sphaerocephalus (Olivier 1795)	0	0.00	2	0.46	0	0.00
	Chlaenius decipiens (L.Dufour 1820)	7	0.92	6	1.38	0	0.00
	Demetrias atricapillus (Linnaeus 1758)	0	0.00	0	0.00	4	1.65
	Carterus dama (Rossi 1792)	0	0.00	2	0.46	0	0.00
	Acinopus sabulosus (Fabricius 1792)	8	1.05	10	2.30	0	0.00
	Ditomus tricuspidatus (Fabricius 1792)	2	0.26	1	0.23	0	0.00
	Tschitscherinellus cordatus (Dejean 1825)	1	0.13	0	0.00	5	2.06
	Harpalus neglectus (Audinet Serville 1821)	1	0.13	0	0.00	0	0.00
	Poecilus purpurascens (Dejean 1828)	6	0.78	2	0.46	2	0.82
Cantharidae	*Cantharis coronata* (Gyllenhal 1808)	14	1.83	26	5.98	15	6.17
	Rhagonycha fulva (Scopoli 1763)	4	0.52	30	6.90	5	2.06
Coccinellidae	*Coccinella septempunctata* (Linnaeus 1758)	40	5.23	31	7.13	9	3.70
Dermestidae	*Dermestes frischii* (Linnaeus 1758)	2	0.26	0	0.00	0	0.00
Chrysomelidae	*Chrysolina bankii* (Fabricius 1775)	4	0.52	7	1.61	4	1.65
	Chrysolina diluta (Germar 1823)	0	0.00	2	0.46	0	0.00
	Chrysolina affinis (Fabricius 1787)	1	0.13	0	0.00	0	0.00
	Lachnaia vicina (Lacordaire 1848)	0	0.00	0	0.00	1	0.41
Silphidae	*Silpha tristis* (Illiger 1798)	83	10.85	0	0.00	0	0.00
	Thanatophilus sinuatus (Fabricius 1775)	25	3.27	59	13.56	15	6.17
Tenebrionidae	*Pachychila salzmanni* (Solier 1835)	139	18.17	83	19.08	66	27.16
	Gastrhaema rufiventris (Walt 1835)	22	2.88	16	3.68	15	6.17
Curculionidae	*Lixus algirus* (Scopoli 1763)	0	0.00	1	0.23	1	0.41
Scarabaeidae	*Oxythyrea funesta* (Poda 1761)	0	0.00	1	0.23	2	0.82
	Aethiessa floralis (Fabricius 1787)	1	0.13	0	0.00	0	0.00
	Gymnopleurus sturmi (Macleay 1821)	0	0.00	0	0.00	2	0.82
Oedemeridae	*Oedemera simplex* (Linnaeus 1767)	0	0.00	0	0.00	14	5.76
14	53	765		435		243	

N: number of individuals, AR%: relative abundance

(August), autumn (September, October and November) to initial days of winter (December) before gradually increasing until peak May (Fig. 3).

In terms of species activity most populations are active in the spring and early summer when the soil is humidified by rains and the temperature is high enough. The same observation has been made by studying the activity rhythms of beetles in Cyrenaic (Libya) by Paarmann (1970) and Yaacobi et al *(*2007) on arid ecosystems stands. Brandmayr and Zetto-Brandmayr (1986) also made similar observations on the arid grasslands of Sicily, with significant beetle activity in the spring while decrease during summer (July-August). It is found that in natural habitats; beetles disappear from late June until September. This inactivity is probably due to the nature of the soil which tends to dry out quickly resulting in the disappearance of many plants followed by various beetles (Petremand 2015). Temperature is a vital factor in the distribution of beetles in a habitat (Judas et al 2002). It remains one of the determining factors in the activity of these set of insects, which are heterothermic organisms However, their abundance is mainly determined by their life cycle because the periods of reproduction differ from species to species, manifested by emergences at specified periods (Larochelle and Lariviere 2003).

Shannon-Weaver diversity index (H') and the equitability index (E): To make a comparison of the three stations calculated the Shannon-Weaver H' index and the equitability index (E) (Fig. 4) for each station. The calculated values allow to have a general idea of the distribution of species according to the environment variation. When the H' value is high the population is considered to be diversified, while when one or more species dominate strongly the index stays low (Gobat et al 2010).The station 3 has the highest diversity and equitability indices (H' - 3.88 & E - 0.75 followed by station 2 (H' - 3.31 & E - 0.65) and station 1 (H'- 3.14 & E - 0.69). The high values of H' are explained by the fact that all three stations have a diversified beetles population. This is confirmed by the Equitability Index (E), whose values are also high at the three stations reflecting the absence of highly dominant species ().

The Shannon-Weaver (H') and equitability (E) indices is used to assess the diversification and ecological balance of environments. Relatively higher habitat stability is found in the natural station (station 3), due to a more stable environment which is absence of anthropogenic activities (Magagula 2003). The low values of Shannon and equitability index in cultivated areas (station1 and 2) reflects differences in vegetation density between the three station, due the impact of certain anthropogenic factors, like the use of pesticides. However, despite the variant pressures in these stations, indices show that all three environments are ecologically balanced.

Table 2. Temporal variation of species richness and abundance across the three stations (2019)

Seasons	Month	Abundance	Specific richness	T°C /month
Spring	March	172	17	18
	April	190	23	20
	May	229	30	22.5
Summer	June	211	19	26
	July	154	13	29.5
	August	62	10	32.5
Autumn	September	44	8	27
	October	49	8	24
	November	64	9	20.5
Winter	December	76	10	175
	January	90	12	14.5
	February	102	14	17

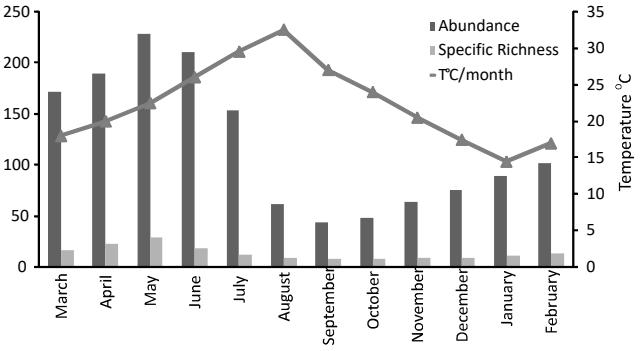

Fig. 3. Monthly variation of abundance and species richness at different stations

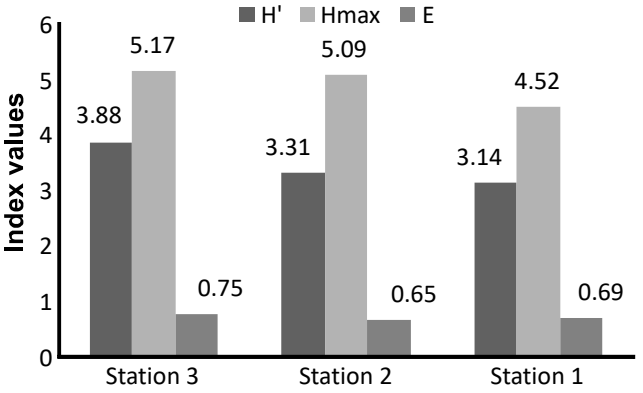

Fig. 4. Shannon indices (H'), H max and equitability (E)

CONCLUSION

Based on the results obtained, can conclude that the

order of beetles is very diverse in the geographical area of Sidi Kacem. Comparing the natural and cultivated areas, it is observed that these have a lower number of species and specimens. These values are probably due to anthropogenic factors (agricultural practices, fertilizer use) that cause disturbances in beetles assemblages (Serrano et al 2005). Fifty-three species of beetles were collected from the three selected biotopes and highlighted the importance of the seasonal factor in the variability of species abundance and biodiversity over time. It is shown that some species are absent from areas exposed to strong anthropic action (station 2 and 3). Keeping them in these areas limits overly destructive agricultural practices. It is also desirable to continue long-term and periodic research that can offer new data on the Coleoptera species. Consequently, additional efforts need to be made to obtain more information on the spatial distribution of the Coleopteran species in all agroecosystems of the Sidi Kacem region to significantly understand the endemic species, rare or endangered requiring conservation. Finally, because of their often relatively easy diversity and determination, beetles appear to be a good tool to study population changes in anthropogenic habitats.

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Invitro Toxicity of Pendimethalin using Ciliate Protozoa *Paramecium caudatum* and *Blepharisma intermedium*

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Abstract: The herbicide pendimethalin was tested for its ability to induce cytological, physiological and genotoxic changes in selected ciliates *Paramecium caudatum* and *Blepharisma intermedium*. Different concentrations of pendimethalin were administered to both the test organisms in acute toxicity studies for 3 hours and threshold. LC_{50} and LC_{100} values were derived using probit analysis. The calculated LC_{50} were to be 15ppm and 34.67 ppm for *P. caudatum* and *B. intermedium,* respectively. The selected sub lethal concentrations of pendimethalin to Paramecium (2, 3, 4 and 5 ppm) and Blepharisma (4, 6, 8 and 10 ppm) induced significant decrease in contractile vacuole and food vacuole activity with that of controls which is concentration dependent. The changes in shape, size and structure of macronucleus were noticed in both the test organisms under pesticide stress. Rod shaped, vacuolated, fragmented, uneven division and karyolysis were the different changes observed in the macronucleus. The bioassay experiments revealed that the *P. caudatum* is more sensitive than the *B. intermedium* and could be used as complementary model in assessing cytotoxic potential of pendimethalin in invitro studies.

Keywords: Pendimethalin, Ciliate protozoa, Acute toxicity studies, Pesticide stress

The freshwater ecosystem comprises of diverse habitats and organisms, which include ponds, lakes, rivers, streams and their associated flora and fauna from unicellular to multicellular (Walter and Whiles 2020). The protozoa are a diverse group with several unicellular organisms commonly found in any zooplankton community. Zooplanktons are strongly influenced by several external climatic factors; therefore, they have been used as bio-indicators to observe and analyze the changes in ecosystem since beginning (Li et al 2000, Jyoti et al 2013). Among other zooplankton, ciliate protozoan communities are effective in sensing the changes in the water quality (Dias et al 2008). Earlier study indicated that the ciliates are efficient quality bio indicators of freshwater ecosystems and can be used in biomonitoring of streams, lakes and reservoirs under different levels of anthropogenic impact (Madoni and Romeo 2006, Dias et al 2008 and Gerhardt et al 2010). Alternatively, freshwater ciliates are also used as valuable tools for ecotoxicological and sub cellular studies, providing chance to study the individual cells as they possess definite characters of individual cells and of complete organism (Vilas Boas et al 2020).

Pesticides have played a major role in the drastic increase of agricultural yield in India, however many of these pesticides may be harmful to non-target organisms through surface run-off from the treated area (Banshtu and Patyal 2017). Pendimethalin is a dinitroaniline group of herbicides and widely used as pre-emergent herbicide to eliminate annual grasses and broadleaf weeds. It is applied on various crops such as wheat, rice, maize, soybean, cabbage, potato, asparagus, carrot etc. and act as a microtubular disruptor in target species and inhibits the growth of shoot and root of plants by preventing the cell division and cell elongation (Vighi et al 2017). The bioassay studies are reliable approaches to determine acute and chronic effects of any toxicant and the suitability of organisms is determined by the substances to be assessed and the sensitivity of the organism (Bae and Park 2014, Shubhajit and Nimai 2021). In this context, *P. caudatum* and *B. intermedium* were used as test species to evaluate toxic effects of pendimethalin, and a comparison was made.

MATERIAL AND METHODS

Test compound: Pendamil is a commercial grade insecticide containing 33.90% pendimethalin, manufactured by Insecticides India Limited, Gujarat, India was used in the study. Stock solution and experimental concentrations of pendimethalin were prepared as recommended by APHA (2017).

Organisms selected for the present studies: *P. caudatum* were isolated from the freshwater samples collected from various water bodies in Hyderabad, Telangana, India. Pure line stock culture of *B. intermedium* was supplied from Carolina Biological suppliers, NC, USA and sub cultured and maintained in the laboratory for experimental studies.

Culturing ciliates: Test organisms were cultured separately

using hay infusion and distilled water in 1:1 ratio at room temperature. Boiled okra was added as nutrient supplement for Paramecia and two grains of boiled wheat for *B intermedium*. Dilution technique was used to isolate *P. caudatum* and pure line cultures were developed. Sterile conditions were maintained in all experiments.

Acute toxicity tests: These tests were conducted for 3 hr duration to assess the immediate response under pendimethalin stress as suggested by Apostol (1973) and 0.5ml concentration of pesticide solution was added to 4.5ml culture medium containing 50 organisms in a cavity block to achieve desired concentration of pendimathalin. Three observations were made for all test concentrations and controls were maintained simultaneously with the same number of organisms. Counting of number of organisms was done for every 10mins interval for the first 1hr and then for every 20mins interval during the next 2hrs with the help of binocular microscope. LC_{50} value was derived using probit analysis.

Contractile vacuole activity: Marsot and Couillard (1973) method was used to study the contractile vacuole activity. 25 organisms of each type were exposed to different sub lethal concentrations such as 5, 10, 15 and 20 ppm for *P. caudatum* and for *B. intermedium*, 12, 18, 24 and 30ppm for 15min. Five replicates and controls were maintained. Observations were recorded on the cells in each concentration and the rate of pulsation for each individual was calculated and compared with the control.

Food vacuole activity: Test organisms were exposed for 1hr to different concentrations of pendimethalin. 25 treated ciliates were mixed with 3% India ink and kept for 10min. Ten organisms from each concentration were taken and immobilized on protamine coated slides for further studies. Preparation of India ink and counting of food vacuoles were done by the method suggested by Bozzone (2000).

Macronuclear aberration studies: Both the ciliate species were treated with different sub lethal concentrations of pendimethalin for 1hr. From each exposed group a drop of culture medium (100 organisms) was placed on the slide and air dried. Ten experimental sets were maintained and a total of 1000 organisms were considered from each concentration for calculating the percent abnormalities. Nuclear staining was done by Feulgen fast green technique as suggested by Rizzo and Nooden (1973). Cells were fixed in carnoy's fixative. The cells were hydrolyzed first briefly in 1N Hcl at room temperature and washed in distilled water. Hydrolysis was followed by transfer of slides into Schiff's reagent and incubated for 1 hr. The cells were immersed in three changes of sodium metabisulfite solution, again rinsed with distilled water, dehydrated in graded alcohols, cleared in xylene and mounted in DPX. These slides were observed under binocular microscope at 200X magnification initially and different nuclear changes were recorded.

RESULTS AND DISCUSSION

Acute toxicity studies: The behaviour and morphology of *Paramecium caudatum* was normal in lower concentrations (up to 5ppm) of pendimethalin for 3hr duration. The movement was changed at above 5ppm concentrations where *P. caudatum* initially showed fast and rotation movements and after few min the movement became weak, sluggish and all the Paramecia were aggregated towards the corner of the cavity block. The morphological alterations such as shortening of longitudinal axis, oval shape deformities, enlargement of cell size, appearance of large protoplasmic vacuoles and darkening of protoplasm were observed at above 10ppm concentrations in concentration dependent manner (Plate 1). Leaking out of cytoplasm and immediate cell death was recorded at 30ppm and this concentration was considered as LC_{100}. LC_{50} value was derived from probit analysis which was 15 ppm (Fig. 1). When *B. intermedium* exposed to different concentration of pendimethalin 10ppm and below concentrations showed no behavioural and structural changes. Jerky and abnormal ciliary strokes were observed at above 10ppm concentrations. Cytopathological changes were noticed in *B. intermedium* when treated with 32, 58 and 70ppm of pendimethalin. Complete cell lysis and instant cell death of *B. intermedium* was observed at 88ppm concentration. The LC_{50} value from probit analysis (Fig. 2) for *B. intermedium* exposed to pendimethalin was 34.67 ppm. The 4, 6, 8 and 10ppm were selected as sub lethal concentrations for further studies.

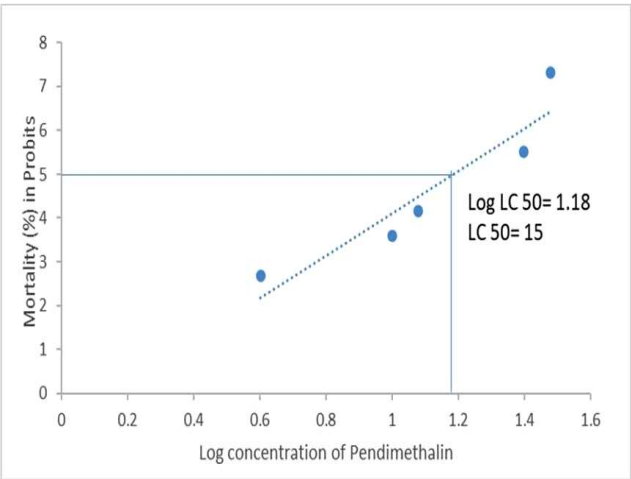


Fig. 1. LC_{50} of *Paramecium caudatum* exposed to different concentrations of pendimethalin

Similar alterations were also reported by several authors with different toxicants. Nageswara Rao (2010) observed that when higher concentrations of Azadiractin was administered to *Oxytricha fallax*, weak and irregular ciliary movements were observed and after a few minutes organisms were dead. Invitro observations of Masood et al (2008) revealed that the weak movements were the first observable change in *P. caudatum* exposed to 135 ppm of carbofuran. Darkening of cytoplasm, deformed cell structure and total lysis of organisms occurred immediately at 320 ppm. Nageswara Rao (2011) observed that cellular activity in *O. fallax* and *P. caudatum* increased at higher concentrations (1000 mg l^{-1}) of monocrotophos in 5min exposure due to pesticide stress but no data available on pendimethalin toxicity in ciliates and limited data is available using higher animals. Ahmad et al (2018) reported that the hepatocytes of exposed rats to lower concentration of pendimethalin exhibited the appearance of hyperplasia and swelling but the appearance of pyknotic nuclei, activated kupffer cells, leukocyte infiltrations and large cytoplasmic vacuolization were very prominent at the middle and highest concentrations. Nabela et al (2011) observed abnormal swimming movement, weak and dark colouration of skin in *Oreochromis niloticus* exposed to 10 and 5% of LC_{50} (0.355 mg/l and 0.177 mg/l) of pendimethalin for an exposure of 96 hrs.

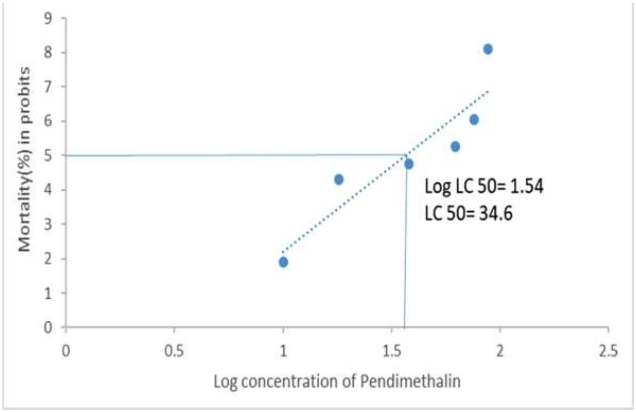


Fig. 2. LC_{50} of *Blepharisma intermedium* exposed to different concentrations of pendimethalin

Activity of contractile vacuole: The significant variation with respect to pulsations per minute in contractile vacuole activity in different treatment groups and control was observed. Different test concentrations (2, 3, 4 and 5 ppm) of pendimethalin caused retardation in pulsations per minute in *P. caudatum* (Table 1). Highest negative impact on pulsations per minute was observed in 5 ppm exposed for 15min with 66.66% decrease in pulsations over control, followed by 4, 3 and 2 ppm. Similarly, significant inhibitory effect in contractile vacuole activity of *B. intermedium* was also recorded in all sub lethal concentrations (4, 6, 8 and 10ppm) of pendimethalin (Table 2). Maximum inhibition in pulsations per min was observed in 10ppm concentration exposed for 15 min with 62.5% decrease and minimum inhibition was in 4 ppm with 29% decrease.

The contractile vacuole activity in *P. caudatum* under sub lethal concentrations of delfin diminished the vacuolar output in time and concentration dependent manner (Nageswara Rao and Masood 2008). Similarly, Shubham Singh and Tejashree (2014) observed inhibitory effect of dimethoate on pulsatory vacuole in Paramecium. Focus-Ultra caused a concentration dependent reduction in pulsations in *P. tetraurelia* (Ouissem et al 2016). Stock et al (2002) stressed on the point that the pressure developed at the pulsatory vacuole membrane might be responsible for the pressure required for the discharge of water content from vacuole through pulsatory vacuole pore. The expulsion frequency of pulsatory vacuole might be changed or influenced by exterior factors. It was further concluded that the contractile vacuole fluid osmolarity is constantly hypertonic to the cytoplasm, and the osmolarity of the cytoplasm is constantly hypertonic to the osmolarity of surroundings. When the surrounding osmolarity increases immediate reduction in the rate of water exclusion was

Table 1. Contractile vacuole activity of *Paramecium caudatum* different concentrations of Pendimethalin exposed for 15 min

	N	Mean	Std. Deviation	95% Confidence Interval for mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Control	5	4.8	0.44721	4.2447	5.3553	4	5
2ppm	5	3.3	0.67082	2.4671	4.1329	2.5	4
3ppm	5	2.6	0.41833	2.0806	3.1194	2	3
4ppm	5	2	0.35355	1.561	2.439	1.5	2.5
5ppm	5	1.6	0.41833	1.0806	2.1194	1	2
Total	25	2.86	1.22916	2.3526	3.3674	1	5

One-way ANOVA: $F_{4,20} = 35.289$; $P < 0.05$

observed. In the present study pendimethalin might have altered the ionic composition of external environment which resulted in inhibition of contractile vacuole activity.

Activity of food vacuole: Concentration dependent inhibition in food vacuole activity of *P. caudatum* was recorded in different concentrations (3, 4 and 5ppm) of pendimethalin (Table 3). Maximum reduction in food vacuole formation was in 5ppm exposure for 1hr with mean 4.5 with 58% reduction as compared to control. The food vacuole activity of *B. intermedium* has shown significant difference with respect to different concentrations of pendimethalin (Table 4). Maximum inhibition in food vacuole activity was in 10 ppm with 55 % reduction over control.

The present results are in consistent with those of Nageswara Rao and Masood (2008), where significant inhibitory effect in phagocytosis of *P. caudatum* was noticed at 100ppm of delfin and it was stated that the reduction in phagocytosis may be due to damge to cell membrane and ciliary structure. Ouissem et al (2016) reported that the alterations in food vacuole formation in ciliates under stress conditions caused by various pesticides and it was also concluded that the changes in external environment, reduced the ability of cytostome contractions, which in turn causes diminish in food vacuole number. Pendimethalin induces changes in the fluidity of any cell (Ahmad and Ahmad 2016, Khaled et al 2016 and Ahmad et al 2017). Changes in the fluidity also known to cause alterations in the phagocytosis. So this could be the reason for the retardation in the food vacuole formation as addition of pendimethalin to the surroundings of ciliate protozoa which might have lead to

Table 2. Contractile vacuole activity of *Blepharisma intermedium* under different concentrations of Pendimethalin exposed for 15 min

	N	Mean	Std. Deviation	95% Confidence Interval for mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Control	5	2.4	0.54772	1.7199	3.0801	2	3
4ppm	5	1.7	0.27386	1.36	2.04	1.5	2
6ppm	5	1.3	0.27386	0.96	1.64	1	1.5
8ppm	5	1.2	0.27386	0.86	1.54	1	1.5
10ppm	5	0.9	0.22361	0.6224	1.1776	0.5	1
Total	25	1.5	0.61237	1.2472	1.7528	0.5	3

One-way ANOVA: $F_{4,20} = 14.565$; $P < 0.05$

Table 3. Changes in food vacuole formation in *Paramecium caudatum* under different concentrations of Pendimethalin for 1 hr

	N	Mean	Std. Deviation	95% Confidence Interval for mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Control	10	10.8	1.22927	9.9206	11.6794	9	12
3ppm	10	7.6	0.96609	6.9089	8.2911	6	9
4ppm	10	5.8	0.91894	5.1426	6.4574	4	7
5ppm	10	4.5	0.84984	3.8921	5.1079	4	6
Total	40	7.175	2.58087	6.3496	8.0004	4	12

One-way ANOVA: $F_{3,36} = 74.352$; $P < 0.05$

Table 4. Changes in food vacuole formation in *Blepharisma intermedium* under different concentrations of Pendimethalin for 1 hr

	N	Mean	Std. Deviation	95% Confidence Interval for mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Control	10	10	1.56347	8.8816	11.1184	8	12
6ppm	10	7.8	0.78881	7.2357	8.3643	7	9
8ppm	10	6.5	0.70711	5.9942	7.0058	5	7
10ppm	10	4.5	0.70711	3.9942	5.0058	4	6
Total	40	7.2	2.24408	6.4823	7.9177	4	12

One-way ANOVA: $F_{3,36} = 74.352$; $P < 0.05$

Table 5. Induction of macronuclear aberrations in *Paramecium caudatum* exposed to different concentrations of Pendimethalin for 1hr.

	N	Mean	Std. Deviation	95% Confidence Interval for mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Control	10	3	0.4714	2.6628	3.3372	2	4
2ppm	10	20.3	1.25167	19.4046	21.1954	19	22
3ppm	10	34.7	0.94868	34.0214	35.3786	34	36
4ppm	10	48.2	1.13529	47.3879	49.0121	47	50
5ppm	10	63	1.33333	62.0462	63.9538	60	65
Total	50	33.84	21.17407	27.8224	39.8576	2	65

One-way ANOVA: $F_{4,45} = 4759.949$ $P < 0.05$

Table 6. Induction of macronuclear aberrations in *Blepharisma intermedium* exposed to different concentrations of Pendimethalin for 1hr

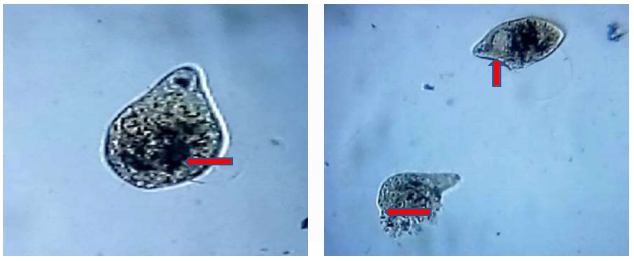
	N	Mean	Std. Deviation	95% Confidence Interval for mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Control	10	5.9	0.56765	5.4939	6.3061	5	7
4ppm	10	27.7	1.05935	26.9422	28.4578	26	29
6ppm	10	36.7	1.76698	35.436	37.964	34	39
8ppm	10	42.1	1.79196	40.8181	43.3819	39	44
10ppm	10	52.3	1.56702	51.179	53.421	50	55
Total	50	32.94	15.91227	28.4178	37.4622	5	55

One-way ANOVA: $F_{4,45} = 1504.241$ $P < 0.05$

alteration in pH in the culture medium and consequently modified the food vacuole activity.

Macronuclear aberration studies: When *P. caudatum* and *B. intermedium* exposed to different sub lethal concentrations of pendimethalin and concentration dependent increase in the total abnormalities in macronucleus was observed. The nuclear aberrations were categorized into rod shaped, unevenly divided, vacuolated, fragmented, karyolysed and other deformities (Table 5 & Plate 2). Significance difference between mean scores of different treatment groups of pendimethalin was observed and P-value of total percent abnormal forms in macronucleus of *P. caudatum* was 0.00. Highest total abnormal forms were in 5ppm with 63% and lowest were in 2ppm with 20.3%. In *B. intermedium*, highest total abnormalities were in 10ppm with 52.3% and lowest were in 4ppm with 27.7% (Table 6 & Plate 3). Fragmented and rod shaped nuclei observed at lower concentration and vacuolization, unevenly divided and karyolysed nuclei at higher concentrations. The results were highly significant in inducing macronuclear changes in both *P. caudatum* and *B. intermedium* and the findings were closely related with that of Masood et al (2008) where carbofuran induced deformities were recorded in Paramecia at 100, 210 and 280 ppm for 1hr. Martin et al (2005) also reported macronuclear chromatin condensation and nucleolar fusion in *C. steinii*, *C. elongata* and *D. revoluta* exposed to different concentrations of Cd and Zn for 24 hr.

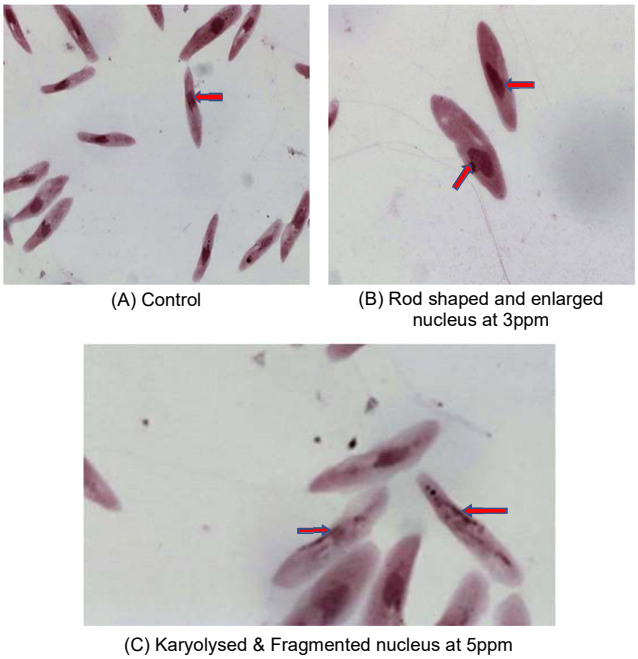
Malathion LC_{50} dose (0.22ppm) at an exposure of 24 hr induced nuclear changes like chromatin condensation and shrinkage in the longitudinal axis of macronucleus in Tetrahymena (Ashish et al 2016). In a comparative assessment of glyphosate, pendimethalin and diquat against mouse bone marrow cells, pendimethalin induced significant micronuclei and chromosomal abberations (Dimitrov et al 2006). Ahmad and Ahmad (2016) reported erythrocytic nuclear abnormalities and micronuclei formation at 0.9, 1.8 and 2.7 mg/L of pendimethalin in *Channa punctatus* after 24 to 96 hr exposure. Pendimethalin is known to cause oxidative stress which could ultimately lead to DNA damage in the cells (Olusegun et al 2019). The reason for macronuclear deformaties in test species could be due to amplification of genetic material as a result of oxidative stress caused by pendimethalin.



(A) Oval shape deformity at 15ppm (B) Blacking of cytoplasm at 20ppm

(c) Blebbing & blacking of cytoplasm at 25ppm (D) Oozing out of cell contents at 30ppm

Plate 1. Cytopathological deformities in *Paramecium caudatum* exposed to different concentrations of Pendimethalin (200X)



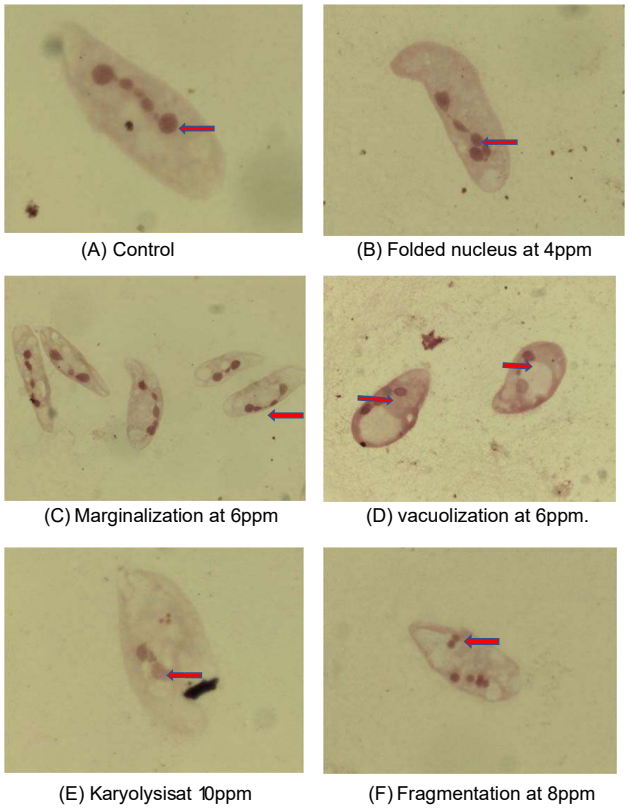
(A) Control (B) Rod shaped and enlarged nucleus at 3ppm

(C) Karyolysed & Fragmented nucleus at 5ppm

Plate 2. Pendimethalin induced nuclear changes in *Paramecium caudatum* exposed for one hour (200X)

CONCLUSIONS

Pendimethalin caused significant damage to cell structure, morphology, internal organelles and their function. The simplicity, low cost and less time span for the experimental procedure enable these tests to be applied in pollution research and water quality assessment.



(A) Control (B) Folded nucleus at 4ppm

(C) Marginalization at 6ppm (D) vacuolization at 6ppm.

(E) Karyolysisat 10ppm (F) Fragmentation at 8ppm

Plate 3. Pendimethalin induced nuclear changes in *Blepharisma intermedium* exposed for one hour (200X)

Pendimethalin is relatively more toxic to *P. caudatum* than *B. intermedium*. Both the test species identified to be useful models for basic toxicity studies replacing higher animal models.

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Insecticidal Activity of *Lantana camara* L. Essential Oil against the Stored Wheat Pest, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae)

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***Abstract*:** This study was conducted to determine the insecticidal activity of *Lantana camara* (Verbenaceae) essential oil against adults of *Tribolium castaneum*. Chemical composition of essential oil isolated by hydrodistillation from the aerial part of *L. camara* was analyzed by GC-MS. 1H-Cycloprop [E]-Azulène (19.23%), Methanophtalène (15.49%) and Caryophyllèneoxide (11.77%) were the main constituents. The results indicate that essential oil of the aerial part of *L. camara* shows toxic effects against adults of *T. castaneum*. The LD_{50} and LD_{90} of the aerial part of *L. camara* against of *T. castaneum adults* was 89.83 and 193.37 µl at 120 hours exposure. The maximum mortality caused by the extracted essential oil was 93.33% at 120 hours exposure at 200 µl. The LT_{50} values were respectively 22.52 hours in dose 200 µl for *T. castaneum* adults.

Keywords: Insecticidal activity, *Lantana camara,* Essential oil, *Tribolium castaneum*

Wheat is the most important cereal crop in the world and consumption is progressively increasing from one year to another, reaching 763, 92 million tons in 2020 and 46.25 million tons in North Africa (USDA 2021). In Algeria, cereals, particularly wheat and its derivatives, constitute the essential needs of the food system. Its consumption reached 10.35 million tons in 2016 (FAS 2017). To ensure a steady supply to consumers, storage of wheat has become a necessity. But unfortunately, during its conservation many pest cause economic loos, mainly insects. The largest losses are caused by different species of Coleoptera and Lepidoptera (Waongo et al 2013, Sankara et al 2017). Post-harvest losses caused by pests of stored food products were estimated to be up to 9% in developed countries and up to 20% or more in developing countries (Phillips and Throne 2010). Currently, the means of protecting post-harvest wheat stocks are increasingly based on the use of chemical pesticides**.** Unfortunately, these chemicals are very toxic to the environment and especially to human health (Mondedji et al 2015, Agboyi et al 2016). To overcome the toxicity problems several studies are focused on the use of natural plant based products (Ben Jemâa 2014, Popovic et al 2014, Zhu et al 2017, Wang et al 2019). *T. castaneum* (Herbst, 1997), considered as an important insect pest, causing damage in the stored wheat (Abdullahi et al 2018, Skourti et al 2020, Hashem et al 2020). The main objective of this study is to determine the chemical composition of *L. camara* and to evaluate its insecticidal activity on *T. castaneum, w*hich is considered one of the major pests in Algerian wheat stocks.

MATERIAL AND METHODS

Plant material: Aerial part of *L. camara* (Verbenaceae) was collected in the Khemis Miliana region, province of Ain Defla, (Algeria) during March and April 2018. The plant was dried by hot oven under low temperature.

Extraction process of essential oil: An amount of 50 g of plant material (aerial part) is placed in a one-liter flask, filled with distilled water at 1/3 of its capacity. The mixture is heated in heater balloon. The evaporated water, bringing with it the constituents of the essential oil which are then channeled into condenser and refrigerated to liquefy at a temperature ranging from 17°C to 22°C. The oil which floats on the surface of the distillation water is recovered in a dropping funnel. The essential oil was packaged in (2 ml eppendorf) tubes and stored in refrigerator at a temperature of 5°C prior to use in tests.

The chemical analysis of the essential oil of *L. camara* was carried out using the GCMS apparatus coupled to the mass spectrometer GCMS (TQ8030NC W/O-RP SHIMADZU CORPORATION) equipped with an RxiR- 5 MS column (30 m x 0.32 mm, 0.25 µm i.d., 1 µm film thickness). The injector temperature was 250°C. Oven temperature used was holding at 40°C for 2 min, heating to 250°C at 3°C/min and keeping the temperature constant at 250°C for 8 min. Helium was used as a carrier gas at a contact flow of 1.0 ml/min and an injection volume of 0.3 µl was employed. The MS scan parameters included electron impact ionisation voltage of 70 eV, a mass range of 40-500 m/z. Identification of

the components of essential oils according to Adams and Sparkman (2007).

Yield of essential oil: The yield of essential oil of *L. camara* was calculated by taking into account the mass of extracted essential oil in relation to the used mass of the plant material (Afnor 1992).

Culture of the insect: Parent adults of *T. castaneum* were obtained from stock cultures maintained at laboratory to obtain the larvae and adults necessary for the bioassays Insects were maintained in breeding room under of the conditions 27±1°C and 60±5% relative humidity (RH) (Mahmoudvand et al 2011). *T. castaneum* adults of 8 - 15 days were used for inhalation toxicity tests.

Inhalation toxicity: The doses used in experiments were: 50, 100, 150 and 200 µl of pure oil, selected after several preliminary tests. Insecticidal tests by inhalation of essential oils were carried out in Petri dishes of 95.37 cm^3.

Experimental protocol: Tests were carried out on ten individuals on non-sexed adults. These are placed in Petri dishes hermetically sealed with parafilm instead of the glass jars (Najem et al 2020). The crude essential oils (4 doses), placed on a filter paper, were placed in a 7 cm^3 volume capsule, covered with aluminum and closed with a piece of tulle. There was no contact between the insects and the essential oil. Killed insects were counted on Petri dishes every 24 hours, till 120 hours after treatment.

Analysis results: To calculate the DL_{50} and the DL_{90} and the TL_{50} and the TL_{90}, we have transformed the doses and times into decimal logarithms and the percentage values of mortality corrected to probit (Finney 1971). These transformations allow us obtaining equations of linear regression of the type: $Y = ax + b$.

Y: probit of corrected mortality. x: logarithm of dose or time. a: slope. b: constant value. The corrected mortality calculated according to the Abbott formula (1925):

$$MC\% = \frac{(NIM-NIMT)}{(NTI-NIMT)} \times 100$$

MC: Corrected mortality percentage (%), NIM: Number of dead insects in the treated population, NIMT: Number of dead insects in the control population.

Statistical analysis: The variance analyse at two classification factor (Dagnelie 1975) was performed using the software statistics. The main factor was the treatment dose with 4 levels (and the second factor was the exposure time with five levels). The regression curves were done using the Microsoft Office Excel 2007 software.

RESULTS AND DISCUSSION

Yield in essential oil: The yield of essential oils of *Lantana camara* obtained from the aerial part was 0.20%. This value seems almost identical to Sousa et al (2012) and Jawonisi and Adoga (2013) with values 0.18% and 0.19% respectively. Badasa et al (2014) in Ethiopia and Nascimento et al (2020) in Ivory Coast observed higher yields of 0.36 and 1.55%.

Chemical analysis of *L. camara* essential oil: The chemical analysis of essential oil of *L. camara* showed about 33 components of which 3 are predominant 1H-Cycloprop [E] - Azulene, methanophthalene and caryophyllene oxide with respective 29.23, 15.49 and 12.10% and rest of elements are in the form of traces (Table 1). The chemical composition of fresh natural leaves of *L. camara* essential oil, harvested in

Table 1. Chemical analysis of the essential oil obtained from the aerial part of *L. camara*

Compounds	Percent
2,3-Dihydroindole-4-ol-2-one,5,7-dibromo-3,3-dimethyl-	0.21
Phellandrène alpha	0.19
1,4 cyclohexadiène	0.82
Camphène	0.06
M-Mentha-4,8-diene	3.01
1-octen-3-ol	0.12
Bicyclo [4.1.0] heptane	0.05
Vinylamylcarbinol	1.47
Thujene alpha	0.40
Octanal	0.05
Limonène	0.84
1,3,7-octatriene	0.04
3-octen-5-yne	0.78
4-Thujanol	0.23
Cyclohexène	0.30
1,6 octadien	0.40
Isovelerate	0.05
Trans hydrate sabinène	0.06
Humulène	0.87
Alpha-Cubibène	0.11
Copaene	0.68
ELEMEN	0.50
1H-Cycloprop [E]- Azulène	29.23
Methanophtalène	15.49
Longifolene	1.79
Cedrene	1.89
Nerolidol A CIS	0.15
Viridiflorol	1.30
AZULENE	3.21
Beta-copaen-4, alpha-ol	2.07
Verbenol	0.34
Aromadendrenoxide-(1)	0.46
Caryophylleneoxide	12.10
Traces	20.73
Total identified	79.27

Bangladesh shows the majority compounds, caryophyllene (13.57%), Alpha-caryophyllene (11.76%), germacrene D (10.88%), Isocaryophyllene (9.59%), y-muurolene (6.85%) andy-elemene (5.65%) (Chowdhury et al 2007). Tesch et al (2011) identified 33 compounds. The major components were germacrene D (31%), followed by beta-caryophyllene (14.8%), a-phellandrene (6.7%), Limonene (5.7%) and 1.8 cinéole (5.2%). Khan et al (2015) found other components in the essential oil from *L. camara* leaves. The major components are cis-3-hexene-1-ol (11.3%), 1-octen-3-ol (8.7%), spathulenol (8.6%), caryophyllene oxide (7.5%) and 1-hexanol (5.8%). According to Nea et al (2020), hydrodistilled essential oils of *L. camara* are dominated by sesquiterpenes such as (E) -β-caryophyllene and α-humulene.

The mean mortality of adults of *T. castaneum* treated by inhalation with *L. camara* essential oil during the five exposure times (Table 2). Mortality of *T. castaneum* adults was 60% in dose 3 and dose 4 in the first day of observation and then increased to 93.33% during the 5th day with dose 4) (Table 3). Rajashekar et al (2014) observed that the leaves of *L. camara* act by inhibiting the acetylcholinesterase of insects of stored commodities such as *Sitophilus oryzae*, *T. castaneum* and *Callosobruchus chinensis*.

Toxicity of the essential oil: The LD_{50} and LD_{90} values of the essential oil of *L. camara* are obtained from equation of linear regression calculated after exposure time of 96 and 120 h (Table 4) (Fig. 1).

The lethal doses obtained in adult *T. castaneum* with *L. camara* essential oil are 93.40 µl for the LD_{50} and 206.50 µl for the DL_{90} after 96 hours of exposure and respectively 89.83 µl and 193.37 µl after 120 hours (Table 5) (Fig. 1). The lethal doses are 89.83 µl [82.33 - 98.00] for LD_{50} and 193.37 µl [163.67 - 252.41] (Table 5) for LD_{90} after 120 hours of treatment. In Egypt according to Abdelgaleil et al (2008), the toxicity against adults of *T. castaneum* LD_{50} was 29.47µl/l. In Bihar India, were also found highly effective as compare to untreated control at 0.1- 0.2- 0.3 and 0.4 percent against *T.*

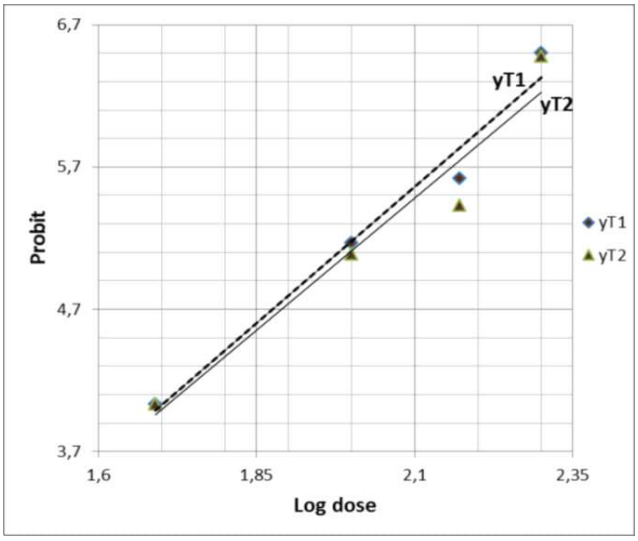

Fig. 1. Linear regression T1 and T2 of adult mortality of *T. castaneum* per dose of *L.camara* essential oil (µl) 96 and 120 h after exposure time of treatment

Table 2. Daily mean mortality of *T. castaneum* adults treated with *L. camara* essential oil

Time	Mean mortality ± SE (%)				
	Control	Dose 1	Dose 2	Dose 3	Dose 4
24h	0	0	16.66±11.55	40±10.00	60±10.00
48h	0	3.33±5.77	33.33±5.77	66.66±5.77	63.33±5.77
72h	0	10±10.00	46.66±5.77	60±10.00	73.33±5.77
96h	0	16.66±11.55	53.33±5.77	66.66±5.77	86.66±5.77
120h	0	16.66±5.77	56.66±5.77	73.33±5.77	93.33±5.77

SE: Standard error

Table 3. Response of adult *T. castaneum* mortality to dose and time factors

Time	Doses			
	50 µl	100µl	150µl	200µl
24 h	0.00^{H}	16.66^{G}	60^{CD}	$60,00^{CD}$
48 h	0.00^{H}	33.33^{F}	$66,66^{BC}$	$63,33^{BCD}$
72 h	10.00^{GH}	46.66^{E}	$60,00^{CD}$	$73,33^{B}$
96 h	6.66^{GH}	53.33^{DE}	$66,66^{BC}$	$86,66^{A}$
120 h	13.33^{G}	56.66^{CDE}	$73,33^{B}$	$93,33^{A}$

Table 4. Decimal logarithms of doses and probits of mortality rates for D1, D2, D3 and D4 of *L. camara* essential oil applied by inhalation to *T. castaneum* adults after 96 h and 120 h exposure

Dosages	Mortality (%)			
	Mean± SE[5] (%)	CM (%)[6]	PM (%)[7]	Lg D[8]
After 96 hours of exposure time				
D1	16,66±11.55	16,66	4,0364	1.69
D2	53,33±5.77	53,33	5,0866	2
D3	66,66±5.77	66,66	5,4298	2.17
D4	86,66±5.77	86,66	6,4821	2.30
After 120 hours of exposure time				
D1	16,66±5.77	16,66	4,0364	1.69
D2	53,33±5.77	53,33	5,0866	2
D3	66,66±5.77	66,66	5,4298	2.17
D4	86,66±5.77	86,66	6,4821	2.30

[1]Control, [5]Standard error, [6]Corrected mortality, [7]Probit of mortality, [8]Decimal logarithm of doses

Table 5. Probit analysis of inhalation toxicity data of *L. camara* aerial part essential oil against *T. castaneum* adults 96 and 120 h after exposure time

ExpT[1]	R-Equa[2]	INT[3]	SL[4]	LD_{50} (µl)[5]	LD_{90} (µl)[6]	R^2
96 h	yT1=3.715x-2.320	–2.509	3.715	93.40	206.50	97%
				(85.35-102.21)	(173.76-272.04)	
120 h	YT2=3.844x-2.509	–2.320	3.844	89.83	193.37	97%
				(82.33-98.00)	(163.67-252.41)	

Significant at P<0.05
[1]Exposure time, [2]Regression equation in time 1 and 2, [3]Intercept, [4]Slop, [5]Chemical concentration that kills 50% of sample population, [6]Chemical concentration that kills 90% of sample population

Table 6. Different equations from the linear regression relating to the calculation of LT_{50} of each dose of *L. camara* essential oil obtained from aerial part

Doses	R-Equa[1]	INT[2]	SL[3]	LT_{50}[4](h)	R^2
50 µl	yD1=5.841x-7.177	-7.477	5.841	136.80	87
100µl	yD2=1.688x+1.729	1.729	1.688	86.63	99%
150µl	yD3=1.081x+3.358	3.358	1.081	33.02	79%
200µl	yD4=1.730x+2.660	1.730	1.730	22.52	81%

Significant at P<0.05, [1]Regession Equation, [2]Intercept, [3]Slop, [4]Chemical concentration that kills 50% of a sample population

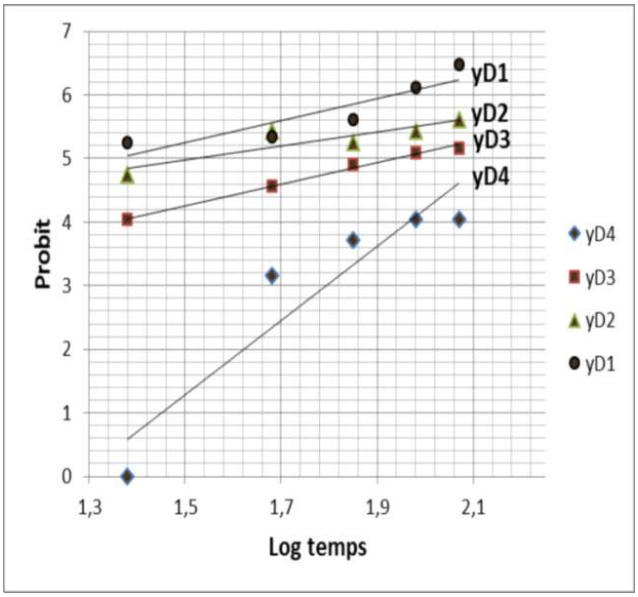

Fig. 2. Efficacy of the different doses, D1, D2, D3 and D4 of the essential oil of *L. camara* on the adults of *T. castaneum*

castaneum, *Sitophilus oryzae* and *Rhyzoperta dominica* (Kumar and Pandey 2021). The essential oils of *L. camara* on adults of *S. oryzae* and *T. castaneum* indicated low insecticidal activity by fumigation with LD_{50} of 0.22 mg/cm^2 (Sousa and Costa 2012). Extracts of *L. camara* with a dichloromethane solvent on adults of *T. castaneum* and gave a strong repulsive action of 62% with an LD_{50} of 53 mg/g after 24 h of treatment (Kalita and Bhola 2014). The essential *thymol component of L. camara* essential oil has strong insecticidal activity against *S. granarius* (Nea et al 2020). Rajashekar et al (2013) isolated a natural bioactive molecule from *L. camara* leaves named Coumaran. The latter is highly toxic and can control insects such as *Tribolium castaneum* at an LC50 of only 0.27 µl/l. The best lethal times (LT_{50}) obtained for the essential oil of the aerial part are respectively 22.52 hours in dose 4 and 33.02 hours in dose 3 (Table 6, Fig. 2).

CONCLUSION

The essential oil of the plant *L. camara*, obtained from the aerial part, has an insecticidal effect and that the insect *T. castaneum* was sensitive to inhalation tests. These results suggested that *L. camara* oil could be used as a potential control agent for *T. castaneum.*

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Taxonomic Studies and Seasonal Variations in Density of Fresh Water Leech *Erpobdella bhatiai* (Nesemann, 2007) Inhabiting Torrential Hill Stream in Greater Himalayas

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***Abstract*:** Present study encompasses the taxonomic characteristics of a freshwater predatory leech, *Erpobdella bhatiai* and variations in its population density in relation to various physico-chemical attributes of habitat. A comparison of its morpho-taxonomic characters with other congeneric species has been done. A detailed and close examination of about 30-35 adult specimens revealed that absence of proboscis, presence of long V-shaped myognaths, multiple testis sacs per somite, and absence of post caeca, accessory male and female pores are genus characters. The length and shape of atrium, atrial horns, 2.5 annuli between gonopores and three post anal annuli are species characters for identification. Highest density value was found in winter (21.6) and lowest in summer (3.3). A strong negative correlation of density with temperature, FCO_2 and positive correlation with chloride ions indicated this species to be tolerant to low temperature and good indicator of chlorides.

***Keywords*:** Taxonomy, Leech, *Erpobdella bhatiai*, Greater Himalayas

Leeches are placed under class clitellata following phylogenetic analysis (Borda and Siddall 2004). Freshwater leeches have been evolved from terrestrial forms and play a crucial role as food of higher predators, as predators of small aquatic benthic organisms and as sanguivorous parasite. About 700 species of leeches have been reported all over the world till date. Out of a total number of seven hundred, 55 species belonging to freshwater leeches have been reported from India so far (Mandal and Mishra 2017). Leeches have remained one of the most ignored groups in terms of studying taxonomy in North-India for almost two decades. Latest information with regard to diversity of leeches in Jammu region, (J&K) dates back to 1983, when Chandra (1983) reported a total of 4 species belonging to family Erpobdellidae. The detailed taxonomic account however, has not been given in that document and therefore, has led to the incorrect information regarding its classification. The three species *Herpobdelloidea lateroculata, Nematobdella indica*, and *Barbronia weberi* are now classified under family Salifidae (Nesemann et al 2004) due to the presence of accessory copulatory pores and pharyngeal stylets in the oral cavity and therefore, only one species, *Erpobdella octoculata*, collected along Doda road, Bhaderwah, actually belongs to family Erpobdellidae. No other survey has been conducted later on in that area. The present species has also been collected from the same type locality and identified as *Erpobdella bhatiai*. Presently reported work has emanated after a lapse of more than four decades and aims to address the wide lacuna in our existing information regarding the taxonomy, diversity and distribution of this vital group of organisms from North-Western region in the Great Himalayas.

The animal under study *E. bhatiai* was described for the first time from Dal lake Floating Gardens, Srinagar by Nesemann et al (2007). Only diagnosis and differential diagnosis with *E. octoculata* was made in the description. Neither the detailed taxonomic account nor the habit and habitat of the species were described at that time. After its first description, not even a single document has been reported with respect to the detailed taxonomy, habit, habitat, life history or population structure of *E. bhatiai* in relation to habitat changes. Leeches of genus *Erpobdella* have natural potential to be used as biomonitoring agent for assessing the levels of polychlorinated biphenyls, a harmful pollutant of water bodies (Macova et al 2009). The capability of *E. octoculata*, a congeneric species of the studied leech, to accumulate trace metals in their tissues was well explored by Friese et al (2003). Such studies indicate the importance of these small organisms in biomonitoring and bioremediation. It, therefore, becomes necessary to explore this very aspect of leeches in detail and for this, knowledge about its accurate taxonomy and ecology becomes a prime requisite. The present study is an effort to study the detailed taxonomy, habitat description, seasonal variation of *E. bhatiai* in relation to variations in physico-chemical parameters of the Neeru

nullah flowing in the torrential terrains of Bhaderwah, the part of Greater Himalayas.

MATERIAL AND METHODS

Study area: The study was conducted in Neeru nullah traversing a small village Dharaija (elevation of 1683m) in Bhaderwah town (32°58′ N- 75°43′ E), UT of Jammu and Kashmir in North-Western Himalayas. Neeru nullah is a perennial torrential hill stream with very fast flowing water and is the main lifeline for local residents. It originates from Kailash lake, locally known as Kablas kund (3900m), located in Mountain Kailash range. After traversing about 35 km in north-west direction, it merges in the Chenab River near Pul Doda. It has gravel bottom and many boulders are present in the stream. The area experiences four distinct seasons in a year *i.e.,* winter (mid November- February), spring (late February-April), summer (May to August), autumn (September – mid November).

Sampling technique and analysis of physico-chemical parameters: Leeches were collected using forceps from underside of stones, crevices in boulders, under degrading leaves and by sieving the sediments and were brought live and reared in laboratory conditions. Fresh specimens were used for investigating taxonomical characters. Leeches were narcotized by adding chloroform to water. After the leech has ceased responding to touch, it is taken out and excess mucous was removed by passing it between fingers. These are then fixed in 10% formalin overnight and preserved in 70% ethyl alcohol. Preserved specimens were washed in distilled water and dipped in glycerol for about 24 hours to enhance the visibility of viscera before dissection. Specimens were photographed, analysed morphometrically and dissected under Olympus SZ61 stereomicroscope. Identification was done using Thorp and Lovell (2019), and confirmed using Nesemann et al (2007). A total of nine physico-chemical parameters *viz.* air temperature (AT), water temperature (WT), water pH, dissolved oxygen (DO), free carbon dioxide (FCO_2), bicarbonates (HCO_3^-), chloride ions (Cl^-), calcium ions (Ca^{2+}) and magnesium ions (Mg^{2+}) were estimated from the selected water body in different seasons during the study period 2019-2020 using A.P.H.A (2000). Seasonal variations in density of leech during study period were calculated using quadrant method and impact of various physico-chemical parameters on its density were determined using Pearson correlation. Data was analysed using SPSS 17.0 version.

RESULTS AND DISCUSSION

Taxonomy of *Erpobdella bhatiai*

Habitat and distribution: Leeches were found attached to underside of stones (not smaller than 10cm), degrading leaves, and to the crevices on the bottom of boulders lying mostly near the bank of streams. They prefer stones with smooth surface. Some specimens were also collected from seasonal ditches in paddy fields attached to weeds and embedded in sediments. Other macro-invertebrates found in the vicinity were psephenidae larva, trichopteran larva and few specimens of *Lymnaea* sp. It is mostly found in higher altitudes of North-western Himalayas. Bhatia (1939) reported it from Pahlgam and Kaimul (7500 feet). Soota (1956) collected it from Srinagar, and misidentified it to be *Erpobdella octoculata*. Later Nesemann et al (2007) described the new species *Erpobdella bhatiai*, collected from Dal lake Floating Gardens, Srinagar (1470m).

Morphological observations: These are based on close examination of about 30-35 adult specimens. Small to medium sized leech with an average length of about 27mm, when extended reach about 60mm in length; maximum mid-body width is 0.5mm. Body is elongated, cylindrical, with tapering ends (anterior end more tapering than posterior end). Colour is olive green below clitellum and dark coloured anteriorly with two dark longitudinal stripes (slightly irregular) running throughout the dorsum with very less inter-stripe distance (Fig. 1). Ventral side is non-pigmented. Clitellum is well marked in breeding adults. Mid-body somite is quinquannulate with b6 slightly more widened (b1=b2=a2=b5<b6) with a light furrow in each annulus. Dorsum has numerous pale sensillary papillae on it which are hard to see with naked eyes and appear only as pale spots on dorsum. a2 annulus of each somite has a transverse row of 10-15 spots whereas other annuli of somite have irregular arrangement of papillae. Oral sucker is ventrally directed, mouth occupy entire sucker cavity, lack jaws and is armed with muscular pharyngeal ridges. Pharynx is strepsilamatous and extends upto about 1/4th of body length. Oral cavity has three V**-** shaped pseudognaths alternating with pharyngeal ridges. Post caeca are absent. Four pairs of equal sized conspicuous eyes are present, arranged in two groups consisting of two pairs each. One group of cephalic eyes directed anteriorly, arranged in parabolic arc. First pair is present in II annuli and second pair on the furrow of II/III. Second group is of labial eyes which are directed slightly to the lateral side and present on IVa2. Posterior sucker is directed ventrally and attached to body by a small constriction called pedicel. Dorsally it has 7-8 bright radiating stripes which indicate fused somites. It is hermaphrodite. Gonopores are present ventrally separated by two and half annuli and in rare cases by three annuli. Male gonopore is present in XIIb2 (in first case) or on XIIb1/b2 (second case) while female pore is constant in furrow of XIIb5/b6 (Fig. 2).

Multiple testis sacs are present per somite arranged in clusters. Spermatic ducts are highly undulated, and extend upto somite XI before entering to atrial cornua resulting in pre-atrial loops. Anus is situated on the furrow XXVa2. Three post-anal annuli are present. Cocoon is oval-oblong, light brown enclosing four juveniles, and is found cemented to stones (Fig. 5-6).

Differential diagnosis: The sole morphological character that predicts the phylogenetic relationship among erpobdellids is the number of labial eyes (Siddall 2002). The species like *E. octoculata*, *E. subviridis*, *E. bykowski*, *E. obscura*, *E. dubia*, *E. parva*, *E. testacea*, *E. japonica*, *E.villnensis* and *E. bhatiai* are closely related as all of them possess 2 pairs of labial eyes. A comparative account of morphological characters between these species is also depicted in Table 1. Character that can be used for differential diagnosis of *E. bhatiai* is the number of annuli between gonopores. The species *E. octoculata*, *E. bhatiai*, and *E. japonica* are separable from other erpobdellids in having same number of annuli between gonopores. The three mentioned species have male pore located in annulus, female pore in furrow and both are separated by 2.5 annuli. Further *E. japonica* is differentiated from *E.octoculata* and *E. bhatiai* due to comparatively large body length and dorsum colour. *E.octoculata* and *E. bhatiai* have close resemblance to each other due to the same body colouration and dot patterns. The latter species can be differentiated from each other by comparing body length, shape of atrium and length of ovisacs. Body length of *E. bhatiai* is comparatively shorter than *E. octoculata*. Atrium is 0.5 neurosomite (ns) long which is small in comparison to *E.octoculata* where it is 1 ns long. Atrial horns are thick, curved, directed medially (Fig. 3-4), whereas, it is goat horned, directed anteriorly in *E.octoculata*. Angle between atrial horns and atrial body is acute in *E.bhatiai* whereas it is almost right in case of *E. octoculata*. Ovisacs are above 5 ns long in *E.octoculata,* while it is only about 3.5 ns long in present species. The animal under study bears close resemblance to *E. octoculata*, but is identified to be *E. bhatiai* based on above findings.

Seasonal variations in density: Average density of leeches reported was 10.2 individuals/m^2 which is much close to what reported by Mushatq (2014) in *E. octoculata* (13 individuals/m^2). The leech density was highest in early winter and lowest in summer, following the trend winter > spring > autumn > summer (Table 2). The air and water temperature throughout the study period varied from 6.2°C-24.9°C and 5.1°C-21.3°C, respectively. Temperature was negatively correlated with DO which ranged from 6.1-10.7 mg/l *i.e.,* lowest in summer and highest in winter. The results are in accordance with Palaq et al (2020) and in contradiction to

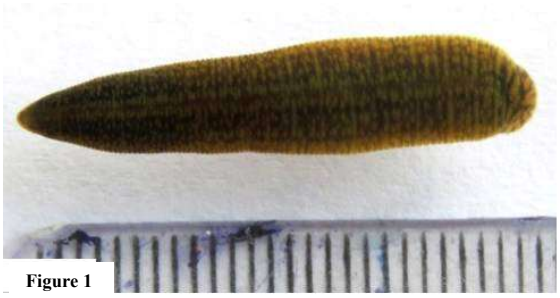

Figure 1

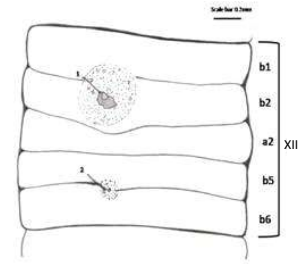

Figure 2

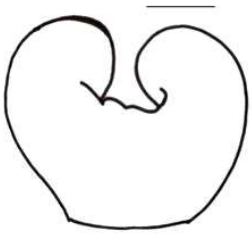

Figure 3

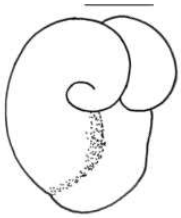

Figure 4

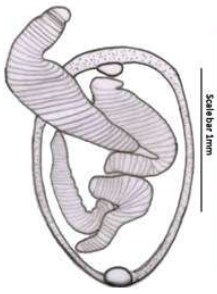

Figure 5

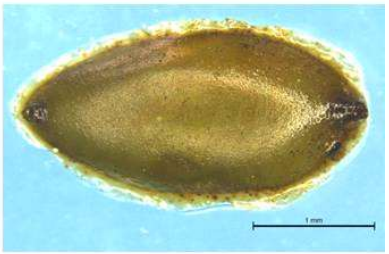

Figure 6

Fig. 1. Adult of *Erpobdella bhatiai*. **Fig. 2.** Camera lucida diagram showing ventral side of leech to depict the location of male and female gonopores (scale bar- 0.2 mm). **Fig. 3**. Camera lucida diagram of atrium (scale bar-1mm). **Fig. 4.** Camera lucida diagram of lateral view of atrium (scale bar- 1mm). **Fig. 5.** Camera lucida diagram of four eyed cocoon (Scale bar-1mm). **Fig. 6.** Empty cocoon (scale bar- 1mm)

Yousuf and Jamila (2018) who reported highest values of DO during spring in Dal Lake as lentic water bodies freeze in the area due to harsh winter and uptake of air are possible only when it melts in spring. Density of leeches have a strong negative correlation with temperature (r = -0.963, -0.976). In winter, leeches were highly abundant in December, but exclusively absent in January and February because of extreme cold temperature which ceases their metabolic activities. During these months, only cocoons are found attached to stones in natural water conditions, but in laboratory conditions where temperature was complimentary, adults continued to survive and even laid cocoons in early February. Mushatq (2014) also observed complete absence of leech *E. octoculata* during harsh winter months in basins of Dal lake. A strong negative correlation of density with FCO_2 (r = -0.966) is witnessed as increase in FCO_2 leads to anoxia, and hence death of individuals which is probably a reason that accounts for low density values during summer and autumn seasons (Table 2). A slight high positive correlation was found between chlorine (r = 0.795) and density of leeches (Table 3). Macova et al (2009) concluded that leeches have a tendency to accumulate high levels of polychlorinated biphenyl compounds in their tissues which are otherwise harmful for many other aquatic animals such as fishes. Owing to their ability to tolerate high levels of chlorine, leeches act as good indicators of chlorinated

Table 1. Comparative morphology of *Erpobdella bhatiai* with other related species of *Erpobdella*

Parameters	*E. subviridis* (Nesemann and Neubert 1994)	*E. bykowski* (Nesemann and Neubert 1999)	*E. obscura* (Klemm 1982)	*E. dubia* (Klemm 1982)	*E. parva* (Klemm 1982)	*E. testacea* (Nesemann and Neubert 1999)	*E. octoculata* (Moore 1924)	*E. japonica* (Nesemann 1995)	*E. villnensis* (Nesemann and Neubert 1999)	*E. bhatiai* Present species
Average size	80mm	80-140mm	100mm	20-60mm	25-30mm	40mm	30-70mm	55mm	45mm	27mm
Dorsum colour	Brown	Whitish red or pink	Greenish brown	Greenish	Unpigmented/ smoky gray	Orange-brown	Greenish yellow to red brown	Dark brown/ yellowish brown/ reddish brown	Dark reddish brown to black	Olive green
Mid-dorsal stripe	+	-	-	+	-	+	+	+	+	+
Spots	-	-	+	+	-	/	+	+	+	+
Position of male gonopore	furrow	Furrow	Furrow	Annulus	Annulus	furrow	Annulus	Annulus	Furrow	Annulus
Position of female gonopore	Furrow	Furrow	furrow	Furrow	furrow	Furrow	furrow	furrow	furrow	furrow
Annuli between gonopore	6-9	2	2	3.5-4	3.5	4	2.5-3.5	2.5	3	2.5
Ovarian sac length	/	/	/	/	/	/	>5ns	4ns	/	3.5ns
Angle between atrial body and horns	obtuse	Right	acute	Right	right	acute	right	right	Right	acute

(/ indicates that information is not available)

Table 2. Seasonal variation in physico-chemical parameters of perennial torrential stream and density of *Erpobdella bhatiai*, in Neeru nullah (2019-2020)

Seasons	AT (°C)	WT (°C)	pH	DO (mg l^{-1})	FCO_2 (mg l^{-1})	HCO_3^- (mg l^{-1})	Ca^{2+} (mg l^{-1})	Mg^{2+} (mg l^{-1})	Cl^- (mg l^{-1})	Density (ind/m^2)
Winter	6.20	5.10	8.17	10.70	2.10	32.50	9.10	2.10	2.12	21.6
Spring	12.20	10.90	7.60	8.40	4.30	21.30	5.70	1.37	1.91	10.6
Summer	24.90	21.30	7.90	6.10	7.00	16.20	6.10	1.62	1.11	3.3
Autumn	16.50	15.00	8.00	7.40	6.40	29.20	8.94	2.21	2.00	5.3

compounds. The details regarding the physiological implication of chloride levels in their body however, needs further investigations. Calcium and magnesium ions reveal a weak positive correlation with density of leeches (Table 3). Due to lack of bony endoskeleton and exoskeleton (shell/carapace), leeches are not much dependent on calcium for their growth. But still small amount of calcium is required by leeches for signal transmission via glial cells (Lohr and Deitmar 2006). Since magnesium is essential for many biochemical reactions occurring inside body of animals, this slight positive correlation of density with Mg^{2+} ($r = 0.380$) is evident and justified.

Leech density increased from summer (3.3 individuals/m^2) to winter (21.6 individuals/m^2). High density can be correlated with diverse type of food organisms which are abundantly and readily available in the form of many dormant insect cocoons, snails, water penny beetle larva found attached to stones during winter. For a predatory and not a very active swimmer, as the leeches are, such conditions are particularly favourable for adults that are about to lay cocoons and whose food requirements at this particular stage are at the peak. This may also be due to less anthropogenic activities in winter which are restricted due to heavy snowfall in the area. Lowest density in summer season may be due to an increase in the water column as during this season, due to melting of ice, water level increases leading to flooded conditions. This in turn results in a fall in levels of O_2 in benthic zones as compared to surface layers of water. Benthic habitat, therefore temporarily becomes unfavourable for these organisms due to a shift in physico-chemical attributes of this particular zone (benthic). Leeches, being benthic in nature, ecological parameters (particularly low oxygen) no more remain in their favour. The increased water flow in streams causes small stones to move along with water current and as leeches remain attached to stones for most of the time, therefore, a fraction of their population is also flushed along with moving stones which in turn accounts for a decline in the population of leeches during summer months. A comparatively high density of leeches in spring (10.6 individuals/m^2) is due to the appearance of favourable conditions in spring. Advent of spring season coincides with arrival of favourable ecological conditions (particularly temperature marks an increase which in turn facilitates hatching of cocoons). It is worth mentioning here that more than 60% of the population recorded during spring comprises of juveniles indicating the extent of contribution made by newly hatched cocoons.

Table 3. Pearson correlation between Physico-chemical parameters and density of leech *Erpobdella bhatiai* collected from Neeru nullah

		AT	WT	pH	DO	FCO_2	HCO_3^-	Ca^{2+}	Mg^{2+}	Cl^-	Density
AT	r =	1									
WT	r =	0.998**	1								
	p value	0.002									
pH	r =	-0.245	-0.267	1							
	p value	0.755	0.733								
DO	r =	-0.972*	-0.985*	0.386	1						
	p value	0.028	0.015	0.614							
FCO_2	r =	0.941	0.962*	-0.269	-0.981*	1					
	p value	0.059	0.038	0.731	0.019						
HCO_3^-	r=	-0.410	-0.415	0.958*	0.494	-0.347	1				
	p value	0.590	0.585	0.042	0.506	0.653					
Ca^{2+}	r =	-0.486	-0.475	0.861	0.514	-0.345	0.970*	1			
	p value	0.514	0.525	0.139	0.486	0.655	0.030				
Mg^{2+}	r =	-0.277	-0.264	0.875	0.311	-0.132	0.956*	0.974*	1		
	p value	0.723	0.736	0.125	0.689	0.868	0.044	0.026			
Cl^-	r =	-0.894	-0.862	0.226	0.789	-0.689	0.472	0.629	0.470	1	
	p value	0.106	0.138	0.774	0.211	0.311	0.528	0.371	0.530		
Density	r =	-0.963*	-0.976*	0.452	0.997**	-0.966*	0.559	0.575	0.380	0.795	1
	p value	0.037	0.024	0.548	0.003	0.034	0.441	0.425	0.620	0.004	

*,** Correlation is significant at the 0.05 level and 0.01 level (2-tailed) respectively.

CONCLUSION

The study highlights the identification features of fresh water leech *E. bhatiai* and is a first report on its density variations in relation to changing physico-chemical parameters. Leeches when placed in glycerol for 24 hours before dissection showed better visibility of viscera and thus eased identification process. *E. bhatiai* showed close resemblance with *E. octoculata* in morphology and can be differentiated from it in having an acute angle between atrial horns and atrial body and about 3.5 ns long ovisacs. Density was positively correlated with pH, DO, Ca^{2+}, Mg^{2+} and Cl^{-} and negatively correlated with temperature and FCO_2. A positive correlation of density with chlorine strengthens its future potential use in biomonitoring of our natural water bodies as it is a good indicator of chlorinated compounds.

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Levels and Pattern of Consumption Expenditure of Non-Farm Households in Rural Punjab

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Abstract: The present paper deals with consumption pattern of 440 rural non-farm households, sampled from 44 villages of all 22 districts of Punjab. A household member, on an average, spends around a half of the monthly consumption expenditure on food items and slightly less than half of the percent of its total consumption expenditure per month on non-food items. Among the food items, more than two-fifth of the total expenditure was spent on milk and milk products. Among the non-food items, around one-fourth of the expenditure was on education which was a good sign for human development. However, it was observed that the total consumption expenditure was unevenly distributed among the various groups. The bottom ten per cent household members has only less than one-twentieth share of total per capita consumption expenditure. The upper most ten per cent household members share less than one-fourth of the total per capita consumption expenditure, which shows inequality prevailing among the rural non-farm categories. The absolute level of per capita expenditure on all items of consumption was fairly higher for the service category households as compared with those of self-employment category households.

Keywords: Self-Employed category, Service category, Consumption pattern, Food items, Non-food items

There was changing in the consumption expenditure from traditional food items to non-food items from 1973. Traditional food items were dominated by cereals among other changes higher expenditure on beverages and milk and milk products. Similarly, in non-food expenditure consumption on goods and services has risen, these include educational and medical expenses (Gupta 2016). Among various households in rural Kerala, casual labour in agriculture and non-agriculture has the lowest living standard. On the other hand, the regular wage/salary earning and self-employed in agriculture enjoys a much better lifestyle (Biji 2017). The living pattern of the people has been changing, which reflected in the change in the consumption pattern of the rural people, especially the youth and with changes in the consumption pattern, the cropping pattern also changes. The relative importance of cereals and non-cereal crops was changed and also change in the occupational structure of rural household due to the high income in others sectors (non-farm sector). With the passage of time, non-farm activities were becoming the alternative source of livelihood for the rural people (Pal and Biswas 2011). The activities related to fishing and hunting, animal husbandry, forestry and logging form the part of the agriculture sector, are commonly included in the non-farm sector. Other rural non-farm economic activities consist of wide-ranging various traditional and modern manufacturing activities, mining and quarrying, construction, trading, transport storage and communication, hoteling and those are rendering community and personal services (Dave and Dave 2012). A study conducted by IEG (2015) has found that the small unit at the village level and was operated by a single person, engaging family members, provide employment opportunities in the absence of more profitable alternatives, and constitute secondary sources of income (IEG 2015). The present paper focuses up on the levels and pattern of consumption expenditure of non-farm households in rural Punjab.

MATERIAL AND METHODS

The sample of 440 non-farm households (10 from each sampled village was taken from 44 sampled villages located in all 22 districts of Punjab, considering the geographical spread of the region as well as keeping the representativeness of the sample. Two villages have been selected from each of the districts, one located relatively near the main city (preferably the district headquarter) and the other one situated comparatively far away from the same city. For the collection of the data, two villages each have been selected from the all the 22 districts of Punjab, one near to the city (less than 12 km. away) and the other far from the city (more than 12 km. away). The data was collected in the year of 2015 by field survey in rural Punjab. The present study was based on the primary data, a well-structured schedule was used for collecting information about the sampled households. The selected villages were spread all over the agro-climatic regions of the state. For calculation and

Fig.

analysis the data, simple average, percentage, t test and Ginni coefficient has used.

RESULTS AND DISCUSSION

Total monthly per capita consumption expenditure - on average, sampled households spends Rs. 1971.99 per capita monthly for full filling its own needs. Out of this, average monthly per capita expenditure on food items was Rs. 987 and on non-food items were Rs. 985. Across all the 22 categories, the maximum average monthly consumption expenditure of Rs. 2858 was observed in the households of the Public Administration and Defense (SRPD) household category, followed by Human Health and Social Work (SRHS) household category and the minimum per capita average monthly consumption expenditure for transportation and storage (SETS) household category.

Food items: On an average, household spends Rs. 987 on monthly consumption of food items. The maximum per capita monthly expenditure on food items was of Rs. 1474 by the other Service (SROS) household category, followed by of

Table 1. Category classification according to the national industrial classification (NIC)

Abbreviation	Household category
SE	Self-Employed
SEAF	Self-Employed in Accommodation and Food Service related RNFAs
SECT	Self-Employed in Construction related RNFAs
SEMF	Self-Employed in Manufacturing related RNFAs
SEPT	Self-Employedin Professional, Scientific and Technical related RNFAs
SETR	Self-Employed in Wholesale andRetail Trade; Repair of Motor Vehicles and Motorcycles related RNFAs
SETS	Self-Employed in Transportation and Storage related RNFAs
SR	Service Category
SRAF	Service in Accommodation and Food Service related RNFAs
SRAR	Service in Arts, Entertainment and Recreation related RNFAs
SRAS	Service in Administrative and Support Service related RNFAs
SRCT	Service in Construction related RNFAs
SRED	Service in Education related RNFAs
SRFI	Service in Financial and Insurance related RNFAs
SRHS	Service in Human Health and Social Work related RNFAs
SRIC	Service in Information and Communication related RNFAs
SRMF	Service in Manufacturing related RNFAs
SROS	Service in Other Service related RNFAs
SRPD	Service in Public Administration and Defense; Compulsory Social Security related RNFAs
SRPT	Service in Professional, Scientific and Technical related RNFAs
SRRE	Service in Real Estate related RNFAs
SRTR	Service in Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles related RNFAs
SRTS	Service in Transportation and Storage related RNFAs
SRWS	Service in Water Supply; Sewerage, Waste Management, and Remediation related RNFAs

accommodation and food service (SRAF) household followed by public administration and defense (SRPD). The 50 per cent of it's average monthly consumption expenditure on food items.

Non-food items: The per capita monthly consumption expenditure on non-food was Rs. 985. The maximum per capita monthly expenditure on non-food items by SRPD of Rs. 1572 followed SRHS category. Percentage-wise, a person, on an average, spends 49.9 per cent of its total consumption expenditure per month on non-food items. Prasad (2015) observed that the households spent majority of their income on food, followed by nonfood items, medicine and education. The results show almost equal distribution of expenditure between food and non-food items. This, in way, reflects that people were investing more in household's assets and enjoying a better standard of life.

Table 2. Per Capita monthly consumption pattern

(in Rs.)

RNFA Categories	Food Items	Non-food items	Total monthly consumption
SEAF	1107	495	1601
SECT	958	891	1849
SEMF	942	844	1786
SEPT	828	740	1568
SETR	958	1002	1960
SETS	606	588	1193
SE	900	760	1660
SRAF	1301	685	1986
SRAR	1129	690	1819
SRAS	982	1116	2098
SRCT	860	632	1493
SRED	1176	1281	2457
SRFI	1013	895	1909
SRHS	1262	1391	2653
SRIC	1038	1015	2053
SRMF	906	1077	1983
SROS	1474	922	2396
SRPD	1286	1572	2858
SRPT	1171	998	2169
SRRE	1026	655	1681
SRTR	1052	829	1881
SRTS	984	1024	2008
SRWS	760	549	1308
SR	1089	958	2047
Total Sample	987	985	1972

Per capita monthly consumption expenditure of food items by the sampled households: Total per capita monthly expenditure on food items was Rs. 987 per month. The maximum 41.9 per cent were spent on milk and milk products, followed by 22.5 per cent on vegetables and 11.8 per cent on wheat. This reflect the economic well-being of our sample households as more the per capita monthly expenditure on milk and milk products, vegetables and wheat means a more nutritious and healthy food, was enjoyed by rural non-farm households. In the self-employed category, total per capita monthly expenditure on food items was Rs. 900 per month and 39.6 per cent was spent on milk and milk products, followed by on vegetables with 23.6 per cent. In service category, total per capita monthly expenditure on food items was Rs. 1089.per month with maximum of 45.6 per cent on milk and milk products, followed by vegetables with 21.2 per cent. Across the categories, the maximum total per capita monthly consumption expenditure was of the household category of Other Services (SROS), followed by (SRAF), (SRPD) and lowest expenditure by (SEPT), and followed by (SRWS) and (SETS). Gupta (2016) and Kharwade (2017) support the present study that in rural area, food consumption was more for cereals, pulses, milk and milk products and sugars. Toor (2015) also observed maximum were spent on milk and milk products, followed by on wheat. The absolute level of per capita expenditure on all items of consumption was fairly higher for the service category households as compared with those of self-employed category households. The total per capita expenditure, were higher for service category households as compared to self-employed category households.

Per capita monthly consumption expenditure of non-food items: There was on an average Rs. 985 per capita monthly expenditure on the consumption of non-food items. Out of this, maximum expenditure of 23.8 per cent was on education which was a good sign for human development. This was followed by 18.9 percent on fuel and lighting and 16.1 per cent on health and medicine. Gupta (2016) observed that the contribution of miscellaneous goods and services and durable goods which has increased significantly in rural areas. The share of fuel and light and pan and tobacco and intoxicants has decreased in rural areas. Rao (2015) concluded that the people with higher incomes may spend relatively more on children's education, to shape their future in a better way. Educational and health consciousness were on the upward movement in rural areas. Biji (2017) observed that people spend more on durable goods, medicine and conveyance were second and third largest expenditure in rural Kerala.

A minimum expenditure was on rent and on purchase of some durable purchased in one year preceding the survey.

The increasing spending on non-food items by sample households showing the improving levels of livings of rural non-farm households. Toor (2015) found that in rural area maximum expenditure of income was on transportation for commuting their workplace followed by on purchase of some durable item and the expenditure on education. In the self-employed category**,** total per capita monthly expenditure on non-food items was worth Rs. 759 per month and maximum expenditure of Rs. 181 was in education, followed by Rs. 140 on fuel and lightning. In service category, total per capita monthly expenditure on non-food items was Rs. 958.3 per month and a highest expenditure was on fuel and lighting, followed by on education .Overall, share of all commodity groups in the total per capita expenditure, were higher for service category households as compared to self-employed category households, except share of education which was slightly high for self-employed category. In self-employed as well as service category signifies the consumption reorientations ushered in by the expanding levels of household incomes. The percentage share of non-food items has also been increasing which shows the better standard of living of rural households.

Comparison between consumption pattern of self-employment and service categories: Most of the food-items such as cereals, gram and pulses, salt and spices were regularly consumed. There were other items such as clothing

Table 3. Per capita monthly consumption pattern of food items

(in Rs.)

RNFA	Wheat	Pulses	Rice	Pickles	Sweets	Beverages	Non-veg	Bread etc.	Fand FD	Sand S	Veg	Tea	Oil	Milk and M. products	Sugar	Total value
SEAF	124	30	11	8	14	16	0	24	32	3	269	33	30	472	40	1107
SECT	105	35	13	4	17	15	2	16	15	4	244	45	24	382	38	958
SEMF	116	35	10	8	17	15	6	17	16	3	211	31	22	391	44	942
SEPT	119	37	9	6	13	13	3	15	10	3	190	29	24	319	40	828
SETR	111	36	11	7	18	21	8	19	18	4	221	33	23	389	44	958
SETS	109	27	6	2	11	13	5	15	9	4	142	22	16	189	39	606
SE	114	33	10	6	15	15	4	18	17	3	213	32	23	357	41	900
%	(12.7)	(3.7)	(1.1)	(0.6)	(1.7)	(1.7)	(0.4)	(2.0)	(1.8)	(0.4)	(23.6)	(3.6)	(2.6)	(39.6)	(4.5)	(100)
SRAF	97	47	12	3	28	22	7	31	15	4	264	40	23	659	50	1301
SRAR	88	40	10	13	25	25	0	25	38	4	228	30	23	532	50	1129
SRAS	121	35	11	6	17	17	6	23	21	4	217	33	22	408	42	982
SRCT	109	34	9	6	14	11	5	16	14	3	198	29	20	355	38	860
SRED	113	40	12	7	19	18	5	26	30	4	263	33	22	534	51	1176
SRFI	98	36	10	8	30	20	1	26	26	4	216	35	22	441	43	1013
SRHS	125	37	12	8	23	22	8	28	35	5	274	38	22	581	46	1261
SRIC	93	32	10	12	18	18	4	20	6	3	250	24	24	487	36	1038
SRMF	114	35	11	6	16	13	3	15	12	4	208	33	24	371	43	906
SROS	117	40	13	17	28	28	17	33	33	5	222	40	30	811	40	1474
SRPD	143	37	10	10	30	28	13	32	33	4	268	35	30	569	45	1286
SRPT	122	35	10	7	26	24	5	29	32	4	260	30	23	526	39	1171
SRRE	116	30	10	5	21	19	7	21	21	2	178	19	23	520	34	1026
SRTR	137	37	14	6	19	19	5	20	22	4	276	32	26	390	47	1052
SRTS	115	37	11	7	15	18	7	18	21	4	204	29	20	435	41	984
SRWS	93	28	10	7	15	19	0	16	5	3	175	25	15	317	33	760
SR	113	36	11	8	21	20	6	24	23	4	231	32	23	496	42	1089
%	(10.3)	(3.3)	(1.0)	(0.7)	(2.0)	(1.8)	(0.5)	(2.2)	(2.1)	(0.3)	(21.2)	(2.9)	(2.1)	(45.6)	(3.9)	(100)
Total Sampled	116	36	11	7	18	18	6	20	19	4	222	32	23	414	43	987
%	(11.8)	(3.6)	(1.1)	(0.7)	(1.8)	(1.8)	(0.6)	(2.0)	(2.0)	(0.4)	(22.5)	(3.2)	(2.3)	(41.9)	(4.3)	(100)

and bedding, footwear, etc., which were not regularly purchased and hence, the number of positive respondents in their case was markedly less among the total sample households. Similarly, expenditure on durable goods, marriage and other social ceremonies was not incurred as regularly as on food items. In both the categories, in case of food items, maximum expenditure was on milk and milk products, vegetables and wheat. The minimum amount was spent on salts, non-vegetarian items and pickles. In case of non-food items, total per capita monthly expenditure on non-food items was worth Rs. 759 per month in the self-employed category. The maximum expenditure was on education, fuel and lighting, health and medicines and minimum expenditure was on rent for the residential accommodation and on purchase of some durable goods in one year preceding the survey. In service category, total per capita monthly expenditure on non-food items was Rs. 958 per month. The highest expenditure was on fuel and lighting, education, health and medicines. On lower side, the minimum expenditure was on rent for the residential accommodation and purchase of some durable goods

Monthly average propensity to consume among the sampled RNFA households: The APC was less than one for all the categories except SEPT and SRIC which indicate that sampled households have the capacity to save some income. The overall APC for all categories was less than unity

Table 4. Per capita monthly consumption expenditure of non-food items

(in Rs.)

Categories	Edu	Durable Good	Social ceremonies	EN	CT	Rand M	HR	CS	Comm.	HC (NI)	C/TC	I and D	Footwear	Sand D	Toiletries	Personal	FandL	Cand B	Total value
SEAF	37	0	12	38	13	7	0	14	26	12	92	6	36	11	5	33	71	82	495
SECT	324	0	14	51	14	11	0	16	29	52	24	14	41	16	7	32	160	87	891
SEMF	214	1	12	29	11	54	0	15	29	84	30	5	42	13	5	33	175	91	844
SEPT	100	0	14	22	11	9	2	13	19	211	19	0	39	12	6	27	154	82	740
SETR	301	2	14	30	11	19	0	16	27	156	34	5	44	13	6	37	192	95	1002
SETS	112	2	29	17	9	30	0	11	23	93	42	5	27	9	4	22	91	62	588
SE	181	1	16	31	12	22	0	14	26	101	40	6	38	12	5	31	141	83	760
%	(23.9)	(0.1)	(2.1)	(4.1)	(1.5)	(2.8)	(0.03)	(1.9)	(3.4)	(13.3)	(5.3)	(0.8)	(5.0)	(1.6)	(0.7)	(4.0)	(18.5)	(10.9)	(100)
SRAF	42	0	14	54	16	10	0	18	25	38	21	7	49	17	7	49	208	111	685
SRAR	0	0	25	38	10	10	0	15	75	25	125	21	63	13	6	52	88	125	690
SRAS	343	2	13	31	11	9	4	15	32	228	43	6	43	13	5	33	193	92	1116
SRCT	65	0	10	29	12	40	1	13	23	122	21	4	38	11	6	36	116	85	632
SRED	382	6	17	37	13	9	4	17	43	252	40	8	48	12	7	40	241	105	1281
SRFI	151	0	41	43	11	33	0	15	40	87	61	9	63	14	7	44	143	134	895
SRHS	380	4	21	49	11	10	0	20	39	235	56	10	59	14	8	44	298	134	1391
SRIC	0	0	8	28	10	46	0	28	70	63	67	0	42	15	6	33	500	100	1015
SRMF	140	1	15	30	12	349	2	15	22	138	20	4	43	12	5	39	151	80	1077
SROS	33	0	14	67	21	14	0	19	33	33	22	28	69	19	7	42	333	167	922
SRPD	482	5	32	39	12	176	0	23	38	169	48	14	53	15	10	62	272	122	1572
SRPT	149	1	24	31	10	8	0	16	42	157	49	13	52	14	9	43	265	116	998
SRRE	128	8	16	20	9	7	0	14	26	59	18	7	48	11	6	36	154	90	655
SRTR	181	0	13	36	13	11	0	18	22	129	22	2	43	17	7	36	184	95	829
SRTS	203	0	16	33	13	19	3	17	30	285	43	7	40	12	7	34	172	91	1024
SRWS	142	0	7	42	11	7	0	14	17	54	14	2	43	11	5	33	68	80	549
SR	176	2	18	38	12	47	1	17	36	130	42	9	50	14	7	41	212	108	958
%	(18.4)	(0.2)	(1.9)	(3.9)	(1.3)	(4.9)	(0.1)	(1.8)	(3.7)	(13.5)	(4.4)	(0.9)	(5.2)	(1.4)	(0.7)	(4.3)	(22.1)	(11.2)	(100)
Total Sample	235	2	16	32	12	63	1	16	29	158	34	6	44	13	6	38	186	95	985
%	(23.8)	(0.2)	(1.6)	(3.2)	(1.2)	(6.4)	(0.1)	(1.6)	(2.9)	(16.1)	(3.5)	(0.6)	(4.5)	(1.3)	(0.6)	(3.8)	(18.9)	(9.7)	(100)

Table 5. Comparison between self-employment and service categories

Per Capita expenditure	SE		SR		Total sampled		t-Test
Items	Average	Percent	Average	Percent	Average	Percent	
Food Items							
Wheat	114	12.7	113	10.3	116	11.8	0.19
Pulses	33	3.7	36	3.3	36	3.6	-1.37
Rice	10	1.1	11	1	11	1.1	-1.02
Pickles	6	0.6	8	0.7	7	0.7	-1.67
Sweets	15	1.7	21	2	18	1.8	-2.64*
Beverages	15	1.7	20	1.8	18	1.8	-2.24*
Non-veg	4	0.4	6	0.5	6	0.6	-0.929
Biscuits and bread etc.	18	2	24	2.2	20	2	-2.31*
Fruits	17	1.8	23	2.1	19	2	-1.25
Salt and spices	3	0.4	4	0.3	4	0.4	-8.09
Vegetables	213	23.6	231	21.2	222	22.5	-1.06
Tea	32	3.6	32	2.9	32	3.2	0.128
Edible oil	23	2.6	23	2.1	23	2.3	0.086
Milk and milk products	357	39.6	496	45.6	414	41.9	-2.45*
Sugar	41	4.5	42	3.9	43	4.3	-0.67
Sub Total	900	100	1089	100	987	100	-2.18*
Non-food Items							
Education	181	23.9	176	18.4	235	23.8	0.076
Durable good	1	0.1	2	0.2	2	0.2	-0.77
Ceremonies	16	2.1	18	1.9	16	1.6	-0.507
Entertainment	31	4.1	38	3.9	32	3.2	-1.22
Consumer tax (Road cess, chowkidari tax, municipal rates, other taxes)	12	1.5	12	1.3	12	1.2	-0.543
Repair and Maintenance	22	2.8	47	4.9	63	6.4	-0.679
House Rent	0	0.03	1	0.1	1	0.1	-0.831
Consumer Services (Services of driver, coachman, cleaner, cobbler, blacksmith, unskilled labourers, etc.)	14	1.9	17	1.8	16	1.6	-1.83*
Communication	26	3.4	36	3.7	29	2.9	-1.54
Health care facilities and medicine	101	13.3	130	13.5	158	16.1	-0.723
Communication and conveyance	40	5.3	42	4.4	34	3.5	-0.137
Intoxicant and drugs	6	0.8	9	0.9	6	0.6	-0.947
Footwear	38	5	50	5.2	44	4.5	-2.88*
Soap and detergent	12	1.6	14	1.4	13	1.3	-1.18
Toiletries	5	0.7	7	0.7	6	0.6	-1.98*
Personal	31	4	41	4.3	38	3.8	-2.89*
Fuel and lightening	141	18.5	212	22.1	186	18.9	-1.54
Cloth and bedding	83	10.9	108	11.2	95	9.7	-2.39*
Sub total	760	100	958	100	985	100	-1.55
Total sampled	1660	-	2047	-	1972	-	-2.16*

Table 6. Average monthly propensity to consume among the sampled RNFA households

RNFA categories	Saving (S)	APC=C/Y
SEAF	2248.72	0.772
SECT	5023.39	0.652
SEMF	1011.55	0.909
SEPT	-625.29	1.097
SETR	121.19	0.987
SETS	1144.92	0.853
SE	1487.5	0.850
SRAF	4053.33	0.686
SRAR	6481.33	0.529
SRAS	3283.42	0.751
SRCT	4118.09	0.662
SRED	13530.43	0.471
SRFI	6644.06	0.540
SRHS	11792.85	0.494
SRIC	-2515.75	1.325
SRMF	1353.98	0.875
SROS	7311.67	0.496
SRPD	16892.02	0.430
SRPT	20198.52	0.357
SRRE	12925.31	0.450
SRTR	902.16	0.901
SRTS	6186.82	0.611
SRWS	274.83	0.969
SR	7089.6	0.575
Total sampled	4260.82	0.693

Y=Average income level, C=Average consumption expenditure, S=Average saving level, APC=Average propensity to consume (C/Y

(0.693) i.e. around 70 per cent. Out of the 22 categories, only 2 categories have negative savings. Rest of the categories have positive savings, which shows higher level of income earned and the better employment opportunities available in the rural non-farm sector. There were more savings in service category and less saving in self-employed category, in relation to the level of average income. The accrual of savings in service category was directly attributable to higher income which was made possible due to better employment opportunities in the non-farm sectors.

Chand et al (2017) analysed that the service sector in rural areas witnessed deceleration in output as well as employment after 2004-05and was due to increased reliance of rural consumers on service providers located in urban areas. Kadrolkar (2014) pointed that self-employed units were employing both hired and family labourers. Only 50% of the self-employed units have sustained for 5 years. Thus, modern service sector are more income generating, in comparison to the self-employed sector.

Distribution of per capita consumption expenditure of RNFA: Ginni coefficient was used to analyze the level of inequality prevailing among the sampled household. The total consumption expenditure was unevenly distributed among the various docile groups. The bottom 10 per cent household members have only 4.04 per cent share of total per capita consumption expenditure.

Furthermore, comparing the shares of bottom and top 50 per cent household members' share in total consumption expenditure, the bottom 50 per cent household members account only 30.64 per cent of total per capita consumption expenditure, whereas top 50 per cent get more than double the share, i.e. 69.36 per cent of total per capita consumption,

Table 7. Distribution of per capita consumption expenditure of RNFAs

	Cumulative percentage persons												Remaining categories	All sampled categories
	SEMF	SEPT	SETR	SRAS	SRCT	SRMF	SRPD	SRPT	SRTS	SRED	SRHS	SRTR		
10	5.15	4.42	4.0	2.62	5.40	3.73	3.28	2.99	3.76	1.48	3.56	3.0	7.37	4.04
20	11.37	9.76	9.3	6.83	11.84	8.74	7.02	9.07	8.22	5.18	9.20	6.4	16.44	9.40
30	18.53	15.61	15.2	11.92	19.44	14.26	11.66	15.62	12.96	9.0	15.68	10.3	23.20	15.72
40	26.26	22.33	22.0	18.63	28.22	20.44	17.63	24.40	20.41	13.3	22.31	14.4	35.82	22.76
50	34.97	29.71	29.7	25.93	37.44	26.98	23.92	34.42	28.80	18.3	29.55	18.7	45.19	30.64
60	44.64	38.24	38.6	34.54	47.38	33.72	31.18	44.81	37.98	24.2	37.55	31.2	55.22	39.86
70	56.05	46.94	48.5	44.19	58.16	40.89	38.74	55.56	48.67	36.5	45.66	45.1	66.80	50.38
80	69.34	56.62	59.9	55.05	70.02	49.53	51.19	66.88	61.23	52.5	53.91	60.4	77.06	62.23
90	82.26	68.64	73.4	69.08	83.81	63.67	64.94	81.02	78.52	74.3	74.08	77.8	90.20	76.5
100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Ginni Coefficient	0.20	0.31	0.29	0.36	0.17	0.37	0.40	0.23	0.29	0.43	0.31	0.37	0.065	0.276

which shows a highly inequitable distribution of consumption expenditure among the sampled non-farm household members. Nearly half of the consumption expenditure was shared by around 70 per cent of the bottom household members and remaining half of the consumption expenditure was shared by top 30 per cent of the persons only. For all the sampled non-farm household categories, the Gini coefficient was 0.276. Hence, it can be concluded that a high degree of inequality exists among the sampled household members as far as distribution of consumption among them was concerned.

CONCLUSIONS

The absolute level of per capita expenditure on all items of consumption was fairly higher for the service category households as compared with those of self-employment category households. Across all the 22 categories, the maximum average monthly consumption expenditure was observed in the households of the Public Administration and Defense (SRPD) household category, followed by Human Health and Social Work (SRHS) household category. The minimum per capita average monthly consumption expenditure was observed for transportation and storage (SETS) and water supply (SRWS) household category. A person, on an average, spends a half of average monthly expenditure on food. Hence, it can be concluded that inequality exists among the sampled household members as far as distribution of consumption among them was concerned.

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Does India Achieve Agenda 2030 Targets: A Multiple Lens Analysis

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Abstract: The study compares three most prominent methods to measure Sustainable Development Goals performance at the country and state-level. By using indicator approach and statistical weight method, performance of State and Union Territories was assessed towards Sustainable Development. The study results suggest a strong discrepancy in existing methods, depending on the chosen indicators and methods applied, states can receive substantially different relative evaluations. The differential results highlight the constraints and opportunities for States/UTs that are lagged behind the national targets. Out of 36 States/UTs 14 are show relatively decline social status compare to 2018 in 2019.Our findings suggest that several SDG indicators could be refined in term of their wording, and their underlying objective could be further clarified. The findings also point out potential pitfalls in interpreting progress on the SDGs, since different evaluation methods can lead to different conclusions. Lack of progress in attaining any one of these latter goals, such as climate action may on its own be sufficient to constrain future progress towards all other SDGs.

Keywords: SDGI Index, Differential methodologies, Regional analysis, Sustainable development

The Sustainable Development Goals (SDGs) is a fitting framework that calls attention to the challenges to a sustainable future and organizes individual and collective responses (United Nations 2018). The overall picture of the SDGs is a set of goals; all are seriously relevant and needed as guidance for attaining Sustainable Development (UNIRISD 2016). India, home to one-sixth of all humanity, is recognizant of its role and responsibility in working towards a sustainable future of the planet and all its life (UNDP 2019). The SDG India Index (SDGII), in this direction, provides a holistic assessment of status, challenges, and opportunities in the path of Sustainable Development. The SDGII- 2018 and SDGII- 2019 reveal that States belonging to the Himalayan region is least performing, except Himachal Pradesh, while states belonging to plains regions are the front runners. A significant improvement in goal- 6 is largely driven by the success of the *'Swatch Bharat Abhiyaan'* in eliminating open defecation. Improvement in goal- 7 can be credited to the extensive coverage of LPG for households and saturation of electricity connections. The progress recorded under goal- 9 can be largely attributed to the improvement in rural road coverage, and higher mobile and internet penetration. However, when we see India's commitment towards Agenda 2030 by a critical lens, we find that in 2019, India's score has 60 out of 100. With social and economic obstacles, Goals; No Poverty, Zero Hunger and Good Health & Well-being are to be dealing with a holistic socioeconomic development initiative. In India, more than 20% of the population is living under extreme poverty without any social protection programme (NITI Aayog 2019).

As far as health status is concern, more than 60% of women finds hardship to get any maternity benefits, 40%of children aged under five are stunted, and 50% of pregnant women are anaemic(NFHS 2016).Similarly, Goals; Clean Water and Sanitation and Affordable and Clean Energy are proactively deal with health. The recent report of National Sample Survey Organization (NSSO 2016) highlights that the major source of drinking water has *hand pump* (untreated water), i.e., about 42.9% of rural population using *hand pump* as a principle source of drinking water. Further, about 18.01% of the Development Blocks (administrative unit) in the country are over-exploited to ground water (NITI Aayog 2019). As far as goal; affordable and clean energy is concern, India's total primary energy demand is expected to grow by 63% by 2030, while India's contribution to world energy-related carbon dioxide (CO_2) emission is also expected to rise from 6.7% to 10%. The lack of sufficient human resources, capabilities and funds for supporting renewable energy is a critical challenge. Further, expanding the supply of electricity at a faster rate to meet the current and future demands of industry, commerce, and households is another challenge (NITI Aayog 2019).

Aforesaid, evidences reveal that the India needs a holistic approach to deal with inadequate access to resource, poverty, unemployment and energy demand in such a way, where each and every actor has their own targets and

accountability to achieve the targets within a time-frame for Sustainable Development. The present study aims to compares three most prominent methods to measure SDGs performance at the country and state level. Study highlights crucial weaknesses that should be addressed to provide a context-dependent analysis to measure SDGs performance. The study results suggest a strong discrepancy in existing methods, depending on the chosen indicators and methods applied, states can receive substantially different relative evaluations. The remainder of the paper is organized as follows. Section 1 highlights the nexus of natural disasters and sustainable development goals (SDGs); Section 2 provides methods and material compassing data and analytical tools used; Section 3 presents the results of the study, while Section 4 summarizes conclusion and policy implications.

MATERIAL AND METHODS

The present study uses secondary data obtained from the National Institution for Transforming India (NITI Aayog) for the years, i.e., 2018 and 2019. In order to coordinate all the SDGs effects at the national and sub-national levels, NITI Aayog acts as the nodal institution in India. At the same time, owing to the federal structure of the country, the States/ Union Territories play a significant role in ensuring the success of the SDG agenda. Withholding 17% world's population, India is facing multiple challenges in several sectors of development, be it health, nutrition, education, sanitation, and infrastructure. Therefore, to track the progress, identifying priority areas, facilitate peer learning, highlight data gaps, and promote healthy competition among the actors, a “Sustainable Development Goals India-Index (SDGII)” was developed for 2018 and 2019. The SDGII- 2018 was the first effort by the Government of India and perhaps anywhere globally to rank sub-national governments by computing composite index on SDGs. It is constructed using 62 indicators, covers 54 targets across 13 goals out of 17 SDGs (leaving out Goals 12, 13, 14, and 17). The SDG India Index is intended to provide a holistic view on the social, economic and environmental status of the country and its States and UTs.

Estimation Method: The SDGII- 2018 and 2019 were developed using equal weights methodology to assess the status and performance of states and Union Territories (UTs), which is not a correct methodology. India has diverse socioeconomic and demographical profile, and even access of sanitation, affordable energy also inadequately distributed across the States and UTs. In other words, equal weights provides biased results. Hence, the present study has given judicious weights using statistical techniques (Table 1). Further, SDGs are reclassified into three mainstream SDGs, i.e., social, economic and environmental (Table 2). The modified methodology can help in identifying human populations at major risks, and as a result, resources can be targeted towards those most in need. These goals are selected as representatives of focal policy objective, and a stepwise method for addressing livelihood security, development linkages, and the economic, social and environmental dimensions (Singh and Nayak 2020). Using Iyenger and Sudharshan (1982) and Singh (2020) methodology, indicators were first normalized to the scale of zero (0) and one (1), premised on their functional relationship with the dimension. The indicator has positive relationship with SDGs, then equation (1) was employed.

$$Y_{ij} = \frac{K_{ij} - Min\,(X_{ij})}{Max\,(X_{ij}) - Min\,(X_{ij})} \qquad (1)$$

Where, Y_{ij} is the index for the i^{th} indicator related with j^{th} State, K_{ij} is the actual/observed value of i^{th} indicator for the j^{th} State, Max (X_{ij}) and Min (X_{ij}) is the maximum and minimum value of i^{th} indicator among all the L (I= 1……36) States, respectively. If the indicator has negative functional relationship with SDG, then equation 2 was employed.

$$Y_{ij} = \frac{Max\,(X_{ij}) - K_{ij}}{Max\,(X_{ij}) - Min\,(X_{ijk})} \qquad (2)$$

Weight

The assignment of appropriate weight for different components is an important issue in the construction of an index. Therefore, using equation (3 & 4), weights were calculated.

$$[W_i = \frac{K}{\sqrt{Var\ (Cid)}}] \qquad (3)$$

$$[K = \frac{1}{\left\{\frac{1}{\sum_{i=1}^{n}\sqrt{Var\ (Cid)}}\right\}}] \qquad (4)$$

Where, 'W_i' denotes the weight, Var (Cid) is variance of Y_{ij} Weight is multiply in the index value calculated in equation 1 or 2 as follows.

$$Z_j = \frac{\sum_i^k Y_{ij} * W_i}{\sum_i^k W_i} \qquad (5)$$

Z_j is the index score for the j^{th} State; W_i is the weight corresponding to i^{th} indicator; k is the total number of indicators; and $\Sigma^k_i W_i$ is the summation of weights. The index value close to zero (0) shows lower Sustainable Development status and the index value close to one (1) shows higher Sustainable Development.

RESULTS AND DISCUSSION

The validation of index has foremost task for framing development policies. Hence, this sudy compares

Table 1. Indicators and sub-components, weight assigned for indicators and sub-components for Sustainable Development Goals Index

Sub-components	Indicators	Direction	Sub-component weight (%)
No poverty	Population living below National Poverty line (%)	Negative	10
	Households with any usual member covered by any health scheme or health insurance (%)	Positive	
	Persons provided employment as a percentage of persons who demanded employment under MGNREGA (%)	Positive	
	Proportion of the population (out of total eligible population) receiving social protection benefits under Maternity Benefit	Positive	
Zero hunger	Ratio of rural households covered under public distribution system to rural households where monthly income of highest earning member is less than Rs.5,000	Positive	10
	Children under age 5 years who are stunted (%)	Negative	
	Pregnant women aged 15-49 years who are anaemic (11.0g/dl) (%)	Negative	
	Rice, wheat and coarse cereals produced annually per unit area (Kg/Ha)	Positive	
Good health-being	Maternal Mortality Ratio	Negative	10
	Under-five mortality rate per 1,000 live births	Negative	
	Children aged 12-23 months fully immunized (BCG, Measles and three doses of Pentavalent vaccine) (%)	Positive	
	Annual notification of Tuberculosis cases per 1 lakh population	Negative	
	Number of governmental physicians, nurses and midwives per 1,00,000 population	Positive	
Quality	Adjusted Net Enrolment Ratio at Elementary (Class 1-8) and Secondary (Class 9-10) school (%)	Positive	5
	Correct responses on Learning Outcomes in Language, Mathematics and EVS for Class 5 students (%)	Positive	
	Correct responses on Learning Outcomes in Language, Mathematics, Science and Social Science for Class 8 students (%)	Positive	
	Children in the age group of 6-13 who are out of school (%)	Negative	
	Average Annual Drop-out rate at secondary level (%)	Negative	
	School teachers professionally qualified (%)	Positive	
	Elementary and secondary schools with Pupil Teacher Ratio less than/equal to 30 (%)	Negative	
Gender equality	Sex Ratio at Birth (female per 1000 male)	Positive	5
	Average female to male ratio of average wages/salaries received per day by regular wage/salaried employees of age 15-59 for rural and urban	Positive	
	Married women aged 15-49 who have ever experienced spousal violence (%)	Negative	
	Seats won by women in the general elections to state legislative assembly (%)		
	Ratio of Female Labour force participation rate to Male Labour force participation rate	Positive	
	Women in the age group of 15-49 years using modern methods of family planning (%)	Positive	
Clean water and sanitation	Population having safe and adequate drinking water in rural areas (%)	Positive	10
	Rural households with individual household toilets (%)	Positive	
	Districts verified to be Open Defecation Free (%)	Positive	
	Installed sewage treatment capacity as a proportion of sewage created in urban areas (%)	Positive	
	Annual ground water withdrawal against net annual availability (%)	Positive	
Affordable and clean	Households electrified (%)	Positive	5
	Households using Clean Cooking Fuel (%)	Positive	
	Renewable share of installed generating capacity (%)	Positive	
Decent work and economic	Annual growth rate of GDP per capita (at constant price of 2011-12)	Positive	5
	Average unemployment rate per 1000 persons for males and females	Negative	
	Households with a bank account (%)	Positive	
	Number of ATMs per 1,00,000 population	Positive	

Cont...

Table 1. Indicators and sub-components, weight assigned for indicators and sub-components for Sustainable Development Goals Index

Sub- components	Indicators	Direction	Sub-component weight (%)
Industry, innovation and infrastructure	Targeted habitations connected by all-weather roads under Pradhan Mantri Gram SadakYojana (%)	Positive	10
	Number of mobile connections per 100 persons in rural and urban area (Mobile Tele density)	Positive	
	Number of Internet Subscribers per 100 population	Positive	
	Gram Panchayats covered under Bharat Net (%)	Positive	
Reduced inequality	Palma Ratio of Household Expenditure in Urban India	Positive	4
	Palma Ratio of Household Expenditure in Rural India	Positive	
	Ratio of Transgender Labour force participation rate to Male Labour force participation rate	Positive	
	Scheduled Caste Sub Plan fund utilised (%)	Positive	
	Tribal Sub Plan fund utilised (%)	Positive	
Sustainable cities and communications	Houses completed under PMAY as a percentage of net demand assessment for houses	Positive	8
	Urban households living in slums (%)	Negative	
	Wards with 100% door to door waste collection (%)	Positive	
	Waste processed (%)	Positive	
Life on land	Total land area covered under forest (%)	Positive	10
	Decadal change in extent of water bodies within forests from 2005 to 2015 (%)	Positive	
	Change in forest area from 2015 to 2017 (%)	Negative	
	Change in estimated population of wild elephants over 5-year period (%)	Negative	
Peace, justice and strong institutions	Reported murders per 1 lakh population	Negative	8
	Reported cognizable crimes against children per 1 lakh population	Negative	
	Estimated number of courts per 10 Lakh persons	Negative	
	Estimated reported corruption crimes per 10 million population	Negative	
	Births registered (%)	Positive	
	Population covered under Aadhaar (%)	Positive	

Source: Author's Calculations, 2020.
Note: Negative indicates negative relationship with SDGI and positive indicates positive relationship with SDGI.

Table 2. Indicators and sub-components, weight assigned for indicators and sub-components for Sustainable Development Goals Index

Indicator	Sub- components	Direction	Sub-component weight (%)
Economic	No poverty	Positive	34
	Zero hunger	Positive	
	Good health and weil-being	Positive	
	Decent work and economic growth	Positive	
	Industry, innovation and infrastructure	Positive	
Environmental	Clean water and sanitation	Positive	23
	Affordable and clean energy	Positive	
	Life on land	Positive	
Social	Quality education	Positive	43
	Gender equality	Positive	
	Reduced inequality	Positive	
	Sustainable cities and communities	Positive	
	Peace, justice and strong Institutions	Positive	

Source: Author's estimation, 2020

methodologies evolved over a period of time (Table 3). Each methodology has its own implications. Firstly, Iyenger and Sudarshan (1982) were determined the functional relationship of a respective indicator with targeted index (column 1). They have developed a scientific method to calculate weight for respective indicator. Secondly, NITI Aayog, was developed a new methodology by introducing *T* function (targeted value) keeping in consideration of Agenda 2030 (column 2). Further, Aayog uses equal weight to all indicators and uses the arithmetic mean for the final composite index.

However, the validity of aforesaid methods always questioned. There are five major research gaps were identified that questioned the validity of Indices of SDGII as follows. First, the index does not measure indicators of SDG 17 owing to the unavailability of suitable data at the State/UT level. Second, the indicators and data from State/UT statistical systems and non-government sources have not been included, to ensure data comparability and uniformity across them. Third, assigning equal weights to the indicators. Fourth, mismatched in the indicators, viz., 62 in SDGII- 2018, and 100 in SDGII- 2019. Lastly, for some indicators, data for all States/UTs are not available. Hence, we have developed a new innovative methodology. Our methodology has features of both previous methodologies: (i) scientific weight for each indicator, (ii) use of the arithmetic mean for final indexing, and (iii) index value ranges between 0-100 (column 3).

Validation of Sustainable Development Goals India Index (SDGII)

This section compares the performance of States and UTs by combing all 13 SDGs and 62 indicators (Table 4). The composite indices revealed that Himachal Pradesh was topped on the position, while Uttar Pradesh was bottomed as per the NITI Aayog method. However, the calculated results from Iyenger and Sudarshan (1982) method revealed that Kerala has a secure top position (rank 1), while Meghalaya remains the bottom line. While, the present study's results also revealed that Kerala has the top position, while Assam remains the bottom line. The differential results highlight the drawbacks of the methodology used by NITI Aayog.

Tracking the Performance of SDG India Index

Though, the SDGII- 2018 and SDGII- 2019 are not comparable. Because in SDGII- 2018, 62 indicators and 13 goals were undertaken, while in SDGII- 2019, 100 indicators and 16 goals undertaken. Table 5 highlights the comparative performance of India's commitment to sustainable development by 2030. The composite score for India improved, from 57 in 2018 to 60 in 2019. This indicated that the country has overall progressed forward in its journey towards achieving the SDGs. Five Goals drive the positive push: Goal- 6(clean water and sanitation), Goal- 7 (affordable and clean energy), Goals- 9 (industry, innovation, and infrastructure), Goal- 15 (life on land) and Goal- 16 (peace, justice, and strong institutions), where India has scored between 65 and 99. Goals; Zero Hunger and Gender Equality demand special attention, as the overall country score is below 50.

As far as the performance of State/UTs is concern, the top three states in overall improvement deserve special attention, viz., Uttar Pradesh, Odisha, and Sikkim. Uttar Pradesh had improved its overall score from 42 in 2018 to 55 in 2019, and it is the highest gainer. The biggest improvement

Table 3. Deferent methodologies of indexing

Direction	Iyenger and Sudarshan (1982)	NITI Aayog Methodology	Modified Methodology
	1	2	3
Positive	$x' = \frac{x - Min(x)}{Max(x) - Min(x)}$	$x' = \frac{x - \min(x)}{T(x) - Min(x)} * 100$	$x' = \frac{x - Min(x)}{Max(x) - Min(x)} * 100$
Negative	$x' = \frac{Max(x) - x}{Max(x) - Min(x)}$	$x' = [1 - \frac{x - T(x)}{\max(x) - T(x)} * 100$	$x' = \frac{Max(x)}{Max(x) - Min(x)} * 100$
Weight	$\left[W_i = \frac{K}{\sqrt{Var(Cid)}} \right]$	Equal weight for all indicators	$[W_i = \frac{K}{\sqrt{Var(Cid)}}]$
	$[K = \frac{1}{\left\{ \frac{1}{\sum_{i=1}^{n} \sqrt{Var(Cid)}} \right\}}]$		$[K = \frac{1}{\left\{ \frac{1}{\sum_{i=1}^{n} \sqrt{Var(Cid)}} \right\}}]$
Range	0-1	0-100	0-100
Final indexing	Summation	Arithmetic Mean	Arithmetic Mean

Source: Author's calculation, 2020

has been in Goal-7 (affordable and clean energy), where the jump has been by 40 points. Scores in Goal- 6 (clean water and sanitation) and Goal- 9 (industry, innovation, and infrastructure) have climbed by 39 and 34 points, respectively. Further, Odisha stands second in overall improvement, with an increase of 7 points, from 51 to 58.

Table 4. Comparison of NITI Aayog, Iyenger and Sudarshanand modified methodologies

State	Iyenger and Sudarshan (1982)	Rank	NITI Aayog method	Rank	Modified method	Rank
Kerala	0.464	1	69	2	51	1
Manipur	0.370	12	59	17	44	2
Chandigarh	0.426	2	68	3	44	3
Tamil Nadu	0.391	6	66	4	43	4
Mizoram	0.377	9	59	16	43	5
Karnataka	0.395	5	64	9	43	6
Pondicherry	0.376	10	65	5	43	7
Goa	0.406	3	64	6	43	8
Himachal Pradesh	0.397	4	69	1	43	9
Gujarat	0.368	14	64	7	42	10
Punjab	0.386	7	60	15	41	11
Uttarakhand	0.379	8	60	14	41	12
Chhattisgarh	0.366	16	58	20	41	13
Tripura	0.362	18	55	25	41	14
Maharashtra	0.367	15	64	10	40	15
Haryana	0.359	21	55	26	40	16
Rajasthan	0.363	17	59	18	40	17
Arunachal Pradesh	0.362	20	51	32	40	18
A & N Islands	0.373	11	58	19	39	19
West Bengal	0.353	23	56	24	39	20
Sikkim	0.354	22	58	21	39	21
Andhra Pradesh	0.362	19	64	8	38	22
Delhi	0.369	13	62	12	38	23
Daman and Diu	0.352	24	63	11	37	24
Jharkhand	0.335	29	50	33	37	25
Madhya Pradesh	0.337	26	52	29	37	26
Odisha	0.337	27	51	30	36	27
Lakshadweep	0.330	31	57	22	36	28
Telangana	0.334	30	61	13	36	29
Jammu and Kashmir	0.341	25	53	27	36	30
Meghalaya	0.305	36	52	28	35	31
Nagaland	0.314	34	51	31	35	32
Bihar	0.318	33	48	35	34	33
Uttar Pradesh	0.321	32	42	36	34	34
D & N Haveli	0.335	28	57	23	34	35
Assam	0.312	35	49	34	34	36
India	0.361		57		39	

Source: Author's Calculation (2020)

Table 5. Performance of SDG India Index

States/UTs	2018	Rank	2019	Rank
Andhra Pradesh	64	8	67	4
Arunachal Pradesh	51	32	53	34
Assam	49	34	55	31
Bihar	48	35	50	36
Chhattisgarh	58	20	56	29
Goa	64	6	65	9
Gujarat	64	7	64	11
Haryana	55	26	57	26
Himachal Pradesh	69	1	69	3
Jharkhand	50	33	53	34
Karnataka	64	9	66	7
Kerala	69	2	70	1
Madhya Pradesh	52	29	58	23
Maharashtra	64	10	64	11
Manipur	59	17	60	20
Meghalaya	52	28	54	33
Mizoram	59	16	56	29
Nagaland	51	31	57	26
Odisha	51	30	58	23
Punjab	60	15	62	16
Rajasthan	59	18	57	26
Sikkim	58	21	65	9
Tamil Nadu	66	4	67	4
Telangana	61	13	67	4
Tripura	55	25	58	23
Uttar Pradesh	42	36	55	31
Uttarakhand	60	14	64	11
West Bengal	56	24	60	20
A and N Islands	58	19	61	17
Chandigarh	68	3	70	1
D and N Haveli	57	23	63	14
Daman and Diu	63	11	61	17
Delhi	62	12	61	17
Jammu and Kashmir	53	27	59	22
Lakshadweep	57	22	63	14
Pondicherry	65	5	66	7
India	57		60	
Target	100		100	

Source: Author's Calculation, 2020

Goal- 9 (Industry, Innovation, and Infrastructure) has contributed most to the rise with a jump of 40 points. Goal- 6 and 7 follow, with an increase of 39 and 27 points, respectively.

Sikkim is the third-best State in overall improvement: from a score of 58 to that of 65, indicating an increase by 7 points. The State has achieved commendable improvement in goal- 7 where it has recorded an increase by 55 points. In goal- 9, Sikkim has made a jump of 26 points. Performance in goal- 11 (sustainable cities and communities) has been by 18 points, which is the third biggest contributor to Sikkim's improvement.

Identifying Vulnerable Areas: Social, Economic and Environmental Perspective

In order to understand the extent and dimensions, the present study asserts here that an important starting point for this is a reconceptualization of the current SDG framework, whereby the environmental goals, i.e., 6, 7 & 15, are recognized as a necessary precondition for achieving sustainable development. While a comprehensive list of goals, i.e., 1, 2, 3, 8 & 9 (economic development) has helped the SDGs become more precise and quantifiable than their Millennium Development Goals (MDGs) predecessors. The goals, i.e., 4, 5, 10, 11 & 16, highlight the social status of the society. The SDGs cover multidimensional issues in which Healthy Ecosystems; Clean Energy; Food Security; Water Security; Lives and Livelihood; and Governing for Sustainability are equally mobilizing to achieve steady economic growth. Healthy ecosystems support these development areas analogously to a tree whose branches depend upon its roots for survival and growth; serving the branches and trunk from the roots of a tree necessarily seals its fate. In much the same way, we assert that social and economic goals cannot be attained wholly independent from their environmental underpinning.

Table 6 depicts that two (2) Union Territories (Pondicherry and Chandigarh) and one (1) State (Himachal Pradesh) is the best performer among the States/UTs. Pondicherry ranked first in economic development, while Chandigarh ranked topped in environmental protection. As far as social development is concern, Himachal Pradesh ranked first among the States. The differential results highlight the constraints and opportunities for States/UTs that are lagged behind the national targets. Out of 36 States/UTs 14 are show relatively decline social status compare to 2018 in 2019.Similarly, 25 states show relatively decline economic status compare to 2018 in 2019. Finally, environmental status broughtin limelight past 30 years. It was observed that all 36 States/UTs reported decline in environmental status.

Table 6. Differential performance of SDGs

States/UTs	Economic		Environmental		Social	
	2018	2019	2018	2019	2018	2019
Andhra Pradesh	65	59	89	56	56	62
Arunachal Pradesh	47	47	78	45	47	49
Assam	48	46	79	40	47	50
Bihar	43	44	66	39	49	49
Chhattisgarh	47	45	82	58	55	59
Goa	61	59	90	57	59	63
Gujarat	63	59	81	60	61	60
Haryana	60	56	66	43	57	52
Himachal Pradesh	63	59	79	63	75	71
Jharkhand	49	42	76	42	53	56
Karnataka	55	61	88	57	60	59
Kerala	74	72	82	49	66	67
Madhya Pradesh	45	41	83	53	57	51
Maharashtra	57	56	87	59	59	62
Manipur	49	58	86	46	57	58
Meghalaya	49	53	74	36	49	53
Mizoram	49	52	79	54	52	60
Nagaland	41	40	80	45	51	57
Odisha	55	49	78	42	51	51
Punjab	63	61	74	47	61	58
Rajasthan	50	54	71	44	59	63
Sikkim	57	48	92	56	63	57
Tamil Nadu	65	66	90	57	61	58
Telangana	59	54	88	50	65	64
Tripura	58	54	71	39	47	58
Uttar Pradesh	46	40	73	33	52	43
Uttarakhand	59	51	88	58	60	60
West Bengal	60	56	76	46	54	53
A and N Islands	44	43	81	53	63	66
Chandigarh	63	58	92	70	66	64
D and N Haveli	60	35	90	68	55	57
Daman and Diu	55	48	89	67	58	62
Delhi	65	67	80	48	57	56
Jammu and Kashmir	54	50	78	46	51	51
Lakshadweep	43	43	71	65	55	54
Pondicherry	68	77	73	39	68	62
India	55	52	75	51	58	55
Target	100	100	100	100	100	100

Source: Author's calculation, 2020

CONCLUSION

This paper began by asking how useful the SDGs are informing country and sub-national-level empirical analysis across the key dimensions, viz., social, economic and environment. We compare the mainstream methodologies and came out the reliable, easy to use robust methodology to track the progress of India's Sustainable Development journey. We have collected a reliable literature from mainstream online databases to identifying the obstacles and opportunities to achieve Agenda 2030. A total 62 indicators and 13 goals were compared at sub-national (i.e., state) levels using 2018 and 2019 data. The study results suggest a strong discrepancy in existing methods, depending on the chosen indicators and methods applied, states can receive substantially different relative evaluations. The differential results highlight the constraints and opportunities for States/UTs that are lagged behind the national targets. Out of 36 States/UTs 14 are show relatively decline social status compare to 2018 in 2019. As far as policy implications are concern, our findings suggest that several SDG indicators could be refined in term of their wording, and their underlying objective could be further clarified. The findings also point out potential pitfalls in interpreting progress on the SDGs, since different evaluation methods can lead to different conclusions. Lack of progress in attaining any one of these latter goals, such as climate action may on its own be sufficient to constrain future progress towards all other SDGs.

Overall progress has occurred simultaneously towards goals that are largely associated with “economic” or “social” aims, whereas there has been less success in attaining “environmental” SDGs. The decline in environmental goals may constrain or undermine progress towards achieving sustainable development, even with improvement in economic and social goals in the future. Long-term data are not available for most of the indicators which are necessary for more accurate projections of future trends. This would simply create homogeneous outline and access at national level. For the same reason, we were unable to perform any statistical analysis. In future, analysis and freely available data at state and district level should be prepared and maintained, both for general awareness and scientific research purposes. Also, enough data should be generated to redesign policy framework or restructure governance in accordance with scientific findings.

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Using *Imperata cylinderica* as Natural Low-Cost Biosorbent for Rapid and Efficient Removal of Zinc(II) Ions from Aqueous Solutions

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***Abstract*:** Zinc in lower quantities is considered as toxic affecting on the human health. The *Imperata cylinderica* was collected from the farmland abandoned as agricultural waste as an adsorbent to Zinc(II) ions adsorption from aqueous solution by utilizing Fourier transforms infrared spectroscopy, EDX spectra and electron microscopic scanning (SEM) of cylinderica. Simulating aqueous solution was used in batch experiments, the tests completed in ideal statuses of pH, initial Zinc (II) ions concentration, contact time and adsorbent dosage. The Langmuir, Freundlich, Temkin and Harkins-Henderson isotherm models were tested and isotherm models constants (which represented the adsorption efficiency) were 0.99, 0.95, 0.92 and 0.94, respectively. The Langmuir model was more suitable for describing the adsorption process than the other models. The kinetics results were, 0.989 for Pseudo-first-order, 0.947 for Pseudo-second order, 0.969 for Intra particle diffusion study and 0.905 for the Elovich model. Pseudo-first-order kinetic equation best described the kinetics of the reaction. The thermodynamics study affect temperature changes on the parameters of thermodynamic like change in free energy ($\Delta G°$), enthalpy ($\Delta H°$) and n entropy ($\Delta S°$). The study indicates that *Imperata cylinderica* is an appropriate adsorbent to rid Zinc ions from wastewater.

Keywords: Adsorption, *Imperata Cylinderica*, Isotherm, Kinetics, Thermodynamic, Zinc(II) ions

Many toxic heavy metals have been discharged into the environment as industrial wastes, causing serious soil and water pollution. Discharging the heavy metal to aquatic ecology occur from different sources like plastics effluents, pesticides, fertilizers uses, microelectronics, textiles industry, wood preservatives industries producing, metal smelters and tanning industries. The bed rock also consists of the toxic metals. Many industries containing oil refining, textile industry, metal plating facilities, electroplating, mining operations, pigments and dyes manufacturing, fertilizer, and batteries produce heavy metals. There are toxic pollutants from heavy metals in industrial aqueous solutions like copper, lead and zinc and key contaminant the groundwater. Plants and animals needs the zinc element in high concentration and is toxic at ≥3000ppm and act as animals poison and photosynthesis impairment, chlorosis of leaf and inhibition of root growth in plants . Acid Mine drainage effluent wastewater contain zinc ions, natural zinc ores in addition to municipal discharges of wastewater treatment, galvanizing factories, and galvanized structures leachate also contribute Zinc pollution. Thus, zinc rid from industrial wastewater is most significant.

Conventional processes that used to remove the zinc ions from wastewater were very costly and inefficient in low quantities of zinc in solution. Chemical precipitation is most significant process using to remove or reduce the metal concentrations in industrial wastewater followed by ion-exchange, electro dialysis and ultra-filtration. Different researches have removed the toxic metal ions by use biological and physicochemical processes. The main factor to select the adsorbent substances is the cost. Generally, assume that adsorbent should be natural available, by-product, waste substance from agriculture or industrial activities and low-cost. There are many low-cost materials used for adsorption Zinc ions like, Bagasse fly ash, natural zeolite, purified carbon nanotubes, synthetic nanocrystalline akaganéite pulp waste, succinyl-grafted chitosan, Faba bean. In the present work, *Imperata cylinderica* as a novel and natural plant adsorbent, examined for the removal of Zinc (II) ions from aqueous solutions.

MATERIAL AND METHODS

Procedure: From roadsides in Baghdad city and the abandoned farmland was collected the *Imperata cylinderica* as agricultural waste and was washed, dried, crushed and milled to mesh size between 150-210 µm for experimental using. The predetermined amount of zinc chloride was dissolving in 1 L of distilled water, prepared a typical solution of Zinc (II). For preparation of the required concentration samples, diluting the stock solution used in experiments was done. Utilizing 1 M NaOH or 1 M HCl for adjusted the pH of the experimental solutions. By atomic absorption

spectrophotometer (Varian AA220) was determined concentration of residual zinc (II) in the liquid solution. The chemicals utilized were of analytical grade. Firstly, 100 ml of a prepared solution containing Zn(II) ions was used to study the ability of *I. cylindrica* to adsorb Zn(II) ions from solution. The factors investigated were the dose of adsorbent (1,5,10 and 50 g), temperature (25,35,45 and 55 °C), the contact time (10,40,60and 90 min) and pH of the solution (2,4,6 and 7). The rotational speed of the mixer was 200 rpm. The adsorption process of Zn(II) ions needs to optimal design and it's so significant side in adsorption development. Analyzing statistical optimization to calculate the experimental data by developing the general model of adsorption.

Adsorption capacity: The adsorption capacity *q* in(mg/g) was calculated from the difference between the initial concentration(c_o) and equilibrium adsorbate compound concentration(c_e) in (mg/l), which is as follows the equation:

$$q = \frac{V(C_0 - C_e)}{M} \quad (1)$$

M is the adsorbent dosage (g) and *V* is the solution volume (L).

The Zn (II) ions removal percentage can be calculated as follows:

$$(\%)\ \text{Zn (II) ions removal} = \frac{C_0 - C_e}{C_0} \times 100 \quad (2)$$

RESULTS AND DISCUSSION

Fourier transforms infrared spectroscopy (FT-IR) and Energy Disperse X-ray spectra (EDX) investigation: The FT-IR spectra images of the EDX spectra *Imperata cylinderica* were recorded (Fig. 1). The medium length and two peaks observed at 2,916 cm^{-1} and 2849 cm^{-1} are attributed to the presence of the C-H asymmetrical stretching and symmetrical stretching respectively. The peak at 1731.91 cm^{-1} was assigned to C=O stretching of the carboxylate group, 1462 cm^{-1} is related to C=C stretching of the alkenes group. The SEM spectrum chart showed a white region that represents Imperata cylinderica contain a high percentage of Si, also EDX chart notice is so interesting. The best method for elements identify onto the adsorbent surface is by EDX. The *I. cylinderica* surface existence Si, O, and C ions that certain through the tops 1.7, 0.5, and 0.2 ke.V respectively**,.**

Scanning Electron Microscopic (SEM) investigations: The SEM images for the Imperata cylinderica surface are shown in Figure 2. It can be considered as a porous adsorbent and has an irregular and rough surface with many creases

Effect of pH: Generally, the changes in the solution pH were effect on the metal ions adsorption, due to the activity of protons and ions. The pH changes effect on the Zn (II) ions

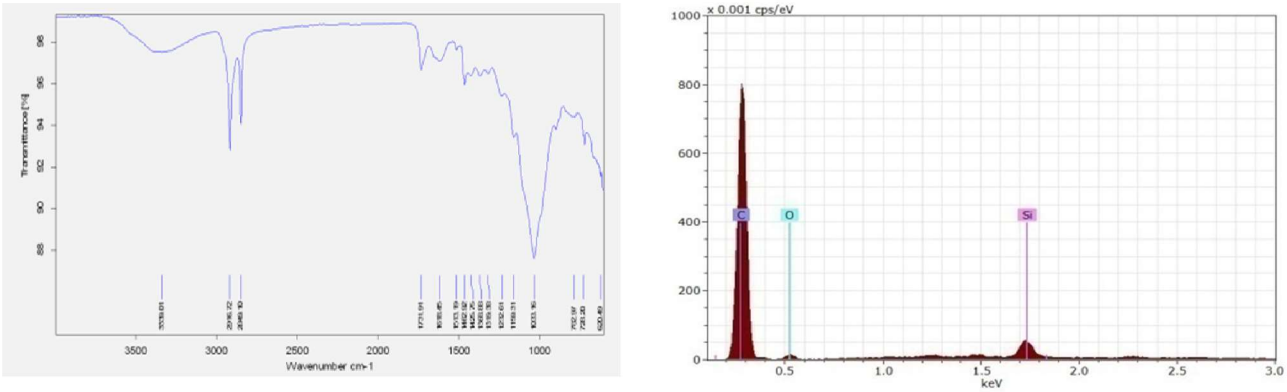

Fig. 1. Fourier transforms infrared spectroscopy and EDX spectra of *I. cylinderica*

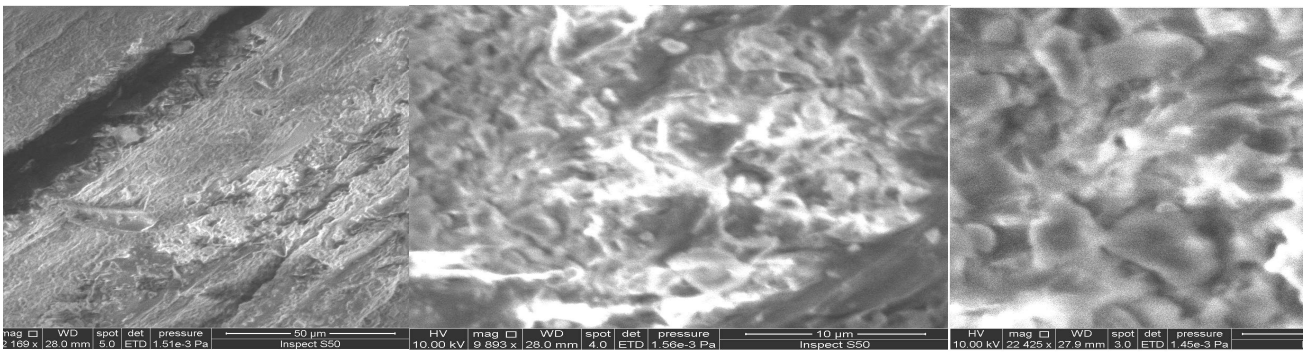

Fig. 2. Scanning Electron Microscopic (SEM) of Imperata cylinderica

adsorption by *I. cylinderica* as adsorbent material. The solution pH changing affected slightly on the Zn(II) ions adsorption (Fig. 3). At pH=4, the adsorption of Zn(II) ions was increased slightly to 98.8%, then pH<4 decreases slightly. When the solution pH between 5 to 6.5, the adsorption percentage relatively was constant between 98.8% to 99%, but at pH = 7 the adsorption efficiency decreasing to less than 95% because the Zn (II) ions started to precipitate that mean the Zn (II) ions converted to the solid-state at pH≤7.

Effect of Temperature: The increase in system temperature causes increase the solubility of the Zn (II) ions in wastewater and correspondingly, removal of Zn (II) ions would increase.

Effect of adsorbent dose: The removal of Zn (II) ions increased with increasing adsorbent dosage and attained a maximum value (100%) at an adsorbent dosage of 0.753 g/100 ml (Fig. 5). The phenomenon is associated with an increase in available binding sites for adsorption in higher sorbent dosage, but sorption capacity decreases with an increase in sorbent dosage.

Effect of contact time: The Zn(II) ions removal increased with contact time. The rapid adsorption in the first 5 to 30 minutes can be attributed to the increased availability of vacant surface sites at the initial stages. The optimal contact time was 45 minutes. The adsorption rapidly occurs and normally controlled by the diffusion process from the bulk to the surface.

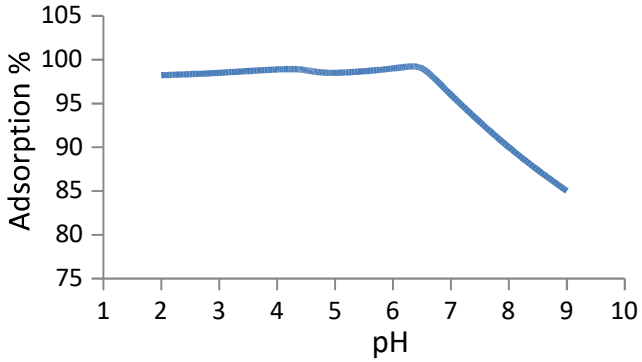

Fig. 3. Effect of pH on Zn(II) ions adsorption efficiency onto *Imperata cylinderica*

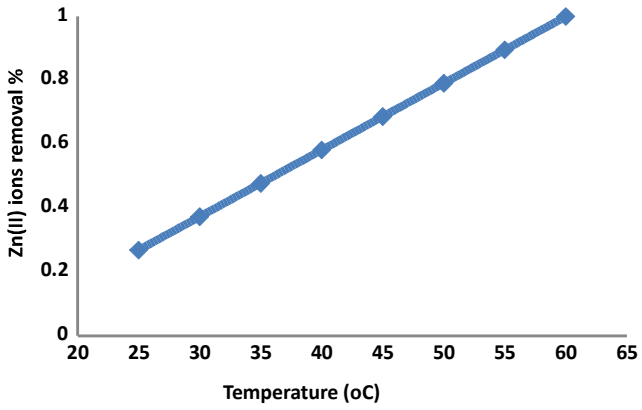

Fig. 4. Effect of temperature on Zn (II) ions removal at adsorbent (dose= 5 g/100ml, t= 60 min)

Isotherms Models for Adsorption: Describing of mathematical isotherms models for adsorption are the species of adsorbate distribution of through the solid phase and the liquid phase, there are series of hypotheses which regarded to the homogeneity/ heterogeneity of the solid surface, covering type, and the adsorbate reaction possibility. The models were tested in this study as following:

Langmuir model

$$q_e = \frac{K_l C_e}{1 + a_l C_e} \qquad (3)$$

where K_l (dm^3/g) and a_l (dm^3/mg) represent Langmuir constants

Freundlich mode $q_e = a_f C_e bf$ (4)

a_f (mg/g) indicates the multilayer adsorption capacity and b_f an empirical parameter related to the intensity of adsorption.

Temkin isotherm model

$q_e = RT/b \ln AC_e$ (5)

Here (RT/b)= B(j/mol), which is Temkin constant, A (l/g) is the equilibrium binding constant, R is the universal gas constant and T(K) is absolute solution temperature

Harkins-Henderson Model

$$q_e = \frac{K_{H-H}^{1/n}}{c_e^{1/n}} \qquad (6)$$

$_n$ and K_{H-H} are isotherm constants.

From the above isotherm models the results were obtained, the linearized form of Langmuir, Freundlich, Temkin, and Harkins-Henderson isotherm models, using equations (3), (4), (5) and (6) respectively, were analyzed using Microsoft Excel Software to find the isotherm constants. These constants presented in Table 1, indicate that the regression correlation coefficient (R^2) of the Langmuir equation (R^2 =0.998) is more linear when compared with that of other equations, implying that the adsorption isotherm data are well fitted by the Langmuir isotherm. Figure 7 shows the experimental curve and isotherm model curves.

The fact that the Langmuir isotherm fits the experimental data very well. The adsorption is single-layer and the maximum adsorption corresponds to a saturated monolayer of Zn (II) molecules on the *I. cylinderica* surface, the energy of adsorption is constant, and there is no transmigration of Zn (II) in the plane of the surface. The hypothesis of Langmuir isotherm model depends on there are a limited active sites distributed on the adsorbent surface homogeneously. The affinity of active sites is same to a monomolecular layer

adsorption and no reaction between adsorbed molecules.

Adsorption Kinetics: The kinetics of adsorption describes the rate at which adsorbate is adsorbed on the adsorbent. The adsorption kinetics is required for selecting optimum operating conditions for the full- scale batch process. It is also helpful for the prediction of the adsorption rate, giving important information for designing and modeling the process. Several kinetic models are used to analyze adsorption kinetics data. The models were tested in this study as following:

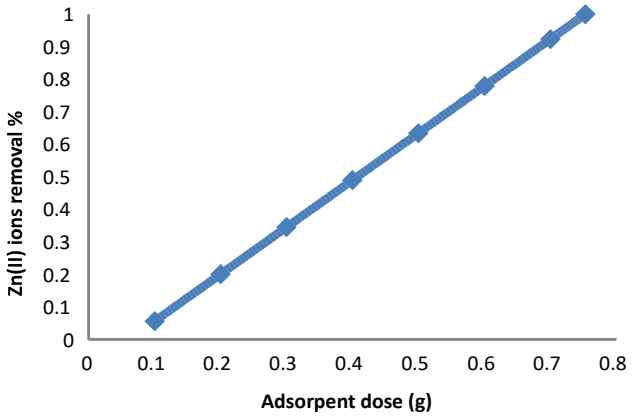

Fig. 5. Effect of adsorbent dose on Zn(II) ions removal (t=60 min, T=45°C)

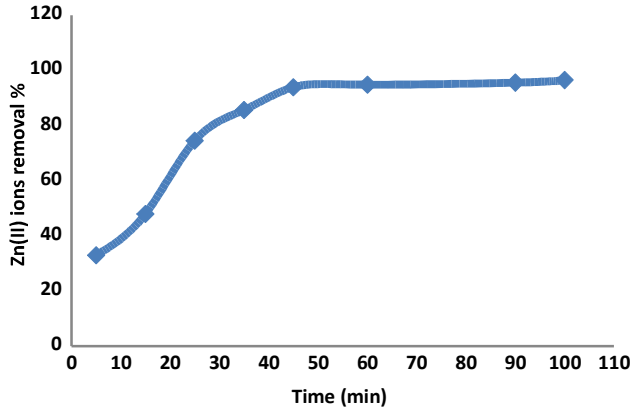

Fig. 6. Effect of contact time on Zn(II) ions removal (dose= 5 g/100 ml, T= 45°C)

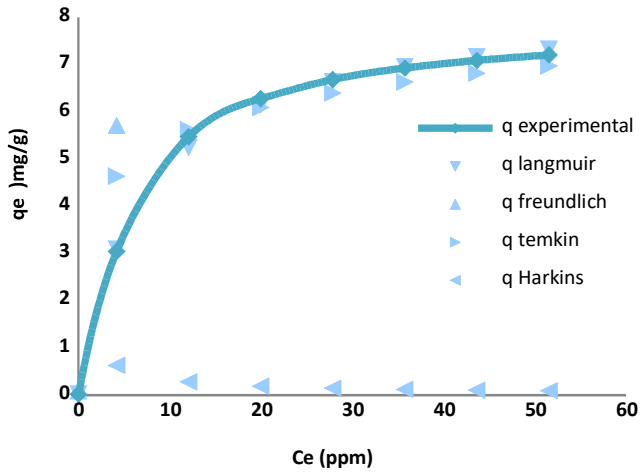

Fig. 7. Adsorption isotherm of Zn(II) ions adsorbed onto *I. cylinderica*

Pseudo-first-order kinetic model. proposed by Lagergren.

$$\text{Log}(q_e - q_t) = \log q_e - k_1 t/2.303 \quad (7)$$

qe (mg/g) and q_t (mg/g) are adsorption capacity at equilibrium and at time t respectively. k_1 is the rate constant of pseudo first-order adsorption (min^{-1}).

- Pseudo-second-order kinetic model.

$$\frac{dq_t}{dt} = k_s (q_e - q_t)^2 \quad (8)$$

Where k_s is the rate constant of adsorption, g/(mg.min).

- Intra particle diffusion study..

$$q_t = k_{id} t^{1/2} + C \quad (9)$$

Where k_{id} and C are the intra-particle diffusion rate constant.

- Elovich model.

$$q_t = 1/\beta \ln(\alpha\beta) + 1/\beta \ln t \quad (10)$$

Where, α is the initial biosorption rate (mg/g min) and β is related to the extent of surface coverage and the activation energy for chemisorption (g/mg).

The kinetic models indicated the instantaneous adsorption of the batch process was investigated using four different models. These kinetic models included the pseudo-first-order, pseudo-second-order, intra-particle diffusion, and Elovich models. The experimental results were employed to derive the kinetic parameters using these models. The contacts for these models were obtained using Microsoft Excel Software. The Table 2 shows the results of these analysis and Figures. 8, 9, 10 and 11 represent the adsorption capacity with the fitted model. (Fig. 8) represents the relation of log (qe-qt) and time for pseudo-first-order model, (Fig. 9) represents the relation of (time/qt) and time for pseudo-second-order model (Fig. 10) represents the relation

Table 1. Isotherm models constants

Isotherms	Parameters	Values
Langmuir	q_L	0.125
	K_L	1.14
	R^2	0.99
Freundlich	b_f	0.65
	a_F	1.67
	R^2	0.95
Temkin	B	0.88
	A	32.50
	R^2	0.92
Harkins-Henderson	n	1.229
	K_{H-H}	2.15
	R^2	0.94

of qt and (time)0.5 for intra-particle diffusion model, and (Fig. 11) represents the relation of qt and pn (time) for Elovich model. By comparing the correlation coefficient (R^2) values of each curve for all five models it seems that the kinetics of Zn (II) ions adsorption onto Imperata cylinderica was found to be fitted with a pseudo-first-order model more than other models.

Thermodynamic observations: Observed the effect of Zn (II) ions adsorption on the temperature, temperature ranging from 20 to 60 °C. Thermodynamic parameters such as Gibbs energy change (ΔG°), standard enthalpy change (ΔH°) and

Table 2. Kinetic models constants for the adsorption of oil onto *I. cylinderica*

Isotherms	Parameters	Values
Pseudo-first order	q_e	145.7
Equation (7)	K_1	0.0354
	R^2	0.989
Pseudo-Second Order	q_e	0.635
Equation (8)	K_s	1.955
	R^2	0.947
Intra-Particle Diffusion	K_{id}	0.945
Equation (9)	C	0.455
	R^2	0.969
Elovich	α	2.559
Equation (10)	β	0.487
	R^2	0.905

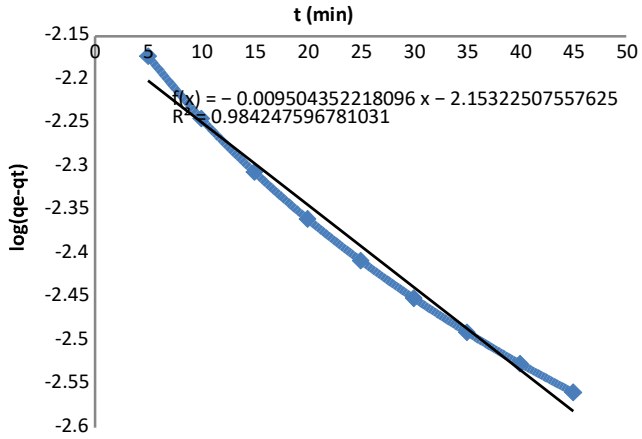

Fig. 8. Pseudo-first-order adsorption kinetics of Zn(II) ions onto *I. cylinderica*

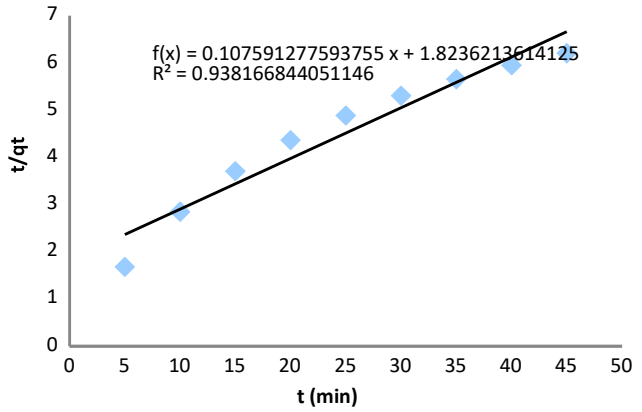

Fig. 9. Pseudo-second-order adsorption kinetics of Zn(II) ions onto *I. cylinderica*

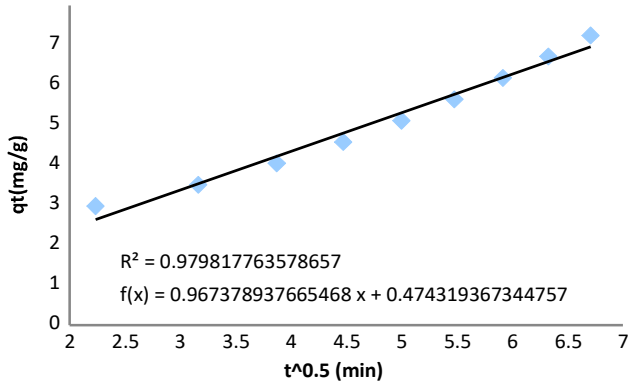

Fig. 10. Intra particle adsorption kinetics of Zn(II) ions onto *I. cylinderica*

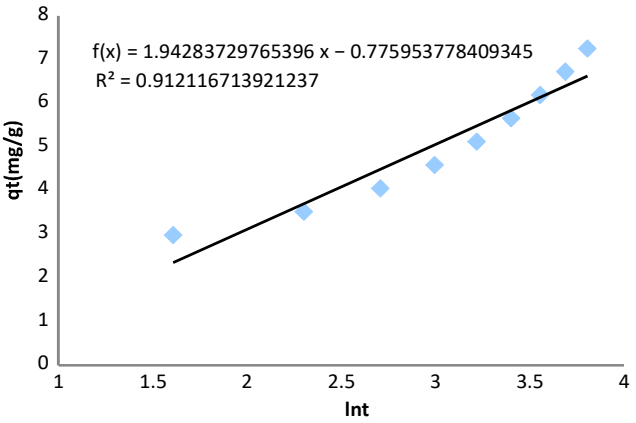

Fig. 11. Elovich model for adsorption kinetics of Zn(II) ions onto *I. cylinderca*

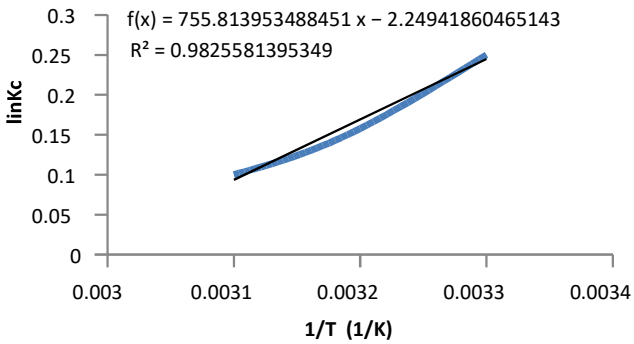

Fig. 12. Thermodynamic Parameters for Zn(II) ions adsorption onto *I. cylinderica*

standard entropy change (ΔS°) were calculated:

$$\Delta G^o = -RTIin \qquad (11)$$

$$\Delta G^o = \Delta H^o - T\Delta S^o \qquad (12)$$

From Equ.(11) and Equ. (12) obtained:

$$^{lin} K_c \frac{\Delta S^o}{R} - \frac{\Delta H^o}{RT} \qquad (13)$$

According to Equation (13), (ΔH°) and (ΔS°) parameters can be calculated from the slope and intercept of a plot of $linK_c$ versus 1/T, respectively (Fig. 12)

The parameters of thermodynamic can present insight into the mechanism and type of an adsorption process. Values of free energy change ΔG° are negative confirming that oil adsorption is spontaneous and thermodynamically favorable since ΔG° became more negative with an increase in temperature (-0.27,-0.39 and-0.63KJ/mol) at 25,35 and 55C° respectively, indicating the higher adsorption capacity result high driving force at a higher temperature. ΔH°in positive value that indicates the adsorption reaction endothermic (0.756 KJ/mol.). A little but positive value of ΔS° (0.0225 KJ/mol.K) in the temperature range 20-60°C, during Zn(II) ions adsorption several of water molecules were displace therefore increase the solid-solution interface randomness suggested .

CONCLUSIONS

Imperata cylinderica was effective in adsorption Zn (II) ions from wastewater. The Langmuir model equation fits the experimental data for equilibrium isotherm of Zinc (II) ions removal more than other model equations. The pseudo-first-order adsorption is predominant for the kinetics study. The thermodynamics study effect temperature changes on the thermodynamic parameters such as standard free energy change (ΔG°), standard enthalpy change (ΔH°) and standard entropy change (ΔS°).

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Performance of Serrated Sickle and Pedal Operated Paddy Thresher for Harvesting of Paddy by Hill Farm Women

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***Abstract*:** Harvesting is perceived as a drudgery prone task in agriculture domain. Manual harvesting of paddy accumulates high physical strain and fatigue during peak seasonal period causing drudgery in farm women. The present study was planned for mechanized intervention of paddy harvesting and to compare and assess the economics and rate of drudgery among farm women in traditional and mechanized paddy harvesting practices using serrated sickle and pedal operated paddy thresher. Efficiency of paddy harvesting increased by using serrated sickle, as one farm women could harvest paddy with an output of 104.6 $m^2 hr^{-1}$ using serrated sickle and 87.8 $m^2 hr^{-1}$ through traditional/local sickle. 100% of the respondents reported serrated sickle as a comfortable tool for harvesting paddy with experience of less fatigue. Farm women were satisfied with pedal operated paddy thresher as it was easy to handle and to operate by them, was light in weight and could be easily carried from one terraced field to another. Most of the cultivated land in hilly area is under terraced farming and under the category of small and marginal farmers whose threshing requirements are less and can be met with this low cost thresher.

***Keywords*:** Paddy harvesting, Serrated sickle, Paddy thresher, Performance, Farm women

In India, women play a significant and crucial role in agricultural activities and women work force in agriculture and allied sectors is estimated to be around 92 million which amounts to 40 per cent of the total rural workers in the country (Singh et al 2007). Various studies on women in agriculture point to the fact that women are generally employed in the operations which are either not mechanized or least mechanized and involve a lot of drudgery. Most of the activities are not only drudgerious but time consuming also so, a farm woman suffers a lot of drudgery while performing operations (Srinath et al 2010). The most drudgery prone activities experienced by women in various farm operations are sowing, harvesting, threshing, manuring, weeding and intercultural operations. During the activities, they adapt awkward body posture due to which their physiological workload increases and also they faces many types of musculo-skeletal problems as a result the efficiency of women to work decreases to a greater extent. Harvesting is perceived as a drudgery prone task in agriculture domain. It accumulates load of work on farmwomen during peak seasonal period of work. The work environment and the tools used by women in agriculture are also some of the important reasons to lower down the productivity and increase in health hazards. Poor posture and tool design can increase the discomfort of both healthy as well as less fit individuals. Majority of harvesting of paddy by farm women is done by local sickles made by local artisans using bending and squatting postures for a long time (Patel et al 2013). The ordinary sickle being used for harvesting is very simple and the design has not been changed for years. The sickles are very rough to handle and gives poor working efficiency and serrated sickle for harvesting purpose is lesser in weight, easy to handle and also saves harvesting time. The serrated sickle consists of a steel blade with special serration and a special handle that makes operation of the sickle easy and comfortable compared to the traditional sickle. The good quality steel used and the special serration gives a cutting tooth profile that easily cuts both dry and wet crops. The special shape of the handle gives protection of fingers from getting rubbed to the soil or stubbles.

Women are the backbone of agriculture in Himachal and about 80% of the field work in agriculture, from sowing to harvesting and in addition post-harvest management and dairy management is also done by women farmers. The rice cultivation activities are usually performed by women who suffer with high physical strain and fatigue during various operations. These agricultural operations are time and energy consuming and therefore the farm women are needed to be mechanized appropriately for increasing their productivity, income and reducing the drudgery involved in various agricultural activities. By promoting mechanization, the work and work environment can be improved, physiological workload can be reduced and efficiency/work output can be improved significantly. Therefore, it becomes

imperative to empower farm women with scientific knowledge and gender friendly appropriate technology based on principles of ergonomics to bridge the gap in access to appropriate technology to reduce drudgery, ill health, stress, enhance efficiency, productivity, better health and satisfaction. Keeping this in view, the present study was planned for mechanized intervention of paddy harvesting and to compare and assess the economics and the rate of drudgery among farm women in paddy harvesting practices using serrated sickle and pedal operated paddy thresher.

MATERIAL AND METHODS

To evaluate the paddy harvesting activity through ergonomic point of view, thirty farm women were divided into two groups. One group (n=15) was allowed to use the desi ordinary sickle whereas another group (n=15) was provided with serrated sickle. Healthy farm women involved in paddy cultivation for a long time were selected randomly. The investigation was carried out in October. Similarly, healthy farm women actively engaged in threshing activity were selected at random to conduct both operations viz. manual beating of paddy and by the use of pedal operated paddy thresher (n=15 per group). The respondents were trained in operation of the tools before start of the actual experiment. All the subjects were right handed, physically fit and were not suffering from any physical abnormalities to perform the selected activity. These tools were studied for their productivity, comfort ability and as drudgery reducing tools by comparing them with traditional methods. The subjects were allowed to take sufficient rest before starting the activity. Subjects were asked to perform the action for a time period of 20 minutes and their physiological parameters were noted down. After completing the task for scheduled time, subjects were given adequate rest so that all the physiological parameters regained to their resting level. The resting heart rate (HR_{rest}) of the subjects was measured at rest and 15 minute prior to conducting the experiment. The heart rate of the subjects was measured by polar heart rate monitor. During and after continuous work operation, working heart rate (HR work) and recovery heart rate were measured. Based on these values, energy expenditure was worked out (Singh et al 2007). Based on the energy expenditure values, the categorization of the work was done (Nag et al 1980). Muscular stress during the performance of the activity was measured by recording the incidence of pain perceived by the subjects from the body map indicating different parts of the body.

RESULTS AND DISCUSSION

Inventory of all agricultural tasks suggests harvesting as one of the most drudgery prone task with high energy cost, thereby making it amenable to ergonomic interventions in terms of improved technologies to relieve women from high energy demands, time spent, associated drudgery and ill health (Patel et al 2013). The local sickle was heavy in weight, had wider width of blade which had more concavity than the improved sickle. The serrated sickle had effective handle length and diameter with more cutting surface and was lighter in weight. Heart rate at rest (beats/min) was 73.91and 72.54 for local sickle and serrated sickle group respectively (Table 2). In this order, heart rate at work was as 112.45 and 100.84 beats/min when paddy was harvested for a total given time of twenty minutes. The average energy expenditure of farm women was 16.02 for traditional sickle and 14.15 for serrated sickle. The efficiency of paddy harvesting increased by using serrated sickle, as one farm women could harvest paddy with an output of 104.6 m^2 hr^{-1} using serrated sickle and 87.8 $m^2 hr^{-1}$ through traditional/local sickle (Table 3). Reduced concavity and enhanced cutting surface of the sickle improved harvesting proficiency. The 100% of the respondents reported serrated sickle as a

Table 1. Dimensions of studied sickles

Particulars	Dimensions of sickles (mm)	
	Serrated	Local
Base plate for blade of sickle	52	15
Maximum width of blade	28	32
Blade thickness	2	1.5
Cutting surface	254	220
Outer length of blade	287	270
Concavity of blade	32	50
Sickle length	370	320
Maximum handle length	145	120
Effective handle length	122	90
Maximum handle diameter	34	15
Length of ferrule	22	40
Size of sickle	240	185
Weight (g)	163	190

Table 2. Ergonomic assessment of serrated vs local sickle

Ergonomic assessment	Local sickle	Serrated sickle
HR_{rest} (beats min^{-1})	73.91	72.54
HR_{work} (beats min^{-1})	112.45	100.84
Average energy expenditure	16.02	14.15
Musculoskeletal problems	Pain in lower back, wrist/hands and shoulders	Mild pain in right arm initially

comfortable tool for harvesting paddy with experience of less fatigue (93.33%). The 86.66% supported it for having easy grip for its effective handle length and diameter and causing less pain in muscle due to light weight and work efficiency and the decrease in angle bend (80%). The serrated sickle provided safety to the farm women due to its better construction that reduced musculoskeletal discomforts. Gite and Agarwal (2000) concluded that improved sickle with serrated edge reduced drudgery of farm women by about 16.5% as compared to local sickle for harvesting wheat crop. Apart from that, it is necessary to maintain proper posture while performing any agricultural operation that reduces the shifting of body gravity and thereby tension of involved muscles.

Farm women reported that though they were habitual in using the local sickle for fodder and crop harvesting but when asked to assess, they could feel mild pain in lower back, wrist/hands and shoulders which may be due to its heavier weight and the impact or pulling action as against sawing action by serrated one. The respondents added that use of serrated sickle initially caused mild pain in right arm initially which may be due to use of new tool. It required time to adjust with it. They were satisfied with the serrated sickle due to its comfort level of usage and increased efficiency of the new tool in terms of ergonomic design, field capacity and balanced mode of working. The design of traditional sickle is not comfortable for the user as sometimes the fingers as well as lower portion of the hand get rubbed with the soil and cause pain. On the other hand, the design of serrated sickle is farmer friendly and does not result in any damage to the worker. Hence, it reduces the drudgery amongst the farm women while working in the fields. In addition, ordinary sickle requires its grinding more frequently which wastes time as well as money whereas serrated sickle does not require it at all.

In many parts of the state, paddy grains are still threshed manually by beating or by use of animal treading followed by winnowing. It is slow and drudgery oriented process. With the use of a paddy thresher, paddy threshing in hills could be mechanized. Besides, the drudgery involved in threshing of paddy could also be reduced. Therefore, a pedal operated paddy thresher is of great significance for hilly farmers to mechanize paddy crop for threshing of the paddy at farmers' field as it saves time, labour and cost. The overall dimensions (L×W×H) of pedal operated paddy thresher used in the present investigation were 80x79x95 cm. The threshing drum was of size -47x35 cm (length x diameter) and the weight of the thresher was 36.25 kg.

Fifteen farm women subjects were randomly selected for ergonomical assessment of traditional method of paddy threshing as well as for paddy thresher. Before doing the operation, mean heart rate of the subjects at rest was 75.37 and 72.54 beats/min for traditional and mechanised threshing and while doing the activity it was recorded as 116.22 and 112.84 beats/min, respectively (Table 4). During the threshing of paddy, one person was engaged for supplying the crop bundles to the person operating the thresher. During threshing, pedal operation is continuous, one leg is placed on the pedal and the other leg on the ground. In addition to that, the operator keeps on spreading the crop bundle on the threshing drum so that ear heads get detached. This requires suitable hand orientation to keep the crop spreading. The body parts discomfort was mainly due to

Table 4. Ergonomic assessment of traditional method vs pedal operated paddy thresher

Ergonomic assessment	Traditional method	Pedal operated paddy thresher
HR_{rest} (beats min^{-1})	75.37	72.54
HR_{work} (beats min^{-1})	116.22	112.84
Musculoskeletal problems	Pain in wrist/hands, shoulders and back	Mild pain in operating feet and legs

Table 5. Performance evaluation of thresher

Particulars	Traditional method	Pedal operated paddy thresher
Moisture content of grain, db (%)	15.8-16.6	15.6 to 17.2
Capacity of threshing (kg hr^{-1})	25 -30	35-40
Threshing efficiency (%)	96	94 to 96
Labour requirement (man-h q^{-1})	8	6
Cost of operation (Rs q^{-1})	320	240

Table 3. Ergonomic appraisal of serrated vs local sickle (n=15 each)

Tools		Easy grip	Comfortable	Decrease in angle bend	Less pain in muscle	Less fatigue	Area covered m^2/hr
Local sickle	No.	11	9	10	9	9	87.8
	%	73.33	60	66.66	60	60	
Serrated sickle	No.	13	15	12	13	14	104.6
	%	86.66	100	80	86.66	93.33	

bending posture adopted while beating of paddy crop bundle whereas in case of manually operated paddy thresher discomfort was maximum in lower leg due to pedalling and feeding the crop in bent posture. The farmers were quite enthusiastic in working on it as it required no fuel in any form. However, they required time for acclimatization to the new machine. They were satisfied with the thresher as it was easy to handle. It was light weight as compared to the power operated paddy thresher and could be easily carried from one terraced field to another. Farm women could also operate it easily. Most of the cultivated land in hilly area is under terraced farming and under the category of small and marginal farmers whose threshing requirements are less and can be met with this low cost thresher.

CONCLUSION

The use of serrated sickle and pedal operated pedal thresher by the farm women is desirable for harvesting and threshing of paddy due to the fact that they reduces drudgery on one hand and saves time and money on the other hand. Hence, such improved technologies need to be demonstrated on a large scale among the rural farm women.

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Bioeconomic Appraisal of Wheat and Black Gram under Peach, Apricot and Pear based Agroforestry System

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***Abstract*:** Land-use options for sustainable livelihood security were generally taken into consideration in this study. The experiment was laid out in randomized block design (factorial) with five treatments Recommended fertilizer, FYM, vermicompost, Jeevamrut and no manure that were applied) under four different systems (Peach, Apricot, Pear and open system after treatment), replicated thrice. The results in general indicated that maximum cost of cultivation (Rs 39475.74 ha^{-1}) incurred in practice, where wheat was grown under pear tree. Maximum net return (Rs 19108.06 ha^{-1}) was obtained in wheat when recommended dose of fertilizer was used in peach tree. The application of vermicompost resulted in higher cost of cultivation under peach based agroforestry system. Highest B:C ratio (5.08) was observed under peach tree in wheat.

On one hand agri-horti system is emerging as one of the viable and sustainable option to fulfill the ever increasing demand of food to human and fodder to livestock whereas on the other hand it is also treated as an opportunity to maximize the land cover under trees. This system is an improvised indigenous intercropping system in India and can significantly increases the return per unit area and time by full utilization of the growing season. The total production, output and return from land can be enhanced Agri-horticulture system mainly by choice of short duration crops between the alleys of fruit crops (Dhillon et al 2012). Fruit tree based agro forestry system involves intentional and simultaneous association of perennial fruit trees with annual or perennial crops on the same land unit. These systems enjoy high demand and popularity among producers worldwide because of relatively short juvenile (pre-production) phase of fruit trees, high market value of products and the contribution of fruits to household dietary needs (Sangwan et al 2015). Lands with low nutritional status can be exploited for establishing orchards, thus making agricultural systems economically viable. It also generates better employment opportunities for landless labours and small/marginal farmers. Generally, the systems are economically rewarding with high benefit-to-cost ratios and total system-productivity in fruit tree + annual mixed systems remaining high.

MATERIAL AND METHODS

Study area: The experimental farm of Department of Silviculture and Agroforestry, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) is located in the mid-hill zone of Himachal Pradesh at 30° 51' N latitude and 76° 11' E longitude, with an elevation of 1200 m above mean sea level having slope of 7-8 per cent.

Experimental methodology: The experiment comprised of five treatments with three replications and was laid out in randomized block design. Peach var. nectarine (*Prunus persica*), Apricot (*Prunus armeniaca*) and Pear (*Pyrus communis*) in East to West direction at a distance of 9m x 4m were used as a tree component for the experiment. The spacing of 20cm for wheat and 30cm for black gram was maintained for consecutive two years. Sowing was done in the month of July for black gram and in December for wheat. Light irrigations were given after sowing to facilitate the germination. The experimental plots were maintained properly and kept free from weeds. FYM, Vermi-compost and other chemical fertilizers were evenly spread and mixed with the soil before sowing. Thereafter, Jeevamrut (5%) was applied as foliar application on nitrogen equivalent basis after the 15 days of sowing. Data for different parameters were collected after harvesting.

Analytical technique: The entire data of the present study were statistically analyzed by using analysis of variance (ANOVA) for Randomized Block Design (RBD) in accordance with the procedure outlined by Gomez and Gomez (1984), where effects exhibited significance at 5 per cent level of probability and then critical difference (CD) was calculated.

The cost of cultivation of medicinal and aromatic plant and harvest of its produce was worked out on the basis of net cropped area per hectare. The requirements of labour and mechanical power for different operations such as ploughing, harrowing, weeding and harvesting were calculated per hectare as per the rates prevalent at experimental farm. Cost of inputs such as seeds, farm yard manure and Jeevamrut was calculated based on the actual amounts applied to the land use system. Similarly, cost of cultivation of trees (*Prunus armeniaca* and *Prunus persica*) and harvest of its produce was computed with respect to variable cost involved in harvesting of fruits on per hectare basis during the year of study. The prevailing local market prices were used to convert yield of medicinal and aromatic plant into gross return in rupees per hectare. Gross returns were obtained by multiplying the quantity of produce with the prevailing prices in the market.

Net returns were worked out by subtracting the cost of cultivation from the gross returns.

Net return (Rs. ha^{-1}) = Gross returns - Cost of cultivation

The net returns per rupee invested ratio were calculated as per following formula:

Net returns = Benefit cost ratio/Cost of cultivation (Rs. ha^{-1})

RESULTS AND DISCUSSION

The economics of different agroforestry system consisting of wheat and black gram as intercrop was calculated. The cost of cultivation, gross return and net returns of four different agroforestry systems was determined separately in the presence and absence of trees to know the economic profitability of tree-crop combination. The economics of four systems showed that the maximum cost of cultivation (Rs 39475.74 ha^{-1}) incurred in treatment T_3 under pear based agroforestry system. The maximum net return (Rs 19108.06 ha^{-1}) was obtained when recommended dose of fertilizer was used under peach tree. The application of recommended dose of fertilizers resulted in higher gross return (Rs 53277 ha^{-1}) under peach based agroforestry system. Highest (5.08) B:C ratio was observed under peach tree; where no manure was applied. However, for black gram the highest cost of cultivation (Rs 35236.51 ha^{-1}) under pear based agroforestry system with the application of farm yard manure. Net return for black gram was reported maximum (Rs 14218.80 ha^{-1}) for the treatment T_4 under peach based agroforestry system. The highest cost of cultivation (Rs 41787 ha^{-1}) was recorded in treatment T_1 under pear tree. B:C ratio was recorded maximum (5.05) under peach based

Table 1. Bioeconomic appraisal of *Triticum aestivum* and *Vigna mungo* under Peach based agroforestry system

Particulars	Peach based agroforestry system											
	Gross return from intercrop (Rs ha^{-1})		Cost of cultivation (Rs ha^{-1})		Net return from intercrop (Rs ha^{-1})		Net return from tree (Rs ha^{-1})		Total net return from AGF system (Rs ha^{-1})		BC ratio	
	Wheat	Black gram	Wheat	Black gram	Wheat	Black gram	Wheat	Black gram	Wheat	Black gram	Wheat	Black gram
T_1	53277	35634.6	34168.94	28891.11	19108.06	6743.49	126047.863	131325.692	145155.93	138069.18	4.25	4.78
T_2	45906	34917.25	36266.80	30933.95	9639.20	3983.30	111734.304	117067.152	121373.51	121050.45	3.35	3.91
T_3	50127	34168.5	38198.88	28637.66	11928.12	5530.84	109677.571	119238.787	121605.69	124769.62	3.18	4.36
T_4	37464	31884.3	26659.89	23904.11	10804.11	7980.19	90078.9917	92834.7745	100883.10	100814.97	3.78	4.22
T_5	23902	26979.2	22085.46	22630.15	1816.54	4349.05	110409.178	109864.485	112225.72	114213.53	5.08	5.05

Table 2. Bioeconomic appraisal of *Triticum aestivum* and *Vigna mungo* under Apricot based agroforestry system

Particulars	Apricot based agroforestry system											
	Gross return from intercrop (Rs ha^{-1})		Cost of cultivation (Rs ha^{-1})		Net return from intercrop (Rs ha^{-1})		Net return from tree (Rs ha^{-1})		Total net return from AGF system (Rs ha^{-1})		BC ratio	
	Wheat	Black gram	Wheat	Black gram	Wheat	Black gram	Wheat	Black gram	Wheat	Black gram	Wheat	Black gram
T_1	50540	37674	35375.97	29009.21	15164.03	8664.79	39040.077	45406.845	54204.10	54071.64	1.53	1.86
T_2	44441	36133.2	36516.33	32576.39	7924.67	3556.81	63403.108	67343.054	71327.78	70899.87	1.95	2.18
T_3	49343	37200.6	38719.17	29429.58	10623.83	7771.02	55142.285	64431.874	65766.12	72202.90	1.70	2.45
T_4	38665	35944.2	26384.92	24407.20	12280.08	11537.00	46410.675	48388.398	58690.75	59925.40	2.22	2.46
T_5	26676	26838	22790.42	23041.63	3885.58	3796.37	59644.785	59393.574	63530.37	63189.95	2.79	2.74

Table 3. Bioeconomic appraisal of *Triticum aestivum* and *Vigna mungo* under Pear based agroforestry system

Particulars	Pear based agroforestry system											
	Gross return from intercrop (Rs ha^{-1})		Cost of cultivation (Rs ha^{-1})		Net return from intercrop (Rs ha^{-1})		Net return from tree (Rs ha^{-1})		Total net return from AGF system (Rs ha^{-}		BC ratio	
	Wheat	Black gram	Wheat	Black gram	Wheat	Black gram	Wheat	Black gram	Wheat	Black gram	Wheat	Black gram
T_1	52136	41787	34961.30	30400.70	17174.70	11386.30	35091.99855	31868.90005	52266.70	43255.20	1.49	1.42
T_2	46645	39902.4	37353.66	35236.51	9291.34	4665.89	35067.98975	29138.28616	44359.33	33804.17	1.19	0.96
T_3	51224	41106.6	39475.74	29986.74	11748.26	11119.86	48402.50642	48127.26208	60150.76	59247.12	1.52	1.98
T_4	42351	40235.4	27592.75	26016.60	14758.25	14218.80	44427.24716	35200.40282	59185.49	49419.21	2.14	1.90
T_5	29811	27771.9	23860.49	24205.50	5950.51	3566.40	48602.70642	37388.21542	54553.21	40954.61	2.29	1.69

Table 4. Bioeconomic appraisal of wheat and gram based system (sole crop)

Particulars	Sole crop			
	Gross return (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net return (Rs ha^{-1})	BC ratio
T_1	90439.7	61151.19	29288.51	1.48
T_2	82214.8	66430.03	15784.77	1.24
T_3	88584.1	64927.69	23656.41	1.36
T_4	77450.3	47665.14	29785.16	1.62
T_5	57412.75	42696.76	14715.99	1.34

agroforestry system when no manure was applied. Kareemulla et al (2012) and Dhillon and Chauhan (2012) recorded higher BCR under agroforestry system as compared to conventional crop rotation. Fruit based agroforestry systems were more profitable as compared to sole cropping. Dutt and Thakur (2004) reported that net returns were more under agroforestry system combining the returns from both intercrop and tree as compared to sole crop. B:C ratio exclusive of tree yield was found to be maximum in Jeevamrut. Kasbe et al (2009) also reported that application of jeevamrutha is one of the cheap and efficient organic substitutes for other organic manures like vermicompost in integrated approach for high crop yield and profitability, besides improving the nutrient status of soil. Results found are in line with Meena (2008), Nayak (2011) and Thakur (2018). Hence, it proves that carrying out tree canopy management activities like lopping not only increase crop yield but also gives economic returns leading to increased B:C ratio from the system.

CONCLUSION

The study revealed that agroforestry systems were found to be more profitable as compared to sole crop. On the basis of these findings, it can be concluded that although wheat and black gram underperformed in agroforestry systems but due to high net returns for systems, crops can be grown successfully under fruit tree based agroforestry systems.

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Social Behaviour of Chital (*Axis Axis*) in Kota Zoo and In Mukandra Hills Tiger Reserve, India

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Abstract: Social behaviour of the chital (*Axis axis*) or spotted deer includes grooming, play, antagonistic, and reproductive behaviour. The comparative study was conducted in captivity and in the wild, using scan sampling technique to examine the effect of captivity on social behaviour. Captive animals interacted more with each other in the confined habitat. Hence, social behaviour frequency among all diurnal activities was found almost twice in captivity as compared to wild. Grooming was the principal social act in both research sites, but with an enhanced prevalence in captivity. Play activity of fawns was also more recurrent in captivity, as there was no risk of predation by predators. Chital showed increased antagonistic behaviour in captivity, because of close association and more struggle for feed, area, and partner. Reproductive behaviour was more common during summer in both research sites but Chital was a less seasonal breeder in wild as fawns were reported throughout the year in wild. Thus, social behaviour patterns differed between habitats depending upon their adaptation in behaviour strategies. Overall captive Chital was found more social than their wild counterparts.

Keywords: Antagonistic, Captivity, Grooming, Reproductive, Wild

Chital (*Axis axis*) or spotted deer is an inhabitant of the Indian subcontinent and prefers damp and dry deciduous forest and live, small groups and represents fission-fusion or fluid group formation (Bagchi et al 2008, Ramesh et al 2012) with a home range of 1.5-2.0 km. As in most of the cervids, a matriarchal leadership strategy is typical in chital. Chital formed a bulk of ungulate biomass in the wild (Bagchi et al 2004, Dave 2008). It has proven chital important herbivores in the food chain. Chital-Tiger relationship is a prey-predator relationship and plays a crucial part in the ecosystem. Besides, being a natural grazer, it feeds upon grasses, fallen leaves, and browse in monsoon, winter, and summer respectively (Chandra 2013). Chital has great adaptability to the different habitats, and it flourishes with high reproductive fitness there. Comparative research on the social behaviour of chital in captivity and in wild was conducted to explore the effect of confinement. Mukandra Hills Tiger Reserve (MHTR) covers a 759.99 km^2 in the south-east (semi-arid) Rajasthan (India) with Sub-tropical Dry Deciduous Forest (Sultana 2007, Nama et al 2013, Khan 2015). Kota Zoo (KZ) is a mini zoo in Kota (Rajasthan), with a considerably small enclosure for Chital.

MATERIAL AND METHODS

The study was conducted from October 2017 to September 2018 and observed the study animals from dawn to dusk for continuously one week in every month and competed thus 12 schedules in each research area with equal distribution in every season (winter, summer and monsoon). Direct visual observations collected information using a scan sampling technique (Mathur 2005). A Nikon binocular and Canon camera were used for observation and photographs. An elaborate check sheet was used to note the social activities at a regular interval of every 10 minutes. Social behaviour was categorized into four categories: antagonistic, reproductive, grooming and playing. Antagonistic behaviour is a sign of aggression in individuals of a group and reproductive behaviour includes activities related to breeding. Grooming includes muzzling, scratching, and licking by antlers or legs. Play activities (rapid striking, zigzag running, kicking, and jumping) were usually performed by fawns.

RESULTS AND DISCUSSION

The mean group size for chital in wild and captivity was 9.44 and 69.25, respectively. There were 41.98 males and 49.34 fawn per 100 females in wild and 83.33 males and 68.5 fawns per 100 females in captivity. Thus, population structure showed a skewed female sex ratio in wild. Group and age-sex composition influenced social behaviour in both research sites. In wild, chital mostly formed small groups whereas, in captivity, chital were in a single large herd, enclosed in a Fenced enclosure. There were 1304 and 679 social activity frequencies observed during the study in KZ and MHTR, respectively. Thus, the social activity frequency was observed almost double in captivity (15.09%) as compared to

wild (7.85%) among all activities from dawn to dusk. Animals performed more social activities in captivity because they were in close association. Hence, they showed increased interaction because of more competition for food, space, and partner.

Antagonistic behaviour*:* Sparring among sub-adult males and biting followed by pushing among females were the major antagonistic activities. Fighting was exceptionally more frequent in the wild, because of the territorial tendency among adult males.

Reproductive behaviour: There was no adverse effect of captivity on the reproductive behaviour of the study animal. During rut Antler rubbing, Pawing/thrashing and preaching were frequent in hard antlered males. Chital males usually sniff female's urine and vagina to know her receptiveness for mating. Males usually followed the female and attempted to force for mating. These were the sign of reproductive behaviour because of the increased hormonal level and peak breeding was in summer.

Grooming: Grooming mainly performs the function of cleaning of coat from dirt or parasites or it may be regardless of any specific purpose. Animals of all age-sex performed grooming as a major social activity. It also strengthens the mother-infant relationship.

Play behaviour: Fawns mostly showed playing in association with mothers in the wild and in a group of fawns in captivity. Thus, there was a notable disparity in the pattern of social behaviour in imprisonment and natural habitat (Fig. 1, Table 1 and 2). Seasonal variation: The significant differences in social behaviour were observed during the three seasons in captivity. Thus, the chital was a less seasonal breeder in the wild. The social activity were significantly different between captivity and wild during winter) and summer (but there was no significant difference during the monsoon (Table 3).

Diurnal variation: In captivity, social activities were most frequent in the evening and least frequent during noon. In the

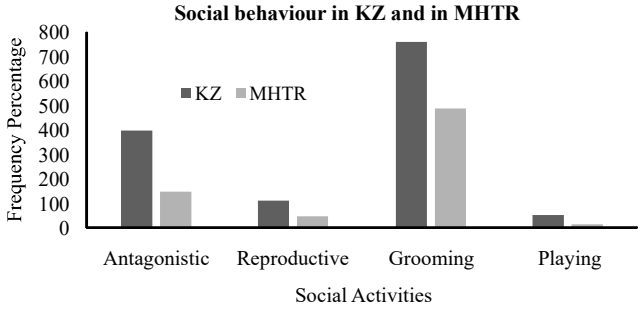

Fig. 1. Comparison of observed social activities frequency in KZ and MHTR

Table 1. Social activity frequency in KZ and in MHTR

Social activity	KZ	MHTR
Antagonistic behaviour		
Head up display	9	3
Head down display	8	3
Present threat	6	2
Antler threat	7	2
Pawing & thrashing	5	3
Preaching	2	1
Antler rubbing	60	11
Body rubbing	8	6
Sparring	130	54
Fighting	10	14
Circle & parallel walk	20	2
Chasing	3	2
Biting & pushing	80	18
Nudging	49	21
Reproductive behaviour		
Marking	1	1
Following	19	9
Driving	1	1
Sniffing	53	9
Flehmen	15	8
Mounting	5	4
Matting call	6	5
Copulation	5	4
Grooming	756	485
Playing	46	11

Table 2. Social behaviour in KZ and in MHTR

Chi-Square tests	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	70.304	23	.000
Likelihood ratio	76.172	23	.000
Linear-by-linear association	28.554	1	.000

Table 3. Social behaviour during different season in KZ and MHTR (%)

Season	Winter	Summer	Monsoon
KZ	13.61	19.96	7.7
MHTR	6.31	7.77	9.47

Table 4. Temporal distribution of frequency percentage of social activity among all diurnal activities

Time session	KZ %	MHTR %
Morning	5.92	2.51
Noon	3.12	2.75
Evening	6.04	2.59

evening sub-adult males performed sparring and fawn performed the play as a major social activity. In wild, during noontime, social activities frequency was maximum, because of more grazing during the morning and evening hours. There was a significant difference in social activity between morning, evening and noon in captivity (and in wild (Table 4).

CONCLUSIONS

Chital in captivity showed increased social behaviour because of the large herd in limited space. Overcrowding produced more aggression in captive animals. The higher reproduction rate in captivity proved higher adaptability of the chital to a distinctive habitat. The animals were busy feeding in the forest at dawn and dusk, so were socially less active. The animal in the forest spent a majority of time in search of food, so less time remained left for social activity.

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