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Artificial Recharge Structures for Heggada Devana Kote Taluk in Southern tip of Karnataka, India using Geospatial Tools

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***Abstract*:** Global warming, climate change, deforestation, rise in water demand for industrial uses rather than domestic purposes has posed serious threats to surface and subsurface water resources. Karnataka is one of the agrarian states in India where groundwater dependency showed always high. The present study involved the artificial techniques in groundwater augmentation analysis by modifying surface runoff in GIS environment with AHP (Analytical Hierarchy Process) methods. Important thematic maps are generated using toposheets, satellite data by GIS insights. Suitable sites for Artificial Recharge Structures (ARS) are derived through AHP by assigning specific weightages depending upon features priority. The results enumerate geospatial technology and AHP tools in achieving best suitable sites for ARS.

***Keywords*:** ARS, Geospatial tools, AHP, Heggada Devana Kote

Scarcity of water and its crisis still rising even though the annual average rainfall of 1100mm is recorded recently in our country. Karnataka State records over-exploited class for groundwater is 26%; whereas other blocks are observed under critical class. Groundwater is the vital component of irrigation and domestic activities in Heggada Devana (H.D) Kote taluk, however the increasing demand of water resources and its over-withdrawal with gradual rise in population impacts the aquifer equilibrium and ecological imbalance (Manjunatha et al 2019). High intensity of rainwater run-off on hill slope regions loses sufficient amount of water to other lands without much infiltration (Manjunatha et al 2019). Groundwater dependency may rise in near future by both manmade and natural processes. In hard rock terrains, ARS sites need detailed assessment of lithology, geomorphology, lineaments that are controlled by climate, weathering grade, drainage pattern, landforms, slope, permeability, fracture extent, and land use patterns (Fateme Falah et al 2016).

The present study aims in identifying suitable ARS sites for H.D kote taluk in an effort to maintain the aquifer equilibrium and store sufficient amount of water for summer seasons (Manjunatha et al 2019). AHP methods are analyzed in order to find best ARS sites by opting specific priorities within the best options (Thomas Saaty 1980). Pair-wise comparison are interpreted in assigning specific weights through Saaty's continuous rating scale of AHP through GIS.

MATERIAL AND METHODS

Site description: The study taluk falls under $11^0 44'$ to $12^0 17'$ N latitudes and $76^0 06'$ to $76^0 33'$ E longitudes with an area of 1611.29 km^2 (Manjunatha and Basavarajappa 2021) (Fig. 1). The plain regions elevated at 660 mts above MSL, whereas higher elevation ranged at 960 mts above MSL observed in southern parts. H.D kote taluk lies at southern tip of Karnataka that connects to Kerala state through Yerahalli village main road (Manjunatha and Basavarajappa 2021). Annual average rainfall recorded is 832 mm with temperature ranges from 21^0 to 31^0C (CGWB 2012). It is a part of Southern Transition Zone of hilly regions showing cool and moist weather along with sub-humid to semiarid tropical type conditions (CGWB 2012). About 67% of irrigated land is dependent on bore wells and hardly any dug wells (CGWB 2012). Paddy, Maize, Ragi, Sugarcane, Tobacco, Oilseeds and vegetables were grown extensively in the taluk (CGWB 2022). Gneisses and schistose are well exposed major rock groups in hilly terrains along with residual and transported soils.

Data Used: Toposheets (57A/1, 5, 6, 9; 57D/4, 7, 8, 11, 12) of 1:50,000 scale are collected from Bengaluru-Survey of India (SoI) office and digitized as the base maps for taluk boundary extraction (Manjunatha and Basavarajappa 2021). IRS-1D, LISS-III (Nov-2001 & Jan-2002) is collected from ISRO-NRSC, Hyderabad with 23.5 mts and PAN of 5.8 mts; whereas DEM satellite data is downloaded freely from USGS-earthexplorer (Fig. 2a) (Manjunatha et al 2019). Both Digital Image Processing (DIP) and Visual Image Interpretation Technique (VIIT) are applied on LISS-III image in extraction of thematic layers (Fig. 2a to 2l) along with limited field survey using Garmin eTrex-10 GPS (Manjunatha and Basavarajappa 2021).

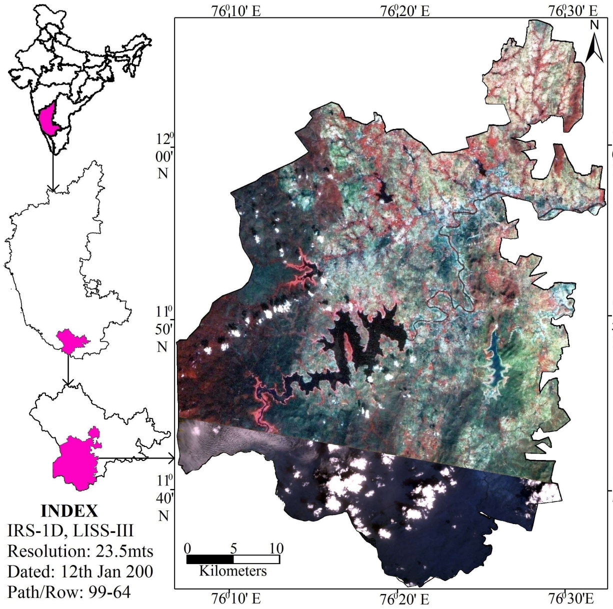

Fig. 1. IRS-LISS-III Satellite data of H.D kote taluk

Data analysis: GSI Quadrangle maps 57D and 58A of 1:250,000 scale are utilized in generating the lithology map; while geomorphology layer is digitized using 1:250,000 scale of geomorphological map of Karnataka (Manjunatha et al 2019). DEM data of 30m resolution is overlaid on SoI topo map in extraction of drainage patterns (Fig. 2d) and (Manjunatha et al 2019). Land use/ land cover categories and lineaments are extracted from PAN+LISS-III image of 5.8m resolution (Fig. 1) (Manjunatha et al 2019); whereas slope map is digitally extracted from DEM data (Manjunatha et al 2019). All seven layers of H.D kote taluk have been overlaid by pair-wise comparison using weighted method and ARS best sites are portrayed in Fig.3 (Table 1, 2, 3).

RESULTS AND DISCUSSION

Lithology: Weathered zones of granitic-gneisses and alluvium of shallow aquifers are observed along the stream courses in NNE parts of the taluk (CGWB 2012). The hard rock terrain of taluk consists of migmatites, amphibolites,

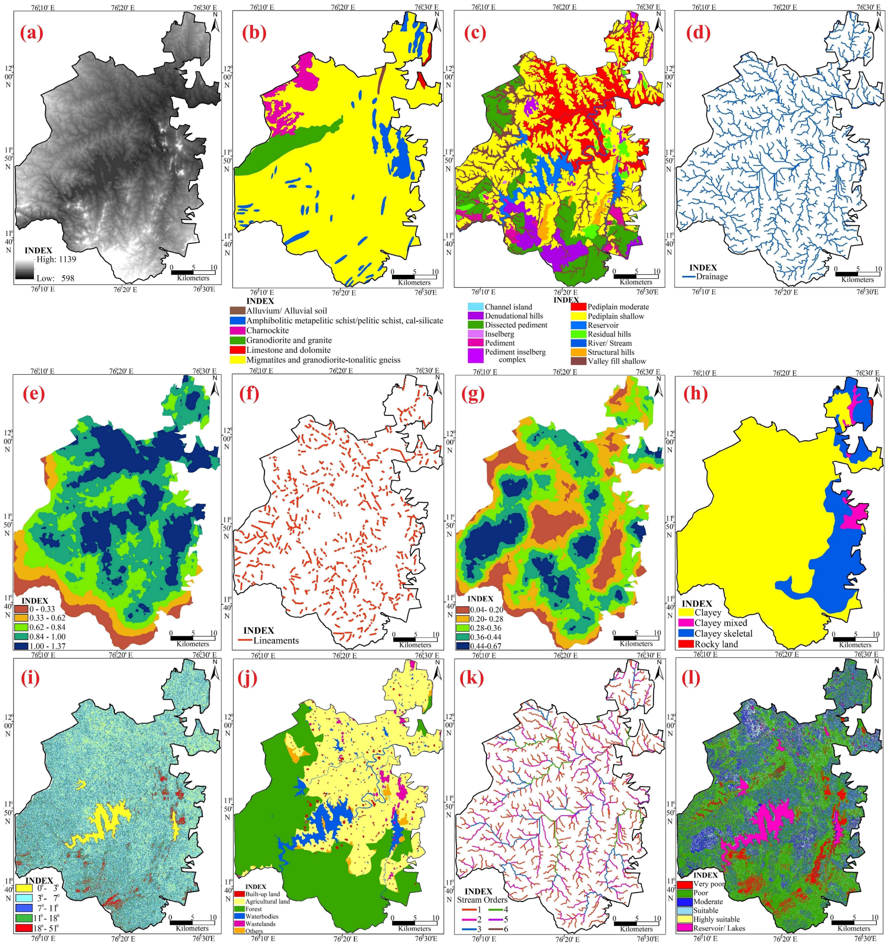

Fig. 2. (a) DEM (b) Lithology (c) Geomorphology (d) Drainage (e) Drainage Density (f) Lineament (g) Lineament Density (h) Soil map (i) Slope map (j) LU/LC (k) Stream Order and (l) Overlay weightage map of H.D Kote taluk

charnockite, limestone and dolomite (Fig. 2b). Tonalitic gneisses granodiorite, migmatites are observed extensively; whereas charnockites are restricted to NW parts following this amphibolites with pelitic/ metapelitic schist noticed at many locations. Weathered granitic-gneisses are noticeably seen along discontinuities and caused complex weathering profiles. The hard bedrock of kote taluk reveal little groundwater infiltration rates and percolations that need ARS to arrest surface water runoff through artificial methods of infiltration.

Geomorphology: Geomorphic units of kote taluk are delineated as dissected pediment, denudational hills, channel island, pediment, inselberg, pediment inselberg complex, pediplain shallow, pediplain moderate, river/stream, residual hills, structural hill, reservoir, and valley fill shallow (Manjunatha et al 2019) based on NRIS classification system (Fig. 2c). Pediplain moderate and valley fill shallow features showed excellent for groundwater potential areas while pediplain shallow features exhibits good to moderate; pediment and pediment inselberg complex features reveal moderate to poor; inselbergs, residual hills, and denudational hills indicate poor to very poor potential areas for kote taluk (Srinivasa et al 2005). Granitic-gneisses and charnockite rocks exhibits continuous range of hard surfaces that perform high runoff. Priorities based weightages are considered for each geomorphological features that help in better ARS site suitability except for river/ streams, reservoir and hills (Table 3).

Drainage & its density (Dd): Dd forms vital component for ARS sites. It's a computation of sum of the channel lengths per unit area along with relief and slope gradient. High Dd indicate channel closeness exhibiting impermeable or feeble subsurface; while low Dd reveal permissible soil or highly resistant material, low relief with thick vegetation cover in kote. Coarser drainage texture showed mountainous relief, scanty greenery type; while finer drainage texture convey high and closeness of drainage patterns. Higher runoff are more common in higher Dd areas that are not suitable for ARS, whereas little runoff in low Dd areas implies highly suitable (Fig. 2e).

Lineament & its density: Groundwater occurrences and its distribution are controlled by fractures, lineaments direction & joints and bore wells yield high water located on these zones. Lineaments/ faults filled with clay and silt of impermeable material will arrest further flow of groundwater. Eminent lineaments of kote observed along directions of NW-SE and NNE-SSW and strongly influence static water levels, boreholes yields, groundwater distribution & occurrences (CGWB 2012) (Fig. 2f). Rocks of kote taluk are hard and compact that imply higher runoff with low infiltration rates observed along fractures, seepages, weak planes, dykes and hence higher Lineament density (Ld) is essential to determine. Ld are digitally generated using Line Density tool on IRS-LISS-III data. Very high, high, moderate, low, and very low classes (Anirudh Datta et al 2020) are showed through lineament density layer (Fig. 2g) and their weightages for ARS sites are shown in Table 3. Higher Ld indicates more suitability for ARS with higher groundwater recharge potential zones.

Table 1. Continuous rating scale of Saaty's analytical hierarchy process

1/9	1/7	1/5	1/3	1	3	5	7	9
Extremely	Very strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very Strongly	Extremely
Less Important				Equal	More Important			

Source: Saaty (1980)
Note: 1/8, 1/6, 1/4, 1/2, 2, 4, 6, 8 can also be used if more number of classes exists

Table 2. Percentage of influencing factors based on Saaty's Analytical Hierarchy Process (AHP)

Influencing factor	Saaty's scale (in fraction)	Saaty's scale (in decimal)	Percentage influence = (Saaty's Scale/sum * 100)	Relative influencing factor
Lithology	1	1	38.71	39
Geomorphology	1/2	0.5	19.35	19
Drainage Density	1/3	0.33	12.77	13
Lineament Density	1/4	0.25	9.67	10
Soil types	1/5	0.20	7.74	8
Slope categories	1/6	0.16	6.19	6
LU/LC	1/7	0.14	5.42	5
		Sum = 2.583		

Table 3. Assigned weight according to Saaty's analytical hierarchy process

Influencing factor	Class intervals or features	Saaty's scale (Fraction)	Saaty's scale (Decimal)	Percentage Influence = (Saaty's scale/ sum) * 100	Relative influencing factor
Lithology	Limestone & Dolomite	1	1	48.07	48
	Migmatite and Granodiorite	1/2	0.5	24.03	24
	Amphibolite /Metapelitic Schist	1/3	0.33	15.86	16
	Charnockite	1/4	0.25	12.01	12
			Sum=2.08		
Geomorphology	Pediplain	1	1	40.98	41
	Pediment	1/2	0.5	20.49	20
	Pediment inselberg complex	1/3	0.33	13.52	14
	Reservoir	1/4	0.25	10.24	10
	River/ Streams	1/5	0.20	8.19	8
	Hills	1/6	0.16	6.55	7
			Sum=2.44		
Drainage density (m/m^2)	0.99 – 1.32	1	1	43.85	44
	0.82 – 0.99	1/2	0.5	21.92	22
	0.60 – 0.82	1/3	0.33	14.47	14
	0.31 – 0.60	1/4	0.25	10.96	11
	0 – 0.31	1/5	0.20	8.77	9
			Sum=2.28		
Lineament density (m/m^2)	0.38 – 0.64	1	1	43.85	44
	0.29 – 0.38	1/2	0.5	21.92	22
	0.19 – 0.29	1/3	0.33	14.47	14
	0.09 – 0.19	1/4	0.25	10.96	11
	0 – 0.09	1/5	0.20	8.77	9
			Sum=2.28		
Soil types	Clayey-skeletal	1	1	54.64	55
	Clayey	1/2	0.5	27.32	27
	Rocky land	1/3	0.33	18.03	18
			Sum=1.83		
Slope categories	0 – 3 degree	1	1	43.85	44
	3 – 7 degree	1/2	0.5	21.92	22
	7 - 11 degree	1/3	0.33	14.47	14
	11 – 18 degree	1/4	0.25	10.96	11
	18 – 51 degree	1/5	0.20	8.77	9
			Sum=2.28		
Land use/ land cover	Wastelands	1	1	43.85	44
	Agricultural land	1/2	0.5	21.92	22
	Forest cover	1/3	0.33	14.47	14
	Water bodies	1/4	0.25	10.96	11
	Built-up land	1/5	0.20	8.77	9
			Sum=2.28		

Soil: Soil highly influences the groundwater infiltration in ARS site suitability analysis. Surface water flow and infiltration rates are controlled by permeability and porosity of various soil types. Charnockite and granitic-gneisses are the parent rocks of soil types observed in kote taluk (Fig. 2h). Deeply well drained and slight salinity are shown by clayey soils; whereas moderately well drained with and slight salinity are observed by clayey-mixed soils (CGWB 2012, Basavarajappa et al 2013). Very deep, well-drained with slight erosion are noticed by clayey-skeletal soils in association with gravelly clay soils of shallow to excessively drain and moderately eroded (CGWB 2012). Deep to moderately drain on gently sloping areas with modest eroded particles are noticed from rocky land soils (Basavarajappa et al 2013). Basic intrusions in contact with schist rocks showed mixed soil types localized at certain junctions of kote taluk. The soil textures and types of various infiltration capacity are analyzed to determine best sites for ARS with specific weightages (Table 3).

Slope: Surface water runoff and infiltration capacity are determined by slope classes. Slopes are classified into five categories and proper (Fig. 2i, Table 3). Flat to gentler slope zones imply low runoff and longer water residing time for higher infiltration rates that are benefitted for ARS sites; whereas moderate to greater slopes increase surface runoff making unsatisfactory for ARS. Nearly flat terrain (0-3 degree) is most acceptable lands for 'Very Good' ARS category with higher infiltration capacity. Gentler to slightly undulating lands (3-7 degree) are moderately acceptable as 'Good' ARS category which accepts some amount of runoff. Moderate slopes of 7-11 degree exhibit little infiltration capacity due to higher surface runoff; whereas moderately steep slopes (11-18 degree) represents much higher runoff. Steeper slopes (18-51 degree) imply highest runoff with negligible infiltration capacity.

Land use/ land cover: Built-up, waterbodies, forest, agricultural land, wastelands, and other features are successfully digitized in ArcGIS platform (Fig. 2j) (Manjunatha and Basavarajappa 2021). The agricultural practices of H.D kote taluk are regularly impacted by the surface and sub-surface hydrologic factors of surface flow, evaporation, catchment area, infiltration capacity and interception. Manmade land patterns are assigned with least weight, since this affects recharge. Appropriate weightages are provided based on various land patterns and their specific utilization that may influence ARS sites (Table 3).

Stream Order (Sμ): Identification of stream orders is an essential part in the interpretation of drainage basin. Lithology, morphology and precipitation influences the variation of total stream number and its length in the terrain (Basavarajappa et al 2014). The kote taluk denotes medium precipitation and nearly flat to steeper sloppy areas. Greater discharge are recorded from higher stream orders. Six number of streams are extracted from DEM image for the present study and denoted as 1st to 6th (Fig.2k). Gentler slope lands in association with the stream orders of 2nd, 3rd or 4th are satisfactorily acceptable for ARS percolation tank and other storage tanks (Table 2, 3).

Analytical Hierarchy Process (AHP)

Weighted overlay method: Each thematic layers are assigned proper weightages in accordance with their respective contribution towards the best ARS results for H.D kote taluk. All layers are transformed into raster format using ArcGIS and later the pair-wise interpretation was analyzed in computing the overall score of each criteria. Highly suitable, suitable, moderate, poor, and very poor categories are obtained by using standard deviation classification scheme. Settlements, temples, telephone lines, power lines, taluk & state roads, and other features are ruled out while mapping ARS best site (Fig. 3). Considering the respective significance among the factors portray the real ground conditions.

Need for artificial recharge structures: The effective improvement of groundwater recharge is required for strengthen of major/ minor irrigation and balances between demand-supply equilibrium to all water requiring sectors in H.D kote taluk. ARS is a vital components and major strategies in groundwater management planning for natural

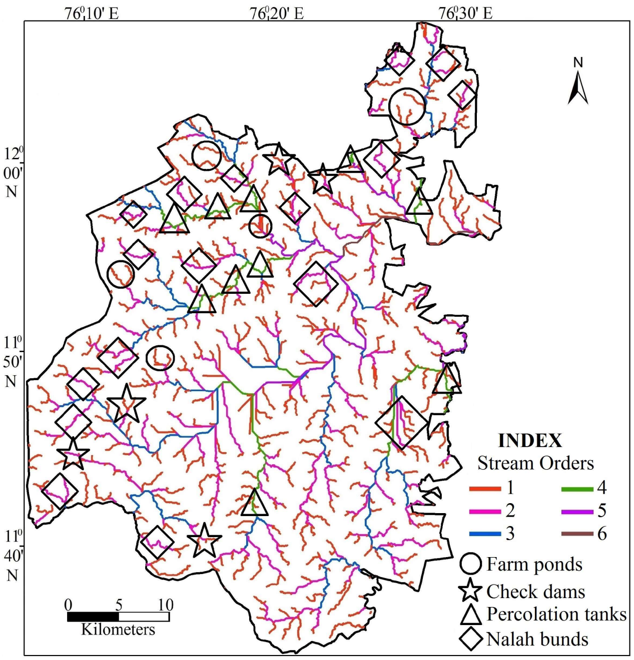

Fig. 3. Final output map to implement ARS for H.D Kote taluk

supply of groundwater. Farm ponds, check-dams, percolation tanks, nalah bunds, barrages are the efficient storage methods of rain water especially for agricultural practices in the taluk which is majorly rainfall dependent. This acts as a sustainable strategy in groundwater augmentation especially in lean seasons.

Farm ponds are compact sized and rectangular shaped trenches that receive surface run-off water over agricultural lands by a narrow stream having 10% ground slope on either sides (Fig. 3). Shrub/ barren types with moderate infiltration capacity of soils are acceptable land to build farm ponds (Manjunatha et al 2019). The elevation of these ponds must be higher than any irrigated lands where it can deliver prime goal for irrigation (Manjunatha et al 2019). These ponds receives the groundwater recharge from post-monsoon periods also. The groundwater contaminations are diluted by interconnecting nearby farm ponds for effective recharge of better quality water. Both soil erosion and conservation of water are addressed by series of check dams that harness water over larger areas. These dams must be built near the crop types of higher potential for better allocation of harvested water. The gentler slopes of 1st and 2nd stream orders are most appropriate for these structures (Fig.3). They store runoff water most of confined type to stream course with less than 2m height from ground level.

Best conventional method of groundwater recharge especially in India is Percolation tanks in case of both hard rock terrains as well as alluvial such as H.D kote taluk (ARS Guide 2000). These are artificially managed surface water on permeable lands observed parallel to the streams in such a way that it can achieve maximum percolation with least evaporation lose. Small streams with gentler slopes of 3-7 degree are most satisfactory for these tanks (Fig. 3) that stores monsoon runoff over larger lands of soil types having moderate to higher pores/ voids. Nalah bunds are small earthen dams of 2 to 3 m high, 1 to 3 m wide and, 10 to 15 m long which normally acts as mini percolation tank (Manjunatha and Basavarajappa 2021). These are best suited across bigger streams of gentler slopes and contour/ graded bunding lands of having lower annual rainfall of 1000mm and should vulnerable to water logging (Fig.3) (ARS Manual 2007, CGWB 2012). Taluk show plain regions in central and northern parts; whereas hilly area are restricted to southern region. The elevation difference had modified the irregular patterns of groundwater flow that falls under Kapila river basin. Principal aquifers of H.D kote taluk are schist & gneisses and hence the circulation of groundwater is controlled by secondary porosity caused by weathering and fracturing of hard rocks. Lineaments trending NE-SW and NW-SE are expected to yield greater. The taluk was categorized under safe zone with groundwater exploration of 47% (CGWB 2022). However ARS is essential especially during extreme summer conditions where sufficient amount of water cannot be supplied for paddy, sugarcane and tobacco which are high water intensive crops.

Nalah bunds (17), percolation tanks (10), farm ponds (5) and check dams (5) are identified to implement best ARS sites for H.D kote taluk using AHP in GIS platform. Southern and eastern parts of H.D kote taluk shows hilly and rugged topography where nalah bunds are appropriate to build; whereas on flat to nearly gentler areas are suitable for percolation tanks (Fig. 3). These structures also helpful to reduce future water crisis that may occur due to global warming, industrial and agricultural water demands. The infiltration rates are noticed to be high near waterbodies, croplands and floodplains that exhibits best ARS sites; whereas low infiltration rate lands show least suitability.

CONCLUSION

Check dams and nalah bunds are suited as a management method to tackle over-withdrawal of water and to avoid fall in groundwater table. AHP and WOM are the excellent approach for ARS sites in ArcGIS insights that significantly enhance the crop yield, irrigation capacity, and sustainability of water sources for demographic growth and demands. Geospatial technology proved to be a policy making in controlling surface water runoff and larger recharge to deep aquifers through cost effective techniques. AHP is the best site suitable analysis in assigning priority based weightages for arresting subsurface flows and groundwater augmentation.

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REFERENCES

Anirudh Datta, Himanshu Gaikwad, Ajaykumar Kadam and Bhavana N Umrikar 2020. Evaluation of groundwater prolific zones in the unconfined basaltic aquifers of Western India using geospatial modeling and MIF technique. *Modeling Earth Systems and Environment* **6**: 1807-1821.

ARS Guide 2000. *Guide on Artificial Recharge to Groundwater*, Central Ground Water Board, Ministry of Water Resources, New Delhi, p 1-59.

ARS Manual 2007. *Manual on Artificial Recharge of Groundwater*. Central Ground Water Board, Ministry of Water Resources, Govt. of India, New Delhi, p 1-198.

Basavarajappa HT, Parviz Tazdari and Manjunatha MC 2013. Integration of soil and lineament on suitable landfill sites selection and environmental appraisal around Mysore city, Karnataka, India using Remote Sensing and GIS techniques, *International Journal of Civil Engineering and Technology* **4**(6): 177-185.

Basavarajappa HT, Dinakar S and Manjunatha MC 2014. Analysis of Land Use/ Land Cover Classification around Mysuru and Chamarajanagara district, Karnataka, India using IRS-1D, PAN+LISS-III Satellite data. *International Journal of Civil Engineering and Technology* **5**(11): 79-96.

CGWB 2012. Central Ground Water Board, Groundwater Information Booklet. Mysuru district, Karnataka State, South Western region, Govt. of Karnataka, Bengaluru: p 1-21.

CGWB 2022. Report on Aquifer mapping and Management plan, Heggadadevanakote Taluk, Mysore district, Karnataka. Central Ground Water Board, South Western Region, Bengaluru: p 1-22.

Fateme Falah, Samira Ghorbani Nejad, Omid Rahmati, Mania Daneshfar and Hossein Zeinvand 2016. Applicability of generalized additive model in groundwater potential modeling and comparison its performance by bivariate statistical methods. *Geocarto International* **32**(10): 1069-1089.

Manjunatha MC, Madhu SP, Sharath HP, Rakshitha J, Inchara K and Divya 2019. An approach to delineate artificial recharge structures for Piriyapatna taluk of Mysuru district, Karnataka, India using Geoinformatics. *Journal of Emerging Technologies and Innovative Research* **6**(5): 163-178.

Manjunatha MC and Basavarajappa HT 2021. Artificial Recharge Structure for Groundwater sustainability in Krishna Raja Nagara taluk of Karnataka State, India using Geospatial technology. *International Advanced Research Journal in Science, Engineering and Technology* **8**(7): 355-366.

Srinivasa Vittala S, Govindaiah S and Honne Gowda H 2005. Evaluation of groundwater potential zones in the sub-watersheds of North Pennar river basin around Pavagada, Karnataka, India using Remote Sensing and GIS techniques. *Journal of Indian Society of Remote Sensing* **33**(4): 473-483.

Thomas Saaty L 1980. The Analytic Hierarchy Process, *McGraw Hill International*.

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