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# Surface Water Mapping using Google Earth Engine (GEE) for South Gujarat Forest

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***Abstract*:** The spatial and temporal changes in surface water area were analyzed in Dang district of south Gujarat. The time series of normalized difference water index (NDWI) with Google earth engine (GEE) open source online planetary processing platform was used. Spatial distribution precipitation, LST, NDVI and ETa were also analyzed. The surface water availability showed high positive correlation with precipitation (0.76), LST (0.93) and $ET_a$ (0.90). The surface water availability varied month wise, minimum surface water area was observed in May while maximum in January. Availability of surface water increases NDVI and ETa thus decrease LST and *vice-versa*.Present results would be helpful to planner and forest department to make decisions for water conservation activities in forest area.

***Keywords***: Remote sensing, Surface water, Forest hydrology, Water conservation

Surface water in forests plays an important role in regulating local and regional climates by influencing temperature, humidity, and precipitation patterns. Surface water is essential for maintaining the forest ecosystem health and biodiversity, and regulating a range of ecological processes in turn provides several services. Water bodies need to be analysed and monitored consistently for efficient management of the forest water resources. Precise spatial and temporal information of surface water in forest area gives vital data for forest hydrology, planning of water conservation structures, providing crucial knowledge for preparing of water hole in forest for wild animal and assisting in the monitoring water-based ecosystems. Changes in forest cover, water yield and evapotranspiration can alter surface water dynamics (Bruijnzeel 2004, Jackson et al 2009).

Effective methods are important for monitoring the spatial and temporal changes in surface water which can analysed by remote sensing technologies as remote sensing is far more effective than conventional *in situ* measurements since it can continually track the Earth's surface at various scales (Huang et al 2018). This has emerged as a cutting-edge technology method for quickly obtaining water information because of its benefits of real-time, extensive coverage, and comprehensive information (Li et al 2022). Water indices, which are derived from two or more bands and used to distinguish between water and non-water areas, has been a quick and efficient technique to extract water (Huang et al 2018). Normalized difference water index (NDWI) derived from satellite images are commonly and successfully utilized in surface water body detection and mapping (Du et al 2014, Özelkan 2020). NDWI was used to detect the surface water bodies in parts of Upper Krishna River basin, Maharashtra State of India (Ashtekar et al 2019). However, this type of analytical operations needs specific high-end software and voluminous downloaded data sets to create desired output which is time cumbersome process. Therefore, high-performance data computing platforms based in the cloud, like Google Earth Engine (GEE), have emerged as better alternative options. Moreover, this platform's impressive satellite image archives, coupled with sophisticated in-built processing and analyzing toolkits, immensely help remote sensing-based studies. Now a day GEE is widely used (Amani et al 2020) in various study such as land use land cover change (Sidhu et al 2018), wetland inventory (Amani et al 2019), crop land mapping (Xiong et al 2017), irrigated area mapping (Magidi et al 2021), flood monitoring (DeVries et al 2020), water bathymetry mapping (Li et al 2021), forest monitoring (Jahromi et al 2021 and Piao et al 2022), costal ecosystem assessment (Wang et al 2020) and drought assessment (Sazib et al 2018). The availability of water bodies has changed over time and space, and the scarcity of water resources is getting worse in the south Gujarat forest area, as a result, the monitoring of water bodies is indispensable. Even though the Dang district receiving highest rainfall than other district of Gujarat, but it is experiencing low availability of surface water particularly during dry months. Hence, the present study aims to delineate and assess the spatial and temporal change in surface water of dang district using the Google earth engine.

## MATERIAL AND METHODS

**Study area:** The study was conducted in the Dang district, which fall in the heavy rainfall zone of the southern part of Gujarat (Fig. 1). The Dang is a hilly district, primarily populated by tribal people and located in eastern part of the western Ghat of India. It has the highest forest density (77.16%) in the state and covers an area of 1766 $km^2$ (ISFR, 2019).

**Data used:** Sentinel 2 satellite data was used for assessing spatial and temporal change in surface water body. QGIS software and Google earth engine were used for NDWI index generation, classification and extract water bodies. Other climatic parameters were derived for the study area using climate engine (Huntington et al 2017). The detail of the data used in the study is given in Table 1.

The images were accessed from the GEE platform (https://earthengine.google.org/). The images were geometrically referenced and were top-of-atmosphere (TOA) images. While constructing the image archive, a cloud filter criterion of 10% was implemented across region of interest (ROI). Further, for more precise construction of the data achieve, monthly median data was generated along with mosaic data sets for the ROI. The standard code for delineation of water surface body was written using java script for cloud computing in Google earth engine. The flow chart of surface water mapping is shown in Figure 2.

NDWI is calculated with the following equation.

$$NDWI = \frac{Green - NIR}{Green + NIR}$$

where, the B3 band represents the green band for sentinel 2 images, while the B8 band represents the NIR band. This study, for each NDWI calculated, pixels with NDWI >0 were considered water and pixels with NDWI ≤0 were marked as non-water.

In addition, climatic parameters were derived for the study area from climate engine from 2016 to 2022. The MODIS land surface temperature, NDVI and were converted into annual data where as CHIRPS Precipitation and Actual Evapotranspiration (MODIS SSEBop) data set were daily and converted in to annual data for comparison and correlation with surface water availability.

## RESULTS AND DISCUSSION

The extent of surface water body for Dang district during post monsoon month from 2017-2022 estimated using multidate NDWI (Fig. 3, Table 2) indicated that surface water availability varied from month to month and higher surface water area was observed during January month. The lowest surface water was observed in May due to the higher land surface temperature and increases in evapotranspiration the study area. The resultant effect of bioclimatic parameters greatly influence the water surface area during dry months. The availability of surface water in respective months differ due to amount of rainfall, temperature, actual evapotranspiration and other climatic parameters (Table 3).

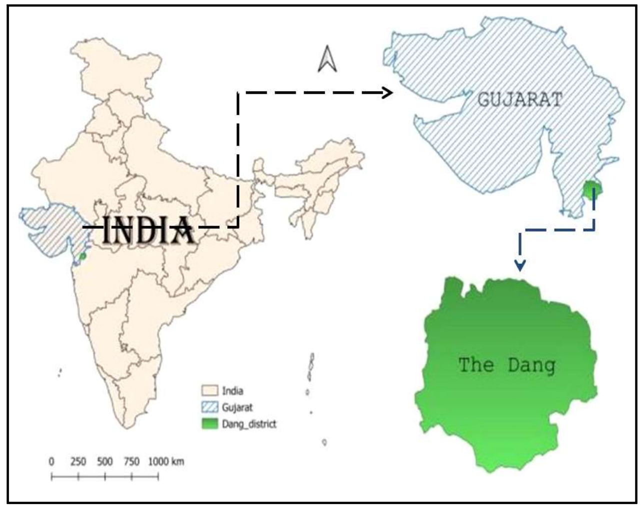


**Fig. 1.** Location of Dang district

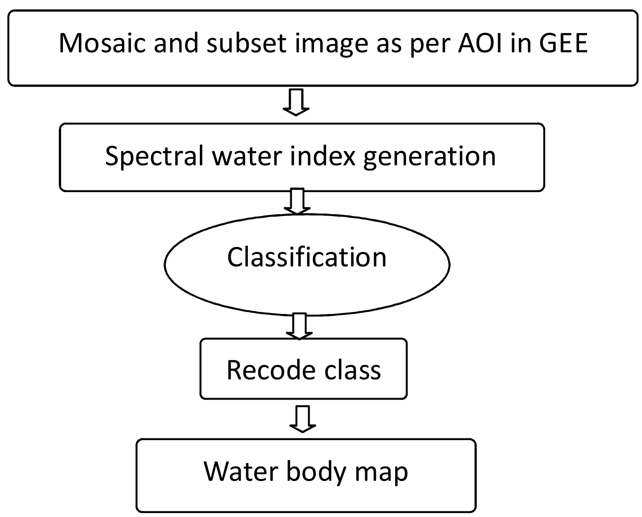


**Fig. 2.** Schematic for the surface-water mapping

**Table 1.** Data used for the study

| Product | Resolution | Duration |
|---|---|---|
| Sentinel 2 | 10 m | 2017-2022 |
| MODIS Terra Daily (LST) | 1000 m | 2017-2022 |
| MODIS Terra Daily (NDVI) | 500 m | 2017-2022 |
| CHIRPS Precipitation Daily | 4800m | 2016-2021 |
| MODIS SSEBop (Actual Evapotranspiration) $ET_a$ | 1000 m | 2017-2021 |

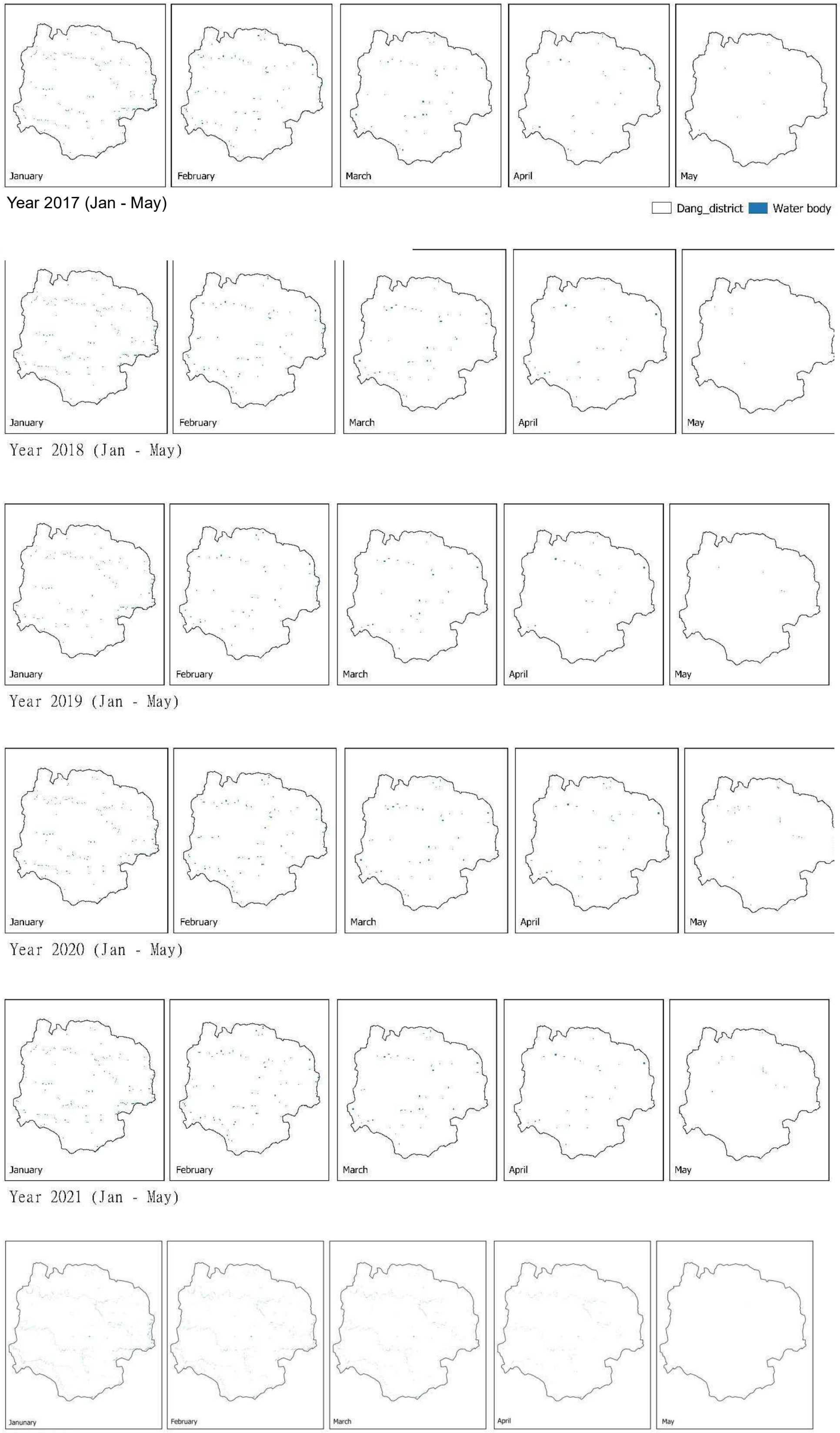


**Fig. 3.** Spatial and temporal surface water availability map for the year 2017-2022 (Jan-May)

The spatial distribution of the different parameters precipitation, LST, NDVI and ETa are given in Figure 4, 5, 6 and 7, respectively. Vegetation contributes significantly in reduction of LST which indirectly contributed in surface water availability. Interestingly, surface water availability was highly positively correlated with precipitation (0.76), LST (0.93) and $ET_a$ (0.90). It is evident that availability of surface water mainly depends upon the quantity of rainfall occurred during previous year and thus increases NDVI and ETa while reduces LST. The amount of rainfall in previous year is the driven factor affecting the availability of surface water that triggered the increase/decrease LST, NDVI and ETa. For instance, lowest rainfall occurred in the year of 2018 showed higher LST in contrary NDVI and ETa observed lowest in the

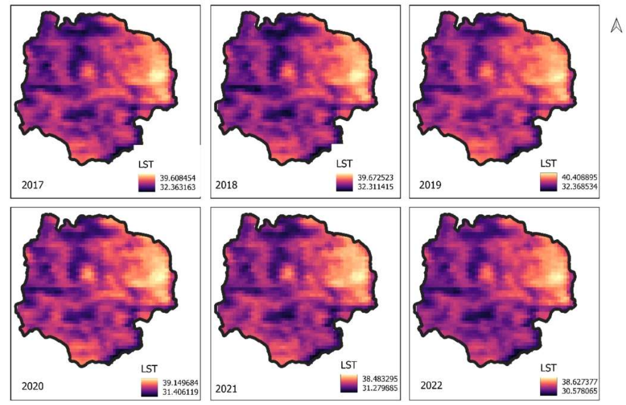


**Fig. 5.** LST map of the Dang district during year 2017 to 2022

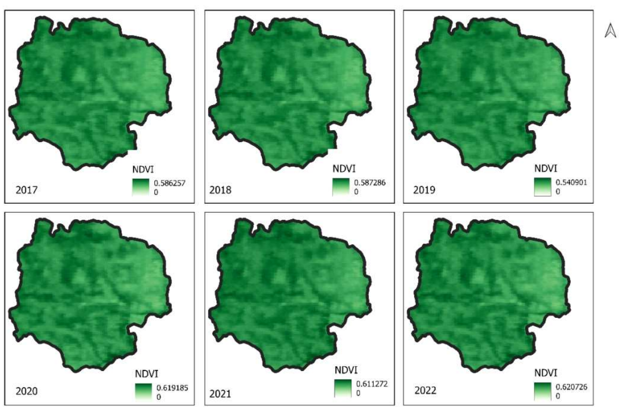


**Fig. 4.** NDVI map of the Dang district during year 2017 to 2022

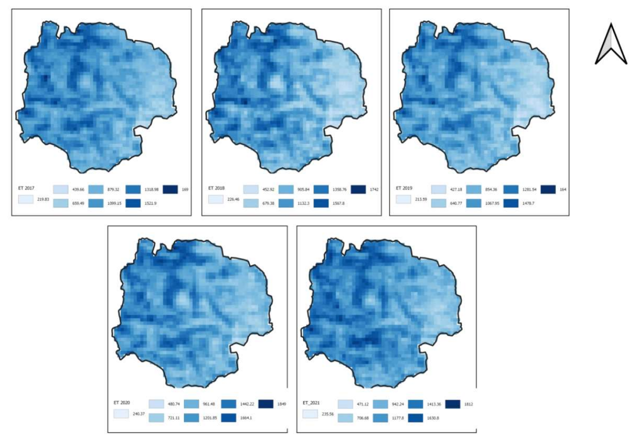

**Fig. 6.** $ET_a$ map of the Dang district during year 2017 to 2021

**Table 2.** Surface water area of the Dang district

| Year | Surface water area (km$^2$) | | | | |
|---|---|---|---|---|---|
| | January | February | March | April | May |
| 2017 | 9.50 | 7.20 | 4.00 | 2.11 | 0.42 |
| 2018 | 10.04 | 7.11 | 4.81 | 2.06 | 0.36 |
| 2019 | 8.05 | 5.19 | 3.11 | 2.11 | 0.49 |
| 2020 | 10.05 | 7.80 | 4.70 | 3.09 | 1.85 |
| 2021 | 10.22 | 7.80 | 4.63 | 2.34 | 1.17 |
| 2022 | 9.73 | 8.04 | 5.62 | 2.82 | 0.08 |

**Table 3.** Average annual climatic parameter for the Dang district

| Year | Precipitation (mm) | Year | LST ($^0$C) | NDVI | ETa (mm) |
|---|---|---|---|---|---|
| 2016 | 1205 | 2017 | 35.62 | 0.457 | 1057.02 |
| 2017 | 1212 | 2018 | 35.58 | 0.459 | 1027.15 |
| 2018 | 941 | 2019 | 36.30 | 0.426 | 942.43 |
| 2019 | 1498 | 2020 | 35.15 | 0.482 | 1127.99 |
| 2020 | 1756 | 2021 | 34.59 | 0.495 | 1175.59 |
| 2021 | 1223 | 2022 | 34.15 | 0.487 | - |

year 2019.Further, higher precipitation in the previous year (2020) accumulates more surface water availability and thus increases NDVI and ETa, while following year LST will be lower during 2021indicate that LST had negative relationship to surface water availability, whereas rainfall, NDVI and Eta had positive relationship with surface water availability. This spatial and temporal information of surface water facilitate a valuable insight especially in the forest such as migration of wild animals, site suitability for develop nursery, planning of water conservation structure, *etc*. Rapid spatial and temporal surface-water assessment using remote sensing techniques opens up a lot of possibilities for managing, monitoring, and planning of forest water resources.

## CONCLUSION

Monthly changes in surface water availability coupled with precipitation, LST, NDVI and ETa were reflected in this study. Lowest rainfall occurred in the year of 2018 showed higher LST in contrary NDVI and ETa observed lowest in the year 2019. Higher is the previous year precipitation (2020) accumulates more surface water availability and thus increases NDVI and ETa, while following year LST will be lower during 2021. Therefore, Remote sensing and GIS significantly contribute in rapid assessment of surface water availability in open-source platform like Google Earth Engine which reduces the cost and time for different decision-making process of forest and its conservation.

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