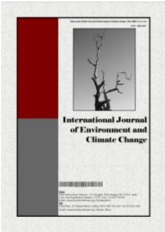

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Mapping Spatio-temporal Variations of Surface Water Area of Tanks in Coimbatore Corporation Using Google Earth Engine

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Surface water is one of the most significant elements of the earth's ecosystem. It is the basic information for analysing the changes in the environment. Therefore it is important to monitor water resources accurately. Nowadays remote sensing plays a major role in extraction of water spread area. In this study, change in water spread area of tanks was mapped for Coimbatore corporation from 2000 to 2021. The analysis was performed in Google earth engine platform using Landsat ETM+ and Landsat OLI datasets. The images for pre monsoon and post monsoon season were scrutinized and classified using random forest classifier in Google earth engine. The area of each tanks and their deviations were calculated for the study period. Results of the study showed that the lowest water spread area was observed in the period from 2000 to 2005 for both pre monsoon and post monsoon season. The tank has maximum water spread area during post monsoon season. The difficulties that has been confronted during the research is the unavailability of images due to cloud cover. The study shows that the random forest classifier can be effectively used to extract water features and water spread area.

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Keywords: Google earth engine; landsat; random forest classifier; surface water; tanks.

1. INTRODUCTION

Tanks are one of the vital sources of irrigation which is found in all parts of India, especially in Southern India. The state Tamil Nadu has around 39000 tanks but nowadays due to the use of other sources like bore wells, these tanks are losing their significance. A tank consist of feeder channels, water spread area, catchment area, outlet structures (sluices), flood disposal structures (surplus weir) and command area [1]. Tank irrigation helps to store the rain water and also the runoff from the catchment which can be effectively used for agriculture and other domestic purposes. Coimbatore district is a part of Tamil Nadu's upland plateau region, which features various hill ranges, hillocks, and undulating topography with mild slopes to the east and mountainous terrain to the west. The numerous depressions created by the undulating topography were effectively employed as tanks for storage of rain water for agriculture and other direct and indirect uses.

Conventional methods for extracting the water spread area are time consuming, costly, and require a substantial amount of labour. As a substitute, the traditional approaches are replaced by remote sensing techniques. They are preferred because they are cost and time efficient when estimating the water spread area [2]. Remote sensing is extremely beneficial for gathering data on water resources and managing them using satellite data. Changes in surface water resources, water quality evaluation and monitoring, flood hazard, damage assessment and management, and water-borne disease epidemiology are all examples of remote sensing applications in water resources. Surface water mapping is important for describing its spatial and temporal change [3, 4].

Google Earth Engine, a cloud based computing platform has recently gained attention of remote sensing based methods. Users can use a web-based Integrated Development Environment (IDE) code editor to examine all accessible remotely sensed images without having to download them to their systems. In this study Google Earth Engine is used for the spatio-temporal mapping of surface water which can be used for proper monitoring and management of water resources. Also Google Earth Engine facilitates the rapid processing of satellite images. In this study, the water spread area of Coimbatore District Corporation was analyzed using Google Earth Engine for pre monsoon and post monsoon season during 2000-2021.

2. MATERIALS AND METHODS

2.1 Study Area

Coimbatore Corporation is a part of the Coimbatore district, is located in the western region of Tamil Nadu state. It lies between 10°13’ N and 11°23’ N latitudes and 76°39’ E and 77°30’ E longitudes.The study area is given in Fig. 1 which consist of eight tanks and the details of each tank is given in Table 1.

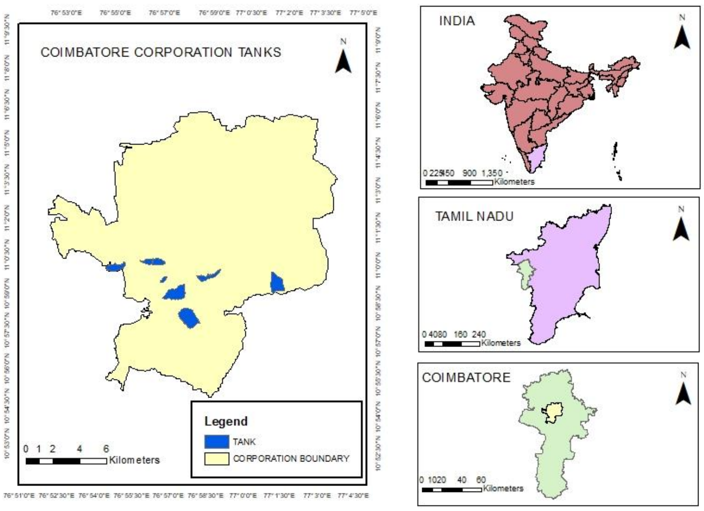

Fig. 1. Study area map

Table 1. Details of tanks used in the study

Sl. No.	Name of tank	Latitude and Longitude	Catchment Area	Water storage capacity
1	Narasampathy tank	11° 0' 3. 5" N and 76° 54' 54" E	963 ha	4.45 Mcft
2	Selvampathy tank	10° 59'27" N and 76° 56'42" E	400 ha	3.02 Mcft
3	Kumaraswamy tank	11° 0' 7.2" N and 76° 56' 38.4" E	1600 ha	6 Mcft
4	Selva Chinthamani tank	10°59' 24" N and 76° 56' 52.79"E	1600 ha	3 Mcft
5	Periyakulam tank	10° 56' 48" N and 76° 57' 28.79"	6300 ha	97 Mcft
6	Valankulam tank	10° 59' 31.2" N and 76° 58' 26.4" E	480 ha	16.7 Mcft
7	Kurichi tank	10° 57'56" N and 76° 57'54" E	1624 ha	60.00 M.cft
8	Singanallur tank	10° 59' 16.79" N and 77° 01' 37.2" E	1178 ha	30 Mcft

2.2 Methodology

Frequent change in water spread area is observed every year. Therefore time series of Landsat image is used to quantify the changes in water spread area of each tank. United States Geological Survey (USGS) Landsat calibrated top-of-atmosphere (TOA) reflectance, or orthorectified images available on the Google Earth Engine as image collections were used for extracting surface water in this study. Supervised classification method was performed in this study for mapping of water spread area of tanks. The first step was to import images having cloud cover lesser than 20 percentage for both pre monsoon and post monsoon period into Google Earth Engine. LANDSAT ETM+ data for the period of 2000-2013 and LANDSAT OLI for 2013-2021 were used in this study. The images were pre-processed in Google Earth Engine platform and classified by providing training datasets for each land use classes. Training datasets were provided based on the visual interpretation of the images for water bodies, urban area, vegetation and barren land. Random Forest classification algorithm was employed for classifying the images in Google Earth Engine. The four major land use classes classified for this study in Random Forest are water, urban, vegetation and barren. Agricultural area and forest are considered as vegetation whereas tanks and lakes are considered as water. The classified images in Google Earth Engine were exported as GeoTiff format. The area of each tank was calculated using GIS software by digitizing the tanks and calculating the area for both pre monsoon and post monsoon months from attribute table using calculate geometry tool.

2.3 Random Forest Classifier

Random Forest Classifier has been used in the study for classifying the images in Google Earth Engine. The Random forest Classifier uses Bootstrap sampling method for extracting the number of samples from the training sample and the sample size of each sample, are the same as that of the original training set. A number of trees were created for the samples and classification results were obtained based on the number of samples [5]. Random Forest Classifier is a kind of tree algorithm classification and is one of the popularly used classifier for classifying satellite data across time and space [6]. A decision tree is an accurate deterministic data structure employed for modelling decision rules for a specific classification problem. One feature is selected at each node to make class determining the decision. Each tree in the classifier is built from a sample drawn with replacement from the training set. [7].Comparing to other classification approaches like SVM, ANN the Random Forest Classifier produces high classification accuracies [8]. It has following merits compared to other classifiers as:

- The random forest classifier uses little or no manual involvement as it identifies data characteristics by itself [9].
- Even though the random forest algorithm provides various data characterisations, it usually has a quick processing speed compared to other algorithms [10].

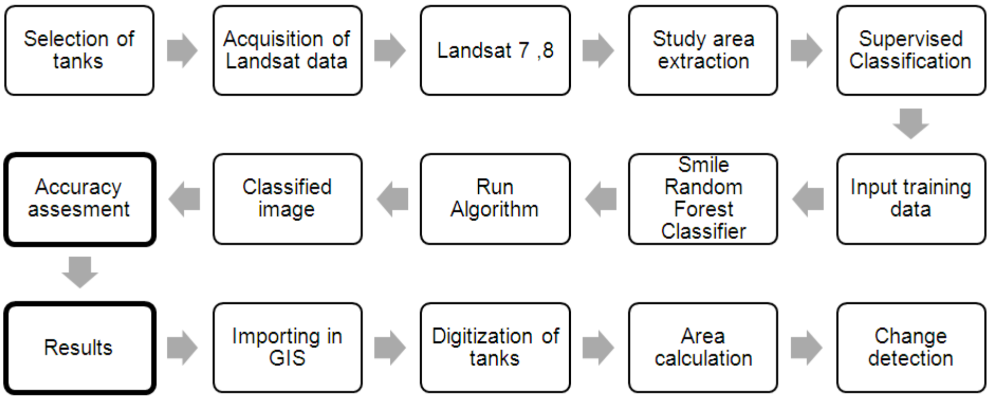

Fig. 2. Flowchart of the study

2.3 Data Acquisition and Processing

From the past few decades Landsat satellites are providing continuous imagery. The images used in this study are a part of Google Earth Engine's public data archive which can be applied for monitoring and detecting changes in environment. The details of the satellite data used in study are given in Table 2.

The Landsat 7 Enhanced Thematic Mapper Plus (ETM+) images exhibited wedge-shaped scan-to-scan gaps due to the failure of scan line corrector (SLC) on May 31, 2003. In this study, the Landsat 7 images exhibiting the gaps has been corrected by using the focal mean function in Google Earth Engine. To promote the visual interpretation, composite of the Landsat Bands such as Near Infra-red, Red and Green bands were produced. It is a commonly used band composite for determining vegetation, crops and water bodies. In this combination the vegetation appears in the shades of red, clear water appear dark bluish, urban appears grey and barren land appears light brown. The best band color combination for identifying surface water was dark blue.

Table 2. Specification of satellite data used in the study

Sl No.	Data	Sensor	Path/Row	Spectral resolution(μm)	Spatial Resolution (m)	Temporal Resolution (days)
1	Landsat 7	ETM +	144/052	0.45 - 0.52:Blue	30 x 30	
				0.53 - 0.61:Green	30 x 30	
				0.63 - 0.69:Red	30 x 30	
				0.78 - 0.90:NIR	30 x 30	16
				1.55 - 1.75:NIR	30 x 30	
				10.4 - 12.5:Thermal	60 x 60	
				2.09 - 2.35:MIR	30 x 30	
				0.52 - 0.90:PAN	15 x 15	
	Landsat 8	OLI	144/052	0.43 - 0.45:Visible	30 x 30	
2				0.45 - 0.51:Blue	30 x 30	
				0.53 - 0.59:Green	30 x 30	
				0.63 - 0.67:Red	30 x 30	
				0.85 - 0.88:NIR	30 x 30	
				1.57 - 1.65:SWIR	30 x 30	
				2.11 - 2.29:SWIR	30 x 30	16
				0.50 - 0.68:PAN	30 x 30	
				1.36 - 1.38:Cirrus	15 x 15	
				10.6 - 11.19	30 x 30	
				11.5 - 12.51	100 x 100	
		TIRS			100 x 100	

3. RESULTS AND DISCUSSION

An increasing trend in water spread area can be observed for Coimbatore corporation tanks while analysing the maps obtained through random forest classification. Both pre monsoon and post monsoon spatial variability has been investigated. A small difference in water spread area is observed between pre monsoon and post monsoon months. The month of April and May was chosen for pre monsoon and September to November is chosen for post monsoon season. Due to cloud cover, images for 2001, 2002, 2006, 2010, 2013 and 2017 were unavailable. Also for some months due to unavailability of cloud free images adjacent month images are used for classification. Because of this reason the pre monsoon water spread area is more than the post monsoon water spread area in some tanks. Year wise pre monsoon and post monsoon classified image are given in the Fig. 3 and Fig. 4.

3.1 Narasampathy Tank

From the Fig. 5 it can be noticed that the tank water spread area reduced in post monsoon period and slightly increased in pre monsoon period from 2005 to 2011. It is determined that tank area decreased by 0.298 km^2 in post monsoon period and increased by 0.009 km^2 in pre monsoon period. After that in 2015 a reduction is seen in both pre and post monsoon water spread area and it is determined to be 0.0025 km^2 for pre monsoon and 0.0232 km^2 in post monsoon period. Later the water spread area has been increased from 2015 to 2021 and it is found to be increased by 0.224 km^2 in pre monsoon period and 0.199 km^2 in post monsoon period.

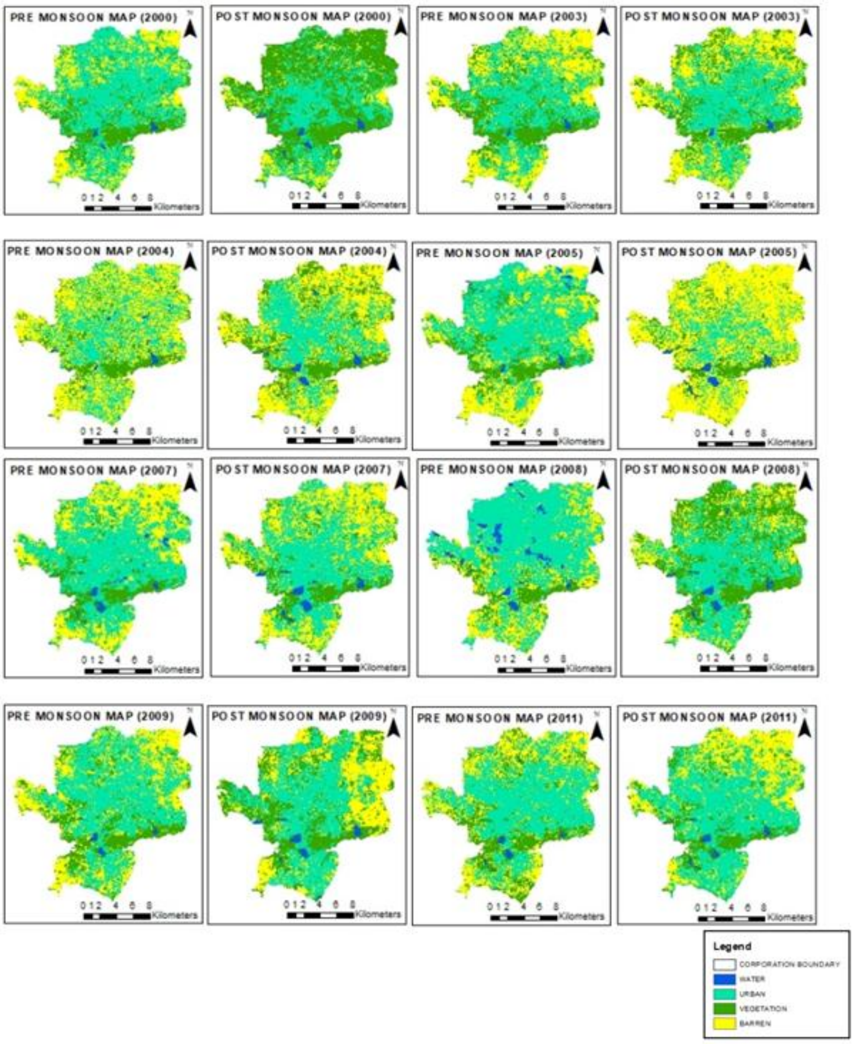

Fig. 3. Water spread area from 2000 to 2011

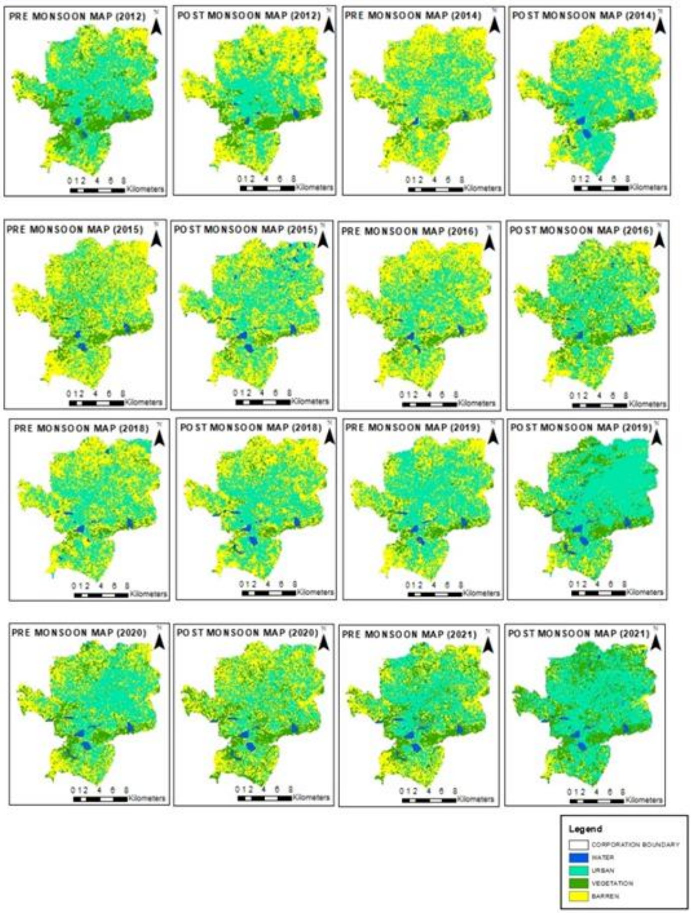

Fig. 4. Water spread area from 2012 to 2021

The details of change in water spread area of each tank are discussed below:

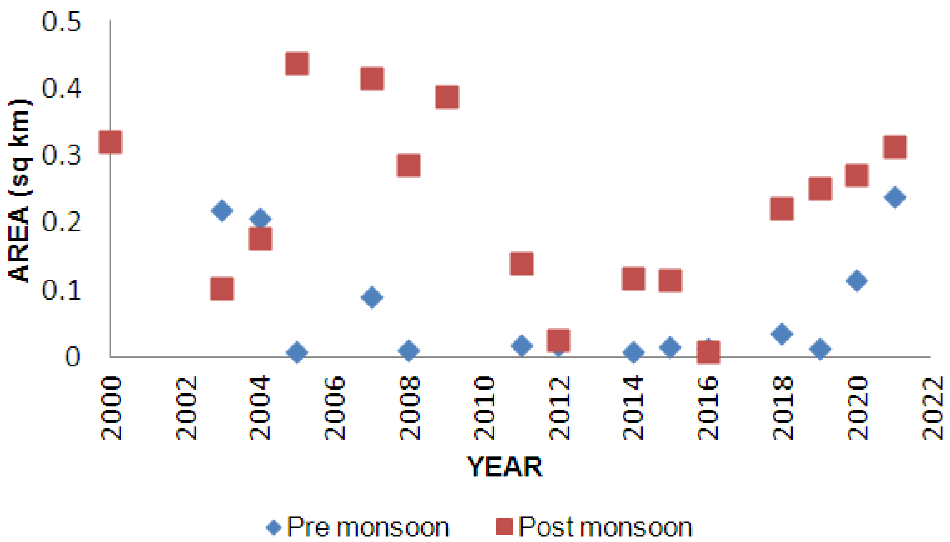

Fig. 5. Water spread area variability of Narasampathy Tank

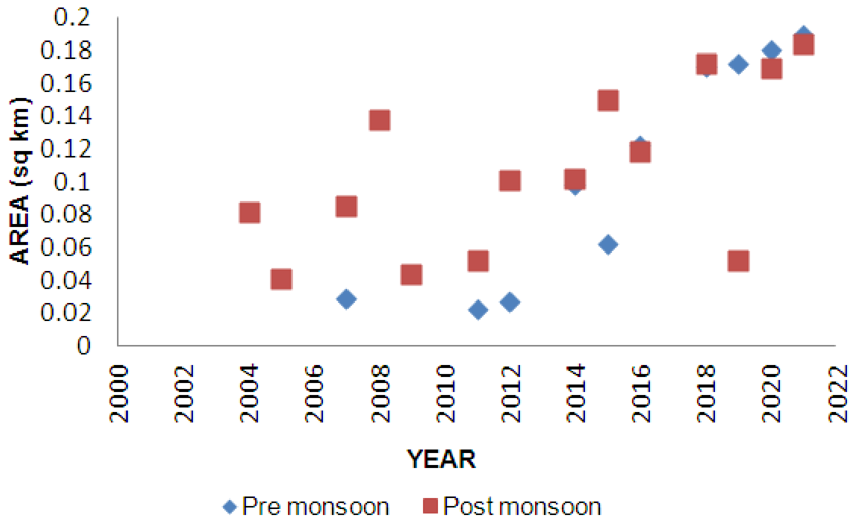

Fig. 6. Water spread area variability of Selvampathy Tank

3.2 Selvampathy Tank

Up to 2010 the tank water spread area is negligible. Thereafter the area has been increased from 2011 to 2015 and it was observed as 0.0397 km^2 for pre monsoon season and 0.098 km^2 for post monsoon season. Similar trend is seen from 2015 to 2021 as the water spread area has been increased by 0.127 km^2 and 0.0343 km^2 in pre monsoon and post monsoon period respectively.

3.3 Kumaraswamy Tank

The tank water spread area is negligible till 2005. Then it is noticed that the water spread area of tank up to 2011 expanded by 0.0193km^2 in pre monsoon period decreased by 0.043km^2 in post monsoon period. Analyzing the period from 2011 to 2015, there is an increase in area for both pre monsoon and post monsoon period by 0.076 km^2 and 0.096 $km^{2.}$ Similarly the area has been increased from 2015 to 2021 by 0.171km^2 pre monsoon and 0.029 km^2 post monsoon period.

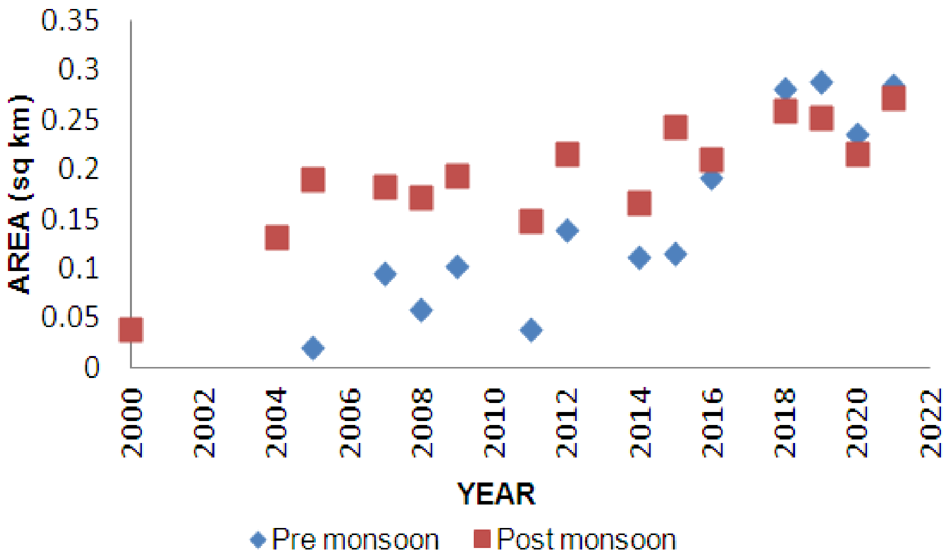

Fig. 7. Water spread area variability of Kumaraswamy Tank

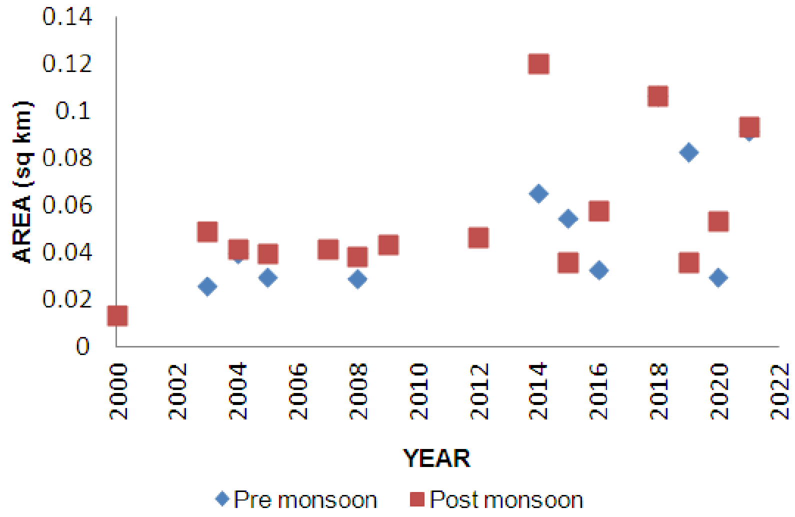

Fig. 8. Water spread area variability of Selvachinthamani Tank

3.4 Selvachinthamani Tank

From the Fig. 8 it can be seen there in only small variation in tank water spread area till 2012 and thereafter the water spread area has been increased. It was seen that the water spread area increased by 0.0365km^2 in pre monsoon season and 0.057 km^2 in post monsoon season.

3.5 Periyakulam Tank

This is the biggest tank of Coimbatore city. From analyzing the graph it can be seen that water spread area has been increasing and decreasing. The water spread area was increased for post monsoon season by 0.406 km^2 and reduced by 0.0564 km^2 in pre monsoon season in the period from 2000 to 2005. Later in 2011 there is reduction in water spread area in post monsoon season by 0.151 km^2 and increased in pre monsoon season by 0.2928 km^2. Subsequently both pre monsoon and post monsoon water spread has been increased from 2011 to 2015 by 0.132km^2 and 0.356 km^2. In 2021, a reduction 0.197 km^2 was noticed in post monsoon season whereas the water spread area has been increased by 0.238 km^2 in pre monsoon period.

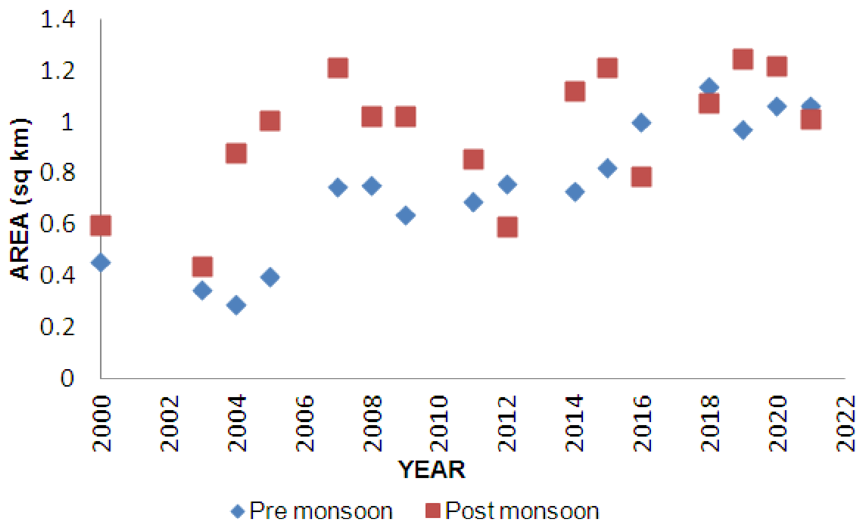

Fig. 9. Water spread area variability of Periyakulam Tank

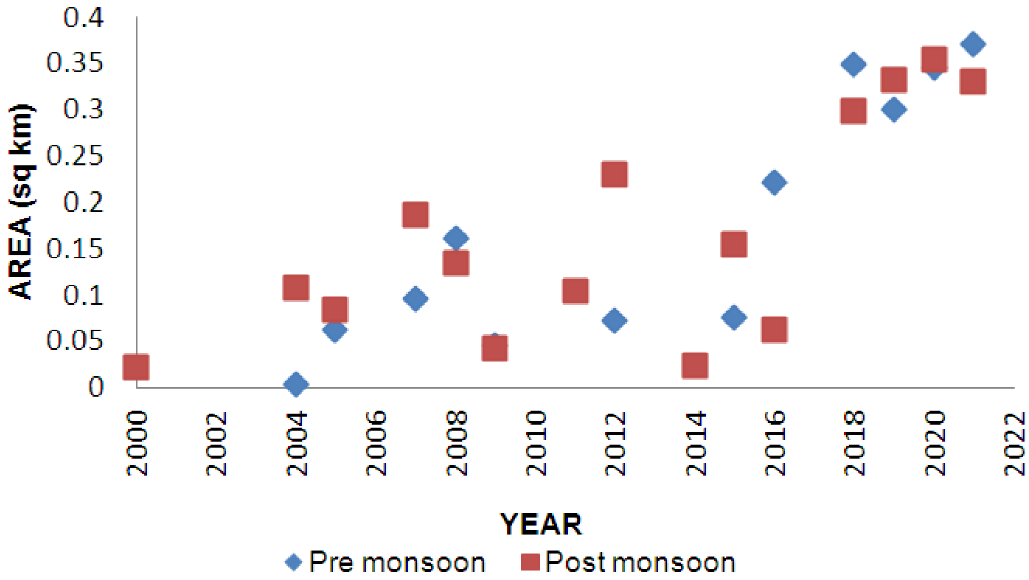

Fig. 10. Water spread area variability of Valankulam Tank

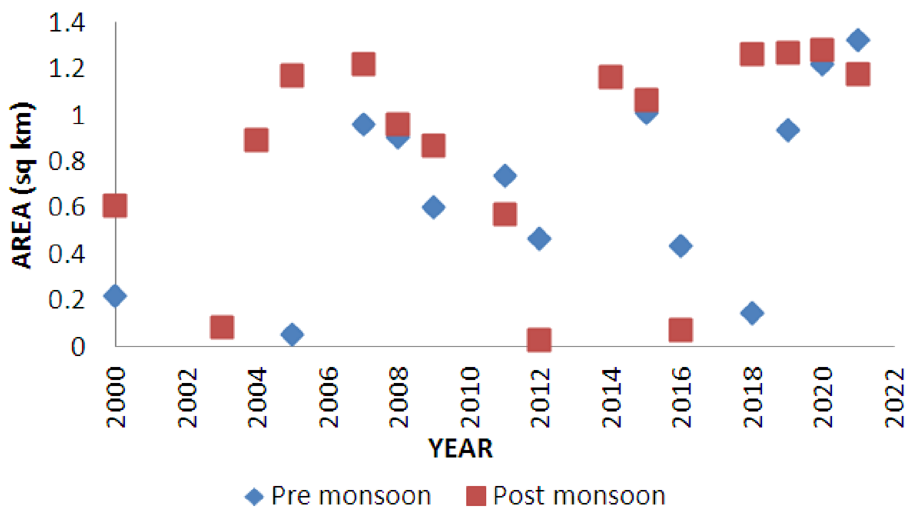

Fig. 11. Water spread area variability of Kurichi Tank

3.6 Valankulam Tank

It can be analyzed from the Fig. 10 that up to 2015 the water spread area has increased and then decreased with small variation. After that in 2021 there was an overall expansion in water spread area by 0.295 km^2 in pre monsoon season and 0.175 km^2 in post monsoon season.

3.7 Kurichi Tank

There is shrinkage in water spread area by 0.169 km^2 in pre monsoon season whereas the water spread area has expanded by 0.561 km^2 in post monsoon period in 2005. While in 2011 the water spread area of post monsoon season reduced by 0.599 km^2 and an increase is observed in pre monsoon season by 0.686 km^2 .Thereafter there is an overall increase in water spread area in 2015 and 2021. In 2015, it was expanded by 0.271 km^2 in pre monsoon and 0.491 km^2 in post monsoon season. In 2021 it was increased by 0.316 km^2 and 0.113 km^2 in pre monsoon and post monsoon season respectively. A drastic reduction in water spread area can be observed from Fig. 11 in 2003, 2016 and 2012 for post monsoon season.

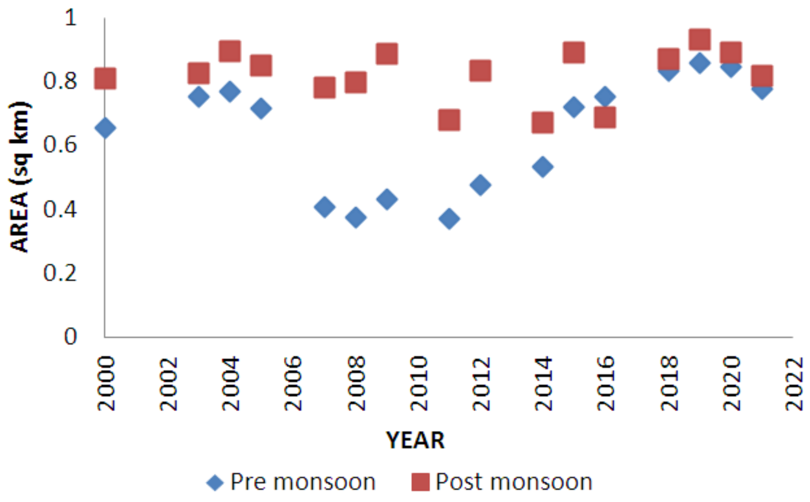

Fig. 12. Water spread area variability of Singanallur Tank

3.8 Singanallur Tank

An increase and decrease of water spread area was observed from Figure. An overall increase in water spread area was observed in 2005 by 0.059 km^2 for pre monsoon and 0.040 km^2 for post monsoon period. Then reduction was observed in 2011 for both pre monsoon and post monsoon period by 0.344 km^2 and 0.170 km^2 respectively. There after an expansion was seen in water spread area in 2015 for pre monsoon period by 0.346 km^2 and for post monsoon period by 0.208 km^2. In 2021 a small reduction is seen for post monsoon period by 0.071 km^2 whereas an increase was observed in post monsoon period by 0.059 km^2.

3.1 Accuracy Assessment of Mapping Surface Cover

In this study, Landsat images with a spatial resolution of 30 m were used to detect the surface water dynamics of Coimbatore Corporation tanks. The surface cover was divided into the water body, urban, vegetation and barren land. The overall accuracy of classification was in the range between 83.64-96.33%, the producer's accuracy was 85.33 - 98%, and user's accuracy ranged between 86.50-94.38%. It can be observed that the results of accuracy's evaluated is high.

3.2 Advantages and Limitations of Using Google Earth Engine

The key benefits of using Google Earth Engine is reduced processing time and increased capacity to process high resolution data [11]. The Google Earth Engine provides a stable platform and processing environment for this work, allowing free access to a set of Landsat image data as well as a quick assessment of surface water changes of Coimbatore corporation tanks. Unlike traditional image processing approaches like ENVI and Arc GIS, the Google Earth Engine can process large amounts of data rapidly and free of cost .The Google Earth Engine's convenient mechanism allows the scientist and researchers to share the data and code via URL. However there are some limitations in using Google Earth Engine as we need to have basic knowledge on JavaScript and Python programming languages. Moreover, the present Google Earth Engine platform does not integrate with other open source geospatial analytic tools like R and QGIS [12].

4. CONCLUSION

In this study, Landsat ETM+ and Landsat OLI data were used to detect the water spread area change of Coimbatore corporation tanks from 2000 to 2021. For mapping of water body, Random forest classifier has been used in Google Earth Engine and the classified image has been imported in GIS to find the water spread area of each tank [13-26]. It could be concluded from the results that during the study period, the water spread area was increasing and then decreasing for tanks such as Kurichi, Singanallur and Periyakulam for both pre monsoon and post monsoon season. For other tanks, the water spread was increased and maximum water spread area can be observed after 2015. This random forest approach is useful for identifying and mapping surface water features. Many advances have been made in recent years for differentiating and identifying water bodies using remote sensing techniques. In spite of its complexity in finding the water spread area by traditional approaches on the other hand Google Earth Engine has provided the better results and showed a constructive variation of surface water.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Muthiah, Krishnaveni, Siva. Sankari S, Rajeswari. Rehabilitation of Irrigation Tank Cascade System Using Remote Sensing GIS and GPS. International Journal of Engineering Science and Technology. 2011;3:1624-1629.
2. Aeliza Aurellia Dondor Ritshong J, Satish Kumar. Assessment of Water Spread Area by Sub pixel Classification in Umiam Reservoir, Meghalaya, India. International Journal of Engineering Research & Technology (IJERT) Geospatial. 2016;4.
3. Deoli Vaibhav, Kumar, Deepak. Remote Sensing and GIS Approach for Spatiotemporal Mapping of Ramganga Reservoir. International Journal of Current Microbiology and Applied Sciences. 2019;8:775-783.
4. Deoli, Vaibhav, Kumar, Deepak, Kumar, Manish, Kuriqi, Alban & Elbeltagi, Ahmed. Water spread mapping of multiple lakes using remote sensing and satellite data. Arabian Journal of Geosciences.2021;14: 2213.
5. Magidi, James & Nhamo, Luxon & Mpandeli, Sylvester & Mabhaudhi, T. Application of the Random Forest Classifier to Map Irrigated Areas Using Google Earth Engine. Remote Sensing. 2021;13:876.
6. Ge Pu, Lindi J. Quackenbush. Stephen V. Stehman. Using Google Earth Engine to Assess Temporal and Spatial Changes in River Geomorphology and Riparian Vegetation. JAWRA Journal of the American Water Resources Association. 2021;57.
7. Wagle, Nimisha, Acharya, Tri, Kolluru, Venkatesh & Huang, He & Lee, Dongha. Multi-Temporal Land Cover Change Mapping Using Google Earth Engine and Ensemble Learning Methods. Applied Sciences. 2020;10:8083.
8. Wagle, Nimisha, Acharya, Tri, Kolluru, Venkatesh, Huang, He, Lee, Dongha. Multi-Temporal Land Cover Change Mapping Using Google Earth Engine and Ensemble Learning Methods. Applied Sciences. 2020;10:8083.
9. Schmidt J, Marques MR, Botti S, Marques MA. Recent advances and applications of machine learning in solid-state materials science. NPJ Comput. Mater. 2019;5:1–36.
10. Hatwell J, Gaber MM, Azad RMA. CHIRPS: Explaining random forest classification. Artif. Intell. Rev. 2020; 53:5747–5788.
11. Li J, Peng B, Wei Y, Ye H. Accurate extraction of surface water in complex environment based on Google Earth Engine and Sentinel-2. PLoS One. 2021;16(6):e0253209.
12. Wang C, Jia M, Chen N, Wang W. Long-Term Surface Water Dynamics Analysis Based on Landsat Imagery and the Google Earth Engine Platform: A Case Study in the Middle Yangtze River Basin. Remote Sens. 2018;10:1635.
13. Kompella, Sai, Reddy, Bharath K, Abdul Hakeem, Issac, Annie & Lesslie, A. Accuracy Assessment and Normalisation of Water Spread Area Estimate from Multi-sensor Satellite Data. Journal of the Indian Society of Remote Sensing. 2020;48.
14. Zhaohui, Zhang, Prinet, Véronique, Songde Ma. Water Body Extraction from Multi-Source Satellite Images. International Geoscience and Remote Sensing Symposium (IGARSS). 2003;6:3970 – 3972.
15. Faizan, Mohammed, Sadhak, Sabreen, Sabreen, Khadeeja. Spatio-temporal mapping of the Chembarambakkam Reservoir of Tamil Nadu-India using GIS and Remote Sensing; 2021.
16. Du, Zhiqiang, Linghu, Bin, Ling, Feng, Li, Wenbo, Tian, Weidong, Wang, Hailei, Gui, Yuanmiao, Sun, Bingyu, Zhang, Xiaoming. Estimating Surface Water Area Changes Using Time-Series Landsat Data in the Qingjiang River Basin, China. Journal of Applied Remote Sensing. 2012;6.3609.
17. Sreekanth PD, Krishnan, Pandian, Rao N, Soam, Sudhir, Ch, Srinivasrao. Mapping

surface-water area using time series landsat imagery on Google Earth Engine: a case study of Telangana, India. Current Science. 2021;120:1491-1499.

18. Selvakumar R, Nagoor, Nasir. Estimating the Loss of Water Spread Area in Tanks Using Remote Sensing and GIS Techniques in Ambuliyar Sub-basin, Tamilnadu. 2021:227-237.
19. Sakthivel, Shanmuga Priyaa, Jeyakanthan, Sivalingam, Cyril, Heltin Genitha, Sanjeevi S. Estimation of Water-Spread Area of Singoor Reservoir, Southern India by Super Resolution Mapping of Multispectral Satellite Images. Journal of the Indian Society of Remote Sensing. 2017;46:121-130
20. Acharya, Tri & Subedi, Anoj & Huang, He & Lee, Dongha. Application of Water Indices in Surface Water Change Detection Using Landsat Imagery in Nepal. Sensors and Materials. 2019;31:1429-1447.
21. Magsar, Amgalan, Matsumoto, Toru, Enkhbold, Altanbold, Nyam-Osor, Nandintsetseg. Application of Remote Sensing and GIS Techniques for the Analysis of Lake Water Fluctuations: A Case Study of Ugii Lake, Mongolia. Nature Environment and Pollution Technology. 2021;20:2051-2059.
22. Khan, Rabia Munsaf, Salehi, Bahram, Mahdianpari, Masoud, Mohammad imanesh, Fariba. Water quality monitoring over Finger Lakes region using sentinel-2 imagery on google earth engine cloud computing platform. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences. 2021;3: 279-283.
23. Dinh, Quang, Nguyen, Linh, Ho, Tam, Viet, Nguyen. Remote sensing applications for reservoir water level monitoring, sustainable water surface management, and environmental risks in Quang Nam province, Vietnam. Journal of Water and Climate Change. 2021;12:3045-3063.
24. Subedi, Anoj, Acharya, Tri. Small Water Bodies Detection and Evaluation using Normalized Difference Water Index (NDWI) from Landsat Image in Western Terai, Nepal. 2021;6:89-96.
25. Acharya, Tri & Subedi, Anoj & Lee, Dongha. Evaluation of Machine Learning Algorithms for Surface Water Extraction in a Landsat 8 Scene of Nepal. Sensors.2019;19:2769.
26. Al-Saady, Younus, Merkel, Broder, Al-Tawash, Balsam, Al-Suhail, Q. Land use and land cover (LULC) mapping and change detection in the Little Zab River Basin (LZRB), Kurdistan Region, NE Iraq and NW Iran. FOG - Freiberg Online Geoscience. 2015;43:1-32.

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