Impact Study on Desiltation of Water Tanks in Rural Areas Using Spatial Technology: A Case Study Work Under MGNREGA

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Abstract This study was conducted under the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) in Gural Mandal, Vizianagaram District, Andhra Pradesh, to identify the improvement around irrigation tanks which were desilted under this programme. In rural areas, small tanks serve as the major source for irrigation and groundwater. Improper soil management has led to a significant reduction in water tank surface spread area and depth due to the accumulation of the sedimentation process. Desiltation of these selected tanks would improve the water spread area, thus improving total volume. Remote sensing and GIS support continuous analysis of the study tanks using satellite images and Modified Normalized Difference Water Index (MNDWI) before and after desiltation work. This index has supported the seasonal water storage/spread area, crop pattern change and income level in rural villages.

Keywords MNDWI · MGNREGA · Desiltation · Water spread area · Remote sensing

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1 Introduction

Monitoring small water tanks with 1–14 hectares is essential to improve agriculture in rural areas. Often these tanks are small in size but a quite large number in rural areas with the highest agriculture potential support. Landsat images with the optimal spatial resolution are suitable for small water tank surface area mapping and land cover change analysis for long-term analysis. The importance of small agriculture water tanks due to their number and geographical distribution in rural areas has gained wide importance in India due to water storage and infiltration in the form of base flow, thus improving groundwater. In Andhra Pradesh, minor tanks are traditional water storage reservoirs designed to capture monsoon run-off and store rainfall. The tanks are designed to store water, based on the seasonal and inter-annual rainfall at a particular spatial extent. The irrigation system supported by tanks exists from Vedic times [1]. The tank systems were created with indigenous technology which harvests the rainfall run-off from unpredictable monsoon with wide distribution.

The irrigation tanks contribute as a major source of water for agriculture support. These tanks are presently being monitored by local governmental authorities and departmental officers with the support of local people participation. Small irrigation tanks lose their storage capacity due to sedimentation, which results in a reduction in storage capacity and storage volume at different elevations. To improve the tank storage capacity and irrigation system, tank rehabilitation/restoration/renovation was undertaken by the water management groups. The rehabilitation is a term which is used for dysfunctional tanks which are brought to normal functioning [2]. The maintenance of irrigation tanks with a command area of 40–2000 ha is undertaken by the Minor Irrigation Department (DMI). The tanks with command area less than 40 ha are maintained by District and Panchayat Raj of villages. Identification of water surface spread area at various storage levels would help in estimating current storage and pattern of water spread in the selected irrigation tanks. Satellite remote sensing plays a vital role because of its synoptic and repetitive coverage.

Measurements from satellite remote sensing provide a means of observing and quantifying land hydrological variables over a geographic area and their temporal description. Temporal fluctuation in water tanks happens seasonally with great variation in water spread area during pre-monsoon to post-monsoon. A conventional technique helps to identify and measure these changes on a regular basis to maintain the systematic inventory. Remote sensing satellite data at multiple spatial resolutions and at regular time intervals and surface water bodies can be mapped and monitored in terms of the occurrence of water spatial extent and volume. There are many traditional image classification methods using multispectral data, namely supervised, unsupervised and pixel-based spectral indices like Modified Normalized Difference Water Index (MNDWI) to extract water bodies. These methods are effective to delineate different land classes and surface water bodies like large lakes, reservoirs, rivers, streams, etc. The automatic extraction algorithm for water body extraction using AWIFS and LISS data was developed by many researchers. Venkatesan et al. [3]

estimated surface area and volume of the small tanks using GPS field data by developing a relationship between SRTM DEM 90 m and GCP data. The small tanks with 0.2–7.8 ha area were extracted by using high-resolution imagery from Google Earth, Bing maps and Sentinel-2 to extract flooded lakes based on visual interpretation. The desiltation work was under process in the study area from 2016. Total 17 tanks work was started initially and completed by April 2017.

Changing climate and poor water harvesting techniques have resulted in a serious problem to the ecological balance, surface area and volume of water bodies in rural India. GIS and satellite images have proven to be strong investigating tools to monitor changing water distributed area for proper and effective planning of surface water resources. Landsat and Sentinel images of 30 and 20 m spatial resolution are freely available for land cover classification with frequent revisit period. This paper has been carried using Landsat images from 2010 to 2018 to provide a great possibility to understand the local water resources like tanks in Gurla Mandal. These images were used to identify water tanks using spectral indices which were more effective like MNDWI using GREEN and SWIR bands to differentiate water and land area.

2 Methodology

Landsat 5 and 8 images of 2010, 2011, 2015, 2016, 2017 and 2018 images were used for the MNDWI index. Study area water tanks were occupying a very small area, where images with 30 m resolution would be bigger than a tank. Hence, these images were resampled to 10 m pixel. Landsat has receptivity for every 16 days for data collection. The images with less than 20% cloud cover were selected for atmospheric correction and dark object subtraction. All objects on earth interact with incoming solar radiation thus emitting a specific wavelength of radiation back to the sensor. Landsat green (G) and shortwave infrared (SWIR) bands were used for the extraction of water pixels enabling the identification of water tanks and surface spread area. The surface water is delineated using MNDWI index Eq. (1) [4].

$$\text{MNDWI} = \frac{\rho_{\text{GREEN}} - \rho_{\text{SWIR(2)}}}{\rho_{\text{GREEN}} + \rho_{\text{SWIR(2)}}} \tag{1}$$

Modification of Normalized Difference Water Index (MNDWI) is a water index and is developed by Xu [4]. For Landsat 5, MNDWI = Band 2 − Band 7/Band 2 + Band 7. Similarly for Landsat 8, MNDWI = Band 3 − Band 7/Band 3 + Band 7 Table 1.

Table 1 Green and SWIR band wavelengths for Landsat 5 and 8

Band (μm)	Landsat 5	Landsat 8
Green	0.52–0.60	2.09–2.35
Shortwave infra red	0.53–0.59	2.10–2.29

3 Study Area and Data Collection

Gurla is one of the Mandal in Vizianagaram district. The total geographical area of the Mandal is 163 km^2. There are 39 revenue villages consisting of 37 Grama Panchayats, and the total households in the Mandal are 15,571 with 64,695 population. The average annual rainfall of the Gurla Mandal is 1039 mm with predominantly south-west monsoon. Major crops grown in the Mandal are paddy, maize but area under mango is increasing gradually. The study area is situated in between 83° 27′ 8″ and 83° 32′ 00″ E longitudes, 18° 10′ 35″ and 18° 16′ 40″ N latitudes. The study area includes 13 Panchayats, namely Garida, Tettangi, Polayavalasa, Badaripeta, Jammu, Jammupeta, Kella, Vallapuram, Gudem, Achutapuram, Chukkapeta, Gujjangivalasa and Meesalapeta which covers 64 km^2 of geographical area (Fig. 1). In the study area, most of the tanks were filled with water during the monsoon season, i.e. from

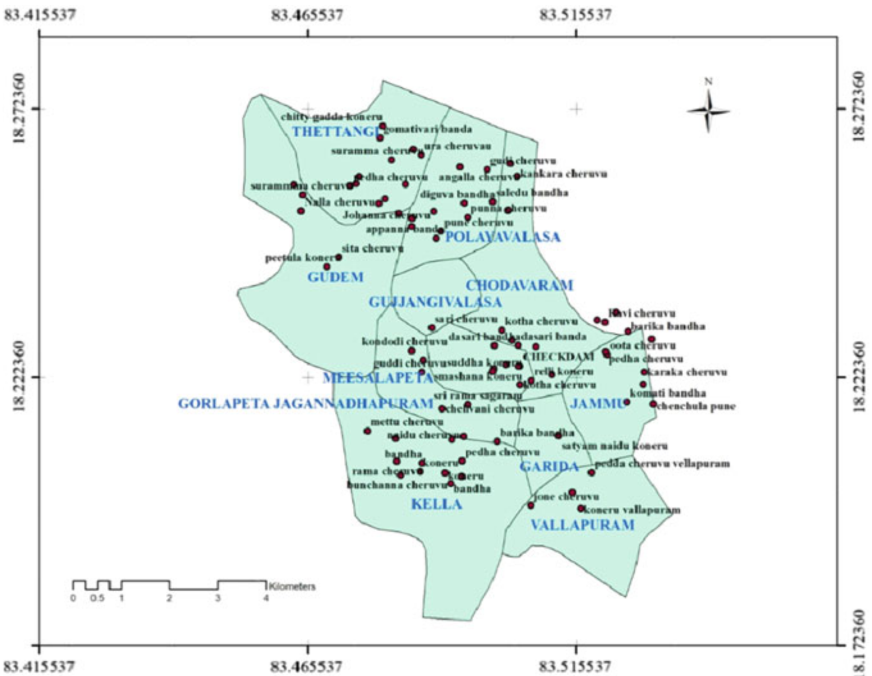

Fig. 1 Gurla Mandal at village level map with proposed tanks for renovation work

Table 2 Dates of Landsat images collected

2010	2011	2015	2016	2017	2018
26-Jan	13-Jan	24-Jan	11-Jan	13-Jan	16-Jan
11-Feb	29-Jan	9-Feb	12-Feb	29-Jan	1-Feb
27-Feb	14-Feb	25-Feb	15-Mar	2-Mar	5-Mar
3-Jun	2-Mar	13-Mar	31-Mar	18-Mar	21-Mar
22-Aug	6-Jun	29-Mar	16-Apr	3-Apr	6-Apr
23-Sep	26-Sep	30-Apr	2-May	19-Apr	8-May
28-Dec		23-Oct	19-Jun	5-May	9-Jun
		8-Nov	21-Jul	21-May	25-Jun
		10-Dec	7-Sep	10-Sep	29-Sep
		26-Dec	25-Oct	28-Oct	31-Oct
			10-Nov	13-Nov	16-Nov
				29-Nov	
				15-Dec	
				31-Dec	

August to November. This water supports Rabi crop which is sown in the ending of the monsoon season. Few tanks support 2–3 crops per annum. Almost all tanks fall under 40 ha catchment area. These water bodies have been observed from different sources like toposheets from a survey of India (1:50,000), memoirs of minor irrigation tank, etc., identified and digitized the tank boundaries from the topo map. Satellite images were collected for different months as shown in Table 2.

4 Modification of Normalized Difference Water Index (MNDWI)

The objective of this MNDWI index is to identify the water body with existing water at different seasons and months. Total water tank boundary is taken from SOI toposheet, and the available water extent is identified with the help of MNDWI. The absorption and reflection of light between water and land use features show variation in different wavelengths. The reflection of water is very low in infrared than visible bands. The water occupied cells were automatically extracted by MNDWI. MNDWI values range between −1 and 1. Theoretically, these values for water regions will be larger than 0 in MNDWI but due to surface parameters and vegetation influence MNDWI varies for some images smaller or larger than actual range. These pixels overestimate the water tank boundaries due to residual soil moisture within the tank boundary. To avoid such type of interferences, the threshold values are adjusted manually. To get more accurate boundary of the tank spread area, visual interpretation technique of images in FCC is adopted to adjust the boundaries (Fig. 2). Total 19 tanks were

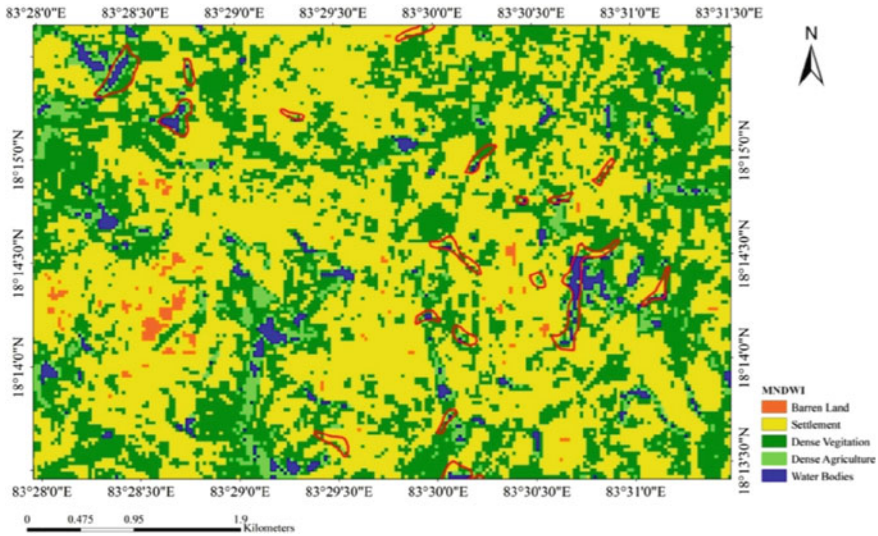

Fig. 2 MNDWI coverage of the study area with few water bodies (red shapes)

considered in this analysis of MNDWI variation for 2010, 2011, 2015, 2016, 2017 and 2018 Table 3. Rainfall data are shown in Table 4.

These tanks are explained cluster wise based on their geographical distribution and elevation. Each cluster contains three or more than three tanks.

Cluster 1 It includes three tanks named as Komati Banda, Poonu Cheru and Vura Cheru. Komati Banda and Vura Cheru (Fig. 3) come under Chodavaram Panchyat, while Poonu Cheru comes under Garida Panchayat. The average slope of this area is 3% which is an almost flat surface with first- and second-order stream network. The annual average rainfall is 915.412 mm. Poonu Cheru and Komati Cheru have two sluice outlets, whereas Vura Cheru has four sluices to irrigate water into agriculture area. For the year 2015 and 2016, MNDWI values (Fig. 4) were between −0.0.2 and +0.4. Lower and negative values show the absence of water during the dry season from February to June. Positive values show an increasing trend from the beginning of the monsoon season, i.e. from July to October. Poonu Cheru for 2015 and 2016 almost continues with positive values which gives an indication of sufficient water availability during the dry season. Komati Banda and Vura Cheru MNDWI values were very low till −0.15 for 2015 and 2016 which further continued till 2018 reaching −0.2. After desiltation work, MNDWI values have raised between 0.22 and 0.27 during the rainy season for the three tanks Table 5.

Komati Banda shows drastic improvement from 2016 to 2018, i.e. 0.10–0.27. Other two tanks also show improvement after desiltation.

Cluster 2 It includes four tanks named as Yerra Cheru, Pilakavani Cheru, Uppada Banda and Rayi Cheru (Fig. 5). Yerra Cheru and Uppada Banda come under Achyutapuram Panchayat, and Pilakavani Cheru and Rayi Cheru come under Chodavaram

Table 3 Tank names with associated command area and hydraulic details

Tank name	Latitude	Longitude	Catchment area (acres)	Tank water spread area (ha)	Length of tank bund (m)	Top width of tank bund (m)
Uppada Banda	18.2218008	18.2218008	18	2	210	3
Komati_Banda	18.2429733	83.5091633	12	3.2	250	3
Guddi_Cheruvu	18.2605033	83.4988317	10	6	600	3.5
Poonu_Cheru	18.2384567	83.517155	15	6	450	3
Pilakavani_Cheru	18.246315	83.509965	15	1.2	200	3
Yerra_Cheru	18.2485217	83.5027867	5	1.2	360	2.5
Laxmana_Cheru	18.2229133	83.5004133	4	1.2	650	3
Lankavane_cheruvu	18.2372767	83.499565	25.87	2.4	200	3
Jaganna_cheruvu	18.25482	83.4793233	26	2.8	685	3
Seera_Banda	18.23492	83.5024333	8.09	1.6	230	3
Pedda_Cheruvu	18.2584767	83.4741333	8	5.2	930	3
Modiavane_cheruvu	18.2236817	83.5006483	28	7.36	490	3.5
Patha_Cheruvu	18.24093	83.50271	6	1.6	510	3
Rayi_cheruvu	18.2474767	83.5136483	16	4.8	320	3
Sudha_cheruvu	18.2229133	83.5004133	2	0.1	215	2.5
Vura_Cheru	18.2406033	83.5113433	82	14.4	700	4
Dasari_Banda	18.2276667	83.49996	20	4	210	3
Seetha_Cheru	18.22766	83.50873	5	2.4	420	3
Joganna_Cheru	18.253355	83.4889217	15	4	300	3

Panchayat. The average slope of this area is 3%. Pilakavani Cheru has two, and Rayi Cheru has one sluice outlet. Yerra cheru has resulted in with least MNDWI values during February to May and the highest values in September month. Table 6 shows maximum MNDWI values in each year. Yerra cheruvu recorded the lowest value in October 2017, whereas monthly rainfall for that month was 1.4 mm. May to August months of 2018 received below average rainfall. October month shows the highest MNDWI value with 0.16 after removal of silt and encroachment. Among the four years, 2015 October recorded with lowest MNDWI value with 0.14 because October month normal rainfall is 181 mm and actually received is 33.60 mm and 2018 September with 0.19. 2016 and 2017 have shown 0.11 and 0.14. Land encroachment is identified as 3 acres occupying water surface area which has contributed increased value even though annual precipitation was below normal. Uppada Banda shows a gradual increase in values from 2016 to 2018 from 0.13 to 0.23 (Fig. 6).

Table 4 Rainfall (mm) from 2015 to 2018 of the study area

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean
Normal	5.0	11.0	11.0	24.0	95.0	119.0	167.0	183.0	154.0	181.0	84.0	5.0	1039
2015	0.00	0.00	0.00	20.80	10.00	252.80	139.00	329.80	178.80	33.60	46.60	0.00	1011.4
2016	0	0.0	0.0	20.8	10.0	252.8	139.0	329.8	178.8	46.6	0	0	977.8
2017	0.0	0.0	0.0	0.0	162.6	166.9	188.0	168.9	339.7	1.4	0.0	0.0	1027.5
2018	0	0.0	82.2	0	40.0	123.1	70.3	–	–	–	–	–	315.6

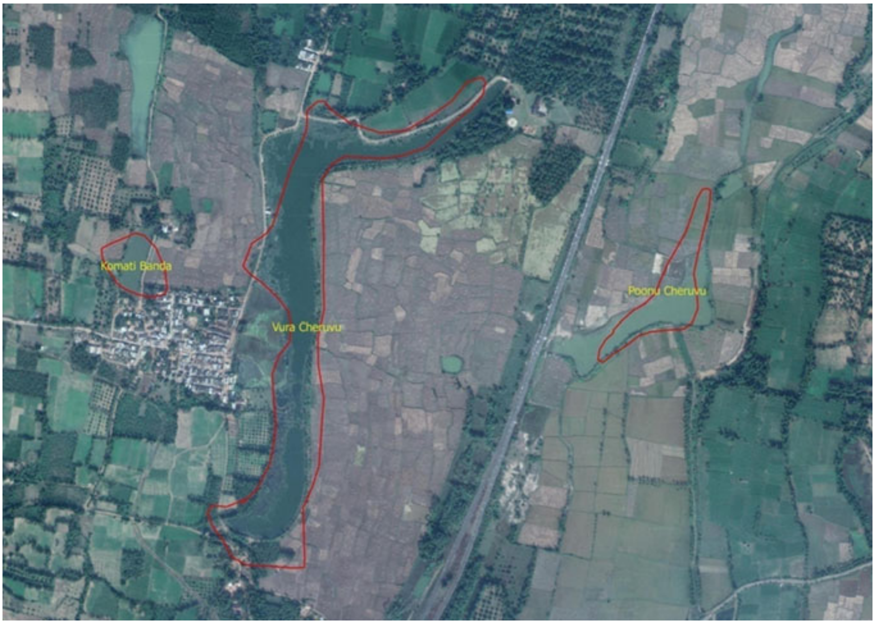

Fig. 3 Google image of Komati Banda, Vura Cheruvu and Poonu Cheruv

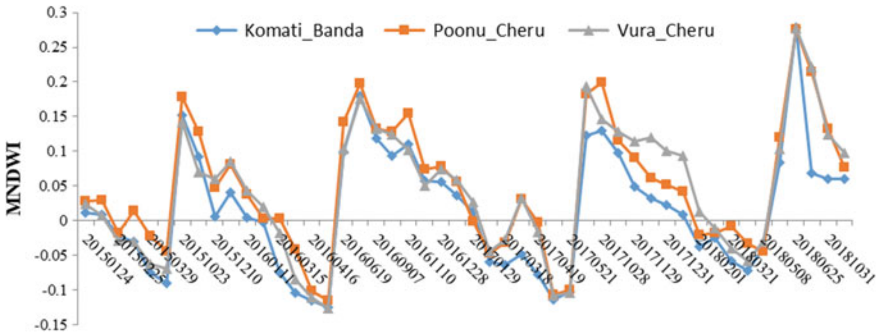

Fig. 4 Cluster 1 MNDWI values from 2015 to 2018

Table 5 MNDWI maximum values for cluster 1

Year	Komati_Banda	Poonu_Cheru	Vura_Cheru
2015	0.151351	0.178938	0.142824
2016	0.109442	0.154547	0.124111
2017	0.129212	0.198624	0.145793
2018	0.277994	0.214623	0.221091

Fig. 5 Google image of study cluster 2

Table 6 MNDWI maximum values for cluster 2

Year	Yerra_Cheru	Pilakavani_Cheru	Uppada_Banda	Rayi_cheruvu
2015	0.144105	0.141745	0.174252	0.145985
2016	0.177201	0.113043	0.131552	0.197692
2017	0.144045	0.141143	0.185383	0.197279
2018	0.162992	0.191975	0.235064	0.181184

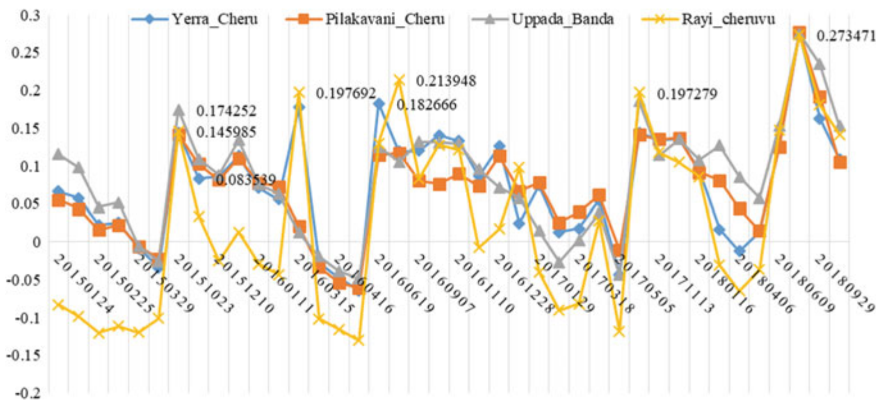

Fig. 6 Cluster 2 MNDWI values for 2015 and 2018

Desiltation significantly improved MNDWI values with 1027.5 mm rainfall in 2017 and below normal level precipitation in 2018 from the month of June onwards. Yerra Cheruvu with the least encroached area could able to maintain the same values irrespective of low annual rainfall. This can be attributed to effective groundwater recharge, proper maintenance of sluice and filling water from the upper tank connected in a cascading system

Cluster 3 It shows three tanks, namely Patha Cheruvu, Lankavani Cheruvu and Seera Banda (Fig. 7). Three of these tanks belong to Chodavaram village, in the Gurla Mandal. Average annual rainfall is 915.12 mm. Water spread area of Patha Cheruvu and Seera Banda is 1.6 ha and Lankavani Chruvu is 2.4 ha. These tanks often suffer from weed spread above 50% of the tank surface. These tanks support single and double crops in their command area. Compared to 2010 and 2011 tank, MNDWI values show variations due to siltation. Figure 8 clearly shows that 2015 MNDWI values are comparatively lesser than 2010 which has led to shrinking of the lake in terms of depth and surface area. Table 7 gives maximum MNDWI values for all three tanks. Among them, all tanks are showing gradual improvement in values.

Cluster 4 It includes four tanks named as Modiavane_cheruvu, Dasari_Banda, Sudha_cheruvu and Seetha_Cheru (Fig. 9). All the four tanks come under Garida Panchayat. The average slope of this area is 3%. Modiavane_cheruvu, Dasari_Banda and Seetha_Cheru have three sluices outlets. Moidavani Cheruvu comes under the above medium irrigation tank with 7.36 ha with 50% weed infestation. For October

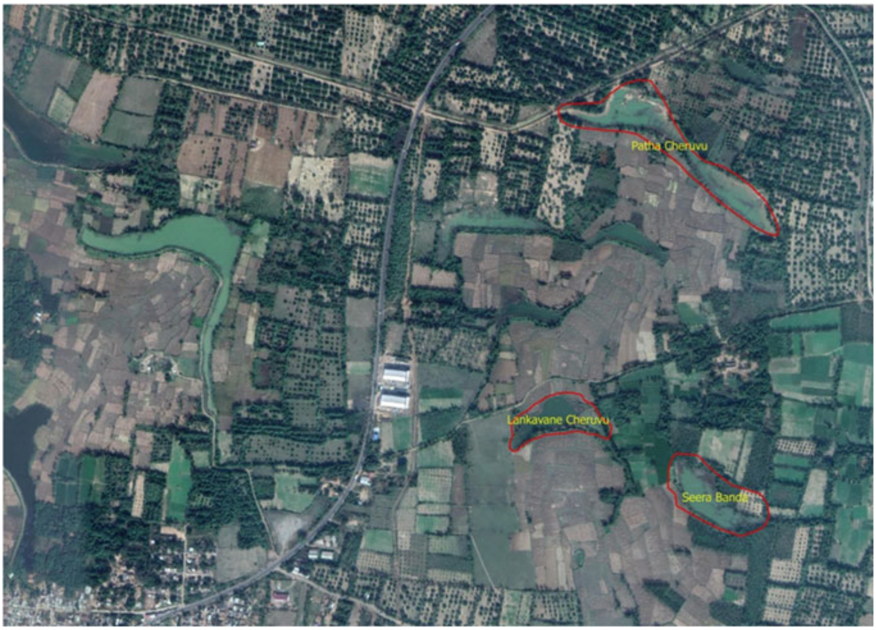

Fig. 7 Google image of cluster 3 tanks

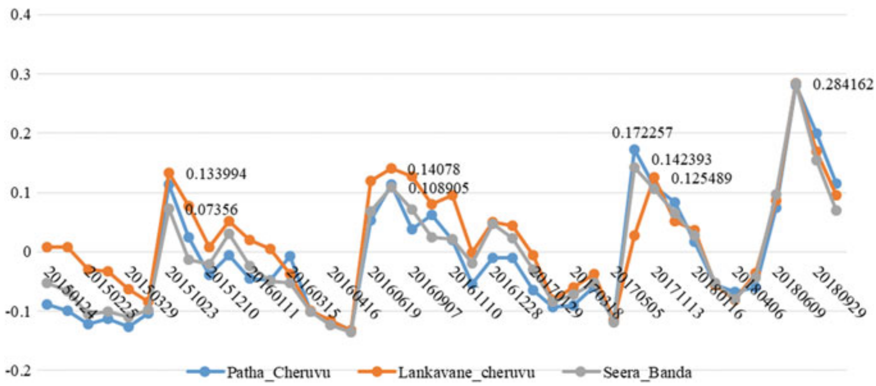

Fig. 8 MNDWI values of cluster 3 tanks for 2015–2018

Table 7 MNDWI maximum values for cluster 3

Year	Patha_Cheruvu	Lankavane_cheruvu	Seera_Banda
2015	0.114319	0.133994	0.07356
2016	0.114403	0.140781	0.108905
2017	0.172257	0.125489	0.142393
2018	0.200107	0.170119	0.153863

Fig. 9 Google image of cluster 4 tanks

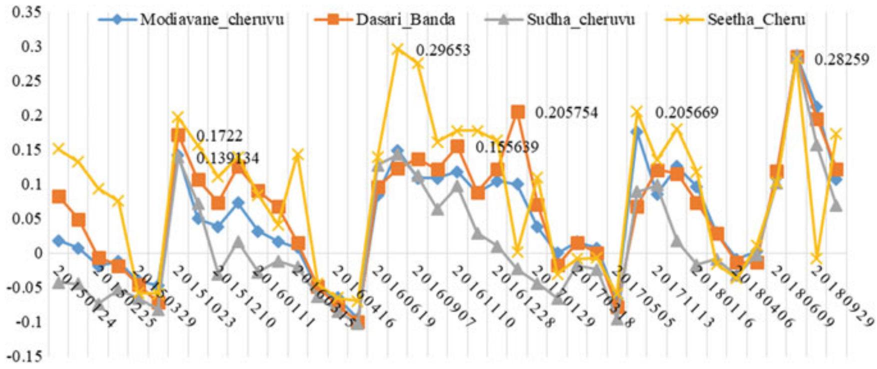

Fig. 10 Cluster 4 MNDWI variation from 2015 to 2018

Table 8 MNDWI maximum values for cluster 4 tanks

Year	Modiavane_cheruvu	Dasari_Banda	Sudha_cheruvu	Seetha_Cheru
2015	0.142681	0.172200	0.139134	0.197554
2016	0.149461	0.155639	0.143015	0.296530
2017	0.175677	0.185136	0.171618	0.205669
2018	0.287357	0.285708	0.284059	0.282410

month from 2015 to 2018, MNDWI values increase in all the four tanks like for Moidavani Cheruvu it raised from 0.10 to 0.21 after desiltation work. It can be attributed to the removal of 3 acres of encroached land and desiltation. Dasari Banda is situated in Meesalapeta village with 12.48 acres of Ayacut area with 15 farmers cultivating this land. This tank was taken for renovation works as the reconstruction of three sluices and inlet waterway from Laxmana Cheruvu. Surplus course widening and desiltation work improved MNDWI values gradually from 2016 to 2018 (Fig. 10). Sudha Cheruvu and Seetha Cheruvu also show changed MNDWI values with tank renovation work Table 8.

Cluster 5 It includes five tanks named as Pedda Cheru, Jaganna Cheru, Laxmana Cheru, Joganna_Cheru and Guddi Cheru (Fig. 11). All the five tanks come under Polayavalasa Panchayat. Pedda cheruvu and Jagganna Cheruvu are relatively bigger tanks. Due to siltation of tanks, farmers could able to irrigate Ayacut area only for one month. During the rainy day, these two tanks easily get full level but not sufficient volume. Pedda Cheruvu surplus water moves into Jagganna cheruvu and Laxmanna cheruvu. Desiltation work in these tanks supports more water accumulation. Table 9 and Fig. 12 show the changing MNDWI values in all the five tanks. Removal of encroached area and silt can retain more water in monsoon season thus recharging more water into the ground level. Ayacut area farmers can irrigate through bore wells/wells during less water in tanks.

Fig. 11 Google image of cluster 4 tanks

Table 9 Year wise maximum MNDWI values in each tank

Year	Pedda_Cheruvu	Jaganna_cheruvu	Laxmana_Cheru	Joganna_Cheru	Guddi_Cheruvu
2015	0.172	0.163	0.121	0.129	0.155
2016	0.219	0.170	0.155	0.144	0.168
2017	0.225	0.152	0.189	0.182	0.190
2018	0.291	0.289	0.288	0.286	0.273

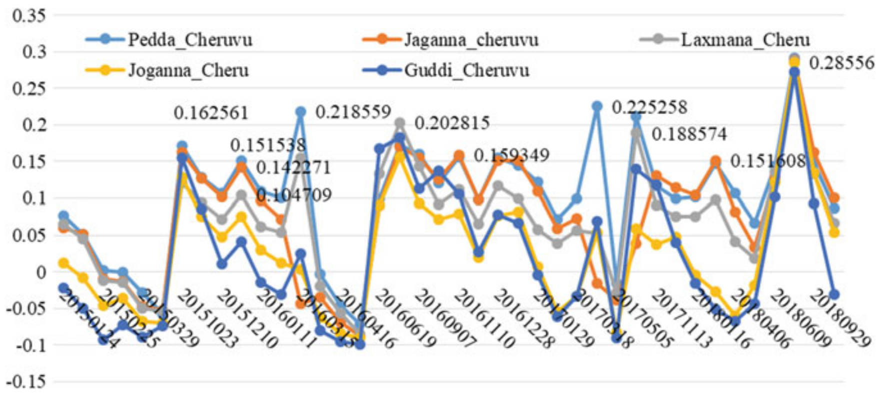

Fig. 12 Cluster 5 MNDWI variation among tanks for 2015 and 2018

5 Conclusions

With increasing remote sensing and geospatial technology in the recent past years made easy of monitoring land cover type and water resources. Monitoring lakes and ponds at the local and regional level requires high-quality maps accompanied by field data and ground truth. The present study has taken water tanks lesser than 20 ha which needs high-resolution data. The present study is carried out using 30 m satellite image which was resampled to 10 m with a proper atmospheric correction to improve the quality of the image. Data were collected with a low cloud cover percentage. MNDWI index functions based on the reflectance of ground features and automatically derives water pixels. This method allowed water surface separation from other surfaces.

Tanks after desiltation from 2017 onwards could be able to give high MNDWI values when compared to before desilation period. The range of the water pixel values varied before and after desiltation which is a significant factor to prove that the depth of the lake has been improved. Almost all tanks are connected in a cascading system with one upper and one lower tank. Surplus water filling in lower tanks also resulted in varied MNDWI values in other than the rainy season. Overall desilation work has improved water during dry season, i.e. April and May months in larger tanks. Farmers are now using this water for mango tree plantation and coconut plantation in the offshore area of the tanks. A single crop is grown in Rabi season because of sufficient water supply. Further improvement of tanks depth could assist the second crop in the Kharif season also.

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