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Positive Effect of Natural Resources Management Interventions on Bio-physical Indictors in Polla Watershed Project of Srikakulam District, Andhra Pradesh, India

P. Venkataram Muni Reddy [a*], Kona Sasidhar [a], C. P. Reddy [b], R. V. Sagar Kumar Reddy [a], B. Janardhan Reddy [a], R. V. Ramana [c], D. V. S. R. L. Rekha [c] and K. Veerabhadra Rao [c]

[a] Panchayat Raj and Rural Development Department, Tadepalli, Guntur, Andhra Pradesh–522501, India.
[b] Department of Land Resources, Govt. of India, New Delhi –110011, India.
[c] WAPCOS Limited, Koti's Court, 6-3-1239/2/A/601, Rajbhavan Road, Somajiguda, Hyderabad-500082, Telangana State, India.

Authors' contributions

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

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Original Research Article

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**Corresponding author: E-mail: venkat.agri@gmail.com;*

ABSTRACT

Aim: This Investigation was taken up to detect the changes in the Bio-Physical Indicators of Polla Watershed project implemented under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) watershed project in Srikakulam District of Andhra Pradesh, India.

Place and Duration of Study: This study was conducted at the Polla watershed area of Seetham pet mandal of Srikakulam District, which is under drought Prone Area Project (DPAP) by the Panchayat Raj and Rural Development (PR and RD) Department, Andhra Pradesh during 2013 to 2020.

Methodology: High-resolution satellite data like Resourcesat-2, Linear Imaging and Self Scanning-IV (LISS-IV) of 2013 (pre-treatment) and 2020 (post-treatment) and ArcGIS 10.8 software were used in this project to measure the changes in land use/land cover and biomass during the project period (2013-20).

Result: The results showed a reduction in wastelands by 59.67% (786.59 ha) and an increase in cropland and plantation by 32.68% (756.34ha) and 2.16% (24.55ha) respectively. There is an increase in dense vegetation 49.36 ha (3.93 %), medium vegetation412.04ha (28.36 %), Low Vegetation 247.93ha (19.25 %) and a decrease in nil vegetation 709.33 ha (-57.99 %). Another positive indicator of watershed development in the project area is the increase in waterbodies by 17.10 %, due to the construction of rainwater harvesting structures i.e., 21 percolation tanks, 10 rockfill dams,18 loose boulder structures, 19 Mini Percolation Tanks etc.

Conclusion: This study reveals that an additional area of 5.69ha (17.10%) increased under water bodies and 786.59 ha of wasteland converted to cultivable land due to the construction of rockfill dams, percolation tanks, mini percolation tanks, check walls and loose boulder structures. This area is reflected in cropland and plantations.

Keywords: Watershed; land use/land cover (LULC); normalized difference vegetation index; (NDVI); remote sensing; geographical information system (GIS).

1. INTRODUCTION

"India is an agrarian country where agriculture and allied sectors viz. Horticulture, Livestock, forestry, and fisheries together contribute 18.8% of the country's Gross Value Added (GVA) for the year 2021-2022 and employ more than 50% of the nation's workforce. It also assumes prime importance that about 60% of India's agricultural land is rain dependent. As rainfed crops account for 48% area under food crops and 68% area under non-food crops, all efforts need to be taken to address the concerns of rainfed areas. Despite India ranking first in rainfed agriculture globally in terms of areas and production, productivity is among the lowest in the world. Rainfed agriculture suffers from several biological and socio-economic constraints" [1]. These include low and erratic rainfall, land degradation and poor productivity, low level of input use and technology adoption, low drought power ability, inadequate fodder availability, low productive livestock, resource-poor farmers, and inadequate credit availability. Therefore, Govt. of India has created the National Rain Fed Area Authority (NRAA) as a crucial component of the new watershed policy to address the rain-fed areas. A watershed is a system-based approach that facilitates the holistic development of agriculture and allied activities in the selected watershed area. The stress is on the improvement of wasteland, runoff reduction, water conservation and protective irrigation mechanism. As recommended by Parthasarathy Committee [2] "Integrated Watershed Management Programme (IWMP) was started, w.e.f.26-02-2009 for the development of areas, combining all other existing rainfed area development programs. As per common guidelines for watershed development projects – 2008 (revised edition 2011), the period for completing watershed development projects is four to seven years". After approval of PMKSY the IWMP was subsumed as one of its components and IWMP is now implemented as WDC-PMKSY w.e.f. 01.07.2015.

In Andhra Pradesh, the program is being implemented by State Level Nodal Agency (SLNA) under the PR & RD Department. A total of 373 projects are being taken up in the State in five batches in all the districts except Krishna district. In Srikakulam District, a total of 10 projects in the fifth batch are being implemented.

"The present study pertains to Polla Project which was completed in the year 2020 under Batch-V (2013). The study aimed to know the changes in bio-physical indicators viz; Land Use/Land Cover (LU/LC) and Normalized Difference Vegetation Index (NDVI) due to the implementation of watershed programs from 2013 to 2020 using Remote Sensing and Geographical Information System (GIS). Satellite remote sensing provides an excellent source of data from which updated Land Use/Land Cover changes can be extracted efficiently. This is the most effective method which has been adopted by many researchers" [3-5]. This method involves the development of spatial and temporal databases and analysis techniques. In Polla, several natural resources (soil and water conservation) and production system improvement (PSI) activities were taken up during the project period. These programs were likely to increase the area under cultivation, decrease the area in the wasteland, conversion of annual cropland to horticulture, and change water body areas and biomass.

2. MATERIALS AND METHODS

2.1 Study Area

Polla Watershed is a part of Seethampeta Mandal in the DPAP block of Srikakulam district, Andhra Pradesh. The watershed is located between latitude $18^0$45'89" and longitude $84^0$03'49" at ridge point and between latitude $18^0$40'02" and longitude $84^0$58'76" at valley point. It is at a distance of 17.00 km from its mandal headquarters and 67.50 km from the district headquarters. The watershed is located at an elevation of 700 m above MSL. The highest point in the watershed is 1000 m above the MSL. The total geographical area of the watershed is 4956 Hectares (Ha). The average annual rainfall (five years) in the area is 1050 mm. The temperature in the area is in the range between 42^0c during summer and 30^0c in winter. The soils of the project area are fertile red sandy to red sandy clay loam with medium water holding capacity. There are 22 habitats in the cluster spread over 6 micro watersheds. The main occupation of the watershed community is rainfed agriculture which is vulnerable to drought, failure of monsoons and affected by cyclones.

2.2 Biophysical Indicators

The biophysical indicators viz; Land Use and Land Cover (LULC), Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) are studied with the help of Remote Sensing and GIS techniques. Based on data availability, on cloud-free days for pre and post-project periods, terrain-corrected Resource Sat-2 LISS-IV for the years 2013 and 2020 have been used for the study. Survey of India (SoI) topographical sheets of 1:50,000 scale, ground truth data and PMKSY monitoring reports from Panchayat Raj and Rural Development, Government of Andhra Pradesh have been used for reference. Land Use and Land Cover change analysis were carried out utilizing onscreen visual interpretation technique, using pre-Resources Sat-2 LISS-IV images and ArcGIS 10.8 background. Similarly, the post-LULC layer has been generated by overlying the pre-LULC layer onto the post-Resource Sat-2 LISS-IV images and identifying the changes and editing [6]. Normalized Difference Vegetation Index (NDVI) is calculated with the equation;

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

where NIR represents the reflection of the near-infrared spectrum and RED represents the reflection in the red range of the spectrum. The NDVI is a basic indicator of green vegetation. Normally it is generated to understand vegetation that changes depending on seasonal variations and also to monitor different growth phases of crops to analyze primary productivity [7]. The NDVI images for pre and post-project have been generated using Erdas Image 2015 software. Normalized Difference Water Index (NDWI) is used to identify water features from land and vegetation. It is calculated with the formula,

$$NDWI = \frac{(GREEN - NIR)}{(GREEN + NIR)}$$

where NIR represents the reflection of the near-infrared spectrum and GREEN represents the reflection in the Green range of the spectrum The NDWI values range from -1 to+1. Negative values correspond to non-water features such as drylands, rocky areas and barren land and positive values represent water features and wet surfaces.

2.3. Data used

The temporal satellite data is used for monitoring the watersheds. The study is executed using the following data sets: LISS-IV satellite data (Pre-& Post-treatment); Fusion (LISS IV + Cartosat-2) data; Survey of India (SoI)topo sheets for reference; PMKSY monitoring reports from the department.

2.4 Indicators considered for Evaluations of Watershed

To analyze the changes taking place during the project period, the following indicators are adopted: Vegetation cover; Water body area; Shift from annual crops to plantation crops; Additional area brought under cropping.

2.5 Major Developmental activities of the Watersheds

The developmental works are the construction of structures like Loose Boulder Structure, Rock fill dams and check walls for soil conservation; Percolation tanks; mini percolation tanks, Water absorption trenches at foothill for water conservation; Other works like drainage line treatment, Nala bank stabilization, filter strips etc., have also been developed.

3. RESULTS AND DISCUSSION

3.1 Changes in Land use / Land cover

Spatial distribution LULC categories and area statistics are shown below in Figs. 1(a) to 1 (e).

Fig. 1(a) represents the pre and post-LISS-IV images of the Polla watershed which were utilized for detecting the changes in land use pattern. Fig 1(b) indicates the changes that occurred during the project period in the operational area due to the implementation of various soil and water conservation techniques. The land use pattern viz; built-up area, cropland, forest area, plantation area, scrubland/fallow land and waterbodies indicated by different colours in map helps to detect the change in land use pattern through technical processing of Remote sensing imageries. Fig. 1(c) reveals an interchange of land use categories whereas the IRSR2 LISS-IV image (Fig.1(d)) shows the change from cropland to water bodies in the Duggi area of the project while Fig. 1(e) exposes the change from scrubland/fallow land to cropland near the Kosamanuguda area of the Polla watershed [8,9].

The data (LULC maps and table) indicate a significant decrease (59.67%) in scrubland/fallow and an increase in cropland (32.68 %), plantation (2.16%) and waterbodies (17.10%). The waterbodies indicate water features, surface waters and wet surfaces which are resultant of existing natural streams, and rainfall. This could be attributed to the improvement of land quality of wasteland after the implementation of Integrated Watershed Management Practices (IWMP) in the study area which was brought under cultivation [10,11].

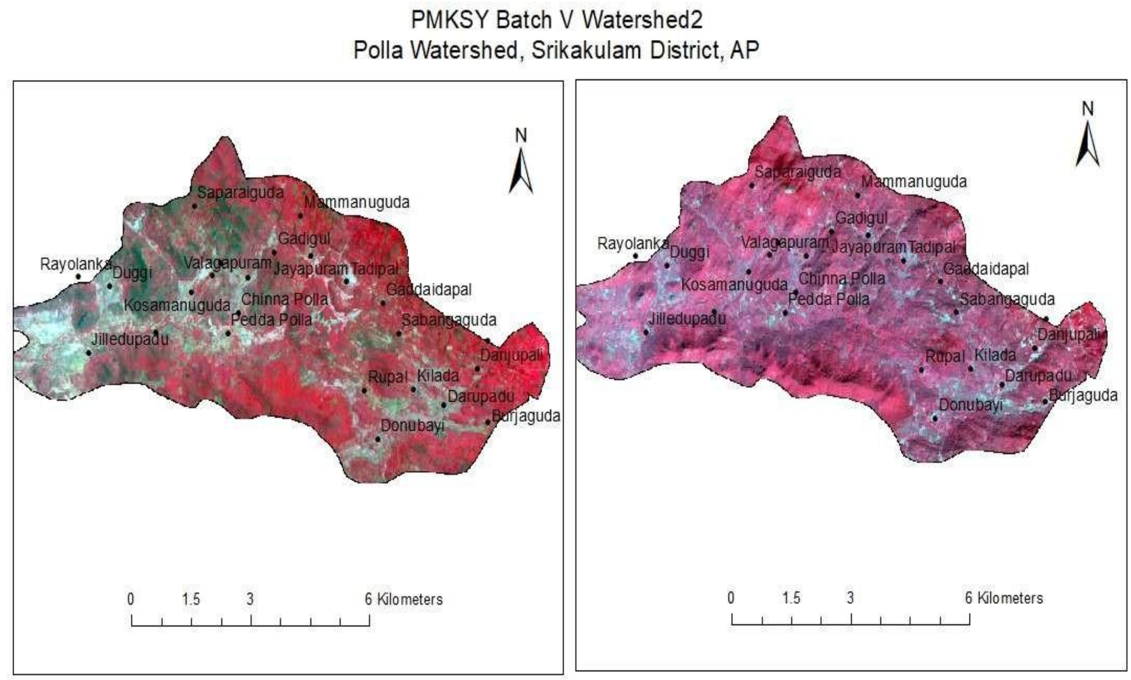

Fig. 1(a). Pre and post LISS-IV images of Polla Watershed

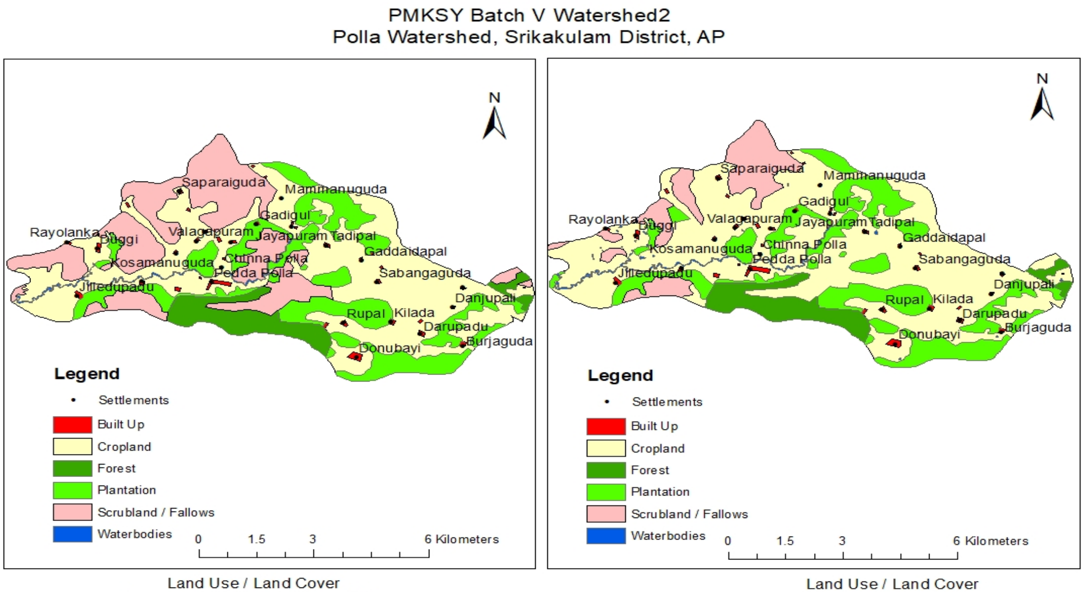

Fig 1(b). Change detection-land use land cover

Table 1. Change in LULC in Polla project from 2013 to 2020

S. No.	LULC category	Pre-project	Post project	Difference	Difference in %
		Area in Ha			
1	2	3	4	5 (4-3)	6
2	Built-Up	54.24	54.24	0.00	0.00
3	Cropland	2314.74	3071.08	756.34	32.68
4	Forest	363.81	363.81	0.00	0.00
5	Plantation	1136.46	1161.01	24.55	2.16
6	Scrub/Fallow	1318.17	531.58	-786.59	-59.67
7	Waterbodies	33.28	38.97	5.69	17.10
	Total Watershed Area	5220.70	5220.70		

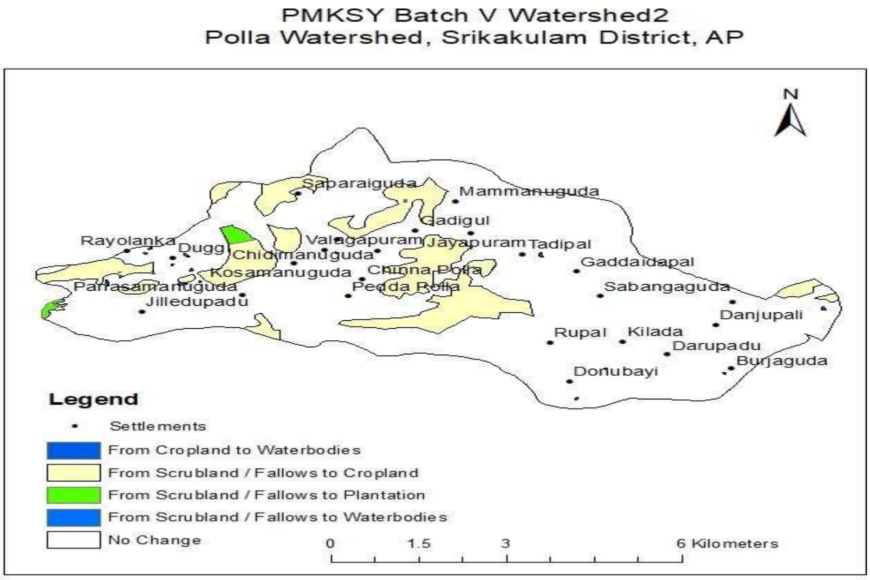

Fig 1(c). Land use change map

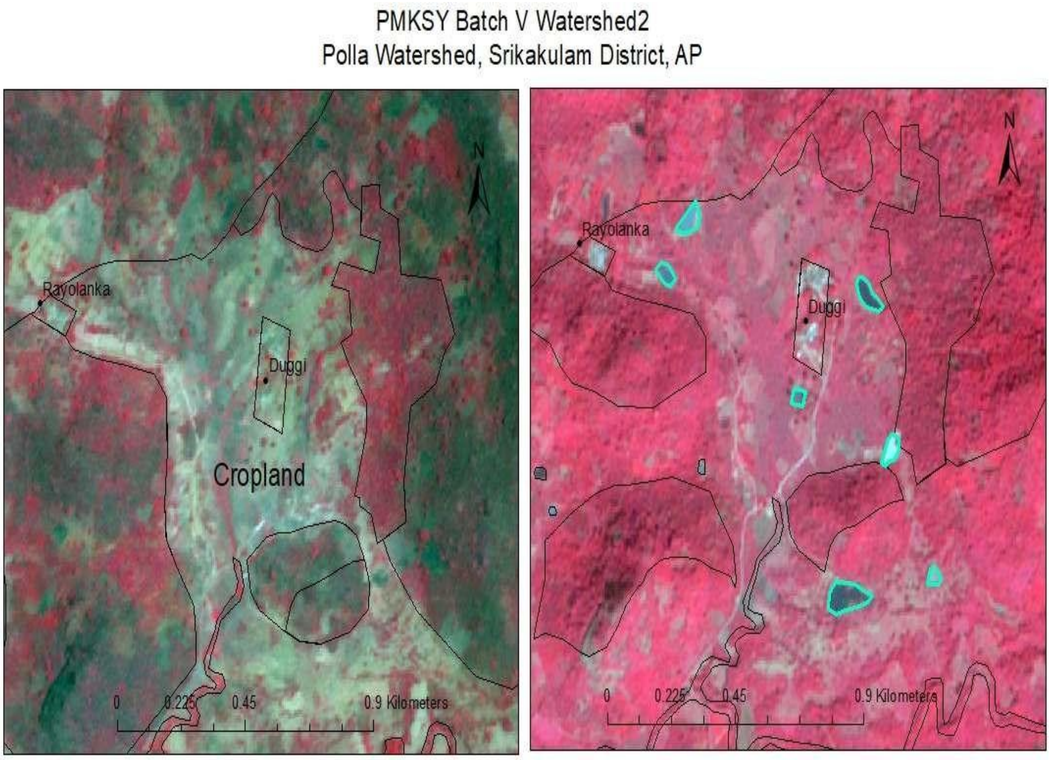

Fig. 1(d). Pre and Post IRSR2 LISS-IV images showing land use change

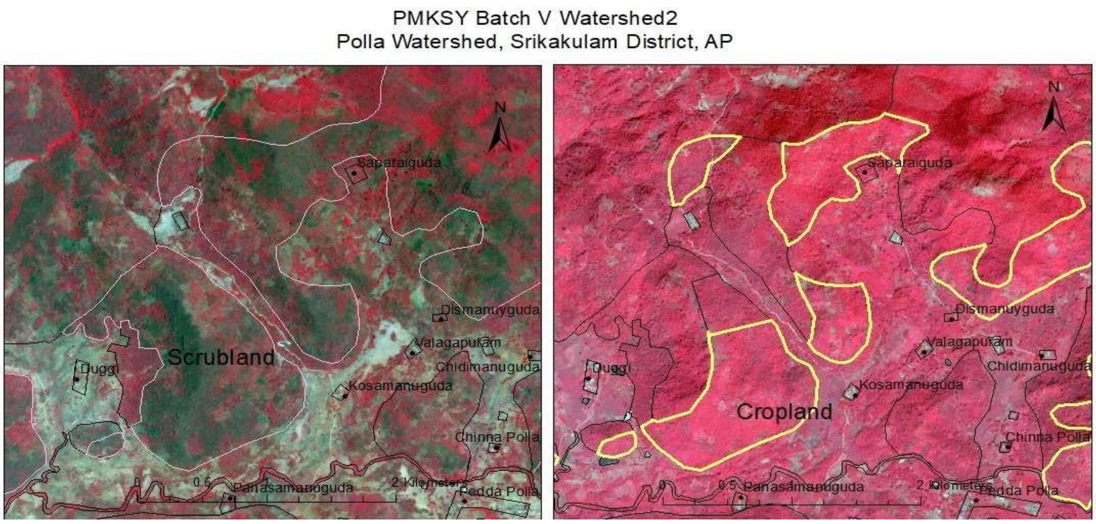

Fig. 1(e). Pre and Post IRSR2 LISS-IV images showing land use change

3.2 Changes in Normalized Difference Vegetation Index

The NDVI images were generated for pre-project (2013) and post-project (2020) and based on NDVI values, the project area was classified into four vegetation vigour classes, namely, nil vegetation (Zero vegetation i.e., fallow land), low vegetation (Vey few trees or plants grown in a small area), medium vegetation (Few trees or plants grown) and dense vegetation (The trees & other plants in a large densely area). The results are presented in Fig. 2 and Table 2.

It is clear from the pre and post-NDVI data that there is an increase in dense vegetation (3.93 %), medium vegetation (28.36 %), Low Vegetation (19.25 %) and there is a decrease in nil vegetation (-57.99 %). The increase in this vegetation may be due to a lot of greenery created around water bodies like rockfill dams, percolation tanks, mini percolation tanks, loose boulder structures etc. which are also reflected in low and medium vegetation [8,9].

3.3 Changes in Normalized Difference Water Index

Changes in water body area (NDWI) is a good indicator of rainwater harvesting activities taken up in the project area. The increase in waterbodies by 0.30 ha (107.14 %,) as furnished in (Table 3) may be due to the construction of rainwater conservation structures like percolations tanks, rockfill dams, mini percolation tanks and loose boulder structures etc. (Table 4) during the project implementation period. Due to the effective execution of IWMP interventions in watershed programs, an overall positive impact was brought out in the study area [12,13]. “Biophysical indicators of watershed impact evaluation in rainfed areas are highly sensitive to weather conditions, mainly rainfall. Even one rainfall event makes a huge difference in the analysis of vegetative cover and water spread area in the waterbodies and water features” [14,8,9].

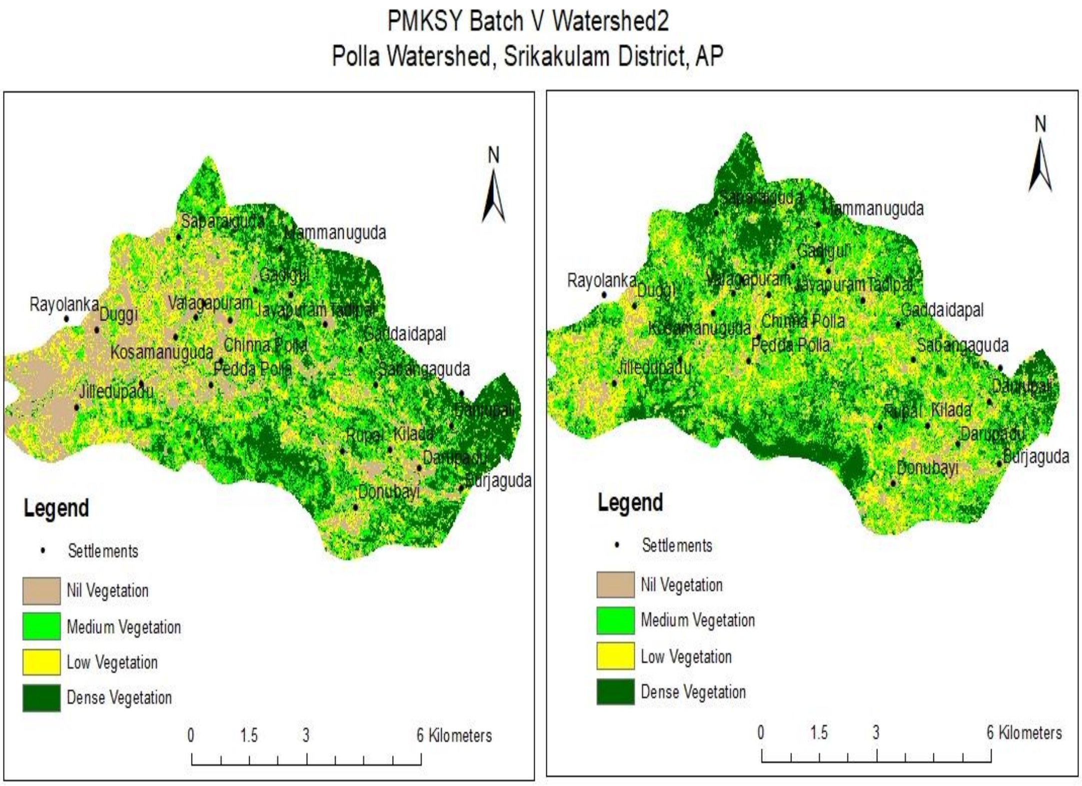

Fig. 2. Pre and post NDVI images

Table 2. Change in vegetation cover (NDVI) in Polla watershed from 2013 to 2020

S. No.	NDVI Classes	Pre-project	Post project	Difference	Difference in %
		Area in Ha			
1	2	3	4	5 (4-3)	6
1	Nil Vegetation	1223.22	513.89	-709.33	-57.99
2	Low Vegetation	1288.15	1536.08	247.93	19.25
3	Medium Vegetation	1452.69	1864.73	412.04	28.36
4	Dense Vegetation	1256.63	1305.99	49.36	3.93
5	Total Watershed Area (TWA)	5220.70	5220.70		

Table 3. Change in waterbodies

NDWI Classes	Pre-Project Period (Area ha)	Post-Project Period (Area ha)	Difference (ha)	% difference
Water bodies	0.28	0.58	0.30	107.14

Table 4. Rain water conservation works taken up in Polla project area from 2013 to 2020

S. No.	Rainwater conservation works	No. of Works
1	Rockfill Dams	10
2	Percolation Tanks	21
3	Mini Percolation Tanks	20
4	Water absorption trenches at foothills	1
5	Loose Boulder Structures including wire mesh	26
6	Gabion SMC	9
7	Check walls	3

4. CONCLUSION

The evaluation of the polla watershed project using Geospatial Technology (Remote Sensing and GIS) has shown a significant decrease (59.67%) in scrubland/fallow and an increase in cropland (32.68 %), plantation (2.16%) and waterbodies (17.10%) due to the construction of rainwater conservation structures like percolations tanks, rockfill dams, mini percolation tanks and loose boulder structures etc. There is an increase in dense vegetation (3.93 %), medium vegetation (28.36 %), Low Vegetation (19.25 %) and there is a decrease in nil vegetation (-57.99 %). The increase in this nil vegetation may be due to a lot of greenery created around water bodies like rockfill dams, percolation tanks, mini percolation tanks, loose boulder structures etc. [12,14].

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COMPETING INTERESTS

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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