Original Research Article

Evaluation of Watershed Development Programme in Prakasam District of Andhra Pradesh using Remote Sensing and GIS Technology

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ABSTRACT

Aim: This study was taken up to investigate the usefulness of Remote Sensing & GIS tools for the evaluation of fourteen watershed projects implemented under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) project in the Prakasam District of Andhra Pradesh.

Place and duration of study: This study was conducted by Panchayat Raj and Rural Development Department, Andhra Pradesh2009 to 2022.

Methodology: Remote Sensing based methodology is adopted through temporal satellite data for monitoring the watersheds. This research study was investigated using high-resolution data like Resourcesat-2, and LISS-IV of 2011 (pre-treatment) and 2016 (post-treatment)to assess the changes in land use/land cover and biomass that have changed within a period of five years (2011-16).

Results: There is a significant reduction in fallow land area from 31727 ha to 23893 ha, which is attributed to dense and open vegetation categories in 2016. The output of the Normalized Difference Vegetation Index classification indicates the increase in dense vegetation from 16955 ha to 23256 ha, which indicates there is an improvement in the open vegetation category due to the reclamation of fallow land.

Conclusion: This study reveals that an additional area of 419ha (07.53%) increased under water bodies and 2792ha of wasteland converted to cultivable land due to the construction of farm ponds, percolation tanks and check dams. This area is attributed to cropland and plantations.

Keywords: Watershed, Remote Sensing,Normalized Difference Vegetation Index, Land use land cover

1. INTRODUCTION

"A watershed is an area that supplies water by surface or subsurface flow to a given drainage system or body of water such as a stream, river, wetland, lake or ocean" [12]. The watershed management concept has been introduced to respond to the complex challenges of natural resource management and to ensure the efficient use of both natural and social capital of the district in addition to the state.Conventional ground-based sampling has proved costly and time-consuming. The newly improved satellite's repeated coverage provides an excellent opportunity to monitor land resources and evaluate land cover changes by comparing images acquired for the same area at different times. Changes like increased area under cultivation, conversion of annual cropland to horticulture, change in surface water bodies, afforestation or soil reclamation can be monitored through the use of satellite remote sensing.

In this context, to reduce the cost and time, satellite remote sensing has been used as an evaluation tool in many of the studies [1-3]. "Unfortunately, monitoring and evaluation have not got their share of attention and therefore has become very difficult to quantify and assess the changes made by the development programmes which have taken place in natural resources and the livelihoods of people" [4-9]. "There is not often enough room for midterm adjustments in the ongoing programmes due to the lack of a proper monitoring system. Therefore, the need arises to identify a quick and cost-effective technique for monitoring the impact of such development programmes on a 'before project – after project' temporal scale as well as during the project implementation stage" [4-10]. "Remote Sensing (RS) and Geographical Information Systems (GIS) have proven to be effective tools to monitor and manage natural resources to assess the impact of watersheds during pre- and post-development. Change detection in watersheds was observed by spatial and temporal databases and analysis techniques. The efficiency of the techniques depends on several factors such as classification schemes, the spatial and spectral resolution of the RS data, ground reference data and effective implementation of the result" [13,14]. Therefore, the present study attempted to assess the spatial and temporal changes in the watershed. The objective of this study is to evaluate the changes in the cropped area, land use/land cover, vegetation vigour, rainfall, and soil moisture changes during the study period.

2. MATERIAL AND METHODS

The Prakasam district is one of the coastal districts of Andhra Pradesh. It is located in the South-eastern part of the state and is bounded by the Guntur district in the North, the Mahbubnagar district of Telangana in the Northwest, the Kurnool district in the West, the SPS Nellore district in the South, YSR Kadapa district in the Southwest and Bay of Bengal to the East. The district lies between north latitudes 14°57' - 16°17' and East longitudes 78°43' - 80°25' and is spread over an area of 17,626 sq. km. The average annual rainfall of the district is 798.6 mm.

The present study has implemented fourteen watersheds under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) project (Batch-1) during 2009-10. The list of watershed projects was presented in (Table 1).

S. No	Project Code	Project Name	Mandal Name	Project Area in Ha.
1	Prakasam-Iwmp-1/2009-10	Ramachandrapuram	VoletivariPalem	5300
2	Prakasam-Iwmp-2/2009-10	Ulchi	Ongole	4600
3	Prakasam-iwmp-3/2009-10	Mynampadu	SanthanuthalaPadu	5800
4	Prakasam-iwmp-4/2009-10	Mutukula	Pullalacheruvu	5100
5	Prakasam-iwmp-5/2009-10	Dharmavaram	Marripudi	5300
6	Prakasam-iwmp-6/2009-10	Mundlapadu	Giddaluru	4700
7	Prakasam-iwmp-7/2009-10	Pusalapadu	Bestavaripeta	3700
8	Prakasam-iwmp-8/2009-10	Chinakothapalli	Addanki	4800
9	Prakasam-iwmp-9/2009-10	Chinnairlapadu	Kanigiri	4700
10	Prakasam-iwmp-10/2009-10	Yadavalli	Dornala	4900
11	Prakasam-iwmp-11/2009-10	Ummanapalli	Hanumanthunipadu	5000
12	Prakasam-iwmp-12/2009-10	Chennupalli	Ballikurava	4800
13	Prakasam-iwmp-13/2009-10	Polavaram	Mundlamuru	4600
14	Prakasam-iwmp-14/2009-10	Potlapadu	Kurichedu	4300
				67600

Table1:ListofwatershedsintheDistrict

Remote Sensing based methodology is adopted through temporal satellite data for monitoring the watersheds [15]. This research study was investigated using high-resolution data like Resourcesat-2, and LISS-IV of 2011 (pre-treatment) and 2016 (post-treatment)to assess the changes in land use/land cover and biomass that have changed within a period of five years (2011-16). The methodology adapt for the study is presented in fig.1. The land features were grouped into different land use/land cover categories using supervised classification by maximum likelihood algorithm with a minimum mapping unit of 2.5 ha.

The land area was classified into different vegetation levels using the Normalized Difference Vegetation Index (NDVI) approach. The classified outputs of land use/land cover and vegetation cover from NDVI of the two time periods were compared to derive information on changes that occurred over time for each watershed.

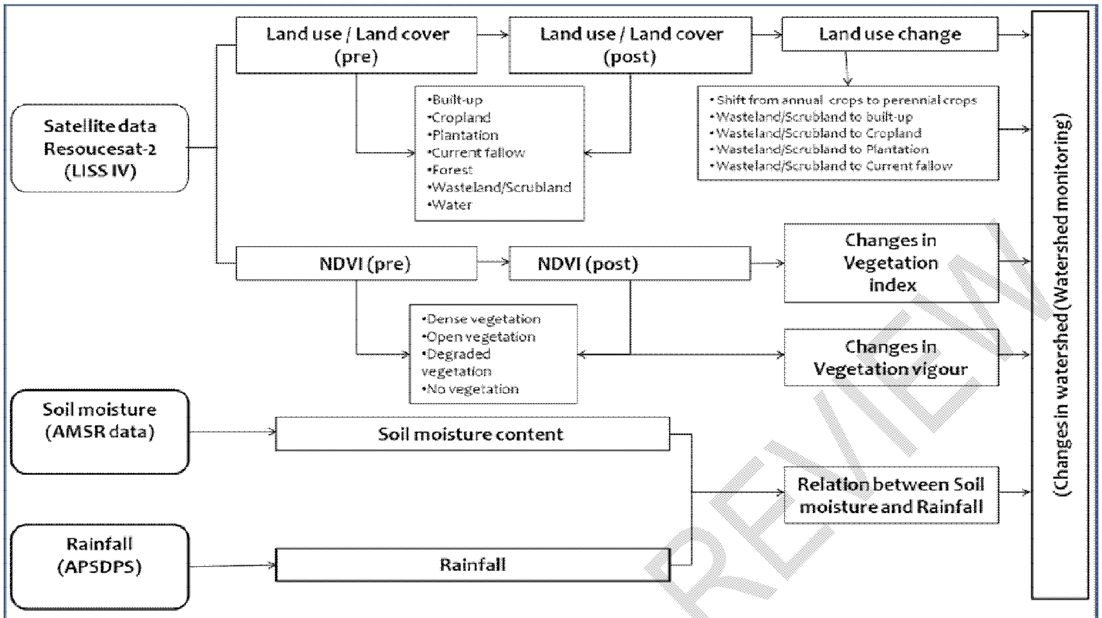

Fig 1: Methodology adapt for the study

<u>2.1 Land use / Land cover changes:</u>

Using the maximum likelihood algorithm, supervised classification was performed for both pre and post-treatment satellite data that have been clustered with a pixel of similar spectral characteristics into homogenous classes. This algorithm assumes Gaussian distribution and each pixel is considered a separate entity independent of neighbours. The classified output images have various land use/land cover categories about before and after treatment periods [16]. The output image has been used to compare and evaluate the changes which have taken place during the period.

<u>2.2 Vegetation vigour changes:</u>

Vegetative parameters such as green leaf biomass, and leaf area (photosynthetic activity indicator) are highly correlated with NDVI. Normalized Difference Vegetation Index (NDVI) was derived using the ratio of the difference between the reflectance of NIR and Red to a total of NIR and Red bands NDVI values ranging from -1 to 1. Higher values of NDVI showed high vegetation area because of their relatively high NIR reflectance and low red reflectance. Rocks and bare soil have NDVI values around zero. Water, snow and clouds have negative IR radiation. Based on these NDVI values, vegetation vigour was classified into dense, open and degraded vegetation. The fallow was classified as having no vegetation [10,11].

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; SOI topo sheets for reference; PMKSY monitoring reports from the department; Soil Moisture data from AMSRE-2 data; Rainfall data

2.4Indicators 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 perennial crops; Additional area brought under cropped area; Soil Moisture availability through wetness indicators; Reclamation of wastelands

2.5Major Developmental activities of the Watersheds:

The developmentswill be the construction of structures like Loose Boulder Structure, Rock fill dams and check dams for soil water conservation; Farm ponds and percolation tanks; Plantations in individual farmer's land; Other works like drainage line treatment, Nala bank stabilization, filter strips etc., have also been developed.

3. RESULTS AND DISCUSSION

Normalized Difference Vegetation Index (NDVI) maps were generated for the watershed area for 2011 and 2016. Based on the NDVI values the vegetative cover land was classified into different vegetation vigours classes like Dense, Open Degraded and Fallow. The spatial distribution of vegetation cover during 2011 and 2016 is shown in fig.2&3 whereas the statistics are presented in (Table 2).

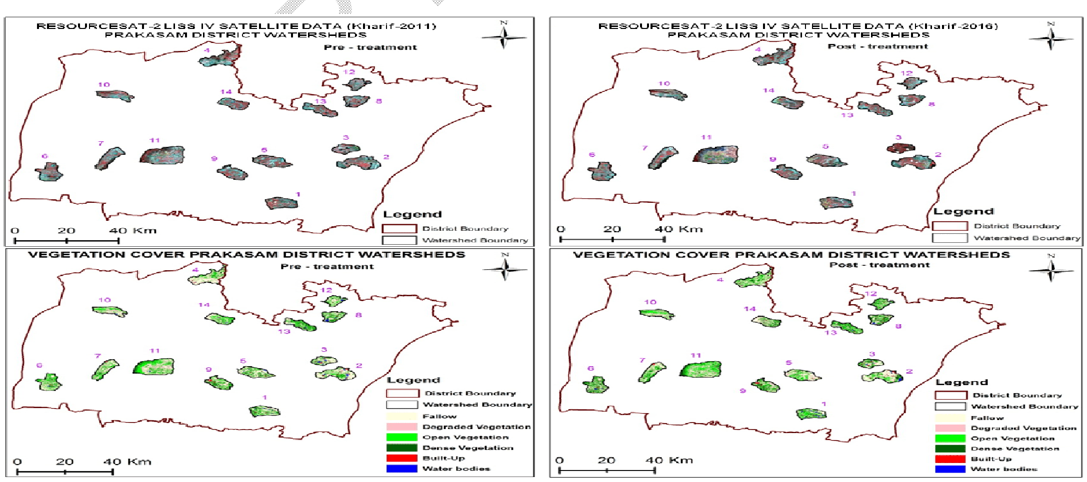

Fig 2: Comparison of Vegetation Cover maps

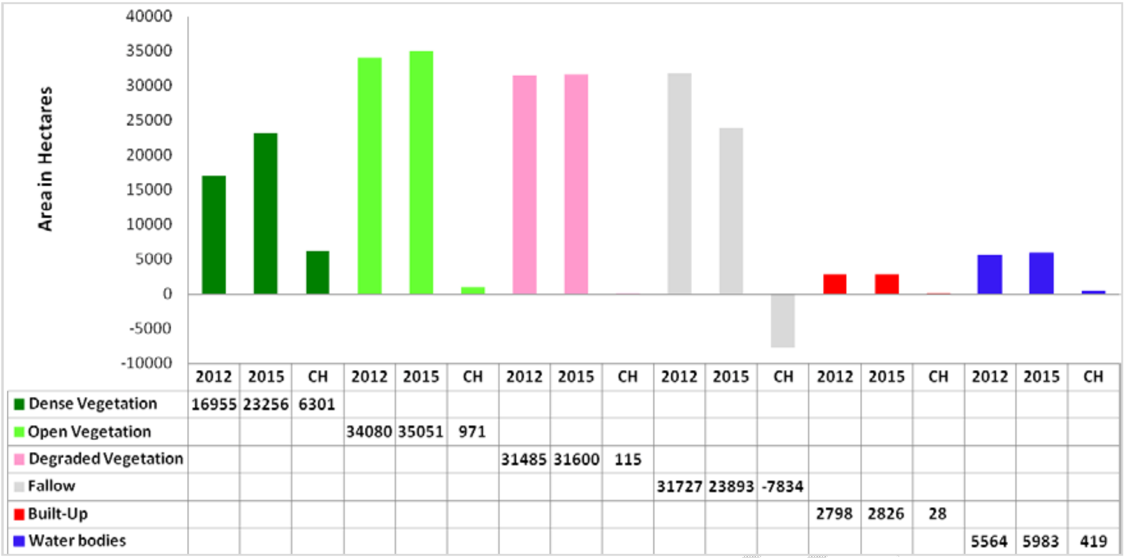

Fig 3: Distribution of Vegetation Cover Changes

Table – 2: Changes in Vegetation cover (Units in Hectares)

Vegetation Vigour Type	Pre-Treatment		Post-Treatment		Change ±	
	Area	%	Area	%	Area	%
DenseVegetation	16955	14	23256	19	6301	37
OpenVegetation	34080	28	35051	29	971	3
DegradedVegetation	31600	26	31485	26	115	0
Fallow	31727	26	23893	19	-7834	-25
Built-Up	2798	2	2826	2	28	1
Waterbodies	5564	5	5983	5	419	8
Total	**122609**	**100**	**122609**	**100**		

The vegetation maps indicated that the areas under dense and open vegetation increased significantly during the period between 2011 and 2016. This increase in vegetation is due to sufficient rainfall during this period, which has been analyzed in the chapter given below. There is a reduction in the area under fallow and degraded categories from 31727 ha to 23893 ha and 31600 ha to 31485 ha respectively during the project period, which is attributed to dense and open vegetation categories in 2016 [13,16]. Fig.4 shows the vegetation index during the project period of the watershed area. It clearly states that a positive change of increase in vegetation cover.

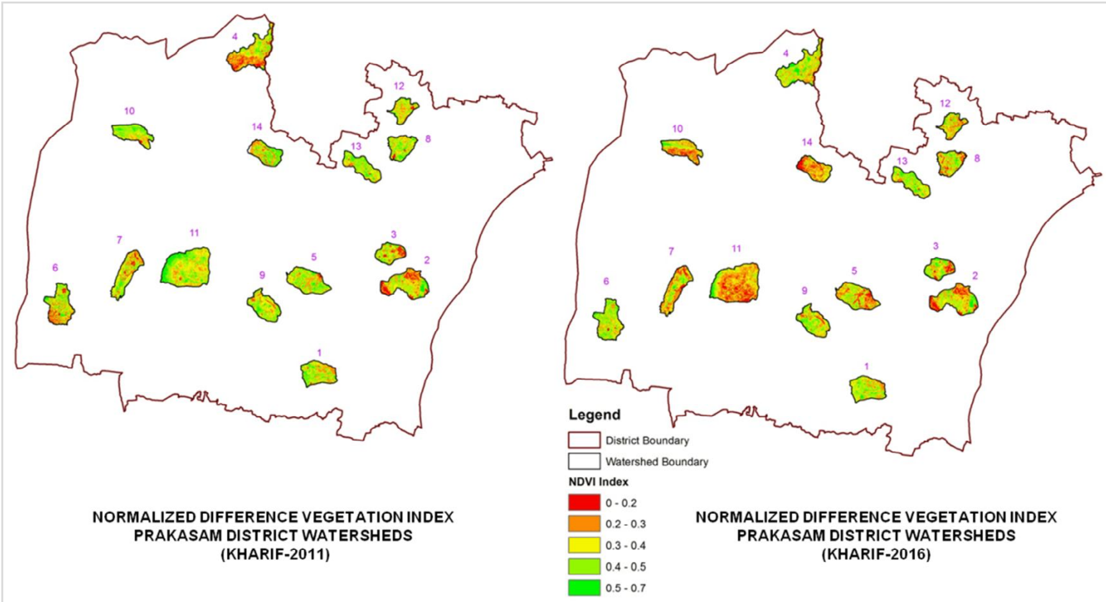

Fig4:Normalized difference vegetative index comparison for 2011 and 2016

The satellite images of both periods (pre and post treatments) were classified into different land use/ land cover categories. The area under agriculture and plantations had increased considerably and reductions in the area under current fallow and waste lands were noticed [3, 12, 16]. Spatial distributions of different land use/land cover categories during 2011 and 2016 are presented in fig.5 while the land use changes are shown in fig.6.

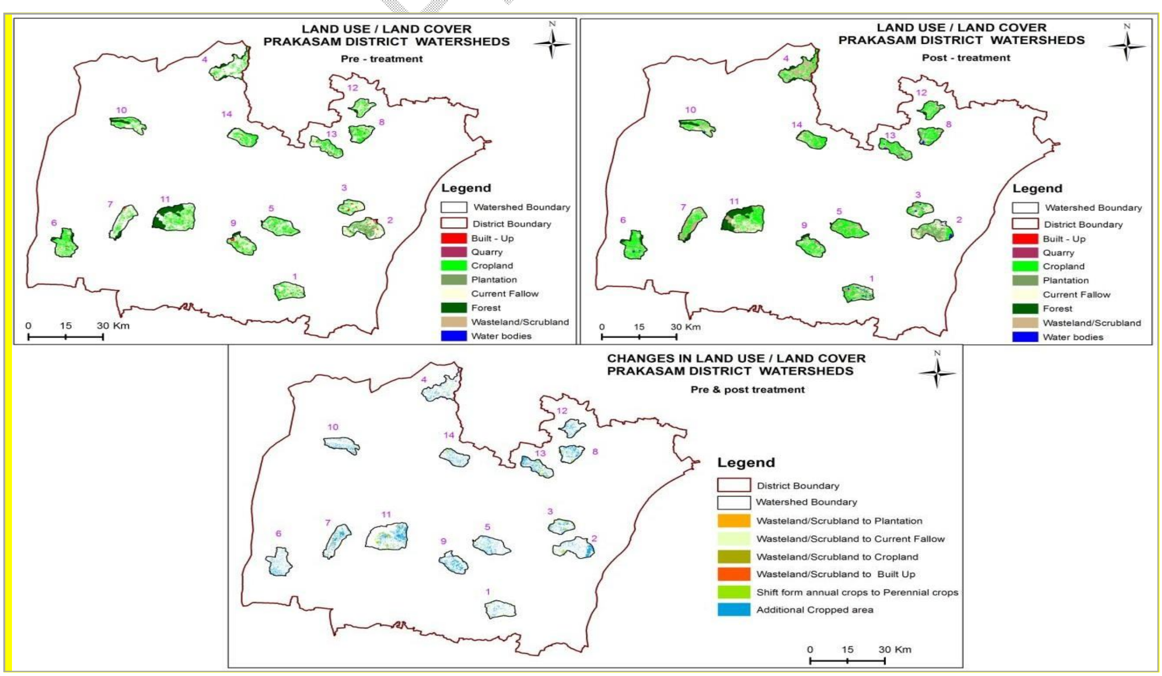

Fig 5: Land use land cover maps comparison

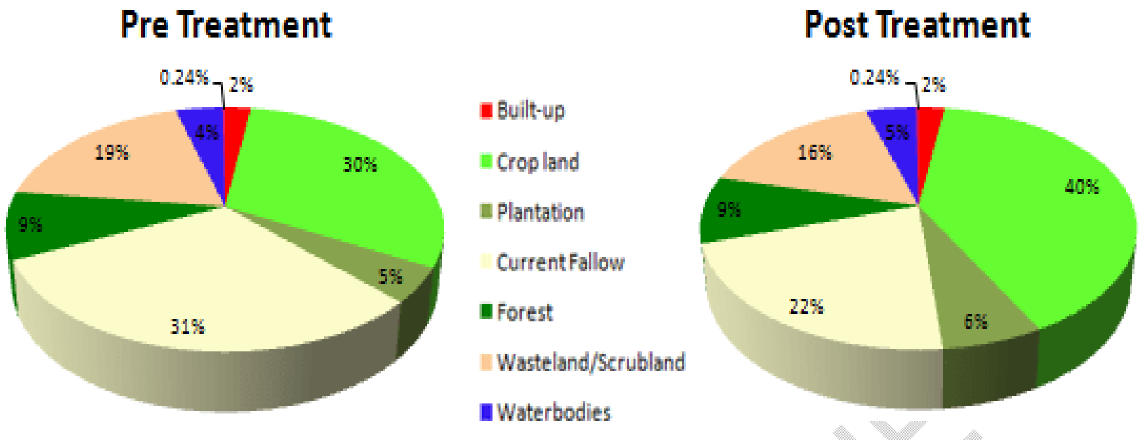

Fig 6: Land use / Land cover distribution

(Table-3) showed the statistics of the area under different land use/land cover categories for both periods. As before the cropland area was observed, which is due to promoting agriculture and horticulture crops. Under land use classes, cropland occupied an area is 37480 ha during 2011 and 48897 ha in 2016, indicating an increase of 11417 ha which is about an increase of 30.46% from its initial 37480 ha. The current fallows decreased significantly from 37534 ha (30.61%) to 26416 ha (21.54%) between 2011 and 2016 [17-20]. This is mainly due to the implementation of drought-proofing works which is accounted for in cropland in 2016. Notified forest boundary is extracted from SOI toposheet.

Table – 3: Major Land use/ Land cover changes (Units in Hectares)

Landuse/cover class	Pre-Treatment		Post-Treatment		Change±	
	Area	%	Area	%	Area	%Increase/ Decrease
Built-up	2798	2.28	2826	2.30	28	1.00
Cropland	37480	30.57	48897	39.88	11417	30.46
Plantation	5666	4.62	7773	6.34	2107	37.19
CurrentFallow	37534	30.61	26416	21.54	-11118	-29.62
Wasteland/Scrubland	22835	18.62	20043	16.35	-2792	-12.23
Waterbodies	5088	4.15	5471	4.46	383	7.53
Quarryarea	269	0.22	281	0.23	12	4.46
Total Area	**122611**	**100**	**122611**	**100**		

Changes in water body area are a good indicator of any watershed intervention activities. The water body area is extracted using LISS-IV satellite data for 2011 and 2016. A gradual temporal change in the water body area has been noticed. The water body area contributed to 5088 ha in 2011 and 5471 ha in 2016 which is about a 7.53% increase from its initial 5088 ha. The increase in the water body area is due to the construction of farm ponds, percolation tanks and check dams as shown in fig.7.

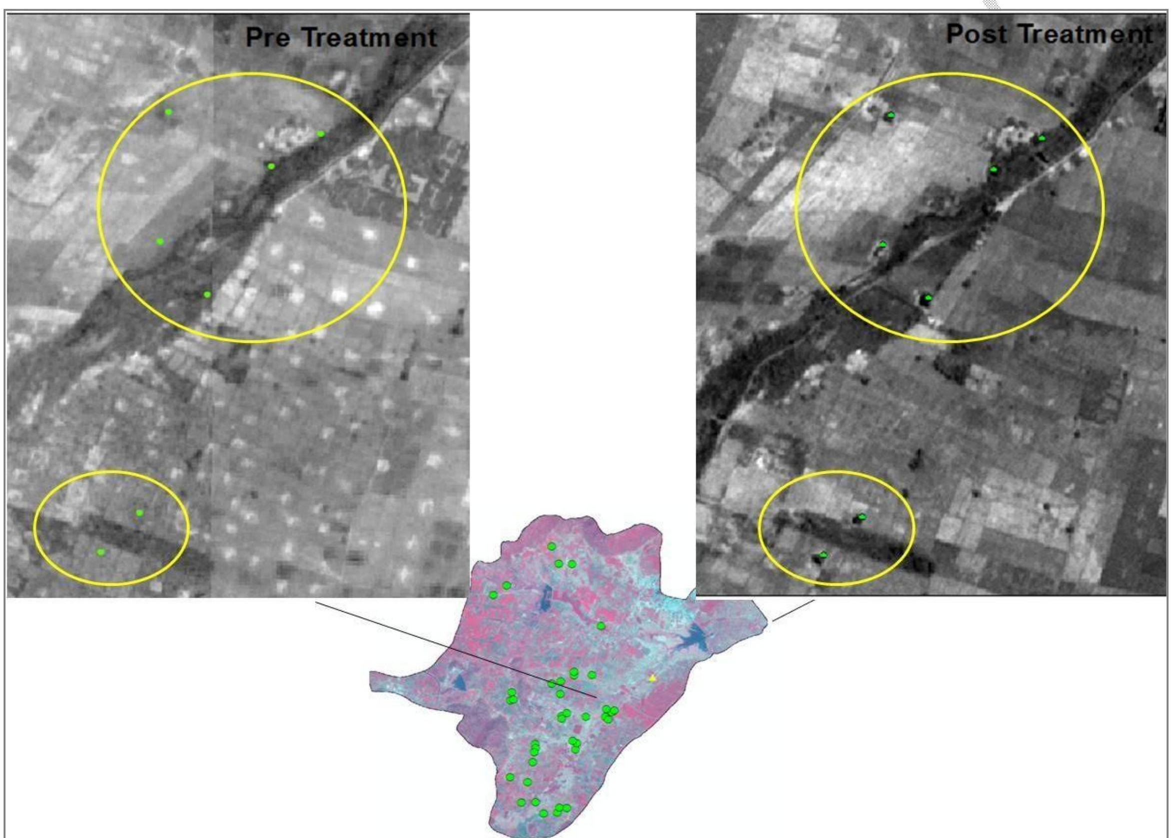

Fig 7: Major activities in the project area

The plantation cover occupied 5666 ha (4.62%) in 2011 and it has increased to 7773 ha (6.34%). It is found that 2107 ha of croplands are converted into perennial crops during the project period which is attributed to plantations in 2016 [17-20]. This may help protect from soil erosion, improve soil structure, increase ecosystem nutrient retention, carbon sequestration, and water infiltration, and it can contribute to climate change adaptation and mitigation measures.

Due to the implementation of the watershed developmental activities, an area of 11417 ha has been brought under cropped area. This is attributed to cropland and plantations in the year 2016. It clearly shows that the changes that occurred in the watershed area are progressive in nature [17-20]. The changes in cropland are shown in Fig 8.

Under the watershed development activities, the reclamation of wastelands is the major activity. These wastelands were reclaimed for productive use by adopting suitable treatment measures like contour ploughing, strip farming, terracing, leaching and changing agriculture practices. The wasteland reclamation measures are implemented in the project area and resulted in bringing 2792 ha into cultivable land. In this, the major area is under fallow [16-

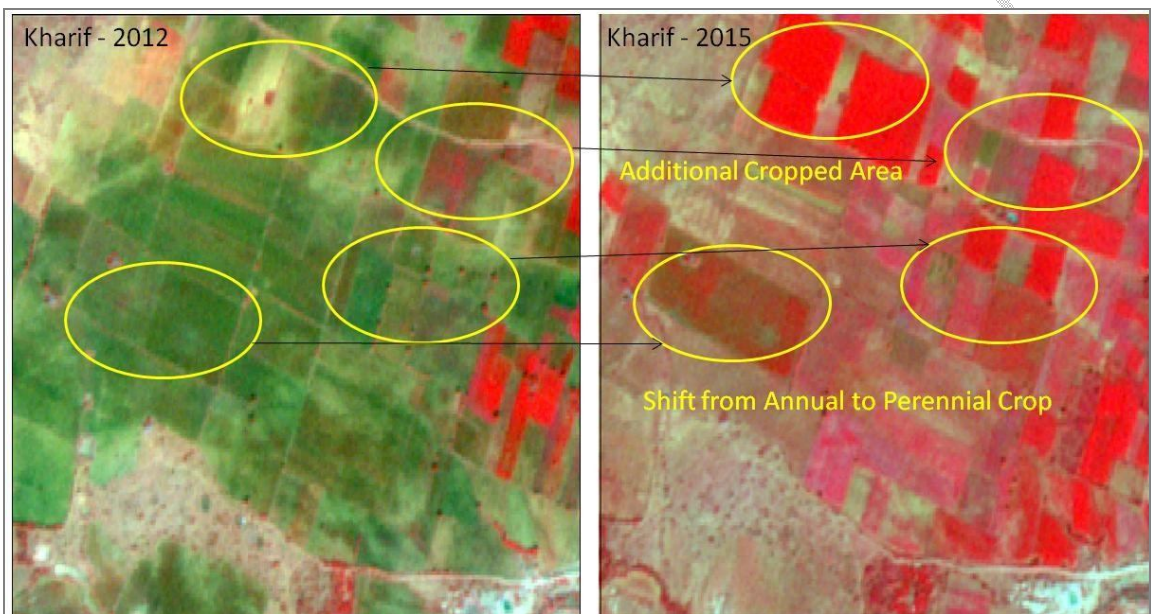

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Fig 8: Major changes in the watershed project area

4. CONCLUSION

Change detection studies have been carried out for the evaluation of nine watersheds in the Chittoor district and concluded that there has been an increase in plantation area from 5666 ha (4.62%) in 2011 to 7773 ha (6.34%). The cropland also increased from 37480 ha (30.57%) in 2011 to 48897 ha (39.88%) in 2016. It is also found that cropland and plantations area has increased the cost of fallow land. The output of NDVI classification indicates an increase in dense vegetation from 16955 ha to 23256 ha due to the sufficient rainfall received during the project period. NDVI studies indicate that there is an improvement in the open vegetation category due to the reclamation of fallow land. The current fallows decreased significantly from 37534 ha (30.61%) to 26416 ha (21.54%) between 2011 and 2016. This is mainly due to the implementation of drought-proofing works which is accounted for in cropland in 2016. The water body area contributed to 5564 ha in 2011 and 5983 ha in 2016 which is about a 7.53% increase from its initial 5564 ha. The increase in the water body area is due to the construction of farm ponds, percolation tanks and check dams. The wasteland reclamation measures are implemented in the project area and resulted in bringing 1792 ha into cultivable land.These wastelands were reclaimed for productive use by adopting suitable treatment measures like contour ploughing, strip farming, terracing, leaching and changing agriculture practices.

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