*Original Research Article*

# Application of Remote Sensing & GIS Technology for Evaluation of Watershed Development Programme in Chittoor District, Andhra Pradesh, India

.


## ABSTRACT

**Aim:**This study was taken up to investigate the usefulness of Remote Sensing & GIS tools for evaluation of nine watershed projects implemented under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) project in Chittoor 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:** High resolution data like Resourcesat-2, Linear Imaging and Self Scanning-IV (LISS-IV) of 2011 (pre-treatment) and 2016 (post-treatment) were used in this project to measure the changes in land use/land cover and biomass during project period (2011-16). Due to implementation of the watershed developmental activities, an additional area of 7093 ha has been brought under cultivation.

**Results:** There is a significant reduction under fallow and degraded land area categories from 17922 ha to 11981 ha and 20064 ha to 15375 ha respectively, which is attributed to dense and open vegetation categories in 2016. The output of Normalized Difference Vegetation Index classification indicates the increase in dense vegetation from 2709 ha to 7428 ha, which indicates there is an improvement in open vegetation category due to the reclamation of fallow land.

**Conclusion:** This study reveals that an additional area of 349ha (18.02%) increased under water bodies and 231ha waste land converted to cultivable land due to 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” [18,19,20]. “Watershed management concept has been introduced to respond to the complex challenges of natural resource management and to ensure efficient use of both natural and social capital of the district in addition to state” [21,22].The 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 [1-4]. “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” [5-13]. “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” [14,15,16,8,9,10, 11,12,13]. “The 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, spatial and spectral resolution of the RS data, ground reference data and effective implementation of the result” [24,25,28]. 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

Chittoor district is bounded on the North by Ananthapur and Kadapa districts; on the East by Nellore district of Andhra Pradesh; Chengalpattu and North Arcot districts of Tamil Nadu; on the south by North Arcot Ambedkar and Dharmapuri districts of Tamil Nadu; and in the west by Kolar district of Karnataka. The district lies between 12°37' - 14°08' north latitudes and 78°03' - 79°55' East longitudes and spread over an area of 15,359 sq. km. The district has its headquarters at Chittoor which is the largest city in the district. It receives an annual rainfall of 918mm and both South west and north east monsoons are the major sources of rainfall. On an average, this district receives 438 and 396 mm rainfall through the south west monsoon and north east monsoon, respectively and the rest from summer. In the present study, nine Integrated Watershed Management Programme(IWMP) projects have been implemented in Chittoor district of Andhra Pradesh under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)project (Batch-1) during 2009-16 (Table 1).

**Table 1: List of Watersheds in the District**

| Sl. No. | Project Code | Project Name | Mandal Name | Project Area in Ha. |
|---|---|---|---|---|
| 1 | Chittoor-Iwmp-1/2009-10 | Muddanapalle | Ramakuppam | 4978 |
| 2 | Chittoor-Iwmp-2/2009-10 | T.Pasalavandlapalle | Gurramkonda | 4977 |
| 3 | Chittoor-Iwmp-3/2009-10 | Musalikunta | Peddamandyam | 2610 |
| 4 | Chittoor-Iwmp-4/2009-10 | Katiperi | Chowdepalle | 4227 |
| 5 | Chittoor-Iwmp-5/2009-10 | G.C.Palle | Baireddipalle | 5041 |
| 6 | Chittoor-Iwmp-6/2009-10 | Yellamanda | Yerravaripalem | 3666 |
| 7 | Chittoor-Iwmp-7/2009-10 | M.C.Palle | Punganur | 4405 |
| 8 | Chittoor-Iwmp-8/2009-10 | Vempalle | Madanapalle | 4676 |
| 9 | Chittoor-Iwmp-9/2009-10 | Nagiripalle | Kalikiri | 3445 |
| | | | | 38025 |

Remote Sensing based methodology is adopted through temporal satellite data for monitoring the watersheds [27,29]. This research study was investigated using high resolution data like Resourcesat-2, LISS-IV of 2011 (pre-treatment) and 2016 (post-treatment)to assess the changes in land use/land cover and biomass that have changed with in a time span 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 minimum mapping unit of 2.5 ha.

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

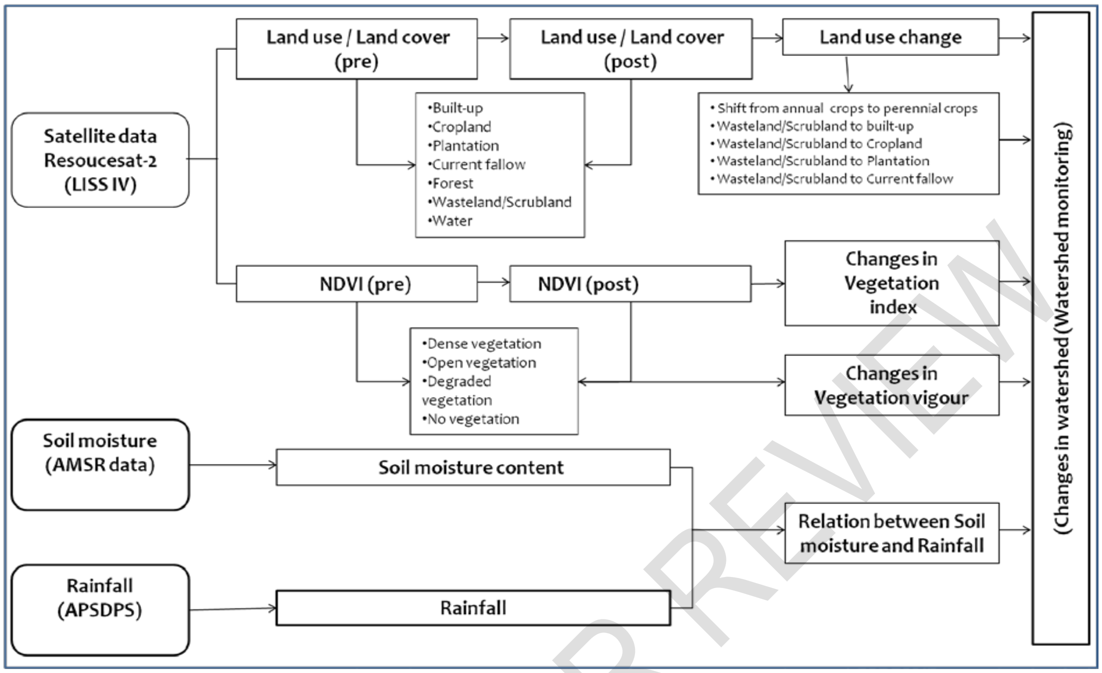



**Fig 1: Methodology adapt for the study**

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

Using maximum likelihood algorithm, supervised classification was performed for both pre and post treatment satellite data have been clustered with the 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 pertaining to before and after treatment periods [30]. The output image has been used to compare and evaluate the changes which have taken place during the time period.

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

Vegetative parameters such as green leaf biomass, leaf area (photosynthetic activity indicator) are highly correlated with NDVI. Normalized Difference Vegetation Index (NDVI) derived using the ratio of the difference between reflectance of NIR and Red to total of NIR and Red bands NDVI values ranged 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 no vegetation [16,17].

**<u>2.3 Soil moisture and Rainfall analysis:</u>**

The effect of soil moisture content and rainfall over the watershed area, daily soil moisture content and rainfall data havebeen analyzed from 2009 to 2016 [26]. For soil moisture mapping, the level-3 daily soil moisture products from Aqua Advanced Microwave Scanning Radiometer - Earth Observation System (AMSR-E) and AMSR-2 have been utilized. In order to justify the variation in moisture content, the daily rainfall data from Automatic Weather Station (AWS) have also been compared over the periods. These daily rainfall and soil moisture data have been converted in to weekly data. The rainfall mostly occurs from June to December in SW monsoon period. Hence, the same period is considered to plot the variation of rainfall and soil moisture. The relationship between the rainfall and soil moisture content for each and every watershed area was analyzed by plotting the graph between these two parameters. The x-axis (bar graph) represents the rainfall and y-axis (line plot) represents the soil moisture. The similarities in the dynamics in soil moisture content and rainfall were observed over the given time period.

### 2.4 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

### 2.5 Indicators considered for Evaluations of Watershed:

In order to analyze the changes taken 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

### 2.6 Major Developmental activities of the Watersheds:

The developmentswill be 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 watershed area for 2011 and 2016. Based on the NDVI values the vegetative cover land was classified into different vegetation vigour classes like Dense, Open Degraded and Fallow. Spatial distribution of vegetation cover during 2011 and 2016 is showed in fig.2&3 whereas the statistics are presented in (Table 2).

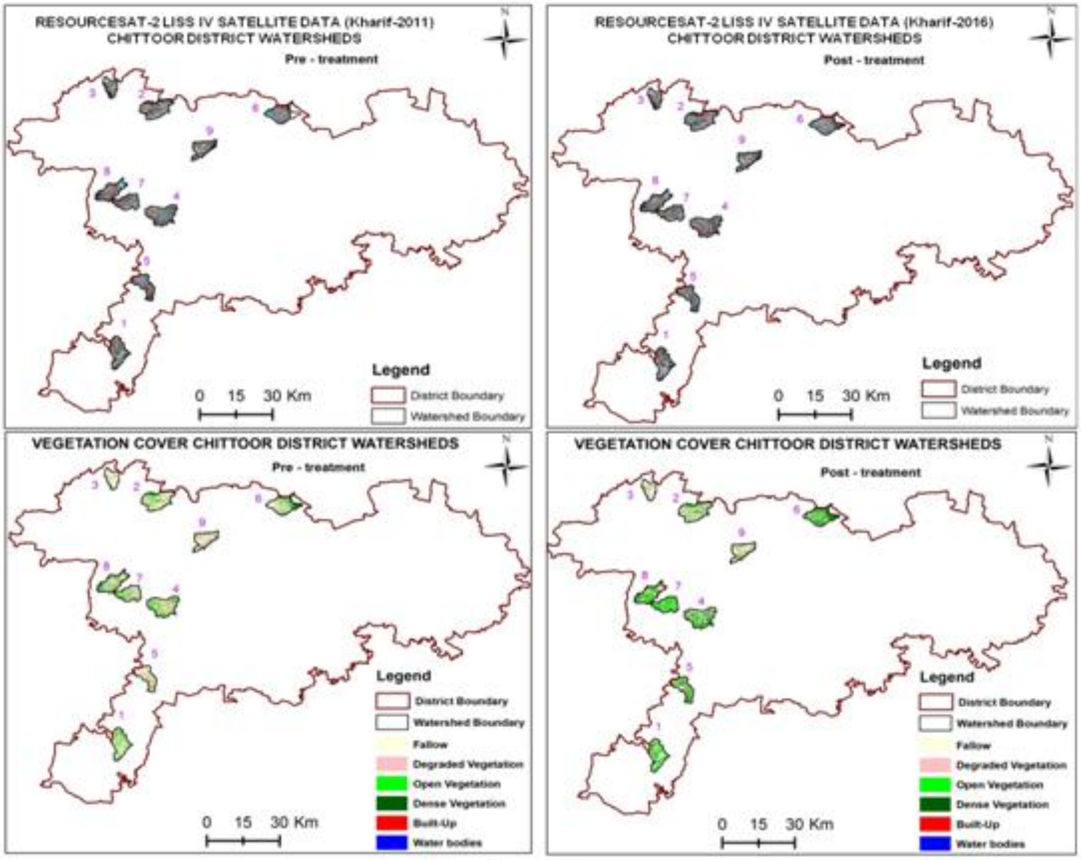
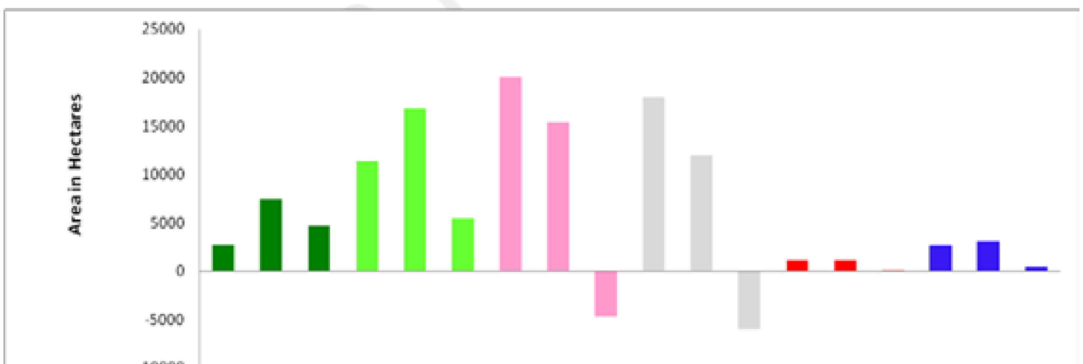



**Fig 2: Comparison of Vegetation Cover maps**




| | 2012 | 2016 | CH | 2012 | 2016 | CH | 2012 | 2016 | CH | 2012 | 2016 | CH | 2012 | 2016 | CH | 2012 | 2016 | CH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dense Vegetation | 2709 | 7428 | 4719 | | | | | | | | | | | | | | | |
| Open Vegetation | | | | 11343 | 16825 | 5482 | | | | | | | | | | | | |
| Degraded Vegetation | | | | | | | 20064 | 15375 | -4689 | | | | | | | | | |
| Fallow | | | | | | | | | | 17922 | 11981 | -5941 | | | | | | |
| Built-Up | | | | | | | | | | | | | 1100 | 1157 | 57 | | | |
| Water bodies | | | | | | | | | | | | | | | | 2635 | 3007 | 372 |

**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** | **% Increase / Decrease** |
| Dense Vegetation | 2709 | 5 | 7428 | 13 | 4719 | 174 |
| Open Vegetation | 11343 | 20 | 16825 | 30 | 5482 | 48 |
| Degraded Vegetation | 20064 | 36 | 15375 | 28 | -4689 | -23 |
| Fallow | 17922 | 32 | 11981 | 21 | -5941 | -33 |
| Built-Up | 1100 | 2 | 1157 | 2 | 57 | 5 |
| Water bodies | 2635 | 5 | 3007 | 5 | 372 | 14 |
| **Total** | **55773** | **100** | **55773** | **100** | | |

The vegetation maps indicated that the areas under dense and open vegetations 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 are from 17922 ha to 11981 ha and 20064 ha to 15375 ha respectively during the project period, which is attributed to dense and open vegetation categories in 2016 [18, 21, 25, 30].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.

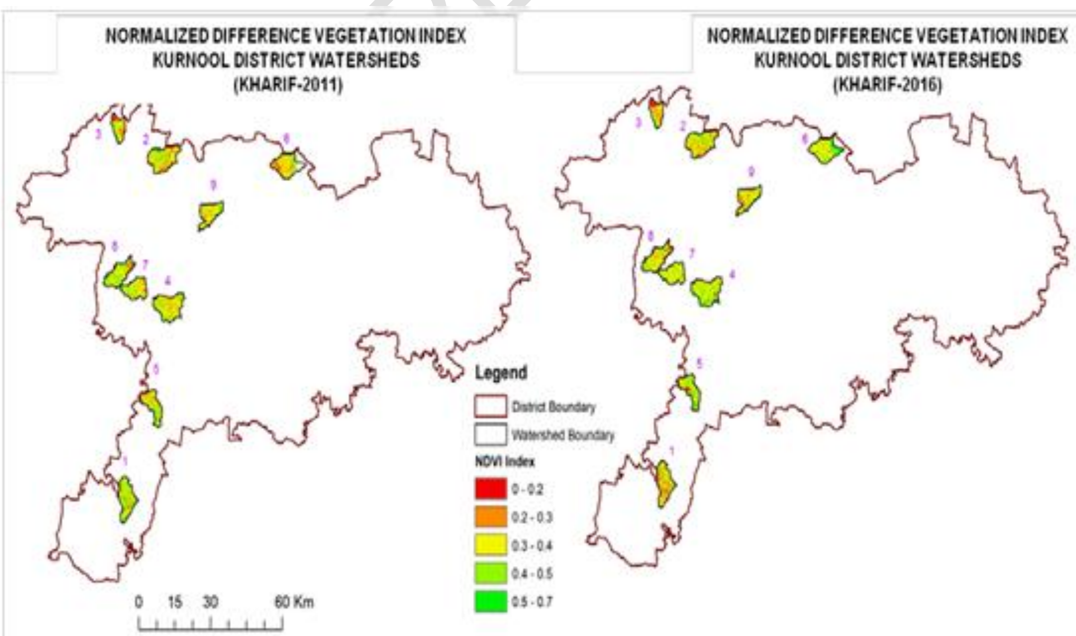



**Fig4:Normalized difference vegetative index comparison for 2011 and 2016**

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 [4, 19, 20, 30]. Spatial distributions of different land use / land cover categories during 2011 and 2016 presented in fig.5 while the land use changes shown in fig.6.

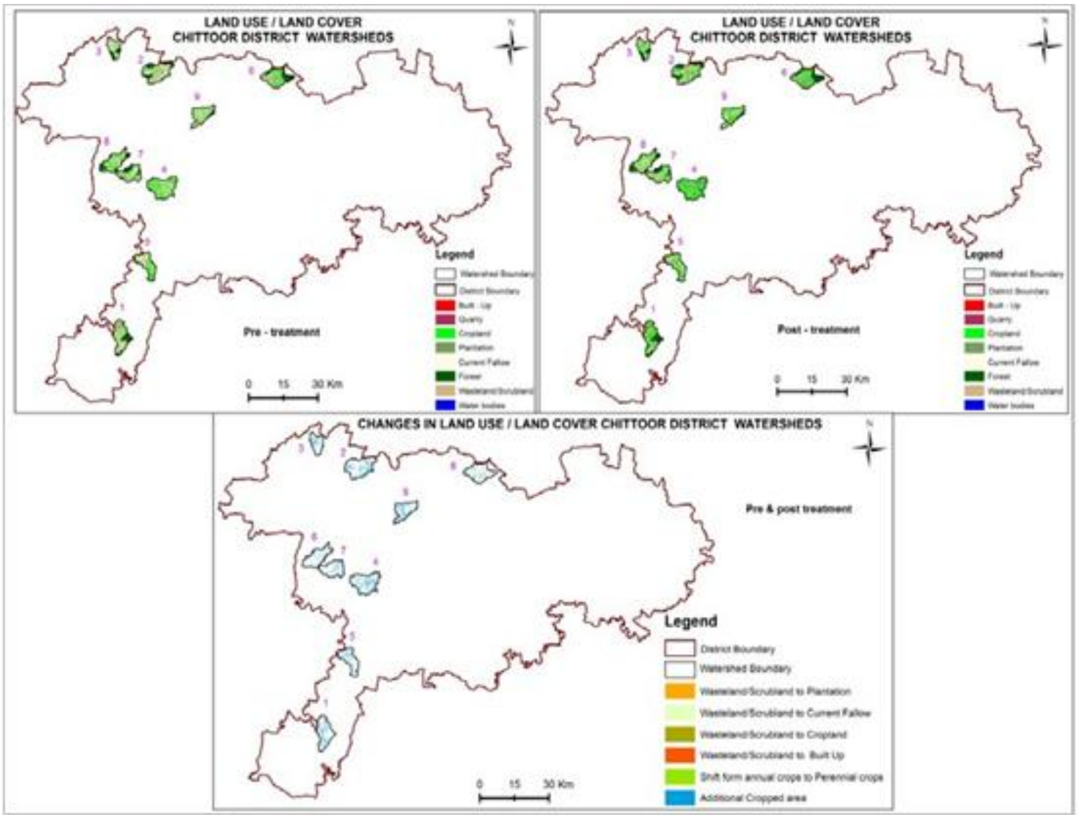



**Fig 5: Land use land cover maps comparison**

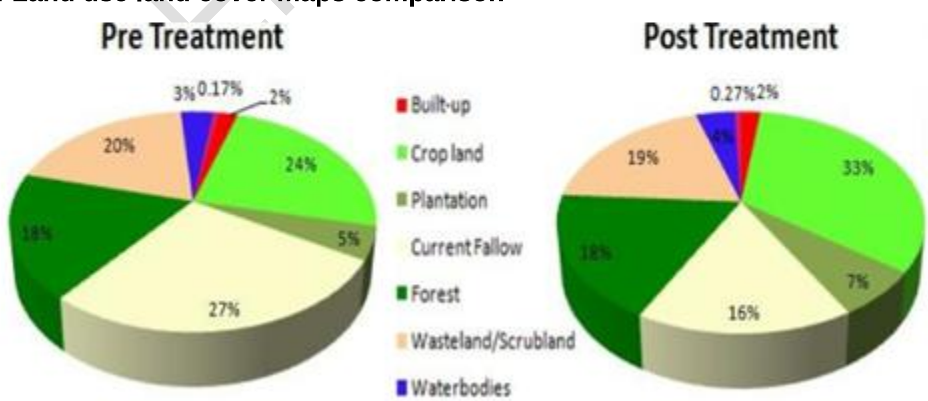



**Fig 6: Land use / Land cover distribution**

(Table-3)showed the statistics of the area under different land use / land cover categories for both periods. As before in the cropland area was observed, which is due to promoting agriculture and horticulture crops. Under land use classes, cropland occupied an area is 13299 ha during 2011 and 18385 ha in 2016, indicating an increase of 5086 ha which is about an increase 38.24% from its initial 13299 ha. The current fallows decreased significantly from 15261 ha (27.36%) to 8955 ha (16.06%) during 2011 and 2016[31,32]. This is mainly due to implementation of drought proofing works which is accounted in cropland in 2016. Notified forest boundary is extracted from SOI toposheet.

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

| S.No | Major Land Changes | **Pre-Treatment Area (In Ha.)** | **Post-Treatment Area (In Ha.)** | **Change Area (In Ha.)** |
|---|---|---|---|---|
| 1 | Crop land area | 13299 | 18385 | 5086 |
| 2 | Current Fallow | 15261 | 8955 | 6306 |
| 3 | Water Body Area | 1937 | 2286 | 349 |

Changes in water body area are a good indicator of any watershed intervention activities. Water body area is extracted by using LISS-IV satellite data for the years 2011 and 2016. A gradual temporal change in the water body area has been noticed. The water body area contributed to 1937 ha in 2011 and 2286 ha in 2016 which is about 18.02% increase from its initial 1937 ha. The increase in the water body area is due to construction of farm ponds, percolation tanks and check dams and shown in fig.7.

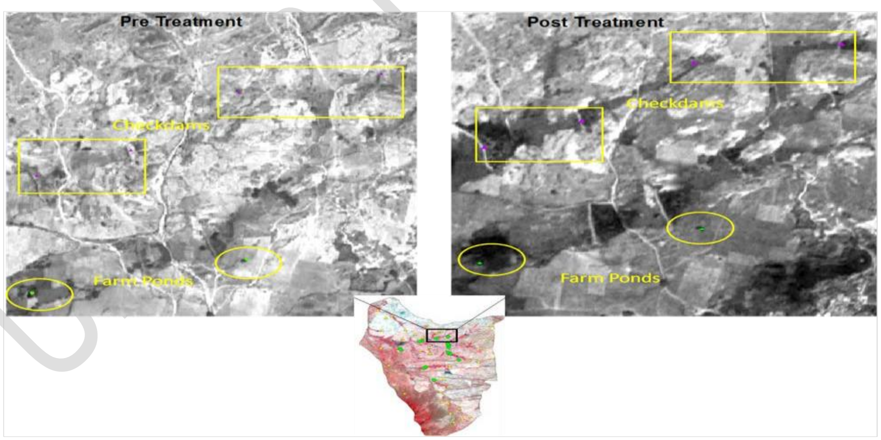



**Fig 7: Major activities in project area**

The plantation cover occupied 2708 ha (4.86%) in 2011 and it has been increased to 3706 ha (6.64%). It is found that 998 ha of croplands are converted into perennial crops during the project period which is attributed in plantations in 2016 [31,32]. This may help protect from soil erosion, improve soil structure, increase ecosystem nutrient retention, carbon sequestration, water infiltration, and it can contribute to climate change adaptation and mitigation measures.

Due to implementation of the watershed developmental activities, an area of 7093 ha has been brought under cropped area. This is attributed in cropland and plantations in the year 2016. It clearly shows that the changes occurred in the watershed area are progressive in nature[31,32]. The changes in cropland are shown in Fig 8.

Under the watershed development activities, 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 project area and resulted in bringing 231 ha into cultivable land. In this, major area is under fallow [24,26,30].

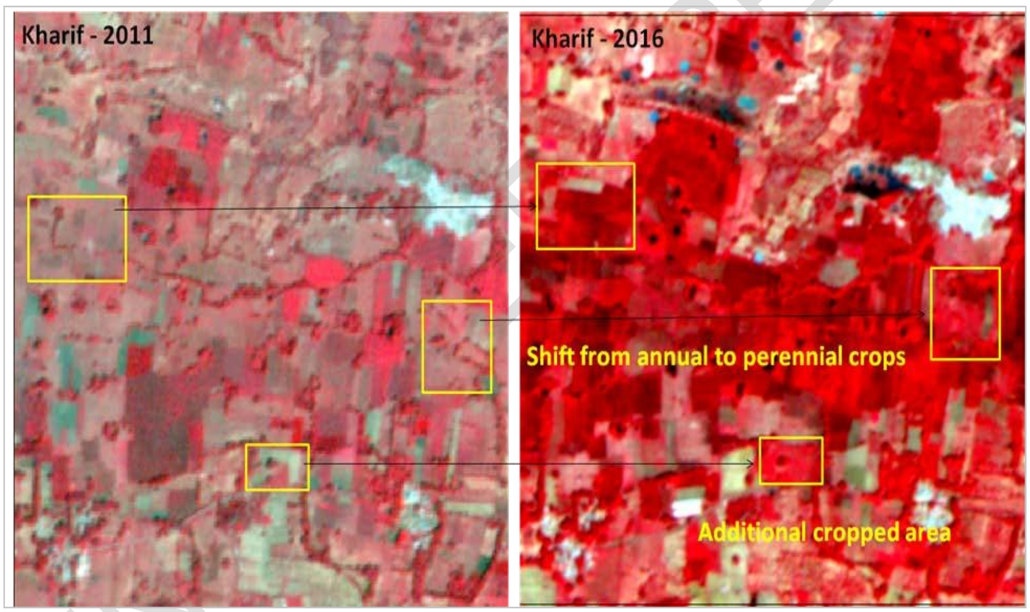



**Fig 8: Major changes in watershed project area**

The district receives maximum rainfall from July to December months of the year. In this context, the variation between rainfall and soil moisture has been analyzed during the project period. The time series analysis of soil moisture content and rainfall for the above said period showedhuge similarities over the years from 2009 to 2016 The X-axis represents meteorological weeks, the Y1-axis is Rainfall (bar graph) and Y2-axis (line plot) represents the soil moisture. The year-wise analyses are used to understand the impact assessment within the watershed.

## 4. CONCLUSION

Change detection studies have been carried out for evaluation of nine watersheds in Chittoor district and concluded that there has been an increase in plantation area from 2708 ha (4.86%) to 3706 ha (6.64%). The cropland also increased from 13299 ha (23.84%) in 2011 to 18385 ha (32.96%) in 2016. It is also found that cropland and plantations area has increased at the cost of fallow land. The output of NDVI classification indicates increase in dense vegetation from 2709 ha to 7428 ha due to the sufficient rainfall received during the project period. NDVI studies indicate that there is an improvement in open vegetation category due to the reclamation of fallow land. Under land use classes, cropland occupied an area is 13299 ha during 2011 and 18385 ha in 2016, indicating an increase of 5086 ha which is about an increase 38.24% from its initial 13299 ha. The current fallows decreased significantly from 15261 ha (27.36%) to 8955 ha (16.06%) during 2011 and 2016. This is mainly due to implementation of drought proofing works which is accounted in cropland in 2016. The water body area contributed to 1937 ha in 2011 and 2286 ha in 2016 which is about 18.02% increase from its initial 1937 ha. The increase in the water body area is due to construction of farm ponds, percolation tanks and check dams. The wasteland reclamation measures are implemented in project area and resulted in bringing 231 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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