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Evaluation of Anantapuramu District Watershed Projects Using Remote Sensing & GIS Technology

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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

Change detection studies have been carried out for evaluation of fifteen watersheds in Anantapuramu District of Andhra Pradesh. The study was carried out using high resolution Resourcesat-2, Linear Imaging and Self Scanning-IV (LISS-IV) data of 2011 (pre-treatment) and 2016 (post-treatment) to assess the changes in land use/land cover and biomass over a period of five years (2011-16). With the implementation of the watershed developmental activities, an additional area of 14440 ha has been brought under cultivation. The output of Normalized Difference Vegetation Index classification indicates

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the increase in dense vegetation from 5842 ha to 13160 ha. An additional area of 396 ha increased under water bodies and 1101 ha waste land converted to cultivable land due to construction of farm ponds, percolation tanks and check dams.

Keywords: Integrated watershed development programme; remote sensing and geographic information system; resourcesat-2; Linear Imaging and Self Scanning-IVdata.

1. INTRODUCTION

Anantapuramu district is one of the four districts of Rayalaseema region and the largest among the 13 districts of Andhra Pradesh. The district is economically backward and chronically drought affected. The district lies between 13°40' - 15°15'North Latitude and 76°50' - 78°30'East Longitude with an area of 19,130sq. km. The district occupies the Southern part of the state and is bounded on the North by Kurnool District, on the Southeast by Chittoor District, on the East by YSR District, and on the West and Southwest by Karnataka state. The district has its headquarters at Anantapuramu which is the largest city in the district. The average annual rainfall (2009 to 2016 years Rainfall data from Agriculture Research Station, Anantapuramu) of the district is 535 mm, which ranges from nil rainfall in February and March to 129 mm in September. September and October are the wettest months of the year. The mean seasonal rainfall distribution is 316 mm during southwest monsoon (June-September), 146 mm during northeast monsoon (Oct-Dec), 1 mm rainfall during winter (Jan-Feb) and 72 mm during summer (March-May). In the present study, 13 watersheds have been implemented under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) project (Batch-1) during 2009-10. The list of watershed projects is presented in Table 1. They are distributed over 6 districts viz. Srikakulam, Prakasam, Kurnool, YSR Kadapa, Chittoor and Anantapuramu districts. The spatial distributions of watersheds are shown in Fig. 1. “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” [1]. The concept of watershed management has been introduced to respond to the complex challenges of natural resource management. Their related programs are implemented to ensure the efficient use of both the natural and social capital of the district and the state. It is necessary to holistically assess and evaluate the long-term effects from the activities and impact through the reliable methods in integrated watershed management. 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 [2,3]. “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 programs on a ‘before project – after project’ temporal scale as well as during the project implementation stage” [4-10]. “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” [11,12]. 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. MATERIALS AND METHODS

Sixty-two watersheds have been implemented under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) project (Batch-1) during the period of 2009-10, distributed over 6 districts *viz*., Srikakulam, Prakasam, Kurnool, YSR Kadapa, Chittoor and Anantapuramu districts. The spatial distributions of watersheds are shown in Fig. 1. The RS based methodology is adopted through temporal satellite data for monitoring the watersheds [13]. The whole study was carried out using the Resourcesat-2 LISS-IV data collected from 2009-11. The 2015-16 satellite datasets are used after the treatment of each watershed. The comprehensive methodology is presented in Fig. 2. The images were classified into different land use/land cover categories using supervised classification by a maximum likelihood algorithm with a minimum mapping unit of 2.5 ha. The classification was done into different vegetation levels using the normalized differencevegetation 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 and the effects of soil moisture and rainfall over 5-year time span (2009 to 2016) for each watershed.

2.1 Land Use / Land Cover Changes

Both the pre- and post-processed satellite data were supervised and classified using the maximum likelihood algorithm, which resulted in the data being clustered into homogenous classes based on their shared spectral characteristics across the pixels. Each pixel in this algorithm was treated as though it was entirely autonomous from its neighbours and the algorithm assumes a Gaussian distribution [14]. Before and after treatment, the images were classified into separate land use/land cover categories.

2.2 Vegetation Vigour Changes

The NDVI is an indicator of photosynthetic activity and has a strong positive correlation with green leaf biomass and leaf area. Therefore, it is very helpful for distinguishing between the different types of vegetation and analysis of primary productivity of the seasons and growing conditions. The infrared and red reflectance in spectral bands were used for the calculation of NDVI. Vegetation vitality data was extracted by comparing NDVI images capturing both dates using a different algorithm. Vegetation vitality was measured using these NDVI values and then categorized as dense, open, or degraded. As there was no vegetation in the fallow, it was designated as such [10,15].

2.3 Soil Moisture and Rainfall Analysis

Daily soil moisture and rainfall data from 2009 to 2016 were analyzed to determine how soil moisture and rainfall affect the watershed. The AMSR-E and AMSR-2 level-3 daily soil moisture products were used for soil moisture mapping. Daily rainfall data from the Automatic Weather Station (AWS) have been compared to explain the moisture content variation. The daily rainfall and soil moisture data are obtained on a weekly basis. The South-West monsoon rains occur from June to December. Thus, the same period plots rainfall and soil moisture variation. The graph between rainfall and soil moisture content for each watershed area was examined.

2.4 Data Used

The temporal satellite data is used for monitoring the watersheds. The study was carried out using the following data sets: LISSIVsatellitedata(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

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

2.6 Major Developmental Activities of the Watersheds

The development activities taken up in the watershed are as follows: The structures are constructed like Loose Boulder Structure, Rock fill dams and check dams for soil water conservation; Farm ponds and percolation tanks were constructed; Plantations in individual farmer's land are another major activity. Other works like drainage line treatment, Nalla bank stabilization, filter strips etc., have also been implemented.

3. RESULTS AND DISCUSSION

3.1 Changes in Vegetation Cover

The 2011–2016 watershed NDVI maps were generated for vegetation vigour groups including dense, Open degraded, and Fallow. Vegetation cover distribution from 2011–2016 are shown in Fig. 3a. The 2011–2016 vegetation maps showed a small rise in open vegetation. Fallow land showed a decrease in vegetation. There is a reduction in the area under fallow land from 63702 ha to 45890 ha during 2011 and 2016 It clearly states that there is a positive change of increasing in vegetation cover [16,17].

3.2 Changes in Land Use / Land Cover during 2011 and 2016

Both pre-and post-period satellite photos were analyzed for differences in land use and land cover. The amount of land farmed grown was a noticeable amount, and the amount of land left fallow had decreased. Data for both time periods are presented in Fig. 3b for the area under various land use/land cover categories. Measures done to encourage the agricultural and horticultural production explained the dramatic expansion of cultivated land. It was observed that the area under cropland increased considerably i.e. 10239 ha.A marked increase in area under cropland is observed, which is due to promoting the agriculture and horticulture crops as well as scrub lands. Under land use, cropland occupied an area of around 16235ha during 2011 and 26473 ha in 2016, indicating an increase of 10239 ha which is about 63.07% over the initial 16235 ha. The current fallow, which was 52120 ha (51.52%) during 2011 moderately decreased to 42440 ha (41.95%) in 2016 due to the construction of drought proofing structures like LooseBoulderStructure,Rockfilldams, check dams,farmpondsandpercolationtanks. The same portion of current fallow was converted to cropland in 2016 [16,17].

3.3 Changes in Water Body Area

“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 is being noticed. The increase in the water body area from 2476 ha to 2872 ha” [16,17]. This is due to the construction of farm ponds, percolation tanks and check dams.

3.4 Shift from Annual Crops to Perennial Crops

The plantation cover occupied 1681 ha (1.66%) in 2011 and it has been increased to 2303 ha (2.28%). It is found that 622 ha of croplands are converted into perennial crops during the project period which is attributed in plantations in 2016 [16,17]. This may be helpful to protect soil erosion, improve soil structure, increase ecosystem nutrient retention, carbon sequestration, water infiltration, and it can contribute to climate change adaptation and mitigation.

Table 1. List of watersheds in the district

Project Code	Project Name	Mandal Name	Project area in Ha.
Anantapuramu-iwmp-1/2009-10	Bandlapalli	Narpala	2584
Anantapuramu-iwmp-2/2009-10	Tavalam	Tanakal	4076
Anantapuramu-iwmp-3/2009-10	Thagarakunta	Kanaganapalle	3669
Anantapuramu-iwmp-4/2009-10	Vajrakarur	Vajrakarur	4568
Anantapuramu-iwmp-5/2009-10	Nallamada	Nallamada	3927
Anantapuramu-iwmp-6/2009-10	Ratnagiri	Rolla	4104
Anantapuramu-iwmp-7/2009-10	Gorantla	Gorantla	4986
Anantapuramu-iwmp-8/2009-10	Puttaparthi	Puttaparthi	3709
Anantapuramu-iwmp-9/2009-10	Varadayapalle	Peddapappur	4974
Anantapuramu-iwmp-10/2009-10	Muttala	Atmakur	2535
Anantapuramu-iwmp-11/2009-10	M.N.Palle	Kalyandrug	4570
Anantapuramu-iwmp-12/2009-10	Thumbiganoor	Kanekal	4817
Anantapuramu-iwmp-13/2009-10	Jakkalacheruvu	Gooty	3449
Anantapuramu-iwmp-14/2009-10	Muradi	D.Hirehal	2300
Anantapuramu-iwmp-15/2009-10	Lakshampalli	Settur	4937

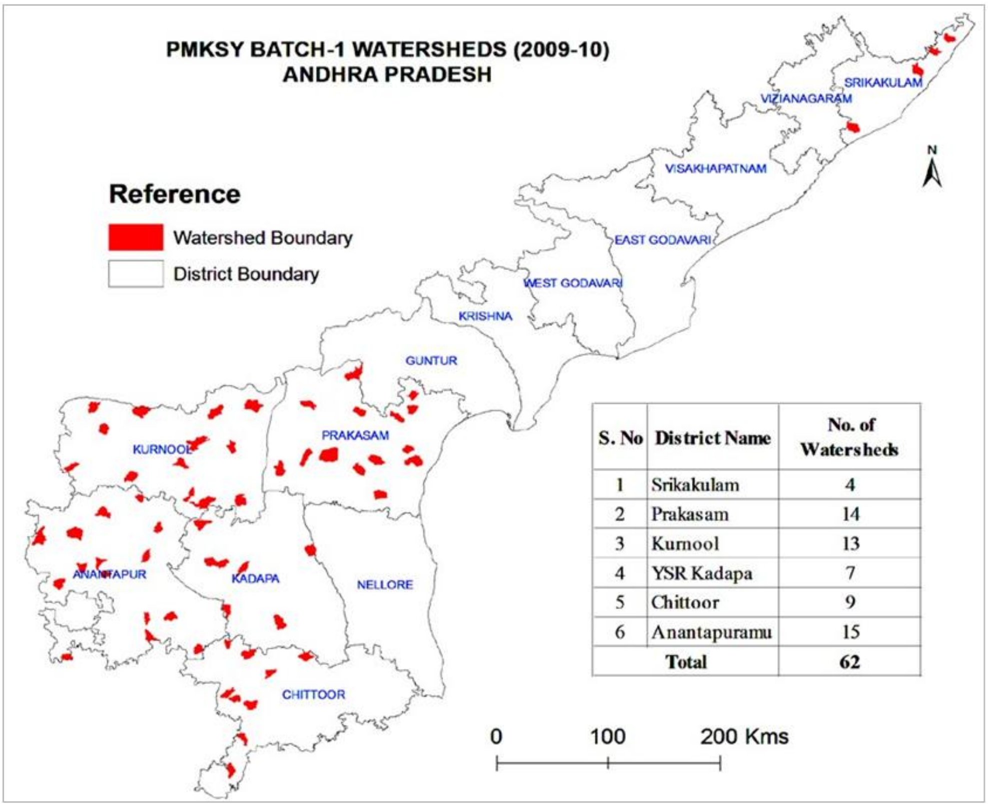

Fig. 1. Location map of watersheds

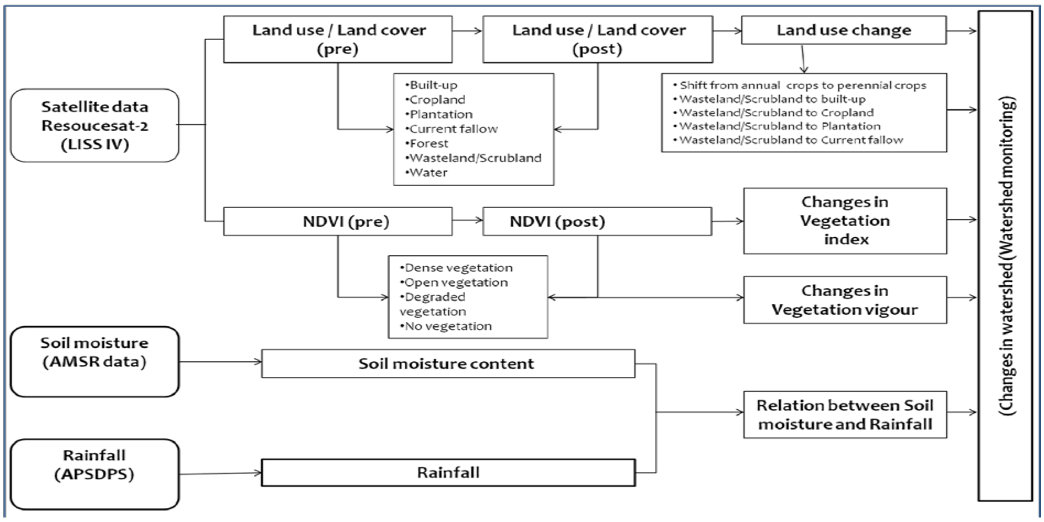

Fig. 2. Methodology workflow

3.5 Reclamation of Wastelands

Under the watershed development activities, the reclamation of wastelands is one of the major activities and it included contour ploughing, strip farming, terracing, leaching and changed agriculture practices. The wasteland reclamation measures were implemented in the project area and resulting in bringing 1101 ha into cultivable land [16,17].

3.6 Soil Moisture Availability through Wetness Indicators

The maximum rainfall occurred from April to November only. Thus, the variation between rainfall and soil moisture has been analysed during the project period. The X-axis represents meteorological weeks, Y1-axis as Rainfall (bar graph) and Y2-axis (line plot) represents soil moisture2016 are shown in Fig. 3c. The year-wise analyses are used to understand the impact assessment within the watershed. Comparing the rainfall and soil moisture during the period of 2009-2016, it is found that high rainfall and soil moisture were observed during 2009 and 2010, while low soil moisture and rainfall have been recorded during 2011 and 2014, respectively.

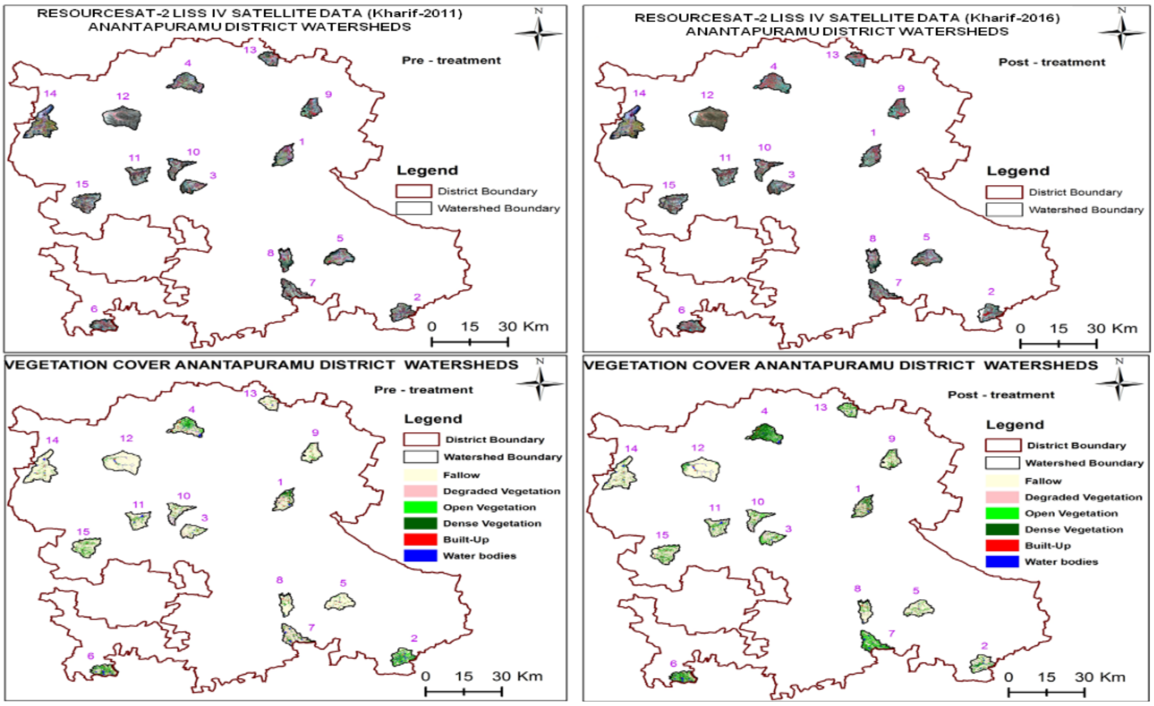

Fig. 3a. Changes in Vegetation cover

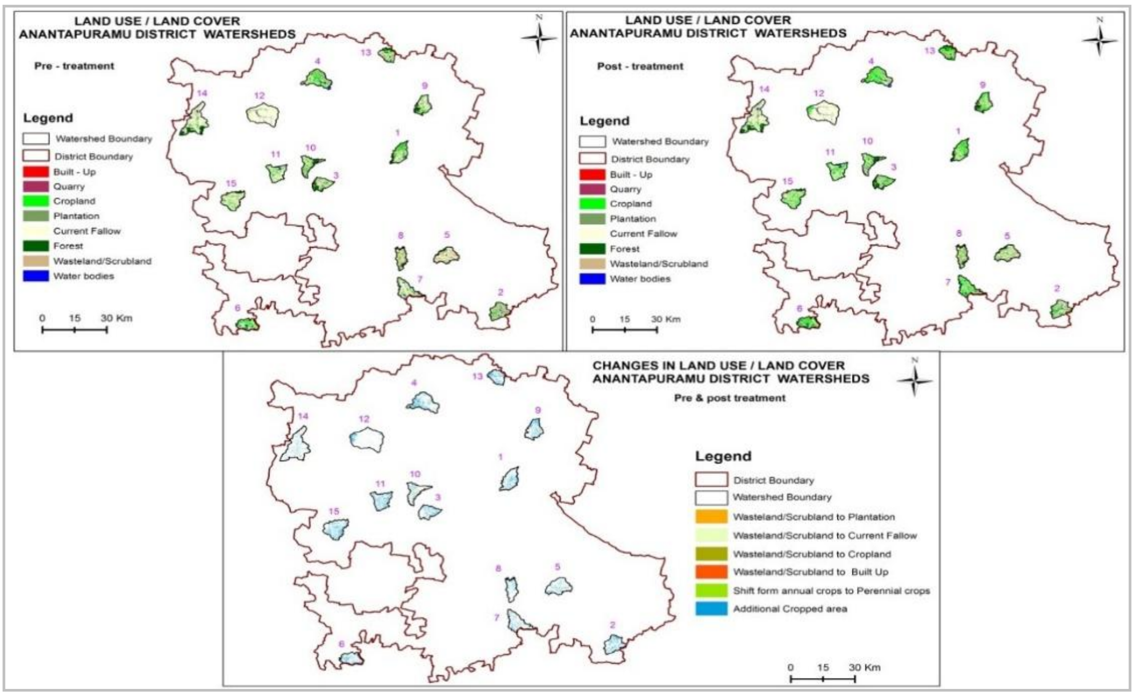

Fig. 3b. Changes in Land use/land cover

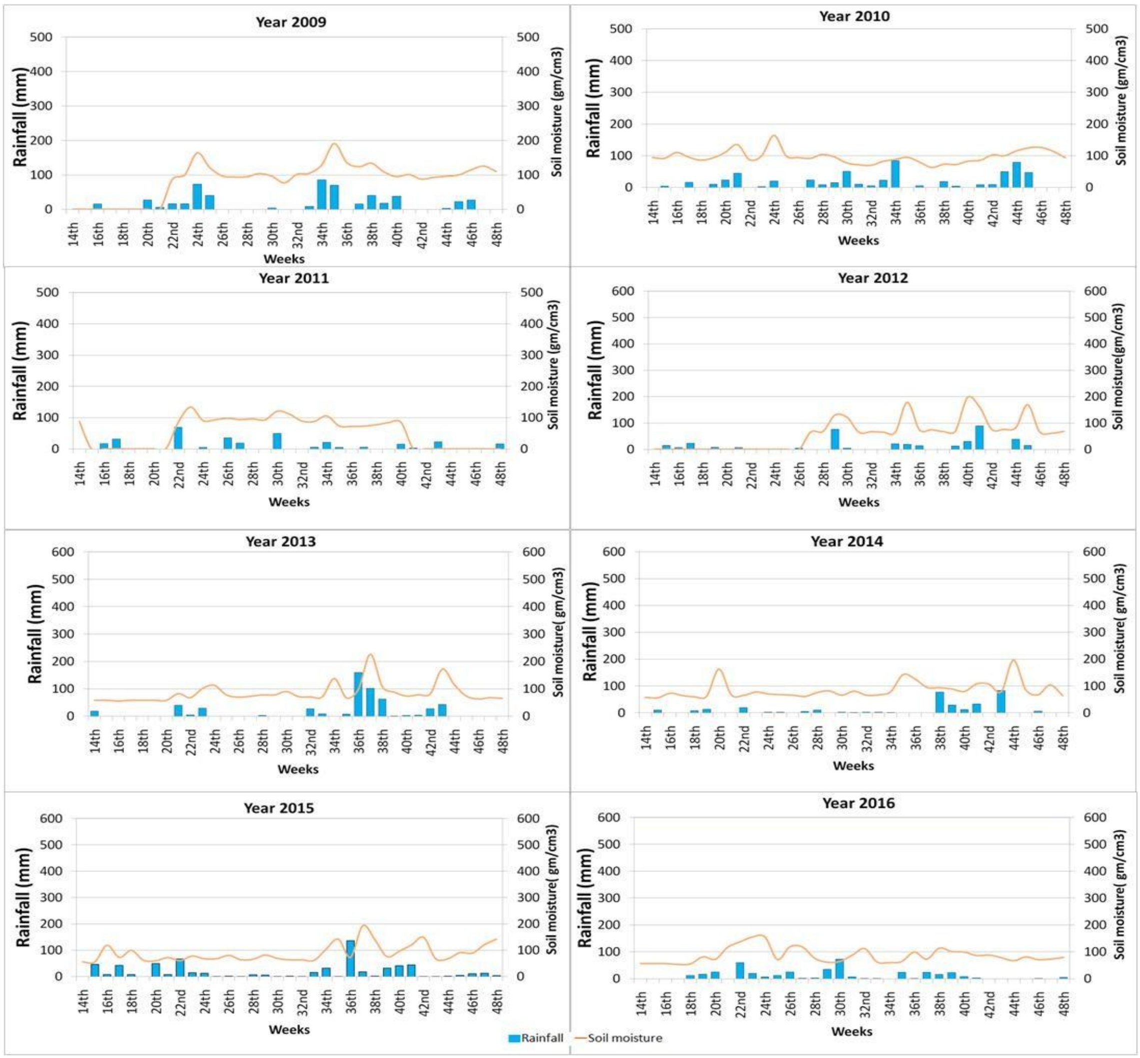

Fig. 3c. Weekly Soil moisture Vs. Rainfall in the watershed during April – November months (2009-2016)

4. CONCLUSION

Change detection studies have been carried out for evaluation of fifteen watersheds in Anantapuramu district and it is observed that there is slight increase in plantation area (622 ha). The cropland significantly increased from 16235ha (16.05%) to 26473 ha (26.17%) from 2011 to 2016 respectively. It can be noted that cropland area has increased at the cost of current fallow land. The output of NDVI classification indicates increase in dense vegetation from 5842 ha to 13160 ha due to the watershed developmental activities and drought proofing works. NDVI studies indicated that there is a huge improvement in dense, open and degraded vegetation categories due to the occurrence of moderate rainfall during 2011 and 2016.

DATA AVAILABILITY

All the data of this manuscript are included in the MS. No separate external data source is required. If anything is required from the MS, certainly, this will be extended by communicating with the corresponding author.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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