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Scientific Evaluation of Integrated Watershed Development Programme Projects in Kurnool District of Andhra Pradesh, India

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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

The current study was taken up to investigate the utility of the Remote Sensing (RS) and Geographic Information System (GIS) tools for evaluation of 13 Integrated Watershed Development Programme watershed projects implemented during 2009-2016 in Kurnool District of Andhra Pradesh. The study was carried out using high resolution Resourcesat-2, Linear Imaging self-Scanning System (LISS)-IV data of 2011 (pre-treatment) and 2016 (post-treatment) to assess the

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changes in land use/land cover and biomass over a period of five years (2011-16). Due to implementation of the watershed developmental activities, an additional area of 15100 ha has been brought under cultivation. The vegetation maps indicated that 20531 ha of fallow land converted to dense (9533 ha) and open vegetation (10249) categories during the project period due to the adoption of soil and water conservation practices. An additional area of 280 ha (5.72%) increased under water bodies and 1352 ha 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 in the year 2016.

Keywords: Integrated watershed development programme; remote sensing and geographic information system; resourcesat-2; LISS-IV data.

1. INTRODUCTION

Kurnool is the third largest district of Andhra Pradesh. This district is bounded on the north by Tungabhadra and Krishna rivers. It is located in the west-central part of the state and is bounded by the Mahabubnagar district of Telangana in the north, the Bellary district of Karnataka in the west, the Anantapuramu district in the south and the Prakasam district in the east. The Kurnool district lies between latitudes 14° 54' N and 16°11' and longitudes 76°58' and 78°25' E. The altitude of the district varies from 200m to 700m above mean sea level. The area of the district is 17,658 sq. km. The average annual rainfall of the district is 665.5 mm. 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. 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 [1,2]. 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 [3,4]. 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 [5-7].

In this context, to reduce the cost and time, satellite remote sensing has been used as an evaluation tool in many of the studies [8-11]. "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" [12-20]. "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" [21,22,23,15,16, 17,18,19,20]. 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 [24,25]. 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 [26-29]. 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. 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 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 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 the 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 neighbors and the algorithm assumes a Gaussian distribution. Before and after treatment, the images were classified into the 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 analysing the 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 [23,30].

2.3 Soil Moisture and Rainfall Analysis

Daily soil moisture and rainfall data from 2009 to 2016 were analysed 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: 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

To analyse 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 are 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 were shown in Fig. 3a. The 2011–2016 vegetation maps showed a small rise in open vegetation. Fallow land showed a decrease in vegetation. Open vegetation has the largest positive rating, representing a 50% increase from 20531 ha. Fallow land has the largest negative score, indicating high conversion to dense (9533 ha) and open vegetation (10249) categories.

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

Both pre-and post-period satellite photos were analysed 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. The total area of cropland increased from 36715 hectares in 2011 to 51692 ha in 2016, a growth rate of 40.79%. Current fallows totaled 41957 ha in 2011, however, when drought-proofing measures were put in place, that number dropped to 27362 ha in 2016.

3.3 Changes in Water Body Area

Changes in water body areas are good indicators of any watershed intervention activities. The extent of the 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 from 4891 ha in 2011, an increase to 5171 ha in 2016. The overall water bodies have contributed 5.72% from the initial 4891 ha in the pre-year. The change in the water body area was due to the implementation of water conservation work.

3.4 Shift from Annual crops to Perennial Crops

The plantation cover occupied 990 ha (0.84%) in 2011 and it has increased slightly to 1414 ha (1.19%). It was found that 424 ha of croplands are converted into perennial crops during the project period which is attributed to plantations in 2016. This may help with soil erosion, improve soil structure, increase ecosystem nutrient retention, carbon sequestration, and water infiltration, and it can contribute to climate change adaptation and mitigation. Due to the implementation of the watershed developmental activities, an area of 15,100 ha has been brought under cropped area. This is attributed to cropland and plantations in the year 2016. It clearly showed that the changes which have occurred in the project area are positive in nature.

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 1352 ha into cultivable land.

Table 1. List of watersheds in the district

Project Code	Project Name	Mandal Name	Project area in Ha.
Kurnool-Iwmp-1/2009-10	Kota kandukur	Allagadda	5673
Kurnool-Iwmp-2/2009-10	Indireswaram	Atmakur	5364
Kurnool-Iwmp-3/2009-10	Gutupalli	Bethamcherla	5351
Kurnool-Iwmp-4/2009-10	Bilehal	Halaharvi	5165
Kurnool-Iwmp-5/2009-10	Tangadancha	Jupadu Bungalow	5155
Kurnool-Iwmp-6/2009-10	Belagallu	Kosigi	5004
Kurnool-Iwmp-7/2009-10	Somayajulapalli	Orvakal	5510
Kurnool-Iwmp-8/2009-10	Sangapatnam	Owk	2988
Kurnool-Iwmp-9/2009-10	Giddaluru	Sanjamala	5090
Kurnool-Iwmp-10/2009-10	Chennampalli	Tuggali	5113
Kurnool-Iwmp-11/2009-10	Gundrevula	C.Belagal	5469
Kurnool-Iwmp-12/2009-10	Bheemavaram	Nandyal	2080
Kurnool-Iwmp-13/2009-10	Kotekal	Yemmiganur	5048

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 moisture. 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.

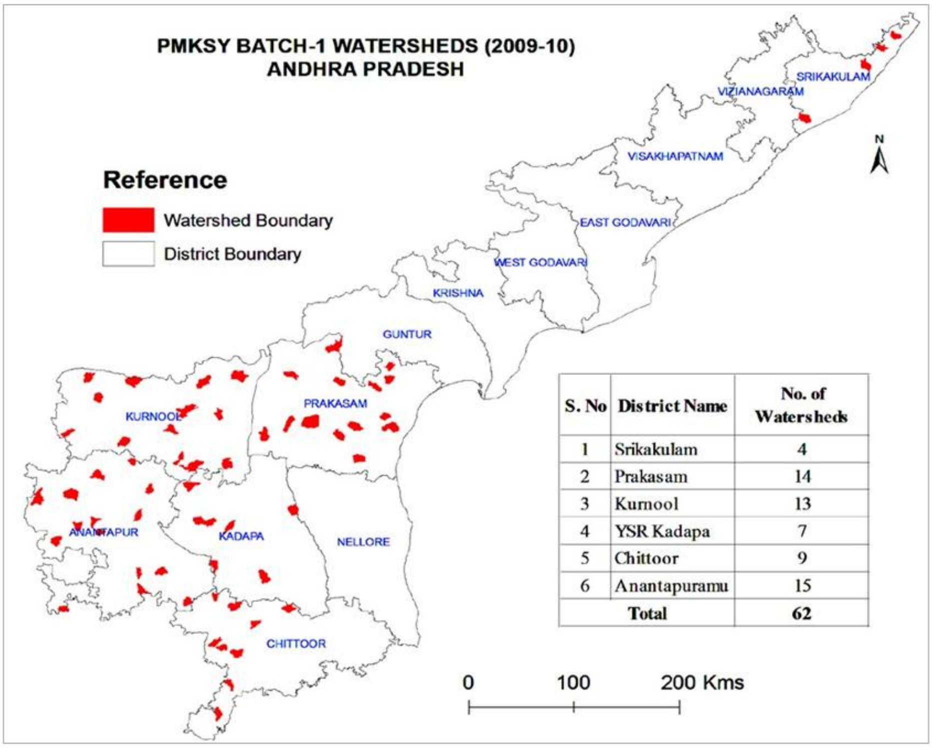

Fig. 1. Location map of watersheds

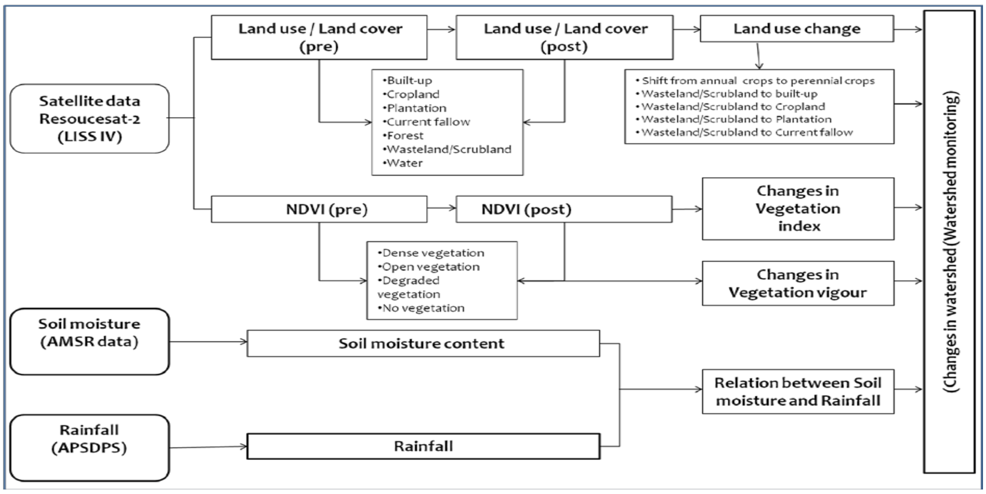

Fig. 2. Methodology workflow

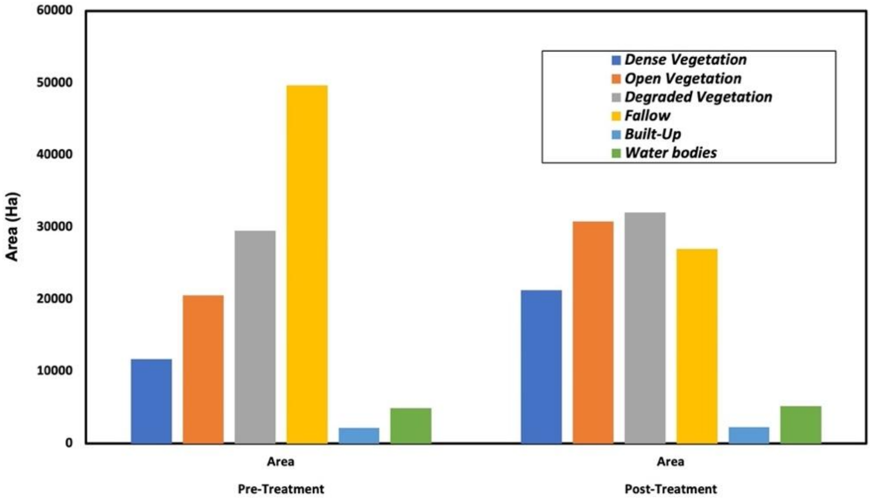

Fig. 3a. Changes in Vegetation cover

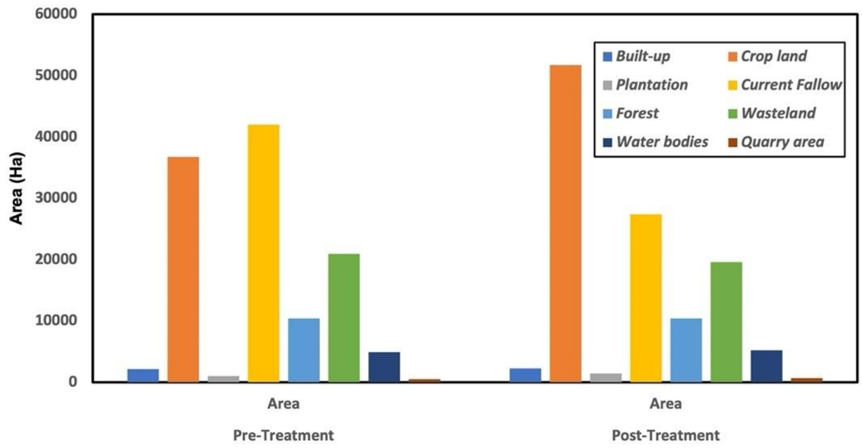

Fig. 3b. Changes in Land use/land cover

4. CONCLUSION

Change detection studies have been carried out for the evaluation of the thirteen watersheds in the Kurnool district, and it has been observed that there are slight changes in the plantation area. However, a tremendous change in the cropland observed was about 36715 ha in 2011 to 51692 ha in 2016. It is also noted that cropland has increased at the cost of fallow land. The output of NDVI classification indicates an increase in dense and open vegetation categories from 10% to 18% and from 17% to 26% respectively between 2011 and 2016. This is due to the watershed activities and drought-proofing works. The NDVI studies also indicate that there is an improvement due to the decrease in the fallow category.

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 through the corresponding official mail; XXX@gmail.com

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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