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Impact Assessment of Halvi Watershed in Kurnool District in Andhra Pradesh, India, using Geospatial Technologies

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ABSTRACT

Watershed monitoring and management is a comprehensive integrated approach to watershed and natural resources management. It implies that the judicious use of all the resources i.e. land, water, vegetation in an area for providing an answer to alleviate drought, prevent soil erosion, improve water availability and increase food, fodder, fuel on a sustained basis. In this study, Halvi Watershed in Kurnool District in Andhra Pradesh has been taken for Land Use/ Land Cover and Vegetation Change detection and analyses were carried out for evaluation of the Halvi Watershed, using high Resolution Satellite Images of Resources at-2 LISS-IV (2010-11 and 2017-18) by the Remote Sensing and GIS Techniques. The images were classified into different land use/land cover categories using supervised classification by maximum likelihood algorithm with a minimum mapping unit of 2.5 ha. They were also 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 that were compared to derive information on changes which occurred over a period of time for each watershed. Cropland area has been increased from 1898 ha to 3,907 ha, i.e. 2,009 ha during *kharif* from 2010-11 to 2017-18 period. During the *rabi* season, cropland area has increased from 1,850 ha to 1,967 ha, i.e. 117 ha from 2010-11 to 2017-18. The plantations have also increased from 33 ha to 60 ha, i.e. 27 ha during *kharif* and in *rabi*, it increased from 36 ha to 45 ha, i.e. 9 ha from 2010 to 2017. It should be noted that the cropland area has increased at the cost of current fallow and wasteland. The output of NDVI classification indicates that there is an increase in dense vegetation from 9% to 32% due to the watershed activities. NDVI study also indicates that there is an improvement in open and degraded vegetation category due to the decreased fallow category. The overall vegetation vigour has increased from 2,161 ha (33%) to 5,554 ha (85%), i.e. 3,393 ha from 2010-11 to 2017-18. The overall vegetation cover has been increased significantly from 2,161 ha (33%) to 5,554 ha (84%) during pre-implementation to post-implementation of the watershed period, which is due to proper implementation of watershed activities. Large cropland area has increased in this watershed i.e. 2,009 ha in *kharif* and 118 ha in *rabi* season. It is observed that the water body area increased considerably from 344 ha to 347 ha. However, the plantation covered area significantly increased by about 27 ha in nine watersheds during the project period.

Keywords Watershed, Monitoring, Land Use / Land Cover, NDVI, Change detection.

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INTRODUCTION

The idea of conservation of natural resources through land and water management on a watershed basis is not new. However, focused efforts on watershed management were started after 1983 when Government of India (GoI) launched model watershed projects with the involvement of the Indian Council for Agriculture Research. Under this program, 47 model watersheds were identified in different agro-climatic zones all over the country. The Planning Commission while emphasizing the role of local level planning in VIII Five Year Plan highlighted the role of drought-prone and dry land areas in augmenting the food production of the country by adopting the watershed approach. Later, to cover major dryland areas, National Watershed Development Program for Rainfed Area (NWDPRA) was launched as a centrally sponsored program by GoI in 1990-91 (RNRM 2007).

Integrated watershed management program (IWMP)

The Integrated Watershed Management Program (IWMP) aims at the prevention of soil erosion, regeneration of vegetative cover, an introduction of rainwater harvesting and recharging of groundwater (www.maps of India.com, Report - Watershed Development 2001). The IWMP seeks to bring together all government agencies under one common program to address all these problems and improve the quality of life and health of these people through enhanced livelihood opportunities. The main objectives of the IWMP are to restore the ecological balance by harnessing, conserving and developing degraded natural resources such as soil, vegetative cover and water (www.iwmp.ap.gov.in). The outcomes are the prevention of soil run-off, regeneration of natural vegetation, rainwater harvesting and recharging the groundwater. This enables multi-cropping and the introduction of diverse agro-based activities, which help provide sustainable livelihoods to the people residing in the watershed area.

The objectives of the program are to (Wani et al. 2011) conserve the natural resources, along with the co-existent capitals for optimizing their utility to benefit the livelihoods of the community. Improve income levels of different communities involved in the farm, non-farm and off - farm and service sectors in the project area, thus sustain the production systems through a holistic approach of development in the areas. Increase per capita productivity and thus improve the well-being of the local people. Help communities adopt self-sustainable practices in conserving and managing the resources with their continued efforts.

Key benefits of IWMP envisaged– Drought mitigation. Climate change mitigation. Developing degraded lands. Overall socio-economic development of the poor. Employment generation and poverty alleviation. Livestock development. Increased productivity. Increased afforestation. Reduced soil erosion.

Indicators considered for evaluations of watershed

In order to analyze the changes that took place during the project period, the following indicators are adopted: Vegetation cover. Water body area. The shift from annual crops to perennial crops. Additional area brought under the cropped area. Soil moisture availability through wetness indicators. Reclamation of wastelands.

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, Nala Bank stabilization, filter strips, have also been implemented.

Impact assessment the watershed

As the watershed development approach is an integrated one with the involvement and efforts of various departments and considerable budget, there is a need for a suitable indicator to assess the progress of project implementation (Singh et al. 2010). It is necessary to holistically assess and evaluate the long term effects and the impact of the activities through reliable methods. Conventional ground-based sampling has proved costly and time-consuming. The repetitive coverage of the satellite provides an excellent opportunity to

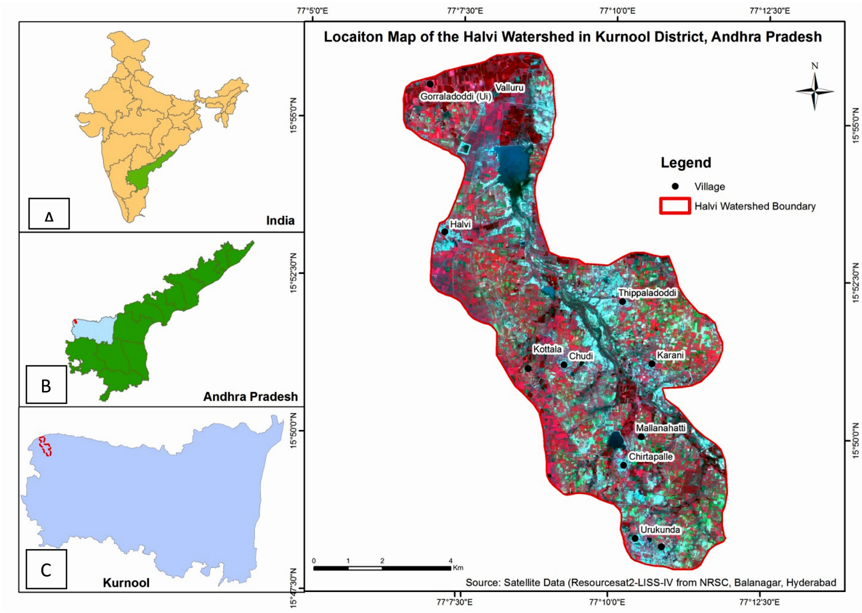

Fig. 1. Location map of the Halvi Watershed: (A) India, (B) Andhra Pradesh, (C) Kurnool, (D) Halvi Watershed with False Color Composite of Resourcesat - 2 LISS - IV Image (27th Oct 2017) (NRSC 2017).

monitor the land resources and evaluate the land cover changes through a comparison of images acquired for the same area at different time periods. Changes like the increased area under cultivation, conversion of annual cropland to horticulture, change in surface water bodies, afforestation, soil reclamation, could be monitored through satellite remote sensing. Over the years, it's a utility to detect and determine the extent and nature of changes over a period of time which has successfully been demonstrated. In this context, to reduce the cost and time satellite remote sensing has been used as an evaluation tool.

Study area

Halvi Watershed is located in North Western part of the Kowthalam mandal in Kurnool District. The treated area is 6,570 ha in the watershed. It lies between 15º 47´ 45.401´´ to 15º 56´ 9.15´´ North latitudes and 77º 06´ 37.84´´ to 77º 11´ 48.79´´ East longitudes.

Remote Sensing (RS) and Geographical Information System (GIS) have been proved as effective tools to monitor and manage the natural resources and assess the impact on watersheds during the pre and post-development (Rao 2000). Change detection in watersheds help in enhancing the capacity of local governments to implement sound environmental management. This involved the development of spatial and temporal database and analyses techniques. The efficiency of the techniques depends on several factors such as classification schemes, the spatical and spectral resolution of remote sensing data, ground reference data and also an effective implementation of the result.

The study noticed changes in groundwater level, surface water, irrigation facility, water regeneration capacity, land use pattern, cropping pattern, livestock production, employment generation, income generation and debt reduction. These changes are observed in all watershed development programs with certain variations. But, the changes like land use pattern, cropping pattern, crop diversification, are more prominent in the watershed regions (Singh et al. 2010).

For the present study, Halvi Watershed has been implemented under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) project (Batch-2) during 2010 - 11 located in Kurnool District in Andhra Pradesh. The spatial distribution of the watershed is shown in Fig. 1.

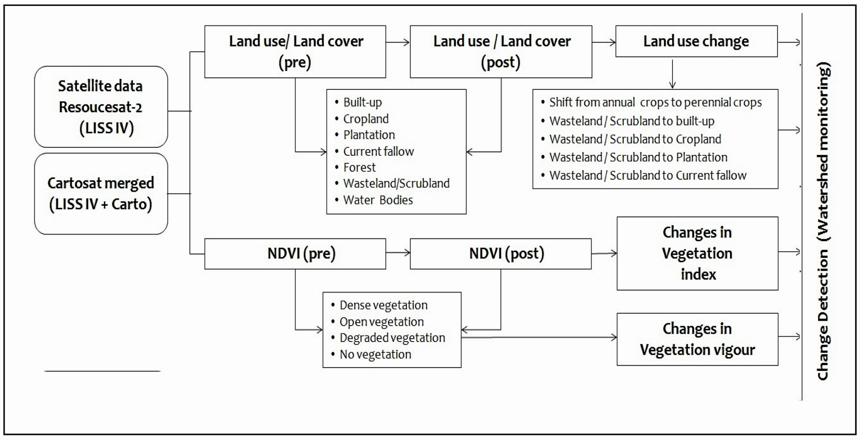

Fig. 2. The comprehensive methodology.

MATERIALS AND METHODS

The remote sensing based methodology is adopted through temporal satellite data for monitoring the watershed. The study is carried out using Resourcesat-2 LISS-IV Satellite data for pre (2011) and post (2017) (NRSC 2011 and 2017) implementation of the watershed. The comprehensive methodology is presented in Fig. 2. The images were classified into different land use/land cover categories using supervised classification by maximum likelihood algorithm with a minimum mapping unit of 2.5 ha. They were also classified into different vegetation levels using 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 which occurred over a period of time for each watershed.

Land use / Land cover changes

Supervised classification was performed using maximum likelihood algorithm for both pre and post-treatment of *kharif* and *rabi* seasons and the satellite data have been clustered with the pixel similar spectral characteristics into homogenous classes (Anderson and Hardy et al. 1976). This algorithm assumes Gaussian distribution and each pixel is considered a separate entity independent of neighbours. The classified images have different land use / land cover categories pertaining to pre and post- treatment periods. The classified outputs have been compared in order to evaluate the changes which have been taken place over a period of time.

Vegetation vigour changes

The NDVI is highly correlated with vegetative parameters such as green leaf biomass, leaf area and is an indicator of photosynthetic activity. Hence, it is of considerable value for vegetation discrimination and seasonal growing conditions for making primary productivity analysis. NDVI is computed using the infrared and red reflectance bands (Jensen et al. 2002). These values for NDVI range from -1 to 1. Vegetative areas show generally high values of NDVI because of their relatively high NIR reflectance and low visible reflectance. Water, snow and clouds have negative IR radiation. Rocks and bare soil have NDVI values around zero. Only green vegetation has positive NDVI values whereas high values are associated with higher vegetation vigour. The differencing of NDVI images generated for both the dates has been carried out to derive information on changes with reference to vegetation vigour. Based on these NDVI values, vegetation vigour was classified into dense, open and degraded vegetation. The fallow was classified as no vegetation.

Cropping intensity

Cropping intensity is the ratio of the area under crops for each season during the year to the cultivable area

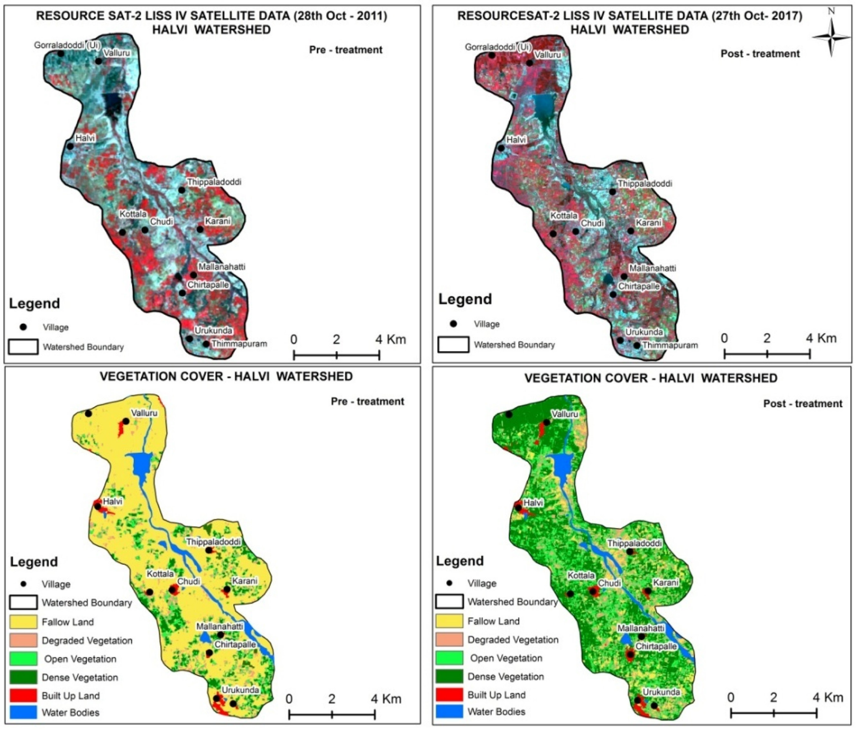

Fig. 3. Comparison of vegetation cover for pre and post - treatment in *kharif* season.

operated by the farmer. It is presented as a percentage. Cropping intensity is calculated as annual cropped area (sun of area under all crops in a year)/net land area (State of Indian Agriculture 2015-16).

Greening of hillocks

Sustainable natural resource management is the key for regenerating of hillocks in arid and semi-arid areas. Hillocks play a vital role in ecosystem management and land use. These hillocks are the ridge points for watershed management and also the key areas for green cover. Agro-climatic conditions, socio-economic and climatic factors severely affect the successes of hillock afforestation and plantation activities. Suitability for Greening of the Hillock's area is identified based on Multi-Criteria Decision Analysis (MCDA) that includes natural resource datasets like Lithology, Geomorphology, Soil, Land use / Land cover, Wastelands, Land degradation, Slopes, Rainfall and Temperature, with the support of secondary and primary data.

Data used

The temporal satellite data are used for monitoring the watersheds. The study is carried out using the following data sets : LISS - IV Satellite data (pre and post - treatment) (NRSC 2011 and 2017). SOI topo sheets for reference (SOI 2017). PMKSY monitoring reports from the department (www. iwmp.ap.gov.in).

RESULTS AND DISCUSSION

For the assessment of spatial and temporal changes in the watershed, Resourcesat - 2 LISS-IV Satellite data have been used for pre and post-treatment of the *kharif* and *rabi* season of 2012 to 2018 period. The satellite images of both periods were classified into different land use / land cover categories and

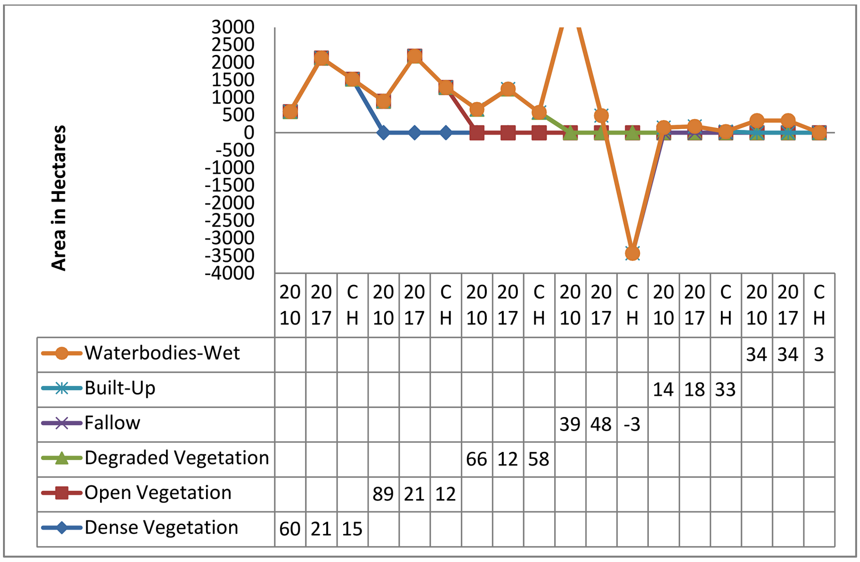

Fig. 4. Distribution of vegetation cover and changes.

vegetation vigour classes for analyzing the impact of the watershed development program.

Changes in vegetation cover

For analyzing the changes in vegetation cover, Normalized Difference Vegetation Index (NDVI) has been computed by using NIR and Red bands of the satellite data for the watershed area during 2010 and 2017 which is represented in Fig. 3. These NDVI have been classified into different vegetation vigour classes like Dense, Open Degraded and Fallow. The spatial and statistical distribution of vegetation cover maps are represented in Fig. 4 and statistics are presented in Table 1.

Table 1. Changes in vegetation cover from September 2010 to October 2017 (*kharif*).

Vegetation vigour type	Vegetation index (Area in hectares)					
	Pre-treatment		Post-treatment		Change ±	
	Area	%	Area	%	Area	%
Dense vegetation	601	9	2124	32	1523	253
Open vegetation	895	14	2183	33	1288	144
Degraded vegetation	665	10	1247	19	582	88
No vegetation	3918	60	489	7	– 3429	– 88
Built-up	147	2	180	3	33	22
Water bodies	344	5	347	5	3	1
Total	6570	100	6570	100		

Normalized Difference Vegetation Index (NDVI)–*kharif* 2010 to 2017–Halvi Watershed in Kurnool

The vegetation maps and table are indicating that the areas under dense (1,523 ha), open vegetation (1,288 ha) and degraded vegetation (582 ha) have been increased followed by as a reduction in the area under fallow (3,429 ha) is observed during the period from 2010 to 2017. This increase may be due to the adoption of soil and water conservation practices. The vegetation index during the project period of the watershed area is shown in the following table, which clearly states that there is a progressive impact of the watershed program in the form of an increase in vegetation cover (Fig. 5).

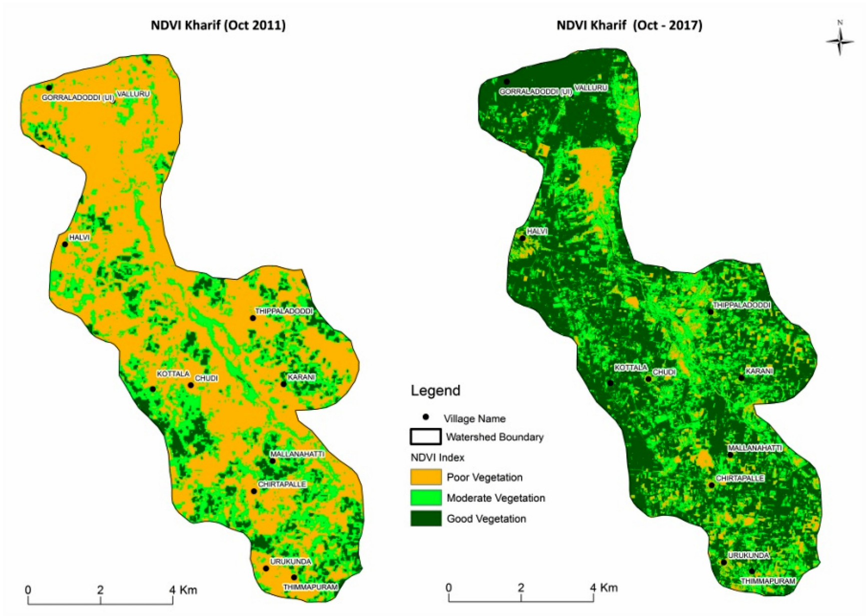

Fig. 5. Comparison of Normalized Difference Vegetation Index (NDVI).

Land use / Land cover distribution and its changes–Halvi Watershed in Kurnool District for *kharif* October 2011 to October 2017

The satellite images of both periods (pre and post) were acquired and classified into different land use / land cover categories. Spatial distributions of different land use / land cover categories during *kharif* season of 2010 to 2017 are presented in Fig. 6 and the area distribution shown in Table 2 and Fig. 7. It is observed that the area under cropland has increased significantly, it has increased by about 2,009 ha and plantation has increased to an extent of about 27 ha and reductions in the area under current fallow and wastelands are noticed, which are due to the adoption of water conservation measures and implementation of watershed activities.

The Table 3 and Fig. 8 show the statistics of the

Table 2. Land use / Land cover distribution and its changes in water body area.

Land use distribution and change in *kharif* season of 2010-11 to 2017-18 (Area in hectares)						
					Change ±	
	Pre-treatment		Post-treatment			% Increase/
Land use / cover class	Area	%	Area	%	Area	Decrease
Built-up land	147	2	180	3	33	22.78
Cropland	1898	29	3907	59	2009	105.86
Plantation	33	1	60	1	27	81.73
Current fallow land	3454	53	1506	23	– 1948	– 56.39
Forest	123	2	123	2	0	0.00
Quarry / Mining / Industrial	39	1	36	1	– 3	– 8.57
Wastelands	532	8	410	6	– 122	– 22.92
Water bodies	344	5	347	5	3	0.92
Total	6570	100	6570		0	

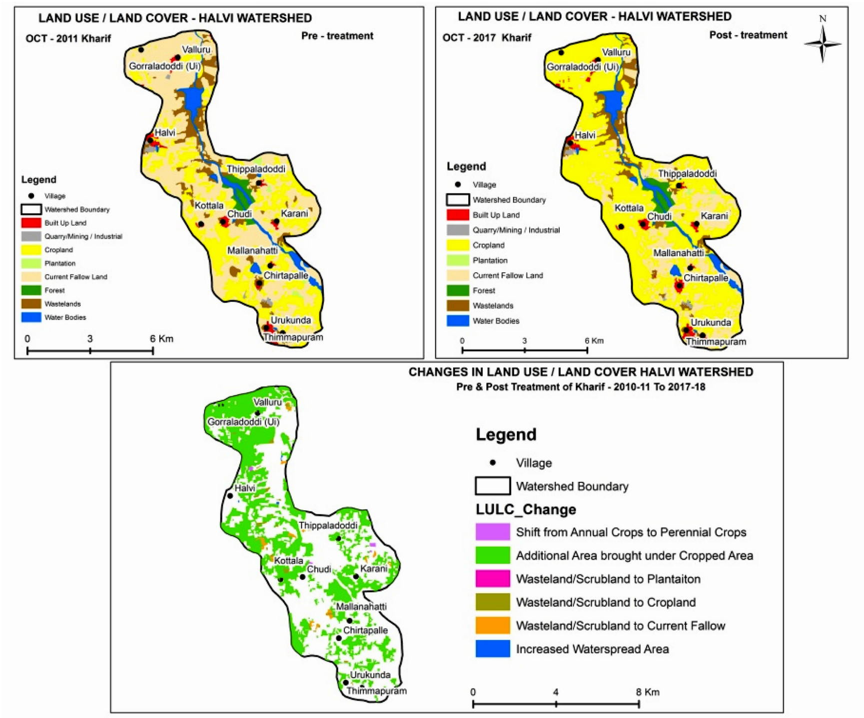

Fig. 6. Comparison of Land use / Land cover maps (*kharif*).

area under different land use / land cover categories for both periods. Cropland area has been increased from 1,898 ha to 3,907 ha, which is due to the implementation of watershed development works. There is an increase up to 2,009 ha cropland area, which has happened at the cost of current fallow and wastelands. The current fallows were decreased from 3,454 ha (53%) to 1,506 ha (23%) during pre and post years. Wastelands were decreased from 532 ha to 410 ha. This decrease in fallow and wastelands is due to an increase in cropland and plantations. It is observed that there is a considerable increase in the plantation area which is about 27 ha.

Land use / Land cover distribution and its changes – Halvi Watershed in Kurnool District for *rabi* –– February 2012 to March 2018

The Table 4 and below Fig. 9 show the statistics of

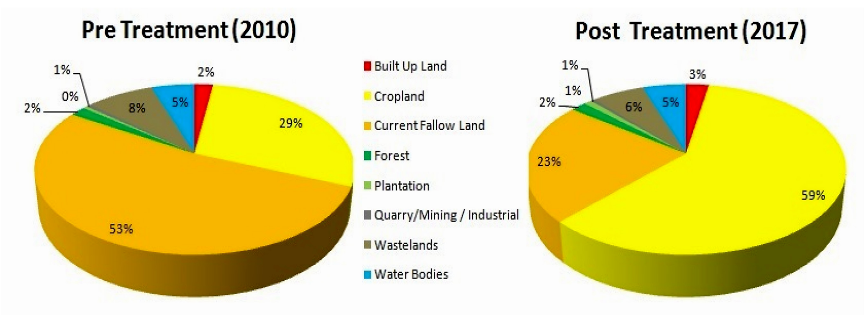

Fig. 7. Land use / Land cover distribution.

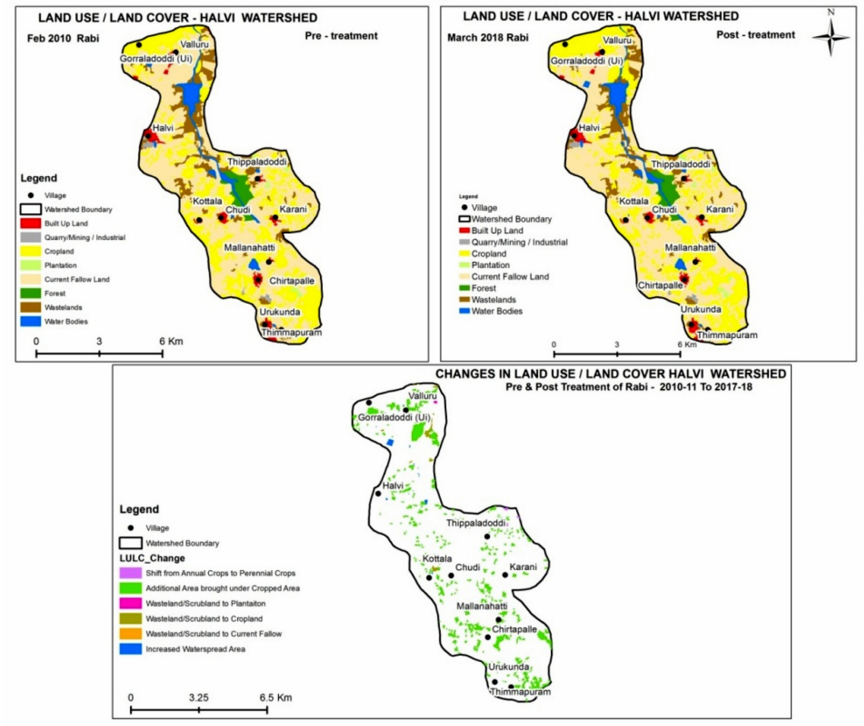

Fig. 8. Comparison of Land use / Land cover maps (*rabi*).

the area under different land use/land cover categories for both periods during the *rabi* season. Cropland area has been increased considerably, i.e. from 1,850 ha to 1,967 ha. There is an increase of 118 ha in cropland area, which has happened at the cost of current fallow and wastelands. The current fallows were decreased from 3,543 ha to 3,453 ha during pre and post years. Wastelands were decreased from 554 ha to 511 ha, this decrease in fallow and wastelands is due to an increase in cropland and plantations. It is observed that there is a small increase in the plantation area which is about 8 ha water body area is extracted by using LISS-IV Satellite data for the years 2010 and 2017. A gradual annual increase in the water body

Table 3. Land use/Land cover distribution and its changes in water body area.

Land use distribution and change in *rabi* season of 2010-11 to 2017-18 (Area in hectares)

Land use / cover class	Pre-treatment Area	%	Post-treatment Area	%	Change ± Area	% Increase/ Decrease
Built-up land	169	3	169	3	0	0
Cropland	1850	28	1967	30	118	6.36
Plantation	36	1	45	1	8	23.09
Current fallow land	3543	54	3453	53	– 90	–2.55
Forest	141	2	141	2	0	0
Quarry / Mining / Industrial	35	1	35	1	0	0
Wastelands	554	8	511	8	– 43	–7.81
Water bodies	242	100	250	4	7	3.06
Total	6570		6570		0	0

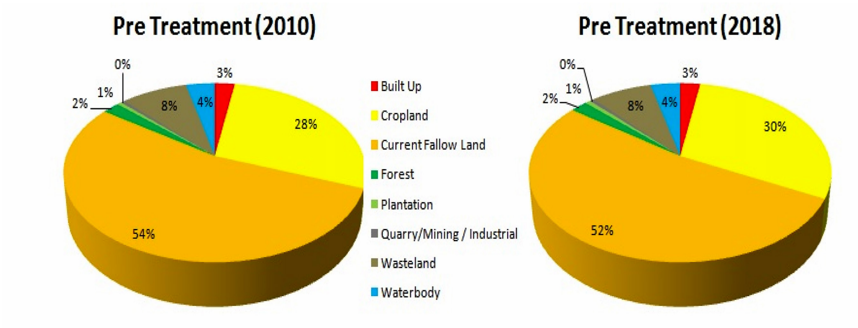

Fig. 9. Land use / Land cover distribution (*rabi*).

area has been noticed with an increase of 7 ha between 2010 and 2017. The area consisting of water bodies contributed to 242 ha in 2010 and increased to 250 ha in 2017. This increase in area is due to the construction of check dams and farm ponds which are shown in the figure.

Shift from annual crops to perennial crops

The plantation cover occupied 33 ha in 2010 and it increased to 60 ha in 2017 in *kharif* season, while the same plantations in *rabi* season occupied 36 ha in 2010, increased to 45 ha in 2018. It was observed that 27 ha plantation area got increased during *kharif* season and there was an increase of 8 ha in *rabi* season from 2010 to 2017 pre and post-implementation period. This increased plantation area of the post year came from cropland and current fallow of the pre year. This implies 27 ha and 8 ha of annual crops are converted into perennial crops during *kharif* and *rabi* season of this project period. The spatial distribution of this area is shown in Fig. 10.

Additional area brought under the cropped area

The cropland area has been increased in *kharif* season from 1,898 ha to 3,907 ha and in *rabi* season it increased to 1,850 ha to 1,967 ha during the project period of 2010 and 2017. Due to the proper adoption of soil and water conservation measures, an area of 2,009 ha and 118 ha of the area has been brought un-

Table 4. Major Land use / Land cover changes in *rabi* (2010–11 to 2017–18).

Sl. No.	Changes from pre-treatment	Changes from post-treatment	Area in ha
1	Annual crops	Perennial crops	19
2	Wasteland	Built up	21
3	Wastelands	Cropland	42
4	Additional cropped area		2611
5	Increased water spread area		3

Table 5. Major Land use / Land cover changes in *rabi* (2010–11 to 2017–18).

Sl. No.	Changes from pre-treatment	Changes from post-treatment	Area in ha
1	Annual crops	Perennial crops	6
2	Wastelands	Cropland	25
3	Wastelands	Plantation	2
4	Wastelands	Current fallow	12
5	Additional cropped area		648
6	Increased water spread area		14

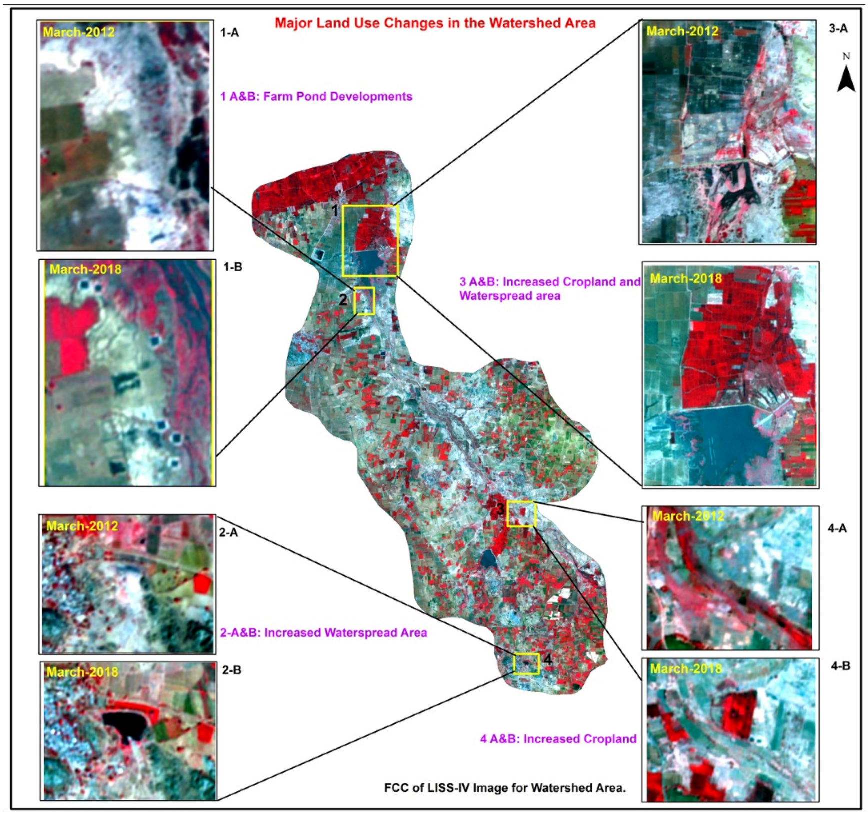

Fig. 10. Watershed developments in the project area.

der the cropped area during *kharif* and *rabi* season. The additional cropped area is coming from current fallow and wasteland / shrubland. It clearly shows that there is a progressive change in the project area. The little bit of area that changed from fallow to cropland has been shown in the figure.

Reclamation of wastelands

The wasteland reclamation activities are implemented in the project area like contour Bunding, Strip farming, Terracing, Leaching and changing agricultural practices. Due to the wasteland reclamation measures, 122 ha and 43 ha of the wasteland decreased from 2010 to 2017 during the *kharif* and *rabi* season. The area was converted into built up, cropland and fallow land. The major land use changes in *kharif* and *rabi* season are shown in the Table 5 below.

Cropping intensity (CI)

Cropping intensity is the ratio of the area under crops for each season during the year to the cultivable area operated by the farmer. It is presented as a percentage. The Halvi Watershed cropping intensity was 196% in 2010 and it is decreased to 150% in 2017.

CONCLUSION

As per the study, a good number of Water Harvesting Structures are constructed. As there is an overall increase in vegetative cover, the soil erosion in the watershed areas is likely to reduce. However, the variation in the percentage of reduction primarily depended on the quality of soil and moisture conservation activities in the respective watersheds. In view of a good number of WHS constructed in the watersheds, there is a likely reduction in run-off and an increase in soil moisture. There is a positive change in the land use pattern reported in most of the watersheds. In these watersheds, many wastelands are converted for productive use. These have resulted in an increase in net sown areas. Further, a better land use pattern has helped in increasing agricultural intensification and thus, there was enhancement in agricultural production. The study also suggests that the impact of the watershed is more focused towards physical and biological achievement. There are certain positive trends towards the growth of water level, soil fertility, land use pattern, cropping pattern, livestock production. The present assessment of Halvi Watershed in Kurnool District provides a fairly positive indication. It is observed that 90% of the watershed area performed positively in terms of increased vegetation cover and cropland based on remote sensing analysis. Remote sensing and GIS techniques are quite useful tools for the detection of major changes in the watershed. The integration of remote sensing data and application of GIS provides powerful platforms for efficient watershed management and monitoring. Various watershed components are assessed to identify the impact of the watershed development program. Monitoring of watershed for impact assessment using remote sensing and GIS tools should be carried out at regular intervals as geospatial tools and techniques provide better mapping, assessment and evaluation in stipulated time.

REFERENCES

Anderson JR, Hardy EE et al. (1976) A land use and land cover classification system for use with Remote Sensor Data, US Geological Survey.

https://www.maps of India.com/Integrated Watershed Management Program.

Jensen John R, Olson Gunnar, Schill Steve R, Porter Dwayne E, Morris Jim (2002) Remote Sensing of Biomass, Leaf-Area-Index and Chlorophyll a and b Content in the ACE basin National Estuarine Research Reserve using Sub-meter Digital Camera Imagery-Geocarto International 17 (3) : In press.

Rao DP (2000) Role of remote sensing and geographic information system in sustainable development, National Remote Sensing Agency (Department of Space, Govt of India) Balanagar, Hyderabad. Int Arch Photogrammetry and Rem Sens 33, Part B7, Amsterdam.

Report on Natural Resources Management (2007) Eleventh Five Year Plan, Volume I, Government of India Planning Commission.

Report—Watershed Development (2001) Rainfed Farming and Natural Resource Management, Government of India Planning Commission.

Satellite Data: Resourcesat–2 LISS–IV from NRSC (National Remote Sensing Center), Balanagar, Hyderabad.

Singh Prem, Behera HC, Singh Aradhana (2010) Impact and Effectiveness of Watershed Development Programs in India, Center for Rural Studies National Institute of Administrative Research Lal Bahadur Shastri National Academy of Administration Mussoorie.

State of Indian Agriculture (2015-16) Government of India Ministry of Agriculture & Farmers Welfare, Department of Agriculture, Cooperation & Farmers Welfare, Directorate of Economics & Statistics, New Delhi.

Topographical Maps from SOI (Survey of India), Uppal, Hyderabad.

Wani Suhas P, Rockstrom Johan, Sahrawat KL (2011) Integrated Watershed Management in Rainfed Agriculture. CRC Press E–Book (Taylor & Francis Group).

www.iwmp.ap.gov.in