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Watershed Programme Impact Assessment Study on LULC and NDVI using Remote Sensing and GIS in Srikakulam District of Andhra Pradesh

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The present study was taken up to assess the impact of watershed programme on LULC & NDVI using remote sensing & GIS in Muddada Watershed project (2010-2011 to 2017-2018) of Srikakulam dist, Andhra Pradesh. The study was carried out using IRS Resourcessat-2 LISS-IV satellite imageries data of 2011 (Pre 17-Oct-2011) and 2017 (Post 02-Nov-2017) covering the watershed to assess the changes in land use / land cover and NDVI for a period of five years (2011-2017). The images were classified into different land use/land cover categories using supervised classification by maximum likelihood algorithm. They were also classified into different vegetation levels using Normalized Difference Vegetation Index (NDVI) approach. The results revealed that the area under crop land and plantation were increased by 612.42 ha (17.61%) and23.85 ha (1.08%) respectively. This was due to the fact that parts of wastelands and fallow lands were brought into cultivation. This increase in the area may also be attributed to better utilization of surface and ground waters, adoption of soil and water conservation practices and capacity building of the watershed community. The area under current fallow decreased by 209.33 ha (67.34%) and waste lands by 379.26 ha (55.43%). Substantial increase in the area under dense vegetation (35.12%) and open vegetation (26.90%) was also observed. The water body area also increased from 57 ha to 63 ha might be due to rain water conservation activities taken up in the project area.

Introduction

Agriculture plays a vital role in India's economy and rural livelihood and provide employment to more than 50% of the total population of the country. About 56% of the net cultivated area of the country is rainfed accounting for 44% food production (GoI, 2017). The problems of rainfed areas are degradation of the natural resources, rainwater runoff, soil erosion, frequent droughts and desertification, low agriculture productivity, reduced forest cover, poor water quantity &quality. Watershed development is deeply rooted in the culture and social fabric of India. Several programs were taken up by the Govt. of India to improve the rainfed areas. One of the flagship programs taken up by the Dept. of Land Resources (DoLR), Ministry of Rural Development is the Integrated Watershed Development Programme (IWMP). Watershed approach has become a growth engine for sustainable intensification of rainfed areas. The program is expected to treat approximately 25 million hectors of rainfed areas during 12th plan period (2012-13 to 2016-17) spending considerable amount. Subsequently, the IWMP has been changed to “Pradhan Mantri Krishi Sinchayee Yojana” (PMKSY) – Watersheds Programme. In Andhra Pradesh, the Dept. of Panchayat Raj and Rural Development through the State Level Nodal Agency (SLNA) is implementing 372 watershed projects with an outlay of Rs. 1985.16 crores covering an extent of 15.83 lakh ha in 5 Batches from 2009-10 to 2013-14.

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. The outcomes are prevention of soil loss through run-off, regeneration of natural vegetation, rain water harvesting and re-charging of ground water. 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.

As the watershed development approach is an integrated one with the involvement and efforts of various departments and considerable budget, there is a need to assess the impact of the programme holistically and evaluate the long-term effects and the impact of the activities through reliable methods. Post project evaluation of any intervention is essential to understand the overall impact of the intervention for the intended objectives, vis-à-vis to learn lessons for the future actions. Impact evaluation in case of watershed technology is imperative to know an overall impact of the activities taken up in a particular watershed. It also helps in learning of the appropriateness of the method employed in carrying out the project activity and to estimate the social and economic benefits of the activity as well as its efficiencies and impact in the context of stated objectives of the project.

Conventional ground-based sampling for watershed assessment has proved costly and time consuming (Shanwad *et al.,* 2008). Remote Sensing (RS) and Geographical Information System (GIS) have been proved as effective tool to monitor and manage the natural resources and assess the impact on watersheds during the pre- and post-development. This involved development of spatial and temporal database and analysis techniques. Efficiency of the techniques depends on several factors such as classification schemes, spatial and spectral resolution of remote sending data, ground reference data and also an effective implementation of the result *(Meenakshi B et. al., 2018).* The repetitive coverage of the remote sensing satellite over a particular area provides an excellent opportunity to 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 increased area under cultivation, conversion of annual crop land to horticulture, change in surface water bodies, afforestation etc. could be monitored through satellite remote sensing. Over the years, it’s utility to detect and determine the extent and nature of changes over a period of time has successfully been demonstrated (Gopal Kumar et al, 2014, Meera Gandhi et al, 2015, Ranjit Basha *et al.*, 2019, Sharma G, &R.N. Sharma, 2020).

The present study was taken up to investigate change in LULC & NDVI due to the project implementation in Muddada Watershed project (2010-2011 to 2017-2018) of Srikakulam district of Andhra Pradesh.

Study area

Muddada watershed is part of Etcherla Mandal in DPAP Block of Srikakulam district of north costal Andhra Pradesh. The watershed is located between the latitude 18°13'47.36"N and longitude 83°51'43.76"S at ridge point and between latitude 18°12'43.84"N and longitude 83°54'45.69"S at valley point. It is at a distance of 13 kms from the district headquarters and is located at an elevation of 16m above the MSL. Highest point in the watershed is19m above the MSL at ridge.

The total geographical area of the watershed is 8663.98 hectares and net treatable area is 4158.00 ha. The average annual rainfall (5 years) in the area is 1045 mm. Most of the soils are red sandy to red sandy loam with low water retention capacity and poor fertility. The temperatures in the area are in the range between 43^{0}C during summer and 25^{0}C during winter. There are 42 no. of habitations spread over in 9 micro watersheds.

The main occupation of the watershed community is agriculture, mostly under rainfed cultivation which is vulnerable to drought, failure of monsoons and also effected by cyclones as well.

Materials and Methods

In this study Remote sensing technique is adopted for pre- and post-change analysis in Land use- Land cover using IRS Resourcessat-2 LISS-IV satellite imageries for the years 2011 (Pre 17-Oct-2011) and 2017 (Post 02-Nov-2017) on cloud-free days, following the given methodology:

Pre and post Satellite imageries are procured for the years 2011 and 2017.

SOI topographical sheets procured for reference maps.

Two working methodologies are adopted for change detection analysis

Supervised classification (maximum likelihood classification) was conducted to measure the changes in vegetation cover

Normalized Difference Vegetation Index (NDVI) was carried out to identify the difference between NDVI values for the years 2011 and 2017.

Land use – Land cover categories like crop land, fallow land, plantation, forest, degraded lands etc classes are arrived at using supervised classification method.

NDVI range of index values for different class categories like, dense vegetation, medium vegetation and degraded vegetation are prepared.

Results of both methods are studied and analysed for assessing the changes occurred due to implementation of the watershed programme.

Land use-Land cover

Remote sensing-based image processing method of supervised classification technique is used to extract land use classes like crop land, fallow land, plantation, forest, degraded lands etc from the IRS Resourcessat-2 LISS-IV satellite imagery. The land use-land cover class wise statistical values are compared in order to evaluate the changes in the period of time from year 2011 to 2017.

Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) is calculated in accordance with the formula**:**

NDVI = (NIR-RED)/(NIR+RED)

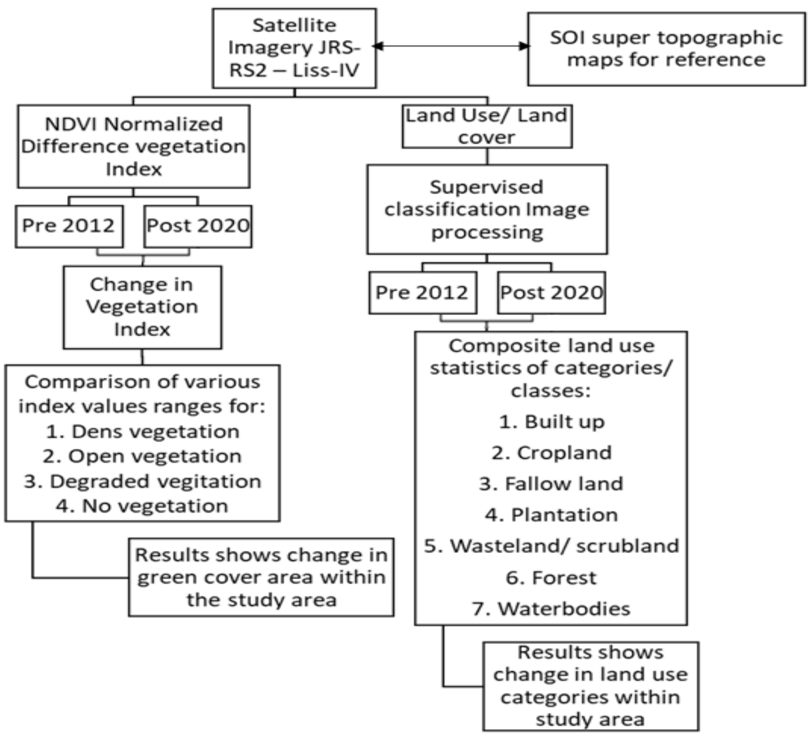
Where

NIR – reflection in the near-infrared spectrum
RED – reflection in the red range of the spectrum

NDVI is a measure of the state of plant health based on how the plant reflects light at certain frequencies. Index defines values from -1.0 to +1.0, basically representing greenness. Chlorophyll (a health indicator) strongly absorbs visible light, and the cellular structure of the leaves strongly reflect near-infrared light. Using the range of index values for different categories like, dense vegetation, medium vegetation and degraded vegetation are compared and analysed for the pre- and post-periods for the study area. NDVI measured on the fly-in-change detection monitoring of green vegetation for a period of time (Years 2011 and 2017) in the study.

The methodology adopted is presented in the flow chart:

Flow chart depicting the methodology



Consequence of the methodology

Statistical results of pre- and post-values generated form the above methods are compared with the field investigation reports. The results are used to analyse the changes taken place during the project period for studying the impact of the watershed programme.

Results and Discussion

Changes in Land use / Land cover during 2011 and 2017

Spatial distribution statistics of Muddada Project area under different land use / land cover categories for both the periods are shown in Fig 1 and in Table 1.

In Muddada watershed project there is significant change in land use/land cover area distribution during the project period. Considerable increase in area under cropland (Fig 4) and plantations are observed. Under cropland, there was 3477.20 ha during 2011 and 4089.62 ha in 2017, indicating an increase of 612.42 ha amounting to 17.61% during the project period (*Sharma G & Sharma R N, 2020 compared the data of land use pattern of the year 2011 & 2018 and found that the total agriculture area has increased by 8% after implementation of watershed programme in Jaipur Dist., Rajasthan).*

The current fallow area which was 310.84 ha during 2011 decreased to 101.51 ha in 2017 due to implementation of watershed works. This is a desirable change. Better land use pattern is one of the important objectives of the watershed management project. There was decrease in waste land/scrub land from 684.26 ha to 305.00 ha from pre-project to post-project period accounting to 379.26 ha which might have been converted into crop land and plantation. This might be due to several activities like soil and water conservation works taken up like check dams, percolation tanks, farm ponds, agriculture demonstrations and training programmes etc., taken up during the project period.

The results achieved in Muddada watershed project was to the expected levels (DoLR, 2015).

Table.1 Changes in Land use / Land cover during 2011 and 2017

S. No.	LULC Category	Pre project	Post project	Difference	Difference in %
		Area in Ha			
1	Built-up	137.37	137.37	0	0
2	Cropland	3477.2	4089.62	612.42	17.61
3	Plantation	2200.58	2224.43	23.85	1.08
4	Current Fallow	310.84	101.51	-209.33	-67.34
5	Forest	1301.09	1256	-45.09	-3.47
6	Wasteland / Scrubland	684.26	305	-379.26	-55.43
7	River/Water bodies	56.66	62.85	6.19	10.92
8	Quarry Area	25.11	16.33	-8.78	-34.97
9	**Total**	**8193.11**	**8193.11**		

Table.2 Changes in Vegetation Cover

SL.No.	Change in vegetation	Pre project	Post project	Difference	Difference in %
		Area in Ha			
1	**Dense vegetation**	2785	3763	978	35.12
2	**Open vegetation**	2130	2703	573	26.90
3	**Degraded vegetation**	1967	1147	-820	-41.69
4	**Fallow/ No vegetation**	1065	328	-737	-69.20
5	**Built-up**	137	137	0	0
6	**Water Bodies**	57	63	6	10.53
	Total	**8141**	**8141**		

Fig.1 Changes in Land use / Land cover during 2011 and 2017

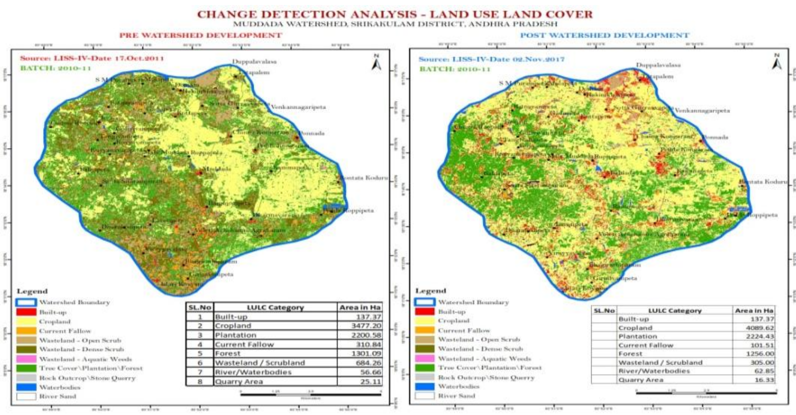


Fig.2 Changes in Vegetation Cover

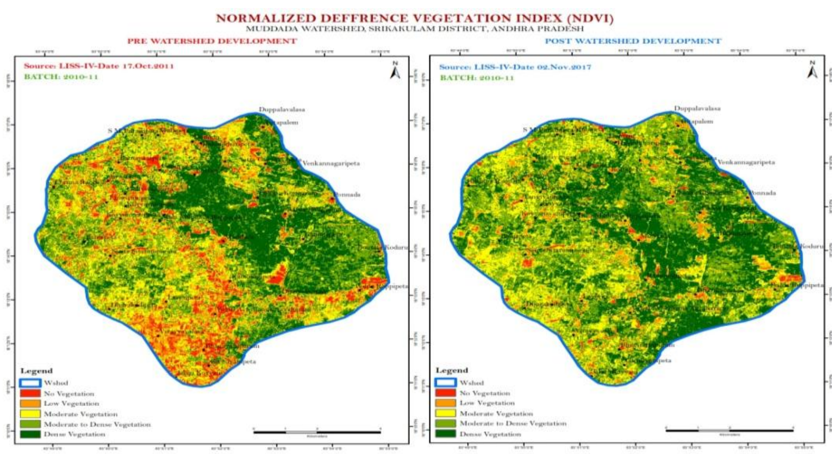


Fig.3 Changes in Water body Area

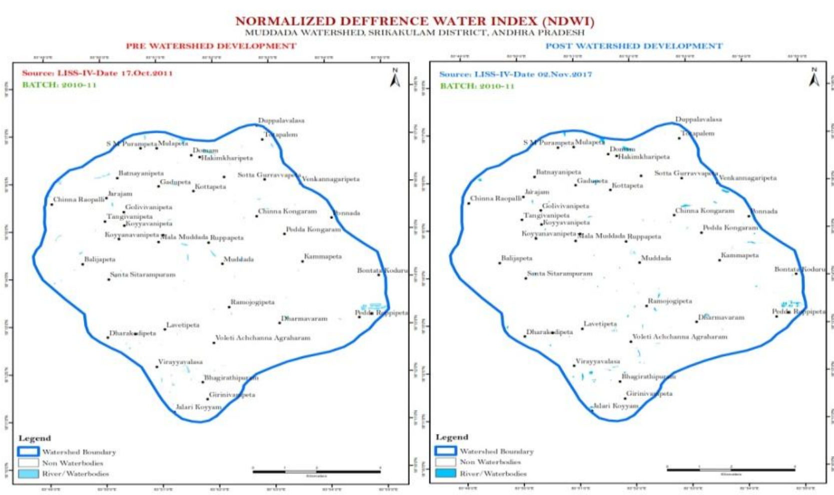
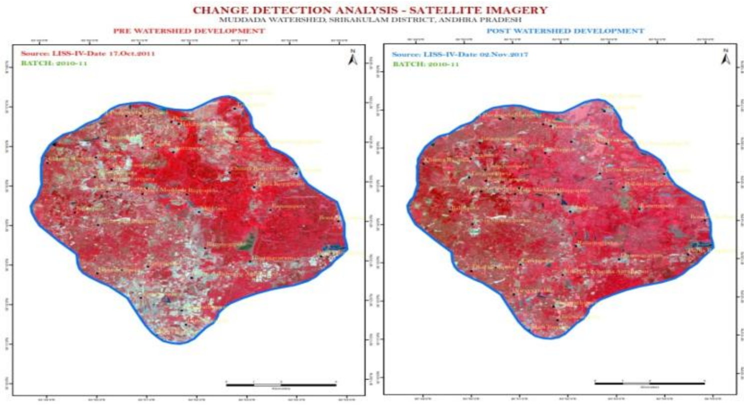


Fig.4 Change in cropped area



Shift from Annual crops to Perennial crops

The plantation cover occupied 2200.58 ha in 2011 and it has increased to 2224.43 ha in 2017 an increase of 23.85 ha. It was due to conversion of crop land area into perennial crops like cashew, mango, banana etc., during the project period. This may be helpful to protect the lands from soil erosion, improve soil structure, increase ecosystem nutrient retention, carbon sequestration, water filtration and also can contribute to climate change adaptation and mitigation.

Changes in Vegetation Cover

The Normalized Difference Vegetation Index (NDVI) maps were classified into different vegetation vigour classes like Dense vegetation, Open vegetation, degraded vegetation and no vegetation. Statistics are presented in Table 2 and in Fig2. There was increase in dense vegetation by 35.12% and that of open vegetation by 26.9% during the project period*(Area under the crop land due to watershed program implementation was reported by Gopal Kumar et al., 2014, Ranjit Basha et al., 2018, reported increase in dark green vegetation in Asoli-Yavatmal cluster of watersheds by about 8.1% during 3 years period from 2007-2010, Madhavarao et al., 2012, Nagaveni Ch & Ravibabu M V. 2017, Takkar A K et. Al, 2017)*. This was due to afforestation and plantation programmes taken up in the government and private lands. At the same time, there was decrease in area under degraded vegetation and no vegetation which might have been converted into dense and open vegetation.

Changes in Water body Area

Changes in water body area is a good indicator of any watershed intervention activities. The increase in the water body area of the project was from 57.00 ha to 63.00 ha, an increase of 6 ha (Table 2, Fig 3). This might be due to increase in surface water and stream flow in the watershed areas due to the construction of farm ponds, percolation tanks, check dam etc. Increase in surface water and stream flow is an indicator that can help establishing positive impact of watershed development programmes on physical factors. Increase in water body area results in increase in ground water table due to percolation of water into the ground. With increase in water availability farmers are inclined to new cropping pattern and agricultural diversification. Both agricultural diversification and intensification lead to increase in agriculture productivity in the watershed areas.

The present study concluded that in Muddada PMKSY-Watershed, the programmes taken up have shown significant positive change in the land use and land cover. Similarly, it has positive impact on vegetation vigour. The water body area also significantly increased due to rain water conservation activities due to project implementation.

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