Impact of watershed management on Bio-physical, Hydrological and Agricultural indicators in the Lakkonda watershed project of East Godavari district, Andhra Pradesh, India

ABSTRACT

The present study was taken up to evaluate the impact of the Lakkonda Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) watershed, East Godavari district, Andhra Pradesh which was implemented during the period 2014-15 to 2020-21 under the Batch-V group with a treatable area of 4986 hectares covering seven micro watersheds. The impact of watershed interventions mainly on bio-physical, hydrological and agriculture indicators. The Land Use Land Cover (LULC), Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) were assessed utilizing the Remote Sensing and Geographical Information System technique. The results indicated that the area under cropland and plantation increased by 92.95 ha (2.54%) and 154.08 ha (30.01%) respectively. The scrubland/fallow area was decreased by 269.42 ha (19.72%) which might be converted into plantations and cropland. The area under medium vegetation, 67.98 ha (3.93%) and dense vegetation, 441.51 ha (33.82%) increased, whereas other vegetation classes (nil and low) were substantially decreased. The water body areas also increased from 5.92 ha to 10.95 ha which might be due to rainwater harvesting and water conservation, structures undertaken in the project area. An increase in hydrological features like waterbodies and groundwater table was observed as indicated by the rise of the water table in dug wells(1.84m) and tube wells (0.57m). The cropping intensity raised to 120.82 from 100.19% resulting in a 20.61% increase in the study area, because of watershed management interventions mainly soil and water conservation methods and rainwater harvesting structures constructed during the project period and which shows increased productivity of major crops in the project area i.e., rice (26.64 to 79.03%) pulses (14.69to113.47%) cotton (73.30%) and cashew (167.76%) increased during the post-project period. The overall benefit-cost ratio of import crops was increased and among the observed crops high returns for the rupee invested were from the green gram.

Keywords

Geographic Information System, Bio-physical indicator, Normalized Difference Vegetation Index, Normalized Difference Water Index, Copping intensity, Benefit, Cost ratio

1. INTRODUCTION

The backbone of the Indian economy is agriculture and allied fields which mostly depend upon an abundance of natural resources like rainfall, water resources, soil and forest vegetation. As these resources are limited and depleted yearly, there is an utmost need to stabilize and conserve these resources. The adoption of watershed management is one of the globally accepted practices to restore and stabilize natural resources, especially in high-altitude rainfed areas. The aim of the integrated watershed management program (IWMP) now Prime Minister Krishi Sinchayee Yojana (PMKSY)program is to restore the ecological balance by conserving and developing degraded natural resources such as soil, water and vegetative cover with expected benefits of soil loss reduction, improving natural vegetation and recharging of groundwater through rainwater harvesting structures. This program may bring the possibility to improve vegetation on the land and develop water features in and on the soil surface leading to crop diversification, cropping intensity and productivity enhancement, ultimately resulting in the sustainable economic development of the watershed beneficiary.

There are some important aspects to be considered in watershed development program which needs time to visualize their complete impact. Watershed development programs are implemented with dual objectives of soil and water conservation and sustainable improvement in the livelihood of watershed beneficiaries [7]. Various types of interventions carried out in watershed projects comprise soil and moisture conservation in agricultural lands (contour /field bunding and summer ploughing) drainage line treatment measures (loose boulder check dams, minor check dams, major check dams and retaining walls) water resource development/ management (percolation ponds and farm ponds) crop demonstration, horticultural plantation and afforestation [4]. Therefore, the watershed development concept has been internationally accepted as a holistic approach to natural resource management. Department of Land Resources (DoLR) under the Ministry of Rural Development (MoRD), Government of India has been implementing the PMKSY Watershed Program since 2009. In Andhra Pradesh, the Department of Panchayat Raj and Rural Development through the State Level Nodal Agency (SLNA) is implementing 372 watershed projects covering an extent of 15.83 lakh hectares in five batches from 2009-10 to 2013-14. In the Lakkonda area of East Godavari in Andhra Pradesh the PMKSY Watershed Program was initiated in 2013-14 and completed seven years project period. The project has been completed by 2020-21 and assumed that the watershed interventions' impact will be spectacular on biophysical changes in the study area, cropping pattern, cropping intensity and productivity of agriculture and commercial crops.

In this context, to reduce the cost and time, satellite remote sensing has been used as an evaluation tool in many of the studies [15-17]. “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 programs which have taken place in natural resources and the livelihoods of people”. “There is not often enough room for midterm adjustments in the ongoing programs 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” [18-23]. 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, the spatial and spectral resolution of the RS data, ground reference data and effective implementation of the result [24-26].

2. MATERIALS AND METHODS

2.1 Description of Study Area

In Lakkonda of Gangavaram mandal in East Godavari district, the Watershed Project of PMKSY was sanctioned during the year 2014-15 and implemented by Andhra Pradesh Government with a fund allocation of Rs.747.90 lakhs. The geographical area of the project is 6100 hectares with a treatable area of 4986 hectares having 11 habitations spreading over seven (07) micro watersheds. The project is completed seven years gestation period. The Lakkonda project is located between the latitude N $81^0$42’28” to Longitude, E $17^0$25’21” at ridge point and between latitude N $81^0$42’25” to Longitude E $77^0$25’21” at valley point. The study area is mainly hilly terrain with moderate to very deep slopes and has three (03) major streams mainly dependent on rainfall, draining the watershed area. The biophysical indicators, hydrological indicators and agricultural indicators are studied as per the approved methodology to arrive at valid conclusions on the watershed interventions.

2.2 Biophysical Indicators

The biophysical indicators viz; Land Use and Land Cover (LULC), Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) are studied with the help of Remote Sensing and GIS techniques. Based on data availability, on cloud-free days for pre and post-project periods, terrain-corrected Resource Sat-2 LISS-IV for the year 2014-15 and 2020-21 have been used for the study. Survey of India (SoI) topographical sheets of 1:50,000 scale, ground truth data and PMKSY monitoring reports from Panchayat Raj and Rural Development, Government of Andhra Pradesh have been used for reference. Land Use and Land Cover change analysis were carried out utilizing an onscreen visual interpretation technique, using pre-Resources Sat-2 LISS-IV images and ArcGIS 10.8

background. Similarly, the post-LULC layer has been generated by overlying the pre-LULC layer onto the post Resource Sat-2 LISS-IV images and identifying the changes and editing (NRSC). Normalized Difference Vegetation Index (NDVI) is calculated with the equation; NDVI=(NIR-RED)/(NIR+RED) where NIR represents the reflection of the near-infrared spectrum and RED represents the reflection in the red range of the spectrum. The NDVI is a basic indicator of green vegetation. Normally it is generated to understand vegetation that changes depending on seasonal variations and also to monitor different growth phases of crops to analyze primary productivity [12]. The NDVI images for pre and post-project have been generated using Erdas Image 2015 software. Normalized Difference Water Index (NDWI) is used to identify water features from land and vegetation. It is calculated with the formula NDWI = (Green-NIR/ (Green + NIR). The NDWI values range from -1 to+1. Negative values correspond to non-water features such as drylands, rocky areas and barren land and positive values represent water features.

2.3 Hydrological indicators

Hydrological indicators refer to different water resources; groundwater, rainfall, other irrigation sources like natural streams etc. and natural resources management like soil and moisture conservation, rainwater harvesting, afforestation etc. To highlight the effect of hydrological indicators, the depth of groundwater in open wells and bore wells in the project area, and total annual rainfall are considered. The category-wise natural resource management activities with financial allocation in PMKSY are furnished in Table 1 [13-14].

Table 1. NRM works Undertaken in Lakkonda Watershed Projects in East Godavari Districts

S. No	Nature of work	Physical (No.)
1	Land development works	-
2	Soil moisture conservation works	68
3	Water harvesting structures	95
4	Repairs to existing WHS	1
5	Livestock related works	15
	Total no. of NRM works	179

2.4 Agricultural indicators

Agriculture is the primary livelihood activity of the watershed community, especially SC, ST and other communities mainly depend on cultivation with available water and land resources. In the study area data on available irrigation facilities and crops grown before and after implementation of the watershed program are collected in the household survey, mini-meetings and Focus Group Discussions (FGD) during the field visits of the project area. For the collection of data and the indicators suggested by the State Level Nodal Agency (SLNA), open-ended questionnaires developed by Monitoring Evaluation Learning and Documentation (MEL&D) agency were used. During the survey, the changes due to the implementation of the PMKSY watershed were noted in the questionnaires. The other participatory method utilized for obtaining the required data was focused group discussions [13-14].

2.5 Data collection in the target area

While collecting data care was taken to include all communities residing in all micro watersheds of the project area. Minorities, women-headed households, landless, marginal small and big farmer households presenting all habitations in each micro watershed were interviewed. The pre-project survey was carried out in 100% (1550) of the household out of which 5% (77) of the total households in each micro watershed was interviewed in the post-project period (Table 2.). The schedules designed by M E L and D agencies were used for collecting household data as per the sample size in each micro watershed. The field investigators have visited all the micro watersheds in the PMKSY watershed of the Lakkonda project of East Godavari district to collect data from the selected households following, sample selection criteria. Focus discussions were conducted in all seven micro watersheds with the support provided by the staff of respective micro watersheds involving various stakeholders of the watershed community. Wherever necessary the support of RBKs (Rythu Bharosa Kendra) was taken to improve the accuracy of the data. Secondary data was collected from the unpublished records of WCC, Project Implementation Agency

(PIA) and District Water Management Agency (DWMA). The information about the pre-project period was obtained from Detailed Project Report (DPR). The data thus collected were analyzed using simple methods such as difference and double difference. The post-project changes have been assumed to be the impact of the interventions implemented during the project period.

Table 2. Particulars of Households Surveyed in the Lakkonda Project

S. No	Name of Micro-Watershed	No. of Households surveyed	
		Pre-Project Period	Post-Project Period
1	Amudalabanda	338	17
2	Lakkonda	332	17
3	Gangavaram	423	21
4	Marripalem	186	9
5	Yendapalli	120	6
6	Doramamidi	108	5
7	Yerrampalem	43	2
	Total	**1550**	**77**

3. RESULT AND DISCUSSION

3.1 Biophysical effects

3.1.1 Land Use /Land Cover

Watershed development activities significantly brought positive changes in the study area of the Lakkonda project. Land Use Land cover data as affected by different interventions during the project period under different categories for both periods are shown in Fig. 1a, 1b and Table 3. The data indicates that there is a significant change in land use and land cover in the project area. Considerable areas in plantation and cropland are observed to increase due to watershed interventions. An increase of 154.08 ha (30.01%) in plantation and 92.95 ha (2.54%) under crop plant was observed at the end of the Project Period [6,8]. The increase in the area may be due to better utilization of surface and groundwater, adoption of soil and water conservation practices and change in land utilization. The area under scrubland/ fallows decreased by 269.42 ha (19.72%) which were converted into cropland or plantation area.

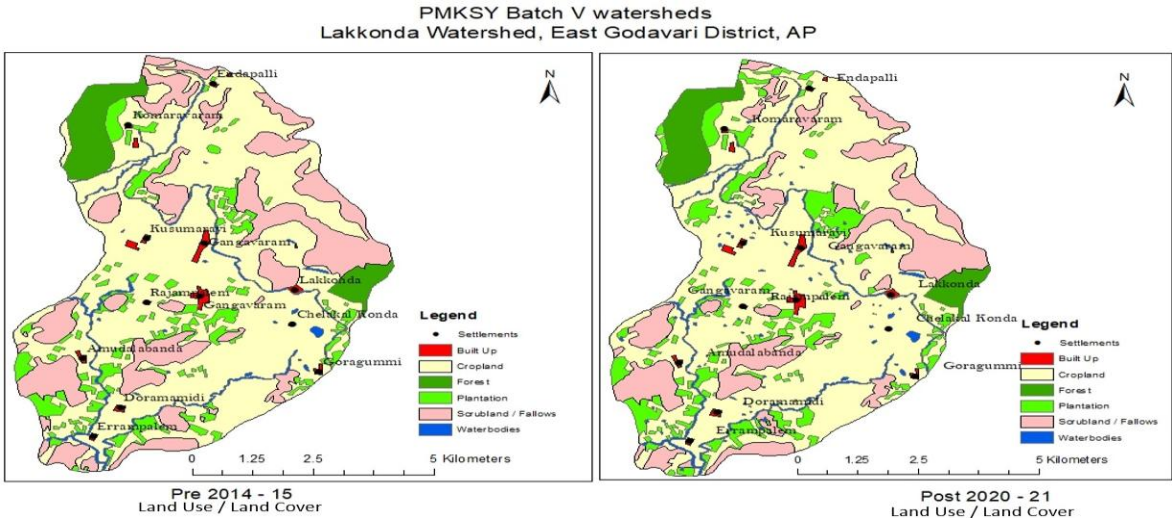

Fig. 1(a). Change Detection-Land Use Land Cover

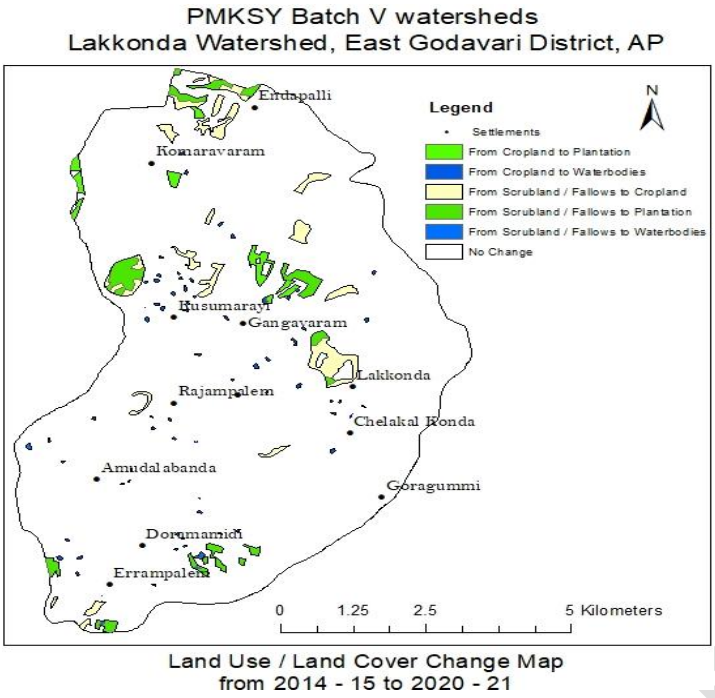

Fig. 1(b). Land Use Change Map

Table 3. Change in Land use /Land cover in Lakkonda Project

S. No	Classes	Area in Ha			
		Pre –Project Period 2014-15	Post-Project Period 2020-21	Change	Percent change
1	Built-Up	58.15	58.15	0.00	0.00
2	Cropland	3662.06	3755.01	92.95	2.54
3	Forest	333.44	333.44	0.00	0.00
4	Plantation	513.41	667.49	154.08	30.01
5	Scrubland / Fallows	1366.49	1097.07	-269.42	19.72
6	Waterbodies	149.36	171.74	25.38	16.99
	Total Watershed Area (TWA)	**6082.89**	**6082.89**		

3.1.2 Vegetative cover

Changes in vegetative cover as identified by satellite imagery LISS-IV data for both pre and post-project periods in the Lakkonda project are presented in Fig. 2 and Table 4. The vegetation vigour of the area was classified into four classes viz; nil, low, medium and dense vegetation following Normalized Difference Vegetative Index (NDVI). Substantial increase in the area under medium and dense vegetation classes 67.98 ha (3.93%) and 441.51ha (33.82%) respectively [6]. The increase in medium and dense vegetation might be due to interventions of watershed development programs, afforestation and plantation programs taken up in the government and private land. The decrease in the area under nil and low vegetation might have been converted into dense and medium vegetation [10-14].

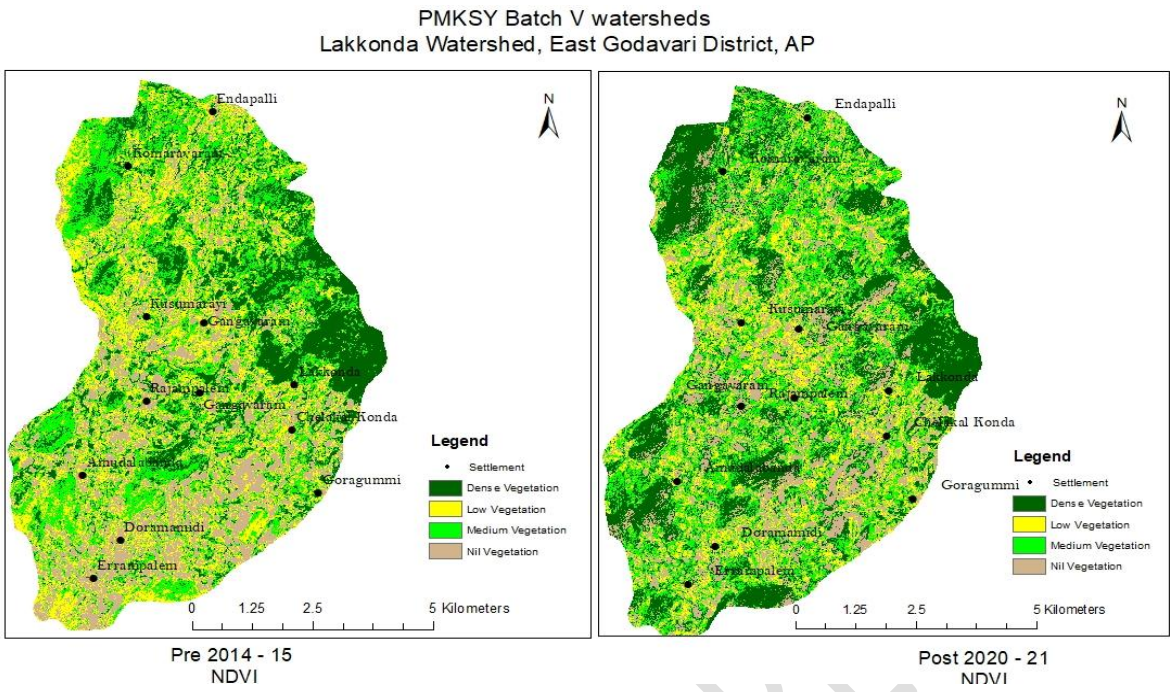

Fig. 2. Pre and Post NDVI images

Table 4. Change in Vegetation cover (Ha) Lakkonda Project

S. No.	NDVI Classes	Pre-project period (2014-15)	Post project period (2020-21)	Change	Percent Change
1	Nil Vegetation	1356.96	1314.10	-42.86	-3.16
2	Low Vegetation	1689.15	1222.52	-466,63	-27.63
3	Med. Vegetation	1731.46	1799.44	67.98	3.93
4	Dense Vegetation	1305.32	1746.83	441.51	33.82
Total Watershed Area		6082.89	6082.89		

3.1.3 Normalized Difference Water Index

Water features/moisture areas/ water bodies can be detected by the satellite map for interpretation of the changes over a while, due to watershed interventions. It is a good indicator of any watershed development activities. The changes in water bodies as identified by satellite imageries in the Lakkonda watershed are furnished in Fig. 3 and Table 5. The data indicate an increase in the water body area of the project from 5.92 to 10.95 ha resulting and increase of 5.03ha (84.97%). This may be due to various water conservation and rainwater harvesting activities undertaken during the project implementation period [13-14].

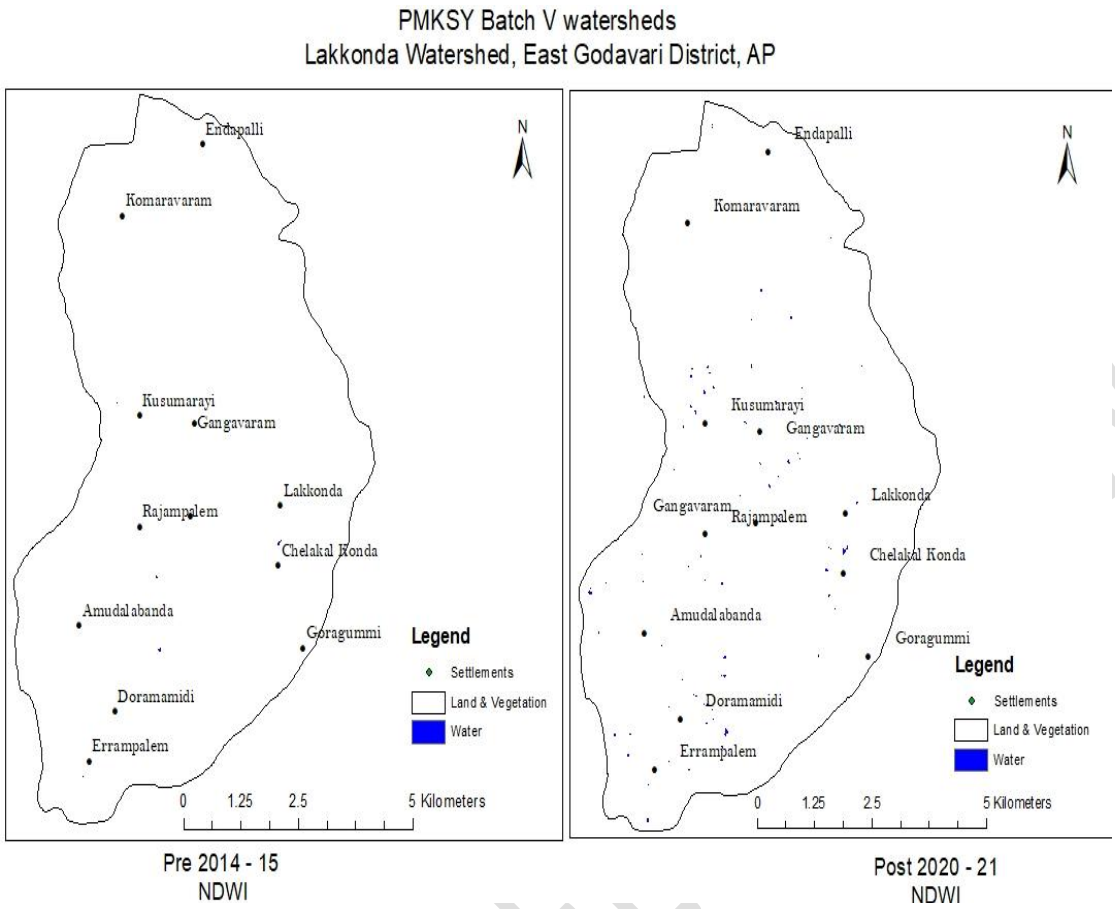

Fig. 3. Pre and Post-NDWI images

Table 5. Change in water body cover (Ha) in Lakkonda Project

S. No.	NDWI Class	Pre-Project Period (2014-15)	Post-Project Period (2020-21)	Change	Percent Change
1	Land and Vegetation	6076.97	6071.94	-5.03	-0.08
2	Waterbodies	5.92	10.95	5.03	84.97
Total Watershed Area		6082.89	6082.89		

3.4 Hydrological indicators

3.4.1 Changes in groundwater

Variation in groundwater depends on rainfall and water conservation and rainwater harvesting activities. The average rainfall per annum in the Lakkonda project area varied from year to year and the deviation from normal rainfall of 1103.9 mm was given in Fig. 4. It indicates that only during the year 2014-15 there was a deficit of 530.2mm (48.03%) rainfall whereas in all the years it was above the normal rainfall.

The depth of water availability in dug wells and tube wells was given in Table 6. The data indicates a positive change in the available water. In dug wells, the water table was raised to the tune of 1.84 m (11.76%) and in tube wells 0.57m (3.15%) in the post-project period. This phenomenon improved the irrigated area by 28.94 % from 104.82ha to 135.16 ha recording an increase in the irrigated area of the Lakkonda project to 30.4 ha. Conservation of soil moisture and rainwater harvesting structures (table.6.) along with abundant rainfall in six out of seven years resulted in the rise of the groundwater table [5].

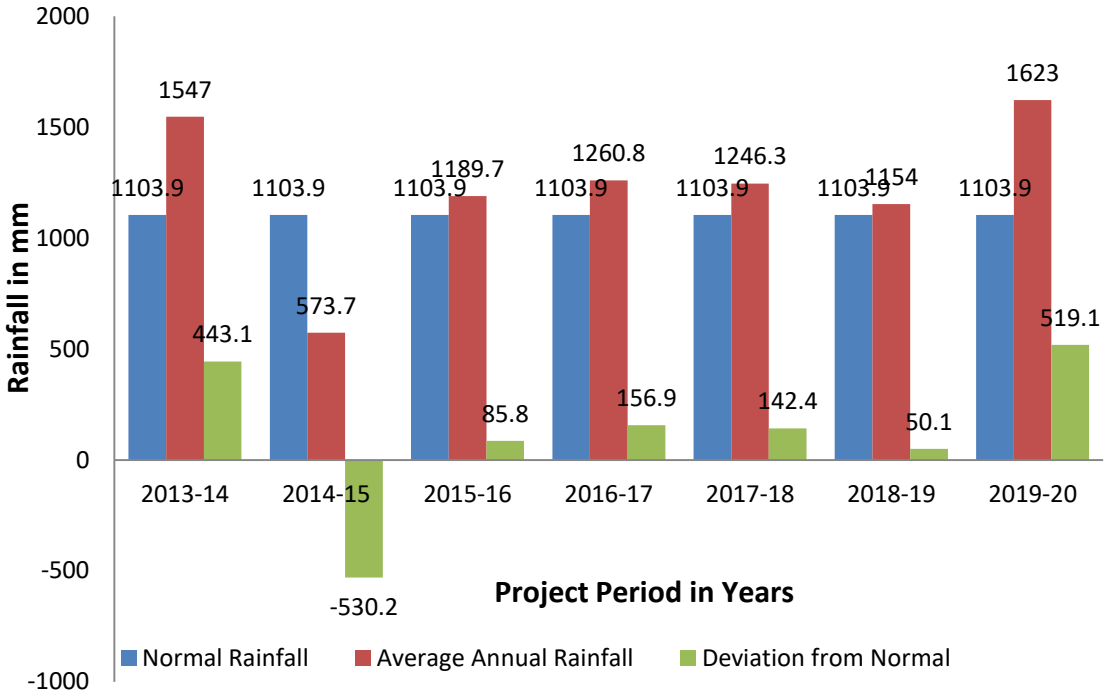

Fig. 4. Annual Rainfall (mm) and Deviation from Normal in Lakkonda during Project Period

Table 6. Changes in Groundwater and Irrigation Potential in Project area as affected by Watershed Interventions

S. No.	Items	Unit	Lakkonda Project			
			Pre-project status	Post-Project Status	Difference	% Difference
1	The average depth of water table in dug wells	Meter	15.65	13.87	-1.84	11.76
2	The average depth of water table in tube wells	Meter	18.09	17.52	-0.57	3.15
3	The number of groundwater structures rejuvenated	Nos.	1	3	2	-
4	Increase in Irrigation potential	Ha.	104.82	135.16	30.34	28.94

3.5 Agricultural Indicators

3.5.1 Change in area(ha)based category and source of irrigation

Based on the possession of the land the sample households were grouped into marginal (<1ha), small (1to2 ha) and medium and big (>2ha) categories besides the landless group for both the study period. As the samples for medium and large farm holding were small these two size groups have been considered as a single unit. From Fig. 5. there is a change in the category of the area from the pre to post-project period. Some of the respondents moved to adjacent higher groups that from landless to marginal, marginal to small and so on, at the end of the period of implementation of project activities. This indicates the efforts of the PMKSY watershed management in implementing the various activities successfully.

Further, the total area in selected holdings of the Lakkonda project was divided into dry and irrigated land based on the source of irrigation and presented in Fig. 6. It is clear that the area under rainfed was more compared to irrigated. However, there was an increase in irrigated areas i.e., from 36.48 to 37.35 ha from the pre to post-period due to an increase in groundwater availability in borewells, dug wells and rainwater harvesting structures of the project area. This helped not only the farmers but also landless households in augmenting their income. The irrigated area increased due to infrastructure development under watershed activities resulting in the reduction of the rainfed area [13-14].

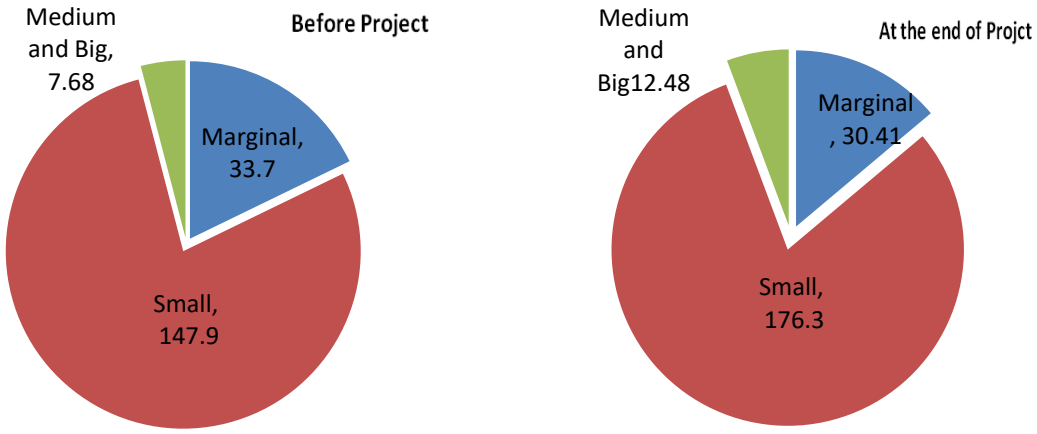

Fig. 5. Change in the area (ha) of Land Holdings Due to Watershed Interventions in the Lakkonda Project

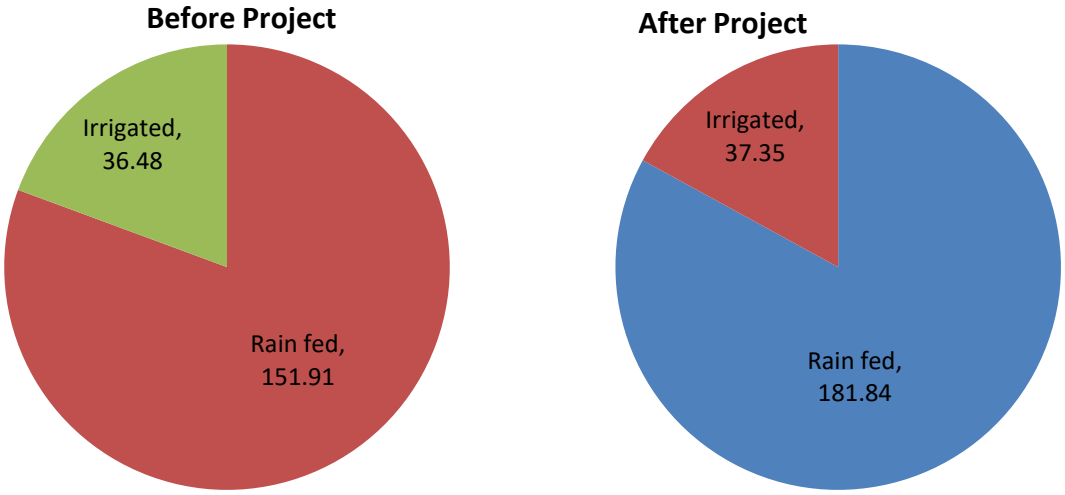

Fig. 6. Change in the area (ha) based on the source of Irrigation in the Lakkonda Watershed

3.5.2 Cropping Pattern

In the Lakkonda project during the post-project period, a spectacular change in the cropping pattern was observed when compared to the pre-project period. Red gram, Maize and sesame were taken up by the farmers due to the availability of irrigation water and increased arable land. The status of different crops in the pre and post-project periods was given in Fig. 7. Cereal, millets, and pulses were the predominant crops in the watershed area constituting about 73% of the cultivated area. Horticultural crops like cashew, banana, guava and vegetable crops were 23%. The other crops grown were oil seeds 3% and cotton 1%.

The cropping pattern did not change much except for the addition of maize, red gram and sesame due to an increase in the cultivable area which resulted from soil moisture conservation and rainwater harvesting structures constructed through various interventions of the watershed Management program. In the post-project period the area under paddy declined from 18 to 17 %, pulses from 44 to 41% and horticulture crops from 27 to 21 % fig.8. However maize, red gram and sesame were added in the area. It was possible due to the group meetings, demonstrations on crop technology, and distribution of oilseeds and pulses during the project implementation period. Cultivating higher and quick-income crops like sweet corn and vegetables were also encouraged by the watershed committee which was readily accepted by the farmers [2]. Watershed beneficiaries always are ready to adopt new technologies and new crops as they are much more accessible to water resources when compared to non-beneficiaries.

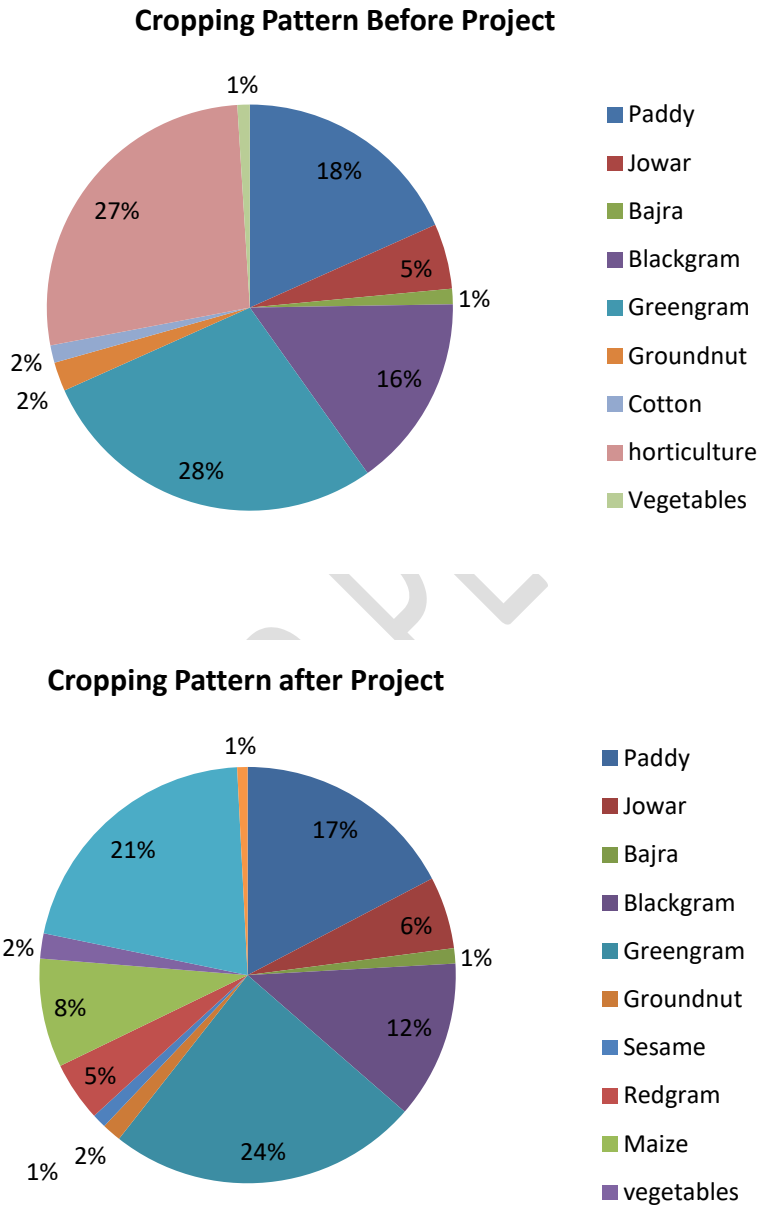

Fig. 7. Change in Cropping Pattern in Lakkonda as Effected by PMKSY Watershed Management Interventions

3.5.3 Crop productivity

Productivity of crops increased in the project area during the post period. The per-hectare yields of the major crops were higher when compared to the pre-project period due to the adoption of integrated crop management practices, the best utilization of rainwater and judicious use of groundwater. The productivity of paddy increased by 26.64 to79.0 3%, pulses by 14.69 to 113.47%, cotton by 73.30% and cashew by 167.76 % (fig.8.) during the post period [11-14]. Higher change in productivity was reported by many scientists who worked with different watersheds. The productivity of newly added crops (maize, red gram, and sesame) in the project area which was observed during the post-project period is not included in the figure as the pre-project data for comparison was not available.

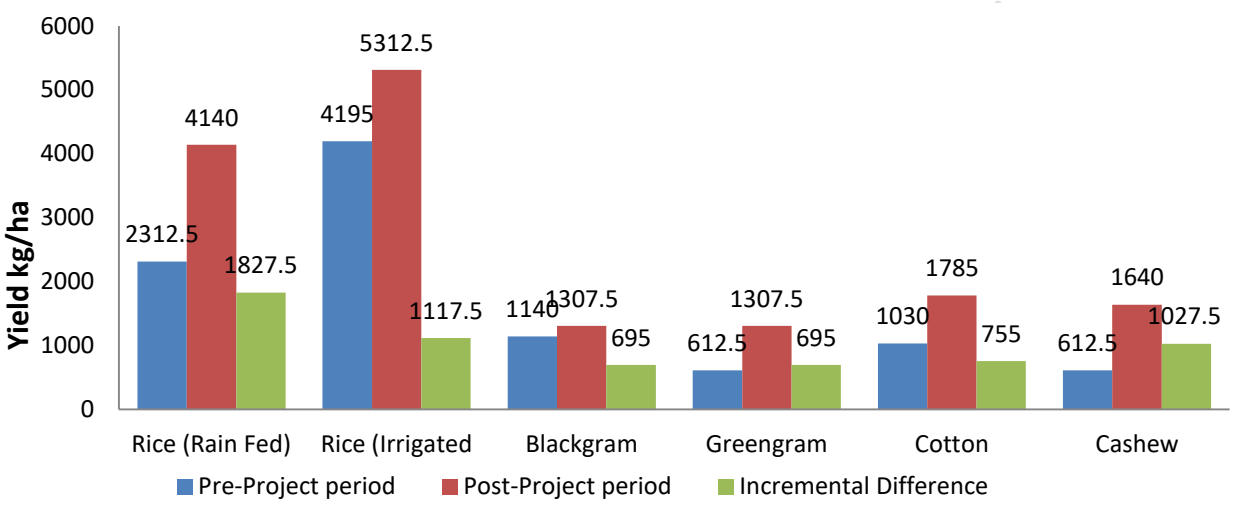

Fig. 8. Change in Crop Productivity due to Watershed Interventions in the Lakkonda Project area

3.5.4 Cropping intensity

In the project area with the inception of the PMKSY project management interventions, the farmers are interested in cultivating different crops as the availability of moisture was not a constraint till the harvesting of the crop. The area under agriculture increased from 3126.55 hectares in the pre-project period to 3450.51 ha in the post-project period, recording an increase of 323.96 ha (10.36%). Apart from the Kharif and Rabi areas the double crop area also increased from 102.86 to 126.71 ha due to the availability of supplemental irrigation water which was made possible by the soil moisture conservation measures and rainwater harvesting structures established in PMKSY project management interventions. Therefore, the cropping intensity in the Lakkonda project area increased from 100.19 (pre-project) to 120.82% (post-project) (Table. 7.) [1,3].

Table 7. Cropping Intensity as effected by Interventions during PMKSY Project Period in Lakkonda Watershed

S. No	Particulars	Pre-Project (ha)	Post-Project (ha)	Change (ha)	% Change
1	Khari	2822.18	3236.29	414.11	14.67
2	Rabi	207.54	314.28	106.74	51.43
3	Double Croppe Area	102.86	126.71	23.85	23.18
	The cultivable area from the wasteland	-	100.37	100.37	
4	Total Cropped Area	3132.58	3777.65	645.07	20.59
5	Area Under Agriculture	3126.55	3450.51	323.96	10.36
6	Cropping Intensity (%)	100.19	120.82	20.63	

3.5.5 Benefit, Cost ratio of crops

Based on the current prices of crops grown in project area B: C ratio was worked out. The B: C ratio for rice was 2.32 to 2.35 for pulses 7.74 to 8.94 for cotton 2.69 and for cashew it was 8.31(table.8.) during the post-project period. The corresponding values during the pre-project period were low. The lowest BC ratio was 1.27 for rice and the highest was 5.67 for black gram in the pre-project period. During the post-project period the highest BC ratio was for green gram 8.94 followed by cashew 8.31. The data indicates that green gram in the Lakkonda project area would be the most profitable crop [9].

Table 8. Effect of Lakkonda Watershed Project Interventions on B: C Ratio of important crops

S. No	Name of the Project	Pre-Project			Post-Project		
		Cost of Cultivation (Rs/acre)	Gross Income (Rs/acre)	B: C Ratio	Cost of Cultivation (Rs/acre)	Gross Income (Rs/acre)	B: C Ratio
1	**Rice (Rain Fed)**	10850.12	12117.50	1.27	14575.23	33782.40	2.32
2	**Rice (Irrigated)**	11897.60	21981.80	1.85	18456.58	43350.00	2.35
3	**Black gram**	3456.23	19608.00	5.67	4258.12	32949.00	7.74
4	**Green gram**	2548.45	11025.00	4.33	4258.12	38048.25	8.94
5	**Cotton**	9147.56	15244.00	1.67	16458.56	43411.20	2.69
6	**Cashew**	4896.56	98000.00	2.00	7895.56	65600.00	8.31

4. CONCLUSIONS

In Lakkonda the impact of PMKSY watershed management interventions was noted to increase the plantation area by 154.08 ha and the cropland area by 92.95 ha at the end of the project period. A substantial increase in the area under medium (67.98 ha) dense vegetation (441.51 ha) and water bodies (5.03 ha) was noticed through Remote Sensing satellite imageries. In the project area, the water table of the dug wells (1.84 m) and tube wells (0.57m) rised due to the soil moisture conservation project area and rainwater harvesting structures adopted, leading to improvement in arable land and cropping intensity. Though there was not much change in cropping pattern, crops like red gram, maize and sesame were additionally cultivated by watershed beneficiaries. The productivity of paddy (26.64 to 79.03%) pulses (14.69 to113.47%) cotton (73.30 %) and cashew (167.76 %) increased substantially. The BC ratio of all the crops indicated above improved and the green gram with an 8.94 BC ratio evolved as the most profitable crop in the Lakkonda watershed.

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:

COMPETING INTERESTS:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

1. Ani Kulshreshtha, Sen SK, Singh YK and Gupta AK. Impact of participatory approach in Management of Watershed Practices in Micro-Watershed Mainabasai in Morena District of Madhya Pradesh. Green Farming. 2015;6:1408-1410.
2. Gourav Chovdhary, Vikas Pewariya and Sajjan Jheeba. Impact Evaluation of Cropping Pattern and Production Pattern due to Watershed Development Project in Rajasthan. Indian Journal of Economics and Development. 2015;11(01): 157-165.
3. Hemant Panwar, Zala C, Pundir RS, and Mishra RK. A study on Impact of Watershed Development Project of Antisar Watershed in Kheda District of Gujarat. International Journal of Agricultural Sciences. 2016;12(2):355-364.
4. Palanisami K and Suresh kumar D. Impact of Watershed Development Programmes: Experiences and Evidence from Tamil Nadu. Agricultural Economics Research Review. 2009;22:387-396.
5. Senthilnathan SS, Govind Raj D, Periyar Ramaswamy and Sekar C, 2010. Economic and Environmental Impacts of Soil and Water Conservation Activities in Watershed Area; Madras agricultural journal .97, 10: 418-410.
6. Shanwad UK, Patil VC, Gowda HH and Dasog GS. Application of Remote Sensing Technology for Impact Assessment of Watershed Development Programme.Journal of the Indian Society of Remote Sensing. 2008;36(4): 375-386.
7. Sharma BR, and Scott CA. Watershed management challenges: Introduction and overview: Improving productivity, Resources and Livelihoods. International Water Management Institute (IWMI) and International Crop Research Institute for Semiarid Tropics (ICRISAT) publication. Malhotra Publishing House, New Delhi.2005:245-257.
8. Sharma, G. and Sharma RN. Application of GIS and Remote Sensing for Impact Assessment of Integrated Watershed Management Program: A Case Study of Bassi Block, Jaipur District. International Journal of Scientific and Technology Research. 2020;9(01):983-989.
9. Srivastava PK, Kumar Surendra and Singh Narendra. Evaluation of benefits from harvested rainwater in farm ponds. Indian jungle love soil conservation. 2015;43(3): 471-476.
10. Thakkar AK, Desai R, Patel A and Potdar MB. Application of Remote Sensing in Analysis of Impact Assessment using Biomass Vigour changes of Watersheds, Journal of Environmental Biology. 2017;38:543-551.
11. Tekale VS, Mosami Ingale,Vidya V Tayde .2017 .Impact of intensive watershed development project. Agriculture Update 12 (2): 288 -291.
12. Vani V and Pavan Kumar K. Crop Condition Assessment of Groundnut using time series NDVI data in Anantapur District, Andhra Pradesh. Journal of Rural Development. 2018; 37(2):167-178.
13. Venkataramamuni Reddy P, Sasidhar Kona, Reddy CP, Sagar Kumar Reddy RV and Janardhan Reddy B. Evaluation of watershed projects in YSR Kadapa District of Andhra Pradesh using remote sensing and GIS technologies. The Journal of Research ANGRAU 2022; 50(3): 38-51.
14. Venkataramamuni Reddy P, Sasidhar Kona, Reddy CP, Sagar Kumar Reddy RV and Janardhan Reddy B. Evaluation of watershed development programme in Prakasam district of Andhra Pradesh using Remote Sensing and GIS Technology. International Journal of Environment and Climate Change. 2022;12(12):1488-1496.
15. Liu WT, Negron Juarez RI. ENSO drought onset prediction in north-east Brazil using NDVI. International Journal of Remote Sensing. 2001;22:3483–3501.
16. Schmidt KS, Skidmore AK. Exploring spectral discrimination of grass species in African range lands. International Journal of Remote Sensing. 2001;22:3421–3434.
17. Roy PS, Dwivedi RS, Vijayan D. Remote Sensing Applications. NRSC Publication, Balanagar, Hyderabad. 2010;100-150.
18. Keith J Virgo, Jyotsna Sitling. Measuring the impact of watershed management projects. Waterlines. 2003;22(1):12-14.
19. Shanwad UK, Patil VC, Honne Gowda H, Dasog GS. Application of remote sensing technology for impact assessment of watershed development programme. Journal of Indian Society of Remote Sensing. 2008;36:375-386.

20. Srinivasa Vittala S, Govindaiah S, Honne Gowda H. Prioritization of sub-watersheds for sustainable development and management of natural resources: An integrated approach using remote sensing, GIS and socio-economic data. Current Science. 2008;95(3):345-354.
21. Martin D, Saha SK. Land evaluation by integrating remote sensing and GIS for cropping system analysis in a watershed. Current Science. 2009;96(4):569-575.
22. Gopal Kumar, Sena DR, Kurothe RS, Pande VC, Rao BK, Vishwakarma AK, Bagdi GL, Mishra PK. Watershed impact evaluation using remote sensing. Current Science. 2014;106(10):1369-1378.
23. Meenakshi Bai R, Raghavendra, Rajesh V. Application of remote sensing and GIS techniques in watershed management. Research Journal of Chemical and Environmental Sciences. 2018;6(5):01-04.
24. Patel, N.R., Mehta, A.N and Shekh, A.M. Canopy temperature and water stress quantification in rainfed pigeonpea (Cajanus cajana L.). Agriculture and Forest Meteorology. 2001;109:614–621.
25. Serman, M.J., Baban and Kamaruzaman. Mapping land use/land cover distribution is a mountainous tropical island using remote sensing and GIS. International Journal of Remote Sensing. 2001;22(10):1909– 1918.
26. Venkataramamuni Reddy P, Sasidhar Kona, Reddy CP, Sagar Kumar Reddy RV, Janardhan Reddy B, Ramana RV, Rekha DVSRL and Veerabhadra Rao K. Positive effect of natural resources management interventions on bio-physical indicators in polla watershed project of Srikakulam district, Andhra Pradesh, India. International Journal of Environment and Climate Change. 2022;12(12):1786-1794.