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Impact assessment of Mutukuru PMKSY watershed project on land use land cover (LULC) dynamics using remote sensing and GIS: A case study from Durgi Block, Palanadu District, Andhra Pradesh

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Abstract
Integrated development of watershed through building sustainable soil and water conservation measures is the major goal of the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). The main objectives of this study were to understand the impact of Mutukuru PMKSY watershed project on Land Use Land Cover (LULC) dynamics and how the changes affected the socio-economic status of the people in the region using remote sensing and Geographic Information Systems (GIS) technologies. LULC images derived from satellite images captured during the pre and post project period indicate that the area under agriculture, vegetation and forest region have increased in both Kharif and Rabi seasons. Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) results shows that there was about 13.6% and 33% increase in dense vegetation and high soil moisture area respectively in Mutukuru watershed. The changes had a positive impact on the socio-economic status of people in Mutukuru region. Implementation of watershed projects in the area facilitated an increment in productivity of all the crops both in kharif and rabi seasons. The number of people engaged in agriculture has increased and there was a notable increase in daily wages and annual income per household. The total milk production per year also increased by 33.9% in the mega watershed by the end of the project.

Keywords: LULC, NDVI, NDWI, Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), production and productivity

1. Introduction
The Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) aims at holistic development of a watershed, giving prime importance to water conservation and its management. The major objective of the movement includes extend the coverage of irrigated area, reduce the wastage and improve the water use efficiency and crop productivity by constructing sustainable soil and water conservation structures and rainwater harvesting structures, recharging the ground water, promoting extension activities related to water harvesting and management, crop alignment and grass root level field functionaries, providing livelihood options and other Natural Resource Management (NRM) options (Palsaniya, 2012; Reddy *et al.*, 2021; Siwach and Singh, 2019) [5, 7, 8]. Each PMKSY-Watershed is a mega project, with a cluster of micro watersheds, covering an average area of 4000 ha. The projects are implemented over a period of 4-7 years duration and in 3 phases viz: Preparatory phase, Work phase and Consolidation phase as per the 'Common Watershed Guidelines for Watershed Development Projects' issued by Government of India, Ministry of Rural Development, Department of Land Resources. The guidelines of PMKSY Watershed Development Component (WDC) recommends the use of advanced technologies such as remote sensing and Geographic Information Systems (GIS) for planning, implementation and impact analysis study of the PMKSY projects.
Remote Sensing and GIS are powerful tools for understanding the Land Use Land Cover (LULC) dynamics over a period of time. Remotely sensed images captured during pre and post project period provide an idea about the major changes in LULC (Kumar *et al.*, 2014) [4]. The satellite data derived products such as Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) give an idea about how the vegetation or cropping pattern and water content of the soil changed over a period of time.

Present study uses the satellite images from Indian Remote Sensing satellite (IRS) Resource sat 2A, LISS-IV sensor to understand the LULC dynamics before and after Mutukuru PMKSY Mega Watershed (MW) project, Palanadu District, Andhra Pradesh. The major objectives of the study include (1) evaluate the changes in LULC of Mutukuru watershed after the implementation of PMKSY watershed project and (2) understand how the project helped to improve the socio-economic status of people in Mutukuru Watershed.

The Department of Panchayati Raj and Rural Development (PR & RD) is the State Level Nodal Agency (SLNA), which monitors and guides the execution of the PMKSY watershed projects in state of Andhra Pradesh. Mutukuru watershed comes under the Batch-V projects in Andhra Pradesh sanctioned in 2013-14 and completed in 7 years. SLNA has awarded the work of impact analysis of the Mutukuru PMKSY project to NABARD Consultancy Services (NABCONS) as a Monitoring, Evaluation, Learning, & Documentation (MEL&D) Agency. The results of impact analysis study performed by NABCONS are furnished in this report.

2. Study Area

Mutukuru Mega Watershed is located in Durgi Mandal of Palanadu district (earstwhile Guntur District), Andhra Pradesh (Fig. 1). It is situated at around 12 km from the mandal headquarters and 125 kms from the district headquarters. Mutukuru watershed is located between latitude 16° 17' 07.12" and longitude 79° 25' 18.69" at ridge point and between latitude 16° 24' 49.35" and longitude 79° 31' 49.35" at valley point. The total geographical area of the IWMP watershed is 8942 hectare and net treatable area is 4968 hectares. The average annual rainfall (10 years) in the area is 687 mm. The temperatures in the area are in the range between 45°C during summer and 29°C during winter. There are two Micro Watersheds (MWS) in the watershed project and details are given in Table 1.

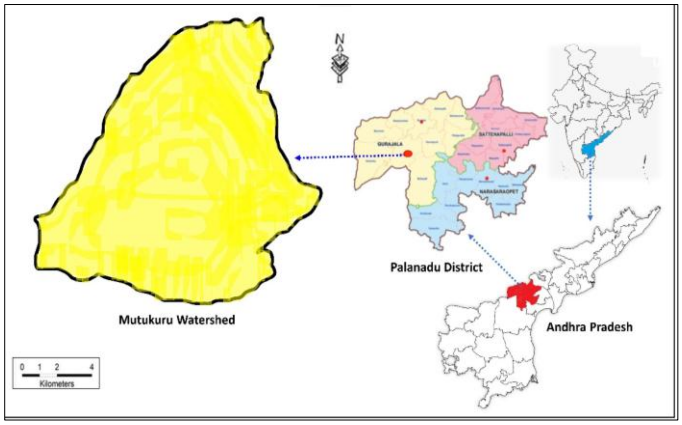

Fig 1: Mutukuru Mega Watershed

Table 1: Details of the Micro Watersheds (MWS) of Mutukuru IWMP project

Sr. No.	Name of the MWS	Geographical Area (ha)	Net Treatable Area (ha)
1	Mutukuru	4558	2968
2	Kolagutla	4384	2000
	Total	8942	4968

The study area is a plain land, bounded by Mutukuru reserve forest on south and Kakirala reserve forest on east. The watershed is located at an elevation of 102 m above the Mean Sea Level (MSL) and the highest point in the watershed is 107 m above the MSL. The major streams in the IWMP cluster are Bandlavagu, Beerlavgu, Rallavagu, Oddulavagu and Chandravagu. The Survey of India (SOI) toposheet of 1:50,000 scale is used for obtaining physiographic details of the watershed. Boundary of the Mutukuru watershed is delineated based on the shape files provided by the SLNA.

3. Materials and Methods

Impact of the watershed activities are measured by observing changes in three components such as LULC, soil moisture availability and vegetation development in pre and post project periods. Satellite images from Indian Remote Sensing Satellite (IRS) Resource sat 2A, LISS-IV sensor with 5 m spatial resolution were used to understand the dynamics in LULC, vegetation and soil moisture. Details of the satellite data used are provided in the Table 2. The ERDAS imagine version 2015 software has been used to process LISS IV satellite data and extract the required indicators through spatial and spectral analysis. The ArcGIS version 10.3.1 was used to prepare the final maps for indicators through the outcomes of ERDAS software.

Table 2: Details of the Satellite data used in Mutukuru Watershed

Sr. No.	Description	Specification	Project
1	Satellite	IRS Resoursesat 2A	
2	Sensor	L4FX	
3	Path and Row	101 and 61	
4	Sub scene	C	
5	Spatial Resolution (metre)	5	
6	Date of Pass	23-Aug-13, 14-Jan-14.	Pre project
		23-Oct-21, 06-Feb-22.	Post project

3.1 Land Use Land Cover (LULC) Classification

LULC classification generally refers to the categorization or classification of human activities and natural elements on the landscape within a specific time frame based on established scientific and statistical methods of analysis of appropriate source materials. In the present study, LULC classification was carried out using on-screen visual interpretation techniques in GIS environment. The classified images having different LULC categories pertaining to pre and post treatment period were compared to derive information on changes (Thakkar *et al.*, 2017; Alemayehu *et al.*, 2009) [1, 2]. Ground tests were undertaken in conjunction with the use of multi-resolution remote sensing data to assess the changes in land use with the implementation of watershed programs. Major LULC classes noticed in the Mutukuru watershed include agriculture land, build-up area, water body, waste land, vegetation, agriculture fallow land and forest.

3.2 Normalized Difference Vegetation Index (NDVI)

NDVI is a dimensionless index used to represent the density of the vegetation on ground, which is mainly calculated to monitor the vegetation status and biomass productivity. It was calculated using the spectral reflectance values from the Red (R) and InfraRed (IR) band of LISS-IV imagery as below:

NDVI = (IR – R) / (IR + R)

The value of NDVI ranges from -1 to 1. Negative values of

NDVI represents water, clouds or snow and the values close to zero indicates rocks or bare soil. Values between 0.2 to 0.3 depicts shrub lands or meadows and high values from 0.6 to 0.8 denotes temperate and tropical forest (Pettorelli *et al.*, 2005) [6]. In this study NDVI images for pre and post project period were categorized in to four classes namely, Dense, Moderate, Low and No Vegetation.

3.3 Normalized Difference Water Index (NDWI)

NDWI is used for remote sensing of vegetation liquid water from space. NDWI was calculated from spectral reflectance values from near Infrared (IR) and Short-Wave InfraRed (SWIR) bands of LISS-IV sensor.

NDWI = (NIR – SWIR) / (NIR +SWIR)

The SWIR reflectance varies with vegetation water content and the spongy mesophyll structure in canopies, while the NIR reflectance is affected by leaf internal structure and leaf dry matter content but not by water content. Therefore, the combination of SWIR and NIR provides details about water content in vegetation. Water and Wet soils appear darker in remotely sensed images. NDWI is maximum for water or fully saturated soil (+1) and is negative for dry land or dry soils (-1) (Gao 1996). In the study, watershed is divided into four NDWI categories such as high, good, medium and low soil moisture.

3.4 Impact of LULC changes on Socio-Economic Status of the Watershed

To understand the impact of LULC changes due to watershed development activities on socio economic status of Mutukuru watershed in terms of agricultural and livestock production, employment, literacy and financial status of people primary and secondary data were collected manually. The primary data was collected through the field surveys conducted by the MEL&D team of NABCONS. The Household Survey and Focus Group Discussion questionnaires, approved by SLNA were used for data collection. From Mutukuru and Kolagutla MWS about 43 and 26 households participated in the survey. The basic information about the changes and watershed development activities were obtained from DPRs. Secondary statistical information regarding the profile of the villagers, crop production and productivity, literacy and employment were obtained from the Revenue Officials of Durgi Mandal, Palandiu District.

4. Results and Discussion

4.1 Changes in LULC

The LULC changes in pre and post project period for Mutukuru watershed is given in Fig. 2. The results shows that the watershed development activities had positive impact on the agricultural productivity from the watershed (Table 3). The total agricultural and vegetated area increased from 636 ha to 935 ha and 1285.6 ha to 1777.3 ha, respectively. Vegetation is a LULC class of natural plants considered collectively or arbitrarily. Forest area also increased by 15%. Increased water availability due to increase in area under waterbody (89 ha to 300 ha) also helped agricultural production. This increase in vegetated and forest area is also indication of the horticultural crops in the study area. The area under wasteland and fallow land has been reduced by 3% and 25%, respectively

Table 3: Area of different LULC classes in Rabi Season

Land Use Class	Pre Project		Post Project	
	Area (Ha)	% of Total Area	Area (Ha)	% of Total Area
Agriculture land	636.7	6.6	935.1	9.7
Built-up area	130.9	1.4	240.7	2.5
Water body	89.9	0.9	300.4	3.1
Waste land	893.0	9.3	610.6	6.3
Vegetation	1285.6	13.3	1777.3	18.4
Cloud	222.5	2.3	364.8	3.8
Fallow land	3794.7	39.3	1399.9	14.5
Forest	2598.1	26.9	4022.6	41.7

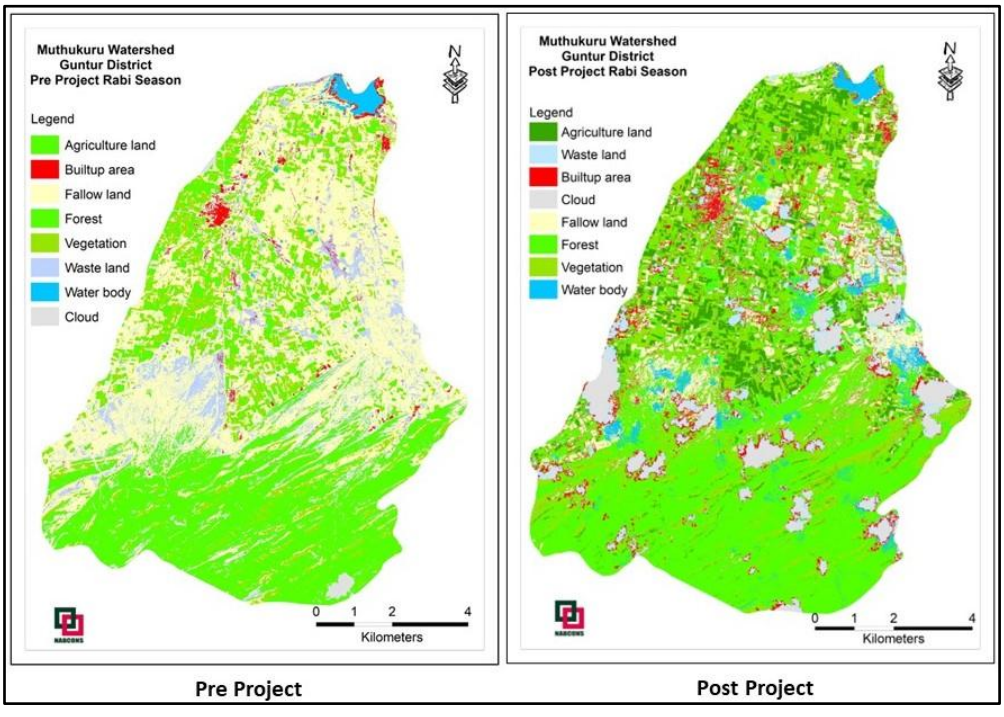

Fig 2: LULC in pre and post rabi seasons in Mutukuru watershed

According to the surveys conducted in the 69 households in Mutukuru mega watershed, it was observed that about 3.4 ha of wasteland has been brought under cultivation on account of implementation of the watershed project. It was further observed that, there was a marked shift from agriculture to horticulture crops. The details of changes in land use pattern from the survey are given in Table 4.

Table 4: Change in area under different land use pattern (ha)

Sr. No.	MWS	Pre Project			Post Project		
		Agriculture	Horticulture	Wasteland	Agriculture	Horticulture	Wasteland
1	Mutukuru	8.5	9.0	2.8	14.7	10.5	1.1
2	Kolagutla	5.4	5.8	3.6	7.6	6.6	2.3
	Total	14.0	14.9	6.5	22.3	17.1	3.4

4.2 Changes in Vegetation Cover and Soil Moisture

Changes in vegetative cover was examined in terms of NDVI. NDVI results for the watershed in pre and post project period period. As a result, there is notable decrease in low vegetation or no vegetation area from 1736 ha to 264 ha and 520 ha to 7.7 ha in the post project period. are furnished in Fig. 3 and Table 5. It was observed that the area under dense and moderate vegetation has increased from 4074 ha to 5388 ha and 3320 ha to 3989 ha in the post project

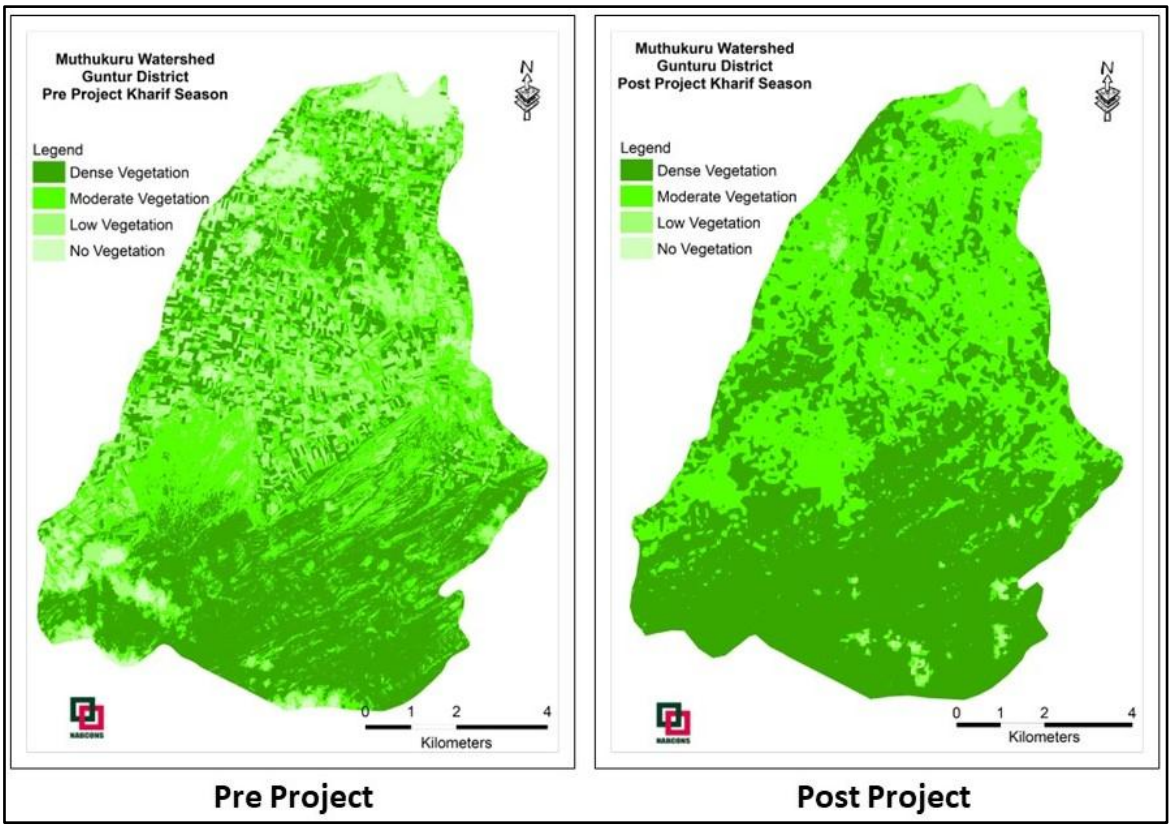

Fig 3: Map of NDVI classification for pre and post project period in Mutukuru watershed

Table 5: NDVI results for pre and post project period in Mutukuru watershed

Vegetation	Pre Project		Post Project	
	Area (ha)	% of Total Area	Area (ha)	% of Total Area
Dense vegetation	4074.2	42.2	5388.8	55.8
Moderate vegetation	3320.5	34.4	3989.9	41.3
Low Vegetation	1736.4	18.0	264.9	2.7
No Vegetation	520.3	5.4	7.7	0.1

NDWI results for Mutukuru watershed in pre and post project period are shown in Fig. 4 and Table 6. The area under high and good soil moisture has significantly increased in post project period from 244 ha to 3415 ha and 1925 ha to 2163 ha, respectively. As a result, there was about 6% and 30 % decrease in area under medium and low soil moisture. It was also found that, the area under dense and moderate vegetation has increased notably in rabi season as well due to improved soil moisture conditions.

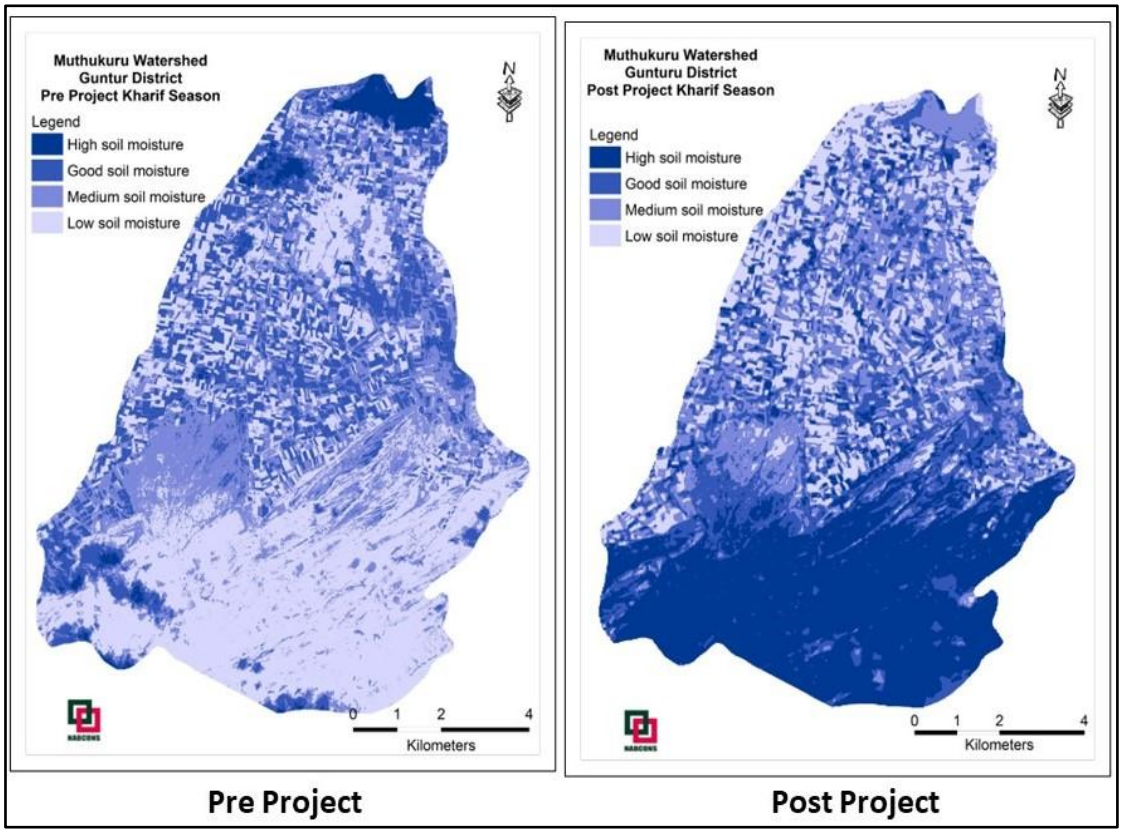

Fig 4: Map of NDWI classification for pre and post project period in Mutukuru watershed

Table 6: NDWI results for pre and post project period in Mutukuru Watershed

Soil Moisture Type	Pre Project		Post Project	
	Area (ha)	% of Total Area	Area (ha)	% of Total Area
High Soil moisture	244.5	2.5	3414.7	35.4
Good soil moisture	1925.5	20.0	2163.1	22.4
Medium soil moisture	3024.2	31.3	2492.1	25.8
Low soil moisture	4457.2	46.2	1581.5	16.4

4.3 Impact on Socio-Economic Status of the Watershed

Watershed development activities under PMKSY project had a significant positive impact on livelihood of farmers in Mutukuru watershed. LULC, NDVI and NDWI results concluded that the area under agriculture, vegetation and good soil moisture has increased evidently in Mutukuru watershed. This section will be discussing about how the changes in LULC impacted on socio-economic status of the people based on household surveys and focus group discussions.

Soil and water conservation structures and rain water harvesting structures built in the watershed area and rejuvenation of existing discarded bore wells helped to improve the ground water table and the period of stream flow in the watershed. The average depth of water in bore well increased by 5.35 m at the end of the project. As a result, area under irrigation expanded from 5.4 ha in the pre-project period to 6.8 ha in the post-project period.

Implementation of watershed projects in the area has facilitated in the increase of crop productivity of all the crops both in *kharif* and *rabi* seasons. The yield increase of crops in post project period was due to effectively conserving and utilizing the soil moisture and this was further facilitated by growing of high yielding crop varieties and adoption of recommended package of practices. As a part of the convergence in the watershed program, the farmers were supplied quality seeds with the help of Agriculture Department. The farmers in the watershed project area were also given necessary trainings on the latest agricultural practices through field demonstrations and exposure visits. The productivity of chilly, one of the major crops grown in the area, has increased by 7.1%. The details of crop productivity of different crops grown in the two micro watersheds during kharif and rabi seasons are given in Table 7.

Table 7: Crop Productivity (Qtl/Ac)

Sr. No.	MWS	Pre Project						Post Project					
		Kharif					Rabi	Kharif					Rabi
		Jowar	Red gram	Green gram	Cotton	Chilli	Bengal gram	Jowar	Red gram	Green gram	Cotton	Chilli	Bengal gram
1	Mutukuru	3.5	4.5	3.5	3.5	13.5	3.4	4.2	6.5	4.5	4.8	14.5	4.5
2	Kolagutla	3.3	4.6	3.7	3.2	13.3	3.7	4.4	6.8	4.3	4.1	14.2	4.2
	Average	3.4	4.5	3.6	3.3	13.4	3.5	4.3	6.6	4.4	4.4	14.3	4.3

Table 8: Occupational Pattern:

Sr. No.	MWS	Pre-Project (%)		Post-Project (%)	
		Agriculture	Non- Agriculture	Agriculture	Non- Agriculture
1	Mutukuru	82.4	17.6	86.5	13.5
2	Kolagutla	79.8	20.2	83.4	16.6
	Average	81.1	18.9	84.95	15.05

The average dependence on agriculture in Mutukuru watershed was 81.1% during the pre-project period. After the implementation of watershed project, it was observed that average dependence on agriculture sector has increased to 84.9% (Table 8). The average agriculture man-days increased from 125.5 to 173.5 in post project period. The average operational land holdings of the house hold surveyed in the pre-project period was 1.5 acres comprising of 1.3 acres of rainfed area and 0.2 acre of irrigated area. In 2022, the average operational holding has increased to 1.6 acres comprising of 1.1 acres under rainfed area and 0.5 acre under irrigation (Table 9). The NRM works and convergence of MGNREGS have also helped in increase of employment in non-agricultural related activities during project period. Average number of man days of non-agriculture work in pre project to post project period increased by 42.5 man-days/ year/ house hold. The wage earned by male and female members increased from Rs.325 to Rs.450 for men and Rs.275 to Rs.375 for women (Table 10). A reduction in number of migration workers was also noted by the end of the project. Due to the increment in the annual income per house hold, the number of students going to school have increased to 15.5%. During the project period three new school were opened taking the total number of schools in the watershed to 7.

Table 9: Average Operational Holdings (acre)

Sr. No.	MWS	Pre Project						Post Project					
		Source of Irrigation						Source of Irrigation					
		Rainfed	Irrigated	Tank/Pond	Check dam	Borewells/ Dugwells	Total	Rainfed	Irrigated	Tank/ Pond	Check dam	Borewells/ Dugwells	Total
1	Mutukuru	1.3	0.2	0	0	0.2	1.5	1.1	0.5	0.1	0	0.4	1.6
2	Kolagutla	1.4	0.2	0	0	0.2	1.6	1.2	0.5	0.1	0	0.4	1.7
	Average	1.3	0.2	0	0	0.2	1.5	1.1	0.5	0.1	0	0.4	1.6

Table 10: Wage Structur (Rs/day)

Sr. No.	MWS	Pre Project		Post Project		Difference	
		Men	Women	Men	Women	Men	Women
1	Mutukuru	350	300	500	400	150	100
2	Kolagutla	300	250	400	350	100	100
	Average	325	275	450	375	125	100

Number of milch cattle in the Mutukuru watershed increased by 23.3 %. The milk productivity in the watershed area improved by 8.7 % by the end of the project due to introduction of improved breeds, artificial insemination, supply of balanced nutrition, improved hygiene and health management in convergence with Animal Husbandry (AH) Department. Milk productivity improved in all the MWS ranging from 3.45 litre to 3.75 litre/ day. The total milk production per year increased by 33.9% in the mega watershed project (Table 11).

Table 11: Milk Production (Kilo ltr/year) & Productivity (ltr/year):

Sr. No.	MWS	Milk Productivity (Ltr/day)			Milk Production (Kltr/Yr)		
		Pre	Post	Diff	Pre	Post	Diff
1	Mutukuru	3.3	3.6	0.3	11.9	16.4	4.5
2	Kolagutla	3.6	3.9	0.3	13.0	16.8	3.9
	Average	3.45	3.75	0.3	12.4	16.6	4.2

Installation of Reverse Osmosis (RO) plants and introduction of piped water supply have significantly increased the availability of the water for drinking purpose in the post project period. There was no regular water supply in the piped water connections in the pre-project period. In the post project not only all the piped water connections have received regular water and 107 new connections were also added. The water supply per house hold has increased to 658 litre/ day at the end of the project period. The time spent in securing drinking water from source of supply was 20 minutes per day per household in the pre-project period, which considerably reduced to 14 minutes per day. Overall development activities under Mutukuru PMKSY mega watershed project had a positive impact on the socio-economic status of the region.

5. Conclusions

Muthukuru watershed had a significant growth in terms of area under vegetation, soil moisture and agricultural productivity after the implementation of watershed development activities. LULC results illustrated that area under agriculture land has increased by 10.8 % in kharif and 3.1 % in rabi season, which indicates the positive impact of soil conservation interventions under the project. The NDVI images demonstrated that there was a significant increase in the area under dense vegetation (13. 6%) and moderate vegetation (6.9%) in both kharif and rabi season. The output of the NDWI classification provided a key indication that there was a significant rise in soil moisture under the watershed project. The high soil moisture area increased by 33% in the post-project period.

LULC changes and increase in vegetated area and soil

moisture have positively impacted the socio-economic status of the people in Mutukuru watershed. The percentage of people depending on agriculture has increased and an average increase of Rs 100 was identified in daily wages. Accordingly, there was a hike in average annual income per household, which lead to increased literacy rate in the watershed and number of migration workers were reduced. Milk productivity of the watershed improved by 8.7%. Installation of piped water connections considerably reduced the distance travelled to collect drinking water and increased the quantity available to households. Based on the above results, it is concluded that in the Muthukuru watershed, LULC changes had made a significant positive impact in the lives of people.

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