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Impact Analysis of Kurichedu *PMKSY* Watershed Project on Land Use, Water Resources, Crop and Livestock Productivity in Prakasam District, Andhra Pradesh, India

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A B S T R A C T

The study was piloted to assess the impact of watershed project interventions from 2011-2018, largely Natural Resource Management (NRM) and Production System Improvement (PSI) measures in Kurichedu *PMKSY* watershed project, Prakasam district, Andhra Pradesh. The specific objectives included detecting changes in agricultural land use, water body surface area, soil moisture; ground water levels, crop diversification, crop yields and livestock productivity. The net treatable area of the project is 4311 ha. Area under cultivated crops, both agriculture and horticulture crops increased by 414 ha, accounting to 16.6% over pre project period. The NRM activities augmented total water body surface area from 57 ha to 67 ha (17.5%).Ground water table was mainly impacted by deficit rainfall. In *kharif* season, the area of rice and plantation crops are reduced, while the area of red gram, cotton and chilli improved. In *rabi* season, the area of tobacco decreased. The horticultural crop area in post project period increased by 84 ha. The productivity of both agricultural and horticultural crops increased during the project period. The yield increase ranged from 2.0 percent in red gram to 12.1 percent in cotton. The milk productivity enhanced from 2.3 to 3.2 L per animal per day with total milk production increase by 15.8 percent. The milk production increase per year in the project period is mainly due to higher milk yield per day per animal.

Introduction

Kurichedu in Kandukur division of Prakasam district, Andhra Pradesh is characterized with dry climate that has fluctuating amounts of rainfall, which often result in drought leading to scarce ground water resource, frequent insufficiency of food and fodder. The arable

area is mostly rain fed with low productivity. Current rain fed farmer's crop yields in India are lower by 2- 5 folds than the achievable potential of rain fed agriculture and this potential needs to be tapped by adopting integrated watershed management approach on a large scale. The semi-arid tropics suffers from one or other kind of natural resource and other production base degradation (Grewel *et al.*, 2001). Conservation of Natural resources would be the foremost challenge, particularly in arid and semi-arid tropics. In such a scenario, it is imperative to conserve natural resources and provide livelihood security through adopting integrated watershed management interventions. In reflection of these ground conditions, the *PMKSY* Watershed Development Component (erstwhile IWMP) is considered. Integrated watershed management has been a prominent approach for resource conservation and livelihood security in these areas (Samra 1997), to influence the productivity and production of crops, augment water resources, changes in land use and cropping pattern, adoption of modern technologies, increase in milk production, etc.

The purpose of the present study was to assess the impact of watershed project interventions such as NRM and PSI measures. The specific objectives included detecting changes during the project implementation period from 2011-2018 in terms agricultural land, water body surface area, soil moisture, ground water levels, crop diversification, crop yields and the livestock productivity, leading to sustainable agriculture and livelihoods for endurable overall development of stakeholders in the watershed area.

Study Site

The present study watershed project was implemented during 2011-18 in Kurichedu, located in DPAP block of Kurichedu *Mandal*, Prakasam district (Fig.1). This *PMKSY* watershed is located between latitude 15°46'87" and longitude 79°35'44" at ridge point and between latitude 14°65'78" and longitude 79°33'21" at valley point. Highest point in the watershed is 30 m above the MSL. The net treatable area is 4311 hectares.

The average annual rainfall in the area is 771.2 mm. The temperatures in the area are in the range of 42.17°C during summer and 25°C during winter. There are 2847 households in the project with a total population of 13,250, inclusive of major social communities like SC-1830, ST-740, BC-5000, Minorities-430, others- 5250. The six Micro Watersheds (MWS) in the watershed project are Bayyaram, Kurichedu, Perambotla Palem, West Veerayapalem, Namahsivayapuram, and Mallayapalem.

Material and Methods

The change in land use and cover was assessed by integrating remote sensing and geographic information systems (GIS). The classified images having different land use land cover categories pertaining to pre and post treatment period were compared to derive information on changes. Remote sensing of vegetation liquid water from space was based on Normal Difference Water Index (NDWI); a satellite derived index from Near- Infrared (NIR) and Short-Wave for calculation of soil moisture. Survey of India Topo sheet in 1:50,000 scale has been consulted for the study of the watershed boundaries. Remote Sensing techniques of parametric models were used to measure the soil loss using the Universal Soil Loss empirical Equation (USLE).

The depth to ground water level in the project area was recorded in pre and post monsoon season during the project period. Piezometers were used as observation wells for recording

groundwater levels. In the project area, two piezometers were installed, one each in the recharge zone (intermediary region) and storage zone (valley region). Month-wise rainfall data as recorded at mandal-level (administrative unit in Andhra Pradesh) was collected for the project period (2011-2018) and presented as annual rainfall received against the normal rainfall. Statistical tools like measures of central tendency (mean value) measures of dispersion (standard deviation) and coefficient of variation were computed.

A total of five percent of households in the project were interviewed during September-October 2019 to collect information on crop yields, crop diversification as well as their livestock wealth by developing a survey tool to capture the relevant information. Another qualitative research tool is used to collect data through focus group discussion (FGD) from each micro watershed. The focus group comprises a small number of watershed community to discuss and assess their perceptions on the impact of watershed interventions on natural resource conservation and use, sustainability of crop and livestock production etc. This was further reinforced with the ancillary data sources, chiefly related to NRM and PSI activities from the Management Information System (MIS) of State Level Nodal Agency, Andhra Pradesh. Quantitative analysis (statistical and numerical) was later carried out to assess and quantify the impact of watershed interventions, wherever necessary.

Results and Discussion

Impact on Land Use Land Cover

In this study, before and after project satellite data was used to evaluate the following landscape changes during the project period from 2011-2018. The satellite imagery for land use land cover are given in Fig-2 and the data for agriculture crop land area and water body surface area are provided in Table 1 and 2.

Change detection in agriculture land use

Change in agriculture land use was assessed by integrating remote sensing and geographic information systems (GIS). These are now providing effective tools for advanced ecosystem and socio economic management (InzamulHaqueMdand RonyBasak, 2017). The Area under cultivated crops, both agriculture and horticulture crops increased by 414 ha, accounting to 16.6% over pre project period (Table-1).Watershed interventions showed significant modification and conversion of land use and cover of the watershed (FikirAlemayehu *et al.*, 2009). Further, land use for agriculture and horticulture crops as assessed qualitatively by field visit through Focus Group Discussion (FGD) with beneficiaries and other sources of the project show that out of these 414 ha of crop area increase, 286 ha are agricultural crops and 128 ha horticultural crops. Agriculture crop area increased by 14.3% in *kharif* season, while the area in *rabi* season decreased from 217 to 189 ha (12.9%). Greater impact was observed in cultivation of horticultural crops, particularly fruit crops with change in area from 75 to 203 ha (170.7%) at the end of project period. The agriculture land area increased during the project period with change in area under vegetation (agro-plantations) and forest. Watershed interventions such as soil and moisture conservation measures, harvesting of rain water and recycling, development of waste lands and fallow lands resulted in land use change. Study of Amee K. Thakkar *et al.*, (2017b) showed an increase in agricultural land and decrease in scrub forest over the period of ten years. The watershed management programs in semi-arid regions

showed significant increase in agriculture crops (Nagaveni and Ravibabu, 2017).

Change detection in surface water

Land use land cover study detected positive change in water body surface during the project period (Table-2).

The thrust area of watershed program for rain water harvesting through natural resource management structures such as farm ponds, percolation tanks, check dams and repairs to existing structures has facilitated effective management of rainfall with improved water storage.

All the NRM activities listed in Table-3 augmented total water body surface area from 57 ha to 67 ha (17.5%). The key land use land cover changes at watershed level in terms of the water body was reported by Amee K Thakkar *et al.,* (2017a).

A number of water harvesting structures are taken up utilizing the funds from WS allocations and in convergence with MGNREGS of Govt of India flagship program; especially the farm ponds, inclusive of dugout ponds, and repairs to existing check dams (Table-3). Convergence of various rural development programmes around the watershed ensured holistic development of watershed areas (Palanisamia and Suresh Kumar, 2009). Implementation of Watershed program has resulted in increase of irrigated area at the end of project period. Overall there is an increase in the irrigated area in the project period to an extent of 4.8 percent in the watershed project.

The expansion in irrigated area due to watershed development activities has been found from 5.6 percent to 68.0 percent across regions and seasons (Palanisamia K and Suresh Kumar, 2009).

Impact on Soil Moisture

Changes in soil moisture was measured based on Normal Difference Water Index (NDWI). Watershed interventions influenced the soil moisture in project areas (Ranjit Basha *et al.*, 2019). The area under low and medium soil moisture improved by 116 and 115 ha, respectively during the project period. However, the area under good soil moisture declined by 236 hectares (Table-4). The soil moisture conservation measures and plantations executed during project period (Table-5) especially in ridge and middle areas of the project under *PMKSY* and MGNREGA has benefited in moisture conservation in low and medium soil moisture areas, while similar impact was not observed in good soil moisture areas.

Category wise soil moisture conservation measures such as staggered trenches in hillock areas, digging peripheral trenches and greening of hillocks; and bund plantations are taken up on private and CPR lands(Table-5). Construction of marginal field bundings, gabions on primary streams, water spreaders in depressions and series of check dams on secondary and tertiary streams in treated watershed reduced the soil and nutrient losses in comparison to untreated watershed (Palsaniya *et al.*, 2012).

Impact on Ground Water

Knowledge about the seasonal groundwater depth provide a vital element with regard to usage and management of groundwater. The ground water level varies with variability in the intensity, recharge, draft and runoff of rain water (JimmiDebbarma and Nibedita Das, 2019).The depth of water table as measured with piezometers show a drop in depth of water table from 6.02 m to 6.85 m bgl (Table-6), in spite of several Soil Moisture Conservation works (SMC) and Water

Harvesting Structures (WHS). Ground water table was mainly impacted by deficit rainfall received in six years, out of eight years, of project implementation; increase in area under irrigation; drawing water from deeper depths; and increasing bore well number. Spatio-temporal change in pre and post-monsoon groundwater level reveals declining trend in groundwater, which may result into lowering of groundwater table, deterioration in the quality of water, and drying up of wells etc. (Jimmi Debbarma and Nibedita Das, 2019).

Rainfall

The actual rainfall received year wise against normal for the project period from 2011 to 2018 are provided in Table-7. In the year 2018, the rainfall received is only 273.8 mm against normal of 771.2 mm. The mean rainfall across the project period is 560.8 mm. The amount of variability or dispersion from the individual data values to the mean is worked out by computing the standard deviation. The computed Standard deviation value of 290.0 showed greater spread of a data distribution. The higher Co-efficient of Variation (CV) value clearly show greater level of dispersion around mean rainfall. Against normal rainfall of 771.2 mm, the actual rainfall was below normal in six years ranging from 13.5 to 181.7 % and above normal by 34.6% in just one year. A strong negative correlation observed between rainfall and groundwater level in pre-monsoon and post-monsoon seasons, which indicate that as rainfall increases the depth of groundwater decreases both in pre and post-monsoon periods (Jimmi Debbarma and Nibedita Das, 2019).

Impact on Soil Erosion

Survey of India Toposheet (Fig.3) in 1:50,000 scale has been consulted for the study of referencing and elevation information. The elevation difference between the minimum and maximum elevation contours of SOI topo sheet is 20m only. The study shows no soil erosion in either of the satellite imageries of LISS IV data and with a spatial resolution of 5.8m. Thus, number of positive effects have resulted, like reduced sedimentation; reduced rainfall runoff; increased recharge of surface and sub-surfaces oil moisture; stabilization of gullies and banks of natural streams; and rehabilitation of degraded lands.

Wolka Kebede (2014) reported promising effects of SWC measures on reducing soil loss, trapping a significant quantity of sediment at early stages and improving soil moisture; crop yield improvement especially after two to five years of the structure in low rainfall areas.

Impact on Crop Diversity

The annual crops as rice, red gram, jowar, cotton, chilli; plantation crops like eucalyptus, subabul; fruit crops such as acid lime, papaya and guava are grown in *kharif* season with shift in extent of areas.

Distribution of crop area (%) depicted in Fig. 4 show reduction in area under rice and plantation crops, while increase in pulses, cotton and chilli at the end of project period in *kharif* season. In *rabi* season, mostly tobacco, bengal gram and castor are grown in pre and post project periods, but the area under tobacco decreased.

The horticultural crop area in post project period increased by 84 ha. In addition to the acid lime, papaya and guava, the other fruit crops like papaya and apple ber are taken up during the project period. Crop area distribution in pre and post project period show that red gram occupy 32.8- 34.4% of total cultivated area followed by cotton (18.6-20.1%), Chillies (11.5-12%).

Table.1 Change detection in agriculture land use

Land Use Class	Pre project	Post project	Change	
	Area, ha	Area, ha	Area, ha	Percent
Agriculture crop land	2489	2903	414	16.6
i. Agriculture	2414	2700	286	11.8
kharif	2197	2511	314	14.3
rabi	217	189	28	12.9
ii. Horticulture	75	203	128	170.7

(Source: NABCONS 2020a&b)

Table.2 Change detection in water body surface area

Land Use Class	Pre project	Post project	Change	
	Area, ha	Area, ha	Area, ha	Percent
Water body	57	67	10	17.5

(Source: NABCONS 2020b)

Table.3 Category wise water harvesting structures in watershed project

Activity	Number		
	PMKSY	MGNREGS	Total
Farm Pond	-	239	239
Mini Percolation Tank	59	-	59
Dugout Pond	128	262	390
Percolation Tank	10	-	10
Check Dam	22	-	22
Recharge Pit	-	46	46
Repairs to Existing Check Dam	-	6	6

(Source: IWMP AP MIS. 2020a)

Table.4 Change detection in soil moisture

Soil Moisture Type	Pre Project	Post Project	Change	
	Area, ha	Area, ha	Area, ha	Percent
Low Soil Moisture	84	200	116	138
Medium Soil Moisture	3155	3270	115	3.64
Good Soil Moisture	3175	2939	236	7.43

(Source: NABCONS 2020b)

Table.5 Category wise soil moisture conservation measures and plantations

Activity	Number		
	PMKSY	MGNREGS	Total
Staggered Trenches (Hillock Areas)	1	0	1
Digging of peripheral trench with machine	1	0	1
Greening of Hillocks	0	1	1
Block Plantation in Private Lands	4	0	4
Bund Plantations	27	47	74

(Source: IWMP AP MIS. 2020a)

Table.6 Depth to ground water levels in the project area

Year	Depth to water level, bgl in metres	
	Pre monsoon season (May)	Post monsoon season (November)
2011	4.86	5.59
2012	5.98	4.26
2013	6.77	1.00
2014	4.16	4.36
2015	5.27	5.56
2016	7.36	5.83
2017	6.06	4.59
2018	5.81	6.86

(Source: GW&WAD.2019)

Table.7 Annual Rainfall during the project period

year	Total Rainfall, mm (Jan-Dec)			
	Actual	Normal	% of Normal	Above/Below
2011	346.2	771.2	(-) 122.8	Below
2012	798.0	771.2	3.4	Normal
2013	1179.2	771.2	34.6	Above
2014	293.1	771.2	(-) 163.1	Below
2015	468.1	771.2	(-) 64.8	Below
2016	448.7	771.2	(-) 71.9	Below
2017	679.5	771.2	(-) 13.5	Below
2018	273.8	771.2	(-) 181.7	Below
Mean	560.8			
SD	290.0			
CV %	51.8			

(Source: IMD, 2020)

Table.8 Type of PSI Activities in convergence with departments of agriculture and horticulture

Activity type	Number
Custom Hiring Center for Farm Machinery	7
Farm Implements individual	35
Individual High cost Machinery	2
Sprinkler Irrigation System	1
Water Carrying Pipes	114
Tarpaulin Sheets	15
Silpaulins (60x40 with 120 guage)	2
Vegetable Mini Kits for Kitchen Garden	150

(Source:IWMP AP MIS. 2020b)

Table.9 Mean Crop Yields in Pre and Post project Period

Crop	Unit	Crop Yield		
		Pre project	Post project	% of Change
Rice	q/ha	53.9	55.6	3.2
Jowar	q/ha	10.8	12	11.1
Red gram	q/ha	9.8	10	2.0
Cotton	q/ha	14.9	16.7	12.1
Chilli (dry)	q/ha	27.6	28.4	2.9
Tobacco	q/ha	16.4	17	3.7
Bengal gram	q/ha	12	13.1	9.2
Castor	q/ha	8.2	9	9.8
Subabul	t/ha	33.1	35	5.7
Eucalyptus	t/ha	31.2	32.3	3.5
Papaya	t/ha	-	44.7	-
Acid lime	t/ha	22.1	23	4.1
Guava	t/ha	18.1	19.6	8.3
Apple ber	t/ha	-	12.4	-

(Source: NABCONS 2020a)

Table.10 PSI Activities for animal health coverage and infrastructure development

Activity	Number
Animal Health Coverage	
Animal Health Camps	22
Fertility Camps	22
Feed supply to pregnant animals (last 100 days)	372
Infrastructure Development	
Establishment of Travices	10
Livelihood Pursuit	
Buffaloes for dairy	38

(Source:IWMP AP MIS. 2020b)

Table.11 Milch cattle, milk production and productivity

Indicator	Unit	Pre Project	Post Project	% Change
Milch Cattle	Number	2550	2054	(-) 19.5
Milk	L/day	2.3	3.2	41.6
Milk Production	KL/Year	5839	6759	15.8

(Source: NABCONS 2020a)

Fig.1 Location map of *PMKSY* Watershed Project

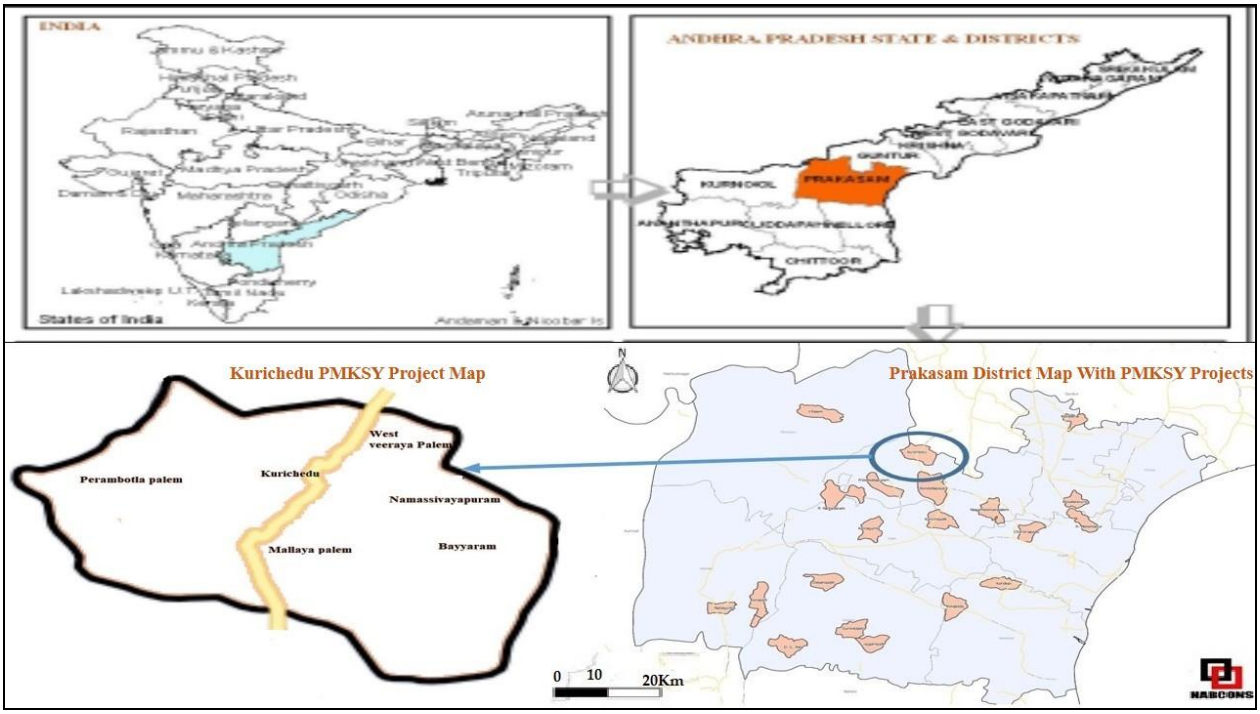


Fig.2 Land use Land cover (a) year 2011and (b) year 2018

A B

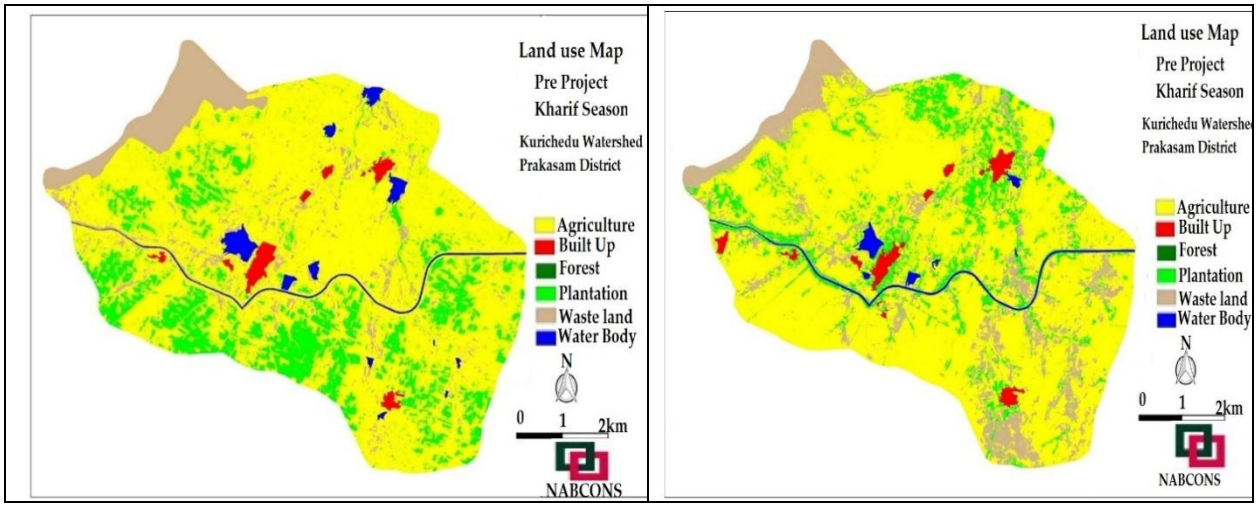


Fig.3 Toposheet of Watershed Project

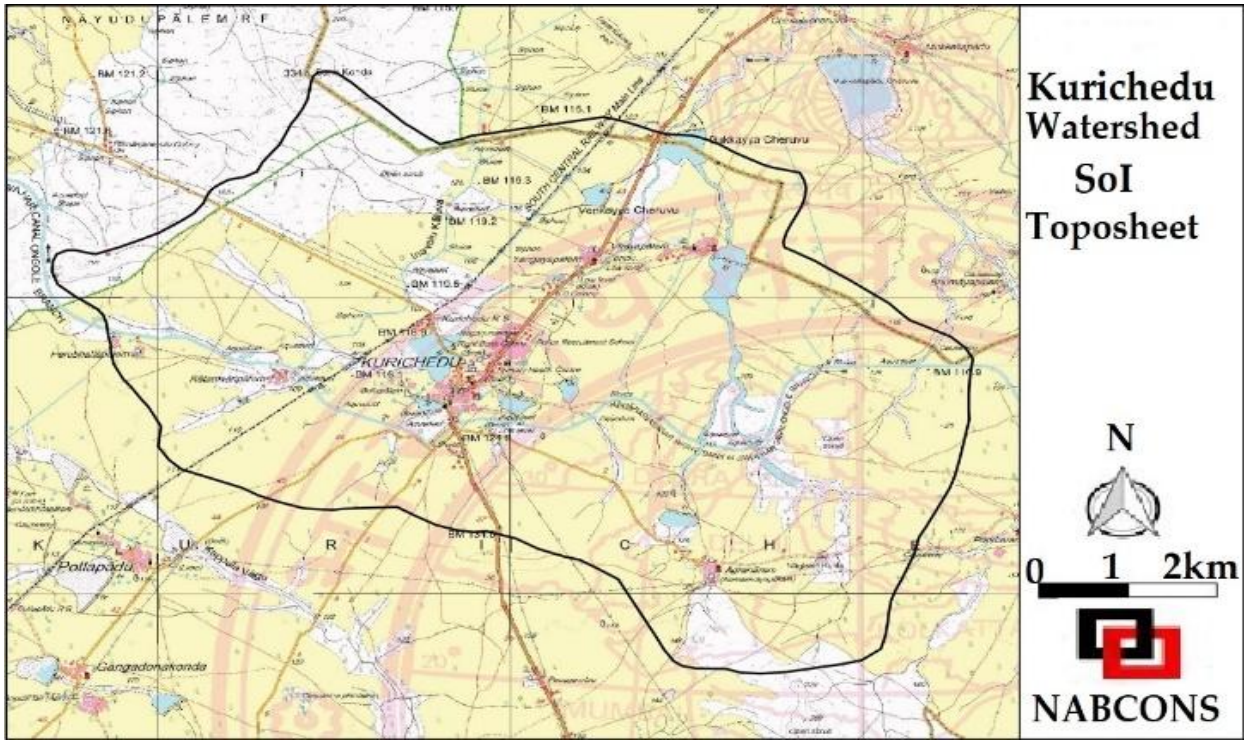
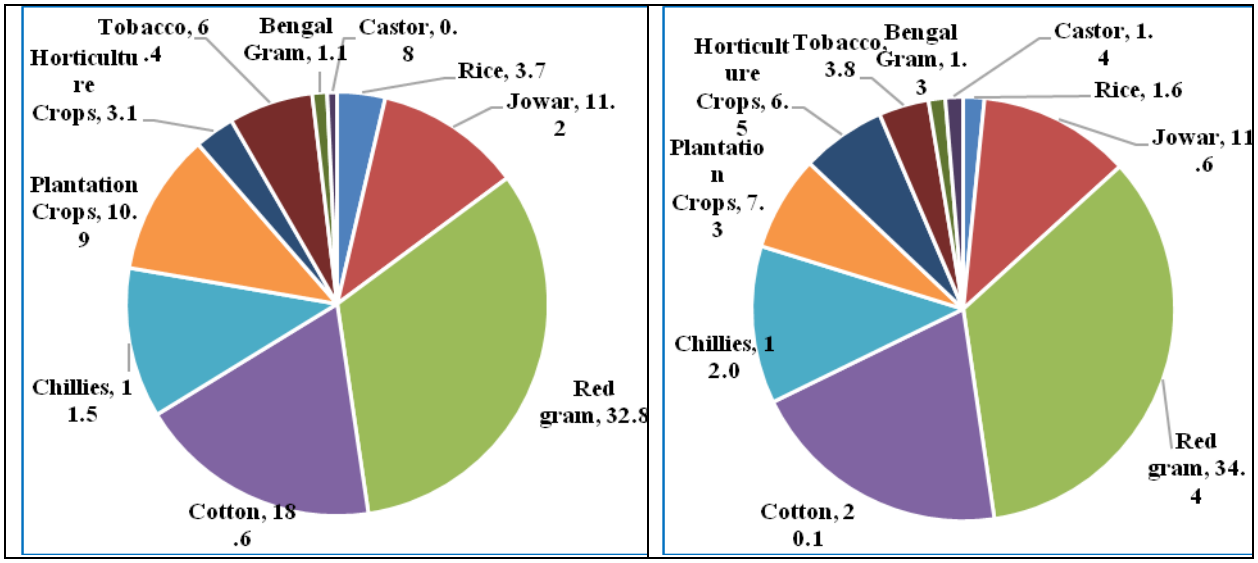


Fig.4 Cropping Pattern in Pre and Post Project period



Availability of water resources changed the crops and cropping pattern in all the season in the watershed area (Garima Sharma and Sharma, 2020). The cropping pattern changes occur in areas under rain fed cultivation and well irrigation (Palanisamia and Suresh Kumar, 2009).

Impact on Crop Productivity

The per hectare economic yield of all major crops in the post project period was higher due to growing of high yielding crop varieties, adoption of recommended package of practices, effectively conserving and utilizing the soil moisture and rainfall. Convergence with agriculture and horticulture departments and associated production system improvement (PSI) activities (Table-8) have helped the farmers. Besides, the farmers were involved in capacity building (CB) programs of training, field demonstrations and exposure visits.The increased productivity in watershed is attributed to enhanced water availability for irrigation, spread of high yielding variety seeds (>70% farmers use high-yielding seeds), optimum and balanced use of fertilizers, etc. (Palsaniya, 2012).

In respect of individual crops, the productivity of both agricultural and horticultural crops increased during the project period. The yield increase ranged from 2.0 percent in red gram to 12.1 percent in cotton (Table-9). The yield of crops are more due to adoption of improved cropping practices, conservation of soil moisture and judicious utilization of available irrigation, growing of high yielding varieties, timely credit supply etc. Yield increase was higher in jowar, cotton, castor and bengal gram. Among fruit crops, guava yielded higher (8.3%), followed by acid lime (4.1%).

Impact on Milk Productivity

Project interventions inclusive of PSI activities in convergence with Animal Husbandry department like animal health camps, fertility camps, establishment of travices, supply of improved breeds (Table-10) to landless poor, marginal and small farmers, beside supply of fodder seed for green forage especially during lean (summer) months has impacted in achieving higher milk productivity in the project period. However, the milch cattle population during the project period decreased from 2550 to 2054 (19.5%),

in spite of supply of milch cattle to certain households. In a study by Reena *et al.,* (2019) found that watershed development programs had weak impact on the population of livestock in watershed areas of Hisar and Kaithal districts of Haryana State. The decrease in cattle number is due to lack of interest among households, non-availability of labour for cattle rearing, increase in wages, shortage of open grazing lands, shortage of fodder supply, unremunerated price etc. and recurring drought conditions. Even though cattle population decreased, the total milk production increased by 15.8 percent from 5839 to 6759 KL/Yr(Table-11).The milk production increase per year in the project period is mainly due to higher milk yield per day per animal due to supply of improved breeds, artificial insemination, improved hygiene, improvement in lactation period, health management and balanced nutrition. The households who own milch cattle have additional or supplementary income to meet the family expenditure, even during drought years.

Implementation of key components of watershed interventions, mainly Natural Resource Management(NRM) and Production System Improvement(PSI) along with other activities, in convergence with the schemes or programs like MGNREGA and participation of related line departments of Government such as agriculture, horticulture, animal husbandry and rural development has impacted in sustainable agriculture area, crop productivity and milk yield, in spite of six deficit rainfall years and reduced ground water resources. This study confirms the importance of *PMKSY* watershed interventions as vital for poverty alleviation and sustainable livelihood.

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