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RESEARCH ARTICLE

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Development of Watershed Programme for Environment and Agriculture Sustainability in SAT Region, Central India

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ABSTRACT

Background: Study has been undertaken in SAT (Semi-arid tropics) region located between 23° 8′- 26° 30′ latitude and 78°11′- 81°30′ longitude with an altitude varying from 230 to 280 m above mean sea level (MSL), Central India for assessing the impact after interventions of natural resource management (NRM) under watershed development programme. Agricultural productivity of Semi-arid tropics oscillates between 0.5 and 2.0 ton ha^{-1} with an average of one ton per ha (Rockstrom *et al*., 2010; Wani *et al*., 2011a, 2011b). The main objectives of this study are to establish agroforestry based crop cultivation which provides nutritional food as well as transform the mankind's living status and also supports the doubling farmer's income goal without associated ecological harm.

Methods: To evaluate the economic feasibility and crop productivity along with agroforestry was worked out on the basis of survey and sampling. To get uniform samples of crops from cultivated fields some specific area selected (1 m × 1 m size) and get about 80 crop samples for measurements from whole watershed. All data has been collected through survey of 40 % households of watershed and then all these data subjected to statistical analysis in the laboratory. To minimize the problem and rejuvenate the water body, water resource development plan helps in identify the available sources so that appropriate and effective with durable solutions can be formulated. The net return of crop cultivated was calculated by subtracting the cost of cultivation incurred from sowing to harvesting, for each crop from the gross return and then benefit-cost ratio was estimated for further improvement or scaled up and livelihood security of former.

Result: The study has revealed that after watershed interventions and agroforestry based Crop cultivation, water level increased 2-6 m, crop production increased by 45-47%, cropping intensity increased 97-98% from 44-46% and migration decreased by 70-72%. During both season, the expenses on irrigation and labour will decrease, crop productivity will improve and benefit-cost ratio increased. Nutrition based food production provided the base for food security as it is a key determination of food availability.

Key words: Crop cultivation, Human population, NRM, SAT region.

INTRODUCTION

Water availability for enhancing agriculture productivity, livelihood security, employment generation and agroforestry based cropping system is an important concern. Due to continuous increase in population, the consumption of water are rapidly increasing. Such a great demand of water can be accomplished only by ground water. Maintain the availability of ground water, natural resource management interventions have to use because ground water depleted at 10-25 mm per year in India and nearly 600 million Indians facing high to extreme water stress. Where more than 40% of the annually available surface water is used every year. Due to inadequate access to safe water about 2,00,000 people dying every year, the situation is likely to worsen as the demand for water will exceed the supply by 2050 (CWMI, 2018). 24 Indian cities will run out of groundwater by 2020, affecting 100 million people; 40% of India's population will have no access to drinking water by 2030 (NITI Ayog, June 15, 2018).

India's agricultural land is 142 million ha with 135% cropping intensity (NAAS, 2009) and 60% is rainfed which is characterized by water scarcity, land degradation, low inputs use and low productivity. Agricultural productivity of these areas oscillates between 0.5 and 2.0 ton/ha with average of one ton per ha (Rockstrom *et al*., 2010; Wani *et al*., 2011a, 2011b). Irrigated land which covers 40% of total agricultural area significantly contributes in satisfying 55% of total food requirement of the country (GOI, 2012) but on the other hand it consumes almost 70% of fresh water resources and has left limited scope for expanding irrigated area further (CWC, 2005). Thus achieving food security of the country in future is largely dependent on rainfed agriculture (Wani *et al*., 2009, 2012).

Here, this study interpretates the analysis in SAT region, central India of natural resource management which improve

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ecosystem services, increase the life living status of mankind specially formers and maintain the environmental status.

MATERIALS AND METHODS

This Study was carried out in SAT region located between 23° 8′- 26° 30′ latitude and 78°11′- 81°30′ longitude with an altitude varying from 230 to 280 m above mean sea level (MSL). The annual rainfall of study area varies from 800 to 1300 mm, about 90% of which is received during South-West monsoon period. Long-term data analysis showed that annual average rainfall has decreased from 950 mm between 1944 and 1973 as compared to an average of 847 mm between 1974 and 2004. This reduction was mainly due to decreased number of low (0-10 mm) and medium rainfall (30-50 mm) events (Singh *et al*., 2014). The length of growing season in this region ranges between 90 to 150 days depending upon rainfall and temperature regimes. Low rainfall and drought are common features.

The agro-climate is characterized by dry and hot summer, warm and moist rainy season and cool winter with occasional rain showers. Mean annual temperature ranges from 24 to 25°C. The mean summer (April-May-June) temperature is 34°C which may rise to a maximum of 46 to 49°C during the month of May and June. The mean winter temperature (December-January-February) is 16°C which may drop to 3-5°C in December and January.

The geology of the study area is dominated by hard rocks of Archaen granite and gneiss and largely composed of crystalline igneous and metamorphic rocks (Tyagi, 1997), Due to undulated topography, poor groundwater potential, high temperature, poor and erratic rainfall, agricultural productivity in this region is very poor (0.5-1.5 t ha^{-1}).

Data collection

Monitoring of crop productivity

The area and productivity of cultivated crops were noted yearly through survey and sampling. To get uniform samples of crops from cultivated fields some specific area selected (1m×1m size) and get about 80 crop samples for measurements from whole watershed (Fig 1). All data has been collected through survey of 40 % households of watershed and then all these data subjected to statistical analysis in the laboratory.

Fig 1: Crop sample collection for analysis.

Water resources development plan

Low rainfall, long dry spells and droughts are common features of the watershed and due to that result water scarcity problem increased. To minimize the problem and rejuvenate the water body, water resource development plan helps in identify the available sources so that appropriate and effective with durable solutions can be formulated. The irrigation intensity has been enhanced through improved recharge of these wells by constructing rainwater harvesting structures at appropriate interval in the ephemeral drains. In water resource development plan various interventions were adopted such as checkdams, low cost checkdams, nalla plug, gabions, spillways, bunding and resized filed along with agroforestry.

Economic feasibility of crop production

To evaluate the economic feasibility of crop production, the economics of all the crops grown during kharif and rabi was worked out. All the fields were digitized in the QGIS environment and the coverage of different crops in both the seasons was marked on a map and estimated using QGIS version 2.6.1. All the in formations about the crops production and its impaction on employment generation were gathered by personal interview using well-structured questionnaires. The net return of crop cultivated was calculated by subtracting the cost of cultivation incurred from sowing to harvesting, for each crop from the gross return and then benefit-cost ratio was estimated for further improvement or scaled up and livelihood security of former.

RESULTS AND DISCUSSION

Plan to augment of water resources

Watershed development program is a best and appropriate technology to rejuvenate the riverine system as well as to enhance the recharge of shallow open dug wells during rainy season. It improves the yield of wells for sustainable irrigation and water supply for crop cultivation. The water availability in watershed has increased in time and scale. Interventions are developed in cost effective with sustainability. These water management interventions included checkdams, low cost checkdams, nalla plug, gabions, spillways, bunding and resized filed etc. supports to enhance the water availability and generate the base flow 2-3 times and increase the water level 2-6 m results the supply of water during whole year (Table 1).

Transformation of watertable depth and its behaviour

After interventions, runoff reduced with increasing infiltration rate which generate the base flow and this base flow increases the water level in the shallow wells as well as rejuvenate the riverine system by enhancing groundwater recharge. Average water column for the months of June and October was recorded as 1.95 and 4.32 m respectively.

Water column depth is being satisfactory in whole year through generation of base flow by 2-3 times and increased the water table by 2-6 m (Fig 2).

Transformation of crop productivity

Crop production of *rabi* crops

The productivity of major *rabi* crops like wheat, gram, pea, mustard and barley was increased and maximum production was also recorded in wheat crop which increased about 82.22% as compared to rest crops while overall production was increased by 45.75%. The productivity of wheat and mustard crops is increased rapidly while in gram, pea and barley production gradually increased (Fig 3).

Table 1: Water level fluctuation during pre and post-monsoon at different levels.

Before interventions			After interventions		
Pre-monsoon (m)	Post-monsoon (m)	Change in hydraulic head (m)	Pre-monsoon (m)	Post-monsoon (m)	Change in hydraulic head (m)
1.60	3.92	2.32	1.30	5.40	4.10
1.30	2.88	1.58	0.05	2.07	2.02
Dry	2.74	2.74	0.60	4.40	3.80
1.60	3.17	1.57	2.29	4.60	2.31
Dry	1.70	1.70	Dry	1.64	1.64
Dry	1.94	1.94	5.40	7.30	1.90
Dry	1.50	1.50	1.05	3.54	2.49
Dry	2.00	2.00	0.30	2.63	2.33
Dry	2.51	2.51	2.21	4.75	2.54
Dry	1.66	1.66	5.22	7.90	2.68
Dry	2.16	2.16	2.10	3.10	1.00
2.00	3.10	1.10	1.46	3.05	1.59
1.30	3.38	2.08	1.17	2.62	1.45
Dry	1.83	1.83	1.05	1.53	0.48
1.40	3.46	2.06	Dry	1.34	1.34
1.80	3.40	1.60	4.70	7.07	2.37
2.20	3.30	1.10	0.98	2.60	1.62
Dry	1.75	1.75	2.55	4.95	2.40
Dry	3.10	3.10	3.06	6.15	3.09
1.50	3.49	1.99	3.20	5.50	2.30
1.30	2.81	1.51	2.72	5.15	2.43
1.40	3.74	2.34	2.95	6.15	3.20
Dry	2.46	2.46	2.25	4.25	2.00
1.50	3.74	2.24	4.30	6.90	2.60
1.70	3.08	1.38	1.47	4.75	3.28
1.80	2.83	1.03	3.00	5.10	2.10
1.60	3.60	2.00	3.62	5.85	2.23
Dry	3.38	3.38	4.71	7.06	2.35
2.00	3.17	1.17	3.95	7.39	3.44
Dry	2.02	2.02	Dry	4.46	4.46
2.10	3.67	1.57	Dry	4.25	4.25
Dry	3.10	3.10	2.50	6.62	4.12
Dry	2.68	2.68	1.89	5.43	3.54
1.90	3.30	1.40	1.05	6.00	4.95
2.00	3.30	1.30	3.90	5.64	1.74
Dry	2.70	2.70	Dry	3.00	3.00
1.80	3.02	1.22	0.50	4.60	4.10
1.40	2.50	1.10	2.80	5.45	2.65
Dry	2.23	2.23	2.50	4.58	2.08
1.70	3.40	1.70	2.54	5.22	2.68
2.20	3.60	1.40	1.15	5.80	4.65
2.00	3.17	1.17	2.50	8.03	5.53

Crop production of kharif crops

After interventions of NRM, productivity of kharif crops *viz.* sorghum, groundnut, sesame and black gram was increased and maximum production was undertaken in sorghum as 0.55 tonne/ha with respect to overall production of 1.26 tonne/ha for *kharif* crops. Overall transformation of production in *kharif* crops was observed in increasing nature and recorded as 46.32%. The graph of crops production shows that production of sorghum is more effective after interventions of NRM comparison to remaining crops (Fig 4).

Transformation of cultivated area and cropping intensity

Changes in cultivated area under *rabi* crops

Availability of sufficient amount of water for irrigation is a great challenge for such type of area but after interventions of NRM patches of crops and cultivated area increased *viz.* wheat, gram and barley by 148, 23, 5.72 ha, respectively (Table 2). The cropping intensity increased by 98.39 % from 46.39%. The cultivated area increased rapidly for wheat crops and gradually for area of pea and mustarded crops reduced and it shifted for wheat crops due to availability of sufficient amount of water and less risk of damage (Fig 5).

Changes in cultivated area under *kharif* crops

The area for *kharif* crops increased as well decreased at different levels *viz.* 6.10, 12.60, 109.30 and 8.60 ha corresponding to crops as sorghum, groundnut, sesame and blackgram with respect to overall 142.70 ha cultivated area (Table 3). Cropping intensity was recorded as 52.26% after interventions of NRM. After interventions of NRM the maximum area covered by sesame crops as compared to others due to less expenditure and less protection and cultivated area also minimized of rest crops (Fig 6).

Table 2: Impact of interventions in cultivated area during *rabi* season.

Parameters	Before intervention culivated area (ha)	After intervention culivated area (ha)
Wheat	54	200.7
Gram	13.5	36
Pea	27	11
Mustard	20.3	10
Barley	3	8
Others	17.2	12

Table 3: Impact of interventions in cultivated area during *kharif* season.

Parameters	Before intervention culivated area (ha)	After intervention culivated area (ha)
Sorghum	24.5	6.2
Groundnut	14	12.5
Blackgram	10.5	107.9
Sesame	12.6	8.8
Others	8.4	5.5

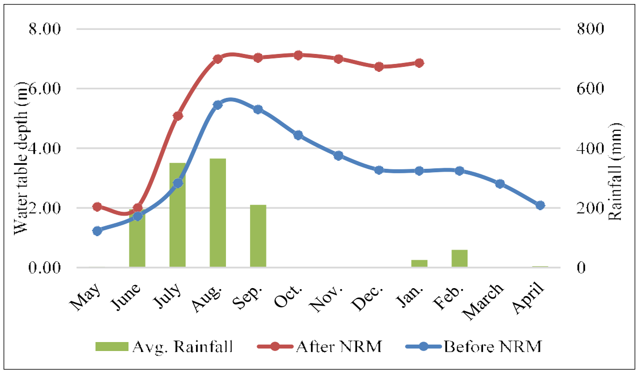

Fig 2: Fluctuation of water table with relation to rainfall.

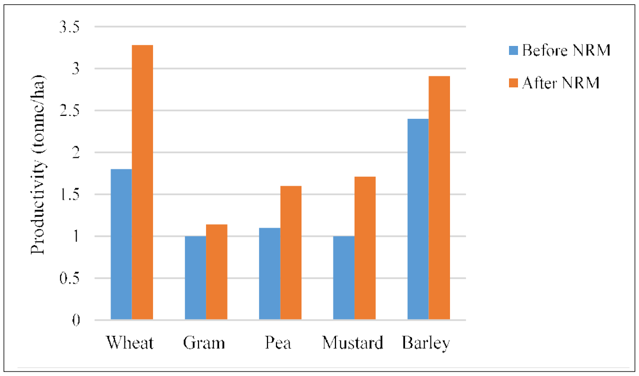

Fig 3: Transformation in productivity of major *rabi* crops.

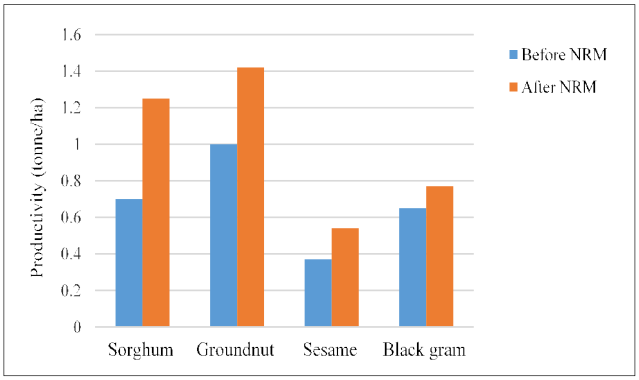

Fig 4: NRM impact in productivity of major *kharif* crops**.**

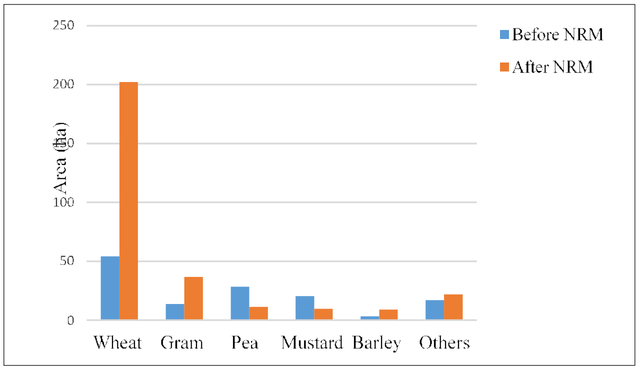

Fig 5: NRM impact in area of major *rabi* crops.

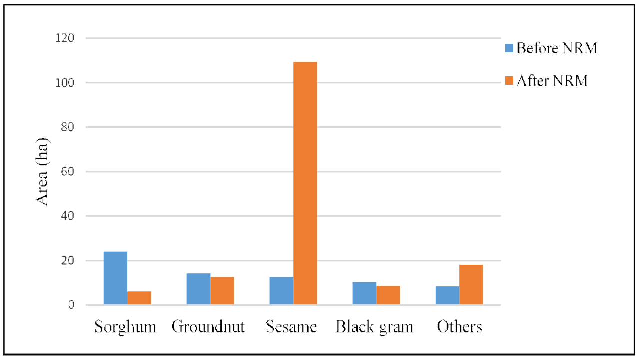

Fig 6: NRM impact in area of major *kharif* crops.

Transformation of migration scenario

People were migrating to meet their needs and livelihood security because most of the cultivated area lying empty/ fellow due to lack of water and in remaining area, production was very hardly and costly. After interventions of NRM, protection of crops possible by different fencing weeds *viz.* canacia selegon and full fill the complete requirement of water which provide livelihood facility and due to result, migration of people decreased as 70.74% whereas 62.75% male and 81.78% female migration decreased.

CONCLUSION

The findings are reveals that after watershed development and agroforestry based Crop cultivation, water level increased 2-6 m, crop production increased by 45-47%, cropping intensity increased 97-98% from 44-46% and migration decreased by 70-72%. In watershed development program, various interventions such as checkdams, low cost checkdams, nalla plug, gabions, spillways were adopted and implemented with the help of QGIS version 2.6.1 which provide suitable location and site according to drainage pattern study and water capturing area for sustainable agriculture and food security. Watershed development program also maintain the ecosystem services by adopting agroforestry based crop cultivation which supports to increase the farmers income and help to provide nutritional food. Sufficient water availability enhance enthuastics among the farmers to transform agricultural land into cultivated land resulting increases the employmentation. Thus overall study of water management interventions in term of watershed development was found satisfactory and beneficial for water availability as well as ecosystem services. Hence, it was necessary to scale-up such type of interventions and approaches in semi-arid and drought prone areas for water resource sustainability and sufficient water supply during whole year.

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