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Sustainable Irrigation through Renovation of Pond: A Case Study on Change of Crop Production, Irrigation, Cropping Pattern and Cropping Intensity Level in Sub Himalayan Terai Region of India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Terai region of West Bengal fall under high rainfall region but 90% rainfall occurs in kharif season and drought observed during rabi season. NICRA project started in the Cooch Behar District during 2011. The project area and plan of work were selected on the basis of participatory rural appraisal method. The experimental trial was conducted from 2011 to 2019. The objective of the experiment

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was to development of sustainable irrigation system through renovation of pond and its impact on crop production. It was found from the study that pond renovation has potential impact on increasing crop yield, cropping intensity, copping system and area of irrigation.

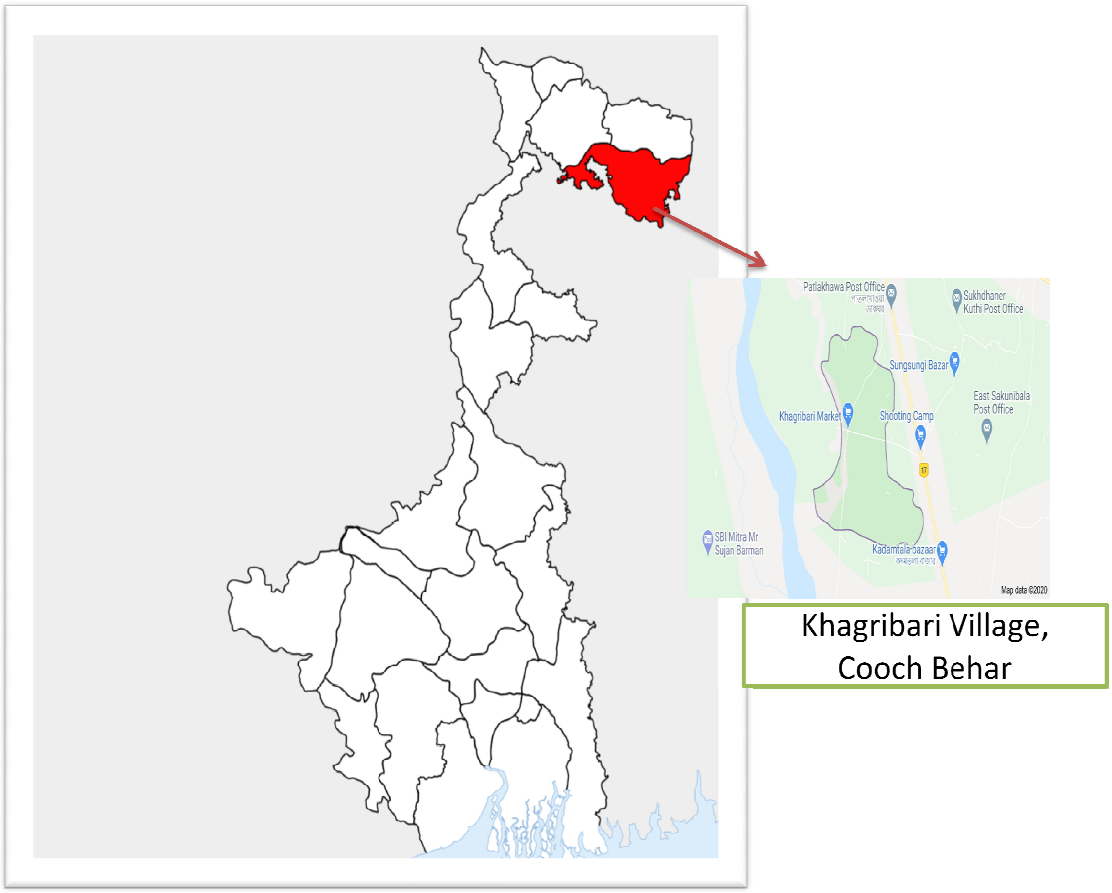
Keywords: Drought; irrigation; NICRA; experimental trial; sustainable; pond renovation; cropping intensity; copping system.

1. INTRODUCTION

National Innovations on Climate Resilient Agriculture (NICRA) is a network project of the Indian Council of Agricultural Research (ICAR). The NICRA projects was started in the Khagribari village of Cooch Behar district during 2011. The major crop cultivated in the villages are paddy, potato, jute, chilli, garlic, pointed gourd, brinjal, maize, pulse, cucumber [1]. Terai region of West Bengal fall under high rainfall region but 90% rainfall (Tables 1 and 2) occurs in kharif season and drought observed during rabi season [2,3] . Rice is the major crops cultivated during kharif season and vegetables are the major crops cultivated during rabi season. Demand of rice, potato, jute, maize and vegetable crops (Tomato, Cucumber, Brinjal, Chilli, Cauliflower, Cabbage and Pointed Gourd) of this region are very high. But due to short of rainfall and less irrigation facility during rabi season different problem were observed during rabi season (Table 3). It was observed from the survey that there were large number of small and semi medium size of the pond were present in this region but majority of the pond were not well maintained. Farm ponds are water harvesting structures used for several purposes [4]. Farm pond is used for storing the monsoon rainwater, which is used for irrigation, fish cultivation, jute retting, household activities and others purposes. Farm ponds are expected to have an impact on cropping pattern, productivity, employment, and income of the farmers [5]. Farm ponds, even though limited in terms of size and water capacity, perform very significant roles in various aspects according to their proper placement in the watershed context [6]. The farm pond impacts indicate not only increasing crop yields in both the rainy and the dry seasons, but also reduction of downstream sediment load [7]. Renovation of farm pond increased cropping intensity due to increasing rabi crops area followed by kharif crops area [8]. The improved crop management practices compared with change in cropping pattern have contributed for providing additional employment among farmers [9]. In addition to this, during off-season, construction of farm-ponds, was also contributed to increasing employment among the farmer who have farm ponds [5]. It was found from a study that copping pattern was changed and irrigated area was increased upto 40.28% after renovation of farm ponds [10]. In India rain fed agriculture contributes 40 per cent to the country's food grain production with 60 per cent area vulnerable for weather vagaries [11]. Variations in the monsoon can cause crop failure in the short run and even drought in the long run [12]. This is a serious concern for the development of the economy as well as for the well-being of the households engaged in agricultural workforce. So a study was conducted to know the development of sustainable irrigation system through renovation of pond and its impact on crop production.

2. METHODOLOGY

The experiment was conducted at Khagribari village of Coochbehar District, West Bengal, India from 2011 to 2019. Purposive sample method was used for selection of the village and pond. Total geographical area of the village is 730.12 hectares. Total population of the village was 6,226. Majority of the households were marginal and semi medium farmers. Soil type of the villages was sandy loam soil and pH of soil was low (5.5 to 6.5). A VCRMC (Village Climate Risk Management Committee) was formed before implementation of the programme. The members of VCRMC were selected from the villagers with the help group discussion and socio matrix method. Based on the resolution of VCRMC 60 no. of farm ponds were selected during the experimental period. The change in productivity in this study refers to production of plant produced of economic importance, expressed in standard units per unit area. The per cent change in productivity of crop were measured on the basis of difference between the average productivity of different crop in q/ha during the study year and base year. The change in cropping intensity due to construction of farm pond was studied in terms of hectares covered under various crops before and after renovation of farm pond to base year 2011 -2012. Descriptive statistics mean, median, mode, standard deviation and percentage were used for analysis of the study.



Map 1. West Bengal and Khagribari village, Cooch Behar (Experimental area)

3. RESULTS AND DISCUSSION

It was found from the study (Table 4) that total 60 number of farm pond were renovated from 2011 to 2019. It was observed from the study that area provided with supplemental irrigation during kharif season was increase upto 47.15 ha from 5.80 ha (Table 4 and Fig. 1). It was also observed that area brought under rabi crop cultivation were increase upto 253.4 ha from 8.5 ha (Table 4 and Fig. 2). It is revealed from the study after renovation of pond area of rabi crops were increases more than kharif crops area [8]. It was shown from the study that more than 800 farmers were benefited with this renovated pond. It was revealed from study (Table 5) that after supplementary irrigation during kharif season rice yield increases upto 16.16% over the irregular irrigation and for timely and adequate irrigation during rabi season rice yield increases upto 19.24% over the irregular supply of irrigation. It was found from the study (Table 5) that after timely and adequate irrigation during rabi season potato yield increase upto 29.85% & mustard yield increase upto 56.66 % over the irregular irrigation. It is found from the study that (Table 6) cropping pattern of the of the study area were change after renovation ponds. Before renovation of ponds majority farmers of the experimental area were cultivated Paddy, Jute, Lentil, Blackgram, Wheat, and after renovation pond majority of the farmers were cultivated Paddy, Jute, Potato, Garlic, Chilli, Pulse, Wheat, Pointed Gourd, Brinjal, Maize and Cucumber [5]. It is also found from the study that cropping system of area was change after renovation pond. It is exposed from the study that before renovation of pond (Table 7.1) 3 major cropping system were followed in the experimental area such as Jute-Rice-Fallow, Rice-Rice-lentil, and Black gram-Rice-Wheat. It is also exposed from the study that after renovation of pond (Table 7.2) 5 different type of cropping system was followed in up and medium land situation such as cucumber/Brinjal-Rice-Potato/winter vegetable, Cucumber- Black Gram-Brinjal/Chilli, Boro rice-

Rice-Potato, Blackgram-Rice-Wheat, Jute-Rice-Wheat and in low land situation 2 cropping system was followed such as Boro Rice-Rice-Garlic and Jute-Rice-Potato. It is found from the study that after renovation of pond and regular supply of irrigated water level of cropping intensity of the experimental area were increase upto 228% from 132% (Table 8). This finding is in line with the study found by [8].

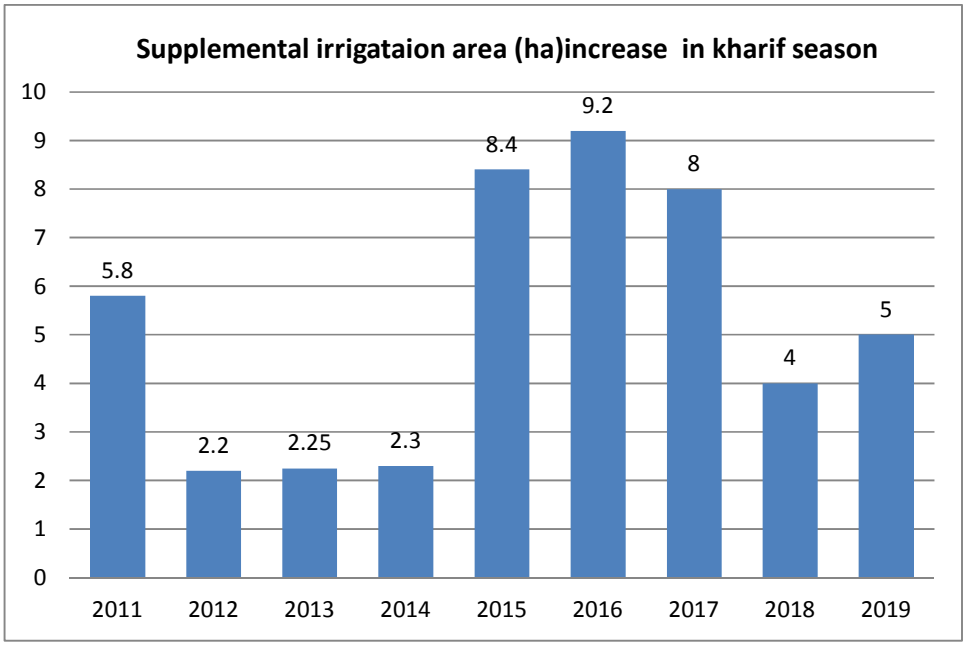


Fig. 1. Supplemental irrigation area (ha) increase in kharif season

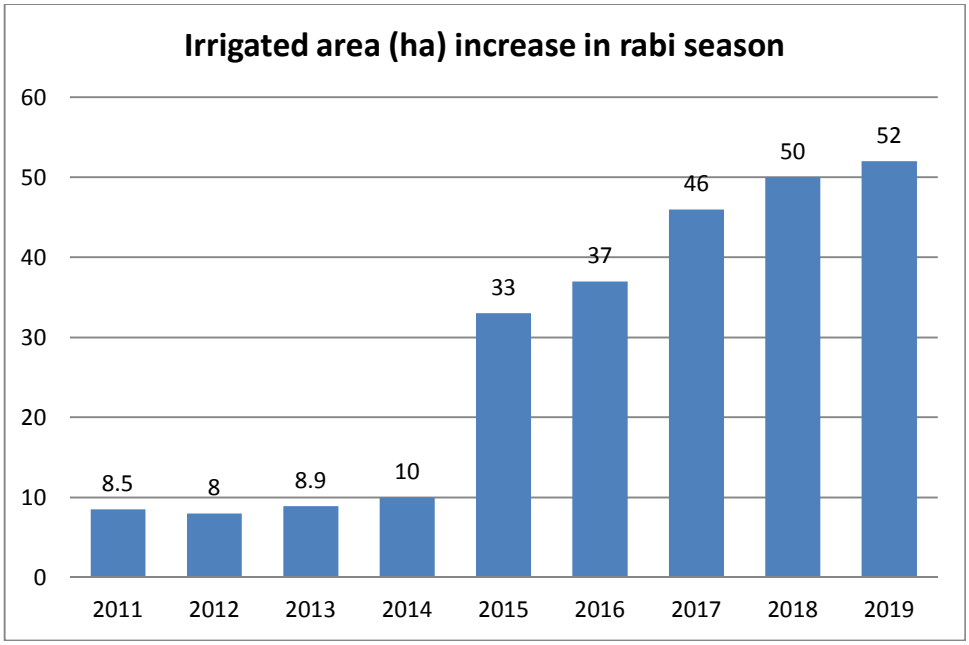


Fig. 2. Irrigated area (ha) increase in rabi season

Table 1. Rainfall received in the NICRA village (mm) (2011-2018)

Month	Normal rainfall (mm)	Actual-2011	Actual-2012	Actual -2013	Actual-2014	Actual-2015	Actual 2016	Actual 2017	Actual 2018
January	5(1)	0(0)	3.6(1)	0.00 (0)	0.0 (0)	21.8 (2)	5.4(2)	0	0
February	5(1)	0(0)	15.0 (1)	18.2(2)	18.2(2)	56.8 (2)	0(0)	0	3.8 (1)
March	50 (4)	55.2(3)	5.7 (1)	4.0(1)	10.4(2)	102.8 (4)	0.8(0)	67.7(6)	101.2 (4)
April	170 (8)	284.1(15)	156.9(11)	191.8(6)	9.4(2)	140.0 (7)	137.6(7)	177.7 (8)	213.6 (8)
May	450 (15)	419.3(12)	434.6(11)	383.4(13)	547.4(13)	372.4 (16)	364.8(12)	391.6 (17)	237.11 (16)
June	700(20)	704.5(18)	1189.6(22)	342.2(14)	689.0(19)	764.6 (21)	886.2(17)	502.5 (15)	334.5 (15)
July	700(20)	967.4(21)	972.1(23)	506.0(12)	232.8(15)	179.60(11)	846.2(25)	413.1 (12)	621.4 (21)
August	450(15)	596.9(14)	426.4(17)	321.6(14)	479.8(18)	892.50(24)	412.8(8)	979.5 (19)	369.3 (17)
September	360(12)	615.1(17)	551.4(16)	586.0(11)	523.0(12)	544.20(13)	498.2(16)	532.4 (13)	419.1 (16)
October	100 (4)	40.2(4)	202.4(4)	151.0(7)	3.8(1)	20.40 (2)	147.7(5)	224.5 (9)	3.9 (1)
November	5 (1)	9.4(2)	0(o)	7.8(1)	0.0(0)	7.20 (1)	0(0)	0	0 (0)
December	5(1)	0(0)	0(0)	0.0(0)	0.0(0)	5.20 (1)	0(0)	0	5.8 (1)
Total	3000(102)	3692.1(106)	3957.7(107)	2512(81)	2513.8(84)	3107.5(104)	3299.7(92)	3289(99)	2309.71(100)

**Indicate the no. of rainy days in parenthesis*

Table 2. Variability in rainfall experienced during the crop growing period from 2011-2018

Year	Dry Spell/Drought*		Flood**		Intensive Rainfall (≥60mm)
	Frequency	Duration (days)	Frequency	Duration (days)	
2011	May:1	9	May:1	6	May:2 (289 mm)
	-	-	-	-	June:3 (311.8 mm)
	-	-	July:2	14	July:7 (732 mm)
	August:1	10	Aug:1	9	August:4(343.2 mm)
	-		Sept.:1	10	Sept.:4 (366 mm)
Total:	2	19	6	39	20
2012	April:1	12	-	-	-
	-	-	-	-	May : 1 (124 mm)
	-	-	June:2	15	June : 6 (717.8 mm)
	-	-	July:1	13	July :4 (661.8 mm)
	-	-	-	-	August:1 (155.4 mm)
	-	-	Sept:1	8	Sept. :3 (285.8 mm)
	-	-	-	-	Oct.:1 (92.6 mm)
Total:	1	12	4	36	16

Year	Dry Spell/Drought*		Flood**		Intensive Rainfall (≥60mm)
	Frequency	Duration (days)	Frequency	Duration (days)	
2013	April:1	10	-	-	April:1(91.6 mm)
	-	-	-	-	May:2(147.4 mm)
	June:1	10	-	-	-
	-	-	July :1	7	July:2 (258.6 mm)
	-	-	-	-	August:1 (116.4 mm)
	Sept:1	11	Sept:1	8	Sept: 3 (391.6 mm)
Total:	3	31	2	15	9
2014	April:1	26	-	-	-
	-	-	May : 1	10	May:3 (292.8 mm)
	-	-	June : 1	8	June:3(260.2mm)
	-	-	-	-	August:1 (106.1mm)
	-	-	-	-	Sept:2 (282 mm)
Total:	1	26	2	18	9
2015	April:1	14	-	-	-
			June:1	12	June : 3 (400.6 mm)
	July-Aug:1	10	-	-	-
	-	-	August:1	10	August:5(503.4 mm)
	-	-	-	-	Sept:2 (282.8 mm)
Total :	2	24	2	22	10
2016	April:1	10			
	-	-	-	-	May:1 (61 mm)
	-	-	June:1	9	June:3 (382.6 mm)
	-	-	July :1	12	July:4 (382.9 mm)
	August:1	8	-	-	August:2 (339.2 mm)
	-	-	-	-	Sept:2 (240.9 mm)
Total:	2	18	2	21	12
2017					June: 3 (134.00 mm)
			July: 1		July: 2 (106.20 mm)
	-	-	August: 1	14	August: 5 (301.20 mm)
	-	-	September: 1	12	September: 4 (115.00 mm)
	-	-			
Total:	-	-	3	26	14
2018	-	-			June: 2 (72.00 mm)
	-	-			July: 1 (249.10mm)
	-	-	August: 1	6	August: 2 (75.00 mm)

Year	Dry Spell/Drought*		Flood**		Intensive Rainfall (≥60mm)
	Frequency	Duration (days)	Frequency	Duration (days)	
	-	-	September: 1	9	September: 3 (103.00 mm)
Total:			2	15	8

Table 3. Average weather in rabi season [13]

Month	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
October	31.09	21.26	91.00	70.25	162.52
November	27.49	15.31	91.00	58.75	9.06
December	25.60	11.78	94.00	62.00	2.87
January	23.03	9.61	92.00	63.25	20.89
February	25.60	12.44	89.00	54.50	26.48
March	29.66	16.47	85.00	46.75	42.66

Table 4. Irrigated area and farmers covered under pond renovation

Category	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Renovated of farm ponds	20	6	6	5	5	7	5	2	4	60
Area provided with supplemental irrigation during kharif (ha)	5.80	2.20	2.25	2.30	8.4	9.2	8	4	5	47.15
Area brought under Rabi cultivation (ha)	8.5	8.0	8.9	10	33	37	46	50	52	253.4
No. of farmers benefitted	25	28	30	35	76	125	157	165	180	821

Table 5. Effect of farm ponds/jalkunds on the crop yields during 2011-19

Year	Intervention	Crop yields (kg/ha)			Number of farmers involved			Area covered (ha)			Yield improvement (%) over farmers practice		
		Paddy	Potato	Mustard	Paddy	Potato	Mustard	Paddy	Potato	Mustard	Paddy	Potato	Mustard
2012	Effect of critical irrigation in kharif crop	4200	0	0	0	0	0	0	0	0	16.66	-	-
	Farmers practice (no irrigation during kharif)	3600	0	0	550	0	0	2.2	-	-	0	0	0
	Bringing additional area under cropping during rabi with irrigation	4400	22000	1100	3	15	10	1	5	2	15.78	22.22	46.66
	Farmers practice (no irrigation	3800	18000	750	80	150	50						

Year	Intervention	Crop yields (kg/ha)			Number of farmers involved			Area covered (ha)			Yield improvement (%) over farmers practice		
		Paddy	Potato	Mustard	Paddy	Potato	Mustard	Paddy	Potato	Mustard	Paddy	Potato	Mustard
	during rabi)												
2013	Effect of critical irrigation in kharif crop	4200	0	0	5	0	0	2.25	0	0	16.66	-	-
	Farmers practice (no irrigation during kharif)	3600	0	0	540	0	0	15	0	0			
	Bringing additional area under cropping during rabi with irrigation	4450	22000	1100	12	18	0	3	5.9	0	17.10	22.22	46.66
	Farmers practice (no irrigation during rabi)	3800	18000	750	78	132	50						
2014	Effect of critical irrigation in kharif crop	4200	0	0	5	0	0	2.30	0	0	16.66	0	0
	Farmers practice (no irrigation during kharif)	3600	0	0	540	0	0	15	0	0	0	0	0
	Bringing additional area under cropping during rabi with irrigation	4500	22000	1100	10	20	5	3	6	1	18.42	22.22	46.66
	Farmers practice (no irrigation during rabi)	3800	18000	750	68	112	45				0	0	0
2015	Effect of critical irrigation in kharif crop	4300	0	0	8.4	0	0	28	0	0	16.21		
	Farmers practice (no irrigation during kharif)	3700	0	0	70	0	0	15					
	Bringing additional area under cropping during rabi with irrigation	4500	24000	1200	22	42	12	10	20	3	18.42	33.33	60
	Farmers practice (no irrigation during rabi)	3800	18000	750	46	70	33						
2016	Effect of critical irrigation in kharif crop	4400			9.2	0	0	28	0	0	15.78		
	Farmers practice (no irrigation during kharif)	3800			70			15					
	Bringing additional area under cropping during rabi with irrigation	4600	24000	1200	42	60	23	10	22	5	21.05	33.33	60
	Farmers practice (no irrigationduring rabi)	3800	18000	750	4	10	10						

Year	Intervention	Crop yields (kg/ha)			Number of farmers involved			Area covered (ha)			Yield improvement (%) over farmers practice		
		Paddy	Potato	Mustard	Paddy	Potato	Mustard	Paddy	Potato	Mustard	Paddy	Potato	Mustard
2017	Effect of critical irrigation in kharif crop	4400			8	0	0	25	0	0	15.78		
	Farmers practice (no irrigation during kharif)	3800			70			15					
	Bringing additional area under cropping during rabi with irrigation	4600	24000	1250	47	80	30	14	25	7	21.05	33.33	66.66
	Farmers practice (no irrigation during rabi)	3800	18000	750	0	0	0						
2018	Effect of critical irrigation in kharif crop	4400			4	0	0	15	0	0	15.78		
	Farmers practice (no irrigation during kharif)	3800			70			15					
	Bringing additional area under cropping during rabi with irrigation	4600	24000	1200	50	85	30	15	27	8	21.05	33.33	60
	Farmers practice (no irrigation during rabi)	3800	18000	750	0	0	0						
2019	Effect of critical irrigation in kharif crop	4400			5	0	0	17	0	0	15.78		
	Farmers practice (no irrigation during kharif)	3800			70			15					
	Bringing additional area under cropping during rabi with irrigation	4600	25000	1250	50	100	30	15	29	8	21.05	38.88	66.66
	Farmers practice (no irrigation during rabi)	3800	18000	750	0	0	0						
	Average yield increased in kharif season										16.16		
	Average yield increased in rabi season										19.24	29.85	56.66

Table 6. Major crop cultivated before renovation of pond (Cropping pattern)

Major crop cultivated before renovation of pond	Major crop cultivated After renovation of pond
Paddy	Paddy
Jute	Jute
lentil	Potato
wheat	garlic
-	Chilli
-	pulse
-	Pointed gourd
-	Brinjal
-	Chill
-	Maize
-	Cucumber

Table 7.1 Cropping system before pond renovation

Pre-Kharif/Summer	Kharif	Rabi/winter
Before pond renovation		
a) Upland and medium land situation		
i) Jute	Rice	Fallow
ii) Direct seeded rice	Rice	Lentil
iii) Black gram	Rice	Wheat
b) Low land situation		
i) Transplanted rice	Rice	Mustard/ late sown wheat/fallow
ii) Jute	Rice	Fallow

Table 7.2 Cropping system after pond renovation

Pre-Kharif/Summer	Kharif	Rabi/winter
After pond renovation		
a) Upland and medium land situation		
i) cucumber/ Brinjal	Rice	Potato / Winter vegetables
ii) Cucumber	black gram	Brinjal/ chilli
iii) Boro rice	Rice	Potato/ Mustard
iv) Black gram	Rice	Wheat
v) Jute	Rice	Wheat
b) Low land situation		
i) Boro rice	Rice	Garlic
ii) Jute	Rice	Potato

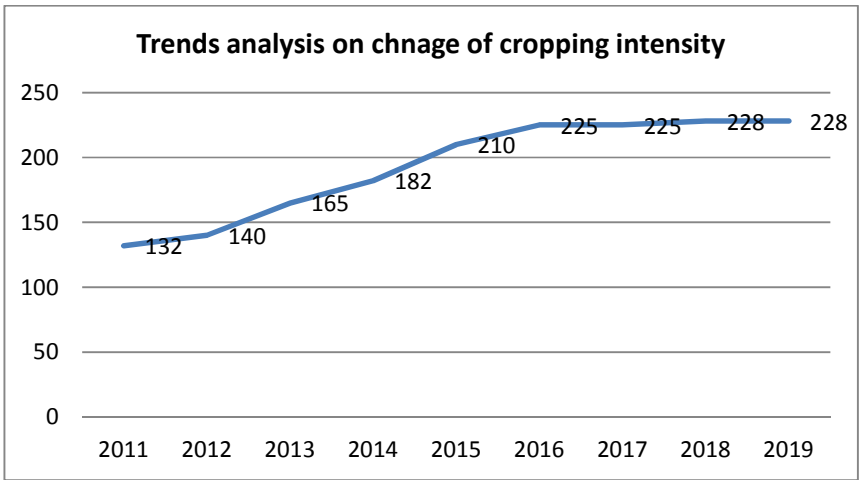


Fig. 3. Time trends analysis on change of cropping intensity level of study area

Table 8. Time trends analysis on change of cropping intensity level of study area (2011 to 2019)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cropping intensity	132	140	165	182	210	225	225	228	228

4. CONCLUSION

It may conclude from the above study that after regular irrigation from renovated pond rice, potato and mustard yield was increases. It is revealed from the study that irrigated area and cropping intensity of the experimental area were increases after renovation of the ponds. It is also revealed from the study that cropping pattern of the study area was significantly changed due to availability of water resources. There may be several factors were involved for increasing crop productivity and cropping intensity but critical irrigation one of the prime factor. It is also concluded from the study that VCRMC play an important role for natural resource management and adaptation and mitigation of climate resilient agriculture system. So it may suggest from the study that renovated of the farm pond practices may adopted by the farmers for recycling of rainwater and providing adequate irrigation to the crops for increasing productivity of crops, cropping intensity and net irrigated area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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