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On - farm rainwater storage for sustaining yield of rice: Wheat cropping system

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Abstract
An experiment was conducted in the farmer's field to assess the effect of on-farm rainwater management on productivity of rice-wheat cropping system in the rainfed medium land in clay loam soil at Puintala block of Bolangir district, western central tableland zone of Odisha. Weir height of 10, 15, 20 and 25 cm were constructed in the rice fields and the excess rain water through these weirs was collected in the refuges (20% area) for recycling for supplemental irrigation. The results revealed that, weir height of 15 cm gave the highest *kharif* rice (*Oryza sativa* L) average grain yield of 3.31 t/ha (average of three varieties i.e. Lalat, MTU 1001 and Swarna) over other weir heights. Among 3 varieties of rice tested, Swarna produced the highest grain yield (3.47 t/ha) with weir height of 15 cm. The average depth of water retained in the refuges at 15 cm weir height in the months of October, November, December, January and February were 1.42, 1.15, 1.04, 0.79 and 0.34 m, respectively. Three varieties of wheat i.e. Sonalika, UP 262 and HUW 234 were grown in the same fields but in 50% of rice area in *rabi* season and 3 irrigations were given to the crop from the stored water in the refuges. The average yields of different varieties of wheat were found to range from 1.61 t/ha to 1.81 t/ha. It was observed that the stored water in the refuge with collection of excess runoff from 15 cm weir height plots gave the highest wheat yield for variety UP 262. Based on the study, it is recommended to grow rice (cv. Swarna) and wheat variety UP 262 at 15 cm weir height with a refuge area of 20% for sustaining the yield of rice-wheat cropping system. From the techno-economic study, the benefit-cost ratio of the cropping system for 15 cm weir height plots along with the refuge is found to be 1.11, the net present value is Rs.1481.00, internal rate of return is 14% and payback period is 15 years. Therefore, techno-economically, this system will be acceptable by the farmers of the area.

Keywords: Rainwater, yield, rice, wheat, cropping system, economic analysis

Introduction
Enhancing productivity and production from the rainfed area is crucial for increasing food production and to reduce regional imbalance in agricultural development. As rainfall is major and many time the only source of water, therefore, its utilization and management holds the key for success in dryland agriculture. Rainfed agriculture in Odisha covers about 70% of the net sown areas. Annual agricultural production in the state is largely dictated by the monsoon rains and its mode of distribution. The average annual rainfall of Odisha is 1480 mm, out of which 77% is received during June-September. During this period more than half of the annual rainfall comes from a few intense showers resulting in high runoff that causes excess soil moisture status and deep ponding even in upland rainfed rice lands [1, 2]. Rice is cultivated in an area of 42 lakh ha during *kharif* and accounts for 88% of the total food grain production of the state. Rainfed rice in Odisha suffers from drought resulting in poor yield almost every year due to poor rain water management practices during the monsoon season. After harvest of rice, often these lands remain fallow in winter due to scanty rainfall and lack of water storage facilities. Hence, there is a great need for rainwater conservation and its optimum utilization in the form of irrigation for achieving sustainability of rainfed agriculture [3].

The present experiment was undertaken with the objective of increasing the productivity of *kharif* rice by standardizing the weir height to harvest excess rain water coming from the rice field in refuges and to recycle it to the same rice field as and when required as well as to ascertain the feasibility of taking a winter season crop wheat in *rabi* season after rice.

Materials and Methods
Study area
A field experiment was carried out at the farmer's field in the village Kadalipali, Puintala block of Bolangir district under Western Central Table Land Zone of Odisha during the year

2013-14 and 2014-15 to assess the effect of different weir heights (10, 15, 20 and 25 cm) on the storage of excess rain water in the refuges and on the grain yield of three rice varieties (Lalat, MTU 1001 and Swarna maturing in 130-140 days) followed by wheat crop (three varieties viz., Sonalika, UP 262 and HUW 234 maturing in 105 days) in rainfed medium land along with their techno-economics. These rice and wheat varieties are selected as these varieties are popularly grown by majority of the farmers in the zone. It receives average rainfall at 1265, 99 and 80 mm during the monsoon (June-September), winter (October to January) and summer (February to May) season respectively. The dominant soil texture is clay loam with pH 6.0 and low in organic matter. The detail physical properties of the soil at the experimental site are presented in Table 1. The treatments comprising 4 weir heights were evaluated with two numbers of replications with three rice and three wheat varieties. Thus, there were altogether 8 plots, each of dimension 30.0 m x 20.0 m including the refuge area. The refuge structures were made at the lower reach of each plot with dimensions top width 5.0 m, bottom width 1 m, depth 2.0 m and side slope 1:1 which is 20% of the total plot area. The length of refuge was maintained as per the width of the plot. At the middle of the lower reaches of rice plots, brick masonary broad crested rectangular weirs of heights 10, 15, 20 and 25 cm were constructed. The length of each weir was maintained at 2 m for spilling of the excess rainwater from the experimental plots. The objective of providing different weir height was to store a portion of rainwater in the rice field upto the weir crest level and to allow excess rainwater above crest level to spill over to the refuge for conservation. Suitable outlets were provided at the lower end of the refuge to drain out the excess water from the refuge after attaining the maximum storage level [4]. Three rice varieties i.e. Lalat, MTU 1001 and Swarna were transplanted in each plot by providing a gap of 40 cm between the respective varieties to test the effect of weir height on the productivity of rice and wheat varieties. The plot of each variety was 23.8 m x 6.4 m. Transplanting of rice was done at a spacing of 20 cm x 10 cm taking 25 days old seedlings in the first fortnight of July in each year. An uniform dose of fertilizer (80:40:40 kg of N-P_2O_5- K_2O) were applied to all the varieties and the normal package of practices were followed. The depth of water stored in the refuges in different months was recorded. After harvest of rice, three wheat varieties Sonalika, UP 262 and HUW 234 were sown during the second fortnight of November in 50 per cent of the experimental rice areas of each plot. An uniform dose of fertilizers (80-50-40 kg/ha of N-P_2O_5 – K_2O) were applied to all the varieties and normal package of practices were followed. Three irrigations were supplied to each wheat variety at crown root initiation, jointing and flowering stages of the crop, respectively.

Table 1: Physical properties of soil at experimental site

Depth (cm)	Mechanical composition (%)			Textural class	Bulk density (g/cc)	Field capacity (%)	Wilting Point (%)	pH	Ec (dsm^{-1})	Organic Carbon (%)
	Sand	Silt	Clay							
0-15	76.8	11.5	11.7	Sandy loam	1.51	17.8	9.4	6.0	0.023	0.59
15-30	66.0	12.5	21.5	Clay loam	1.58	20.0	7.9	6.4	0.031	0.35
30-45	64.0	14.0	22.0	Clay loam	1.60	20.5	7.7	6.5	0.035	0.33

Techno-economic analysis
A present worth of analysis was used to evaluate all the cash flows in order to account the interest and the inflation factor in investment as proposed by Palmer *et al.* [5], Mishra *et al.* [6] and Panigrahi and Panda [7]. The conventional measures of project evaluation like net present value (NPV), payback period (PBP), benefit cost ratio (BCR) and internal rate of return (IRR) were worked out as proposed by the above mentioned researchers to assess the economic viability of the storage structure.

Net present value (NPV)
The most straightforward discounted cash flow measure of project worth is the net present value (NPV). The net present worth may be computed by subtracting the total discounted present worth of the cost stream from that of the benefit stream. The mathematical statement for net present worth of the net present value (NPV) is written as:

$$\text{NPV} = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} \qquad (1)$$

Where,
B_t = benefit in each year
C_t = cost in each year
t = 1, 2, ………….., n
i = discount rate.

Benefit cost ratio (BCR)
This is the ratio obtained when the present worth of the benefit stream is divided by the present worth of the cost stream. The formal selection criterion for the benefit cost ratio for measure of project worth is to accept projects for a benefit-cost ratio of 1 or greater.
Mathematically benefit cost ratio can be expressed as:

$$\text{Benefit cost ratio} = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}} \qquad (2)$$

Internal rate of return (IRR)
The internal rate of return can be found out by systematic procedure of trial and error to find that discount rate which will make the net present worth of the incremental net benefit stream equal to zero. The internal rate of return is the discount rate ‘i’ such that:

$$\sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} = 0 \qquad (3)$$

Payback period (PBP)
The payback period is the length of time from the beginning of the project until the net worth of the incremental production stream reaches the total amount of the capital

investment. It shows the length of time between cumulative net cash out flow recovered in the form of yearly net cash inflows. The following parameters were considered for carrying out economic analysis. The discounting rate is considered to be 8% as compared to bank lending interest rate [8, 9]. The refuge maintenance cost is assumed constant at the rate of 2% of initial investment cost of the refuge [2, 7].

Results and Discussion

Rain water consumption

The monthly rainfall received during crop growing period and the total annual rainfall is presented in Table 2. From the above data it is revealed that the year, 2013-14 received more rainfall than the year, 2014-15. Despite much variation in the rainfall over the years the water level in the refuges were observed to be sufficiently high till the end of February. Rainwater stored in the refuges was used to provide supplementary irrigation to rice during the period of stress. It was observed that the weir height affected the depth of water in the refuges (Table 3). The maximum height of water was found in the weir height of 10 cm. With the increase in weir height there is a decrease in the depth of water in the refuge. The average reduction in water depth at weir heights 15, 20 and 25 cm as compared to 10 cm height were in the order of 2, 10 and 30%, respectively.

Table 2: Monthly rainfall (mm) during the experiment

Year	June	July	Aug	Sep.	Oct	Nov	Dec	Jan	Feb	Mar	Total annual rainfall
2013-14	90.0	409.5	607.4	379.7	115.6	1.2	36.1	0.0	15.5	1.9	1680.6
2014-15	311.6	335.4	248.4	99.1	86.0	0.0	0.0	43.1	7.7	2.0	1136.1

Table 3: Average depth of standing water (m) in the refuges during the experimental period

Weir height (cm)	Year	Months							
		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
10	2013-14	1.71	1.69	1.64	1.45	1.30	1.10	0.86	0.41
	2014-15	1.65	1.64	1.57	1.39	1.24	1.02	0.78	0.36
	Average	1.68	1.67	1.60	1.42	1.07	1.06	0.82	0.38
15	2013-14	1.67	1.67	1.64	1.45	1.18	1.08	0.83	0.37
	2014-15	1.58	1.61	1.54	1.40	1.12	1.00	0.75	0.31
	Average	1.62	1.64	1.59	1.42	1.15	1.04	0.79	0.34
20	2013-14	1.59	1.61	1.59	1.44	1.01	0.87	0.70	0.29
	2014-15	1.51	1.58	1.50	1.38	0.96	0.77	0.64	0.24
	Average	1.55	1.60	1.54	1.41	0.98	0.82	0.67	0.26
25	2013-14	1.51	1.48	1.37	1.31	0.94	0.63	0.28	0.18
	2014-15	1.49	1.42	1.31	1.27	0.90	0.58	0.22	0.14
	Average	1.50	1.45	1.34	1.29	0.92	0.60	0.25	0.16

Effect of weir height on rice yield

The yields of rice varieties at different weir heights were presented in Table 4. Highest grain yield was recovered at 15 cm weir height irrespective of all the varieties. Rice cv. Swarna recorded the highest grain yield (3.47 t/ha) as compared to Lalat (3.15 t/ha) and MTU 1001 (2.88 t/ha when considered over all the weir height (Table 5) and there was significant difference among the varieties tested. The mean grain yield of three rice varieties recorded at 15 cm weir height was highest (3.31 t/ha) which was 2.2, 3.1 and 15% higher than the grain yield recorded at weir height 20, 10 and 25 cm, respectively. Maximum grain yield of 3.66 t/ha was recorded from the variety Swarna at 15 cm weir height. However the mean grain yield obtained from weir heights of 10, 15 and 20 cm were at par.

Table 4: Grain yield of rice varieties as affected by different weir heights

Weir height (cm)	Rice variety	Mean grain yield (t/ha)	
		2013-14	2014-15
10	Lalat	3.29	3.21
	MTU 1001	2.94	2.87
	Swarna	3.53	3.45
15	Lalat	3.37	3.22
	MTU 1001	3.05	2.93
	Swarna	3.72	3.61
20	Lalat	3.26	3.17
	MTU 1001	3.01	2.89
	Swarna	3.60	3.53
25	Lalat	2.89	2.82
	MTU 1001	2.68	2.65
	Swarna	3.22	3.09

Table 5: Mean grain yield of rice varieties as affected by different weir heights

Variety	Mean grain yield (t/ha) of rice at different weir heights (cm)				Mean yield (t/ha)
	10	15	20	25	
Lalat	3.25	3.29	3.21	2.85	3.15
MTU 1001	2.90	2.99	2.95	2.66	2.88
Swarna	3.49	3.66	3.57	3.15	3.47
Mean	3.21	3.31	3.24	2.88	

Effect of weir height on wheat yield

Highest grain yield was recorded at 15 cm weir height irrespective of all the varieties (Table 6). Wheat cv. UP 262 recorded the highest yield 1.78 t/ha as compared to HUW 234 (1.75 t/ha) and Sonalika (1.66 t/ha) when considered over all the weir heights. Wheat varieties produced more or less equal grain yield ranging from 1.61 t/ha to 1.81 t/ha for different weir heights. The wheat varieties should be sown at 15 cm weir heights to get the maximum yield (Table 7). There was no significant difference of grain yield of wheat due to weir heights and varieties.

Table 6: Grain yield of wheat varieties as affected by different weir heights

Weir height (cm)	Wheat variety	Mean grain yield (t/ha)	
		2013-14	**2014-15**
10	UP 262	1.80	1.76
	Sonalika	1.68	1.63
	HUW 234	1.74	1.73
15	UP 262	1.84	1.86
	Sonalika	1.71	1.76
	HUW 234	1.81	1.84
20	UP 262	1.76	1.81
	Sonalika	1.59	1.63
	HUW 234	1.74	1.80
25	UP 262	1.78	1.66
	Sonalika	1.70	1.52
	HUW 234	1.72	1.62

Table 7: Mean grain yield of wheat varieties as affected by different weir heights

Variety	Grain yield (t/ha) of wheat at different weir heights (cm)				Mean yield (t/ha)
	10	**15**	**20**	**25**	
UP 262	1.78	1.85	1.78	1.72	1.78
Sonalika	1.66	1.74	1.61	1.61	1.66
HUW 234	1.74	1.83	1.77	1.67	1.75
Mean	1.73	1.81	1.72	1.67	

Techno-economics

The details of income and expenditure for the refuge area with 15 cm weir height for the maximum yield in rice-wheat cropping system is presented in Table 8. Just like annual costs, the present worth of the annual return from the refuge was computed on a yearly basis. The NPV of the 20 year period is Rs.1481 for the experimental plot considered (Table 8). Based on NPV it can be concluded that the digging of refuge is economical for rice – wheat cropping system. The benefit cost ratio was computed in the yearly basis and then average values were obtained which is 1.11 and it is worth digging a refuge. The IRR is another important factor frequently used by economists for evaluation of the performance of different projects. It is computed as that interest rate at which the BCR is just 1.0 [10]. In the present study the IRR was found to be 14%. As it is more than the discounting rate (8%), the project is economically viable. The PBP for the present study found to be 15 years, which was less than the life span of the refuge (20 years). Thus farmers could pay back their investment in 15 years (Table 9).

Table 8: Cash flow (Rs.) in rice-wheat cropping system

Year	Cash out flow	Present value of cash out flow	Cash in flow	Present value of cash inflow	Net present value, NPV
0	4033	4033.00	0	0.00	-4033.00
1	933	863.89	1529	1415.74	551.85
2	995	855.05	1529	1310.87	457.82
3	995	789.86	1529	1213.77	423.91
4	995	731.35	1529	1123.86	392.51
5	995	677.18	1529	1040.61	363.43
6	995	627.02	1529	963.53	336.51
7	995	580.57	1529	892.16	311.58
8	995	537.57	1529	826.07	288.50
9	995	497.75	1529	764.88	267.13
10	995	460.88	1529	708.22	247.35
11	995	426.74	1529	655.76	229.02
12	995	395.13	1529	607.19	212.06

13	995	365.86	1529	562.21	196.35
14	995	338.76	1529	520.56	181.81
15	995	313.67	1529	482.00	168.34
16	995	290.43	1529	446.30	155.87
17	995	268.92	1529	413.24	144.32
18	995	249.00	1529	382.63	133.63
19	995	230.55	1529	354.29	123.73
20	0	0.00	1529	328.04	328.04
Total		13531.17		15011.95	1480.77

Table 9: Value of different economic indicators (considering average data of two years of experiments)

Economic indicators	Value
NPV (Rs.)	1481
BCR	1.11
IRR (%)	14
PBP (Year)	15

Conclusions
From the study, it may be concluded that, a weir height of 15 cm using rice variety Swarna could stabilize the grain yield in rainfed medium land of western central table land zone of Orissa. Constructing a refuge at 20% of the field size, there is a feasibility of taking second crop wheat after rice by recycling the water stored in the refuges. Wheat variety UP 262 or HUW 234 may be grown after rice in 50% of the rice area for sustaining the yield of rice-wheat cropping system. Also techno-economically, it is found that this system is feasible and can be acceptable by the farmers of the area.

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