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Assessment of production potential of water saving technologies on rice (*Oryza sativa*) in India

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ABSTRACT

The production of rice, the largest consumer of irrigation water, has been threatened due to demand from other sectors of the economy. Among the several options available for increasing water productivity, alternate wetting and drying (AWD) and use of aerobic rice cultures are two viable options and these two options were tried at on-station and on-farm level to assess and quantify the reduction in number of irrigations and their viability on farmers' field. Participatory varietal selection method was used to select aerobic rice cultures and form the basis for further seed supply to farmers. Seeds of promising cultures were supplied to farmers and subsequently impact analysis was done. The impact analysis revealed that there are 2–3 irrigation saving due to adoption of AWD and new rice cultures and consequently, a cost of saving of ₹ 375/tonne of rice was obtained. The results of the simulation exercise revealed that irrigated rice area can be further expanded to another 3.0 million ha and rice production by another 7.2 million tonnes due to adoption of these technologies.

Key words: India, Production potential, Rice technologies, Water saving

Water is a vital input in the agricultural production process. Irrigation water use accounts for 85% of total fresh water use and dominates significantly other sectors. The demand for fresh water is growing from sectors like industry, domestic, energy and environmental use, besides water for irrigation purpose to raise crops (Table 1). As the demand for water by all users grow, ground-water is being depleted, other water ecosystems are becoming polluted and degraded, and developing new sources of water is getting more costly, policy makers and researchers are concerned that water will be the main obstacle to growing enough food in the years to come. International Food Policy Research Institute simulation study predicts that under water crisis scenario, rice prices will rise by 40%, wheat by 80%, maize by 120% and coarse cereals by 85%; and thus, will increase food insecurity in the world by the year 2025. Swaminathan (2010) has opined that to feed Indian population by the year 2050, the area under irrigation should go up from 60 million ha to 114 million ha.

Rice (*Oryza sativa* L.) is the principal crop of India in terms of area coverage, contribution to total foodgrain production and supply of calories in the diet. This crop is grown in all the states of India under diverse agro-climatic conditions from below the sea level in Kerala to an altitude of 3 000 m in Uttarakhand. Among cereals, rice consumes much more water than others and it is estimated that 3 000–5 000 litres of water is required to produce one kg of rice (Bouman 2009). It is projected that the demand for rice in India will be 113 million tonnes by 2020–21 and to achieve this target, the productivity of rice (un-milled) has to be brought to the level of 4 tonnes/ha (Kumar *et al.* 2009). Out of the 44 million ha of rice grown in India, about 25 million ha, i e 57% are grown under irrigated condition (Government of India 2010). The sources of irrigation are canals, tube wells, other wells, tanks and other sources. One of the options to increase the production and productivity of rice is to bring more area under irrigated rice and this can be achieved by increasing the water productivity by adopting water saving rice technologies and thus, with the saved water more rainfed rice area can be brought under irrigation.

Traditionally, irrigated rice is grown under continuous flooded conditions in fields. Under flooded conditions, water is required to match several outflow processes like seepage (lateral subsurface outflows of water underneath the bunds), percolation (vertical downward outflow of water below the root zone), evaporation (release of water into air from the ponded water layer as water vapour) and transpiration (water released into the air as vapour through the plants) by the

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crop. Besides the above, water is also lost from the fields through over-bund flows. Seepage, percolation, evaporation, and over-bund flows are all non-productive flows of water and considered losses at field level. Therefore, there is a major challenge for farmers to increase the productivity of water used to grow rice by decreasing non-productive losses and increasing the transpiration efficiency of rice plant. Many Indian studies (Goswami 2006, Kumar *et al.* 2011, Radha *et al.* 2009, Senthilkumar *et al.* 2009, Senthilkumar *et al.* 2011, Singh *et al.* 2012) have discussed various strategies and technologies like germplasm selection, management practices and system-level management for conjunctive and profitable water use in rice crop, so that the water saved at the field level can be used more effectively to irrigate previously un-irrigated lands.

Table 1 Annual requirement of water to the year 2025 by different uses in India

Different uses of water	Year 2000	Year 2025	% increase
	Billion cubic metre		
Domestic	42	73	73.81
Irrigation	541	910	68.21
Industry	8	23	187.50
Energy	2	15	650.00
Others	41	72	75.61
Total	634	1093	72.40

Source: Government of India 2007.

Alternate wetting and drying (AWD) technique (Bouman *et al*. 2007) reduces water use by rice through reduced evaporation, seepage, percolation and over-bund flows. Adoption of this technique does not decrease yield of rice, but, reduces water use in rice. The technique has been widely accepted in China and covered about 40% of rice area in that country. Against this backdrop, the present paper tries to estimate the production enhancement potential of water saving rice technologies in India through a simulation exercise by using data from on-farm and on-station experiments.

MATERIALS AND METHODS

Out of several options available to save water use of varieties/cultures which require less water during their growing period and adoption of AWD irrigation technique assumed promise at the farmers' field level. Experiments were laid out at on-station and on-farm level to study the viability of aerobic rice (Aerobic rice cultivation is a production system, which involves the growing of specially developed, input-responsive rice varieties in well-drained, non-puddled, and non-saturated soils without ponded water) cultures, AWD irrigation method and the amount of water saved in this technique. On-station trials were laid out at Central Rice Research Institute (CRRI), Cuttack to measure the water saved in the AWD method of irrigation, as well as to study the performance of aerobic rice cultures supplied by International Rice Research Institute (IRRI), Philippines and subsequently selected at CRRI, Cuttack during 2006–07, 2007–08 and 2008–09. The on-farm trials were laid out on the fields of four farmers at two locations during 2007–08 and 2008–09, two each in Cuttack (Ratanpur village) and Jajpur (Samian village) district following the participatory varietal selection (PVS) method. The source of irrigation at both the sites was from government laid out canals. Ratanpur village of Cuttack district is located at the tail end area of the canal originating from river Mahanadi, while Samian village is supplied with irrigation water from a minor irrigation project and both the sites face shortage of water during the growing period of rice. In each trial, 10 aerobic rice cultures were tried along with five check varieties. The trials were replicated twice in each farmer's field. After the crop was transplanted, AWD irrigation method was applied. Piezometers (Piezometer is an 80 cm length, 15 cm diameter perforated PVC pipe. One end is closed to prevent water from entering vertically down below. Only water is allowed to enter laterally) were fixed in each field to monitor the level of ground-water and deciding the timing of application of irrigation. At maturity stage, 150 farmers from the nearby villages were taken around the PVS trials and asked to choose three best varieties by ranking them as first, second, and third according to their perceived selection criteria. The responses of the farmers regarding the 15 cultures/varieties were pooled by giving weightage to the ranks (First=3, Second=2, Third=1) to find out the final rank of each culture/variety. The actual number of irrigations saved in on-farm trials was also recorded.

Subsequently, three best cultures were selected for further promotion by supplying seeds to farmers. Seeds of new cultures were supplied to 170 farmers. Data were collected from 60 randomly selected farmers for impact analysis during 2009–10. During impact studies, mainly three types of information were collected from farmers, i e saving of number of irrigations, yield of AWD vs plots of other varieties and exchange of seeds with other farmers to assess the benefits of water saving rice technologies.

Finally, a simulation exercise was carried out on the basis of results of the experiments and farmers' reactions to AWD technique to find out the possibility of increase in irrigated area and thus increase in production due to adoption of water saving technologies in rice cultivation by taking several assumptions. They are: (a) The water saving due to adoption of AWD method will be 20%, (c) The water saved due to adoption of AWD will be exclusively used to irrigate rainfed rice area during *kharif* and expand rice area during *rabi*/summer season, (d) The potential rice cultivated area during *kharif*, which will adopt water saving rice technologies is 50% of total *kharif* irrigated area, (e) Though there are water losses at other levels of irrigation system (Bouman *et* *al*. 2007), those losses are not taken into account, while computing the production potential.

RESULTS AND DISCUSSION

The on-station trial on AWD indicates that there is water saving of 18% to 33% due to this technique. It is estimated that the conventional system required 2 155 ha mm (13–16 irrigations), while the AWD technique required 1 465 ha mm of water (9–13 irrigations). This amounts to water saving of 3–4 irrigations. While determining the water use efficiency (WUE), the indicative parameter for efficient utilization of irrigation water, it was observed that WUE varied from 2.04 to 2.63 kg grain/ha mm water applied. Among them, three cultures, viz. IR 55423-01, IR 74371-3-1-1, and IR 55419-04 have shown higher WUE beyond 2.4 kg grain/ha mm with maximum (2.63 kg/ha mm) in IR 55423-01.

In the on-farm trials, the cultures/varieties used were IR 72667-16-1-B-B-3, IR 74371-70-1-1, IR 79906-B-192-2-1, IR 78878-53-2-2-2, IR 78875-131-B-1-4, IR 78877-181-B-1-2, IR 79906-B-5-3-3, IR 74371-3-1-1, IR 55423-01 and IR 55419-04 with Khandagiri, Annada, Lalat, Naveen, and Satabdi as the check varieties. Forty per cent farmers have ranked the culture IR 55423-01 as first followed by IR 74371-3-1-1 (20%) and Annada (13%). The other culture, which 7% farmers have given first preference, was IR 55419-04 (Table 2). The second rank was given mainly to four varieties /cultures and they were IR 55423-01 (30%), Annada (20%), IR 74371-3-1-1(20%) and IR 55419-04 (13%). The third rank was given mainly to four cultures/varieties like IR 55423-01 (25%) followed by Annada (15%), IR 74371-3-1-1 (13%) and IR 55419-04 (12%). On the whole, among the new cultures, IR 55423-01 was preferred by most of the farmers followed by IR 74371-3-1-1 and IR 55419-04. The reasons subscribed by the farmers for preferring the varieties were (i) good panicle length and weight, (ii) grain type, (iii) more number of tillers/hill, and, (iv) more straw.

Table 2 Ranking of varieties in Participatory Varietal Selection trials

Variety	Figures (%)			Rank	Yield
	First	Second	Third		(tonnes/ha)
IR 55423-01	40	30	25	1	3.85
IR 74371-3-1-1	20	20	13	2	3.54
Annada	13	20	15	3	3.44
IR 55419-04	7	13	12	4	3.77
Lalat	5	2	8	5	3.35
IR 74371-70-1-1	0	5	7	6	3.80
IR 78878-53-2-2-2	5	0	2	6	3.61
Naveen	3	2	2	7	3.11
Satabdi	1	2	5	8	3.14
IR 79906-B-192-2-1	2	1	2	9	3.44
IR 78875-131-B-1-4	2	0	2	10	3.48
Khandagiri	0	2	3	11	3.24
IR 78877-181-B-1-2	1	1	2	11	3.24
IR 72667-16-1-B-B-3	1	2	0	11	3.19
IR 79906-B-5-3-3	0	0	2	12	2.99
Total	100	100	100		

Impact study carried out with the help of survey data indicates the popularity of the promising cultures among farmers in the water deficit environments. The average yield performance of the three promising cultures, viz. IR 55423-01, IR 74371-3-1-1 and IR 55419-04 is presented in Table 3. It is evident from the table that the yield advantage over the currently grown popular varieties varied from 9.24% to 23.53% in wet season and 9.85% to 18.82 % in dry season. There is no additional cost involved in adopting the new cultures except seed cost. Besides, the advantage of growing these varieties is saving of 2–3 irrigations as observed by the farmers. The savings in irrigations will reduce the cost per tonne of rice by ₹ 375. Above all, the saved irrigation water will be used for expanding area under rice or irrigating rainfed areas.

Table 3 Average yield performance of promising cultures

Varieties	Average yield (tonnes/ha)		% increase
	New promising cultures	Currently grown varieties*	
Kharif			
IR 55423-01	3.99	3.23	23.53
IR 55419-04	3.45	3.12	10.58
IR 74371-3-1-1	3.43	3.14	9.24
Rabi/Summer			
IR 55423-01	5.05	4.25	18.82
IR 55419-04	3.68	3.35	9.85

* Lalat, Khandagiri, Annada, Satabdi and Naveen

Due to superior performance of the three cultures in comparison to the existing varieties, seed exchange among farmers within and outside the sample villages in the same district and outside the district has taken place. The information on exchange of promising cultures is presented in Table 4. Maximum seed exchange has taken place within the village followed by outside the village in the same district and outside the district.

In total, 974 kg of seeds has been exchanged among 94 farmers. Among the three cultures, maximum amount of seed (849 kg) was exchanged for IR 55423-01 culture among 84 farmers. This is due to the fact that initially, seeds of IR 55423-01was supplied to 135 farmers (out of total 170) in comparison to other two cultures (IR 55419-04 = 20 farmers; IR 74371-3-1-1 = 15 farmers). Therefore, it is obvious that less amount of seeds will be exchanged among farmers for the last two cultures.

A season wise simulation exercise was carried out by taking assumptions as mentioned in methodology section.

Table 4 Seeds exchanged by farmers

New promising varieties	No. of farmers exchanged seeds	Amount (kg)
	IR 55423-01	
Within the village	35	510
Outside the village	26	220
Outside the district	23	119
Total	84	849
	IR 55419-04	
Within the village	6	80
Outside the village	2	20
Outside the district		
Total	8	100
	IR 74371-3-1-1	
Within the village		
Outside the village		
Outside the district	2	25
Total	2	25
Grand total	94	974

Table 5 Simulation results of water saving rice technologies

Particulars	Season		
	Kharif	*Rabi* / Summer	Total
Present coverage of rice under irrigation (million ha)	20.5	4.5	25
Absolute increase in additional rice area (million ha)		0.9[a]	0.9
Absolute increase in irrigated rice area (million ha)	2.1[b]	0.9	3
Yield increases due to irrigation expansion (tonnes/ha)	1.5[c]		
Production increase (million tonnes)	3.2[d]	4.0[e]	7.2

The average irrigated *kharif* and *rabi*/summer season rice area in India is about 20.5 and 4.5 million ha respectively. The increase in absolute area during *rabi*/summer season will be 0.9 million ha, with the saved water, due to adoption of water saving technologies like aerobic rice cultures and AWD (Table 5). There is no scope for increase in absolute rice area during *kharif* season. But, due to adoption of water saving technologies, the irrigated *kharif* rice area will increase by 2.1 million ha with the help of the saved water. The yield per ha of irrigated rice is about 1.5 tonnes/ha more than the rainfed rice. Therefore, the total increase in *kharif* rice production will be 3.2 million tonnes. The *rabi*/summer production increase will be 4.0 million tonnes due to expansion of *rabi*/summer rice area. Thus, total rice production (un-milled) increase of 7.2 million tonnes per year will occur due to adoption of water saving technologies.

Faced with growing water shortages, policy makers and experts have called for improved management of irrigation systems. Both central and state governments are incurring huge irrigation and power subsidies for providing irrigation. Therefore, irrigation water is cheaper in India than many other countries and hence, the conjunctive use of water is rarely observed. It is difficult to implement the water pricing policy under the present political scenario. In the area of institutional reform for irrigation system operation and maintenance, the delegation of management and financial responsibility from irrigation system managers to local user groups or water use associations is in the right direction. In case of promotion of water saving rice technology like AWD, some kind of incentive should be given to farmers because it needs co-operation of all farmers in a definite area. AWD needs participation of whole community or group of farmers in an area for management of irrigation water. Therefore, this technology can be promoted through water use associations supplemented by incentives to farmers in the initial years of adoption. This may be waiver of irrigation fees in adopted areas or supply of some inputs, whoever adopts the technologies. That will help in spread of these technologies to newer areas and save huge amount of irrigation water.

Growing water shortage to raise crops has become a subject of discussion for the last three decades because of increasing demand of water from other sectors of the economy. As rice consumes maximum water among cereals, rice production and national food security has been threatened. Therefore, there is increasing pressure on researchers to develop technologies, which will increase water productivity in rice cultivation. Among the several options available to increase water productivity, use of aerobic rice varieties and AWD irrigation technique are two viable options to conserve water. These two options were field tested and found promise for its large scale adoption. The results of field testing revealed that the adoption of these technologies saves 2-3 irrigations and consequently, a cost reduction of Rs 375 per tonne of rice was obtained. The results of the simulation exercise revealed that irrigated rice area can be further expanded to another 3.0 million ha and rice production increase by another 7.2 million tonnes due to adoption of these technologies. However, adoption of AWD and aerobic rice varieties requires right type of incentive to water use associations or group of farmers for its full scale adoption.

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REFERENCES

Ahmed M I, Meera S N and Viraktamath B C. 2007. Seeing is believing: Encouraging adoption through FLDS on rice. *DRR Technical Bulletin No. 23*, Directorate of Rice Research, Hyderabad, India.

Bouman B. 2009. How much water does rice use? *Rice Today* **8**: 28–9.

Bouman B, Barker R, Humpreys E, Tuong T P, Atlin G, Bennet J, Dawe D, Dittert K, Dobermann A, Facon T, Fujimoto N, Gupta R, Haefele S, Hosen Y, Ismail A, Johnson D, Johnson S, Khan S, Shan L, Masih I, Matsumo Y, Pandey S, Peng S, Thiyagarajan T M, and Wassman R. 2007. Rice: Feeding the billions. (*in*) *Water for Food and Water for Life: A Comprehensive Assessment of Water Management in Agriculture,* pp 515–49, David Molden (Eds.). International Water Management Institute, Colombo.

Government of India. 2007. *Compendium of Environmental Statistics of India, 2003*. Ministry of Statistics and Program Implementation, New Delhi, p 197.

Government of India. 2010. *Economic Survey 2009-10.* Ministry of Finance, New Delhi.

Goswami S B. 2006. Water balance and water productivity of summer rice as influenced by land situation in tube well commands. *Indian Journal of Agricultural Sciences* **76**: 11–5.

Kumar M D, Narayanamoorty A, Bassi N and Niranjan V. 2011. Addressing agricultural water management, challenges in the twelfth plan: Some pointers. *Indian Journal of Agricultural Economics* **66**: 289–300.

Kumar P, Joshi P K and Birthal P S. 2009. Demand projections for foodgrains in India. *Agricultural Economics Research Review* **22**: 237–43.

Radha Y, Reddy K Y, Subba Rao G, Chandra S R, Babu G K. 2009. Water-saving rice production technologies in Krishna western delta command of Andhra Pradesh – An economic analysis. *Agricultural Economics Research Review* **22**: 397–400.

Senthil Kumar K, Lubbers M T M H, de Ridder N, Bindraban P S, Thiyagarajan T M and Giller K E. 2011. Policies to support economic and environmental goals at farm and regional scales: Outcomes for rice farmers in Southern India depend on their resource endowment. *Agricultural Systems* **104**: 82–93.

Senthil Kumar K, Bindraban P S, Thiyagaranjan T M, de Ridder N, and Giller K E. 2008. Modified rice cultivation in Tamil Nadu, India: Yield gains and farmers' (lack of) acceptance. *Agricultural Systems* **98**: 82–94.

Singh N, Kaur R, Sharma N, Mahajan G and Bharaj T S. 2012. Changes in yield and grain quality characteristics of irrigated rice (Oryza sativa) genotypes under aerobic conditions. *Indian Journal of Agricultural Sciences* **82**: 589–95.

Swaminathan M S. 2010. Achieving food security in times of crisis. RAP Publication 2010/3, FAO Regional Office for Asia and the Pacific, Bangkok, pp 7–10.