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Resource Use, Profitability and Externality in Aerobic Vis-A-Vis Conventional Rice Cultivation in Karnataka, India

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Abstract

The study was undertaken to analyze resource use, economics of cultivation and externality associated with Aerobic Rice Cultivation (ARC) in comparison with Conventional Rice Cultivation (CRC) in Eastern Dry Zone of Karnataka. Snow ball sampling technique was adopted to collect primary data from 50 farmers each practicing ARC and CRC. The per hectare gross returns was higher in CRC (₹ 1,16,827/ha) compared to aerobic rice cultivation (₹ 1,00,664/ha) since the grain yield was higher in CRC. The aerobic rice cultivation (ARC) was profitable as it generated higher net returns (₹ 24,653/ha) compared to conventional paddy cultivation (₹ 11,046/ha) because of lower cost of cultivation. ARC was sustainable compared to conventional method as resources were optimally used. In addition, ARC resulted in positive externality to the tune of ₹ 7714 per hectare over CRC. Human work was the significant expense part in both ARC and CRC Among the costs in ARC, human labour cost accounted nearly 40 per cent because of high labour requirement for weeding. Imputed irrigation cost was higher in CRC than ARC where water requirement was saved up to 63 per cent. The examination uncovered the predominance of ARC over CRC with regards to cost, net returns and positive externality. Hence, the study helps policy makers and stakeholders in extensive promotion of the technology.

Keywords: Aerobic rice; Positive externality; Methane inventory; Partial budgeting

Introduction

Rice being a staple food of India for almost 60 per cent of the Indian population contributes largely to the nation's food security. As the population of India is growing, demand for rice is supposed to increase continuously in the near future. Rice is majorly grown in Kharif and Rabi seasons in India. Kharif season accounts for almost 89 per cent of total rice area and 85 per cent of total rice production. Similarly, Rabi season accounts for almost 11 per cent of total rice area and 15 per cent of total rice production. Total of 117.94 million tonnes of rice is harvested annually from the area of 44.5 million hectares [1]. Demand for rice is expected to reach 121.2 million tonnes by the year 2030, 129.6 million tonnes by the year 2040 and 137.3 million tonnes by the year 2050 [2]. The current productivity of rice is nearly 2.2 tonnes per hectares presently which should be brought to the level of 3.3 tonnes per hectares to fulfill the needs of the increasing population [3].JVPRThe current production and productivity trend is a matter of concern in meeting the growing export as well as domestic market demand. Thus, new technologies and innovations should be developed in order to meet the growing demand of country.

Asia's food security relies to a great extent upon irrigated lowland rice fields, which produce 3/4th of all rice reaped. Conventional Rice Cultivation (CRC) system requires nearly 2,295 mm of water for the intercultural operations such as puddling, transplanting and irrigation. But the sustainability of the irrigated rice ecosystem is getting threatened by the rising scarcity of fresh water as water is scarce resource and its utilization is supposed to increase shortly at a distressing rate [4]. It is expected that there will be almost 10%-15% of reduction of water availability by the year 2025 due to the demand from other than agricultural sectors such as industry, household used etc. Soon the overall agricultural sector and rice development specifically will confront a significant fall in the accessibility of irrigation water which will have genuine ramifications for meeting the food targets [5].

To reduce the use of water in rice fields, various innovations have been developed to shrink evaporation, seepage and percolation. One approach to lessen water use and demand of labour is to develop Direct Seeded Rice (DSR) rather than the puddled relocated rice. Another emerging improvement in water-saving technologies is the idea of Aerobic Rice Cultivation (ARC) developed by International Rice Research Institute (IRRI). Fields in case of ARC system remain unsubmerged during the whole cropping season. The region where water isn't adequately accessible to grow lowland transplanted rice, yet, adequately accessible for upland yields, can be utilized for growing aerobic rice. The cultivars used in aerobic cultivation have higher yielding capacity and are even nutrient-responsive when compared to conventional rice cultivation. In case of aerobic rice production system, water use is nearly 55–56 per cent lower than the flooded rice along with 1.6-1.9 times greater water productivity. Aerobic rice system saves nearly 45 per cent of water when compared to conventional rice production system [6]. Water saving in aerobic rice system is mainly due to (1) Reduced percolation and seepage (2) Reduced evaporation, and (3) decreased water loss during land preparation.

The main focus of the paper is to analyze the performance of ARC technology in terms of cost, returns and externality over CRC at the farm level. It plays important role in understanding the impact of novel technologies in agriculture sector at the farm level. The results can be used for policy making for the better adoption and awareness of such technologies for prosperity of farmers.

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Materials and Methods

Sampling framework

Eastern Dry Zone of Karnataka was selected purposively because; the aerobic rice varieties were released and distributed exclusively for Eastern Dry Zone. Snow ball sampling technique was adopted for selection of sample respondents, since; it was difficult to locate ARC farmers. The snowball sampling is a non-random sampling technique wherein the initial informants are approached who through their social network nominate or refer the participants that meet the eligibility criteria of the research under study. Consequently, this strategy is likewise called as the reference testing technique or chain examining technique. Snow ball sampling technique was employed since identifying or finding potential respondents was difficult because the respondents were deviant or geographically isolated.

The sample farmers numbering, 50 were selected each practicing ARC and CRC. The sample farmers were interviewed using the pre tested and well-structured schedule to collect the required information to achieve the proposed objectives of the study. The data relating inputs use, labour use, costs incurred and returns obtained from aerobic and conventional paddy cultivation was collected. Similarly, the information pertaining to externalities associated with ARC and CRC were also collected from the sample respondents. The data collected was purely based on the memory of the respondents. The field survey was conducted during January-February, 2019.

Cost analysis

The total costs were grouped into variable and fixed costs. Variable cost comprises cost of inputs (seed, FYM, fertilizer, plant protection chemicals), labour cost, irrigation cost and interest on working capital. Fixed cost comprises depreciation on farm implements, rental value of land, land revenue and interest on fixed capital.

Total cost

Complete expense is the summation of all out fixed cost and absolute factor cost.

Gross returns

Gross return including the gross value of main product and by-product imputed on the basis of post-harvest prices prevailing in the study area.

Net returns over total cost

Net return was computed by subtracting the gross returns from total cost of cultivation.

Cost of production

Cost of production per quintal was worked out by dividing total cost by the yield of main product.

Returns per rupee of expenditure

Return per rupee of expenditure was worked out by dividing the gross return by total cost.

Partial budgeting technique for accounting externality

The Partial budgeting technique was employed to estimate the externality cost associated with rice cultivation under ARC and CRC. Further, to measure the negative externality cost associated with CRC.

Methane inventory formula

The irrigated CRC contribute to methane emission because of the decaying of organic materials under anaerobic condition created by standing water during growing stages of the crop. The amount of methane emitted by rice field was quantified using methane inventory formula used by Bhatia [7]. The quantification was done by multiplying the annual harvested area of irrigated rice with seasonal integrated emission factor for irrigated condition. The quantified methane units were transformed into carbon dioxide equivalent by using the formula given by Anon [8]. The emission cost of methane from rice field was assessed by using the formula given by Pardis [9].

CH_4 emission from rice field per year = ($EF_{i,j}$ *$A_{i,j}$)

Where,

$EF_{i,j}$ = Seasonal integrated emission factor for ith and jth condition kg CH_4 per acre

$A_{i,j}$ = Annual harvested area of rice for ith and jth conditions acre per year

i, j represents water regimes under rice cultivation and methane emission respectively.

GHG emission cost per kg CO_2 of 2019 was estimated by compounding the value obtained by Pardis in 2014 at two per cent social discount rate, it was given by

₹ 0.4632/kg *compounding @ 2 per cent of SDR = ₹ 0.5114/kg

GHG emission cost = CH_4 emission *CO_2 equivalents *GHG cost of 1 kg CO_2

Results and Discussion

Resource-use

The overall break up of resource use in ARC and CRC farms (Table 1) revealed that, the total human labour employed was found to be higher in CRC (78.89 man days) compared to ARC (75.48 man days) and this was found to be statistically non-significant. The marginal difference in labour use was due to higher labour requirement in CRC during nursery preparation and transplanting [10]. The bullock pair days of 2.02 were employed in CRC, whereas, no bullock labour was employed in ARC. The total machine labour used in CRC was higher with 14.27 hours than the machine labour used in ARC and this was mainly attributed to additional machine labour requirement during field preparation and puddling.

Sl. No.	Particulars	ARC (n=50)		CRC (n=50)		't' Value (Qty.)
		Quantity	Value (₹)	Quantity	Value (₹)	
1	Human labour (Man days)	75.00	30193.93	79.00	31554.49	-1.24 NS

2	Bullock labour (BP days)	0.00	0.00	2.02	1817.31	-0.39 NS
3	Machine Labour (hours)	9.00	7161.27	14.00	10704.09	-2.21**
4	Seeds (Kgs)	23.27	255.98	69.31	1663.46	-24.59**
5	FYM (tractor load)	3.05	9147.20	4.73	14182.69	-1.52 NS
6	Fertilizers(50 kg bag)	5.76	4147.20	6.99	6056.09	-0.96NS
7	PP Chemicals		590.65		711.86	-
8	Irrigation (Acre inches)	15	5610.00	41	14022	-13.37**
Return	Return	Return	Return	Return	Return	Return
Return	Return	Return	Return	Return	Return	Return

Note: 1. ** -Significant at one per cent level

2. NS- Non-significant

Table 1: Resource use pattern in ARC and CRC (per ha).

On an average, the seed rate used was 69.31 Kg per ha in CRC, whereas, it was only 23.27 Kg per ha in ARC which is statistically significant. The CRC farms used higher FYM with 4.73 tractor load in comparison with 3.05 tractor load per ha in ARC. The expenditure on per ha use of FYM was ₹ 9,147.20 and ₹ 14,182.69 in ARC and CRC, respectively. In ARC, it was found that the expenditure on fertilizer was ₹ 4,147.20 which was lower compared to ₹ 6,056.09 incurred in CRC. Inputs like FYM and fertilizers were more intensively used in CRC whereas, ARC was highly input responsive [11].

The study revealed that, CRC was resource intensive resulting in higher cost of cultivation. The lower cost of cultivation of ARC was mainly attributed to low labour requirement, reduction in bullock and machine labour use, low seed rate and other inputs such as FYM, fertilizer and also plant protection chemicals and lesser expenditure on irrigation (Table 2).JVPR

Sl. No.	Particulars	Impact analysis			
		CRC	ARC	Difference	(%)
		A	B	C=A-B	[(C/B)*100]
1	Variable cost (₹/ha)	87169	61675	25494	41
2	Total cost (₹/ha)	105781	76010	29771	39
3	Gross returns (₹/ha)	116827	100664	-16163	-16
4	Net returns (₹/ha)	11046	24653	13607	55
5	Irrigation water(acre inch)	41	15	26	63
6	Irrigation cost (₹/ha)	14022	5610	8412	60

Table 2: Comparative economics of ARC Vs.CRC

Yield and returns: The details regarding yield and returns in ARC and CRC. The average grain yield obtained in CRC was 67.31 quintals per hectare whereas in ARC it was 57.76 quintals per hectare. The low yield in ARC was attributed to high weed infestation [12] as well as yield potential of the varieties used. The gross returns include both returns from main-product (grain) and by-product (straw). The per hectare gross returns was higher in CRC (₹ 1,16,827/ha) compared to ARC (₹ 1,00,664/ha). The higher gross returns in CRC was due to higher grain yield compared to ARC.

The net return realized from ARC was higher with ₹ 24,653 per hectare compared to ₹ 11,046 per hectare in CRC. The higher net returns in ARC was mainly due to reduced cost of cultivation compared to CRC. The study conducted by Pandey [13], aptly support the above findings. The cost of production was higher in CRC (₹ 1,572/q) compared to ARC (₹ 1,316/q) and this was mainly due to higher variable costs incurred in production of CRC.JVPR

The returns per rupee of expenditure incurred in ARC was higher with 1.32 compared to CRC with only 1.10. The reason for higher returns per rupee of expenditure was due to reduction in expenditure in ARC and higher expenditure in conventional paddy cultivation CRC. The result is aptly supported by the study conducted by Vinay [14], which highlighted that, returns per rupee of expenditure was 2.13 in direct seeded rice while it was only 1.94 in puddled transplanted rice.

Comparative economics of ARC vs. CRC

The results of comparative economics of CRC and ARC is depicted. The results indicated that the total cost of cultivation was 39 per cent higher in CRC compared to ARC. In other words, up to 39 per cent of costs can be saved in ARC compared to CRC. This was majorly due to low cost of cultivation in ARC. The variable cost was more in CRC by 41 per cent, since input use was higher compared to ARC. The gross return was 16 per cent less in ARC compared to CRC due to reduced grain yield in ARC. However, the net return was higher in ARC by 55 per cent than CRC due to low variable costs incurred in ARC. The results were in accordance with study conducted by Kumar and Sidana [15,16]. The irrigation water and irrigation cost in ARC were saved up to 63 and 60 per cent, respectively. Since there was no standing water condition in ARC, the farmers could save both irrigation water and irrigation cost.

Externality cost associated with ARC over CRC

The estimation of externality cost associated with ARC over CRC is presented. The results revealed that, ARC has positive externality over CRC. It was evident from the positive net gain obtained in ARC. A positive value indicates the net gain from ARC over CRC which is considered as externality cost in Natural Resource Economics (NRE).

Added costs

The additional costs incurred in ARC include human labour for weeding (₹ 4,780/ha), manure and fertilizer application (₹ 1,255/ha) and PP chemicals (₹ 55/ha). Since, weed infestation was the problem in ARC, manual weeding was regularly carried out for better growth of crop. Absence of standing water makes it difficult to control weeds which emerge simultaneously along with crop. The manual incorporation of fertilizers along the crop stand directly into the soil incurs additional labour. The line by line chemicals application in aerobic paddy cultivation also incurs extra labour.

Reduced returns

In view of lower main product and by-product in ARC, the returns were lower by ₹ 13,848 and ₹ 2,314 per hectare, respectively compared to CRC.JVPRSeveral constraints in ARC including weed infestation and uneven crop stand resulted in lower yield in ARC.

Reduced costs

The additional costs incurred in CRC are the reduced costs by taking up ARC. The total cost saved due to ARC over CRC was ₹ 29,966 per hectare. The various costs saved due to ARC include labour from nursery preparation (₹ 1,029/ha), land preparation (₹ 1,077/ha) and transplanting (₹ 2,875/ha). The bullock and machine labour could be saved up to ₹ 5,360/ha, seeds (₹ 1,407/ha), manures and fertilizers (₹ 6,944/ha) and irrigation (₹ 8,412/ha). The environmental damage cost due to emission of methane from CRC was reduced in ARC. It accounted for ₹ 272 per hectare, which is a saving in ARC because there was no methane emission.

Added returns

There were no additional returns in ARC over CRC. This was due to reduced yield in ARC compared to CRC which is included under reduced returns from ARC.

Net gain/loss

The positive value indicated that ARC has positive externality over CRC. The externality cost was ₹ 7,714 per hectare, implying the net gain from ARC compared to CRC.

Conclusion

Rice (Oryza sativa L.) is the most important staple food crop of India and play vital role in ensuring food security of the nation. The regular drought years, failing rains and depleting ground water resources have forced government and institutions to strike a balance between water shortage and aspirations of farmers by alternative less water intensive technologies in agriculture. The major challenge in rice production is to achieve the maximum yield with less water, labour, and chemicals, thereby ensuring long-term sustainability. Aerobic rice technology has been proposed to reduce water requirement, save labour, mitigate greenhouse gas emission and improve environmental sustainability. It is essential to convince and create awareness among farmers regarding the profitability and environmental benefits of less water intensive technology like aerobic paddy cultivation. ARC has resulted in reduction in cost of cultivation and increased the net returns. The net return was 55 per cent higher in ARC (₹ 24,653/ha) compared to CRC (₹ 11,046/ha) indicating the superiority of the technology and a solution for the above addressed issues. Partial budgeting for the assessment of externality revealed ARC resulted in positive externality to the tune of ₹ 7714 per hectare over CRC. Therefore, ARC can be extended to tube well irrigated rice regions to enhance the income of farmers. ARC paves its superiority in sustainable agriculture with reduced water extraction and zero greenhouse gas emission over CRC. Hence, popularizing this technology through intensive extension efforts is the need of the hour.

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Competing Interests

All authors declare no competing interests.

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