DOI: 10.5958/0976-4038.2015.00003.2

Full Research Article

Bio-energy, Productivity and Economics of rice (*Oryza sativa* L.)-based Cropping Systems in Coastal Flood Plain of West Bengal, India

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Article History

Manuscript No. AR868
Received in 31st July, 2014
Received in revised form 19th January, 2015
Accepted in final form 1st February, 2015

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Keywords

Cropping system, coastal saline zone, EUE, energy output

Abstract

A field experiment was carried out at farmers' field in coastal saline zone of West Bengal, India during 2011-12 and 2012-13 with four cropping systems viz. rice-greengram, rice-sunflower, rice-sunflower+greengram and rice-lady's finger. Rice-lady's finger system recorded significantly higher rice equivalent yield, system productivity in both the years. Significantly higher net return (₹ 1,05,670 ha^{-1}) was obtained in rice-lady's finger cropping system, followed by rice greengram, whereas B:C ratio was found at par. Among the management components fertilizer consumed maximum energy followed by operational labour and land preparation. Energy consumption was found significantly higher in rice-lady's finger system (44,902 MJ ha^{-1}) and lowest in rice-greengram system (29,005 MJ ha^{-1}). Total bioenergy output follows the order: rice-lady's finger>rice-sunflower>rice-sunflower+greengram>rice-greengram. But this order was reversed for energy-use efficiency (EUE). Significantly higher specific energy was recorded in rice-sunflower system (3415 MJ t^{-1}) and it was the most energy-investment intensive among them. However, significantly higher energy productivity was observed in rice-lady's finger system (0.63 kg MJ^{-1}) and lowest in rice-greengram (0.30 kg MJ^{-1}). Regarding energy intensiveness the results were contrary to EUE. Rice-lady's finger system was emerged as most energy intensive system as compared to other three cropping systems and the rice-greengram system is the least. It can be concluded that though the yield and net return in rice-lady's finger system were higher than other system, the rice-greengram system is more suitable cropping system in constrains prone coastal saline zone with limited irrigation facilities due to low requirement of non-renewable energy, higher EUE and benefit-cost ratio.

1. Introduction

Coastal flood plain is one of the most constrained zones out of six agro-climatic regions in the state of West Bengal, India (SenGupta, 2001). It broadly covers whole South 24 Parganas district and part of North 24 Parganas, Howrah and East Midnapore districts. This area represents low land agro-ecosystem with heavy textured saline soils, limited availability of irrigation water and very low cropping intensity (134%) as compared to state average of 185% (Anonymous, 2012). Farmers used to grow some low water requiring crops like greengram, lathyrus either rainfed or with life saving irrigation or keep their field fallow during dry period after *kharif* rice.

Diversification of cropping system with food crops like potato, oilseed and vegetables is necessary for obtaining higher yield and return, maintenance of soil health, protection of environment and meeting up daily requirement of human and livestock (Samui et al., 2004). Inclusion of legumes in the cropping system increases soil fertility status (Ghosh, 1987, Upadhyay et al., 2011). A number of soil and climatic parameters decide cropping system of a region, which determine overall agro-ecological setting for nourishment and appropriateness of a crop or set of crops for cultivation. Several forces regarding infrastructure facilities, socio-economic factors and technological development etc. operating interactively at micro-level decide the choice of crop or cropping system, where potential productivity and monetary benefit for a particular crop/cropping system act as guiding principles (Ray et al., 2014).

In the process of technology assessment farmers' concern like their resources, social and economic aspect as well as their perception were often ignored, particularly in case of the resource poor farmers. As a result the potential yield and profitability of a crop/cropping system remains far behind from that of actual. Farmers' participatory research (FPR) emphasizes the process that enables a local farmer to evolve and promote improved agricultural technologies to the field. It values scientists and farmers knowledge equally and underlines the complementary nature of both pools of knowledge in generating and using technologies (Ray et al., 2014). Considering this fact, a participatory research was conducted to evaluate the productivity, profitability and resource efficiency at farmer field representing coastal flood plains of West Bengal. The objectives of the present study were to assess productivity, profitability, and energy efficiency of different rice-based cropping systems at farmers' level through farmers' participatory approach.

2. Materials and Methods

A field experiment was conducted at farmers' field in two blocks namely; Mandirbazar and Kakdwip (21°50.068′ N to 22°06.975′ N latitude and 88°11.858′ E to 88°19.653′ E longitude with an average altitude of 8.18 m above msl) of 24 Paraganas (South) district of West Bengal, India adopted by AICRP on Integrated Farming Systems, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia during two consecutive years 2011-12 and 2012-13 with four rice-based cropping systems viz. rice-greengram, rice-sunflower, rice-sunflower+greengram (2:4) and rice-lady's finger replicated in twenty four farmers' field, taking a block of 100 m^2 area i.e. the area of each cropping system was 25 m^2. All the crops were grown with recommended package of practices. Varieties used for rice, greengram, lady's finger and sunflower were IET 5656, local, pankaj and GK-2002 respectively. The average values of soil properties as well as ranges of experimental fields were: pH 5.43 (4.45-6.99), EC 0.58 (0.15-1.95) dS m^{-1}, organic carbon 0.71 (0.58-0.82)%, available N 140.46 (111.09-186.55) kg ha^{-1}, P 48.07 (39.88-59.82) kg ha^{-1} and available K 305.84 (281.45-324.67) kg ha^{-1}. The area received an annual rainfall of 1626 cm and 1667 cm in the year 2010-11 and 2012-13, respectively.

The observations on yield and other parameters were calculated using SPSS software, IBM Inc. 2009 and least significant was computed at $p\leq 0.05$ as described in Gomez and Gomez (1984). To compare among the cropping systems, the economic yield of component crops was taken into account over the year and converted into rice equivalent yield (REY) on price basis for each cropping system (Verma and Mudgal, 1983). The total economic yield in terms of REY of a cropping system was divided by 365, to get the system productivity (kg ha^{-1} day^{-1}) (Devasenapathy et al., 2008). Net return was worked out by the difference of gross returns and total cost of cultivation of a system. B:C ratio (Returns per rupee invested) of a system was expressed as net returns (₹) $₹^{-1}$ spent.

Input and output energy of different crop components as well as the cropping systems were calculated on the basis of energy equivalents (Table 1) as given by Mittal et al. (1985) and Devasenapathy et al. (2008) and expressed as MJ ha^{-1}. The energy input refers to both operational and non operational energy. Operational input energy refers to human labourers for various intercultural activities and harvesting. Non-operational energy input refers to energy consumed for various management components like seed, fertilizer, irrigation, land preparation (fuel+machinery), plant protection agro-chemicals etc. Energy use efficiency (EUE), specific energy, energy productivity and energy intensiveness were calculated using the following formulae as suggested by Mittal and Dhawan, (1988), Singh et al. (1997) and Burnett, (1982).

$$\text{EUE} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Energy output (MJ ha}^{-1})}$$

$$\text{Specific energy} = \frac{\text{Energy input (MJ ha}^{-1})}{\text{Grain output (t ha}^{-1})}$$

$$\text{Energy productivity} = \frac{\text{Grain output (kg ha}^{-1})}{\text{Energy input (MJ ha}^{-1})}$$

$$\text{Energy intensiveness} = \frac{\text{Energy input (MJ ha}^{-1})}{\text{Cost of cultivation (₹ ha}^{-1})}$$

3. Results and Discussion

3.1. Productivity

The results revealed that rice equivalent yield (REY) registered highest in rice-lady's finger cropping system in both the year of experiment (30911.33 kg ha^{-1}/25249.00 kg ha^{-1}) followed by rice-sunflower, rice-greengram+sunflower and rice-green gram. Rice yield of the system containing lady's finger was significantly higher due to residual effects of high doses of fertilizer and organic manure applied in lady's finger. Similar findings also reported by Ray et al. (2009) and Samui et al. (2004) in rice-potato and rice-lady's finger sequence. Out of the two blocks, Kakdwip recorded the highest yield of *kharif* rice as compared to Mandirbazar. Similar trend was also observed in sunflower and lady's finger. Maximum REY (16,063.74 kg ha^{-1}/14,122.73 kg ha^{-1}) and system productivity (50.21 kg ha^{-1} day^{-1}/ 38.69 kg ha^{-1} day^{-1}) were recorded under Kakdwip block in both the year of experiment (Table 2). This was because of better soil fertility of second block (Anonynous, 2013).

3.2. Profitability

Table 1: Energy equivalent for different inputs and outputs

Sl. No.	Particulars	Units	Equivalent energy (MJ)	Remarks
A.	Inputs			
1.	Human labour	Man-hour	1.96	Weight of machine distributed equally over total life span
2.	Bullocks	Pair-hour	10.10	
3.	Diesel	Litre	56.31	
4.	Farm machinery	kg^{-1} hr	62.70	
5.	Chemical fertilizer			
	(i) Nitrogen (N)	kg	60.60	Require dilution at the time of application
	(ii) Phosphate (P_2O_5)	kg	11.10	
	(iii) Potash (K_2O)	kg	6.70	
	(iv) Zinc sulphate ($ZnSO_4$)	kg	6.70	
6.	Plant protection chemical	kg	120	Require dilution at the time of application
7.	Seed			
	(i) Rice	kg	14.70	
	(ii) Greengram	kg	14.70	
	(iii) Sunflower	kg	25.00	
	(iv) Lady's Finger	kg	25.60	
B.	Outputs			
1.	Main Products			
	i) Rice/Green gram/Sunflower	Same as seed (Inputs)		
	ii) Lady's finger	kg	1.60	
2.	By-products			
	i) Rice straw (dry mass)	kg	12.50	
	ii) Lady's finger straw (dry mass)	kg	18.00	

(Mittal et al., 1985 and Devsenapathy et al., 2008)

Cost of production and net return of *kharif* season crop (rice) was found not significant in different cropping system though for *rabi*-summer crop the same were found significant. During *rabi*-summer season significantly higher production cost incurred in Lady's finger (₹ 85,690 ha^{-1}) followed by sunflower+greengram (₹ 28,630 ha^{-1}), sunflower (₹ 27,950 ha^{-1}) and greengram (₹ 23,250 ha^{-1}). However cost of production of component crops as well as cropping systems were found not significant between the two blocks (Table 3). Production cost in rice-lady's finger was 96%, 98% and 116% higher over rice-greengram+sunflower, rice-sunflower and rice-greengram respectively due to high requirement of labour, fertilizers, plant protection chemicals and irrigation in lady's finger (Table 3). Singh et al. (2013) reported that the rice-lentil and rice-pea crop sequence required fur less cost of cultivation in comparison to rice-frenchbean or rice-mustard sequence.

Though the rice-lady's finger crop sequence was found most remunerative to the farmers with net return of ₹ 1,05,980 ha^{-1} followed by rice-greengram (₹ 51,070 ha^{-1}), rice-sunflower+greengram (₹ 49,380 ha^{-1}) and rice-sunflower (₹ 48,820 ha^{-1}); the benefit:cost ratio was in order rice-greengram (1.94)>rice-lady's finger (1.92)>rice-sunflower+greengram (1.83)>rice-sunflower (1.83) (Table 3). Mandal et al. (2002) also observed that though soybean-wheat crop sequence got highest net return with ₹ 11436 ha^{-1} followed by soybean-chickpea and soybean-mustard, the benefit-cost ratio was in order soybean-chickpea (1.57)>soybean-wheat (1.55)>soybean-mustard (1.41). Similar result was also obtained by Pramilarani et al. (1998) in black clay soil in southern India.

Among the two blocks, significantly higher net return (₹ 75,380 ha^{-1}) and B:C (1.91) were recorded in Kakdwip block than Mandirbazar mainly due to higher yield and less cost of production (Table 3).

3.3. Energy requirements

Among the inputs for different management component, fertilizer component consumed bulk of the energy for all the cropping system and the same trend was also obtained by Mandal et al. (2002) and Biswas et al. (2006). Fertilizers consumed 63.14%, 71.76%, 70.08% and 62.09% of the total system input energy in rice-lady's finger, rice-sunflower+greengram, rice-sunflower and rice-greengram system respectively. Energy consumption for fertilizer was the prime factor (above 60% of the total energy consumption) responsible for placing the rice-greengram cropping system in the lowest position in

Table 2: System rice equivalent yield, system productivity and component crops yield

Treatment	System rice equivalent yield (kg ha^{-1})		System productivity (kg ha^{-1} day^{-1})		Component crop yield (kg ha^{-1})									
					Rice		Greengram		Sunflower		Sunflowe+Greengram		Lady's finger	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Block 1	14612.24	12363.58	35.41	33.87	4553	4395	969	889	1278	1418	643 (469)	1008 (489)	9996	12277
Block 2	16.063.74	14122.73	50.21	38.69	4645	4610	863	828	2044	1802				
SEm±	92.52	88.23	0.55	0.24	15.23	16.06	-	-	-	-	-	-	-	-
CD (p=0.05)	261.26	249.15	1.54	0.68	42.99	45.34	-	-	-	-	-	-	-	-
Cropping Systems														
R-G	9048.04	8460.79	24.92	23.18	4542	4440	916	858	-	-	-	-	-	-
R-S	11375.71	9954.96	31.69	27.27	4584	4476	-		1661	1610	-	-	-	-
R-S+G	10017.00	9307.88	27.78	25.50	4613	4518	-		-	-	802 (435)	994 (429)		
R-L	30911.33	25249.00	86.85	69.18	4658	4576	-		-	-	-	-	17959	18233
SEm±	132.50	124.78	0.77	0.34	21.53	22.71	-		-	-	-	-	-	-
CD (p=0.05)	374.15	352.35	2.18	0.97	60.80	64.12	-		-	-	-	-	-	-

R-G: Rice-Greengram; R-S: Rice-Sunflower; R-S+G: Rice-Sunflower+Greengrm (2:4); R-L: Rice-Lady's finger; data in parenthesis yield of greengram

terms of total energy requirement (29,005 MJ ha^{-1}) (Table 4). Energy consumed by operational labour was the second highest component in all the cropping system. Energy consumed by operational labour in rice-lady's finger (17.82% of the total energy) was the highest among all the cropping system due high labour requirement for intercultural and harvesting of lady's finger. Energy consumed by plant protection agro-chemical was also highest in rice-lady's finger system (1.50% of the total energy) among the all cropping systems (Table 4). These two higher energy consumptions (operational labour and plant protection chemical) made the rice-lady's finger system a higher energy requirement cropping system than the other three cropping systems.

3.4. Energy input-output relationship

Lady's finger produced higher biomass than greengram and sunflower. Lady's finger, a vegetable crop has the ability to utilize solar energy more efficiently to produce more yield as compare to other grain crops. Consequently, the total output energy in rice-lady's finger system was significantly higher (1,84,260 MJ ha^{-1}) than the other three systems and lowest in rice-greengram (1,59,350 MJ ha^{-1}) (Table 5). Similar trend was also observed in total input energy requirements of the cropping systems. Again, rice-lady's finger system gave highest energy productivity (0.63 kg MJ^{-1}) among all cropping systems (Table 5). Mandal et al. (2002) noticed that soybean-wheat crop sequence gave highest energy productivity over soybean-chickpea and soybean-mustard due to its higher input energy and grain yield.

EUE was found highest in rice-greengram cropping system (5.53) followed by rice-sunflower+greengram (5.44), rice-sunflower (5.09) and rice-lady's finger (4.09) (Table 5). This is attributed to the fact that legumes have much less energy expenditure than other crops (Baishya and Sharma, 1990). Mandal et al. (2002) also observed that cropping system with legumes (soybean/chickpea) gave higher EUE than soybean-wheat and soybean-mustard crop sequence. Lowest specific energy (1660 MJ t^{-1}) was observed in rice-lady's finger crop sequence due to higher biomass yield of lady's finger followed by rice-greengram (3334 MJ t^{-1}), rice- sunflower+greengram (3360 MJ t^{-1}) and rice-sunflower (3415 MJ t^{-1}) (Table 5).

Energy intensiveness was significantly higher in rice-lady's finger (0.59 MJ ₹$^{-1}$) followed by rice-sunflower (0.58 MJ ₹$^{-1}$), rice-sunflower+greengram (0.55 MJ ₹$^{-1}$) and rice-greengram (0.41 MJ ₹$^{-1}$) (Table 5). Regarding energy intensiveness of the four cropping systems, the results were contrary to energy use efficiency (EUE). The results confirmed the findings of Baishya and Sharma, (1990) in rice-wheat, Billore et al. (1994) in sorghum-wheat, Joshi et al. (1998) in soybean-chickpea, Vyas et al. (1995) in soybean-wheat, Mandal et al. (2002) in soybean-chickpea crop sequence and Biswas et al. (2006) in

Table 3: Cost of production, net return and benefit-cost ratio of different cropping systems (Pooled data of two years)

Treatment	Cost of production ('000 ₹ ha^{-1})			Net return ('000 ₹ ha^{-1})			B:C ratio		
	Kharif/ Rainy	*Rabi*-Summer	Cropping System	*Kharif*/ Rainy	*Rabi*-Summer	Cropping System	*Kharif*/ Rainy	*Rabi*-Summer	Cropping System
Block 1	29.10	42.31	71.33	14.44	37.65	52.09	1.57	2.18	1.69
Block 2	32.30	40.46	72.76	10.89	64.47	75.38	1.37	2.38	1.91
SEm±	0.65	0.76	1.19	0.27	1.46	1.24	0.011	0.012	0.038
CD (*p*=0.05)	NS	NS	NS	0.76	4.12	3.50	0.031	0.034	0.107
Cropping systems									
R-G	30.70	23.25	53.95	12.41	38.06	51.07	1.49	2.39	1.94
R-S	30.70	27.95	58.65	12.38	36.45	48.82	1.45	2.19	1.83
R-S+G	30.70	28.63	59.19	12.72	36.68	49.38	1.46	2.20	1.83
R-L	30.70	85.69	116.39	13.20	93.06	105.98	1.47	2.35	1.92
SEm±	0.62	1.07	2.05	0.73	2.06	1.48	0.009	0.013	0.059
CD (*p*=0.05)	NS	3.02	5.77	NS	5.82	4.18	0.025	0.037	NS

R-G: Rice-Greengram; R-S: Rice-Sunflower; R-S+G: Rice-Sunflower+Greengrm (2:4); R-L: Rice-Lady's finger; (Average 1 US$=₹ 55.25)

Table 4: Energy consumption (MJ ha^{-1}) in different agronomic practices for blocks and different cropping systems (Pooled data of two years)

Treatment	Crop management components						
	Land preparation (MJ ha^{-1})	Seed (MJ ha^{-1})	Fertilizers (MJ ha^{-1})	Irrigation (MJ ha^{-1})	Plant protection chemicals (MJ ha^{-1})	Operational labour (MJ ha^{-1})	Total input Energy (MJ ha^{-1})
Block 1	2943 (8.38)	1460 (4.16)	24230 (69.01)	2083 (5.93)	293 (0.84)	4102 (11.68)	35112
Block 2	2786 (7.79)	1464 (4.09)	24353 (68.09)	2124 (5.94)	276 (0.77)	4762 (13.31)	35764
Cropping systems							
R-G	2689 (9.27)	1700 (5.86)	18009 (62.09)	1943 (6.70)	244 (0.84)	4420 (15.24)	29005
R-S	2828 (7.78)	1066 (2.93)	26091 (71.76)	1918 (5.28)	146 (0.41)	4311 (11.87)	36360
R-S+G	2792 (8.51)	1140 (3.48)	22980 (70.08)	1824 (5.56)	111 (0.34)	3945 (12.03)	32792
R-L	2914 (6.49)	1750 (3.89)	28352 (63.14)	3211 (7.15)	673 (1.50)	8002 (17.82)	44902

R-G: Rice-Greengram; R-S: Rice-Sunflower; R-S+G: Rice-Sunflower+Greengrm (2:4); R-L: Rice-Lady's finger; Data in parenthesis represents percentage

Table 5: Energy input-output relationship of different cropping systems and blocks (Pooled data of two years)

Treatment	System Input Energy ('000 MJ ha^{-1})	System Output Energy ('000 MJ ha^{-1})	System Net Energy ('000 MJ ha^{-1})	Energy Productivity (kg MJ^{-1})	Energy Use Efficiency (EUE)	Specific Energy (MJ t^{-1})	Energy Intensiveness (MJ ₹$^{-1}$)
Block 1	35.11	174.62	139.51	0.35	4.90	3115	0.53
Block 2	35.76	174.67	138.98	0.43	5.18	2782	0.53
SEm±	0.47	0.45	0.40	0.004	0.34	32.19	0.004
CD (*p*=0.05)	NS	NS	NS	0.011	NS	90.89	NS
Cropping systems							
R-G	29.01	159.35	130.34	0.30	5.53	3334	0.41
R-S	36.36	179.79	143.43	0.31	5.09	3415	0.58
R-S+G	32.79	175.18	142.39	0.31	5.44	3360	0.55
R-L	44.90	184.26	139.36	0.63	4.09	1660	0.59
SEm±	0.95	0.63	0.43	0.006	0.049	45.52	0.005
CD (*p*=0.05)	2.68	1.78	1.21	0.017	0.139	128.09	0.014

R-G: Rice-Greengram; R-S: Rice-Sunflower; R-S+G: Rice-Sunflower+Greengrm (2:4); R-L: Rice-Lady's finger jute-wheat crop sequence. Both EUE and energy intensiveness were found not significant between the blocks.

4. Conclusion

Rice-lady's finger system recorded higher yield, net return, input energy requirement and energy output than other three cropping systems, but its EUE and B:C ratio were low and was considered to be a capital and energy intensive cropping system. Under resource poor conditions, rice-greengram system required less energy input but gave highest EUE and B:C ratio among the four cropping systems. Rice-greengram cropping system should therefore be popularized for the benefit of resource poor small farmers in the constrains prone coastal saline zone of West Bengal with limited irrigation facilities and scarcity of resources.

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