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Sustainable productivity and profitability of diversified rice-based cropping systems in an irrigated ecosystem

R.D. Singh, Shivani, A.R. Khan* and N. Chandra

Crop Research Division, ICAR Research Complex for Eastern Region, Patna, India

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An experiment was conducted at ICAR Research Complex for Eastern Region, Research Farm, Sabajpura, Patna (longitude 85°13′N and latitude 25°37′E), Bihar, India for four consecutive years 2004–05 to 2007–08 to develop a diversified cropping system for an irrigated ecosystem in Bihar by introducing pulse/oilseed/vegetables as a second or third crop in 10 rice-based cropping systems. Four crop cycles have been completed for all the cropping systems. During all years of the experiment there were significant variations among the cropping systems. Maximum paddy yield equivalent was recorded in rice–tomato–bottle gourd (40.44 t ha^{-1}) followed by rice–potato–onion (28.47 t ha^{-1}), rice–coriander–lady's fingers (26.79 t ha^{-1}), rice–carrot–cowpea (24.59 t ha^{-1}) and rice–mustard–tomato (24.44 t ha^{-1}). A higher value for the diversification index (DI) represents a higher level of crop diversification. It is evident from the results, that DI varies from 0.299 on a medium-sized farm to 0.903 on a small farm, with an average DI value of 0.643 among all farm categories. A survey revealed that the average DI value for small-scale farmers was highest (0.741) compared with the medium- (0.591) and large-scale (0.626) categories, and the differences were negligible. This seems reinforce the view that the smaller the farm, the higher the level of crop diversification.

Keywords: crops; crop yields; CDI; system productivity

Introduction

Sustainability in agricultural systems is a global issue. A sustainable agricultural system must meet the changing food, fibre, fodder and fuel needs of a nation and should not be detrimental to its natural resource base. Rather, a good sustainable agricultural system should improve the resource base of a nation. For sustainability in an agricultural system, it is desirable that a particular crop or group of crops is not grown on same soil for a long period, because various crops tap different soil layers to meet their water and nutrient requirements (Singh Ved 2001, Singh RD et al. 2004).

The cropping system in India has attained great significance in terms of area, production and productivity. The cropping intensity of the Eastern Region is as low as 140% (Fertilizer Association of India 2001/2002), and needs to be increased to meet the growing food demands of an ever-increasing population. In Bihar, those who farm areas having medium (2–3 cm of water for 3–4 days) and low (4–5 cm of water for 6–7 days) land (duration and depth of standing water) grow mostly a rice–

*Corresponding author. Email: khan_ar@sify.com

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wheat cropping system. Both cultivars are heavy feeders and exhaustive crops, resulting in an unfavourable effect on the sustainability of soil productivity. There is a pressing need to meet the food grain requirements of the growing population and to sustain a reasonably higher productivity level. Hence, there is an urgency to diversify into new areas like vegetables, fruits, oilseeds, pulses and allied fields.

Crop diversification has been recognized as an effective strategy for achieving the objectives of food security, nutrition security, income growth, poverty alleviation, employment generation and the judicious use of land and water resources, sustainable agriculture development and environmental improvement (Singh RD 2010). Crop diversification essentially means moving away from growing a single crop to a number of crops. Such a move towards crop diversification helps in: (1) the full and better use of available land, labour, water and other resources; (2) reducing the risks arising out of crop failures, yield losses and market failures; and (3) realizing quicker or regular returns for the farmer (Singh RB 2001). Thus, both the number and type of crops included in the cropping sequence are important. For this, heavy reliance on cereal crops needs to be shifted towards other food crops such as potato, vegetables, pulses and oilseeds. The inclusion of potato in rice-based crop sequences in West Bengal has become attractive because of the high yield and remunerative price of potato. Samui et al. (2004) reported that inclusion of a legume increases soil fertility. Gangwar and Ram (2005) reported that inclusion of legumes and other crops using intensification and interruptive approaches, as per resource availability, led to considerable improvement in productivity and profitability, on the one hand, and soil fertility, on the other hand. Hence, it was felt necessary to work out a location-specific cropping system for central Bihar, which can utilize resources judiciously to maximize return, protect the environment and meet the day-to-day requirements of human and animals.

Materials and methods

A field experiment was conducted in randomized block design, replicated three times at ICAR Research Farm, Patna (longitude 85°13′N and latitude 25°37′E), Bihar, India during 2004–05 to 2007–08, to develop a suitable cropping system by introducing pulse/oilseed/vegetables into a rice-based cropping system as a second or third crop.

Ten rice-based cropping systems, namely rice–wheat–blackgram (C_1), rice–capsicum– cucumber (C_2), rice–carrot–cowpea (C_3), rice–mustard–tomato (C_4), rice–potato–onion (C_5), rice–cabbage–French bean (C_6), rice–coriander–lady's fingers (C_7), rice–tomato–bottle gourd (C_8), rice–pea–green chilli (C_9) and rice–lentil–sponge gourd (C_{10}) were undertaken. The plot size for the field experiment was 20 × 6 m. The average maximum temperature varied between 30.5 and 32.0°C and the minimum temperature varied between 19.8 and 20.9°C during 2004–07. Total rainfall was 761.0, 701.7, 1013.5 and 1625.0 mm in 2004, 2005, 2006 and 2007, respectively. Soil samples were collected from the experimental plots (0–20 cm depth) and analysed for physical and chemical properties. The soil texture was silt clay loam (International Pipette Method; Piper 1950) with a mean pH of 7.3, electrical conductivity (EC) was 0.2 dS m^{-1} in a 1:2 soil:water solution (glass electrode pH meter and conductivity bridge; Jackson 1973), organic carbon 0.54% (Walkley and Black 1934 and rapid titration method, Jackson 1973), available nitrogen 253.0 kg N ha^{-1} (0.113 g kg^{-1} soil) [alkaline permanganate ($KMnO_4$)

method as described by Subbiah and Asija 1956], available phosphorus 24.4 kg P ha^{-1} (0.011 g kg^{-1} soil) (Olsen's method; Jackson, 1973) and available potash 394.0 kg K ha^{-1}(0.176 g kg^{-1} soil) (NH_4OAc method, Hanway and Heidal 1952).

The amount of applied fertilizer, plant protection management and vegetation for different crops is shown in Tables 1–3, respectively.

To calculate the diversification index (DI), 28 farms from different categories – small (<2 ha), medium (2–4 ha) and large (>4 ha) – were randomly selected from the Patna district of India. Farmers were interviewed using a structured

Table 1. Amount of applied fertilizer (kg ha^{-1}).

Cropping system	N	P_2O_5	K_2O
Rice–wheat–blackgram	240	160	80
Rice–capsicum–cucumber	260	180	150
Rice–carrot–cowpea	210	140	140
Rice–mustard–tomato	260	160	160
Rice–potato–onion	350	210	220
Rice–cabbage–bitter gourd	280	160	160
Rice–coriander–lady's fingers	280	140	130
Rice–tomato–bottle gourd	280	160	160
Rice–pea–green chilies	250	160	160
Rice–lentil–sponge gourd	180	120	80

Table 2. Plant protection management.

Crop	Insecticides	Fungicides
Rice	Endosulfan 1mL L^{-1}	Seed treatment with 1 g Bavistin + 0.1g streptocyclin kg^{-1} seed
Wheat	–	Seed treatment with 1 g Bavistin + 0.1g streptocyclin kg^{-1} seed
Black gram	Endosulfan 1.5 L ha^{-1} in 800 L	Diethen M-45 2.5 kg $(1000\ L)^{-1}$ ha^{-1}
Capsicum	Monocrotophos 1 mL L^{-1}	
Cucumber	Endosulfan 1.5 L ha^{-1} in 800 l	
Carrot	–	–
Cowpea	–	–
Mustard	Endosulfan 0.01%, 15 days interval	Thiram 2 g kg^{-1} of seed
Tomato	Rogar 1mL L^{-1}	Diethen M-45 + Bavistin 2 g kg^{-1} seed
Potato	–	Diethen M-45 + Radomil MZ-78 2 g kg^{-1} seed
Onion	Metapristax 1.5 mL L^{-1} Three times, 15 days interval	Diethen M-45 2 g kg^{-1} seed
Cabbage	Endosulfan 1.5 mL L^{-1}	Indofil M-45 2 g L^{-1}
Bitter gourd	–	–
Coriander	–	–
Lady's fingers	Malathion 50 EC 1mL L^{-1}	Nuvacron 1mL L^{-1}
Bottle gourd	–	Copper oxichloride 3 g L^{-1}, 15 days interval
Pea	Endosulfan 1.5 mL L^{-1}	Sulfex 2 mL L^{-1}
Green chilies	Endosulfan 1mL L^{-1}	Captan 2 g kg^{-1}seed
Lentil	Monocrotophos 1.5 mL L^{-1}	Diethen M-45 2.5 kg $(1000\ L)^{-1}$
Sponge gourd		Copper oxichloride 3 g L^{-1}, 15 days interval

Table 3. Vegetation duration of different crops in the systems (days).

Kharif	Rabi	Summer
Rice (122)	Wheat (146)	Black gram (82)
Rice (122)	Capsicum (131)	Cucumber (70)
Rice (122)	Carrot (113)	Cowpea (82)
Rice (122)	Mustard (100)	Tomato (93)
Rice (122)	Potato (88)	Onion (92)
Rice (122)	Cabbage (105)	Bitter gourd (85)
Rice (122)	Coriander (149)	Lady's fingers (80)
Rice (122)	Tomato (123)	Bottle gourd (85)
Rice (122)	Pea (121)	Green chilies (97)
Rice (122)	Lentil (113)	Sponge gourd (80)

questionnaire to obtain information on their cropping pattern in different crop seasons, namely kharif (rainy), rabi (winter) and zaid (summer), including the area sown under different crops. In other words, data on the total cultivable area of the selected farms, and the areas under different crops in the kharif, rabi and summer seasons were collected.

Based on the data obtained from farmers, crop diversification indices (DI) were calculated to understand the level of crop diversification in different categories of farms. DI was computed using the following formula:

$$DI = \sum_{i=1}^{n} pi \ \log\ (1/pi) \tag{1}$$

where pi is the proportion of area sown under crop I (Ai/A), Ai is the area put under crop I by the farmer, A is the total cultivable area owned by the farmer, $i = 1, 2, 3, \ldots, n$ and n is the number of crops sown.

The productivity of the different cropping systems was computed by converting the yield of all crops into the rice equivalent yield, based on the prevailing market/minimum support price, and dividing by the number of days per year that crops occupied the land in a particular system. Returns were calculated using the prevailing market price of different commodities in the different years of the experiment. The cost of cultivation is calculated by adding the total expenditure involved in raising a crop, including the rental value of the land.

The relative economic efficiency (REE) was calculated as:

$$REE = (A - B) * 100/B \tag{2}$$

where A is the net return of the diversified system and B is the net return in the existing system, expressed as percentages.

Profitability is the income obtained from the produce after deducting the cost of cultivation. To determine the cost of cultivation, parameters such as land preparation, cost of seed, cost of sowing/transplanting of crops, manure and fertilizers, irrigation, interculture, plant protection, harvesting and bundling, threshing, winnowing, packing, transportation charge and depreciation cost of the land were considered.

Results and discussion

Chemical properties of soil

The soil analyses indicated that there was a decrease in average nutrient status, as measured by EC, organic carbon, available nitrogen and available potash after completion of four crop cycles, with the exception of available phosphorus, which was found to be significantly greater than the others. EC is a measure of the concentration of soluble salt ions (anions and cations) in the soil solution. There was a decrease in nitrogen in the form of nitrate (NO_3^-) and potassium (K^+) ions in the soil solution resulting in a decrease in EC (Singh D et al. 2005). It was also observed that, after completion of the fourth crop cycle, organic carbon mineralized into an inorganic form with different nutrients, resulting in a decrease in the organic carbon content of the soil. However, the rice–potato–onion and rice–cabbage–bitter gourd had higher carbon content. The decrease in available nitrogen is due to: luxury consumption of nitrogen by vegetable crops; leaching from the soil–plant system as either NO_3^- or NH_4^+ ions, which depends upon soil texture, hydrological conditions, water table depth, permeability and the hydraulic conductivity of soil, and may vary from 2 to 50% of applied nitrogen (Sharma 1990); denitrification loss (NO_3^- to NO_2^-); and gaseous (NH_3, NO, N_2O and N_2) losses through denitrification to the atmosphere (Mohanty and Singh 2002). There was a decrease in potassium in the soil after completion of fourth crop cycle because potassium is highly mobile in soil solution (K^+ form) with illite as the dominating clay mineral, resulting in high leaching losses, the luxury consumption of potassium in vegetable-dominated cropping systems and soil erosion (Rao and Brar 2002). Most of the soil parameters are significantly different by comparing the first with the fourth crop cycle. It has been observed that there was a build-up of organic carbon in most of the available nitrogen and available phosphorus in some of the cropping systems after completion of fourth crop cycle due to added nitrogen, phosphorus, litter falls (10–15% of the top portion of dry matter m^{-2} added to the soil every season) and the addition of organic matter through the underground portion of rice and other crops in the systems. However, an increase of available nitrogen and phosphorus was found in some cropping systems. In addition, we added the recommended dose of nitrogen to all the crops, of which only 40–50% is made available to the crop, the remainder being fixed in the soil. This may be the reason for the build-up of organic carbon and available nitrogen in the soil. Available phosphorus and potash decreased from their initial levels in almost all the cropping systems because of the vegetable-dominated cropping system; the phosphorus and potash requirement of vegetables is higher than that of cereals and pulses in the system (Table 4).

System productivity

System productivity (paddy equivalent yield) was considerably higher under the vegetable-dominated cropping systems compared with the other systems. It is evident from the data that there was significant variation among the cropping systems during all four years of the experiment, and similar trends were observed with the exception of the second crop cycle (Table 5). Pooled analysis of paddy yield equivalence revealed that during all experimental years, there were significant variations among cropping systems. Maximum yield equivalence was recorded in rice–tomato–bottle gourd (40.44 t ha^{-1}) followed by rice–potato–onion (28.47 t ha^{-1}), rice–coriander–lady's

Table 4. Chemical properties of soil in diversified cropping systems after completion of four crop cycles (2004–05 to 2007–08).

	Chemical properties											
	pH				EC (dS m^{-1})				Organic carbon (%)			
Treatments	2004–05	2005–06	2006–07	2007–08	2004–05	2005–06	2006–07	2007–08	2004–05	2005–06	2006–07	2007–08
Initial status of soil	7.30	7.60	7.50	7.94	0.20	0.10	0.20	0.09	0.54	0.70	0.80	0.49
Rice–wheat–black gram	7.73	7.60	7.86	7.27	0.10	0.16	0.07	0.10	0.70	0.51	0.10	0.69
Rice–capsicum–cucumber	7.63	7.36	7.90	7.41	0.12	0.21	0.11	0.09	0.56	0.83	0.53	0.66
Rice–carrot–cowpea	7.63	7.57	7.87	7.39	0.11	0.29	0.10	0.12	0.54	1.16	0.57	0.70
Rice–mustard–tomato	7.62	7.51	7.92	7.55	0.13	0.18	0.10	0.09	0.59	0.82	0.64	0.71
Rice–potato–onion	7.55	7.35	7.95	7.43	0.16	0.19	0.09	0.09	0.85	0.68	0.36	0.69
Rice–cabbage–bitter gourd	7.56	7.59	8.03	7.45	0.15	0.12	0.10	0.11	0.86	1.01	0.83	0.70
Rice–coriander–lady's fingers	7.66	7.51	8.06	7.43	0.16	0.14	0.11	0.11	0.73	0.69	0.46	0.86
Rice–tomato–bottle gourd	7.81	7.74	7.97	7.42	0.13	0.19	0.08	0.11	0.74	0.63	0.49	0.95
Rice–pea–green chilli	7.66	7.69	7.89	7.36	0.13	0.13	0.09	0.70	0.63	0.54	0.62	0.74
Rice–lentil–sponge gourd	7.46	7.47	7.99	7.39	0.20	0.19	0.09	1.10	0.86	0.85	0.31	0.95
SEM ±	0.14	0.11	0.07	0.05	0.02	0.039	0.01	0.01	0.08	0.28	0.24	0.13
CD at 5%	0.42	N.S.	NS	0.16	0.05	NS	NS	0.03	NS	0.83	NS	0.37

	Chemical properties											
	Available N (g kg^{-1})				Available P (g kg^{-1})				Available K (g kg^{-1})			
Treatments	2004–05	2005–06	2006–07	2007–08	2004–05	2005–06	2006–07	2007–08	2004–05	2005–06	2006–07	2007–08
Initial status of soil	0.113	0.104	0.143	0.132	0.011	0.009	0.009	0.012	0.176	0.092	0.102	0.061
Rice-wheat-black gram	0.117	0.145	0.131	0.107	0.008	0.011	0.012	0.009	0.096	0.100	0.062	0.079
Rice-capsicum-cucumber	0.098	0.134	0.128	0.098	0.009	0.012	0.011	0.007	0.091	0.108	0.102	0.076
Rice-carrot-cowpea	0.094	0.121	0.140	0.098	0.010	0.010	0.012	0.013	0.116	0.108	0.060	0.079
Rice-mustard-tomato	0.107	0.132	0.131	0.107	0.011	0.010	0.013	0.007	0.089	0.099	0.060	0.083
Rice-potato-onion	0.107	0.140	0.138	0.088	0.009	0.012	0.012	0.007	0.085	0.112	0.063	0.085
Rice-cabbage-bitter gourd	0.103	0.215	0.121	0.098	0.011	0.010	0.011	0.008	0.090	0.098	0.064	0.080
Rice-coriander-lady's fingers	0.098	0.117	0.149	0.093	0.009	0.010	0.012	0.008	0.092	0.099	0.061	0.079
Rice-tomato-bottle gourd	0.093	0.145	0.121	0.102	0.009	0.010	0.013	0.007	0.094	0.092	0.063	0.082
Rice-pea-green chilli	0.107	0.135	0.140	0.098	0.011	0.009	0.012	0.007	0.090	0.105	0.060	0.087
Rice-lentil-sponge gourd	0.112	0.142	0.119	0.102	0.010	0.009	0.011	0.007	0.081	0.100	0.061	0.078
SE (m) ±	0.012	0.028	0.013	0.006	0.0008	0.0012	0.0013	0.0021	0.0077	0.005	0.003	0.004
C.D. at 5%	0.036	0.083	NS	0.019	0.0022	NS	NS	0.0064	0.0231	NS	NS	0.012

Table 5. Paddy equivalent yield and system productivity of different cropping systems (2004–05 to 2007–08).

Cropping systems	Paddy yield equivalent (t ha^{-1})					System productivity (kg $ha^{-1}day^{-1}$)
	2004–05	2005–06	2006–07	2007–08	Mean	
Rice–wheat–black gram	16.74	14.25	12.12	13.26	14.09	40.26
Rice–capsicum–cucumber	16..93	13.36	12.84	21.11	16.06	49.72
Rice–carrot–cowpea	21.70	31.38	22.68	22.61	24.59	77.57
Rice–mustard–tomato	27.39	24.16	21.81	24.39	24.44	77.59
Rice–potato–onion	27.44	35.20	32.12	19.14	28.47	94.27
Rice–cabbage–bitter gourd	19.56	15.80	17.41	31.22	21.00	72.66
Rice–coriander–lady's fingers	27.14	28.30	25.90	25.84	26.79	76.32
Rice–tomato–bottle gourd	51.07	28.07	41.72	40.90	40.44	122.54
Rice–pea–green chilli	12.15	11.23	11.57	17.96	13.23	38.91
Rice–lentil–sponge gourd	20.96	20.86	13.19	22.46	19.37	61.49
SEM ±	0.82	0.54	0.65	1.14	2.58	–
CD at 5%	2.44	1.61	1.93	3.37	7.66	–

Note: Price of paddy Rs. 6000 t^{-1} taken for converting yield of different crops to the paddy yield equivalent.

fingers (26.79 t ha^{-1}), rice–carrot–cowpea (24.59 t ha^{-1}) and rice–mustard–tomato (24.44 t ha^{-1}). This is due to the higher tonnage and per unit value of vegetable crops like tomato, bottle gourd, potato, onion, coriander and lady's fingers. In the upland and medium land situations, the inclusion of vegetables increased productivity and profitability of the different crop sequences (Goswami 2004). Uplands are cultivable land with perfect natural drainage and medium lands are cultivable land for intensive year-round cultivation. Similar higher system productivity (122.54 kg ha^{-1} day^{-1}) was also recorded for the intensified (rice–tomato–bottle gourd) system, closely followed by the interruptive approach of rice–potato–onion (94.27 kg ha^{-1} day^{-1}), rice–mustard–tomato (77.59 kg ha^{-1} day^{-1}), rice–carrot–cowpea (77.57 kg ha^{-1} day^{-1}) and rice–coriander–lady's fingers (76.32 kg ha^{-1} day^{-1}). Intensification and the inclusion of vegetables crops during the rabi and summer seasons may be attributed to higher system productivity. Similar results were reported by Gangwar and Ram (2005) and Katyal et al. (2002).

Diversification index

The value of DI varies between 0 and 1 (Table 6). Similar values were obtained by Acharya (2003) who reported that DI = 0 when a single crop occupied a whole cropped area and DI = 1 when each crop is grown on an equal area. It is evident from the results that DI varies from 0.299 on a medium-sized farm to 0.903 on a small farm, with an average of 0.643 across all categories. The survey revealed that the average DI value was highest (0.741) for small farms compared with medium (0.591) and large (0.626) farms, and the differences were negligible. A higher DI value represents a higher level of crop diversification. This seems to reinforce the view that the smaller the farm, the higher the level of crop diversification. Perusal of the crop diversification pattern further revealed that the majority of farmers were high crop diversifiers (46.4%), followed by medium (35.7%) and low (17.8%) levels. Similar trends were observed for small and large farms across level of crop diversification; in medium-sized farms, it was observed that diversification was evenly distributed among low, medium and high levels to the tune of 33.3% each. The results are in agreement with those of Singh VK and Sharma (2001).

System profitability

Maximum net profit per hectare was recorded in rice–tomato–bottle gourd (Rs.159,904.00) followed by rice–coriander–lady's fingers (Rs. 98,683.00) and rice–

Table 6. Diversification index (DI) and number of farmers in dependence on farm category.

		Number of farmers with levels of diversification			
Farm category	DI	Low	Medium	High	Total number of farmers
Small	0.741	1 (12.5)	3 (37.5)	4 (50.5)	8
Medium	0.591	4 (33.3)	4 (33.3)	4 (33.3)	12
Large	0.626	–	3 (37.5)	5 (62.5)	8
Overall	0.643	5 (17.8)	10 (35.7)	13 (46.4)	28

Note: Figures in the parenthesis indicate percentage.

Table 7. Economics of diversified cropping systems.

Treatments	Paddy yield equivalent (t ha^{-1})	Gross income (Rs.ha^{-1})	Cost of cultivation (Rs.ha^{-1})	Net return (Rs.ha^{-1})	Profitability (Rs.$ha^{-1}$$day^{-1}$)	Benefit–cost ratio	Relative Economic Efficiency (REE)
Rice–wheat–black gram	14.09	84540	57445	27095	77.41	1.47	-
Rice–capsicum–cucumber	16.06	96360	61608	34752	107.59	1.56	28.26
Rice–carrot–cowpea	24.59	147540	62401	85049	268.29	2.36	213.91
Rice–mustard–tomato	24.44	146640	57664	88976	288.46	2.54	328.39
Rice–potato–onion	28.47	170820	89982	80838	267.67	1.90	198.35
Rice–cabbage–bitter gourd	21.00	126000	73504	52496	181.65	1.71	93.74
Rice–coriander–lady's fingers	26.79	160740	62057	98683	281.15	2.59	264.21
Rice–tomato–bottle gourd	40.44	244440	84536	159904	484.56	2.89	490.16
Rice–pea–green chilli	13.23	79380	54823	24557	72.22	1.45	(−) 9.38
Rice–lentil–sponge gourd	19.37	116220	52605	63615	201.95	2.21	134.79
SEM ±	2.58	1418	369	1181	3.59	0.015	4.59
CD at 5%	7.66	4213	1096	3509	10.67	0.04	13.64

mustard–tomato (Rs. 88,976.00). A similar trend was observed for the benefit–cost ratio (Rs. 2.89, 2.59 and 2.54). Maximum profitability (Rs. 484.6 ha^{-1} day^{-1}) and relative economic efficiency (490.2%) were recorded in rice–tomato–bottle gourd followed by rice–mustard–tomato (Rs. 288.5 ha^{-1} day^{-1} and 328.4%) and rice–coriander–lady's fingers (Rs. 281.2 ha^{-1} day^{-1} and 264.2%), whereas the lowest values were found for rice–pea–green chillies (Rs. 72.2 ha^{-1} day^{-1} and −9.38%), where US$1 is equivalent to Indian Rs. 45.00. The difference may be due to the higher productivity and sale price of mustard and tomato compared with coriander and lady's fingers (Table 7). These results conform with those of Gangwar and Ram (2005) and Katyal et al. (2002). It is interesting to note that vegetable-dominated cropping systems were more remunerative than cereal- and pulse-dominated cropping systems.

Conclusion

The cropping intensity of the Eastern Region of India is as low as 140% in an irrigated ecosystem, which can be enhanced to 300% by adopting developed diversified cropping systems.

Of 10 diversified cropping systems studied for a period of four consecutive years (2004–2007), five were seen to be more remunerative, namely rice–tomato–bottle gourd followed by rice–coriander–lady's fingers, rice–mustard–tomato, rice–carrot–cowpea and rice–potato–onion.

Crop diversification in different seasons (kharif, rabi and summer) enhanced the level of employment and regular return to farmers. During the kharif season, rice was taken as a test crop, which gave employment to farmers for six months, followed by different vegetable crops taken during the rabi and summer season, which enhanced the employment status and regular return to the farmers for the remaining six months. On the whole, the developed cropping systems not only enhanced the level of employment, but also provided a regular return to the farmers throughout the year.

Crops sown in different cropping systems during different seasons sustained crop productivity year after year without soil health deteriorating. It was also observed that crops sown during different seasons have a synergistic effect on soil, rather than an antagonistic effect. Pulses sown in the system enhanced the nutrient status and health of the soil.

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