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Diversified cropping systems
for food security

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Depending on just one crop can have grave consequences and leave small farmers open to many hazards. A slump in the market value for a particular crop could greatly reduce the income of the monoculture producers. On the other hand, farmers with diversified production can avoid these risks, provide their families with a healthy diet and derive a whole series of other benefits. Diversification of cropping system generally termed as the desirable change in the existing system towards more balanced cropping system to meet ever increasing demand of food, feed, fibre and fuel on the one hand and maintenance of soil fertility and agro-ecosystem on the other. Diversification is considered to be a good alternative to improve system yield with enhanced profitability. Malnutrition in India, is still an issue of national urgency which has considerable damage on the health and survival of the most vulnerable group (children and women). The major benefits of crop diversification include improving nutrition and meeting the changing consumer demand.

IN our country, more than 250 double cropping systems are adopted, but the major contribution to food basket remains with the few cereal based systems such as rice-wheat, rice-rice, rice-gram, rice-sorghum, maize-wheat, maize-gram, soybean-wheat and sugarcane-wheat due to their extent of cultivation. Widespread occurrence of second-generation problems, such as over-mining of soil nutrients, decline in factor productivity, reduction in profitability, lowering of groundwater tables and build up of pests including weeds, diseases and insects has been reported during post-green revolution era in most of the intensively cultivated, high-productivity, cereal based production systems, which are threatening their sustainability. Considering the specific needs of different regions, concerted efforts have been made to design new alternative cropping system.

Temporal diversification

Intensification in sequential multiple cropping through introduction of non-conventional crops/short duration crop cultivars and intensive input management, is a common way of increasing land use efficiency especially in irrigated ecosystems. Rice-wheat system is among the most productive cropping systems in the world. However, this system has shown signs of fatigue and evidences suggest that a decline in natural resources and micronutrient are two major reasons for reduction of productivity in this system. Through innumerable studies undertaken in different regions and agro-ecological/farming situations of the country in recent years, several alternative cropping systems with higher system productivity, net returns and B:C ratio have been identified for various locations by several workers (Table 1). Comprehensive review of work done in different parts of country has shown that the system productivity of existing rice-wheat ranges from 11 to 13.2 tonnes/ha with mean of 12.1 tonnes/ha in terms of rice equivalent yield. In case of rice-rice system, it ranges from 6.7 to 13.7 tonnes/ha with mean system yield of 9.4 tonnes/ha. However, with diversified high productive systems, the system productivity of rice-wheat and rice-rice can be enhanced to 24.4 and 15.4 tonnes/ha respectively in terms of rice equivalent yield implying that the productivity of these systems can be increased phenomenally with appropriate diversification strategies. Across the locations, it has been found that, system productivity and its net return can be improved by 83 and 81% respectively with identified high

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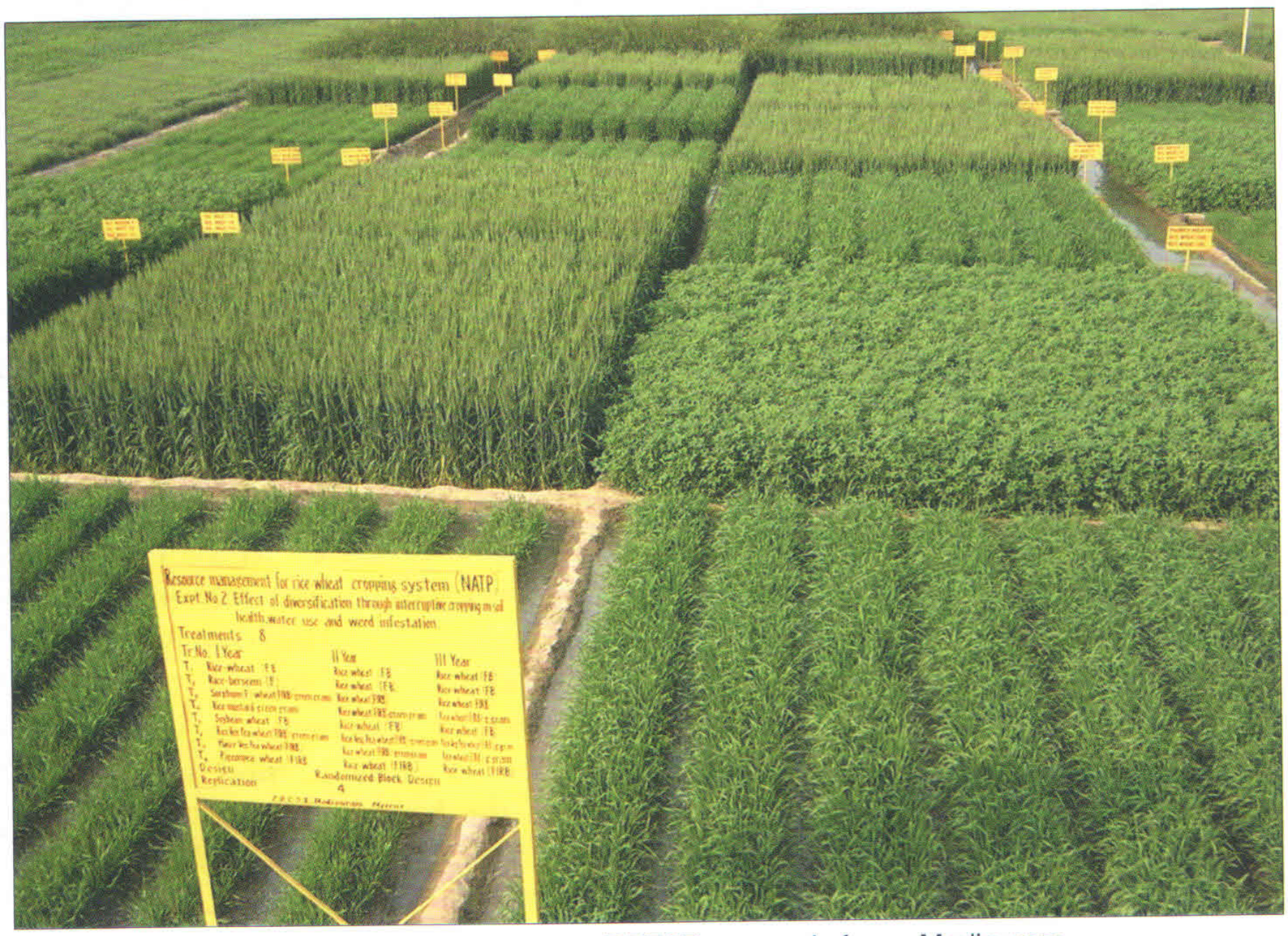
Table 1. Identified high productive systems for selected locations

Locations	Prevailing system			High Productive system		
	System	System Yield (REY) (tonnes/ha)	Net returns (×10³ ₹/ha)	System	System Yield (REY) (tonnes/ha)	Net returns (x10³ ₹/ha)
Jammu, J&K	Rice-wheat	11.3	68.6	Rice-marigold-french bean	30.1	168.0
				Rice-potato-onion	29.5	148.5
Ludhiana, Punjab	Rice-wheat	13.2	59.7	Maize-potato-onion	27.9	125.0
				Groundnut-potato-bajra(F)	23.3	111.8
Modipuram, Uttar Pradesh	Rice-wheat	12.9	32.2	Maize-potato-sunflower	24.2	68.2
				Rice-wheat-moong	15.9	40.3
Sabour, Bihar	Rice-wheat	11.0	43.0	Rice-potato-onion	29.0	83.7
				Rice-wheat-maize	15.7	54.1
Bhubaneswar, Odisha	Rice-rice	6.7	41.3	Rice-maize-cowpea	17.4	69.0
				Rice-maize-greengram	14.8	50.8
Coimbatore, Tamil Nadu	Cotton-sorghum-fingermillet	4.1	48.2	Beet root-greengram-maize+cowpea	7.1	93.1
				Chillies+onion-Sunhemp-okra+coriander	6.6	85.2
Thanjavur, Tamil Nadu	Rice-rice-sesame	13.7	78.0	Rice-rice-brinjal	18.3	108.2
				DS rice-rice-maize+blackgram	17.4	110.3
S.K. Nagar, Gujarat	Groundnut-wheat-fallow	4.1	65.4	Groundnut-wheat-sesame	7.0	125.1
				Groundnut-onion-greengram	5.0	81.4
Bengaluru, Karnataka	Hybrid cotton-sunflower	7.0	12.8	Maize-groundnut	12.2	44.1
				Maize-sunhemp-sunflower	11.3	40.8
Hyderabad, Andhra Pradesh	Rice-rice	7.9	22.9	Maize-onion	12.3	59.6
				Maize-tomato	12.1	48.1
Mean	-	9.2	47.2	-	16.9	85.8

productive systems which ensures food besides required balanced nutrition.

Spatial diversification

Practice of raising two or more than two crops in mixed stands (sowing crop-mixtures without maintaining discrete rows for each crop), has been one of the typical characteristics of traditional agriculture in India. Component crops of the system were, in general dissimilar in nature in respect of rooting, growth cycle or nutrient and water use pattern. This not only provided an assurance against failure of one or the other crop, due to vagaries of weather or disease/pest epidemics in rainfed agriculture, but also enables the farmers to enhance productivity through more efficient use of land, water and solar energy in vertical dimension. However, with the ingress of modern methods into agriculture, i.e. crop management with high input responsive varieties, assured water supply, higher fertilizer use, chemical control of diseases/pests etc., culminated into declining popularity of this practice. But subsequently, it was widely recognised that intercropping system (sowing two or more than two crops in distinct but proximate rows), designed on scientific basis in crop production, hold a great promise in increasing the land productivity under Indian condition. Significant advantages in land-use-efficiency, crop productivity and monetary returns in intercropping, as compared with sole cropping of diverse agro ecological situations are observed. Intercropping results in more efficient use of solar energy and harnessing benefits of positives interactions in crop



Evaluation of alternate cropping systems at PDFSR research farm, Modipuram

associations. These advantages are, in general more pronounced in widespread crops and stress environments. The experimental results on prominent intercropping systems at various locations suggest, scope for promotion of the same by introducing appropriate incentive schemes. The system productivity of sugarcane can be enhanced to 200.6 t/ha of sugarcane equivalent yield with intercropping of maize. Higher net returns of ₹ 2.39 lakh/ha/annum have been reported in Maize + (tomato + garden pea + french bean) relay intercropping system at Almora.

Scientist designed farmer managed cropping systems

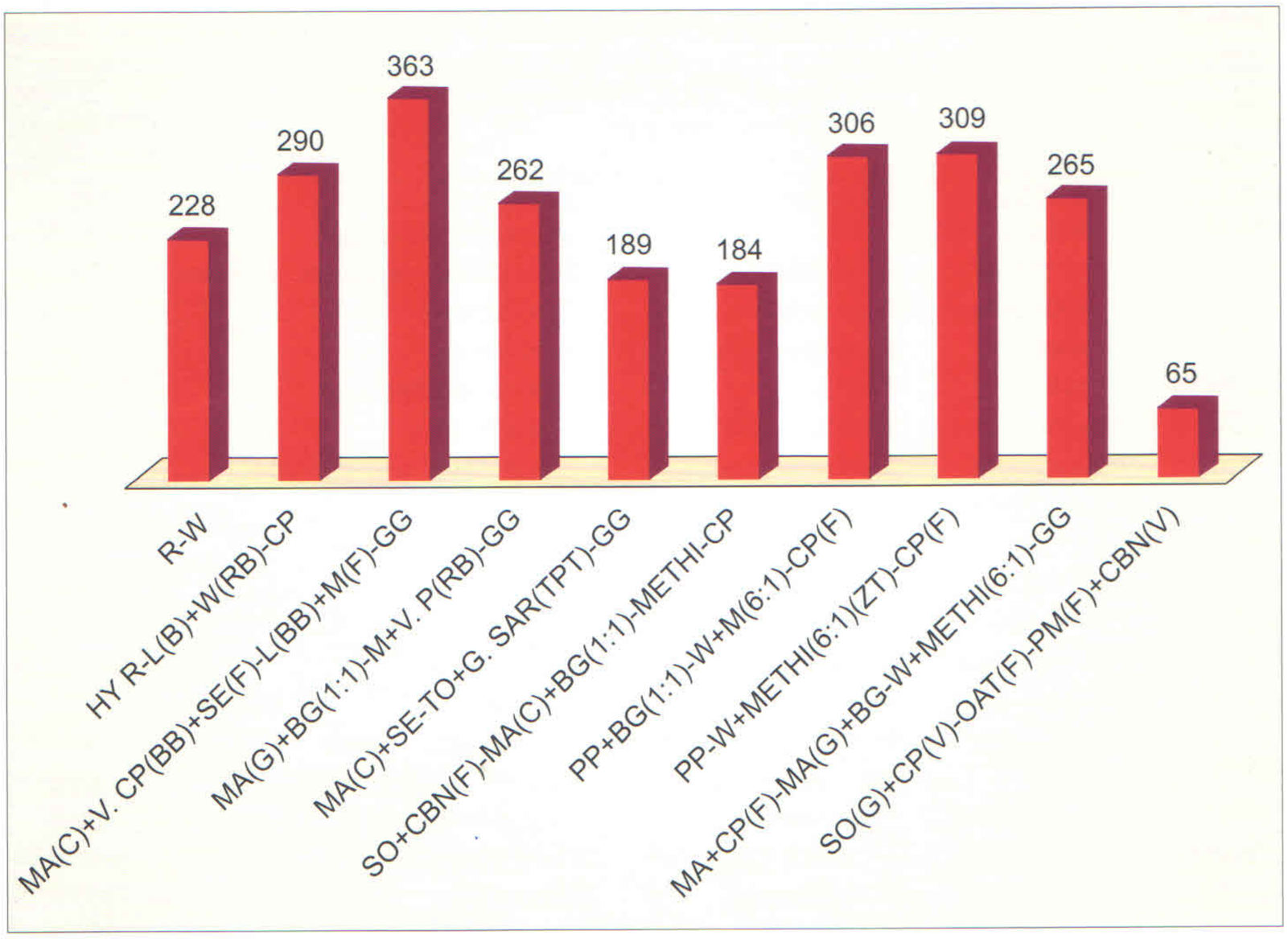
The on-station evaluated alternate systems have been experimented in farmers' field for testing its efficiency under farmer's management conditions. The yield increase over existing systems with alternate efficient cropping systems was found to be 40 to more than 300% in various agroclimatic zones (Table 2). In terms of equivalent yield, profitability and B:C ratio, rice-potato-onion was found be better alternative for rice-wheat in Western Himalayas whereas adding okra in the sequence of maize-wheat in Central Plateau region was found to be more remunerative. Across the locations and systems, the diversified system registered net returns and total calories of ₹ 1,17,156/ha and 29,158 × 1000 kcal/ha compared to the existing system (₹ 60,634/ha and 24,498 × 1000 kcal/ha). On an average, it was found that, the net return and total calories can be increased by 93.2 and 19% through diversification of existing cropping systems with location specific identified alternative systems. In rice-wheat system, on an average, application of recommended package to rice and wheat resulted in 35 and 33% increase in yield respectively across the locations. Among the different constraints addressed in rice-wheat system, introduction of improved variety of rice and wheat recorded higher yield increase of 74.5 and 44.5% respectively followed by nutrient management (32.4 and 28.2% respectively for rice and wheat). The yield increase with adoption of recommended scientific package was found to be 38.8% over farmer's method indicating the yield gap due to production constraints at farmer's field. The yield gap between recommended package and farmer's

Table 2. On-farm evaluation of alternate systems at various locations

Agro climatic zone	Location	Existing system	Alternate systems	% increase in productivity*
WH	Dhansaur	Rice-wheat	Rice-potato-onion	230.7
	Maize-wheat		Maize-potato-onion	338.5
	Pantnagar	Rice-wheat	Rice-potato-vegetable cowpea	123.3
EH	Karimganj	Rice-potato	Rice-rajmah	42.5
LGP	Kakdwip	Rice-greengram	Rice -okra	106.9
MGP	Patna	Rice-wheat	Rice-wheat-moong	59.8
UGP	Saini	Rice-wheat	Sesame-pea	97.8
EPH	Kawardha	Soybean-gram	Soybean-tomato-cowpea	244
	Dhenkanal	Rice-moong	Rice-tomato	116.9
	Gondia	Rice-wheat	Rice-wheat-cowpea	76.3
CPH	Udaipur	Maize-wheat	Maize-wheat-okra	359.6
WPH	Aurangabad	Soybean + Pigeonpea	Soybean-gram-fodder maize	208.4
	Ahmednagar	Soybean-wheat	Soybean-onion	238.9
SPH	Warrangal	Rice-rice	Rice-maize	39.9
	Bangalore	Rice-finger millet	Rice-green brinjal	250.7
	Paiyur	Rice-rice	Rice-tomato	42.2
ECPH	Kendrapara	Rice-moong	Rice-bittergourd	88.9
WCPG	Thiruvalla	Rice-rice-fallow	Rice-rice-okra	243.5
	Roha	Rice-cowpea	Rice-maize	105.7
GPH	Thasara	Tobacco	Tobacco-Fodder Rajka	169.6
		Bajra-wheat	Bajra Bajra-Lucerne (seed)	129.5
	Deesa	Pearlmiller-mustard	Moong-fennel	55.5
		Castor	Fennel-fodder pearlmillet	41.1

WH: Western Himalayas, EH: Eastern Himalayas, LGP, MGP, UGP: Lower, Middle, Upper Gangetic Plains, EPH, WPH, CPH, SPH: East, West, Central, Southern Plateau and Hills, ECPH: East coast plains and hills, WCPG: West coast plains and ghats, GPH: Gujarat plains and hills

Scientist designed farmer managed on-farm crop diversification experiment at Palampur (Himachal Pradesh)



Effect of bio-intensive cropping systems on profitability (₹/ha/day)

method was found to be 40.4, 36.6 and 39.3% in *kharif*, *rabi* and summer respectively in various existing pre dominant cropping systems.

The on-farm studies confirms that across the locations and systems, the best performing diversified system registered net returns and total calories of ₹ 1,69,270/ha/year and 35,273 × 1000 kcal/ha/year compared to the existing system (1,00,718/ha/year and 24213 × 1000 kcal/ha/year). On an average, it was found that, the net returns and total calories production per hectare can be increased by 68 and 46% respectively through diversification of existing system with location specific identified alternative systems.

Bio-intensive complimentary systems

As the fragmentation land holdings occurs and the average holding size of marginal farm is only 0.38 ha, the strategy should be to produce more from less specially to ensure high income for small holders. The various land configurations offers scope for growing more than two crops at the same time in the same piece of land. Ten bio-intensive complimentary cropping systems were evaluated for higher productivity and profitability. Bio-intensive System of raising maize for cobs + vegetable cowpea in 1:1 ratio on broad beds (BB) and *Sesbania* in furrows during *kharif* and mustard in furrows and 3 rows of lentil on broad beds in *rabi* while 3 rows of green gram on beds in summer was found remarkably better than others which produced highest yield of 18.32 tonnes/ha as rice equivalent with productivity of 50.2 kg grain/ha/day and profitability of ₹ 363 ha/day. The complimentary effects could be reflected in the system as in broad bed and furrow (BBF) system, the furrows served as drainage channels during heavy rains in *kharif* which were utilized for *in-situ* green manuring with 35 tonnes/ha green foliage incorporated after 45 days of sowing and timely sown mustard crop in these furrows resulted in a good harvest of 1.94 tonnes/ha and a bonus yield of lentil (1.44 tonnes/ha) could be harvested on one hand and 30% of irrigation water could be saved as applied only in furrows. In the summer season green gram could yield 1.05 tonnes/ha as grain while incorporation of green foliage of about 4 tonnes/ha in the soil further helped the system favourably.

Cropping system diversification with high calories

The diversified system should not only target the yield and income, it should also be able to produce more

Bio-intensive systems to produce more from less

Table 3. Alternate systems in various states with higher calories

State	Existing system	Alternate system	% increase in calories over existing system
Andhra Pradesh	Rice-rice	Rice-maize	7.8
Bihar	Rice-wheat	Rice-winter maize	57.0
Chhattisgarh	Soybean-chickpea	Soybean-potato-vegetable cowpea	135.5
Haryana	Cotton-wheat	Greengram-wheat	25.1
Himachal Pradesh	Rice-wheat	Rice-potato-onion	34.7
	Maize-wheat	Maize-potato-onion	51.4
Jammu and Kashmir	Rice-wheat	Rice-potato-onion	83.2
	Maize-wheat	Maize-potato-onion	59.1
Karnataka	Tomato-cabbage	Tomato-coriander-okra	164.0
	Fingermillet-tomato	Cabbage-coriander-beetroot	233.1
Kerala	Rice-rice	Rice-rice-amaranthus	144.7
Madhya Pradesh	Greengram-wheat	Soybean-wheat	27.7
Maharashtra	Cotton-wheat	Cotton + greengram-wheat	36.3
	Cotton-gram	Cotton+greengram-gram	78.2
	Pearlmillet-wheat	Pearlmillet-fenugreek	58.3
	Rice-cowpea	Rice-maize	63.3
	Rice-wheat	Rice-wheat-cowpea	11.9
Odisha	Rice-greengram	Rice-onion	20.3
		Rice-groundnut	53.7
Uttara Khand	Rice-wheat	Rice-wheat-cowpea	6.4
West Bengal	Rice-greengram	Rice-sunflower	39.3

calories than existing systems. The various systems evaluated under on-farm clearly show that besides productivity and income, the calories can also be increased through diversified systems. The alternate systems having the high calories than existing systems in different parts of the country are given in Table 3 which show that, the total calories produced per year can be increased through diversification approach.

Farming systems approach for livelihood and food security

Crop and livestock cannot be separated for small holder agriculture in India as crop + livestock is the pre-dominant farming system existing in the country and livelihood of 117 million marginal and small farm holdings revolves around this system. Integrated Farming System (IFS) is considered to be powerful tool and holds the key for ensuring income, employment, livelihood and nutritional security in a sustainable mode for small and marginal farmers who constitute 84.97% of total operational holdings and has 44.31% operational area. Integrated system meets the above goals through multiple uses of natural resources such as land, water, nutrients and energy in a complimentary way thus giving scope for round the year income from various enterprises of the system. The initial results of on farm farming system modules evaluated in various NARP zones through AICRP on Integrated Farming Systems promises 6.8 times increase in net returns over variable cost of interventions in improved farming systems with value of household consumption (produced within the farm) increasing by 51.4%. Further, the per day profit of marginal and small households can be increased by 69.2% through low cost interventions such as improved varieties, balanced recommended nutrient application, integrated pest management, good quality round the fodder supply, area and species specific mineral mixture supplementation in feeds, cleaning / grading of farm produces and kitchen gardening in farming systems perspective. Additional employment of 53.6 man days/year can also be generated for the household through these interventions.

SUMMARY

Diversification of small and marginal farms is essential in order to meet the multiple challenges these farms face. However, the diversification should not only aim for higher yield or income, it should also address the issue of total calories produced per ha besides ensuring the balanced diet. Horizontal and vertical diversification are possible as evident from the research results from the on-farm studies which indicate higher productivity and profitability. Farming Systems approach should be the core while formulating the strategies for cropping systems diversification. A well planned cluster approach in farming systems perspective could find way to improve the diversification and meeting goal of food, nutrition and livelihood security. ❑

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