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Production efficiency and profitability of major farming systems in Tamil Nadu

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Abstract This study evaluates the performance of the predominant farming systems in Tamil Nadu using primary data from 192 farmers for 2015–16, and the standard cost and stochastic frontier production function methods. Seven different predominant farming systems were identified, of which the fruits and turmeric farming systems were profitable. The marginal and small farms were more diversified, whereas the large farms were specialized, with high-value crops. The productivity in all the farming systems can be enhanced up to 40% by adopting technologies such as the System of Rice Intensification (SRI), Sustainable Sugarcane Initiative (SSI), and fertigation.

Keywords Farming systems, economic characterization, technical efficiency, crop diversification, agricultural technologies, stochastic frontier production function

JEL codes C21; O12; Q12; Q16; Q18

In 1950–51 India produced 51 million tonnes (mt) of food grains from 97 million hectares (mha); in 2014–15 it produced 254 mt from 123 mha. This increase of 400%, with only 23% increase in gross cultivated area (Economic Survey 2014–15), is a paradigm shift. This shift was enabled the development of high-yielding varieties and the use of improved crop production technologies. The cereals-based cropping systems (rice–wheat, rice–rice, and maize/pearl millet–wheat, etc.) contributed predominantly to the national food basket (IIFSR 2013–14), and intensive farming was vital in improving the cropping intensity in irrigated and rainfed areas and, therefore, increasing food production.

However, in Asia, undernourishment has been estimated to be 12.7% (FAO 2014), and, in India, the requirement of food grains in 2020 has been estimated to be 22% more than the demand (Kumar et al. 2009). To meet this demand the production of food grains needs to increase every year. But productive land has been diverted from agriculture use to infrastructural development, urbanization, and other related activities. The per capita availability of land declined from 0.5 ha in 1950–51 to 0.15 ha by the end of the 20th century, and the availability is projected to decline to less than 0.1 ha in 2020 (Department of Land Resources, GoI 2013). The net cultivated area has hovered between 140–142 mha, and there is almost no possibility of increasing the area under cultivation. In 1995–96, the cropping intensity of the country was 131.2%; it needs to be improved to 150% to meet the food requirement (Pal 2008).

The demand for feed and fodder for the livestock population is increasing, and the sustainability and profitability of farming is seriously challenged by resource degradation, climate change, new pests and diseases, slow growth in farm income, the changing dietary patterns of the population, and export–import policies. Therefore, research and development (R&D) work is needed to develop and implement appropriate strategies and new agricultural technologies that improve farm productivity, profitability, food production and sustain food security.

The farming systems approach is a holistic approach; it boosts crop productivity and profitability sustainably, and it can meet the future food demand without impairing the ecological and environmental balance. No single farm enterprise is likely to generate adequate income and gainful employment for small and marginal farmers year-round; they must adopt integrated farming systems (Mahapatra 1994). Mixed enterprises in the farming system improve the stability of farm income, supply fodder, protect against risks and uncertainty, and help to maintain soil fertility (Sharma and Sharma 2004). Farming systems research, conducted in a holistic manner so that small and marginal farmers can manage their resources (Jha 2003), by integrating various farm enterprises and recycling crop residues and by-products within the farm itself, is imperative to improve productivity, income, and employment (Behera and Mahapatra 1999).

The present investigation is undertaken to identify and characterize the predominant farming systems, estimate their costs and returns, and measure their technical efficiency.

Data, methodology, study area, and sampling

We collected the data, following the guidelines of Indian Agricultural Statistical Research Institute, using a multistage random sample survey method (Sukhatme et al. 1984). We selected the western zone of Tamil Nadu due to its importance in the variations in cropping pattern and agricultural productivity. We selected two districts, Coimbatore and Erode, based on variations in agricultural productivity, at the first stage. Subsequently, we randomly selected two blocks from each district and four villages from each block.

We developed a structured interview schedule based on an extensive literature survey (Dixon et al. 2001), initial case explorations in the field, and expert counsel. We collected data on the socio-economic parameters of households, farm size, infrastructural facilities, farm outputs, value of outputs, prices of outputs received by the farmers, and costs and benefits incurred in farming. Thus, we used the personal interview method to collect data from 192 sample households pertaining to the year 2015–16.

Herfindahl Index

The Herfindahl Index is used to explain either concentration or diversification of crop production activities in a given time and space (Hackbart et al. 1975; De and Chattopadhyay 2010). The Herfindahl Index is one of the criteria used to characterize farming systems, and it is used to measure crop diversification across farming systems in a study area.

$$HI = \sum_{i=1}^{n} P_i^2$$

where n is the total number of crops and P_i represents area proportion of the i^{th} crop in total cropped area.

If diversification increases, the value of the Herfindahl Index decreases. When the concentration is complete, the value of the Index is 1; its value approaches 0 when diversification is 'perfect'. Thus, the Herfindahl Index is bounded by 0 and 1. The value of the Herfindahl Index approaches 0 as 'n' becomes large and assumes 1 when only one crop is cultivated.

Cost and returns analysis

To estimate the profitability of farming systems, we used the standard methodology (CACP 1990) to work out the cost of variable inputs (such as wages, seeds, fertilizers, plant protection, and irrigation) and of fixed inputs (such as the rental value of land, land revenue, and the interest and depreciation on farm buildings and implements).

Stochastic frontier production function approach

The production function represents the maximum possible output for any given set of inputs; it sets a limit, or frontier, on the observed values of a dependent variable. If a farm deviates from the frontier, it is unable to produce the maximum output from its given sets of inputs; the deviation represents the degree of technical inefficiency. A one-sided component captures the measure of inefficiency relative to the stochastic frontier.

The stochastic frontier production function is defined as

$Y_i = f(X_{ki}; \beta_i)\exp(\epsilon_i);$ $i = 1, \ldots, n;$

where, Y_i is the output of the i^{th} farm; X_{ki} is vector of k inputs of the i^{th} farm; β is vector of parameters; ϵ_i is the farm-specific error term. This stochastic frontier is also called a 'composed error' model because the error term is composed of two independent elements:

$\epsilon_i = u_i + v_i;$ $i = 1, \ldots, n$

where v_i is the symmetric component; it represents the statistical 'white noise' and it follows the assumptions of the spherical error term. A one-sided component ($u_i < 0$) reflects the technical efficiency relative to the stochastic frontier, $f(X_i; \beta)e^{v_i}$. Thus, $u_i = 0$ for any farm's output lying on the frontier; it is strictly negative for any output lying below the frontier, representing the amount by which the frontier exceeds the actual output on farm 'i'. Assume that it is identically and independently distributed as $N(0, \sigma_u^2)$, that is, the distribution of u is half normal. Battese and Corra (1977) define g as the total variation in output from the frontier, which is attributable to technical inefficiency, that is, $\gamma = \sigma^2_u$ per σ^2, and so $0 < \gamma < 1$. An estimate of γ can be obtained from the estimates of σ^2 and λ. The empirical model used in the present study is specified in the Cobb–Douglas production function (Saravanakumar and Jain 2008):

$Y = \alpha X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} X_6^{\beta_6} X_7^{\beta_7} X_8^{\beta_8} \epsilon$

Y= yield (kg);

X_1= farm size (acre);

X_2= seed (INR);

X_3= labour (INR);

X_4= fertilizer (INR);

X_5= pesticides (INR);

X_6= machinery (INR);

X_7= animal size (number);

X_8= livestock maintenance (INR);

β_1 to β_8 are coefficients; and

ϵ= composed error term.

Results and discussion

The source or enterprise (crops or livestock) from which farmers earned the maximum net income was identified as the predominant farming system (Singh et al. 2008; Goswami et al. 2012; Prasad et al. 2012). Accordingly, seven predominant farming systems were identified in the study area (Figure 1): cereals-based farming (27% of the farmers), oilseed (coconut, 20%), sugarcane (16%), fruits (11%), livestock (11%), vegetable (8%), and turmeric (7%).

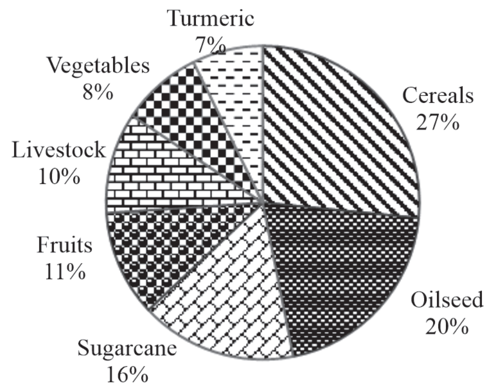

Figure 1 Predominant farming systems

The distribution of farming systems by farm category (Figure 2) indicates that marginal and small farmers widely adopted subsistence farming (cereals, livestock, and sugarcane), while medium and large farmers practised commercial farming (coconut, fruits, and turmeric crops). All farmers rear livestock, but 6.35% of the marginal farmers and 3.65% of the small farmers practise a predominantly livestock-based farming system.

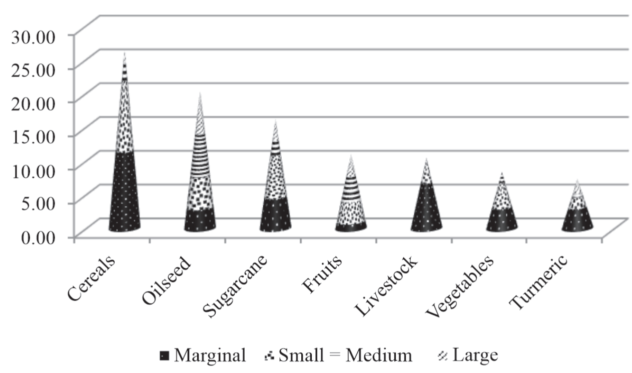

Figure 2 Predominant farming systems by category

Socio-economic characteristics of farming systems

The socio-economic characteristics of the sample households are presented by farming system (Table 1). Each household averaged four members (two adults

Table 1 Socio-economic characteristics of sample households (Tamil Nadu, western zone)

Particulars	Cereal	Livestock	Coconut	Sugarcane	Turmeric	Fruits	Vegetables
Sample size (number)	51	20	39	31	14	21	16
Family size (number)	3.40	4.56	4.50	4.21	4.15	4.10	3.56
Age (in years)	49	53	47	49	47	49	49
Educational index*	3.21	3.67	5.64	3.81	3.92	4.81	4.41
Family labour (number)	1.60	2.38	1.10	1.64	2.08	1.55	1.75
Farm size (ha)	2.92	0.87	3.65	2.88	1.78	3.09	2.42
Herd size (number per ha)	2.33	5.64	2.14	2.61	2.53	1.89	2.17

*Weighted average of formal education received by the household members (illiterate = 0, primary = 1, middle = 2, secondary = 3, higher secondary = 4, graduate = 5 and postgraduate = 6).

and two children). The farmer's age, a proxy for farm experience, ranged from 47 years (turmeric) to 53 years (livestock). The educational index, which exhibits the literacy and knowledge level of farmers in the various farm-related decision-making processes, influences farm efficiency directly and positively. Most of the members of farm households are educated up to the middle or high school level. Livestock farms hold the minimum land, 0.87 ha, and coconut farmers hold the maximum land, 3.65 ha. Livestock-rearing is an integral part of most farming systems. In the fruits-based farming system, 0–3 animals are reared, and the average is 1.89, and up to 7 animals are reared in the livestock-based farming system.

Analysis of cropping pattern

In the western zone of Tamil Nadu, the net cultivated area under cereals, sugarcane, and coconut was about 50% of the total cropped area. In the cereals-based farming system, the maximum area (42.75%) was allocated to cereals, and the rest to pulses cultivation under rice fallow lands, oilseed crops (coconut, groundnut, and sesame), and vegetables. Rice, cultivated by 58% of the farms, was the predominant crop within cereals; 29% of the farmers cultivated maize and 13% cultivated sorghum and minor millets. Most farms in the livestock-based farming system cultivated cereals and pulse crops for the purpose of by-products; 20% of the area was allocated to sorghum fodder and cumbu napier (CN) grass.

In coconut farming, the area allocated to coconut was around 50%; 17% of the area was allocated to vegetables, 7% to fodder, and a meagre portion to fruits and tree crops. Under the sugarcane-based farming system, 52% of the total area was allocated to sugarcane, 11% to oilseed crops such as groundnut and gingelly, 10% to turmeric, and 9% to cereals. Under the fruits-based farming system, 46% of the area was occupied by fruit crops such as banana (G-9, Nendran), banana leaf, and mango, followed by coconut, cereals, pulses, and vegetable crops.

The major crops grown by farmers in the vegetable farming system were bhendi, tomato, brinjal, cauliflower, lablab, cabbage, and onion; cereals, turmeric, coconut, and pulses were also cultivated. In the turmeric farming system, the area allocated for turmeric crop ranged from 31.40% (marginal farms) to 69.10% (large farms), along with onion and chilli as intercrops.

Crop diversification

The Herfindahl Index measures the degree of crop diversification at the farm level based on the number of crops or enterprises undertaken in the net cropped area. Figure 3 presents the degree of diversification by farm category and farming system.

The values of the Herfindahl Index ranged from 0.23 for marginal farms under the cereals-based farming system to 0.36 for small farms under the fruits-based farming system; the degree of diversification was higher in cereals-based farms. Small and marginal farms diversified with horticultural crops, indicating that farmers were shifting from low-value crops to high-value crops. This finding is in line with Velavan and Balaji (2012), which also finds that crop diversification took place in Tamil Nadu from 1960 to 2007. The diversification towards cash crops such as cotton and

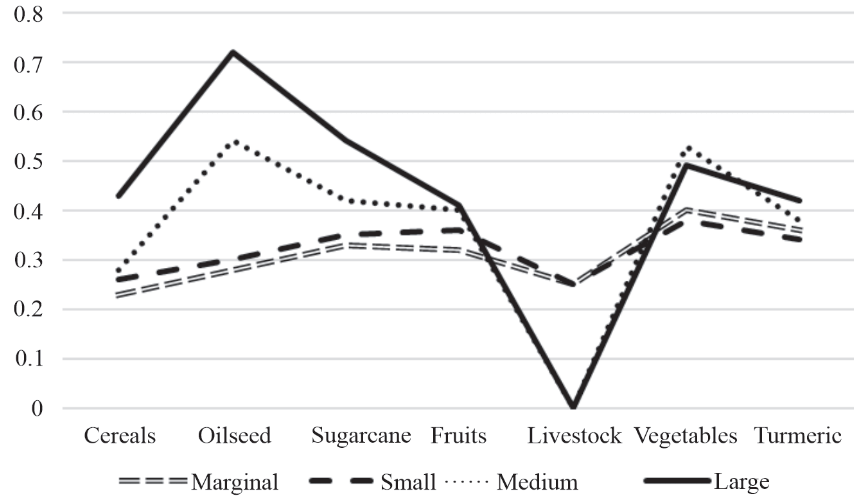

Figure 3 Crop diversification by farming system

sugarcane was significant (Mukherjee 2010), though the rice- and wheat-based cropping systems prevailed during these decades across India.

Under the coconut, sugarcane, and vegetables farming systems among large farms, the values of the Herfindahl Index ranged from 0.50 to 0.72 (nearer to 1), because the inadequate supply of family labour necessitated greater use of farm machinery and capital inputs and tenant farming, and it implies that the degree of specialization with these crops at the level of large farming systems is high. Farm size has a negative relationship with the degree of diversification, that is, marginal and small farms were more diversified than medium or large farms (Mehta 2009).

Employment generation in different farming systems

The patterns and magnitude of total human labour employed per hectare for various crops under different farming systems are presented in Table 2. The highest farm employment was estimated to be 426 person-days per hectare per annum in sugarcane-based farming system, followed by turmeric (406 person-days), vegetables (316 person-days), fruits (279 person-days), coconut (208 person-days), cereals (206 person-days), and livestock (121 person-days). Sugarcane and turmeric are labour-intensive crops, and these require more labour for de-trashing, harvesting, special agronomic practices, and processing operations (Saravanakumar et al. 2012). Drip irrigation and fertigation are used in coconut and fruits farming, and farming is seasonal; therefore, less labour is required.

Cost of crop production in different farming systems

The total cost of crop production was calculated (Table 3). Overall, the total cost incurred by the sugarcane farming system is INR 101,895 per ha. Small farmers incurred a higher cost (INR 109,289 per ha) than other categories, indicating that in this system resource

Table 2 Employment generation (person-days / ha / annum)

Farming system	Marginal	Small	Medium	Large	Overall
Cereal	204	201	215	221	210
Livestock	127	108	-	-	121
Turmeric	446	388	384	259	406
Coconut	210	212	194	212	208
Sugarcane	433	432	419	419	426
Vegetables	320	359	255	251	316
Fruits	-	306	287	222	279

Table 3 Input cost of crop production (Tamil Nadu, western zone)

(INR / ha / year)

Farming system	Marginal	Small	Medium	Large	Total
Cereal	39,685	46,548	49,596	49,707	46,283
Livestock	38,169	34555	-	-	36865
Turmeric	89,490	86,141	84,154	85,990	86,444
Coconut	49,602	49,818	47,232	46,233	48,221
Sugarcane	101,987	109,289	95,257	101,046	101,895
Vegetables	69,874	75,393	73,938	78,577	77,494
Fruits	-	90539	89,415	89,386	89,780

allocation was most efficient in large farms. Overall, the total cost incurred was INR 46,283 per ha by the cereals-based farming system; INR 36,865 per ha by the livestock system, lower than the other farming systems; INR 77,494 per ha by the vegetables system, and INR 89,780 per ha by the fruits system.

In the turmeric-based farming system, the average cost was worked out to be INR 86,444 per ha, of which the major proportion was incurred for human labour (INR 47,913 per ha), fertilizer (INR 10,005 per ha), rhizome (INR 9,529 per ha), plant protection (INR 6,260 per ha), machine labour (INR 6,135 per ha), irrigation (INR 4,179 per ha), and transport (INR 2,425 per ha). Cereals- and livestock-based systems incurred the lowest cost overall as small and marginal holders labour on their farms and depend less on markets.

The percentage share of the various input costs (Figure 4) shows that the labour cost of fruits and vegetables production is huge: 47% for the fruits system and 59% for the vegetables system. The government should make available the appropriate capital-intensive techniques (machinery to plant sugarcane stems, weeders, and harvesting machines) on a subsidy or custom-hiring basis. The cost of seeds accounted for a share of 9%–25%, the second-largest share, in various farming systems. The percentage share of machine labour cost or custom hiring charges to total cost was high in sugarcane and cereal farms (14%). The other input costs (fertilizer, irrigation, and transportation) accounted for 20%–25% of the total cost, the remaining share.

Profitability in different farming systems

The net farm income, a measure of crop productivity and farm profitability, served as the criterion for identifying the predominant farming systems. The net farm income per hectare per annum for different farm enterprises is given in Figure 5. The income was INR 255,432 per annum for fruits-based farming, the highest, and INR 231,036 per annum for turmeric, INR

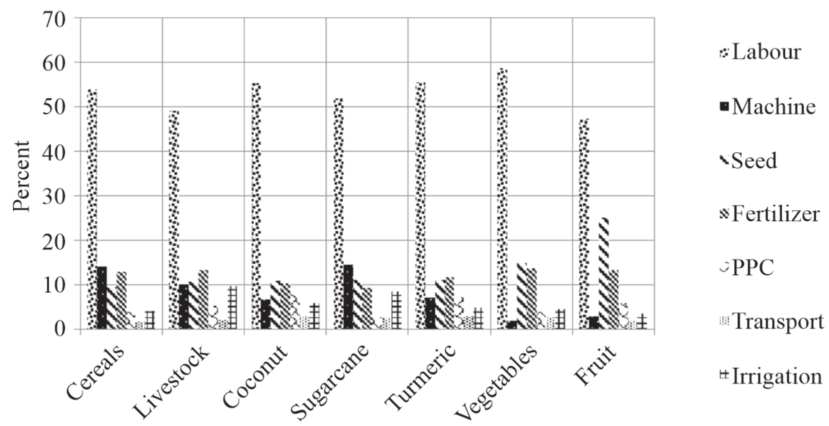

Figure 4 Share of inputs cost to total cost by farming system

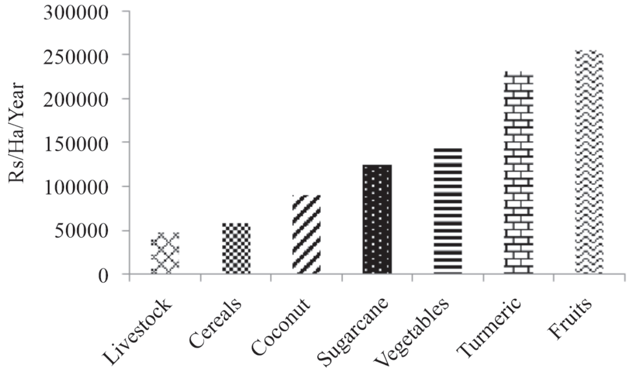

Figure 5 Net income earned per month by farming system

146,460 per annum for vegetables, INR 124,060 per annum for sugarcane, INR 90,300 per annum for coconut, INR 58,752 per annum for cereals, and INR 47,676 per annum for livestock. The profitability of the cereals and livestock farming systems was less for the other farming systems. From 1960 to 2007, the profitability of rice and sugarcane crops decreased, and farmers realized a loss for some years (Narayanamoorthy 2013).

Technical efficiency across different farming systems

The efficiency of the farms was estimated by the stochastic frontier maximum likelihood estimation technique (Table 4). The value of the estimate of log likelihood ratio was significantly different from 0, which followed chi-square distribution, indicating the 'goodness of fit' of the model. The impact of farm size was positive and significant for coconut, sugarcane, and livestock farms. A one-hectare increase in farm size would increase output by 0.13% for coconut, 0.36% for sugarcane, and 0.08% for livestock. Seeds significantly influence output; a one-percent increase in expenditure on seed is expected to raise the output of cereals by 0.13%, sugarcane by 0.07%, and the output of turmeric by 0.11%.

Fertilizer significantly affects the output of all crops, coconut and turmeric are more responsive than cereals or sugarcane to an additional level of fertilizer. Machine power was significant for only the sugarcane crop; its elasticity, 0.21%, indicates that a 10% increase in the machinery level is expected to increase the sugarcane output by 2.1%. The milk output of livestock farms

Table 4 Maximum likelihood estimates

Variable	Cereals	Coconut	Sugarcane	Turmeric	Livestock
Constant	4.2465***	0.9159	6.9088***	1.7916	2.3336***
	(0.8301)	(0.7822)	(0.8804)	(0.3389)	(0.3386)
Farm size	-0.2502	0.1338*	0.3900 ***	0.04385	0.0756*
	(0.0768)	(0.0765)	(0.0932)	(0.0407)	(0.0553)
Seed	0.1341**	0.1169	0.0796*	0.1194***	-0.0197
	(0.0684)	(0.0417)	(0.0494)	(0.0562)	(0.0185)
Labour	0.4623	0.1939***	0.1913	0.0811	0.3094***
	(0.1489)	(0.0724)	(0.1035)	(0.0832)	(0.0769)
Fertilizer	0.0710*	0.2283***	0.0529*	0.2725***	0.0191
	(0.0792)	(0.0496)	(0.0502)	(0.0844)	(0.0622)
Pesticide	0.0281	0.0043	-0.0011	0.0632	-
	(0.0842)	(0.0463)	(0.0357)	(0.0451)	
Machinery	0.0471	0.0315	0.2140**	0.2220	-0.0084
	(0.0824)	(0.0535)	(0.0741)	(0.0617)	(0.0399)
Animal size	-	-	-	-	0.1441***
					(0.0533)
Livestock maintenance cost	-	-	-	-	0.2632***
					(0.3386)
γ	0.7789***	0.8365***	0.8005*	0.7931**	0.8461**
LLF	-54.14	-40.399	17.69	55.67	46.38
N	87	96	39	52	124

(***P<0.01, **P<0.05, *P<0.1)

was determined primarily by labour, animal size, and the cost of livestock maintenance.

The variance parameter g was positive and significant. The value of γ was 0.7789 for cereals, implying that about 77% of the differences in farm productivity were due to farm-specific practices. The value of γ was 0.8365 for coconut, 0.8005 for sugarcane, 0.7931 for turmeric, and 0.8461 for livestock. Therefore, farm-specific variability contributed, respectively, 83%, 80%, 79%, and 84% of the differences in the farm productivity of coconut, sugarcane, turmeric, and livestock; the rest was due to random error, and the total variation in production from the frontier was attributable to technical inefficiency. Therefore, farm productivity can be enhanced by improving farm-specific practices, which farmers control.

Farm-specific technical efficiencies

The farm-specific technical efficiencies under different farming systems and their frequency distribution are estimated and presented in Table 5. The technical efficiency of cereals farms ranged from 64% to 93%; its average, 0.7928, implies that cereals farms realize only 79% of their technical ability. Approximately 26% of cereals farms realized more than 90% of its output, but 74% lost up to 40% (90%<TE>60%) under the existing technology. There is scope for improvement in crop output and, thereby, farm profitability across different farming systems. Specialized farms (coconut farms) were more efficient than diversified farms (cereals farms).

Potential yield improvements

Based on the technical efficiency of the most efficient farm, following the practices of the most efficient farmer can help the average cereals farmer in the sample improve productivity by 16.81%. Improving technical efficiency can increase the average potential for production by 8.92% for coconut, 13.01% for sugarcane, 13.75% for turmeric, and by 13.48% for livestock. This result is in line with Saravanakumar and Jain (2008), which find the technical efficiency to vary from 57% to 100%.

The most efficient farms and their farm-specific practices based on their technical efficiency scores are detailed in Table 6. Following the practices of the most efficient farms can help the average farms enhance productivity; cereals farms can improve productivity by 16.81%, coconut farms by 22.42%, sugarcane farms by 19.01%, turmeric farms by 13.75%, and milk farms by 17.28%.

The most efficient rice farmers adopted components of the System of Rice Intensification (SRI) like line sowing, and they used the Cono Weeder. To extend the crop life, they sprayed pink-pigmented facultative methylotrophs (PPFM) Methylobacterium during conditions of water stress. The most efficient coconut farmers practised drip irrigation for effective water use and fertigation; to harvest the maximum yield of 20,034 nuts per year, they applied micronutrient mixture (MNM) tonic, 50 g of vesicular arbuscular mycorrhizae (VAM), and 100 g of Azophos once in six months.

Table 5 Frequency distribution of technical efficiency (%)

Efficiency level (%)	Cereals	Coconut	Sugarcane	Turmeric	Livestock
90–99 %	26.44	46.88	30.77	21.15	33.87
80–89 %	41.38	38.54	43.59	50.00	55.65
70–79 %	21.84	14.58	20.51	28.85	10.48
60–69 %	10.34	0.00	5.13	0.00	0.00
Total (%)	100.00	100.00	100.00	100.00	100.00
N (No. of farms)	87	96	39	52	124
Mean technical efficiency (%)	0.7928	0.8825	0.8165	0.8225	0.8526
Standard deviation	0.0963	0.0927	0.1217	0.0772	0.0973
Maximum technical efficiency (%)	0.9261	0.9612	0.9227	0.9356	0.9675
Minimum technical efficiency (%)	0.6355	0.7824	0.6925	0.7345	0.7930

Table 6 Productivity enhancement potential

Crop	Average farmyield	Most efficientyield	Productivity increase (%)
Rice (kg)	4,525	5,285	16.81
Coconut (nuts)	16,500	20,034	21.42
Sugarcane (tonnes)	102	122	19.01
Turmeric (kg)	5,380	6,119	13.75
Milk (litre)	9.2	10.49	17.28

The most efficient sugarcane farmers adopted the Sustainable Sugarcane Initiative (SSI) method, and they applied MNM tonic, humic acid, and liquid biofertilizers like Azotobacter (AzoPro) and Phosphate Solubilizing biofertilizer (PhoSol) to attain the maximum yield of 122 tonnes per hectare. The most efficient turmeric farmers in the western zone also practised drip irrigation and fertigation, and periodically applied borax micronutrient mixture. The most efficient dairy farmers practised balanced feeding and properly managed animal health.

Conclusions

Farmers are shifting from low-value cropping systems to high-income generating systems—such as fruits, vegetables, and coconut. This result is in line with those of Mehta (2009) and Mukherjee (2010), which also find that farmers switch to horticultural or high-value crops because their productivity and income are higher.

The Herfindahl Index of crop diversification shows that to avoid risk, marginal and small farmers tend to diversify their cropping pattern with horticultural and high-value crops. The range varied widely by farmer size class, indicating that diversification is greater among marginal and small farmers, and specialization is greater among large farms.

Farms that grow fruits and vegetables generate greater profits than those that grow rice and other subsistence crops such as cereals and pulses. Predominantly marginal and small farms adopt livestock, but these are maintained by all categories of farms. Farming systems based on livestock and cereals utilize by-products and family labour effectively, and their cost of milk production is the lowest.

Our technical efficiency estimates of all the farming systems indicate that their productivity can be enhanced up to 40%; thereby, farm profits can improve, too. Farm productivity can be improved by the widespread adoption of recently developed resource-efficient, productivity-enhancing technologies, like SRI and direct sowing for cereal farms, and SSI among sugarcane farmers. Therefore, farmers should be educated periodically on the latest farming tools, techniques, and technologies—such as drip irrigation, fertigation, raising intercrops, MNM, and biofertilizer use—by agricultural extension services officers through method and result demonstrations, field visits, and training. Farmers need to be encouraged to adopt high-value, low-volume crops such as medicinal and aromatic plants, and also high-productive dairy animals and poultry.

Adopting income stabilization measures, like effective input management strategies, can improve farm productivity. Employment under the Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA) is deployed to meet the demand for agricultural labour in the peak season; this policy should be continued. The labour cost is huge, and the government should make the appropriate capital-intensive tools available on a subsidy or custom-hiring basis.

The main contribution of this study was to examine the profitability, employment generation, and technical efficiency of different cropping systems rather than on a single enterprise basis. Emphasis has been increasing on doubling farmers' income and ensuring zero hunger. In this contemporary agricultural policy context, farming systems have greater potential than single enterprises to mitigate agricultural production risks, improve profitability, utilize resources, and generate income sustainably. To help policymakers understand the productive efficiency and profitability of agricultural production systems from a holistic perspective, the economic analysis of agricultural production should be undertaken from the perspective of farming systems rather than of an individual enterprise.

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