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RESEARCH ARTICLE

SUSTAINABILITY ANALYSIS OF DRY LAND AGRO- ECOSYSTEM IN MADURAI DISTRICT OF TAMIL NADU, INDIA

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ABSTRACT

The study was undertaken in Thirumangalam block of Madurai district and the study covered Sorghum, Black gram, Green gram and Cotton crops. Resource use Efficiency was analyzed with Cobb- Douglas production function and the Technical Efficiency analysis was analyzed with Data Envelopment analysis. Sustainability status delineation was analyzed with farm level indicators and linear programming model was developed for income and employment maximization. Net income was higher for green gram and Sorghum farmers. Technical efficiency was highest for black gram and lowest for Sorghum. In ecological sustainability, black gram and cotton are more sustainable. In economic viability, green gram and sorghum crops was more sustainable. In social acceptability, black gram and green gram are more sustainable. The optimal farm plan suggested was practicing of dairying along with dry land crop activities.

INTRODUCTION

Dry land Agro Ecosystem of the country constitutes 55 per cent of the net sown area of the country and is habitat to two-thirds of livestock and 40 per cent of human population. Agricultural growth in dry land agro ecosystem is a near possibility if poverty is reduced and climate change and environmental problems are tackled. Hence there is a need to identify the opportunities for stimulating agricultural growth and reducing poverty and climate change in dry land areas. This requires creating a typology of dry land agriculture that covers both agro ecological and socioeconomic variables. With this preamble, the following objectives are developed for the study.

- To study the resource use efficiency and technical efficiency of select crops
- To delineate the sustainability status of dry land areas of the district
- To study the dynamics of poverty and climate change in dry land agro ecosystem.
- To evaluate the existing farming systems and to develop an optimal farming system and to suggest policy implications for income and employment generation.

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MATERIALS AND METHODS

The study was undertaken in Thirumangalam block of Madurai district which is predominantly a dry land area and the study covered Sorghum, Black gram, Green gram and Cotton crops. A sample size of hundred was adopted for the study.

Tools of Analysis

Resource use Efficiency was analyzed with Cobb- Douglas production function for the four major crops of Sorghum, Black gram, Green gram and Cotton. The Technical Efficiency analysis was carried out with Data Envelopment for the four major crops. Sustainability status delineation was analyzed with farm level indicators of Ecological, Economic and Social sustainability.

Finally linear programming model was developed for income and employment maximization.

RESULTS AND DISCUSSION

Cost and returns for sample farms

The costs and returns for the sample farms were worked out and the results are given in Table 1. It could be seen from the table that the total cost of cultivation was on par for green gram, black gram and cotton crops and it was ₹13791 per hectare, ₹13824 per hectare and ₹13944 per hectare. The said cost of cultivation was lowest for Sorghum with ₹12476 per hectare. The gross income was highest for green gram with ₹ 26572 per hectare followed by sorghum with ₹ 22557 per hectare and cotton with ₹ 20105 per hectare. For black gram, it was lowest with ₹ 17892 per hectare. Net income also followed the similar pattern in ordering of the crops and it was ₹ 12781 per hectare, ₹ 10081 per hectare, ₹ 6161 per hectare ₹ 4068 per hectare for green gram, sorghum, cotton and black gram respectively.

Resource use Efficiency of dry land crops Green gram

Cobb-Douglas production was used to estimate the output elasticity with respect to key inputs in the production of crops. The estimated Cobb-Douglas production function for dry land crops is furnished in Table 2. It could be seen from the table that adjusted coefficient of multiple determinations ($\overline{R^2}$) was 0.67 revealing that the production function model was a good fit. The ($\overline{R^2}$) value of 0.67 indicated that about 67.00 percent of the variation in green gram yield was influenced by the explanatory variables included in the model. In log linear production function, the coefficient represents the production elasticity of the resources used.

The coefficient of seed, farmyard manure, machine hours and plant protection chemicals were positive and significant at one per cent level with the coefficient values of 0.01, 0.16, 0.46 and0.36 respectively, which indicated that an increase in the usage of seed, farmyard manure, machine hours and plant protection chemicals by one per cent from the existing mean level, ceteris paribus, would increase the yield of green gram by 0.01, 0.16, 0.46 and 0.36 per cent respectively. The variables of chemical fertilizer and human labour were found to be non-significant.

Black gram

The adjusted coefficient of multiple determinations ($\overline{R^2}$) was 0.60 (Table 2) revealing that the production function model was a good fit. The coefficient of seed, farmyard manure, chemical fertilizers and machine hours were positive and significant at one per cent level with the coefficient values of 0.08, 0.03, 0.12 and0.21 respectively, which indicated that an increase in the usage of seed, farmyard manure, chemical fertilizers and machine hours by one per cent from the existing mean level, ceteris paribus, would increase the yield of black gram by 0.08, 0.03, 0.12and 0.21 per cent respectively. The variables of plant protection chemicals and human labour were found to be non-significant.

Cotton

The adjusted coefficient of multiple determinations ($\overline{R^2}$) was 0.57 (Table 2) revealing that the production function model was a good fit. The coefficient of seed, farmyard manure, chemical fertilizers and plant protection chemicals were

Table 1. Cost and returns of dry land crops (in ₹/ha)

S. No.	Particulars	Green gram	Black gram	Cotton	Sorghum
1.	Fixed cost	3817	4764	4429	4963
		(27.67)	(34.46)	(31.76)	(22.00)
2.	Variable cost	9974	9060	9515	7513
		(72.32)	(65.53)	(68.23)	(60.21)
3.	Total cost of cultivation	13791	13824	13944	12476
		(100.00)	(100.00)	(100.00)	(100.00)
4.	Gross income	26572	17892	20105	22557
	Net income	12781	4068	6161	10081

Table 2. Resource use Efficiency of dry land crops

S. No.	Variables	Green gram	Black gram	Cotton	Sorghum
1.	Regression Constant	0.50	1.02	0.49	-1.81
		(0.55)	(0.34)	(0.89)	(1.18)
2.	Seed (kg/ha)	0.01*	0.08**	0.27**	1.85**
		(0.20)	(0.09)	(0.25)	(0.65)
3.	FYM (t/ha)	0.16**	0.03*	0.06*	0.11*
		(0.11)	(0.027)	(0.06)	(0.11)
4.	Machine hours (hrs/ha)	0.46**	0.12*	0.08 ^{NS}	0.64**
		(0.14)	(0.04)	(0.11)	(0.15)
5.	Chemical fertilizer (kg/ha)	0.10^{NS}	0.21 ^{NS}	0.24*	0.08 ^{NS}
		(0.11)	(0.18)	(0.11)	(0.17)
6.	Human Labour (man days/ ha)	0.20 ^{NS}	0.21*	0.06 ^{NS}	0.18*
		(0.17)	(0.10)	(0.53)	(0.21)
7.	Plant protection chemicals	0.36**	0.24 ^{NS}	0.22*	0.13 ^{NS}
		(0.12)	(0.04)	(0.09)	(0.17)
8.	$\overline{R^2}$	0.67	0.60	0.57	0.62

R^2 = 0.73 $\overline{R^2}$ = 0.67 **- Significant at 1% level *- Significant at 5% level NS- Non-significant.

positive and significant at one per cent level with the coefficient values of 0.27, 0.06, 0.24 and0.22 respectively, which indicated that an increase in the usage of seed, farmyard manure, chemical fertilizers and plant protection chemicals by one per cent from the existing mean level, ceteris paribus, would increase the yield of cotton by 0.27, 0.06, 0.24and 0.22 per cent respectively. The variables of machine hours and human labour were found to be non-significant.

Sorghum

The adjusted coefficient of multiple determinations ($\overline{R^2}$) was 0.62 (Table 2) revealing that the production function model was a good fit. The coefficient of seed, farmyard manure, machine hours and human labour were positive and significant at one per cent level with the coefficient values of 1.85, 0.11, 0.64and 0.18 respectively, which indicated that an increase in the usage of seed, farmyard manure, machine hours and human labour by one per cent from the existing mean level, ceteris paribus, would increase the yield of sorghum by 1.85, 0.11, 0.64and 0.18 per cent respectively. The variables of chemical fertilizers and plant protection chemicals were found to be non-significant.

variation in the levels of technical efficiency of black gram ranged from 81.00to 100.00 with mean efficiency of 91.00per cent. The mean level of technical efficiency indicates that on an average 9.00 per cent of black gram growers falling short of the maximum possible level of technology. In cotton, the variation in the levels of technical efficiency ranged from 66.00to 100.00 with mean efficiency of 80.00per cent. The mean level of technical efficiency indicates that on an average 20.00 per cent of cotton growers falling short of the maximum possible level of technology. In sorghum, the variation in the levels of technical efficiency ranged from 81.00to 100.00 with mean efficiency of 57.00per cent. The mean level of technical efficiency indicates that on an average 43.00 per cent of cotton growers falling short of the maximum possible level of technology. In Sorghum, low mean level of technical efficiency was reported. The frequency distribution of technical and scale efficiency measures for dry land crops was furnished in Table 4. The technical efficiency measures indicated that higher proportion of all the black gram, green gram, cotton and sorghum farmers belonged to most efficient category (>95.00 per cent) and the proportion was 75.76 per cent, 54.55 per cent, 48.78 per cent and 55.00 per cent respectively.

Table 3. Technical efficiency of dry land crops

S. no.	Parameters	Technical efficiency			
		Green gram	Black gram	Cotton	Sorghum
1.	Mean	0.82	0.91	0.80	0.57
2.	Minimum	0.71	0.81	0.66	0.81
3.	Maximum	1.00	1.00	1.00	1.00

Table 4. Frequency distribution of efficiency of dry land crops

Frequency	Technical efficiency			
	Green gram	Black gram	Cotton	Sorghum
<90	12.12	18.18	31.71	20.00
90– 95	12.12	27.27	19.51	25.00
>95	75.76	54.55	48.78	55.00

Table 5. Average input use in dry land production

S. No.	Input	Green gram	Black gram	Cotton	Sorghum
1.	FYM (t/ha)	13.84	17.36	18.28	10.20
2.	Fertilizer (Kg/ha)	73.27	83.33	163.09	97.50
3.	Plant protection chemical (lit/ha)	1.80	2.15	3.08	2.10
4.	Labour (in man days)	23.18	47.66	47.59	18.52

Technical efficiency of dry land crops

Data Envelopment Analysis was attempted to measure the technical efficiency of sugarcane and groundnut. The Data Envelopment Analysis (DEA) is a non-parametric mathematical programming methodology based on the works of Farrell (1957) and Fraser and Cordina (1999). The results of DEA, technical and scale efficiencies of dry land crops is furnished in Table 3. It could be observed from the Table 3 that the variation in the levels of technical efficiency of green gram ranged from 71.00 to 100.00 with mean efficiency of 82.00per cent. The mean level of technical efficiency indicated that on an average eighteen per cent of green gram growers falling short of the maximum possible level of technology. Therefore it was possible to increase the sugarcane yield by eighteen per cent of green gram growers on average by adopting the technology used by best performers. Likewise the

Analysis of Sustainability using farm level indicators

Agricultural sustainability was assessed by combining the three sustainability criteria of ecological soundness, economic viability and social acceptability.

Ecological Sustainability

Ecological Sustainability was assessed based on use of chemical fertilizer and management of pests and diseases.

Soil-fertility

The declining soil fertility has been a major concern for agricultural sustainability in the region. It is believed that declining land productivity, to a considerable extent, was due to lack of adequate amounts of organic matter in the soil. The

farmers applied 18.28 t/ha of FYM in cotton and 17.36 t/ha in black gram which was high as compared to other two crops of green gram and sorghum. (Table 5). The same trend was observed for fertilisers and plant protection chemicals. Labour employment was also higher for cotton and black gram with 47.59 man days per hectare 47.66 man days per hectare which showed that input usage higher in these two crops.

Pest and disease management

The pest and disease management in dry land production was presented in Table 6. It could be observed from the table that even though the proportion of chemical alone was higher among all crops, its proportion was lesser for black gram and cotton with 87.88 per cent and 85.37 per cent respectively. Consequently the both chemical and biological proportion was higher for these two crops with a proportion of 12.12 per cent for black gram and 14.63 per cent for cotton. This analysis showed that these two crops of cotton and black gram had better pest and disease management. FYM application and labour employment was also high for these two crops. Thus in ecological sustainability, black gram and cotton are more sustainable.

Stability of yield

The stability of yield crop yield was examined by constructing an index based on farmer's subjective response to a question related to yield trend. The index was lower for all the crops but among them, the index was higher for sorghum with 0.27 followed by black gram with 0.24 which showed their relatively stability (Table 7).

Profitability

The profitability of cropping system was analyzed based on financial and economic returns and value-addition per unit of land to understand the performance of an agricultural system. Profitability of dry land crops was worked out and the results have been presented in Table 8. The output- input ratio was higher for sorghum with 3.00 and green gram with 2.66 as compared to other two crops. Likewise, the net return was also higher for these two crops with ₹10081 and ₹12781. To determine the net contribution of agriculture to the economy, the value of chemical fertilizer, pesticide, fuels and other input services from outside the agricultural sector have to be deducted from the value of the agricultural output.

Table 6. Pest and Disease Management in dry land production (in nos.)

S. No.	Particulars	Green gram	Black gram	Cotton	Sorghum
1.	Chemical alone	93.94	87.88	85.37	90.00
2.	Biological Control alone	-	-	-	-
3.	Both chemical and biological	6.06	12.12	14.63	10.00

Table 7. Stability of yield of dry land crops

Green gram	Black gram	Cotton	Sorghum
0.15	0.24	0.12	0.27

Table 8. Profitability of major dry land crops (in ₹'/ha)

S. No.	Crops	Green gram	Black gram	Cotton	Sorghum
A.	Financial				
i.	Gross return	26572	17892	20105	22557
ii.	Total variable cost	9974	9060	9515	7513
iii.	Output-input ratio	2.66	1.97	2.11	3.00
B.	Economic				
i.	Net return	12781	4068	6161	10081
C.	Value-addition				
i.	Cost of chemical fertilizers	971	1271	1291	411
ii.	Cost of pesticides	504	891	805	448
iii.	Cost of fuel and charge of agricultural machinery use	1590	1896	1563	1186
iv.	Cost of intermediate goods (i+ii+iii)	3065	4058	3659	2045
v.	Value-addition*	23507	13834	16446	20512

*Value-addition =Gross return-Cost of intermediate goods

Table 9. Input self-sufficiency in dry land production (in ₹'/ha)

S. No.	Particulars	Green gram	Black gram	Cotton	Sorghum
1.	Cost of all variable inputs	9974 (100)	9060 (100)	9515 (100)	7513 (100)
2.	Cost of local inputs	6533 (65.50)	8756 (96.64)	5415 (56.91)	4313(57.40)
3.	Cost of external inputs	3065	4058	3659	2045
4.	Input self-sufficiency ratio*	0.65	0.96	0.56	0.57

Economic viability

It was assessed based on three indicators of yield stability and profitability of crops.

The results indicated that the value-addition was higher for green gram with₹23507/ha followed by sorghum with ₹' 20512/ha. Thus the economic viability analyses showed that green gram and sorghum crops was more sustainable by

having higher output-input ratio, net return and value addition as compared to other two crops.

Social acceptability

It was assessed in terms of input self-sufficiency, equity, and food security.

Input self-sufficiency

The high dependency on external inputs, such as chemical fertilizers, pesticides, and diesel and irrigation water increases farmer's vulnerability and reduces profit. The sustainability should seek to minimize dependency on external inputs. Hence, input self-sufficiency in the study area was analysed and presented in Table 9. It could be seen from the table that the dependency on local inputs was higher for pulses of green gram and black gram 0.65 and 0.96 respectively as compared to cotton and sorghum with comparative lower usage of local inputs, such as labour, seed, organic fertilizers and pesticides. These were reflected in the input self-sufficiency ratios.

Equity

Any activity that creates employment opportunities will have a higher equity effect through the process of chain reaction across the rural economy. Thus, it was reasonable to consider labour used and labour cost per unit of output as indicators of the equity effect of any farming system (Nasurudeen and Mahesh, 2006). The details of equity and food security are given in Table 10.It could be observed from the table that labour requirement to produce one Kg. was higher for pulses of green gram and black gram with 0.66 and 0.92 respectively

Food Security

Food security was measured in terms of household's food expenditure on food items .The expenditure on food items was higher for pulses with black gram for ₹ 68967 and green gram for ₹ 73343. Thus the social acceptability analyses showed that pulses of black gram and green gram are more sustainable.

Development of Optimal farm plan

Details of the existing plan in the representative farm of the study area (4.01 ha) are given in Table 11. The existing plan included crops of green gram, black gram, cotton and sorghum. The net income from the existing plan was worked out to Rs. 33091.

Table 10. Equity and Food security in dry land production

S. No.	Particulars	Green gram	Black gram	Cotton	Sorghum
1.	Equity				
i.	Labour requirement to produce one unit of output	0.66	0.92	0.44	0.62
ii.	Labour cost per unit of output (₹)	23.18	47.66	47.59	18.52
2.	Food security				
i.	Expenditure on food items	73343	68967	65536	70565

Table 11. Details of existing plan in the study area

S.No.	Crops	Area (ha)	Net income (Rs)
1.	Green gram	0.93	12781
2.	Black gram	0.68	4068
3.	Cotton	1.40	6161
4.	Sorghum	1.00	10081
	Total	4.01	33091

Table 12. Details of optimal plan I in study area

S. No.	Crops	Area(ha)	Net income (Rs)
1.	Green gram	1.16	14842.45
2.	Black gram	1.00	4068.00
3.	Cotton	1.00	6161.00
4.	Sorghum	1.00	10081.00
	Total	4.16	35152.45

Table 13. Details of optimal plan II in study area

S. No.	Crops	Area(ha)	Net income (Rs)
1.	Green gram	1.00	12781.00
2.	Black gram	1.00	4068.00
3.	Cotton	1.00	6161.00
4.	Sorghum	1.00	10081.00
5.	Dairy	-	83765.71
	Total	0.77	116856.71

The optimal plan I maximizes the net income with the constraints specified in the model and the results are given in Table 12. The minimum land constraints included for all the four crops so as to essentially allocate area under these crops. In this plan, the cropped area was also increased marginally by 0.16 hectare. Optimal plan I revealed that by optimization of available resources, higher net income of Rs. 35142.45 could

be attained and it was 6.20 per cent higher as compared to the existing plan. The optimal plan II presented in Table 13 included dairying along with crop activities. This optimal plan revealed still higher net income of Rs. 116856.71 could be attained and it was 232.43 per cent higher as compared to the optimal plan I. Thus in the study area, the optimal farm plan suggested was practicing of dairying along with crop activities.

Conclusion

Net income was higher for green gram and Sorghum farmers. Technical efficiency was highest for black gram and lowest for Sorghum. In ecological sustainability, black gram and cotton are more sustainable. In economic viability, green gram and sorghum crops was more sustainable. In social acceptability, black gram and green gram are more sustainable. The farmers mostly perceived the decline in yield, decline in net income and pest and disease outbreak as the impact of climate change. The highest technological mitigation was following of mixed/ inter cropping. The optimal farm plan suggested was practicing of dairying along with dry land crop activities.

Policy implications

- The technical efficiency analysis showed that 43 per cent of sorghum farmers are short of frontier yield and hence suitable training programmes should be given to Sorghum farmers by the Agriculture Department to attain frontier yield. Further, the cost of cultivation was lowest for Sorghum with ₹12476 per hectare and net income of Sorghum farmers was second highest with Rs.10081/ha. Hence this crop should be popularized by the Agriculture Department among the farmers of the block.
- The sustainability analyses revealed that there are enhanced returns on the fronts of economic viability, ecology and social acceptability for developing dry land crops and hence Government should devise suitable credit and extension policies for its development.
- The sustainability analysis showed that black gram is relatively socially acceptable but not economically viable. Hence suitable technological interventions should be given to black gram farmers to make the crop more economically viable.
- The sustainable farm plan of raising dairy along with dry land crop activities should be popularized in Thirumangalam block by Agriculture Department as it achieved the highest net income.

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