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Research Article

AN ECONOMIC ANALYSIS OF SUSTAINABILITY IN HILL ECOSYSTEM OF DINDIGUL DISTRICT OF TAMIL NADU

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Abstract: This study was conducted in Dindigul district of Tamil Nadu to assess the agricultural sustainability for Palani and Sirumalai hill and to develop the optimum farm plan for Palani and Sirumalai hills. Analysis of sustainability using farm level indicators involves assessment of ecological soundness, economic viability and social acceptability. This study results indicated that ecological soundness do not have clear cut distinction on sustainability between two hills and Sirumalai hill is comparatively higher sustainable with regard to economic viability and social acceptability. A sustainable rural livelihood framework analysis involves analysis on natural capital, financial capital, physical capital, human capital and social capital. These results showed that Palani hill is more sustainable with regard to Physical and human assets and Sirumalai hill is more sustainable with regard to financial and social assets. Livelihood security analyses also done with comparative livelihood index scores for food security, economic security, education security, habitat security and social network security for both Palani and Sirumalai hill. The results revealed that both hills were not secured with regard to education and social network. Among other indices, Palani hill had higher comparative livelihood security with regard to food and health and Sirumalai hill favoured well with regard to economic and habitat security. The optimum farm plan with inclusion of dairy enterprise was suggested for Palani hills and optimum farm plan with inclusion of acid lime was suggested for Sirumalai hills.

Keywords: *Livelihood security index, Linear programming technique, Sustainable rural livelihood framework analysis*

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Introduction

Forests act as a source of food, medicine and fuel for more than a billion people. However, the world's population is projected to increase from 7.60 billion currently to 10 billion people by 2050. Deforestation threatens not only the livelihoods of foresters, forest communities and indigenous peoples, but also the variety of life on our planet. Land-use changes result in a loss of valuable habitats, land degradation, soil erosion, a decrease in clean water, and the release of carbon into the atmosphere. Sustainable agriculture needs healthy and productive forests. Forests and trees support sustainable agriculture by, for example, stabilizing soils and climate, regulating water flows, providing shade, shelter, and a habitat for pollinators and the natural predators of agricultural pests. They also help provide food security for hundreds of millions of people, for whom they are important sources of food, energy and income during hard times [1]. In order to meet growing population worldwide and to mitigate climate change sustainable agricultural practices should be incorporated in forest ecosystem. There by forest degradation and deterioration of biodiversity can be prevented in every parts of the country. The present study mainly focuses on analyzing sustainability in Palani and Sirumalai hills of Dindigul district in Tamil Nadu. The following objectives were taken for this study,

1. To study the sustainability of forest ecosystem by using farm level indicators and sustainable rural livelihood method.
2. To study the livelihood security of hill farmers.
3. To develop optimum crop plan using programming with environmental components.

Materials and Methods

This study was undertaken in Dindigul district as a result of more forest cover of 1876 square kilometre in the total geographical area. Palani and Sirumalai hills were selected for the assessment of agricultural sustainability in those areas by surveying 120 respondents. Sustainability status studied with Sustainable Rural Livelihood Framework (SRL [2,4,5]. Sustainability using farm level indicators can be done by ecological soundness, social acceptability and economic viability. Ecological soundness involves land use pattern, Cropping pattern, Soil fertility status and Pest and disease management. Economic viability assessed based on three indicators; land productivity, yield stability and profitability from stable crops. Social acceptability refers to self- reliance, equality and improved quality of life. It was assessed in terms of input self-sufficiency, equity and food security. Rural Livelihood framework consists of five capital assets. The selected indicators under Sustainable Rural Livelihood framework are natural capital, financial capital, physical assets, human capital and social capital. Livelihood security indices were developed using indicators given in the livelihood security model of CARE [3, 7]. The selected indicators for Livelihood security are food security, economic security, health security, educational security, habitat security and social network security. The linear programming model was developed for income and employment maximization [6]. Optimum farm plan can be developed by linear programming technique for Palani and Sirumalai hills.

The mathematical form of linear programming could be written as

$$\text{Maximise } z = \sum_{j=1}^{n} C_j X_j \qquad (1)$$

Subjected to constraints

$$\sum_{j=1}^{n} a_{ij} X_j \leq b_i \qquad (2)$$

$$X_j \geq 0 \qquad (3)$$

Where Z_j= Objective function to be maximized
C_j = Value of the j^{th} activity

X_j = Level of the j^{th} activity
a_{ij} = Coefficient that reflects either an absorption of (a>0) or a contribution to (a<0) a constraint resource and
b_j= Available quantity of i^{th} resource or the requirement to be met

The objective function of the model is to maximize the net returns over variable cost per hectare firstly in crop enterprises subjected to the resource constraints specified in the model and then by inclusion of dairy enterprise in Palani hills.

Results and Discussion

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 cropping pattern, soil fertility management, use of chemical fertilizer and management of pests and diseases. These were analysed for the both Palani and Sirumalai hills and are discussed below.

Cropping pattern

Cropping pattern analyses revealed that maize was the major crop in Palani hills and Chow Chow was the major crops in Sirumalai hill. The cropping intensity in Palani hill was 123.14, which was higher than the Sirumalai hill with a cropping intensity of 104.88. This may be due to practicing perennial crops in the Sirumalai hill. Crop diversification index for Palani and for Sirumalai hill was 9.86 and 15.31 respectively. Higher the index of Sirumalai hill indicated lower diversification of crops in Sirumalai hills. Thus the indices of crop intensity and crop diversification revealed that Palani hill is more ecologically sustainable.

Soil-fertility status

It could be observed from the [Table-1] that nitrogen content was low in both the hills. Phosphorous and potassium content were high in both the hills and Palani hill was higher in nitrogen, phosphorous and potassium than Sirumalai hill. The farmers applied about 10.91 t/ha of FYM in Palani hill while in Sirumalai hill, it was about 7.61 t/ha. On the other hand, use of chemical fertilizer was more in Sirumalai hill with 271.74 kg/ha and also plant protection chemical was higher in Sirumalai hills with 7.70 lit/ha. This shows the ecological unsustainability of Sirumalai hills. Labour employment was also higher in Sirumalai hill than Palani hill by 12.60 percent.

Table-1 Soil-fertility status

SN	Soil properties	Soil test value		Interpretation	
		Palani	Sirumalai	Palani	Sirumalai
1	pH	7.1-7.7	7.6-8.0	Basic	Basic
2	EC	0.32	0.25	Slightly	slightly
3	Nitrogen (kg/ha)	227	231	Low	Low
4	Phosphorous (kg/ha)	38	32	High	High
5	Potassium (kg/ha)	498	453	High	High

Pest and disease management

The pest and disease management in both Palani and Sirumalaihill was presented in [Table-3]. It could be observed from the Table that there was significant variation between these two hills in the management of pest and disease. In Palani hill, higher proportion of the farmers with 73.33 percent followed chemical alone for controlling pest and diseases and 26.67 percent of farmers used both biological and chemical method. In Sirumalai hill, most of the farmer followed both biological and chemical methods to control pest and disease with a proportion of 58.33 percent and 35.00 percent of farmers are using chemical alone and only 6.67 percent of farmers followed biological control alone for controlling pest and diseases. Thusthis analysis showed that Sirumalai hill was sustainable than Palani hill. Thus the ecological sustainability analyses showed that Palani hill was more sustainable with regard to cropping pattern and soil fertility and Sirumalai hill was more sustainable with regard to pest and disease management.

Table-2 Average input use in the sample farms

SN	Input	Palani	Sirumalai
1	FYM (t/ha)	10.91	7.61
2	Fertilizer (Kg/ha)	172.45	271.74
3	Plant protection chemical (lit/ha)	6.72	7.70
4	Labour (in man days)	310.4	349.5

Table-3 Pest and Disease Management in the sample farms(in nos.)

SN	Particulars	Palani	Sirumalai
1	Chemical alone	44(73.33)	21(35.00)
2	Biological Control alone	-	4(6.67)
3	Both chemical and biological	16(26.67)	35(58.33)
4	Total	60(100.00)	60(100.00)

Figures in parentheses indicate percentage to total

Economic viability

It was assessed based on three indicators; land productivity, yield stability and profitability of crops. The productivity analyses revealed that that both followed different cropping pattern and the productivity of farms under both hills was almost similar with regard to common crops of banana and lemon. The stability of crop yield was examined by constructing an index based on farmer's subjective response to a question related to yield trend. In Sirumalai hill, the index of yield stability was 0.30 whereas it was 0.14inPalani hill. The higher stability index in Sirumalai hill proved that the said system is stable than the Palani hill by 114.28 percent.

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 maize in Palani hills and chow chow in Sirumalai hill was worked out since it was the major crop in these hills. The results have been presented in [Table-4]. It has been found that performance of the Sirumalai hill was higher better than Palani hill as the output-input ratio was 4.14 in Sirumalai hill as compared to 1.57 in Palani hill. Net return was significantly higher in Sirumalai hill than Palani hill by 906.33 percent. 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. The results indicated that the value-addition was 535373/ha in Sirumalai hill, which was higher than the Palani hill by 418.85 percent. Thusthe economic viability analyses showed that Sirumalai hill was more sustainable by having higher stability and higher profitability as compared to Palani hill.

Table-4 Profitability of Major principle crop in the sample farms, (in /ha)

SN	Crops	Palani	Sirumalai	Difference(%)
A.	Financial			
1	Gross return	114864	550817	379.53
2	Total variable cost	73332	132864	81.18
3	Output-input ratio	1.57	4.14	163.69
B.	Economic			
1	Net return	41532	417953	906.33
C.	Value-addition			
1	Cost of chemical fertilizers	2964	6600	122.67
2	Cost of pesticides	3526	5844	65.74
3	Cost of fuel and charge of agricultural machinery use	5189	3000	-72.97
4	Cost of intermediate goods (i+ii+iii)	11679	15444	32.24
5	Value-addition*	103185	535373	418.85

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

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 analyzed and presented in [Table-5].

It could be seen from the [Table-5] that in Sirumalai hill, the dependency on local inputs was higher as compared to Palani hill with comparative lower usage of local inputs, such as labour, seed, organic fertilizers and pesticides. These were reflected in the input self-sufficiency ratios. It was 0.42 in Palani hill and 0.47 in Sirumalai hill. It clearly showed that Sirumalai hill was relatively self-sufficiency in terms of input dependency than Palani hill.

Table-5 Input self-sufficiency

SN	Particulars	Palani	Sirumalai
1	Cost of all variable inputs	57976.98	101849.05
2	Cost of local inputs	27297.46	43308.76
3	Cost of external inputs	30679.52	58540.29
4	Input self-sufficiency ratio*	0.42	0.47

*Input self-sufficiency ratio = Cost of local inputs / Cost of all variable inputs

Equity

The details of equity and food security are given in [Table-6]. It could be observed from the table that labour requirement to produce one tonne of maize was 34.22 man days in Palani hill and to produce one tonne of chow chow was 45.16 man days in Sirumalai hill. Thus the labour usage was higher in Sirumalai hill than Palani hill which confirmed the sustainability of the Sirumalai hill from the equity point of view.

Table-6 Equity and Food security

SN	Particulars	Palani	Sirumalai
1	Equity		
i	Labour requirement to produce one unit of output	34.22	45.16
ii	Labour cost per unit of output (₹)	6844	9935.2
2	Food security		
i	Expenditure on food items	45300	43780

Food Security

Food security was measured in terms of household's food expenditure on food items. The expenditure on food items was 45300 and 43780 in Palani and Sirumalai hill respectively. Food expenditure in Palani hill was higher by 3.47 percent over Sirumalai hill. Thus Palanihill is having more food security than Sirumalai hills. Thus the social acceptability analyses showed that Sirumalai hill was more sustainable by having higher input self-sufficiency ratio and equity. A Palani hill was of superior with regard to food security. Even though the analysis on ecological soundness do not have clear cut distinction on sustainability between two hills, Sirumalai hill is comparatively higher sustainable with regard to economic viability and social acceptability.

Sustainable rural livelihood framework analyses

The Sustainable Rural Livelihood framework (SRL) included analysis on natural capital, financial capital, physical capital, human capital and social capital. The results of the analysis are furnished in the [Table-7].

Table-7 Sustainable Rural Livelihood assets

SN	Assets	Palani	Sirumalai
I	Natural assets		
	Land value (in ₹)	1475000	1335000
	Area under irrigation (in ha)	96.4	104.8
II	Financial assets		
	Income (in ₹)	270935	401115
	Saving (in ₹)	124100	165800
III	Physical assets		
	Durable assets (in ₹)	89373	65780
IV	Human assets		
	Expenditure on education (in ₹)	39033	21983
	Expenditure on health (in ₹)	7610	4732
V	Social assets		
	Migration (per cent)	0.3	0.2
	Gender ratio	122.47	132.95
	Equity	0.24	0.12

Natural assets

Natural assets were measured in terms of land value and total area under irrigation. It could be observed from the [Table-7] that land value of Palani and Sirumalai hill was 1475000 and 1335000 respectively. The land value of Palani was higher by 10.49 percent over Sirumalai hill. The total area under irrigation was 96.40 ha in Palani hill which is lower when compared to area under irrigation of 104.80 ha in Sirumalai hill by 8.71 percent.

Financial assets

The [Table-7] clearly depicts the financial assets such as income and saving were higher in Sirumalai hill than Palani hill. Income and saving of Sirumalai hill was higher by 48.05 and 3.36 percent respectively over Sirumalai hill. Thus Sirumalai hill is having more valued financial assets.

Physical assets

The value of durable assets reflects the physical assets of both Palani and Sirumalai hill. The value of durable assets in Palani and Sirumalai hill was 89373 and 65780 respectively. The physical assets of Palani hill were higher by 35.87 percent over Sirumalai hill and hence Palani hill is sound in Physical assets.

Human assets

Human assets such as health and education were measured on the basis of expenditure. Expenditure on education was 39033 and 21983 in Palani and Sirumalai hill respectively. Expenditure on health was higher with 7610 Palani hill than Sirumalai hill (4732). The expenditure on education and health of Palani hill was higher by 77.56 percent and 60.82 percent respectively over Sirumalai hill. In human assets also, Palani hill is having more favourable position than Sirumalai hills.

Social assets

It could be observed from the [Table-7] that the migration of Palani and Sirumalai hill was 0.3 percent and 0.2 percent respectively. Migration percentage was relatively high in Palani hill. The gender ratio of males per 100 females was also high in Sirumalai hill (132.95) than Palani hill (122.47). The gini co-efficient value of income for the Palani and Sirumalai hill was 0.24 and 0.12 respectively. The lower gini coefficient ratio reflects that equity was higher in Sirumalai hill as compared to Palani hill. Thus Sirumalai hill is having more social assets with less migration, more gender ratio and more equity as compared to Palani hills. Thus the sustainable Rural Livelihood framework analysis showed that Palani hill is more sustainable with regard to Physical and human assets and Sirumalai hill is more sustainable with regard to financial and social assets.

Table-8 Livelihood security indices

SN	Indices	Palani	Sirumalai
1	Food security		
	Food expenditure	3.37	3.08
	Diet diversity	3.22	2.98
	Aggregate mean score	3.3	3.03
2	Economic security		
	Income	2.93	3.67
	Value of land	3.55	3.52
	Aggregate mean score	3.24	3.6
3	Health security		
	Accessibility to health services	3.22	2.75
4	Educational security		
	Literacy level	2.12	1.98
	Availability of schools	3.52	3.38
	Aggregate mean score	2.82	2.68
5	Habitat security		
	Quality of house	4.1	2.95
	Accessibility to drinking water	1.85	3.13
	Quality of drinking water	3.95	4.1
	Aggregate mean score	3.3	3.39
6	Social network security		
	Level of support(government and other agencies)	2.93	3.1
	Level of active participation in community organization	2.25	2.1
	Aggregate mean score	2.59	2.6

Livelihood security analyses

The livelihood security of sample farmers in both hills were assessed by

constructing five point scales and presented in [Table-8]. The table presents the comparative livelihood index scores for food security, economic security, education security, habitat security and social network security for both Palani and Sirumalai hill.

Food security

Food security was studied in terms of two indicators, namely, expenditure spend on food items and diet diversity. It could be observed from the [Table-8] that aggregate score of food security was slightly higher in Palani hill than Sirumalai hill. Further, the composite index of food security with a value slightly above the midpoint index score in the scale of one to five indicated that both hills having medium food security.

Economic security

Economic security index developed based on the score in the scale of one to five points. It could be observed from the [Table-8] that aggregate mean score of economic security was significantly higher with 3.60in Sirumalai hill than Palani hill where it was only 3.24.

Health security

The health security was measured by the accessibility to health services in the selected villages of both Palani and Sirumalai hill. The results showed that health security of Palani hill was higher with 3.22 where as in Sirumalai hill, it was about only 2.75.

Educational security

The educational security has been captured by indicators like literacy level and availability of schools. It could be observed from the [Table-8] that the literacy score was comparatively lower inSirumalai hill than inPalani hill. Availability of schools was also high in Palani hill than Sirumalai hill. Further, the index score of the overall educational security of both hills was less than the mid values and the score of educational security was slightly higher in Palani hill than Sirumalai hill.

Habitat security

Habitat security was measured by quality of house, accessibility to drinking water and quality of drinking water. The [Table-8] revealed that the score of quality of house was higher with 4.10 in Palani hill and it was only 2.95inSirumalai hill. The score of accessibility to drinking water was higher in Sirumalai hillthanPalani hill. Quality of drinking water was significantly high (4.10) in Sirumalai hill than Palani hill (3.95). The aggregate mean score of habitat security in both Palani and Sirumalai hill was 3.30 and 3.39 respectively. Though the index scores of the overall habitat security of farmers in both the hills were more than the mid values , Sirumalai hill had slightlyhigher habitat security than Palani hill.

Social network security

It could be observed from the [Table-8] that the overall score of the social network security was lesser than the mid-value in the overall scale of one to five points for both Palani and Sirumalai hill. Level of support (government and other agencies) was high in Sirumalai hill as compared toPalani hill. Level active participation in community organization was high in Palani hill was high than Sirumalai hills. The overall score of the social network security was marginally higher in Sirumalai hill than Palani hill. Thus the livelihood security analysis showed that both hills were not secured with regard to education and social network as their score were close to the mid score values. Among other indices, Palani hill had higher comparative livelihood security with regard to food and health and Sirumalai hill favoured well with regard to economic and habitat security.

Optimum farm plan with Linear programming model

Optimum farm plan for Palani hill

A detail of the existing plan in the representative farm of Palani hill for 2.4 ha is given in Table 9. The existing plan included cropsof rice, cotton and maize with the land, labor and capital constraints. The net income realized from the existing plan was Rs. 122100.The optimal plan I maximizes the net income with the given constraints in the model and the results are given in [Table-10]. Optimal plan I indicated that by optimization of available resources and higher net income of Rs. 125024 with the increased area of 0.60 ha and it was 2.39 percent higher as compared to the existing plan. The labor requirement was also decreased by 7.34 percent as compared to the existing plan. The optimal plan II presented in [Table-11] included dairying and poultry along with crop activities. This optimal plan revealed still higher net income of Rs. 170425 and it was 36.31 percent higher as compared to the optimal plan I. Hence crop activities along with dairy would give higher net income than the existing plan and optimum plan I.

Table- 9 Details of existing plan in Palani hill

SN	Crops	Area (ha)	Labour (mandays)	Capital (Rs)	Net income (Rs)
1	Rice	0.8	45	32500	39500
2	Cotton	0.8	42	38650	45600
3	Maize	0.8	30	22000	37000
	Total	2.4	117	93150	122100

Table-10 Details of Optimal plan I in Palani hill

SN	Crops	Area (ha)	Labour (mandays)	Capital (Rs)	Net income (Rs)
1	Rice	-	-	-	-
2	Cotton	1.63	68	63024	74357
3	Maize	1.37	41	30126	50667
	Total	3.0	109	93150	125024

Table-11 Details of Optimal plan II inPalani hill

SN	Crops	Area (ha)	Labour (mandays)	Capital (Rs)	Net income (Rs)
1	Rice	-	-	-	-
2	Cotton	1.63	68	63024	74357
3	Maize	1.25	41	30126	49568
4	Dairy	-	-	-	46500
	Total	2.8	109	93150	170425

Optimum farm plan for Sirumalai hill

A detail of the existing plan in the representative farm of Sirumalai hill for 3.2 ha is given in [Table-12]. The existing plan included crops bush bean, banana and Chow Chow with the land, labor and capital constraints. The net income realized from the existing plan was Rs. 281000.The optimal plan I maximizes the net income with the given constraints in the model and the results are given in [Table-13]. Optimal plan I indicated that by optimization of available resources and higher net income of Rs. 300255 with the area of 3.2 ha and it was 6.85 percent higher as compared to the existing plan. The labor requirement and capital amount was also decreased by 12.21 and 7.81 percent as compared to the existing plan.The optimal plan II presented in [Table-14] included acid lime with other crop activities. This optimal plan revealed still higher net income of Rs. 349535 and it was 16.41 percent higher as compared to the optimal plan I. Hence optimum plan II would give higher net income than the existing plan and optimum plan I.

Table-12 Details of existing plan in Sirumalai hill

SN	Crops	Area (ha)	Labour (mandays)	Capital (Rs)	Net income (Rs)
1	Bush bean	1.6	68	40800	82500
2	Banana	0.8	52	62730	94500
3	Chow Chow	0.8	73	85360	104000
	Total	3.2	193	203890	281000

Table-13 Details of Optimal plan I in Sirumalai hill

SN	Crops	Area (ha)	Labour (mandays)	Capital (Rs)	Net income (Rs)
1.	Bush bean	1.17	50	29784	60225
2.	Banana	2.03	132	159334	240030
3.	Chow Chow	-	-	-	-
	Total	3.2	172	189118	300255

Table-14 Details of Optimal plan II in Sirumalai hill

SN	Crops	Area (ha)	Labour (mandays)	Capital (Rs)	Net income (Rs)
1	Bush bean	0.63	40	42031	45630
2	Banana	1.06	48	48526	90205
3	Chow Chow	0.74	34	54812	93250
4	Acid lime	1.02	65	39876	120450
	Total	3.45	187	185245	349535

Conclusion

Sustainability could be measured through farm level indicators and with Sustainable Rural livelihood (SRL) framework in both hills. Sustainability was assessed by combining the three sustainability criteria of ecological soundness, economic viability and social acceptability in both the hills. The results showed that the Sirumalai hill is more sustainable than the Palani hill. Assessment of sustainable rural livelihood framework under five capital assets indicated that Palani hill is more sustainable with regard to Physical and human assets and Sirumalai hill is more sustainable with regard to financial and social assets. The livelihood security analysis showed that both hills were not secured with regard to education and social network. Palani hill had higher comparative livelihood security with regard to food and health and Sirumalai hill favoured well with regard to economic and habitat security. The optimum farm plan with inclusion of dairy enterprise was suggested for Palani hills and optimum farm plan with inclusion of acid lime was suggested for Sirumalai hills.

Policy Implications

The sustainability analyses revealed that there is a need to increase economic and social viability in Palani hill. Hence government should improvise the economic and social viability in Palani hills by undertaking hill development programmes and Joint Forest Management Programmes Livelihood security analyses revealed that both the hills were not secured with education and social network. So Government should strengthen adult literacy and welfare programmes for Palani and Sirumalai hills. The optimum farm plans developed for Palani and Sirumalai hills should be popularized among the hill farmers by Agriculture Department.

Application of research: Study of agricultural sustainability, Livelihood security and development of optimum plans for Palani and Sirumalai hills.

Research Category: Agricultural sustainability

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