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AN APPLICATION TO SUSTAINABILITY USING EFFECTIVE FACTOR ANALYSIS

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Abstract: Sustainability is a modern concept term used in various situations. In this study an attempt is made to evaluate on the sustainable nature of agriculture. Even though several theoretical concepts and indices have been developed and suggested worldwide, a very few field studies have been undertaken to measure sustainability of different systems. In this study, a pioneering attempt has been made to develop sustainability index and to measure the sustainability level of any wet land farm. This index is expected to serve as an effective tool to measure the level of any farm after appropriating the relevant crops and animal activities in the area. The two main effective factors involved in this concept are the economic factor involving money and the ecological factor concerned with environment. Moreover, the study ascertained that sustainability levels between diversified and non-diversified farm system in terms of the above factors and it will be analysed in Thambiraparani region of Tirunelveli and Thoothukudi districts. A multi stage sampling technique was followed.

Keywords and Phrases: Sustainability, effective factors, factor analysis, diversifies farm system, non-diversified farm system.

2020 Mathematics Subject Classification: 15B15.

1. Introduction

In recent decades, the concept of sustainability has become increasingly prominent in agricultural policy debates. The agricultural sector in India contributes one third of the national income. Diversified farming systems (DFS) are a set of methods and tools developed to produce food sustainably by leveraging ecological diversity at plot, field, and landscape scales. Around the world, DFS depend on diverse cultures, practices, and governance structures to support these locally-adapted management systems. DFS allow critical ecosystem services-like pollination and pest control-to be generated and regenerated within the agro ecosystem, aided by the human knowledge to sustain those processes. In agriculture the sustainability is conceived as "an agro ecosystem which maintains or enhances biological production and productivity and results in attainment and continued satisfaction of changing human needs by conserving and efficiency using renewable, non-renewable and human resources". This concept being an abstract and is difficult for execution. A method has developed with a simple arithmetic mean index and expressed it as a percentage and stated that higher percentage implies higher sustainability.

For sustainable agriculture, no work on models indicate the actual level of sustainability and the limits within which it should lie was undertaken by any one of mathematical knowledge and hence this study will bridge the gap. In this research work, an attempt is made to quantify the factors involved in this with the help of developed factor analysis. Two main factors involved in this concept are (i). The economic factor involving money and (ii). The ecological factor concerned with environment. Moreover, the study ascertained that sustainability levels between diversified and non- diversified farm system in terms of the above factors and it will be analyzed in Thambiraparani region of Tirunelveli and Thoothukudi districts.

2. Literature Review

For sustainable agriculture, various indicators have been suggested by different authors, whose views were reviewed and presented in this section. Francis(1990) opined that sustainable agriculture is represented by organic farming to maximize economic yields. Harrington (1992) concluded that sustainability and sustainable agricultural development could be interpreted in terms of agro-ecology, equity and sustainable growth. Pookpakdi(1993) opined that a sustainable production system should be directed towards three essential goals, namely food security, employment and income generation and natural resources conservation and environment protection.

Senthilnathan(1997) developed an index to measure "Sustainable Production" which was referred to as the increase in production of groundnut per unit area in the year of study over that of preceding year production by means of the correct adoption of cultivation practices recommended. Ravikumar Theodore (1999) has developed a simple arithmetic mean index and expressed it as a percentage and stated that higher percentage implies higher sustainability. Claire Kerman, et al (2012)global trends in agriculture to investigate to what extent industrialized forms of agriculture are replacing former DFS, assess the current and potential contributions of DFS to food security, food sovereignty and the global food supply, and determine where and under what circumstances DFS are expanding rather than contracting.

Farm experience was revealed to have significant and positive influence on the adoption of sustainable agriculture practices (SAP) by studies conducted by Adeola (2010) but it was not found significant influence on the adoption in the studies of Rezvanfar et al. (2009). Nguyen Van Than, et al (2015) suggests that sustainable agricultural perception, economic status, extension courses, education and feasibility of practices were effective factors on banana farmers.

3. Area and Data of Study

The present study was confined to Thambiraparani region of Tirunelveli and Thoothukudi districts. Also, the Thambiraparani region is very lengthy starting from “Pabanasam” and ending with “Thiruchendur”, we divide the same in to three “irrigation areas” like ‘Head’, ‘Mid’ and ‘Tail’. Head means starting point; Mid means middle point and Tail means end of the Thambiraparani region. From each Head, Mid and Tail, blocks were selected first and from each selected blocks villages were selected randomly.

Selection of respondent is characterized by four types of farming systems of Thambiraparani area. They are ’Paddy; Paddy and Banana; Paddy and Dairy; Paddy and Dairy and Banana’. In all these systems Black gram, Gingili and Draught Cereals are optimally present. In each of the above system 30 farmers were selected and among this 15 for diversified farms and 15 for non-diversified farms. On the whole 120 farmers were selected. A farmer who changes crops is classified as diversified farmer.

4. Methodology

The two main factors used in the study are

a). The Economic factor involving money and

b). The Ecological factor concerned with environment.

4.1. Economic Factor

The following nine indicators were selected to measure the economic factor.

4.1.1. Production efficiency(PE)

It referred to the yield per acre or output per animal in the firm.The production efficiency (PE) of the firm was computed by the formula

$$PE = \frac{\sum_{i=1}^{i=n} Pe_i w_i}{\sum w_i},$$

where Pe_i is the production efficiency of the ith activity in the farm, and w_i is the factor corresponding to Pe_i.

4.1.2. Cultivated land utilization index(CLUI)

It indicated the efficiency in utilization of the respondent's farm land by growing various crops within a period of one year. The cultivated land utilization index (CLUI) was computed by the formula

$$CLUI = \frac{\sum_{i=1}^{i=n} a_i d_i}{A \times 365} \times 100,$$

where n is the total number of crop activities; a_i is the area occupied by the ith crop activity; d_i is the ith crop activity occupied by a_i and A is the total cultivated land area available in the farm during the 365 day period.

4.1.3. Net returns (NT)

The net return was expressed as net return to variable cost ratio otherwise called as rate of return (RR) which was computed by using the following formula

$$NT = \frac{\sum_{i=1}^{i=n} \frac{n_i r}{vc_i} w_i}{\sum w_i},$$

where n_ir is the net return of the ith activity in the farm; vc_i is the variable cost of the ith activity in the farm and w_i is the factor score for the ith ratio.

4.1.4. Technology use level (TUL)

The technology use level of each practice was assessed on a three point continuum of'full,'partial,and 'nil' adoption, with scores of two, one and zero respectively. TUL was computed by the following formula.

$$TUL = \frac{\sum_{i=1}^{i=n} \frac{\sum_{i=1}^{i=n} P_i \times 100}{max_i} w_i}{\sum w_i},$$

where $P_i$is the score ith practice; max_i is the maximum score for the ith activity in the farm and w_i is the factor score for the ith activity.

4.1.5. Low cost technology use level(LTL)

It was computed by the formula

$$LTL = \frac{\sum_{i=1}^{i=n} ltl_i \times w_i}{\sum w_i},$$

where ltl$_i$ is the low-cost technology use level for the ith activity in the farm.

4.1.6. Employment generation capacity (EGC)

It was computed by the formula

$$EGC = \frac{\sum_{i=1}^{i=n} egc_i \times w_i}{\sum w_i},$$

where egc$_i$ is the employment generation of the ith activity in the farm.

4.1.7. Farm family employment level (FFEL)

It was computed by the formula

$$FFEL = \frac{\sum_{i=1}^{i=n} n_i}{m \times 365} \times 100,$$

where n_i is the number of man days employed by the ith family member in the farm and m is the number of family members employed in the farm.

4.1.8. Self-reliance level (SRL)

This refers to the extent to which a respondent was self-reliant in terms of capital, labour, inputs and information on agriculture. This was assessed on a three point continuum of ‘completely self-reliant’, ‘partially self-reliant’ and ‘completely dependent’, with scores two, one and zero respectively. The self-reliant level was computed as

$$SRL = \frac{\sum_{i=1}^{i=n} sr_i}{Max} \times 100,$$

where sr_i is the self-reliant level for the ith item and Max is the maximum score which is 18 in this case.

4.1.9. Self-sufficiency level (SSL)

This refers to the extent to which a respondent was self-sufficient in terms of food, fodder and fuel. This was assessed on a three point continuum of ‘completely self – sufficient’, ‘partially self–sufficient’ and ‘completely dependent’, with scores of two, one and zero respectively. This was computed as

$$SSL = \frac{\sum_{i=1}^{i=n} ss_i}{max} \times 100,$$

where ss_i is the self-sufficiency level for the ith item and max is the maximum score which is 6 in this case.

Data pertaining to these nine items were collected for 120 farms. The data was subjected to factor analysis and the factor scores were obtained for each one of the variables. With these as weights the weighted arithmetic mean index was computed and conceived as the "Economic Sustainable Index".

4.2. Ecological Efficiency

To measure this, four indicators were selected. The measurement procedure developed for each indicator is outlined as follows

4.2.1. Eco-friendly technology level(EFTL)

It referred to the extent of adoption of eco-friendly technologies recommended for Cropland animal enterprises.It was assessed on a three point continuum of 'full','partial' and 'nil' adoption with respective scores of two, one and zero. It was computed as

$$EFTL = \frac{\sum_{i=1}^{i=n} etl_i \times w_i}{\sum w_i},$$

where etl_i is the eco-friendly technology use level for the ith activity in the farm.

Also,

$$etl_i = \frac{\sum_{i=1}^{i=n} s_i}{max_i} \times 100,$$

where s_i is the ith practice and max_i is the maximum score for the ith activity in the firm.

4.2.2. Organic recycling level(OR)

Recycling refers to a process by which the life of a resource is extended by means of recycling it or reusing it as an output or output. For this study this is taken as the extent to which the farm by products /waste was recycled. That is the extent to which the by-product of one activity was used as input for another activity. It is computed by using the following formula.

$$ORL = \frac{\sum_{i=1}^{i=n} or_i \times w_i}{\sum w_i},$$

$$\text{where } Or_i = \frac{\text{actual quantity of the ith item utilsed in the farm}}{\text{total quantity of the ith item produced in the farm}}$$

and w_i = factor score for the ith item

4.2.3. Low external input use level(LEUL)

This is taken as the extent to which certain external inputs were used in less quantity by the respondents in their farms. External inputs referred to the artificial inputs that are not produced within the farm. Since, application of external inputs beyond the recommended level is determined to the ecology of the farm its negative effect was considered as LEUL. It was computed as

$$LEUL = \frac{\sum_{i=1}^{i=n} or_i \times w_i}{\sum w_i},$$

$$\text{where } Or_i = \frac{\text{quantity of the ith external input recommended}}{\text{actual quantity of the ith external input used}}$$

and w_i = factor score for the ith external input.

4.2.4. Soil health(SH)

Soil health is determined by organic matter,nutrients, electrical conductivity and PH.Organic matter constitutes carbon, hydrogen and oxygen. These parameters were estimated with the help of experts in that field.Nutrients referred to available N P K in the soil. These were estimated through the experts in that field. Electrical conductivity is the level of salt concentration in the soil solution. PH is the negative of logarithm of the reciprocal of hydrogen ion concentration.

Factor score was used to combine these four items and the combined value was denoted by s_i for the ith item and

$$SH = \frac{\sum_{i=1}^{i=n} s_i}{max} \times 100,$$

where max represents the soil health score can attain in that area and s_i is the score obtained for the ith characteristic or sub characteristic.

These ecological factors were combined again by the factor scores as before and the weighted average is the "Ecological Sustainability Index".

The simple arithmetic mean of two is conceptualized as the "Sustainable Index" of the farm.

4.3. Result and Discussion

4.3.1. Measurement of Economic Factors and Economic Efficiency

The details for the diversified farmers (DF) and non-diversified farmers(NDF) for the nine Economic factors and the economic efficiency are given in Table-1, Table-2 and Table-3.

Table-1; Economic Factors: PE, CLUI, TUL

	PF		CLUI		TUL	
	DF	NDF	DF	NDF	DF	NDF
Mean	60.6420	36.4579	73.7807	71.1428	18.0881	10.4207
Standard Deviation	19.3215	16.4579	15.5093	15.5891	4.3117	3.6604
Skewness	0.059	0.264	-0.015	-0.901	0.022	0.261
Kurtosis	-0.707	-0.857	0.579	0.301	-0.669	-0.998
Maximum	103.69	77.11	97.76	73.28	26.99	18.76
Minimum	23.54	12.04	30.14	30.14	7.20	4.48

Table-2; Economic Factors: LTL , EGL

	LTL		EGC	
	DF	NDF	DF	NDF
Mean	52.1872	38.6638	43.3775	39.7264
Standard Deviation	8.9867	8.5299	15.3932	15.5308
Skewness	0.4	0.234	-0.009	1.053
Kurtosis	0.098	-0.284	-0.598	1.963
Maximum	74.79	60.34	83.45	90.67
Minimum	32.50	20.81	16.14	17.08

Table-3; Economic Factors: FFEL, NR, SRL, SSL

	FFEL		NR		SRL		SSL	
	DF	NDF	DF	NDF	DF	NDF	DF	NDF
Mean	42.4923	34.7702	1.6621	1.3545	41.5085	35.1203	47.3612	24.4442
SD	20.0248	20.3672	0.7103	0.5758	11.6094	14.1898	16.2015	15.0222
Skewness	1.243	1.023	0.074	0.087	0.674	1.104	0.250	0.103
Kurtosis	1.541	1.573	-0.684	-1.097	-0.540	0.154	0.874	0.431
Maximum	100.00	100.67	3.42	2.56	66.67	62.22	100.00	66.67
Minimum	12.50	8.33	0.49	0.39	22.22	22.22	16.67	0.00

Table-4; Economic Efficiency

	Diversified Farmers	Non Diversified Farmers
Mean	48.2577	35.6941
Standard Deviation	7.0778	7.0869
Skewness	0.130	0.005
Kurtosis	0.067	-0.049
Maximum	66.62	48.73
Minimum	32.28	23.66

From the above results obtained from Table 1,Table 2 it is clearly seen that the production efficiency is one of the factor in which there exists a vast difference between the diversified and non-diversified farmers. Considering both TUL and LTL, the mean value is almost double for diversified farmers. Apparently EGC is significantly higher for the diversified farms which are observed from the low values of skewness and kurtosis and their distribution almost appears to be normal. In the case of non-diversified the kurtosis value is nearly 2 which indicate that there is some sort of concentration at a higher level.

On analyzing the Table 3, there is a significance increase in the FFEL for the diversified farms which is seen from the high kurtosis value and a positive skewness which clearly indicates that there is a concentration of FFEL at a higher side for the diversified group. The NR is higher for both the diversified farmers and is having negative value for kurtosis and therefore there is no concentration near any group. The SRL has a higher mean value with less standard deviation for diversified farmers.

The economic efficiency of both diversified and non-diversified farmers appears to be very close which is seen from Table 4. Moreover the distribution seems to be normal in both the cases and the mean for the diversified farmers is significantly higher than that of the non diversified farmers. The main contribution to the higher level might be due to the dairy activity.

From the survey it was observed that most of the diversified farmers maintained graded dairy animals with high milk yield which might have contributed more for the production efficiency. The consistent income obtained through milk might have contributed for a high net return throughout the year. More employments were generated in diversified farmers group to look after the cattle, distribution of milk and its products to the community. In addition, the high cultivated land utilization index, technology usage, low cost technology use and self-reliance level of the diversified farmers might have added favorably for the increased value of economic efficiency. By substituting maximum value for each of the activities in the index, the maximum reachable value for a farmer in the Thamiraparani region for his economic efficiency value is 75.9.

Based upon the Production efficiency, cultivated land utilization Index, Technology usage, Low technology usage, Employment generation, Net return, Farm family employment, Self-reliance and Self sufficiency level the PE, TUL and LTL of the diversified farmers have a big lead over the non- diversified farmers.

4.3.2. Measurements of Ecological factors and Ecological Efficiency

The details for the diversified farmers (DF) and non-diversified farmers (NDF) for the four Ecological factors and the ecological efficiency are given in Table-4 and Table-5.

Table-5; Ecological Factors: EFTL, OR, LEUL, SH

	EFTL		OR		LEUL		SH	
	DF	NDF	DF	NDF	DF	NDF	DF	NDF
Mean	53.6875	44.5837	91.5890	60.5160	67.4647	66.9488	59.2612	59.7328
SD	8.2717	10.0383	13.452	24.2612	16.6854	15.1795	4.9757	5.2776
Skew	0.128	0.107	13.452	24.2612	-0.134	-0.084	-0.011	-0.207
Kurt.	0.196	-0.570	0.372	0.516	0.015	0.423	-0.792	-0.884
Max.	73.49	65.97	100.00	78.531	100.00	100.00	66.67	66.67
Min.	32.56	22.92	46.85	42.853	26.35	34.74	50.00	50.00

Table-6; Ecological Factors

	Diversified Farmers	Non Diversified Farmers
Mean	66.3109	60.6177
Standard Deviation	5.8821	6.4935
Skewness	0.306	-0.048
Kurtosis	0.236	-0.219
Maximum	76.18	71.57
Minimum	43.87	41.47

From Table-5,values of EFTL indicate a significant increase in the mean value for the diversified farmers and the distribution is almost normal for both the groups; the OR values from the Table reveals that the diversified farmers are much superior to the non-diversified farmers. The standard deviation is low for the diversified farmers and the positive skewness for diversified group ensures the fact that there is more number of farmers with high level of OR in the diversified farmers; LEUL have almost the same mean and the distribution pattern is normal in both the cases; SH values indicates identical behavior for the two groups.

The values of Table–6 shows that the significant increase in the diversified farmers might be due to the Eco-friendly technology use and the Organic recycling level. Even here the dairy enterprise might have played a substantial role in increasing the overall ecological efficiency. The maximum attainable value for a farmer in the study area for his historical efficiency by substituting the maximum already attained for each variable constituting the index is 77.64.

Usage of Eco friendly technology, Organic recycling and Low external input level for both crop and animal activities generates significantly higher value with lesser standard deviation for the diversified farmers might be due to high level of knowledge and the higher level of training. Soil health is an assessment of the organic carbon content, NPIC status, electrical conductivity and PH of the soils of the selected villages against prescribed standards and this equality taken care by both the groups.

4.4. Sustainability Level of Diversified and Non–Diversified Farmers

The sustainability index is the simple arithmetic mean of the economic and ecological indices which are given in Table-7.

Table-7; Sustainability Index

	Diversified Farmers	Non Diversified Farmers
Mean	57.2843	48.1559
Standard Deviation	5.1145	5.1702
Skewness	-0.159	-0.353
Kurtosis	0.479	-0.420
Maximum	65.14	57.80
Minimum	40.99	36.51

5. Conclusion

The present study point out that nearly two thirds of the diversified farms are having high economic efficiency whereas two thirds of the non-diversified farms had a very low level of economic efficiency. In sustainability level nearly eight percent of the diversified farms are having higher level of sustainability whereas nearly two third of the non- diversified farms had low level of sustainability and in both the categories the consistency was high. The ecological efficiency of diversified farms is much higher than the non-diversified farms. More consistency was observed in the case of diversified farms than that of the non-diversified farms.

The maximum reachable level of the sustainability index in the present condition for the study area is 76.77.

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