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Estimation of farm energy balances of small farm management: a socio-ecological and techno-managerial analysis

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ABSTRACT

Energy is the driving force in the ecology which changes its forms while transferring from one trophic level to another and from one component of ecosystem to another component i.e. in between animate and inmate forms of life. While transferring from one component of ecosystem there is loss of some energy which is termed as entropy in thermodynamics. Keeping this energy and the energy losses in view the present study "Estimation of Farm Energy Balances of Small Farm Management: A Socio-ecological and Techno-managerial Analysis" has been selected to study the energy balances i.e., consumption and production in crop enterprises as well as in households and its overall impact on social, economic, ecological spheres of ecosystem. Crop Energy Balance (y) is defined as the difference between the energy equivalents of feed taken by the cattle and the energy equivalents of the output from cattle in the form of dung and milk per day per cattle. The variable Crop Energy Balance (y) is the dependent variable being predicted by a set of 14 independent variables. Study was conducted at Saharpara village of Haringhata,in district Nadia of West Bengal. The respondents have been 50 by count and have been selected through both the purposive and random sampling approaches to ultimately derive and elicit their behavioural traits in the energy balances of social, economic, physical and ecological setup. The results show that following new factors, Farm Economy Index, Personal Capacity, Family Resources, Family Motivation have led to consciousness about the energy balances in social ecology and impact of these energy balances on the ecosystem as whole. The Multiple correlation results show Age (X_1) has positive significant correlation with Crop Energy Balance (y) whereas the variables Education (X_2), Homstead Land Size (X_9) and Age (X_1) have had significant impact on the predictant y. All these analytical outcomes can be replicated to other enterprises as well to calculate energy balances. A comparative study can be adopted to conclude whether agriculture or fishery or cattle or poultry enterprises can be comparable with each other or all these enterprises can well be complemented to develop a complex model for energy management, so as to attain a balanced energy consumption pattern.

Key words: Crop energy balance, entropy, farm economy and social ecology.

The energy consumption pattern in India especially, in the operating agro-ecosystem followed by small and marginal farm holdings can be elucidated well against total volume of energy consumed in a positive or a negative balance either. Energy balance is defined as the measurement of proportion as well as analysis of the energy input consumed and output produced out of the different activities to find out the direction of energy consumption pattern of a system. The importance of finding out energy balance in a small farm system lie in the fact that developing country like India where agricultural small holdings form the backbone of its economy, has an energy import dependency (net energy imports as a percentage of total energy consumption) of around 20 per cent (Anon., 2010). It spends over 45 per cent of export earnings for importing energy. Moreover, 45 per cent of India's total primary energy consumption takes place at household level and cost of energy also imposes a heavy financial burden on majority of low income households (Anon., 2010). Optimizing the energy consumption pattern in a small farm system can be of great help to reduce the increasing pressure of energy consumption in agriculture.

If the energy consumption by agriculture continued to grow at the annual rate outlined by the IPCC for 1995 (IPCC 2001), total energy inputs into agriculture would have exceeded 10 EJ in 2005, equivalent to a share of about 2 per cent of global primary energy consumption (Woods *et al.*,2010).

With this issue in mind, the present study has tried to find out the energy consumption pattern in a small farm system by taking into account the direct input and indirect output energy in terms of energy equivalent expressed in joules. The study has been conducted in small and fragmented areas less than 2 hectares to justify its system to be a small holding one. The positivity or negativity in balance of a farm system would indicate its viability in long run and suggest what appropriate measures must be taken to draw a system more towards equilibrium to achieve sustainability. The work also presents the quantitative interaction of various agro-economic and socio-personal factors with energy consumption pattern of the farm system under investigation. The study was undertaken with the following objectives.

1. To generate a conceptual frame work on farm energy balance in a given social ecology *i.e.* the research locale. The input and output energy into a system has been taken into consideration.
2. To identify and customize independent variables those interact with the dependent variable i.e Crop Energy Balance to study their interactive relationships.

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3. To estimate the effect and causal contribution of a set of agro economic and socio-personal variables on the energy consumption pattern of rural respondents.

MATERIALS AND METHODS

Locale of research

Fatehpur Gram Panchayat of the Haringhata block of Nadia district in West Bengal was purposively selected for the study. The village namely Sahapara was selected by random sampling. The research locale has been unique display of small and fragmented holding representative to the West Bengal average operating farming system. It has been perceived in the study that those small and fragmented capsule of farming are subjected to unplanned modernization prodigality of energy expenditures and fragile energy balances. More than 90 per cent of the areas are having a size below 2 hectares being characterized with faster marginalization of net income of unit farm and unit time. This may be due to high rise of cost of input, low efficiency of per unit application, and off course, the unleashing of energy of the farm to some undestined direction.

Sampling design

Purposive as well as simple random sampling techniques were adopted for the study. For selection of state, district, block and gram panchayat purposive sampling techniques was adopted because the area was ideal for climate change study, convenient for researcher and having the infrastructural facilities and in case of selection of villages and respondents simple random sampling technique was taken up.

Variables

The predictors used in this study are Age (X_1), Education (X_2), Family Education Status (X_3), Family Size (X_4), Gender (X_5), Occupation (X_6), Cropping Intensity (X_7), Farm Size (X_8), Homstead Land Size (X_9), Expenditure (X_{10}), Annual Income (X_{11}), Irrigation Index (X_{12}), Economic Motivation (X_{13}), Market Orientation (X_{14})to predict the variable Crop Energy Balance (y). The predictant Crop Energy Balance (y) is calculated by estimating the amount of energy consumed in a small farm in the form of energy equivalent of fertilizer, irrigation, ploughing and plant protection control applied and this is considered as input in a system (small farm). Here, the output is the energy equivalent of biological yield of the small farm.

Therefore,

Crop Energy Balance = Input (Eeq. F + Eeq. I + Eeq. Pl. + Eeq. PPC) – Output (Eeq. BY)

Where,

Eeq. = Energy Equivalent, F = Fertilizer, I= Irrigation, Pl = Ploughing, PPC = Plant Protection Control, BY = Biological yield.

Techniques of data collection

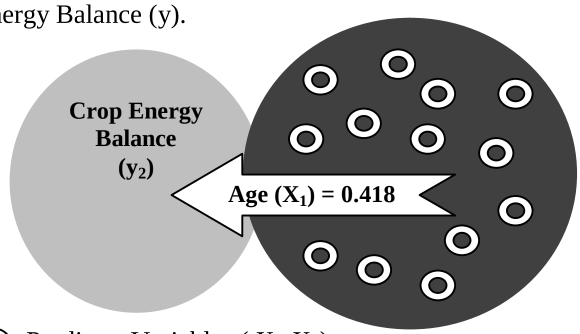
The respondents were personally interviewed using structured interview schedule.

Statistical tools used for analysis of data

The statistical methods used for analysis and interpretation of raw data were – Mean ,Standard deviation , Coefficient of Variance, Correlation of coefficient ,Multiple regression analysis ,Path analysis, Factor analysis.

RESULTS AND DISCUSSION

It has been found that the variable age (X_1) has recorded a positive significant correlation with Crop Energy Balance (y).



Predictor Variables (X_1-X_n)

Significant Predictor

Predicted Variable

Fig.-1: Multiple correlations between the variable y and 14 independent variables.

Chronological age provides the experience factor which is very much needed for the better management of resources and eventually helps to maintain the balance in the crop *i.e*, helps to increase the output per unit of the input used, otherwise if output would not be more, no person will make agriculture his lifelong occupation

Table- 1: Coefficient of correlation ('r') between Crop Energy Balance (y) and 14 variables (X_1-X_{14})

Sl.No	Variables	'r' value
1	Age (X_1)	0.4178**
2	Education (X_2)	-0.5759
3	Family education status (X_3)	-0.0661
4	Family size (X_4)	-0.062
5	Gender (X_5)	0.0376
6	Occupation (X_6)	0.0634
7	Cropping intensity (X_7)	-0.2162
8	Farm size (X_8)	0.238
9	Homstead Land Size (X_9)	-0.3656
10	Expenditure allotment (X_{10})	0.0146
11	Annual income (X_{11})	0.0559
12	Irrigation index (X_{12})	-0.0043
13	Economic motivation (X_{13})	-0.0104
14	Market orientation (X_{14})	0.0736

*r>0.267 *(5% level of significance) r>0.360**(1% level of significance)*

The factor analysis shows that the 14 variables contributing to and characterizing with the energy consumption pattern can be conglomerated into four factors (1-4).

The Factor 1 has included following 5 number of variables *i.e.* age (X_1) farm size (X_6),expenditure allotment (X_{10}), annual income (X_9),and irrigation index(X_{12}) which have contributed 24.774% of variance and has been renamed as Farm Economy Index.

The Factor 2 has included 2 numbers of variables *i.e.* education(X_2) and occupation(X_6) that have contributed 15.814% of variance has been renamed as Personal capacity.

The Factor 3 has included 3 numbers of variables *i.e.* family size (X_4), cropping intensity (X_7) and homestead land size(X_9) which have contributed 9.361% of variance and has been renamed as Family resources.

Table-2: Factor analysis of 14 Predictors

Factors	Variables	Explained Variance %	Explained Variance Cumulative %	Factor rename
1.	Age (X_1) Farm size (X_6) Expenditure allotment (X_{10}) Annual Income (X_{11}) Irrigation Index(X_{12})	24.774	24.774	Farm Economy Index
2.	Education (X_2) Occupation (X_6)	15.814	40.558	Personal Capacity
3.	Family size (X_4) Cropping Intensity(X_7) Homestead Land Size(X_9)	9.361	63.680	Family Resources
4.	Family Education Status (X_3) Gender (X_5) Economic Motivation(x_{13})	13.731	54.319	Family Motivation

Factor 4 has 3 numbers of variables *i.e.* family education status (X_3), gender(X_5) and economic motivation(X_{13}) which have contributed 13.731% of variance and has been renamed as family motivation.

1. Family economy indicates and influences that energy consumption specifically for the communities passing through upcoming modernization process. It is also discernable that the agricultural modernization, invariably and integratedly needs a higher level of energy consumption to support the elements of modernization for transforming farm ecology.
2. Factor 2 indicates that consumption of energy invariably needs capacity building at the personnel level; the capacity involves infrastructural, operational and occupational capacities, in a manner while integrated and orchestered.
3. For any kind of energy consumption family resources extend the support system and at the same time can play a catalytic role in answering the farm modernization process through higher and calculated energy consumption level.

The Multiple Regression Analysis reveals that the following three variables *viz*; education (X_2), homestead land size(X_9) and age(X_1) have exerted substantive impact on the consequent variable Crop Energy Balance(y).

The variable Education has recorded the highest percentile contribution to the total R^2 value. It indicates that the higher education level of farmers leads to higher understanding of the energy use in different farming operation i.e, they are able to increase the efficiency and management of different farm inputs like fertilizer, water, electricity etc. This variable has been followed by the homestead land size (X_9) and age (X_1) i.e, if the homestead size would be in a manageable sphere more efficient management of energy would be maintained and comparatively output would be more, also Age(x_1) chronological age provides the experience of handling different farm operations in a better way which leads to a very good equity status in maintaining Crop Energy Balance. The R^2 value being 0.2001, it is to conclude that 20.01 percent of variance have been explained with the contribution of the 14 causal variables(X_1-X_{14}).

The step down regression analysis forward) has retained one prominent causal variables viz. education (X_2) at the last step. So, this variable has got substantive strategic and operational impact on Crop Energy Balance.

The step down regression presents that at last step of step down analysis variable, education (X_2) has contributed the most to Crop Energy Balance. The knowledge of farmers about new techniques of crop growing, weather, government policies are positively related to the better crop output sources which again is impacted by education. Only education(X_2) has been retained at the last stage of Step-down Regression Analysis which has got solitary contribution of 33.17 percent to the total R^2 value i.e, to say that education deserve to earn a special attention while we intend to make a serious intervention in the domain of Crop Energy Balance.

Table-4 presents the path analysis where in the total effect of exogenous variables on consequent variable has been decomposed into Direct, Indirect and Residual effects. It has been evinced that variable education(X_2) has exerted highest direct effect (-0.5082) and farm size(X_8) as highest total indirect effect (0.399). Education(X_2) has recorded the substantive direct effect on Crop Energy Balance (y) although with a negative value to suggest that Crop Energy Balance (y) has been better for the farmers having lesser 'Education value'.

The other variable farm size(X_8) has exerted the highest total indirect effect to elicit that in Crop Energy Balance (y), the role of farm size(X_8) is extremely associative and can characterize the entire energy balance to discernible extent.

The variable education (X_2) has rented the highest indirect effect as many as six exogenous variables to evince that education of a farmer has been key cognitive and functional capacity to characterize Crop Energy Balance.

The present study thus reveals that the small farm under investigation has a negative energy balance where the output in terms of energy equivalents of biological yield is greater than the inputs in terms of energy equivalents of fertilizer, irrigation, ploughing and plant protection control applied in the studied farm ecosystem. It was also found that chronological age had recorded highest positive significance with crop energy balance indicating that with age, the experience factor increases and better management of resources can be expected from an experienced farm manager. So, for a better balance in output per unit input from a farm it is beneficial to have experienced personnel in a farm to take up vital farm decisions. From factor analysis, following principal component analysis, new factors have emerged like Farm Economy Index, Personal Capacity, Family Resources, Family Motivation. Out of these factors Farm Economy Index has clubbed highest number of variables which clearly show that as agriculture is heading towards modernization the energy consumption is also increasing. This increased energy consumption has to be optimized to avoid energy deficiency at a national scale. Education on the other hand, has exerted around 33.17% impact and has laid direct effect on Farm ecosystem. It signifies that with more formal education, the consumptive use of energy has increased.

Thus, this kind of study can prove to be useful for complex agricultural enterprises where energy management is essential so as to have a balanced energy consumption in an ecosystem to ensure sustainable crop production.

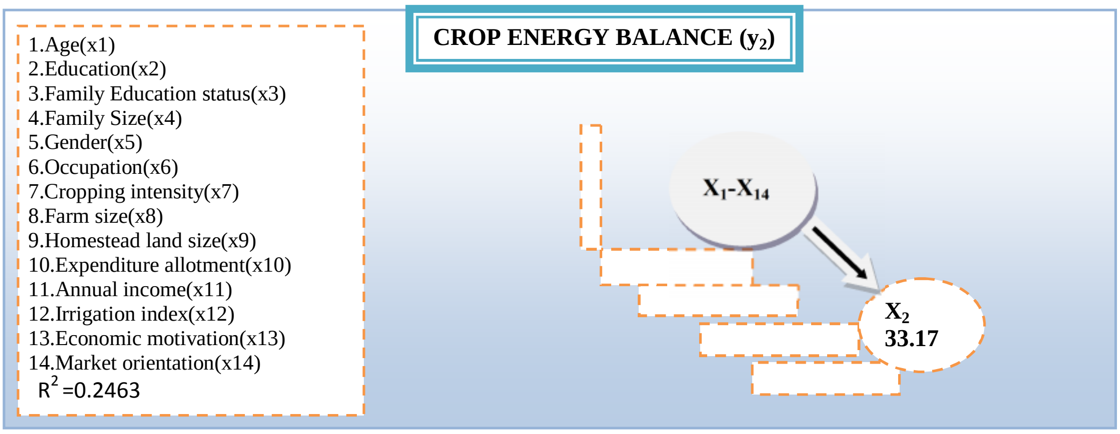


Figure-2: Multiple Regression between y and 14 independent variables

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Table- 3: Regression analysis of crop energy balance (y) vs 14 causal variables (X_1-X_{14})

Sl. No.	Variables	B	β×R	S, Error B	't'	Rank
1	**Age (X_1)**	0.213	**18.078**	6163.511	1.087	**III**
2	**Education (X_2)**	-0.508	**59.502**	6302.832	2.724	**I**
3	Family education	-0.088	1.184	11333.114	0.596	VII
4	Family size(X_4)	-0.290	0.366	35121.789	0.892	XI
5	Gender (X_5)	-0.154	-1.174	23643.306	0.967	VIII
6	Occupation(X_6)	0.144	1.851	31546.997	1.039	VI
7	Crop intensity(X_7)	-0.133	5.585	461.716	0.720	V
8	Farm size(X_8)	-0.161	-7.787	102091.742	0.441	IV
9	**Homestead Land Size**	-0.293	**21.779**		1.188	**II**
10	Expenditure allotment(X_{10})	-0.189	-0.561	5109.319	1.061	X
11	Annual income(X_{11})	0.091	1.035	2.421	0.415	IX
12	Irrigation index(X_{12})	-0.071	0.062	650157.177	0.195	XIII
13	Economic	-0.007	0.015	34472.475	0.047	XIV
14	Market orientation(X_{14})	-0.014	-0.209	35901.656	0.095	XII

R^2 =0.2001 F value =5.88 at 2 and 47 DF

Table-4: Multiple regression analysis showing Model R^2 Value

Model	Variable	B	R	R^2	Adjusted R^2	Standard Error of the estimate	t
1	Education (X_2)	-0.576	0.5759	0.3317	0.3178	3986.370	4.881

Table -5 Path Analysis: **Direct, indirect and residual effect; crop energy balance (y) Vs 14 exogenous variables(X_1 to X_{14})**

Sl. No.	Variables	Total effect (r)	Direct effect (DE)	Indirect effect (IE)=r-DE	Highest indirect effect
1.	Education (X_2)	-0.5759	-0.5082	-0.0677	-0.1372 (X_1)
2.	Farm Size (X_8)	0.2380	-0.1610	0.399	0.1772 (X_4)

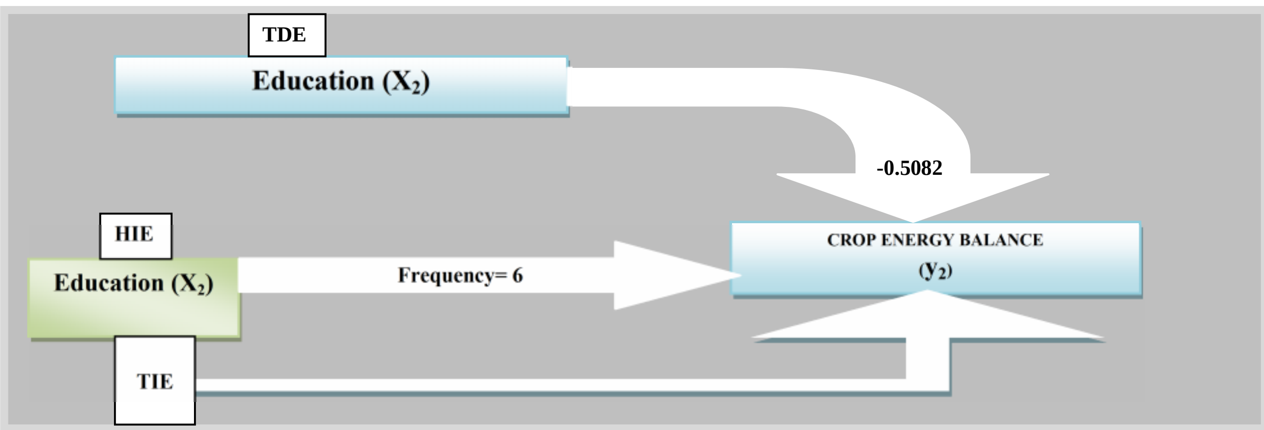

Fig.-3 Path Analysis showing total direct effect (TDE), highest indirect effect (HIE), total indirect effect (TIE) and frequency