

# Dryland Production System Modules for Energy Conservation And Sustainability In Western Agroclimatic Zone (WACZ) Of Tamil Nadu

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## Abstract

To achieve effective use available natural resources, agricultural output must be evaluated using energy budgeting. Consistent increases in agricultural energy use—in the form of fossil fuels, fertilisers, pesticides, herbicides, machinery, and so on—have raised environmental and public health concerns. Thus, in order to evaluate the flow matrix of a farm, this study considers the use of inputs such as seeds, fertiliser, manures, labour, electricity, water, food, feed, and machinery usage within the production systems. Identifying the energy usage help to achieve the farm sustainability earlier. The determents that influence the energy efficiency were founded by using Principal Component Analysis (PCA). The experimental observation was made on 0.8 ha marginal farm field. The energy indices were used to find the energy efficiency in farm field. In the study, total energy input in the marginal production system model was calculated to be 35 GJ, whereas total energy output, net energy gain and energy profitability was recorded to be 77 GJ, 20 GJ and 0.0009 GJ, respectively. This study further analysis the significance level of energy indices and revealed significance. Energy use efficiency (EUE), human energy profitability (HEP), energy profitability (EP), Machinery, soil nutrient (Nitrogen, Phosphorous, potassium) and farm yard manure (FYM) are positioned in right-hand-side coordinates with higher weightage of component (55.9 per cent). A close association between energy parameters and energy productivity is also apparent from PCA graph.

**Keyword:** Dryland production system, Energy matrix, Marginal farm, Principle Component Analysis (PCA).

## INTRODUCTION

Energy budgeting must be used to evaluate agricultural output in order to use the available natural resources effectively. Consistent increases in the energy use in agriculture—in the form of fossil fuels, fertilisers, pesticides, herbicides, machinery, etc.—have led to concerns for the environment and public health. The energy use in agricultural production, processing and distribution is higher to feed the growing population and to achieve other social and economic objectives. Modern agriculture now uses a lot of energy inputs due to the rising demand for food. It has been realised that the sufficient green energy availability and its effective and efficient use are prerequisites for increased agricultural production. Utilizing energy efficiently in agriculture reduces environmental issues and natural resource degradation. Increasing energy use efficiency is the best strategy to lessen the environmental risk associated with energy consumption. Thus, this study considers the use of input such as seeds, fertilizer, manures, labour, electricity, water, food, feed, and machinery usage within the production systems to evaluate the flow matrix of farm. Identifying their energy usage help to achieve the farm sustainability earlier. The determents that influence the energy usage were founded by using Principal Component Analysis (PCA).

Since, crop-livestock production system is one of the most dominant and popular system among the marginal farms in the Western Agroclimatic Zone (WACZ) of Tamil Nadu (TN) and majority of the farmers in this region are marginal farmers, the present study was undertaken to estimate the energy input and output of crops (cereals)-livestock (Cattle, sheep, goat) production system, and to measure its energy use efficiency along with-it determents.

(Rahman et al., 2022) evaluated the energy use efficiency of organic amendments such cow dung, vermicompost, poultry manure, and rice straw and came to the conclusion that energy was wasted during organic treatment and system productivity showed a trend in the opposite direction of EUE. (Yadav et al., 2018) stated that energy budget of the upland rice (*Oryza sativa*) and mustard (*Brassica campestris var. toria*) cropping system was evaluated, and the increasing energy use efficiency (EUE) and energy productivity (EP) of the system was proven by using no tillage practises. (Bos, de Haan, Sukkel, & Schils, 2014) quantified energy usage and stated that energy use per unit milk in organic dairy farming is

approximately 25 per cent lower than that in conventional dairy farming. (P. Singh, Singh, & Sodhi, 2019) studied the energy input-output relationships for wheat cultivation and revealed the higher total energy input consumption in cotton – wheat cropping system than other cropping system in north western India. (Kaab, Sharifi, Mobli, Nabavi-Pelesaraei, & Chau, 2019) assessed the EUE of sugarcane production and concluded that energy use efficiency is mainly attributed to electricity, diesel fuel, human labour, and nitrogen fertilizer in sugarcane production (planted and ratoon). All these studies deal with the assessment of energy production in improved production systems, but only a few studies focused on the energy matrix in existing production systems in the nation and region. As a result, this study is the first to investigate the energy matrix and its drivers in the existing production system.

## MATERIALS AND METHODS

In this study, the Western Agroclimatic Zone (WACZ) of Tamil Nadu (TN), in southern India, was chosen for analysis. TN is divided into seven agro-climatic zones based on rainfall distribution, irrigation pattern, soil characteristics, cropping pattern, and other physical, ecological, and social characteristics: North Eastern Zone, North Western Zone, Western Zone, Cauvery Delta Zone, Southern Zone, High Rainfall Zone, and Hilly Zone. Because of their importance in agricultural production, the WACZ of TN was purposefully chosen as a study area. The Western Zone includes Coimbatore, Tirupur, Erode, and parts of Namakkal, Karur, Dindigul, Madurai, and Theni districts. This zone covers an area of 15,678 square kilometres (15,67,800 ha). The total area under cultivation is 6,98,105 hectares, or 44.5% of the total area. Agricultural activities employ approximately 85 percent of the rural population in this zone.

Drought-prone areas were identified through the study of meteorological data, and demographic information on farms was acquired through project reports, government data books, and annual reports. Then, the WACZ TN was selected as the study region. In the chosen zone, a preliminary survey was carried out in 2021 with the goal of determining the proper location to perform the study. Preliminary fieldwork helps us confirm the practical challenges farmers face about crop management (sowing, weeding, harvesting, and storage), livestock management (proportionate number of cattle, non-dairy cattle, sheep, goats, poultry birds, fodder, feed requirements, and availability), resource management (water availability, nutrient availability, and farm waste utility), and vulnerable farming groups to climate change.

The data was collected using a structured questionnaire, and the questions were designed to elicit responses on the study's objectives. The survey questionnaire form was designed to reflect the conditions of dryland farmers, including demographic questions and farmer input accessibility. Data on farmers socio-economic characteristics, crop types grown, input quantities and unit prices, output quantities and unit prices were collected. We were allowed to observe the farmers in the field during the questionnaire, which allowed us to verify some of their responses.

The observation was made on 0.8 ha marginal farm field in WACZ of TN for the growing season of 2021-2022. The geographical location of the site was 11.39° N, 77.18° E and 270 m AMSL. The field experiment was set up to estimate the energy input-output, energy use efficiency, net energy gain and other energy indices for the different agricultural components. The input data related to labour (man days) for different field operation and component requirement was recorded, household food consumption (Kg), major food type consumed by the household member are rice grain with that rice grain requirement by the farm family were figured, seed requirement for the individual season were observed and recorded, concentrate and roughages feed were calculated using daily consumption by the livestock and conversion were made to one year and represented, season wise fertilizer application were recorded and represented, Soil nutrient (Nitrogen, Phosphorous and Potassium) sample were collected and lab analysed, Farm Yard Manure (FYM) quantity were quantified with the size of the unit, water requirement of cattle, sheep, goat and human as daily consumption were observed and recorded. Machine run hour were recorded season wise and worked for per year. season wise input requirement irrespective farm components were calculated and converted into year<sup>-1</sup>. The calculated physical inputs were represented in the Table 1. The resource was quantified and the energy equivalent of inputs were obtained. Following that energy indices were worked out.

Energy use efficiency ratio (EUE)= Total energy output (TEout)/Total energy input (TEin)

Net energy gain (NEG)= Total energy output – Total energy input

Energy profitability (EP)= Net energy gain / Total energy input

Direct energy (DE)= Labor+Fuel+Electricity

Indirect energy (IE)= Seed+Feed+Fertilizers+Chemicals+Machineries+Water

Renewable energy (RE)=Labor+Organic Fertilizers+Feed

Non-renewable energy (NRE)= Fuel+Electricity+Seed+Fertilizers+Chemicals+Machinery

Human energy profitability (HEP)= Total output energy/ Labour energy input

The equivalent energy (MJ) for different agricultural input and output were represented in Table 2.

## RESULTS AND DISCUSSION

### Total Inputs

Table 3 reveals the percentage energy contribution by different components in production system. The Percentile analysis of the input energy reveals the component wise energy inputs contributions, nutrient resource energy contribution by farm yard manure (FYM) (32 per cent) to crop is higher than the other farm inputs, farm produced nutrient source is used higher

than the other external source of inputs due to the lower operational profit in farms, feed contribution (54 per cent) to the cattle resulted high energy than the other cattle management farm resources, Since farmers could not afford the expense of fodder for livestock compared to other livestock management inputs, internal fodder production for livestock is popular among marginal farms. This boosts the feed contribution of energy. In goat and sheep components labour power has higher energy contribution (97 per cent) than the other associated components, hence the goat and sheep components labour input and energy contributions were larger. Electricity energy contribution (59 per cent) is higher for household. Since marginal farms depend on the rainfall as their prime water source, energy contribution by the irrigation purpose is nil, next to it no special care is given for the livestock component in the farm as compared to the cared commercial production which reduces farm electricity requirement and increases the household energy consumption.

### Energy indices

In the study, total energy input in the marginal production system model was calculated to be 35 GJ, whereas total energy output, net energy gain and energy profitability was recorded to be 77 GJ, 20 GJ and 0.0009 GJ, respectively Table 4. In the present model, the energy use efficiency ratio was estimated to be 0.005 GJ/GJ. Therefore, it can be evidently said that the current model is energy inefficient. The share of direct and indirect energy inputs in this model was estimated as 11 GJ and 97 GJ, respectively, whereas renewable and non-renewable energy inputs were recorded as 93 GJ and 15 GJ, respectively. This study further analysis the significance level of energy indices and revealed significance (0.001) of IDE with RE and EUE with EP, whereas 0.01 level significance were found with EUE with HEP and EP with HEP, 0.05 level significance were found with EUE with NEG and NEG with EP (Fig 1). This relationship analysis help in find the detements of each input and visualizes the possibility of optimization.

### Relationship between the inputs and outputs

EUE, HEP, EP, Machinery, soil N, P, K and FYM are positioned in right-hand-side coordinates with higher weightage of component (55.9 %). A close association between energy parameters and energy productivity is also apparent from PCA graph (Fig 2a). The predicted correlation models revealed that the association between total energy productivity and energy parameters either significant or non-significant and positive or negative (Fig 2b). Possible correlation was found between the soil available nutrient (NPK), FYM and Machinery, whereas negative correlation was observed between the NRE, EUE, NEG, EP and HEP.

## CONCLUSION

The current study discovered a crops-livestock energy flow matrix and its drivers in existing marginal farm to achieve the sustainability earlier. Moreover, the education, awareness, and training about the energy use efficiency of production systems and its importance in agriculture can be provided to the farmers to bring the sustainability in the agriculture sector in India.

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### Tables

**Table 1** Resource input in different agricultural components

Energy source	Unit	Cereals and fodders	Cattle	Goat and sheep	FYM	HH
Labour	Man days	37	180.12	231.1	2	/
Electricity	kWh	/	/	/	/	1200
HH food	Kg	/	/	/	/	200
Seed/ concentrate feed	Kg	57	2520	/	/	/
Feed (Roughages)	Kg	/	2520	/	/	/
Nitrogen	Kg	46	0	/	/	/
Soil N	Kg	51.8	0	/	/	/
Soil P	Kg	0.17	0	/	/	/
Soil K	Kg	313	/	/	/	/
FYM	Kg	16200	/	/	/	/
Water	M <sup>3</sup>	/	87.6	73	/	5.11
Machinery	Hours	4	/	/	/	/

**Table 2** Energy unit conversion for direct and indirect sources of energy

Sl. no	Particulars		Units	Equivalent energy (MJ)	References
	<b>Inputs</b>				
1	Human labour	Man	Man hour	1.96	(Surendra Singh & Mittal, 1992)
2	Tractor drawn	Cultivator	Hour	3.135	(S Singh & Singh, 2002)Singh and Singh 2002

3	Chemical fertilizer	Nitrogen	Kg	60.60	(Surendra Singh & Mittal, 1992)
		Phosphorous	Kg	11.10	(Surendra Singh & Mittal, 1992)
		Potassium	Kg	6.70	(Surendra Singh & Mittal, 1992)
4	Organic manures	FYM	Kg	0.3	(Ram & Verma, 2015)
5	Seeds	Sorghum	Kg	14.70	(Surendra Singh & Mittal, 1992)
		Groundnut	Kg	25.0	(Surendra Singh & Mittal, 1992)
6	Animal feed	Concentrate	Kg	13.3	(S Singh & Singh, 2002)
		Roughage	Kg	18.0	(S Singh & Singh, 2002)
6	Miscellaneous	Water	M3	1.02	(Tuti et al., 2012)
		electricity	Kwh	3.60	(S Singh & Singh, 2002)
		HH food (rice)	Kg	14.70	(Surendra Singh & Mittal, 1992)
	<b>Outputs</b>				
1	Sorghum	Seed	Kg	14.70	(Surendra Singh & Mittal, 1992)
		Straw	Kg	18.0	(S Singh & Singh, 2002)
	Groundnut	Seed	Kg	25.0	(Surendra Singh & Mittal, 1992)
		Straw	Kg	18.0	(S Singh & Singh, 2002)
2	Cattle	Milk	Litre	4.90	(S Singh & Singh, 2002)
3	Sheep	Meat	Kg	8.12	(S Singh & Singh, 2002)
4	Goat	Meat	Kg	8.12	(S Singh & Singh, 2002)

**Table 3** percentage analysis of farm inputs

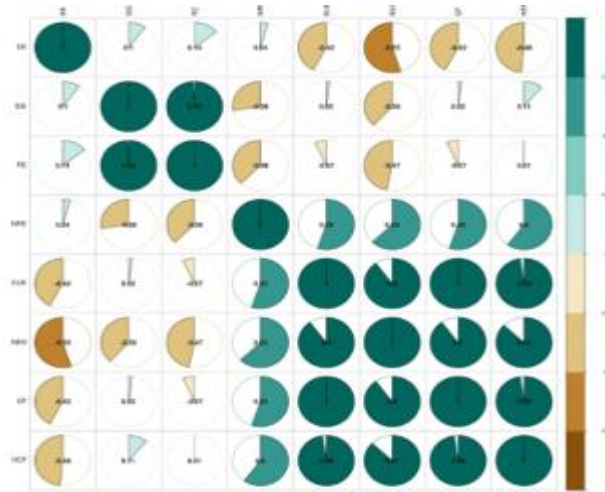
	Cereals and fodders	Cattle	Goat and sheep	FYM	HH
<b>Labour</b>	3.91	3.40	97.99	100.00	/
<b>Electricity</b>	/	/	/	/	59.46
<b>HH food</b>	/	/	/	/	40.47
<b>Seed</b>	9.12	41.94	/	/	/
<b>Feed (Roughages)</b>	/	54.56	/	/	/
<b>Nitrogen</b>	18.80	/	/	/	/
<b>Soil N</b>	21.17	/	/	/	/
<b>Soil P</b>	0.01	/	/	/	/
<b>Soil K</b>	14.14	/	/	/	/
<b>FYM</b>	32.77	/	/	/	/
<b>Water</b>	/	0.11	2.01	/	0.07
<b>Machinery</b>	0.08	/	/	/	/

**Table 4** Energy indices used for analysis

	Cereals and fodders (MJ)	Cattle (MJ)	Goat and sheep (MJ)	FYM (MJ)	HH (MJ)	MJ	GJ
Direct energy	580.16	2824.28	3623.65	31.36	4320.00	11379.45	11.38
Indirect energy	14251.09	80318.25	74.46	0.00	2945.21	97589.01	97.59
Renewable energy	6793.06	83053.18	3623.65	31.36	0.00	93501.25	93.50
Non-renewable energy	8038.19	89.35	74.46	0.00	7265.21	15467.21	15.47
EUE ratio	4.37	0.74	0.88	0.00	0.00	5.99	0.005
Net energy gain	50028.75	-21402.53	-450.11	-31.36	-7265.21	20879.54	20.88
energy profitability	3.37	-0.26	-0.12	-1.00	-1.00	0.99	0.0009
Human energy profitability	111.80	21.86	0.90	0.00	0.00	134.55	0.13

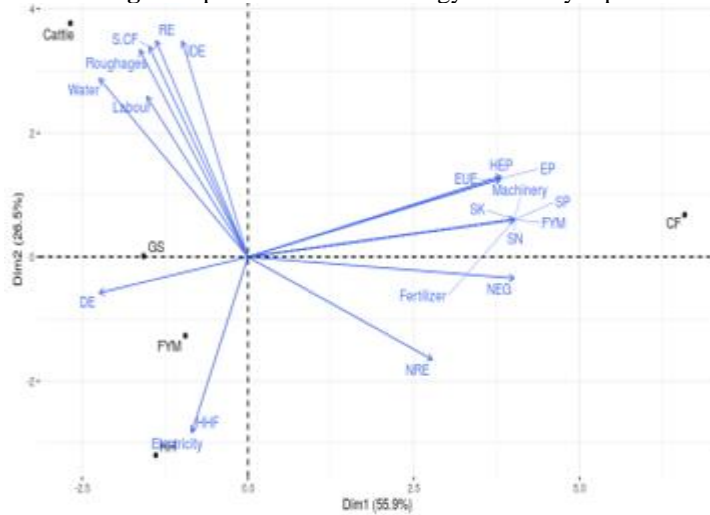
**Figures**

**Fig 1** Correlation matrix of energy indices



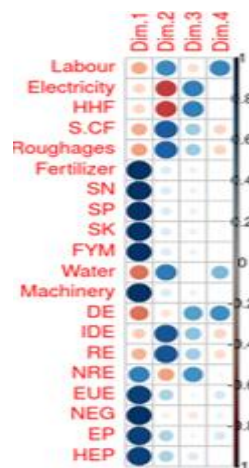
DE-Direct energy, IDE-Indirect energy, RE- Renewable energy, NRE-Non-renewable energy, EUE- Energy use efficiency, NEG-Net energy gain, EP-Energy profitability, HEP-Human energy profitability.

**Fig 2a** Input variables and energy efficiency biplot



HHF-household food, S.CF-seed and concentrate feed, SN- soil nitrogen, SP- soil phosphorous, SK- soil potassium, FYM-farm yard manure, DE-Direct energy, IDE-Indirect energy, RE- Renewable energy, NRE-Non-renewable energy, EUE-Energy use efficiency, NEG-Net energy gain, EP-Energy profitability, HEP-Human energy profitability.

**Fig 2b** Correlation plot of variables vs PCs



HHF-household food, S.CF-seed and concentrate feed, SN- soil nitrogen, SP- soil phosphorous, SK- soil potassium, FYM-farm yard manure, DE-Direct energy, IDE-Indirect energy, RE- Renewable energy, NRE-Non-renewable energy, EUE-Energy use efficiency, NEG-Net energy gain, EP-Energy profitability, HEP-Human energy profitability.

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