__Peer Reviewed Research Article__

Enhancing Sustainability, Profitability, and Energy Efficiency through Input Interventions in Existing Farming System in Southern Plain Zone of Rajasthan, India

Abstract

This study examines technological interventions to enhance the sustainability, profitability, and energy efficiency of small and marginal farmers in the Southern Plain Zone of Rajasthan, India. Covering 120 households over four years in Udaipur and Dungarpur districts, the research analyzes farming practices and productivity. Predominant farming systems include Crop + dairy (70%), Crop + dairy + goatry (20%), and Crop + dairy + poultry (10%). Introduction of improved maize and wheat cultivars resulted in yield increases of 25%-43% in Udaipur and 47%-61% in Dungarpur compared to conventional varieties. Successful vegetable cultivation led to average net returns of 145.9% (₹1,27,989) in Udaipur and 153.17% (₹1,21,039) in Dungarpur, increasing employment opportunities. Livestock management interventions improved milk yield by 650-850 liters per lactation, and goatry and poultry farming revenue increased by 16.07% and 14.20%-15.70%, respectively.

Energy efficiency ratios varied across farming systems, with Crop alone exhibiting the highest ratio (3.25) in Udaipur and Crop + Dairy + Horticulture showing notable efficiency (1.56) in Dungarpur. Livestock systems were least efficient due to high feed requirements. Integration of goat rearing decreased energy use efficiency by up to 10.88%, while vegetable cultivation and poultry rearing increased efficiency by up to 7.58% and 2.75%, respectively. Dungarpur showed higher energy efficiency in crop and vegetable production but lower efficiency in goatry compared to Udaipur. These findings highlight the significance of technological interventions for improving farming sustainability, profitability, and energy efficiency.

Key Word: Farming systems, Interventions, Profitability, Energy use efficiency, and Sustainability.

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(i)Previous work that seems inadequate to warrant a further research.
(ii)The specific problem the study is out to solve
(iii)How to solve it – scope, methodology, data collection, theoretical approach, your findings and concluding end note.

Introduction

Agriculture in India is dominated by many smallholders with scattered fragmented holdings on marginal land by 86 percent. Lack of adequate capital for investment has been the major constraint, leading to a decline in agricultural production. Thus, production has to be diversified and crop production has to be integrated into producing high-value commodities such as milk, meat, fish, fruits, and vegetables. Given risk and uncertainty in agriculture especially with high-value commodities, a farming system approach should be discussed for Indian farmers. This would internalize the complementarities of all the natural resources to realize high productivity, sustainability, profitability, better nutrition, and a low cost of production.

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A Farming System may be defined as an approach involving the allocation of a farm's available resources to its production enterprises, or different areas of production, such as crops or livestock rearing, in a manner that helps the attainment of the goals of maximization of farm income, food security, and employment. The ultimate goal of sustainable agriculture is to develop an appropriate farming system that is productive and profitable, conserve the natural resource base, protect the environment, and enhance health and safety.

Food security in a humanitarian context involves ensuring an adequate supply of food and meeting nutritional needs and cultural expectations, before and after a crisis. Environment, food security, and livelihoods are co-dependent. If the land is degraded or prone to natural hazards less food is produced and significant food shortages can occur. Food-secure communities, especially those reliant on the environment for their livelihoods, require healthy and productive ecosystems.

The Sphere Standards (2018) make the link between environment and food security, livelihoods and nutrition. They state that food assistance should be delivered in a way that protects, preserves and restores the natural environment from further degradation, and highlights the impacts of cooking fuel on the environment and the importance of livelihoods strategies that do not contribute to deforestation or soil erosion (Sphere Standards: Food security standard 5.1, Key Action 4). The Sphere Standards also state that environmentally sensitive options for income generation should be chosen for livelihoods interventions whenever possible (Livelihoods standard 7.2: Income and employment, Key Action 6).

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Briefly discuss the issue of interventions and area of intervention.

In the farming system approach, different enterprises compete for the scarce resources such as land, labour and capital on the farm while simultaneously being interdependent by supplementing or complementing each other. Thus, it is necessary to deal with the farm approach as a whole to minimise risk and increase production and profit. To effectively put this concept into practice, it is necessary to understand the linkages and the mutual synergies of different enterprises in farming systems.

Farmers allocate certain quantities and qualities of the four factors of production that is land, labour, capital and entrepreneurial skills to which they have access, to the three processes i.e. crops, livestock and off-farm enterprises, in a manner which, given the knowledge they possess, helps in attaining the goals set (Norman 1978).

Indian agriculture is characterised by mixed farming, involving a system of combining crop production with one or more of the livestock enterprises, such as rearing of cattle, sheep, goats and poultry. Here, a farmer usually plans his farming system not only with the sole purpose of maximising the net returns but also to include family welfare in terms of family nutrition, risk aversion and assurance of returns from his individual enterprises. A farming system incorporating a wide scope of enterprises, like crops, dairy, poultry and horticulture may help a farmer achieve regular and safe employment opportunities throughout the year along with increased farm income.

The energy use efficiency of agricultural production systems has been considered as an indicator of crop Performance. Hence, agricultural productivity evaluation based on energy input-output relationship is important to make efficient use of existing natural resources so as to ensure economic and environmental sustainability of farming practices.

Agricultural productivity assessment using energy budgeting is essential to make efficient use of the available natural resources (Singh and Mittal 1992, Moraditochaee 2012, Soni et al. 2013). The energy consumption in agriculture has increased consistently in form of various inputs such as fossil fuel, fertilizers, pesticides, herbicides, electricity, machineries etc. causing environmental and human health problems (Chaudhary et al. 2009, Fadvi et al. 2011, Rahman and Barmon 2012). It has been realized that amount of energy used in agricultural production, processing and distribution should be significantly high in order to feed the expanding population and to meet other social and economic goals and therefore, sufficient availability of the green energy and its effective and efficient use are prerequisites for improved agricultural production (Stout 1990).

The efficient energy use in agriculture minimizes environmental problems, destruction of natural resources and promotes sustainable agriculture as an economical production system (Erdal et al. 2007). The best way to lower the environmental hazard of energy use is to increase the energy use efficiency (Esengun et al. 2007). Hence, to maximize the efficiency of modern agricultural technology to farms in a specific region, the farming system should be first characterized to capture the diversity of farming systems (Fadvi et al. 2011). It has been concluded in many studies that the yield and economical parameters increased linearly as level of fertility increased, while reverse trend was observed with energy use efficiency and energy productivity (Erdal et al. 2007, Tuti et al. 2012, Shahamat et al. 2013). An input-output energy analysis provides farm planners and policy makers an opportunity to evaluate economic intersection of energy use (Ozkan et al. 2004). Nowadays, increasing demand for food resulted in intensive use of energy inputs in modern agricultural production systems than earlier (Shahamat et al. 2010).

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Since, crop, livestock, goat and poultry was the most common farming enterprise for integrated farming system in the southern region of Rajasthan, and majority of the farmers in this region are marginal farmers. Therefore, the present study was undertaken to estimate the most income generating and profitable farming system and to estimate the energy input and output of crops (cereals, fodder and vegetables)-livestock (Cow, goat)-poultry in a 0.5 ha integrated farming system model, and to measure its energy use efficiency.

Materials and Methods:

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Study was under taken in Udaipur and Dungarpur district of Southern region of Rajasthan during 2012-13 to 2015-16 and 2016-17 to 2021-22 respectively. A cluster of 6 villages in Salumber, Sarada block (Udaipur) and a cluster of 6 villages in Aspur and Sabla block (Dungarpur) were selected on the basis of higher and lower productivity respectively, and the village were selected by random sampling. Climate of the region is mild hot in summers and serve cold winter. The average maximum temperature is 43.8 ^{o}C, with an average lowest temperature of 11 ^{o}C. The average annual rainfall ranges between 550-1052 mm, of which about 85 % is received through south-west monsoon during June to September and remaining is received during winter months. The major cropping systems are maize-wheat systems. Crop–livestock interaction has been a unique feature of the region. Approximately 90% of farmer families fall into the small and marginal farmer category.

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Between 2012 and 2016 and further research between 2016 and 2022.

The research locations for the farming system were chosen with care, taking into account agro-climatic and socioeconomic conditions, landholding patterns, farming techniques and productivity. Based on this, a cluster of six villages comprising 10 households of each village (60 household of Udaipur and 60 household of Dungarpur block) were selected. The total sample comprised 120 households for which a detailed benchmark survey was carried out during 2012-13 and 2016-17 through a baseline survey, which could form a basis for identifying the constraints and subsequent planning of module-wise IFS interventions.

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During the reporting period of 2012-13 to 2015-16 (Udaipur) and 2016-17 to 2021-22 (Dungarpur), module-wise technological interventions were planned and implemented in the field based on constraint analysis and requirement needs of different categories of farmers. The farming system approach for holistic development of farm households was used, keeping in mind the food, fodder, and other requirements of households for ensuring food and nutritional security besides enhancing farm income. For sustainable development of farm households, the on-farm trial of an improved package of practices with the introduction of improved varieties along with capacity building was carried out. Crop nutrient and pest management were implemented to solve low yield due to unbalanced fertilizer use and inadequate plant protection measures. Critical inputs such as improved varieties of crop, fertilizers, plant protection chemicals, mineral mixture for livestock, poultry chicks, etc., were used in the technological intervention. Component-wise detailed interventions are listed in Table 1.

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Table 1: Module-wise technological interventions.

Modules of IFS	Technological Interventions
Crop and cropping system	• Intensification and diversity of cropping. • HYV, intercropping, INM, IPM, and IWM are all examples of enhanced production technology.
Livestock	• Management of fertility and nutrition in dairy animals. • Vaccination, deworming, and mineral supplements for livestock. • Introduction of improved poultry (Pratapdhan) and goat (Sirohi) breeds. • Diversification of agricultural system for feed and fodder management.
Horticulture	• Demonstration of the enhanced vegetable crop production package of practices. • Growing vegetables for a bigger profit. • Promotion of a nutritional kitchen garden.
Capacity building	• Value addition of farm products.

- Composting and vermicomposting.
- Skill development (composting/vermicomposting, nursery raising, on-farm processing, appropriate agricultural practices.
- Visit to agri-fairs, awareness program, and Kisan gosti.
- Literature dissemination in local languages.

Based on the constraint identified, critical input interventions were made to uplift the existing farming situation at 10 households in each village (A total of 60 households in each block) during 2012-13 to 2015-16 (Udaipur) and 2016-17 to 2021-22 (Dungarpur). To assess the impact of critical input intervention under different enterprises at the household level and other related farming aspects, benchmark households were revisited regularly and information was recorded.

Energy Efficiency

The IFS model consists of different agricultural production sub-systems such as field crops (wheat-maize), vegetables (okra- -tomato-cauliflower), green fodder crops (sorghum-oat) and goat (4 Sirohi goats,). The IFS model was developed only after characterising the major agricultural production systems in the southern parts of the state which has been mostly practised by the small and marginal farmers in the rainfed ecologies. Three cropping seasons were observed in this region, i.e. *kharif* (June- Oct.), *rabi* (Nov.-Feb.), and *summer* (March-May). 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. These energy indices are:

$$\text{Energy use efficiency ratio(EUE)} = \frac{\text{Total Energy Output (TEout}}{\text{Total energy Input (TEin)}}$$

$$Net\ Energy\ Gain\ (NEG) = [Total\ Energy\ Output - Total\ Energy\ Input\ ]$$

$$Energy\ Profatibility\ (EP) = \frac{Net\ Energy\ Gain\ (NEG)}{Total\ Energy\ Input\ (TEI)}$$

$$Human\ Energy\ Profatibility\ (HEP) = \frac{Total\ Output\ Energy}{Labour\ \ Input\ Energy}$$

Table-2: Location Details

Village Name	No. of House Holds	Block	District	Geographical Location	AMSL
Tulsio ka Namla	10	Salumber	Udaipur	24.22^0 N, 73.99^0 E	268 m
Roba	10			24.21^0 N, 73.99^0 E	249 m
Bhujhfala	10			24.21^0 N, 73.97^0 E	232 m
Bovas	10	Sarada		24.27^0 N, 73.85^0 E	264 m
Chanda ji ka Guda	10			24.26^0 N, 73.87^0 E	255 m
Padarda	10			24.24^0 N, 73.92^0 E	237 m
Dhani Katara	10	Sabala	Dungarpur	23.85^0 N, 74.18^0 E	108 m
Dhani Vaglai	10			23.85^0 N, 74.19^0 E	141 m
Dholi Red	10			23.86^0 N, 74.18^0 E	152 m
Chilora Fala	10	Aspur		23.97^0 N, 74.09^0 E	146 m
Lalpura	10			23.96^0 N, 74.06^0 E	119 m
Karkoli Fala	10			23.96^0 N, 74.05^0 E	168 m

Various inputs such as labour, fossil fuel, electricity, feed, seed, organic manures and inorganic fertilizers, chemicals, machineries, water etc. and yield as grains, vegetables, fodder, meat, manure and other products and by-products were taken into consideration to calculate total energy input and output. The energy output for the green fodder crops was estimated based on the dried mass. The average input and output data of all the modules for the duration of 4 yearswith similar components were considered for the energy analysis. Various farm machineries used for different purposes therefore, their energy was estimated based on distributed weight utilized. Distributed weight was derived as [machinery unit weight/ (economic life*365 (366 for leap year)*8))] (Soni et al. 2013). The resource inputs and outputs converted from physical to energy unit (MJ) through various published conversion coefficients (Table 3, 4). The recommended dose of fertilizers and chemicals were applied as per the need of different crops. The land preparation for all crops was done with a tractor drawn disc harrow, cultivator, rotavator and manually. All the data was maintained for each and every input in different agricultural components and once the crop was grown up, harvested yields of main and by-products of each component were measured and recorded.

Table 3 Resource input and their energy equivalent in MJ/unit

Resource Input	Unit	Equivalent (MJ/unit)	Reference
Labour	hr	1.96	Singh & Mittal (1992)
Diesel fuel	l	47.87	Singh & Mittal (1992)
Electricity	kWh	3.60	Ozkan *et al*. (2004)
Nitrogen (N)	kg	60.60	Singh & Mittal (1992)
Phosphorous (P2O5)	kg	11.10	Singh & Mittal (1992)
Potassium (K2O)	kg	6.70	Singh & Mittal (1992)
Zinc sulphate (ZnSO4)	kg	20.90	Singh & Mittal (1992)
Manure/FYM	kg	0.30	Taki *et al*. (2012)
Vermi-compost	kg	0.50	Ram & Verma (2015)
Farm machinery	kg	62.70	Tuti *et al*. (2012)
Herbicides	kg	254.45	Pimentel (1980)
Insecticides	kg	184.63	Pimentel (1980)
Water	m3	1.02	Tuti et al. (2012)
Minerals	kg	2.00	Wells C (2001)
Seed			
Wheat, maize, sorghum, oat	kg	14.70	Singh & Mittal (1992)
Okra, tomato, cauliflower, cabbage	kg	0.80	Tuti *et al*. (2012)
Chick (poultry)	kg	4.56	Gopalan *et al*.(1971)
Goat	kg	8.12	Gopalan *et al*. (1971)
Cow	kg	9.22	

Table 4 Resource output and their energy equivalent

Output	Unit	Equivalent (MJ/unit)	Reference
Wheat, maize, tomato, cabbage, cauliflower, chicken and goat meat	kg		Same as input
Okra	kg	1.9	Tuti *et al*.(2012)
Sorghum, oat and maize (dry mass)	kg	18.0	Singh & Mittal (1992)
Manure	kg	0.30	Taki *et al*. (2012)
By-product (dry mass)			
Straw (Rice and Wheat)	kg	12.5	Singh & Mittal (1992)

Okra, tomato, cabbage, cauliflower, onion, banana (leaves and stem)	kg	10.0	Singh & Mittal (1992) Soni *et al* (2013)
Cow Milk	kg	7.14	Coley DA *et al* (1998)

Result and Discussion:

In order to improve livelihood in southern region of Rajasthan, critical constraints under different farm enterprises were identified and opportunities for its further upliftment were worked out. The major constraints identified in the area were scarcity of water, use of traditional cultivars of crop, fruit and vegetables, imbalance /inadequate nutrition, insect-pest and disease infestation, poor accessibility of market and lack of technical knowledge on improved package of practices.

Farmers holding size

Characterization of farm holding revealed that on an average, 86.1% farmers were under marginal and 13.9% farmers were under small farmer category. None of the farmers was belonging to medium and large farmers categorize in both the studied area.

Socio-personal characteristics

The socio-personal characteristics of questioned farmers were explored in terms of age, education, occupation, home size, family type, monthly income, and participation in social activities. According to the findings, the majority of farmers in the cluster under study were in the middle age group (40 to 55 years), followed by the elderly (>55 years) and the younger age group (35 years), with a tiny percentage of the young farmer population migrating to metropolitan regions in pursuit of work. Most farmers were illiterate or just had primary education, and farming was their principal vocation. The average household had more than five individuals and a monthly income of less than ₹5000.

Pre-Dominant Cropping/Farming System

Crop + dairy farming was the most common farming style in all villages studied. Wheat, mustard, maize, and soybean were the most common crops under cultivation, although fodder and vegetables were cultivated in isolated places where irrigation water was available. Buffalo and cows dominate the dairy farming, whereas goatry and poultry rearing was mainly for meat and egg production purpose.

Table 5 : Pre-Dominant Cropping system for Wheat and Maize

District	Block	Wheat (kg ha^{-1})			Maize (kg ha^{-1})		
		Benchmark	After intervention	Percentage Increase	Benchmark	After intervention	Percentage Increase
Udaipur	Salumber	3020	3780	25.17	1815	2925	37.95
	Sarada	2935	3760	28.11	1710	2550	32.94
Dungarpur	Sabala	2800	3730	33.21	1785	2625	32.00
	Aspur	2535	3625	43.00	1645	2535	35.11

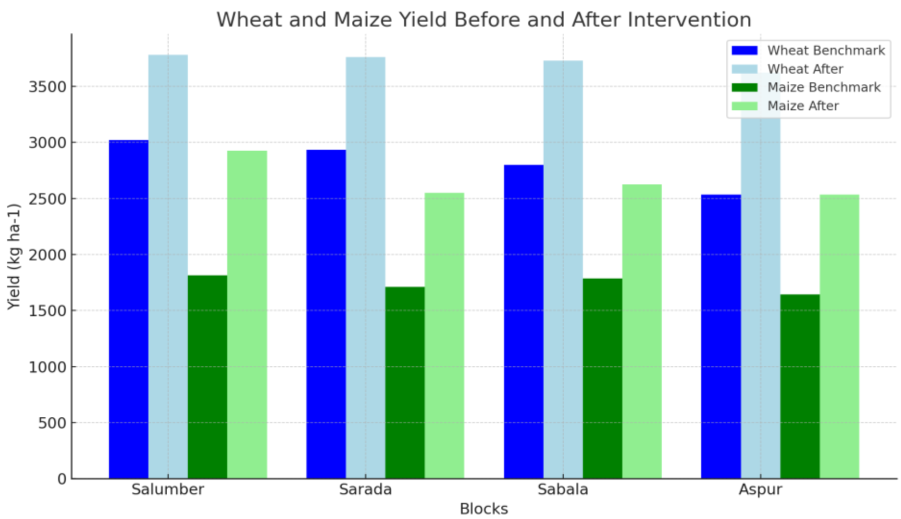
The study found that crop + dairy farming is the most common farming system among households in the study area. It was also observed that the adoption of improved cultivars in different crops was very low and farmers mostly relying on the traditional cultivars. Farmers used to depend on local varieties because of ease of reusing the same varieties for raising next crop due to non-availability of quality seeds in time in the region and lower affordability to purchase seeds of high yielding varieties. Mutual exchange of seeds and planting material is a common practice among villagers. The lower yield of traditional cultivars results in lower crop productivity in the region. Composting of cow dung was also not in practice. Farmer use un-decomposed FYM which become harbour for insect and pest and ultimately lower yield. Very few (<20 %) farmers were using inorganic fertilizer like urea as revealed from survey. Due to irregular availability of fodder for dairy, enterprise was also a neglected component of existing farming system as most families were in the process of downsizing the number of cattle. They are now keeping cows enough only for milk and ploughing the field. The significant decline of cattle adversely impacts soil revitalization coming from manure.

Critical input intervention under different farm enterprise

Promotion of improved cultivars of wheat and maize for higher productivity and profitability:

Technical interventions such as introducing of improved cultivars of wheat (Raj 4079) and maize (PHEM-2) gave additional yield of 25 to 43% in wheat and 47 to 61% in maize (fig-1) over traditional cultivars in both the cluster (Udaipur and Dungarpur), resulting in net gain in income and forms a more practical consideration.

Fig 1 : Productivity improvement in crops after intervention



Balance fertilization:

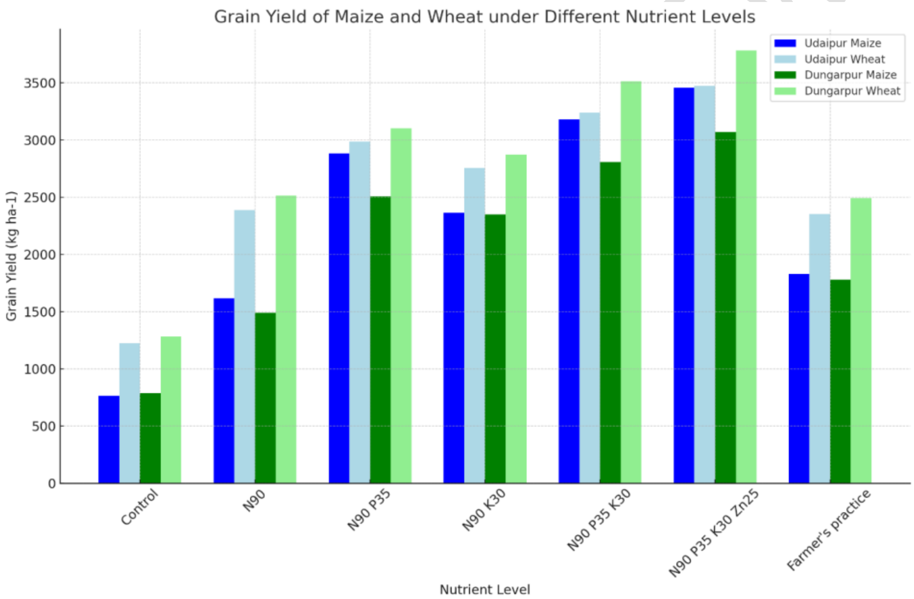
A total of 24 trials were conducted in both the cluster to improve crop yield and quality by managing nutrients with seven treatment. Application of 90 kg N, 35 kg P2O5 and 30 kg K2O/ha along with 25 kg ZnSO4 to maize and 120 kg N, 40 kg P2O5 and 30 kg K2O/ha to wheat significantly improved grain yields of maize and wheat over all the other treatments. Compared to farmers' practice, maize output increased to 88.8, and 72.4% and wheat yield increase to 47.6 and 51.8 % in Udaipur and Dungarpur, respectively (Table 6).

Table 6: On-Farm crop response to plant nutrients in predominant cropping systems

Nutrient level (kg/ha)		**Udaipur** Grain yield (kg/ha)		**Dungarpur** Grain yield (kg/ha)	
Maize	Wheat	Maize	Wheat	Maize	Wheat
Control	Control	763	1223	785	1281

N_{90}	N_{120}	1617	2388	1490	2513
N_{90} P_{35}	N_{120} P_{40}	2883	2988	2508	3104
N_{90} K_{30}	N_{120} K_{30}	2363	2756	2350	2873
N_{90} P_{35} K_{30}	N_{120} P_{40} K_{30}	3181	3240	2808	3515
$N_{90}P_{35}$ K_{30} Zn_{25}	**N_{120} P_{40} K_{30}**	**3458**	**3475**	**3069**	**3783**
Farmer's practice	Farmer's practice	1831	2354	1779	2492

Fig 2



Nutritional Kitchen Gardening/Vegetable cultivation

In both the clusters, farmers use to purchase vegetables from market for their own consumption and spend a sizeable income on it. To make them self-reliance, 48 Farmers were given a better package of practice in the vegetable module for the successful cultivation of vegetables such as tomato, chili, cabbage, cauliflower, brinjil and melon crops for increased profitability and reduce the risk of heavy reliance on a single crop while also generating year-round income and 12 farmers were selected for promotion of kitchen gardening on bare land nearby house/water sources etc. was done by providing mini kit of seasonal vegetables in both cluster.

Cost of these mini kits were ₹ 1200 each. With such intervention, monthly vegetable availability increased from 75 to 110 kg household in both the cluster. Initial bench mark survey made in the study revealed that farmers usually spend about 450 to 650 per month on vegetables, which could be easily saved with kitchen gardening of nutritious vegetables. Among the different season, maximum net saving through kitchen gardening was accrued during Rabi (winter) Kharif season. Over all annual net savings due to kitchen gardening per household was ₹15000 at Udaipur and 12000 at Dungarpur district.

Since adopting a diverse vegetable-based cropping scheme, average net returns of household improved to 145.9 % (₹ 1, 27,989) in Udaipur and 153.17% (₹1, 21,039) in Dungarpur. With only a ₹2000 to 5963 rise in cultivation costs.

Dairy enterprise:

Artificial insemination with high-quality sperm was used to address the problem of infertility. Milch animals were given a mineral mixture and balanced nutrition to increase milk output. Under the livestock module, technological interventions such as infertility and nutrition management in dairy animals, mineral mixtures, calcium and vitamin supplements, promotion and enhancement of indigenous cattle breeds, deworming, and disease control were carried out.

Data obtained from different villages' indicates that improved dairy management practices has pronounced effect on milk yield with improved management practices on additional milk yield of 650 to 850 liter/lactation/ was obtained over existing dairy management practices. Economics computed for different improve dairy management practices indicated that improved dairy management practices had added average income of ₹24285 in Udaipur and ₹16447/lactation/household in Dungarpur over existing management practices. The increased income was mainly attributed to increased higher milk yield, reduced dry period, enhance lactation periods and more farmyard manure production.

Effect on goatry enterprises:

In Southern Rajasthan goatry enterprise was the most common enterprises with marginal house hold (<1 ha area), which rear on wild grazing. Due to rearing of local breed, imbalanced nutrition and improper management practices, survival percentage of goats and their development was very poor. In order to improve health and enhance income through goatry enterprise, Farmers of Udaipur cluster were provided with Sirohi breed and mineral mixture as a food supplement and medicines, viz. anti-mastitis, Anti-parasites and reproduction management were used. Such intervention not only improved the health of these goats but also their numbers were increased significantly per house hold and ultimately annual income from these enterprises was sizably improved.

Assessing the change in income through goatry enterprise at house hold level, an estimated gain of ₹25800/household/annum over the bench mark income (₹8000/household/annum) from goatry enterprise was noticed.

Promotion of Backyard Poultry:

Marginal farmers were provided with backyard poultry for enhancing their livelihood through backyard poultry. Each farmer was equipped with 20 birds of Pratap dhan. Results indicate average ₹17000 & 18250/- increase in their income from poultry rearing in both the cluster.

Effect on overall household income, employment, and nutritional security:

At the end of the study, household income through different enterprises was compared with the initial benchmark year (2011). Results reveal that the integration of different component enterprises (dairy, horticulture, goatry & Poultry) along with crops has an additive effect on total household income. Among the different components, the maximum net economic gain was accrued through crops, followed by goatry, dairy, and horticulture. Use of bare land nearby the hand pump/water sources for kitchen gardening further added a sum of ₹12000 to 15000/household/annum to the net saving along with quality vegetables as well as nutritional security. Total household income was higher at Udaipur as compared to Dungarpur. Product diversification of FYM to vermicomposting reduces fertilizer cost of crops and vegetables and also adds extra average net amount of ₹1188 to ₹5131per household in Udaipur (Table 7) and ₹ 827 to ₹916per household in Dungarpur (Table 8) compared with benchmark year. The net annual income improvement through different component enterprises of integrated farming system approaches was to the tune of 128.94% to 167.54 % at the Udaipur cluster (Table 7) and 115.18% to 153.17% in the Dungarpur cluster (Table 8).

Farming system enterprise diversification:

At the onset of the study, crop component enterprises of the farming system were the most prevalent and occupied about 70-80% of the total household income followed by dairy (20-30%) and goatry or poultry enterprise (5-10%). With different critical input interventions and improved farming awareness programs household enterprise diversification also took place. After 04 years of study, the contribution of dairy, horticulture goatry, and poultry enterprises to total household income was not only improved, but the other ancillary/complimentary enterprises like kitchen gardens and product diversification were also having a sizable contributions to household income (Singh, Hari *et.al* 2017). Such diversification not only led to total higher house hold income but also reduced the dependency on single enterprises of crops.

Similar performances of integrated farming systems (IFS) have been reported by Frei and Becker (2005) and Poonam Kashyap *et al*. (2017) where synergism between farm enterprises increased productivity most studies have focused on the sustainability of IFS in terms of productivity and economic viability.

Employment generation through an integrated farming system approach:

The table number 9 compares the employment performance of various farming enterprises in the Udaipur and Dungarpur clusters, both before and after certain interventions. The data reveals notable improvements in man days across both clusters following the interventions, as indicated by the percentage increases. For Crop the Udaipur cluster saw an increase in man days from 150 to 192, representing a 28 percent rise, while the Dungarpur cluster experienced a higher increase by 37.68 percent. When combining Crop and Dairy, Udaipur's man days jumped by 75.24 percent and Dungarpur by 75 percent increase.

The addition of Horticulture to Crop and Dairy resulted in one of the most substantial man days increases. Udaipur's employment surged from 280 to 538, a 92.14 percent rise, while Dungarpur's man days grew from 230 to 450, marking a 95.65 percent improvement. Similarly, combining "Goat farming" with "Crop and Dairy" led to the largest employment boosts: Udaipur's man days nearly doubled from 260 to 516, a 98.46 percent increase, while Dungarpur saw a significant 108.57 percent rise. Finally, for "Crop, Dairy, and Poultry," Udaipur's employment increased from 230 to 393, a 70.87 percent rise, and Dungarpur's employment went from 225 to 375, reflecting a 66.67 percent increase. Resulting, the interventions led to substantial gains across all farming enterprise combinations, with the addition of more components (such as dairy, horticulture, and livestock) resulting in higher employment increases. The Dungarpur cluster generally exhibited slightly higher percentage improvements than the Udaipur cluster, particularly when goat farming was included.

Nutrition security under the farming system approach:

Our result demonstrated that the integration of Crop + Dairy + Horticulture + Goatery + Poultry had substantial improvement on total protein and carbohydrate production at the household level. As per the Indian Council of Medical Research recommendation annual requirement of protein and carbohydrate for a > 5-member family ranges between 110-125 kg protein and 550- 575 kg carbohydrate which can be easily be met out through an integrated farming system approach.

Table 7 Changes in overall household income (all values in ₹/ha) under different farming systems scenarios in the Udaipur cluster (2012-13 to 2015-16)

Farming system	Crop		Vegetable		Dairy		Goatry		Poultry		Kitchen gardening		Product diversification		Total Household Income		% Increase
	Bench mark	Af. Inv.	Bench mark	Af. Inv.	Bench mark	Af. Inv.	Bench mark	Af. Inv.	Bench mark	Af. Inv.	Bench mark	Af. Inv.	Bench mark	Af. Inv.	Bench mark	Af. Inv.	
Crop alone	50000	62120	-	51161	-	-	-	-	-	-	-	-	-	1188	50000	114469	128.9
Crop+ Dairy	50400	64145	18800	36923	-14200	23655	-	-	-	-	-	-	-	3539	55000	128262	133.2
Crop+ Dairy + Goat	51000	64908	24000	41749	-23000	24250	8000	25800	-	-	-	-	-	3816	60000	**160523**	**167.5**
Crop+ Dairy + Poultry	43100	57625	-	-	-1700	24949	-	-	5800	17000	-	15000	-	5131	47200	119705	153.6
Average	**48625**	**62200**	**10700**	**32458**	**-12967**	**24285**	**8000**	**25800**	**5800**	**17000**	-	**3750**	-	**3418**	**53050**	**130739**	**146.4**

Table 8 Changes in overall household income (all values in ₹/ha) under different farming systems scenarios in Dungarpur cluster (2016-17 to 2021-22)

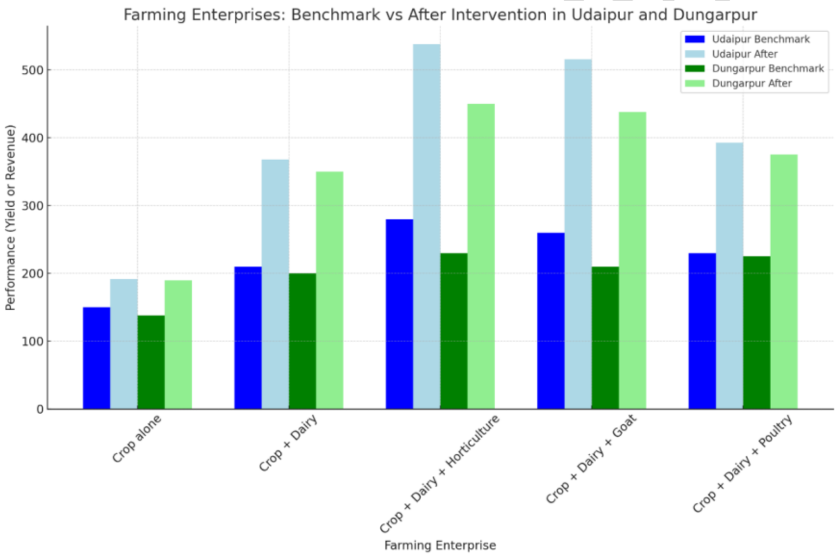
Farming system	Crop		Horticulture		Dairy		Poultry		Kitchen garding		Product diversification		Total Household Income		% Increase
	Bench mark	Af. Inv.	Bench mark	Af. Inv.	Bench mark	Af. Inv.	Bench mark	Af. Inv.	Bench mark	Af. Inv.	Bench mark	Af. Inv.	Bench mark	Af. Inv.	
Crop+ Dairy	46485	70490	0	0	1000	18558	0	0	0	12216	0	916	47485	102181	115.18
Crop+ Dairy +Horti	45545	75400	0	27314	2265	17427	0	0	0	0	0	898	47810	**121039**	**153.17**
Crop+ Dairy + Poultry	43113	70835	0	0	4040	13356	0	18230	0	12216	0	827	47153	115465	144.87
Average	**45048**	**72242**	**0**	**27314**	**2435**	**16447**	**0**	**18230**	**0**	**8144**	**0**	**881**	**47483**	**112895**	**137.76**

Note: - Af. Indicates **After** and Inv. Indicates **Intervention**

Table 9 Employment (man-days/ha) generation through different farming systems approaches

Farming enterprise	Udaipur Cluster			Dungarpur Cluster		
	Benchmark	After Intervention	Percentage Increase	Benchmark	After Intervention	Percentage Increase
Crop alone	150	192	28	138	190	37.68
Crop+ Dairy	210	368	75.24	200	350	75.00
Crop+ Dairy+ Horticulture	280	538	92.14	230	450	95.65
Crop+ Dairy + Goat	260	**516**	98.46	210	**438**	108.57
Crop+ Dairy + Poultry	230	393	70.87	225	375	66.67

Fig 3



Energy Efficiency

The energy flow in system studied by evaluating the energetics for each component of IFS models in both the district (Table-10 & 11). The fodder showed the highest energy use efficiency ratio (7.29 & 7.37) due to higher energy output (25.92 GJ) as against the energy input of 3.55 & 3.52 GJ in both the district respectively. This was followed by cropping system (2.88 & 4.56) and vegetable (1.88 & 2.95) respectively in both district.

The reduced energy ratio in IFS was attributed to low energy output against energy input in animal component due to this the dairy, goatry and poultry was recorded the least energy use efficiency ratio in both districts.

The maximum net energy gain was recorded in wheat-maize (26.97 & 47.01 GJ) cropping system followed by fodder (22.37 & 22.40 GJ). Whereas, dairy and goatry in both district and poultry component in Dungarpur district calculated to be negative energy gain ratio due to low energy output against high energy input.

The energy profitability of different agricultural component was analysed and it was found that green fodder cultivation was most profitable in terms of energy and produced Ep ratio as 6.29 in Udaipur and 6.37 in Dungarpur followed by field crops and vegetables in both study area.

Similarly human energy profitability was also found higher in fodder (78.71 & 88.16) followed by crops (32.03 & 44.78) in both districts. Whereas in livestock component poultry show high HEP ratio (32.75) in Dungarpur followed by Dairy in both districts. Goat rearing found least human energy profitable in both study area.

Table-10: Energy indices of different components of farming system at Udaipur

Components	Area/ Nos	En-Input (in GJ)	En-Output (in GJ)	NEG (in GJ)	EUE	EP	HEP
Crop	0.3 ha	14.35	41.31	26.97	2.88	1.88	32.033
Vegetable	0.1 ha	6.61	12.45	5.84	1.88	0.88	11.029
Fodder	0.1 ha	3.55	25.92	22.37	7.29	6.29	78.717
Dairy	02 nos	46.73	24.73	-22.00	0.53	-0.47	23.02
Goat	04 nos	20.15	15.25	-4.90	0.76	-0.24	5.38

Table-11: Energy indices of different components of farming system at Dungarpur

Components	Area/ Nos	En-Input (in GJ)	En-Output (in GJ)	NEG (in GJ)	EUE	EP	HEP
Crop	0.3 ha	13.20	60.21	47.01	4.56	3.56	44.780
Vegetable	0.1 ha	6.86	20.28	13.42	2.95	1.95	14.700
Fodder	0.1 ha	3.52	25.92	22.40	7.37	6.37	88.163
Dairy	02 nos	46.73	24.73	-22.00	0.53	-0.47	23.02
Goat	04 nos	23.25	14.84	-8.42	0.64	-0.36	3.13
Poultry	20 nos	3.12	8.34	-8.42	0.64	1.67	32.750

Among the different IFS models it was found that the total energy input was required utmost for Crop + Dairy + Goat (91.40 GJ) system in Udaipur and Crop + Dairy + Horticulture (93.57 GJ) in Dungarpur district. Whereas Crop + Dairy system required more energy input in Dungarpur (86.71 GJ) as compare to Udaipur (71.25 GJ), Crop + Dairy + Poultry system was recorded 89.83 GJ energy input in Dungarpur. Least energy input required by Crop alone i.e. 24.51 GJ in Udaipur. Similar trend was found in energy output in which Crop + Dairy + Goat in Udaipur (119.66 GJ/year and Crop + Dairy + Poultry system (134.04 GJ/year) in Dungarpur produced more energy than other models (Table-12 &13).

Moreover, the energy use efficiency ratio was estimated and found to be highest in crop alone (3.25) in Udaipur (Table-12) followed by Crop + Dairy + Horticulture system (1.56) in Dungarpur (Table-13). It is important to mention that livestock were least energy efficient agricultural production system which have produced negative energy mileage (Table-10 & 11). The livestock system required utmost energy input in the form of feed and the energy analysis indicated that their feeds energy efficiency was lesser and required improvement in the feed nutrition (Safeedpari, 2012 & Sanjeev kumar et.al, 2019). In this study it was also found that the goat rearing with dairy animal, decreased the energy use efficiency up to 10.88% whereas, growing vegetables and rearing poultry with C+D increased the energy use efficiency up to 7.58% and 2.75% respectively in farming system module.

Table-12: Energy input-output and energy efficiency of IFS modules at Udaipur

IFS Modules	Area (ha)	En-Input (in GJ)	En-Output (in GJ)	NEG (in GJ)	EUE	EP	HEP
Crop Alone	0.5	24.51	79.68	55.17	3.25	2.251	29.00

C+D	0.5	71.25	104.41	33.17	1.47	0.466	27.32
C+D+G	0.5	91.40	119.66	28.27	1.31	0.309	17.79

Table-13: Energy input-output and energy efficiency of IFS modules at Dungarpur

IFS Modules	Area (ha)	En-Input (in GJ)	En-Output (in GJ)	NEG (in GJ)	EUE	EP	HEP
C+D	0.5	86.71	125.69	38.99	1.45	0.450	43.80
C+D+H	0.5	93.57	145.98	52.41	1.56	0.560	34.35
C+D+P	0.5	89.83	134.04	44.21	1.49	0.492	42.90

During the study it was observed that energy use efficiency of crop &vegetable in Dungarpur is 58.35% & 56.95% higher as compare to Udaipur respectively. Whereas, in goatry energy use efficiency is 15.7% less in Dungarpur as compare to Udaipur.

The increasing demand for food to meet food, nutritional and health security has resulted in intensive use of energy inputs in agricultural production which is threatening public health as well as environment, therefore energy budgeting in agricultural production systems is very essential to get sustainability, profitability in the farming practices and to identify the best performing agricultural practice that can be adopted in the specific agricultural regions (Erdal et al. 2007, Taki et al. 2012, Soni et al. 2013).

The present study revealed that crops (cereals, fodder and vegetables)- livestock (cow)-Goat in an 0.5 ha land based IFS model is more profitable, income generating and an energy efficient module and can be promoted and adopted in the humid and sub humid southern plain zone of Rajasthan. Moreover, the education, awareness and training about the energy use efficiency of farming systems and its importance in agriculture should be provided to the farmers to bring the sustainability in the agriculture sector in India.

The study highlighted the effectiveness of integrated farming systems in enhancing agricultural productivity, household income, and livelihoods in Southern Rajasthan. By addressing constraints and promoting sustainable farming practices, the interventions contributed to improved food security, income stability, and rural development in the region.

Overall, the study underscores the importance of holistic and integrated approaches to agriculture for promoting sustainable livelihoods and rural development in resource-constrained regions like Southern Rajasthan.

Highlights

1. This study examines technological interventions to enhance the sustainability, profitability, and energy efficiency of small and marginal farmers in the Southern Plain Zone of Rajasthan.
2. Study was under taken in Udaipur and Dungarpur district of Southern region of Rajasthan during 2012-13 to 2015-16 and 2016-17 to 2021-22. A cluster of 6 villages in Salumber, Sarada block (Udaipur) and a cluster of 6 villages in Aspur and Sabla block (Dungarpur) were selected on the basis of higher and lower productivity, using stratified random sampling.
3. Module-wise (Farming System) technological interventions were classified.
4. Resource input, output and their energy equivalent were calculated.
5. Critical input intervention under different farm enterprise and productivity improvement in crops after intervention were observed.
6. Crop response to plant nutrients in predominant cropping systems was calculated
7. Effect on overall household income, employment, and nutritional security were examined.
8. Employment generation through an integrated farming system approach and Nutrition security under the farming system approach were calculated
9. Energy input-output and energy efficiency of IFS modules at Udaipur and Dungarpur were calculated.

Commented [h11]: Summary?

General Observation

Commented [h12]: (1)Rework the abstract in order to give us a clear picture of what the entire work entails.
(2)The introduction is weak. Hence makes the foundation of the study inadequate.
(3)Problem of the study/research not clearly stated.
(4)Scope of data collection should either be primary or secondary.
(5)Theoretical framework?
i.Name the propounder of the theory and in what year?
ii.The principles of the theory and its applicability to your work.
(6)Analysis should be preceded with Findings, summary, conclusion and recommendations with end note statement.
(7)Poor referencing.

REFERENCES:

Behera U K, Sharma A R and Mahapatra I C. 2007. Crop Diversification for efficient resource management in India: Problems, prospects and policy. *Journal of Sustainable Agriculture* **30**(3): 97–127.

Babalad, H.B., Gunabhagya, Saraswathi and Navali, V.G. 2021. Comparative Economics of Zero Budget Natural Farming with Conventional Farming Systems in Northern Dry Zone (Zone-3) of Karnataka. *Econ. Aff.*, **66**(2): 355-361.

Coley DA, Goodliffe E, Macdiarmid J. The embodied energy of food: the role of diet. Energy Policy 1998; 26:455e9.

Chaudhary V P, Gangwar B, Pandey D K and Gangwar K S. 2009. Energy auditing of diversified rice–wheat cropping systems in Indo-Gangetic plains. *Energy* **34**: 1091–6.

Ershad S M E. 2005. Performance of hybrid layers and native hens under farmers' management in a selected area of Bangladesh. *International Journal of Poultry Science* **4**(4): 228–32.

Erdal G, Esengun K and Guduz O. 2007. Energy use and economic analysis of sugar beet production in Tokat province of Turkey. *Energy* **32**: 34–41.

Esengun K, Erdal G, Gündüz O and Erdal H. 2007. An economic analysis and energy use in stake-tomato production in Tokat province of Turkey. *Renewable Energy* **32**: 1873–81.

Frei M and Becker K. 2005. Integrated rice-fish culture: coupled production saves resources. *Natural Resources Forum* **29**(2): 135–43.

Fadavi R, Keyhani A and Mohtasebi S S. 2011. An analysis of energy use, input costs and relation between energy inputs and yield of apple orchard. *Research in Agricultural Engineering* **57**(3): 88–96.

Gupta, A.K., Yadav, D., Dungdung, B.G., Paudel, J., Chaudhary, A.K. and Arshad, R. 2020. Integrated farming systems (IFS) – a review paper. *Int. J. Eng. Appl. Sci. Technol.*, **4**(9): 134-137.

Kashyap P, Kansal A, Prusty A K and Singh J P. 2015. Evaluation of horticulture based IFS models for providing nutritional security to small and marginal farmers of Western plain zone of Uttar Pradesh. *International Journal of Economic Plants* **2** (1): 15–7.

Kashyap, P. et al. 2017. Resource integration for livelihood and nutritional security of farmers of Tehri Himalayas of India, *Indian Journal of Agricultural Sciences* 87 (9): 1196–1202.

Kashyap, P.; Prusty, A.K.; Panwar, A.S.; Paramesh, V.; Natesan, R.; Shamim, M.; Verma, N.; Jat, P.C.; Singh, M.P. (2022) Achieving Food and Livelihood Security and Enhancing Profitability through an Integrated Farming System Approach: A Case Study from Western Plains of Uttar Pradesh, *India. Sustainability* 2022, 14.

Khan, A. and Sengupta, A. 2018. An economic analysis on Integrated Farming System Model of Burakocha village in Angara block of Ranchi District, Jharkhand. *Int. J. Sci. Res. Dev.*, **6**(7): 2321-0613.

Mahapatra I C and Behera U K. 2011. Rice-based farming systems for livelihood improvement of Indian farmers. *Indian Journal of Agronomy* **56**(1): 1–19.

Patel N and Rajput T B S. 2003. Yield response of some vegetable crops to different levels of fertigation. *Annals of Agricultural Research* **24**: 542–5.

Patel, A.S., Patel, S.J., Patel, N.R. and Chaudhary, G.M. 2015. Integrated Farming of Crop and Livestock: A Review. *Int. J. Agric. Sci.*, **7**(12): 777-781.

Saxena R., Singh, N.P., Balaji, S.J., Ahuja, U., Kumar, R. and Joshi, D. 2017. “Doubling Farmers’ Income in India by 2022-23: Sources of growth and Approach NIAP”. *Agric. Econ. Res. Rev*... **30**(2): 265-277.

Singh A K, Singh B and Kumar R. 2012. Integrated nutrient management under protected agriculture. *System based Integrated Nutrient Management*, pp 223-37. Gangwar B and Singh V K (Eds). New India Publishing agency, New Delhi.

Singh D P, Singh K P and Yadavika. 1998. Integrated farming systems - a key issue for research education – extension linkages to sustain food security and ecofriendly environment in the 21st Century. In: Singh P, Prasad R, Ahlawat I P S (Eds.), Proceedings of the First International Agronomy Congress: Agronomy, Environment and Food Security for the 21st Century. Indian Society of Agronomy, New Delhi, pp. 474–486.

Singh, Hari & Sharma, S.K. & Dashora, L.N. & Burark, Sukhdeo & Meena, Girdhari. (2013). Characterization and economics of farming systems in southern Rajasthan. Annals of Arid Zone. 52. 67-70.

Singh, Hari & Burark, Sukhdeo & Sharma, S.K. & Jajoria, D. & Sharma, R P. (2017). Economic evaluation of farming systems for agricultural production in southern Rajasthan. Economic Affairs. 62. 47. 10.5958/0976-4666.2017.00025.0.

Singh, H. and Meena, G.L. 2021. Integrated Farming System: A profitable venture for Tribal farmers in southern Rajasthan. *Econ. Aff.*, **66**(2): 349-353.

Yadav R L and Prasad K. 1998. Farming systems research in India: needs and strategies. In: Singh P, Prasad R, Ahlawat I P S (Eds.), Proceedings of First International Agronomy Congress: Agronomy, Environment and Food Security for 21st Century. Indian Society of Agronomy, New Delhi, pp. 333–341.

Yadav G S, Debnath C, Datta M, Ngachan S V, Yadav J S and Babu Subhash. 2013. Comparative evaluation of traditional and improved farming practices in Tripura. *Indian Journal of Agricultural Sciences* **83**(3): 310–4.

Gopalan C, Shashtry B V R and Balasubramanium S C. 1971. *Nutritive Value of Indian Foods*, pp 47–58. National Institute of Nutrition (ICMR) press, Hyderabad.

Kumar Sanjeev, Kumar Ravi and Dey Amitava 2019. Energy budgeting of crop-livestock-poultry integrated farming system in irrigated ecologies of eastern India. Indian Journal of Agricultural Sciences 89 (6): 1017–22,

Moraditochaee M. 2012. Research energy indices of eggplant production in north of Iran. ARPN Journal of Agricultural and Biological Science 7(6): 484–7.

Ozkan B, Akcaoz H and Karadeniz F. 2004. Energy requirement and economic analysis of citrus production in Turkey. Energy Conversion and Management 45: 1821–30.

Ozkan B, Kurklu A and Akcaoz H. 2004. An input–output energy analysis in greenhouse vegetable production: a case study for Antalya region of Turkey. Biomass and Bioenergy 26: 89–95.

Pimentel D and Burgess M. 1980. Energy inputs in corn production. Pimentel D (Ed). Handbook of Energy Utilization in Agriculture, pp 67–84. CRC Press, Boca Raton, FL.

Rahman S and Barmon B K. 2012. Energy productivity and efficiency of the 'gher' (prawn-fish-rice) farming system in Bangladesh. Energy 43: 293–300.

Ram R A and Verma A K. 2015. Energy input, output and economic analysis in organic production of mango (Mangifera indica) cv. Dashehari. Indian Journal of Agricultural Sciences 85(6): 827–32.

Sefeedpari P. 2012. Assessment and optimization of energy consumption in dairy farm: energy efficiency. Iranian Journal of Energy & Environment 3(3): 213–24.

Singh S and Mittal J P. 1992. Energy in Production Agriculture, pp 6–12. Mittal Publications, New Delhi, India.

Singh Hari and Meena G.L. 2021. Integrated Farming System: A Profitable Venture for Tribal farmers in Southern Rajasthan. Economic Affairs, Vol. 66, No. 2, pp. 349-353.

Singh, Hari & Burark, Sukhdeo & Sharma, S.K. & Jajoria, D. & Sharma, R P. (2017). Economic evaluation of farming systems for agricultural production in southern Rajasthan. Economic Affairs. 62. 47. 10.5958/0976-4666.2017.00025.0.

Singh, Hari & Sharma, S.K. & Dashora, L.N. & Burark, Sukhdeo & Meena, Girdhari. (2013). Characterization and economics of farming systems in southern Rajasthan. Annals of Arid Zone. 52. 67-70.

Soni P, Taewichit C and Salokhe V M. 2013. Energy consumption and CO2 emissions in rain-fed agricultural production systems of Northeast Thailand. Agricultural Systems 116: 25–36.

Stout B A. 1990. Handbook of Energy for World Agriculture. Elsevier Applied Science, London.

Taki M, Ajabshirchi Y, Mobtaker H G and Abdi R. 2012. Energy consumption, input–output relationship and cost analysis for greenhouse productions in Esfahan Province of Iran. American Journal of Experimental Agriculture 2(3): 485–501.

Tuti M D, Vedprakash B M, Pandey R, Bhattacharyya D, Mahanta J K, Bisht M K, Mina B L, Kumar N, Bhatt J C and Srivastva A K. 2012. Energy budgeting of colocasia-based cropping systems in the Indian sub-Himalayas. Energy 45: 986–93.

Wells C. 2001. Total energy indicators of agricultural sustainability: Dairy farming case study. Technical Paper, MAF Information Bureau, P O Box- 2526, Wellington.