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Integrated farming for long-term viability of agriculture: A review

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Abstract
Integrated farming systems (IFS) and perspectives on them have changed across time and space. Crop and livestock yields grew over the past 20 years, along with worries about the socio-economic and biophysical trade-offs involved. In response to issues brought on by a predominately reductionist research methodology and a cornucopian view of external inputs, farming systems research (FSR) was applied to agricultural development. Modern technology either generated unintended unfavorable trade-offs or were not welcomed. This essay examines FSR definitions and forms as well as the necessity of modernizing how we approach agricultural growth. Numerous efforts have been made at the ICAR and State Agricultural Universities level to increase the productivity of the various farming system parts, such as crops, dairy, livestock, poultry, piggery, goat keeping, duckery, apiculture, sericulture, horticulture, mushroom cultivation, etc., but their integration into the farming system as a whole has lagged. The integration is designed so that the output of one component should be used as the input for other businesses with strong mutually beneficial relationships. According to the number, kind, and management of firms, preliminary research findings supported the advantages of productivity increases of 30–50%. Here, information on farming systems is given in a methodical manner. The methodology is described in light of the work completed thus far to achieve better productivity, profitability, and sustainable production opportunities, ensure reliable income, and promote agricultural-oriented industry.

Keywords: Integrated farming systems (IFS), modern technology, agriculture, sustainable production, socio-economic and biophysical trade

Introduction

Through agronomic practices like the widespread use of inorganic pesticides and fertilizers, a major rise in agricultural productivity was accomplished in the 20th century. Concerns about the viability and sustainability of the industry were raised, however, as a result of the unfavorable environmental degradation brought on by these practices, such as the excessive use and exploitation of pesticides and fertilizers as well as the rising costs of agricultural operations [4]. Although crops and other businesses coexist in such diversified farming, the main goal is to reduce risk, whereas in IFS, a thoughtful combination of one or more businesses alongside cropping has a complementary effect through efficient recycling of wastes and crop residues, which includes an additional source of income for the farmer. The main focus of IFS work is on a small number of interdependent, connected, and interlinking production systems based on crops, animals, and related ancillary professions. We have been able to provide a framework for an alternative development model to increase the viability of small-scale farming operations in comparison to bigger ones thanks to the creation of Integrated Farming Systems (IFS). The term "integrated farming system" (also known as "integrated agriculture") is frequently and generally used to describe a more integrated method of farming than monoculture methods. It is frequently referred to as "Integrated Biosystems," and it describes agricultural systems that integrate fish and livestock or livestock and grain production. An interconnected group of businesses are employed in this system so that "waste" from one component can be used as an input for another, lowering costs and increasing production and/or profitability. As a system of systems, IFS operates. IFS make sure that leftovers from one type of agriculture can be used in another type. Because it turns wastes into resources, we not only get rid of trash but also ensure that the entire agricultural system is more productive [9].

As an illustration, prices for inputs and outputs frequently fluctuate, as do dependency on outside resources, farm size, farm ownership, and farming practices, frequently as a result of and as a cause of growing population pressures [10, 11, 1]. Such variations in crop yield, market pricing, and farming practices, both within and between nations, represent the historical and spatial evolution of agricultural systems. Additionally, they represent (kind of) victories for the reductionist research philosophies that mostly concentrated on particular commodities like milk and grain [12, 13]. Low agricultural production makes it difficult for small and marginal farmers, as well as the 15 to 18% of landless households living in rural areas, to create profitable employment, and roughly 40% of families are compelled to live in poverty. Trans-migration, in which impoverished families are forced to move to struggling cities while abandoning their agricultural areas, may become a significant national concern due to a lack of food and financial stability. FSR provides the opportunity to potentially address issues with technological development. A farming system approach is becoming more popular among research organizations worldwide, with a strong focus on participatory on-farm research [14].

Definition of integrated farming

The practice of "farming" involves capturing solar energy to produce useful plant and animal goods. The term "system" refers to an arrangement of components or pieces that interact in accordance with some procedure and convert inputs into outputs [7]. It also suggests a collection of linked practices and processes that have been organized into a functioning entity.

Goals of Integrated Farming System

- **Production sustainability:** To increase output while having the least possible negative impact on the environment, IFS aims to minimise waste production and make the best use of its own resources, mostly by utilising the byproducts of one enterprise as a source of raw materials for another.
- **Productivity gains:** By adopting an integrated farming system (IFS) and intensifying agriculture and related sectors, the economic yield per unit area per unit time can be increased.
- **Profitability:** IFS reduces the cost of cultivation, increasing the benefit: cost ratio. This is done by effectively recycling waste materials from one business to use as input in another business that is connected to it.
- **Soil health:** The use of organic manure and pre-existing waste materials as inputs in IFS improves soil health.
- **Food that is balanced:** By using a farming system that combines a variety of enterprises, each of which produces a different type of nutrition (protein, carbohydrates, fats, minerals, vitamins, etc.) from the same plot of land, the widespread issue of malnutrition among marginal and sub-marginal farming households can be reduced.
- **Environmental safety:** A sustainable agricultural system uses byproducts or waste products from one component as inputs in another and incorporates bio-control technologies for the management of pests and diseases. These environmentally friendly techniques directly result in a decrease in the use of dangerous chemicals. As an alternative, IFS can drastically reduce pollution.
- **Cash flow throughout the year:** In addition to crop cultivation, IFS is home to a large variety of companies that make money all year long by selling goods like eggs from poultry, milk from dairies, fish from fisheries, silkworm cocoons from sericulture, honey from apiculture, etc.
- **Employment generation:** Multiple auxiliary operations on a farm increase labour demand, which in turn enhances the farm's capacity to recruit and retain people. This is especially beneficial for solving the underemployment problem in rural areas.
- **Saving energy:** Finding a solution to significantly reduce our reliance on fossil fuels is currently a top priority in the effort to save energy. The system's organic wastes can be turned into biogas with the correct kind of recycling technology. In addition to burning waste items, briquetting stubbles can be utilized to produce electricity and lessen environmental damage.
- **Meeting the fodder crisis:** This system makes effective use of every piece of land. By planting perennial legume fodder trees along field borders that symbiotically fix atmospheric nitrogen, the shortage of access to high-quality fodder for the animal component can be lessened.
- **Establishment of agro-industries**: It is also important to keep in mind that once a farming system has stabilized and reached a commercial level of production, there will be an excess of product available for value addition, which will in turn spur the growth of ancillary agro-industrial sectors in the area.
- **Enhancing Input Efficiency:** The IFS's flexibility allows inputs to be utilized in various components, which enhances input efficiency and the benefit-to-cost ratio.

Benefits of Integrated Farming Systems

- Enhanced productivity through higher economic yields per unit area per time as a result of crop and related industry intensification.
- Increased profitability was primarily attained through cost savings through the recycling of one company's trash as fuel for other systems.
- Due to the integration of many businesses with varying economic relevance, agricultural production is more sustainably produced. Recycling garbage is incorporated into the system, which reduces reliance on external high-energy inputs and preserves natural and limited resources.
- Because a range of food products are produced, integrating various production systems offers a chance to address the issue of malnutrition.
- Recycling trash for use in manufacturing aids in preventing waste buildup and the resulting pollution.
- The farming technique gives the farmer a continuous flow of income through the sale of eggs, milk, edible mushrooms, honey, silkworm cocoons, etc. This will assist farmers with limited resources in escaping the grasp of lenders and collection agencies.
- Cash accessible throughout the year due to the links between dairy, mushrooms, sericulture, fruit, vegetable, and flower agriculture, among other industries, may encourage small and marginal farmers to use new technologies like fertilizer and pesticides.
- The need for chemical fertilizer is decreased by recycling organic waste. The production of biogas can also supply all of the energy needed for a home. In order to address energy emergencies, IFS is quite helpful.
- Included species of forage, pasture, and trees aid in increasing forage production and, in part, resolving

fodder shortages.

- Fuel and wood for construction are provided by the Silvi component of the system.
- Farming systems with a timber component put less stress on forests.
- A more comprehensive knowledge base is required by an integrated farming system, which raises literacy levels.
- Overall, IFS benefits farmers by supplying them with items such edible mushrooms, fruits, eggs, milk, honey, veggies, etc.

Components of integrated farming system & its modeling

Crops, creatures, birds, and trees are the fundamental elements or constituents of any IFS. A crop may consist of multiple tiers of cereals, legumes (pulses), oilseeds, and pasture, or it may be grown as a monoculture, mixed/intercrop, or multi-tier crop. A milk cow, goat, sheep, chicken, or even bees might be considered livestock. The fruits of trees can also be used as fuel, food, and building materials. The main elements of integrated farming systems that are applicable to all agroecological zones in the nation include crop production (including the raising of vegetables), dairy, poultry production (both layer and broiler), goat and sheep rearing, piggery, fish farming, duck and turkey rearing, quail and rabbit rearing, beekeeping, sericulture, etc.

Building farming systems that are more effectively integrated is essential as we transition to agricultural practises that are more effective, economical, and environmentally benign. To prevent harmful impacts on the environment and increase production efficiency, it is necessary to properly integrate the production of feed, use of animals, and recycling of waste.

When crop and fish culture are joined with poultry, preferably close to the fish pond, the extra advantages of a crop-fish-poultry integrated agricultural system are also realised. The crop portion meets the necessities of the household as is customary. Chickens can be fed with other agricultural byproducts, and straw and other farm waste can be used as bedding. Processed poultry manure can be added directly to the fish pond without the need for extra fertilizer, manure, or feed supplements.

You can classify an IFS model as either a simulation model or a linear programming model. Since it doesn't focus as much on illuminating the fundamental mechanisms that underlie the system, the linear programming approach is frequently used in economic research. With this configuration, the optimal answer is found by simultaneously solving a number of equations that describe the production system. While in the simulation model, the emphasis is primarily on utilising mathematics to explain how the components of a farm interact and to calculate their output as a function of time. So, in order to get an idea or estimate of the performance of the farm for the predefined enterprises undertaken under the prevalent agroclimatic conditions of the locality, simulation typically tracks farm processes over a long period of time while taking into account the weather conditions over the farm. Integrated simulation modelling is a key tool for optimising the use of by-products and for reducing the complexity of the intricate relationships between the numerous enterprises carried out in a certain IFS. In order to maximise benefits while maintaining sustainability, various input parameters must be optimised using multi-criteria decision analysis, which integrates linear programming and simulation modelling to handle the input-output flow of resources.

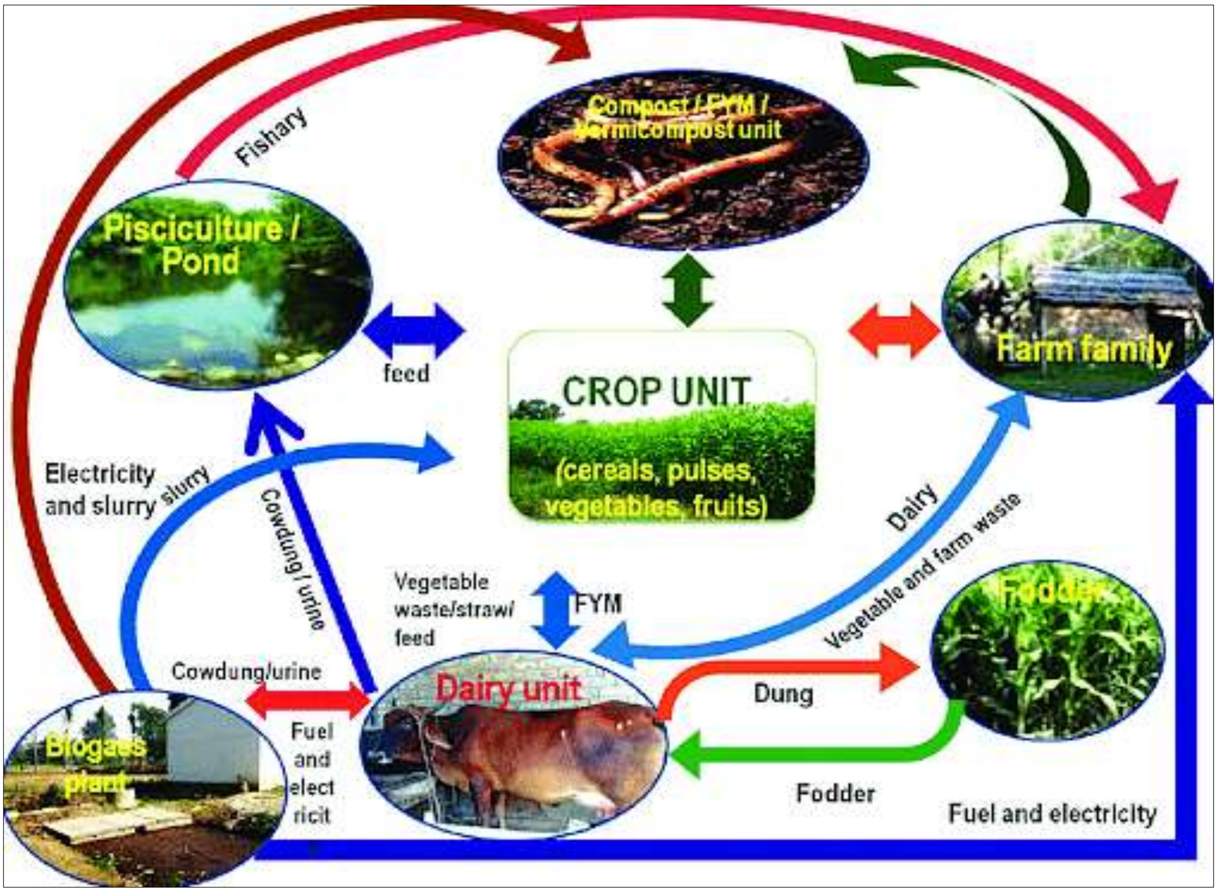

Fig 1: Cycle of integrated farming system

Processing carried out on-site and value addition

Consumer preferences for graded, packaged, and processed food goods used on a regular basis in urban markets, particularly among the middle and upper classes, have already undergone a significant adjustment. In the coming years, when more department shops emerge in townships and begin selling food at low costs, this tendency will undoubtedly spread to rural areas as well. Improved low-cost technologies are necessary to unlock potential, increase market effectiveness, and maintain competitiveness all at once. Additionally, recent patterns have unmistakably demonstrated the increased utilisation of by-products for value addition. For instance, sugar mills today utilise every by-product of sugarcane, including molasses for the manufacturing of alcohol and bagasse for the production of electricity, to make money. Pressmud is also used to create high-quality organic manure. Similar to this, in the case of rice, husk is utilized as a very effective source of fuel in boilers and bran is used to obtain edible oil. Following the advent of refining technology, several vegetable oils that were once thought to be inedible are now widely utilized as edible. It is a given that farmers will have access to all of these technologies for adding value.

One type of IFS is called "Integrated Food and Waste Management Systems" (IF&WMS), which was created by Prof. Chan. The Montfort Boy Farm in Fiji, a vocational school that now serves as a model for the pupils to duplicate in their villages (A Primer on Integrated Farming Systems), is where he first presented this idea. There are many IF&WMS or IFS models available today. These systems combine livestock, aquaculture, agriculture, and agro-industry into an expanded symbiotic or synergistic system so that wastes from one process are used as inputs for other processes, with or without treatment, to provide the production means such as energy, fertilizer, and feed for maximum productivity at the lowest possible cost. Numerous farmers around the world use the IFS concepts. Having a combination of crop and livestock enterprises, as well as maybe combinations of aquaculture and trees, is a frequent feature of these systems. It is a part of farming systems that considers the notions of lowering risk, boosting overall productivity and profits by reducing external inputs through recycling, and enhancing the utilization of organic wastes and crop leftovers. This type of integration typically takes place when, within the framework of agricultural systems, the outputs (mostly by-products) of one enterprise are used as inputs by another. Enterprises in integrated farming systems interact ecologically, spatially, and with one another, in contrast to mixed farming, which does not.

Examples include

1. "Pig tractor" systems, where animals are kept in confinement in crop fields well before planting and "plough" the field by sifting through roots; "chicken tractor"
2. Using chickens to remove bad fruit and weeds while fertilizing the soil in orchards or vineyards after harvest
3. On farms that have both farmland and grassland, cattle or other livestock are permitted to graze cover crops in between crops.
4. Agrosystems based on water that allow for the effective and efficient recycling of farm nutrients, producing fertilizer, fuel, and compost tea/mineralized irrigation water in the process.

Farming Systems Approach

As it became clear that the farming community was considerably more varied than previously believed, the drawbacks of the reductionistic, command-and-control approach to agricultural research became more and more obvious. Farmers in underprivileged areas (as well as those in South American countries) did, in fact, fight these developments and did not adopt the technology packages. This brought to light the necessity to evaluate technology advancements on more than just their short-term effectiveness. Additionally, they required to be adaptable [15] and take into account the farmers' thoughts on the future, their sense of security, as well as their long-term objectives and farming practices [16, 17]. As a result, it was acknowledged that the study strategy needed to be more integrative, systematic, and thorough [18] and that different spatial and temporal scales needed to be considered [16]. Additionally, the limitations of a suggestion based on research were recognised, along with the necessity of adopting an actor-oriented strategy to assure compliance with the socioeconomic context [19]. As a result, there is a new developmental paradigm that Korten describes as a "people-centered learning process" as opposed to the previous "technological blueprint" approach [20]. As a result, the late 1970s farming systems approach was characterised by an interdisciplinary approach (i.e., collaboration between a wider range of disciplines and the inclusion of socio-economic elements) [21] and the participation of farmers in the research process [22, 23]. At first, the emphasis remained on ways to raise the yields of certain crops. In the early days of farming systems, one particular enterprise (or portion of an enterprise) was examined in order to discover changes that might be made while still preserving the integrity of the entire agricultural system [19]. Multiple developments were made possible by this strategy.

- The complexity and variety of farmers' production environments were being recognized by technical scientists more and more. The necessity to incorporate the farmer, with his or her norms and beliefs, decisions, and laws, as a component of the systems they investigated was also noted. They understood that this environment was made up of both physical and social components.
- The farm is viewed as a single system [24]. The farmer, the herd, and the resources are all considered to be part of the same sociotechnical system in the livestock farming system approach advocated by animal scientists) [25]. The system's (self-)regulation characteristics, based on interactions between its constituent parts (information flows, modifications to decision rules, and biological homeostatic controls [26, 27] at various time scales), could theoretically and practically be accounted for in a model, such as Cournut and Dedieu's flock operation model [28].
- The maximization of profit was not the only way economists could explain farmer conduct [29] (Colin and Crawford, 2000). Petit's hypothesis of adaptive conduct, published in 1978 and 1981 [30, 31], Demonstrates how farmers alter their goals and circumstances in real-time. In making decisions for farmers and farm households, factors including long-term desires, security, lifestyle, and quality of life are also taken into account [2, 3, 4].

By combining diverse farm businesses and recycling crop leftovers and byproducts on the farm itself, the method seeks to increase income and employment from small holdings [5, 6].

Empowerment of women through IFS

Women are crucial to home administration, especially agricultural activities. For tribal and hilly places in particular, this is true. By utilizing family labor wisely, adopting creative strategies, and ensuring that different home resources are used in varied ways, it is possible to significantly increase household profitability. Women's empowerment through site-specific trainings and support for crucial needs makes this possible. The importance of women's roles in agricultural and family resource management will grow as educational standards rise in the coming years. As a result, long-term feminization of agriculture is anticipated, and creating women-centric farming system models will be extremely difficult given the migration of males into rural non-farm sectors [14].

Conclusion

As a promising and long-lasting response to the complex issues facing modern agriculture, integrated farming systems have arisen. They support resource efficiency, the preservation of biodiversity, and resilience while providing a wide range of environmental, economic, and social advantages. For integrated agricultural systems to be widely adopted and to be implemented successfully on a large scale, more research, capacity building, and governmental assistance are necessary. A more robust and sustainable agricultural future can be promoted by embracing integrated farming systems. Additionally, integrated farming methods support the socioeconomic growth of rural communities. They increase food security, create job possibilities, and support rural entrepreneurship. These systems frequently encourage regional food production and lessen reliance on imported supplies, so boosting local populations' resilience to external uncertainty. Nevertheless, there are difficulties in implementing integrated farming systems. To achieve efficient integration and ideal performance of various components, the necessary knowledge, technical abilities, and management ability are needed. Because of the complexity of these systems, it is imperative that farmers, researchers, politicians, and other stakeholders work together in a multifaceted and interdisciplinary manner.

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