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INTEGRATED FARMING SYSTEM AN ECO-FRIENDLY AND SUSTAINABLE APPROACH FOR PROMISING FARMERS INCOME UNDER CLIMATE CHANGE SCENARIO - A REVIEW

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ABSTRACT

Climate change is emerging as a major threat to farming, food security and the livelihoods of millions of people across the world. Agriculture is strongly affected by climate change due to increasing temperatures, water shortage, heavy rainfall and variations in the frequency and intensity of excessive climatic events such as floods and droughts. Farmers need to adapt to climate change by developing advanced and sophisticated farming systems instead of simply farming at lower intensity and occupying more land. Climate smart agriculture architecture for fostering and supporting integrated agricultural systems, such as Mixed Farming Systems (MFS), by facilitating the design, the deployment and the management of crop-livestock-forestry combinations towards sustainable, efficient and climate resilient agricultural systems. Integrated farming systems (IFS) is an eco-friendly approach in which waste of one enterprise becomes the input of another thus its make more efficient use of resources from the farm. IFS as a mixed farming system that consists of at least two separates but logically interdependent parts of a crop and livestock enterprises. IFS helps in improving the soil health, weed and pest control, increase water use efficiency and maintains water quality. In integrated farming system the use of harmful chemical fertilizers, weed killers and pesticides should be minimized and also provide safeguards to the environment from the adverse effects. Integrated farming system improves economic condition of the small and marginal farmers which enhanced the education, health and social obligations and overall improvement in livelihood security. Through IFS approach the use of chemicals (fertilizers and pesticides) can be reduced to provide chemical free healthy food to the society. Adoption of Integrated Farming System (IFS) leads to sustainability and stability in farm income through multiple enterprises that aim at maximum utilization of available natural resources to meet the family needs.

Keywords: Integrated Farming System, Eco-friendly, Sustainable crop production, Climate resilience

Introduction

India has become self-sufficient in the production of food grains due to introduction of semi dwarf varieties and the green revolution in early 1960's. By the extensive cultivation of selective crops like rice and wheat in irrigated regions, the nation today has reached honourable heights in food production and self-sufficient in food grain production. But all these achievements occurred at the cost of resource degradation, plateauing productivity (no further increase in crop productivity and reaching saturation), non-profitability, increased greenhouse gases emissions, depletion of water resources and declining soil health *etc* (Behere and France, 2016). Rapid population growth, urbanization, shrinking land resources in the country and increasing cost of agricultural production practically there is hardly any scope for horizontal expansion of land for food production. Only vertical expansion is possible by integrating appropriate farming components that require lesser space and time to ensure reasonable periodic income to farm families (Gill *et al*., 2009).

As such many of complicated issues affect Indian agriculture, mainly diminishing factor productivity, inefficient resource usage, a smaller share of agriculture sector in the economy (17.7%), a high population reliance on agriculture and related industries (52%), and a greater emphasis on the production of annual cereal crops. Another significant threat to the profitability and sustainability of Indian agriculture is the shrinking size of land holdings. The average holding size per person is still 1.1 ha and India has the second-highest amount of arable land in the world (143.0 M ha), accounting for only 44% of all operating land in the country. More than 86% of agricultural households in India are small (< 2.0 ha) and marginal (< 1.0 ha) farm holders, who operate in risky production environments. Most farmers lack important farming equipment and resources, like draught animals, reliable irrigation systems, fertilizers, pesticides and farm machinery which are required for achieving high production (Anonymous, 2022).

The farmer, as a decision maker makes three decisions in farm planning: what to produce, how to produce and how much to produce. To solve those above mentioned inter-related problems farmer must choose between alternate uses of the resources at his or her disposal. In this type of agricultural production system, achieving sustainable crop productivity and profitability requires a solid connection between climate-smart agriculture and the needs of the farmer. In such circumstances, integrating crop production with other agricultural businesses under an integrated farming system (IFS) can lead to increased system productivity, resource efficiency and also employment generation.

Integrated farming system is defined as ‘‘it is a complex of farm and allied enterprises located on the same land interacting with each other towards a common goal of satisfying human needs, maintaining ecological balance and achieving the sustainable crop productivity and profitability’’.

IFS has proven to be the most viable option representing various combinations of agriculture and allied activities *viz*. cropping system, horticulture, forestry, livestock, poultry, goatery, sericulture, duckery, fishery *etc*. Different components of the IFS have complementary effects on one other, by products or waste of one component will be the food or source of energy for the other component, there by reduces the environmental pollution through recycling of farm waste generated within the farm itself and it reduces the dependence on outside farm inputs (cost effective). Animal and plant waste directly or by composting is added to soil, as the large amount of farm waste will be generated in the IFS because of integration and it helps in improving the soil physical, chemical and biological health.

IFS for nutrient recycling and resource use efficiency

In farming systems different components or enterprises are integrated so that they will complement with each other in terms of utilization of resources generated within the farm. By using different natural resources generated on the field, it reduces the farmers' dependence on market or purchased inputs and also on natural resources.

An IFS experiment was conducted by Kumar *et al*. (2017) in main farm, eastern region ICAR research complex for 4 years (2012- 15) in 0.8 ha area. They concluded that combination of crop + duck + fish + goat has produced good quantity of manure *viz*., from poultry - 2.3 tons / year, duckery - 1.6 tons / year, goatry - 2.9 tons / year, cattle - 14.0 tons / year and plant residue - 11.3 tons / year. This generated waste was recycled in the form of FYM, vermicompost, feed *etc*. Waste recycling has produced 56.5 kg N, 39.6 kg P, 42.7 kg K and it was added to the soil system and reduced the cultivation cost by 24%.

Kumara *et al*. (2017) conducted a study on IFS at Devangere dist. of Karnataka State under irrigation condition with an area of 1 ha. from 2013-2016. IFS model including crop + horticulture + dairy + sheep generated 41,749 kg/l/no's of farm waste. The above IFS model requires 300 kg/ha inorganic fertilizers and 3000 kg/ha organic fertilizers. The nutrient availability from the farm waste was 462.50 kg from all sources. As the source is organic, the availability of nutrients will be around 25-30 percent in the year, it is estimated that around 35 percent of the nutrient requirement of present IFS model can be met from recycled products that generated within the system. It reduces the investment on chemical fertilizers in addition it enhances the soil health, by increasing organic matter and microbial enzyme activities in the soil.

An IFS experiment conducted at MPKV, Rahuri by Surve *et al*. (2015), revealed that water use productivity of IFS model (Crop + horticulture + dairy + poultry + fishery) was high at Rs. 991 ha. cm in comparison to conventional farming (soyabean + wheat + fallow) which was Rs. 406 ha. cm. Higher water use productivity in IFS model was because of greater biological activity, efficient utilization of water (because of inclusion of diversified components viz., crop, horticulture, dairy, poultry, fishery).

IFS for improved soil health

To maintain the sustainable production, there is every need to maintain the soil physical, chemical and biological health. To maintain the soil health, addition of organics to soil is pre requisite. In IFS model, from different components organic wastes are generated and those can be recycled in the system by making vermicompost, compost, direct residue incorporation into soil etc. which helps in increasing the organic carbon and microbial activity of the soil. Organic wastes contain essential nutrients in addition it is source of energy to microorganisms. It is also found to be economical as it saves the investment on chemical fertilizers.

IFS model developed in 1 acre for NE India, includes agriculture + horticulture + fishery + poultry has increased the soil health positively. There was increase in the organic carbon, available N, available P, available K by 0.06%, 4 kg/ha, 1 kg/ha, 4 kg/ha respectively after completion of 3 years of IFS practice over initial. This is due to recycling of farm waste *i.e.* poultry waste, crop stubbles, weeds through vermicomposting and its subsequent application in field thereby increasing soil physical, chemical and biological health of soil in long run (Kumar *et al*. 2018).

Ponnusamy and Devi (2017), surveyed the 2 districts of Tamil Nadu and 4 districts of Haryana and observed that an adult cow, buffalo, goat, piggery, sheep, poultry produces manure at an average of 10767, 11862, 638, 1460, 635, 11 kg/year respectively that gives an economic return of 6460, 5100, 319, 627, 319, 616 Rs/year respectively. Similarly, an adult cow, buffalo, goat, piggery, sheep produces urine at an average of 5146, 4453, 255, 547, 317 L/year respectively that gives an economic return of 3087, 1914, 127, 235, 158 Rs/year respectively. Manure and urine increase the soil health by means of increasing the soil aggregation, soil structure, nutrient availability, microbial growth etc.

Vinodakumar *et al*. (2017) conducted an IFS field experiment at NE Karnataka from 2012- 14 and noticed that IFS model crop + goat + poultry birds + HF cow + fishery generated 10 times more crop residues than the crop alone (cotton) cultivation in same piece of land. Similarly, IFS model added 19 times more N, 22 times more P, 7 times more K through residues than the crop alone cultivation. After two years of experimentation there was more net gain in available N, available P, available K (316, 41, 361 kg ha^{-1} respectively) than crop alone cultivation (264, 37, 192 kg ha^{-1} respectively).

IFS an eco-friendly approach

Under the stress of intensive agriculture, environmental degradation has been reported in many economically developed countries from excessive use of high energy inputs such as fertilizers and pesticides. There is a degradation of natural resources due to excessive exploitation by monocropping, continuous growing of exhaustive crops and thus causing the ecological imbalances. To maintain the ecological balance and prevent the degradation of natural resources IFS is very helpful strategy as it involves recycle and reuse of inputs, the harmful by products released from one enterprise can be used as input for other enterprises within the system or it can be converted into less harmful system by decomposing.

Also, emissions from the agriculture and dairy enterprises can be captured and used in bio gas plant for fuel purpose. The wastes that are generated can be used as feed for livestock, composting. Furthermore, IFS system also maintains bio diversity because maintaining the diverse enterprises on the farm is important for maintaining the diversity in the farm, so the ecosystem quality will be enhanced, which provides the ecosystem services effectively (pollination, climatic control, disturbance regulation, pharmacological resources, landscape opportunity).

Datta *et al*. (2009) noticed that integration of rice with fish cultivation was found to be economically sound and environmentally secured form the profit to CO_2 equivalent emitted under flooded low land condition. Rice integration with fish increased the CH_4 emissions and reduced the N_2O emissions from rice fields in comparison with the rice alone cultivation. The percent increase in CH_4 emission was 93 percent and N_2O emissions decreased by 25.5 percent in rice fish integration compared with the rice alone cultivation. Integration of rice with fish resulted in 4.5 times more net profit than the rice cultivation alone. Nevertheless, integration generated 1.76 times more CO_2 equivalents than the rice cultivation alone. When compared with the profit per unit CO_2 equivalent emitted, rice integrated with fish has more value than rice cultivation alone.

Rati *et al*. (2016), conducted a study in two districts of Haryana, India and revealed that integrated farming system was the best approach in reducing the greenhouse gases emission than the reduced tillage, organic farming, improved rice cultivars which emit less methane, adaption of precision farming practices *etc*.

Xu *et al*. (2017) conducted an experiment on integration of rice - duck farming in Baimei farm, Nanjing agricultural university and noticed that the total global warming potential (GWP) of integrated rice – duck farming was 13.3 percent less than the conventional rice cultivation. The rice yields were 1.68 percent higher in the integrated rice – duck farming than the conventional farming (rice cultivation). The reasons for the reduction in the GWP in integrated model was due to bioturbation of ducks in the rice fields, with this availability of oxygen to the methanotrophs increased so that methane oxidation increased which reduced the methane emissions from the fields. In rice – duck farming, ducks feed on weeds, insects and planktons, reducing the oxygen consumption of weeds, insects and placktons, so that dissolved oxygen and redox potential in the water layer increased (oxidising layer increased). So, the methanogenic bacteria became inactive. Other important reason for the reduction in the methanogenic bacteria was the decrease in weeds, insects and placktons, which were fed by ducks. So, the food to the methogenic bacteria was reduced.

IFS for sustainable crop production

Sustainability in the crop production can be achieved through IFS as it involves diversified cropping, horticulture *etc*., moreover it does not exploit too much natural resources requiring the limited external inputs and assuring the required crop productivity. Thus, IFS can be considered as a tool to achieve sustainability in production in agriculture and allied enterprises. Implementation of the Integrated Farming System leads to sustainability and constancy in farm income through multiple enterprises that aim at the utmost utilization of available natural resources to meet the family desires.

Fatima *et al*. (2023) reported that concerning environmental sustainability, the combination of crop + dairy + fishery + poultry + duckery + apiary + boundary plantation + biogas unit + vermicompost recorded considerably higher energy output (517.6 × 103 MJ ha^{-1}), net energy gain (488.5 × 103 MJ ha^{-1}), energy ratio (17.8), and energy profitability (16.8 MJ MJ^{-1}). Furthermore, the system had the lowest greenhouse gas (GHG) intensity (0.164 kg CO_2 equivalent per kg food production). They concluded that an appropriate combination of diversified and complementary enterprises in a form of IFS model is a productive and environmentally robust approach for sustainable food production in the north western part of India.

Patel *et al*. (2020) revealed that integrated farming system with cropping system along with other subsidiaries livestock, boundary plantation, seasonable vegetables, horticultural crops, vermin compost and farm pond is the most beneficial system which can augment the income of small and marginal farmers to improve their socioeconomic status with assured livelihood and nutritional security for long term in North Gujarat Agro Climatic Zone.

An integrated production system encompasses diverse enterprises and is a complex entity that needs precise estimation of energy input–output relationships and economic and environmental sustainability. Co-culturing of rice, turtle, and fish was found to be an energy and economically efficient system compared with rice monoculture (Liu *et al*., 2019).

Korikanthimath and Manjunath (2009) carried out an experiment at ICAR Research Complex Goa. On rice-based IFS revealed that rice-brinjal + mushroom + poultry as best one interns of rice equivalent yield (21.49 t/ha), employment generation (392-man days), energy efficiency and economics. In coconut gardens, integration of fodders (napier bajra hybrid + *Centrosema*) for supporting dairy unit proved the best based on above criteria used in rice-based IFS. Similarly, integration of cardamom in are canut gardens, arable crops and livestock in cashew nut, and poultry/duck-fish IFS were found more profitable and sustainable.

IFS as a tool to meet the household needs

The basic household needs can be broadly categorized into food and nutrition, fuel, energy, shelter, clothing, income *etc*., an IFS model will support and provide these basic requirements because it is integration of many enterprises.

Panwar *et al*. (2018) conducted and experiment which comprised of one hectare area with 5 members family farming model comprising of diversified cropping systems (0.78 ha) + horticulture (0.14 ha) + dairy (2 cows) + goat (11 no’s) + fish (0.1 ha) + ducks (25 no’s) + boundary plantation (subabul, 225 plants & Moringa, 50 plants) developed for the South Bihar Alluvial Plain zone. The diversified cropping systems [rice - wheat - greengram (grain + residue incorporation), rice - maize + potato - cowpea (fodder), rice - mustard - maize (grain) + cowpea (fodder), sorghum + rice bean – berseem / oat- maize + cowpea (fodder) and seasonal vegetables (brinjal, tomato, cauliflower, cabbage, vegetable pea, okra, lettuce) grown in 0.78 ha area could meet the full family requirement of 1100, 95, 125, 185 & 640 kg of cereals, pulses, oilseeds, fruits (guava & papaya) and vegetables and livestock requirement of 29.5 & 6.6 t of green and dry fodder per annum. The model also meets the milk, egg and fish requirement of 550 litres, 900 no's and 120 kg respectively. The model also ensured fuel wood availability of 4 t/ year for the family and could add 4 t of enriched vermicompost and 2.3 t of manure to improve the soil health. Besides meeting the family and livestock requirement, the model produced marketable surplus of 4810, 986 and 35 kg of cereals, vegetables and fruits with surplus of milk, egg and fish of 4243 litres, 950 numbers & 124 kg respectively which resulted in round the year income. It provided round the year income which ranges between Rs 13,160 (September) to 51,950 (April)/ha/month The value of recycled products and by-products model works out to be Rs 1.29 lakhs which reduces the total cost (Rs 3.1 lakhs) of the model by 42%. The family labour (730-man days) contributed to save 37% of cost. Hence, only 21% (Rs 0.68 lakhs) of total cost is involved in the form of inputs purchased from the market. A total net return of Rs 3.14 lakhs which is 3.2 times higher than existing pre-dominant crop + dairy system of the zone.

Sheikh *et al*. (2021) revealed that Integrated Farming System (IFS) is the main source of livelihood of nearly 65% of rural masses dependant on agriculture. IFS is holistic approach and considers interactions among the different component of IFS. Specialized Integrated Farming System (SIFS) has been developed with 4 components *viz*., basal crops, medium duration cash crops, super short/short duration cash crops and value addition. The study was conducted during 2009–2012 in villages of Barabanki and Raebareli districts of Uttar Pradesh, India. Out of 42 families for whom data was recorded and evaluated, 24 families followed the rice-wheat-oilseeds cropping system, reared cow/buffaloes (1-3 Nos.) and vegetables on part of the land. Also, in the SIFS model, rural poultry, off season vegetables and gladiolus were used for resource generation and expansion of the livelihood base.

IFS for employment generation

Farm labour who depends on agriculture, remain unemployed for 1/3rd of the year, because farm activities engage them in cropping season, while they remain un employed during off season. But the IFS model helps in gaining handful of employment, especially to family members due to maintenance of diverse enterprises which are linked to each other, resulting in more labour employment (man days).

Kumar *et al*. (2012) noticed that integration of crop + fish + duck + goat has produced 752 man days which was followed by crop + fish + cattle (722 man days) which was much more than conventional farming (rice - wheat). Even in the crop component, employment generation was increased due to diversification of crops. Integration of diverse components increased the labour requirement which helped the farmers to get employment year-round and had scope for employment to family labour even in lean periods when compared with tradition system.

Sharma *et al*. (2017) developed 2 IFS models, One 3.5 acre model for rainfed and the other 1.5 acre model for irrigated systems. The models generated employment of 659 and 1033 man days respectively. The extra employment generated in irrigation system is due to intensive cultivation, animal husbandry activities and diversed nature of enterprises compared with rainfed model. This helps in engaging the family labour more time in field and increases the employment in rural areas.

Govardhan *et al*. (2018), conducted an IFS experiment in Telangana state, and concluded that IFS model including crop + dairy + sheep + rabbit + hen + quails generated 750 man days of employment whereas rice – maize cropping system, a prevalent cropping system in the state generated 225 man days of employment in 1 ha. area.

IFS for generation of income and profitability

In India most of the farmers are small and marginal land holders and such small holdings are not economically viable to farmers in the present economic scenario.

Vinodakumar *et al*. (2017) reported that IFS model crop + goat + cow + poultry + fishery gave higher net returns Rs 1,89,069/ha/yr compared to conventional cotton alone 74,552.0/ha/yr, which was 2.5 times less than the IFS system. This may be due to inclusion of livestock component in the system which generated regular income to farmer.

Mitra *et al*. (2018) observed that the IFS model fish culture + duck farming + azolla + pulses, given 3 times more income (Rs 1,38,673/yr) compared with conventional farming (Rs 45,320/yr) and in a sustainable manner. The benefit cost ratio in IFS model is 2.28 compared to conventional model (1.14).

Kashyap *et al*. (2017) noticed that, in the beginning years of IFS, crop component enterprise was most prevalent and gave highest income. As the years progressed, the sizeble contribution of dairy, goatery, horticulture enterprises to income increased. In addition to it value addition has started generating income. As diversification increased, income increased and reduced the dependency on single enterprise.

IFS as a resilience tool for climate change scenario

Using process-based model simulations to represent an annually grazed cover crop rotation with soybeans typical of southern Brazil, we showed that livestock integration with best management practices resulted in higher field-level productivity and resilience to chronic climate stress compared to a similar specialized system (no livestock integration). Winter grazing often resulted in yield penalties (up to 1,200 kg ha^{-1}) for soybean in rotation, but this penalty was typically outweighed by the additional benefit generated by animal production. Field-level productivity (including income from both crop and livestock enterprises) was higher in the integrated system in 77% of years under historical climate conditions and in 95% of years under future climate conditions. While in many cases the multifunctionality of the integrated system was reflected in superior resilience to weather anomalies and to chronic climate stress under future conditions, outcomes were dependent on disturbance type (Peterson *et al*., 2020).

According to Nasr *et al*. (2020) rural areas in semi-arid Tunisia are characterized by overall vulnerability (more than 80%). It showed that income and access to food (IFA), adaptive capacity (AC), and productive and non-productive assets (AA) are key determinants of farm's resilience levels. Irrigation water access and diversification of farmers' activities are the main adaptation strategies adopted by farmers. Crop diversification is adopted as an adaptation strategy against climate change.

Seo (2010), Martin *et al*. (2016), and Gil *et al*. (2017) who conclude that integrated farming systems are more resilient under global warming than specialized farms. The use of family labour can also be considered as a positive factor of adaptive capacity, especially during peak periods such as sowing and harvesting periods. Thus, 48.3% of surveyed farmers use family labour.

Conclusions

It can be concluded that diversification of existing farming systems with change in crop (s), cropping systems, addition and improvement of livestock components, inclusion of horticulture, kitchen garden, primary and secondary processing, boundary plantations are essential to improve the on-farm income of small holders in India. This also paves way for meeting the household demand of balanced food, improved recycling of nutrients and water besides increasing the on-farm employment for family. Diversification of existing farming systems clearly demonstrated the advantages. It has been observed that productivity gain of 2 to 3 times and increase in net return of 3 to 5 times is possible with improved systems. Further, resource saving of 40 to 50% can also be ensured besides enhancing the income of household to the level of at least Rs 400 to 500/day. Additional employment generation of 70 to 80% is also possible. Improved diversified systems also ensure household nutritional security. Also, IFS helps in build-up resilience against current climate change and conserves the surrounding ecosystems and environment.

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