**Integrated Farming Systems in Sericulture**

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**Abstract**

Integrated Farming Systems (IFS) involve combining multiple agricultural practices to maximize resource utilization, sustainability, and income generation. In the context of sericulture, several IFS options have emerged, linking silk production with livestock, horticulture, agriculture, forestry, artisans, poultry, fungi, and apiculture. These integrated approaches leverage the symbiotic relationships between sericulture and allied enterprises, promoting waste utilization, nutrient recycling, and multiple income streams for farmers. This chapter presents an overview of different IFS options in sericulture, emphasizing their benefits in terms of improved soil fertility, enhanced crop yields, additional income, and sustainable farming practices. The integration of sericulture with diverse agricultural activities opens new avenues for entrepreneurs, supports rural livelihoods, and contributes to environmental conservation.

**Keywords -** Integrated Farming Systems, Sericulture, horticulture, agriculture, forestry, artisans, poultry, fungi, and apiculture.

1. **Introduction**

In the quest for sustainable development and ecological balance, the importance of integrating diverse agricultural practices into harmonious agro-ecosystems cannot be overstated. Among the myriad of agricultural pursuits, sericulture stands out as a time-honored practice, boasting a rich history spanning millennia. Sericulture, or the cultivation of silk through the rearing of silkworms, not only epitomizes a remarkable alliance between humans and nature but also exemplifies the potential for achieving synergistic benefits within agricultural landscapes. The inherent synergy of sericulture lies in its ability to intertwine with various agro-ecosystems, contributing to the creation of integrated and dynamic agricultural landscapes. This integration brings forth a multifaceted array of ecological, social, and economic benefits that collectively foster sustainable development at both local and global scales. As we face mounting challenges such as climate change, food insecurity, and biodiversity loss, orchestrating integrated agro-ecosystems becomes an imperative step towards fostering resilience and a regenerative approach to agriculture.

**A. Seri-Livestock Integrated Farming System**

Sericulture and animal husbandry are two important agricultural practices that can be effectively integrated into a sustainable farming system. Mulberry leaves are also favorably palatable and easy to digest by herbivorous animals; thus, many countries use the leaves as the main forage for ruminants. As well as a supplement of mulberry as forage for cows (Sanchez, 2002) will increase nutritional status (Takahashi [1998](https://link.springer.com/chapter/10.1007/978-3-030-41552-5_19#ref-CR48); Rohela *et al.,* 2020). Singh *et al.* ([1984](https://link.springer.com/chapter/10.1007/978-3-030-41552-5_19#ref-CR44)) reported the advantages of supplementing mulberry leaves in the diet of Angora rabbits for better wool production. Therefore, mulberry can be utilized in cocoon price-crash situations as fodder for ruminants and other animals, which will provide additional benefits to entrepreneurs. Similarly, during the process of rearing, waste generated (top layer of fresh bed waste) can be used for rearing sheep / goat. It has been observed that 10-12 sheep / goat can be maintained / hectare of mulberry garden by utilizing the waste. Even chawki rearing centers are making full use of the rearing waste generated during the activity, and it has been observed that the rearing waste and leaf waste generated from chawki of 1000 DFLs is sufficient to rear 4-5 sheep or goats. In some sericulture-intensive districts, it has been reported that the use of sericulture waste for cattle feeding is a common practice, and thus silk and milk go hand in hand. Apart from these, the symbiotic relationship between sericulture and animal husbandry extends indirectly by benefiting the farm women for fodder in dry spells to sustain the livestock. And the faecal pellets of sheep and goats are being used as organic manure in the mulberry garden. It is recorded that for every herd of 15 sheep or goats (stall feeding), one tone of manure is obtained in three months. Furthermore, the grazing of sheep / goat herds in the mulberry garden after every shoot harvest acts as natural pruning of the mulberry plants along with a nutrient source. Based on these, the proposed integration of sericulture with other agro-production systems has been provided in Table 1 and Figure 1. Further, Nagaraju and Raghavendra (2016) reported that adoption of integrated farming, particularly in combination with crop, dairy, sheep, and sericulture, generated the most beneficial results for the farmers in terms of both income and employment generation, which was recorded at 322 man days per year. Thus, utilizing mulberry as fodder for animals during cocoon price-crash situations can provide additional benefits to entrepreneurs.

**B. Seri-Horti Integrated Farming System**

Horticulture production can be increased by increasing the area under cultivation and adopting the idea of mixed cropping. Mulberry, the host plant of the silkworm *Bombyx mori* can be planted as tall trees under mixed cropping systems or on side bunds of vegetable crop fields. Among various horticulture crops, mango, coconut, and sapota can be easily integrated with mulberry cultivation (Kerutagi *et al*., 2019).Thus, the farmers need not engage their entire land for mulberry cultivation and can generate additional income by practicing sericulture on a part-time basis. Moreover, the concept of byproduct utilization works well in this direction as the waste generated during silkworm rearing, including silkworm litter, undersized and dead worms, left-over leaves and twigs, etc., can be recycled to produce organic manure when mixed with residual wastes of other agricultural crops, which can serve as an excellent bio fertilizer to boost the growth and nutritive value of vegetables and fruits, thus minimizing the dependency on chemical fertilizers (Wani *et al.,* 2019). Similarly, adoption of floriculture through small nurseries with limited space and time provides a significant and profitable start. Sericulture wastes recycled into biofertilizers can be used to promote the growth of flower crops. Moreover, the cultivation of flowers as an intercrop in mulberry fields can also be adopted for additional benefits (Baishya *et al.,* 2004). Cultivation of flowers like marigold and *Gladiolus* or cut flowers can be easily incorporated into IFS (Kumar *et al.,* 2012). The floriculture with marigold has internal benefits for the mulberry plantation as it is effective in getting rid of mulberry nematodes. Marigold may reduce nematode populations by several means, including acting as a non-host or poor host, producing allelopathic compounds that are toxic or inhibit PPN development, creating an environment that favors nematode antagonistic flora or fauna (Wang *et al.,* 2001), or (4) behaving as a trap crop (Pudasaini *et al.,* 2008).

**C. Seri-Agri Integrated Farming System**

Integrating sericulture with agricultural crops through intercropping in agro forestry systems provides multiple benefits, including enhanced soil fertility, increased yields of mulberry leaves and intercrops, additional income for farmers, and improved benefit-cost ratios. Mulberry leaf, being the sole food for the silkworm *Bombyx mori* L. in sericulture, contributes around 38.20% towards successful cocoon production. Limiting the use of chemical fertilizers and supplementing the nutritional requirements of mulberry by intercropping with pulses in agroforestry systems enhances the soil's productivity and improves the quality of mulberry (Qadri *et al.,* 2004). Intercropping short-duration pulses such as green gram, black gram, horse gram, soybean, and cowpea with mulberry not only maintains soil fertility but also increases leaf yield, grain and fodder yields, and supplements bulk organic matter (Babu and Dandin, 2009). In regions where saffron cultivation is prevalent, intercropping mulberry with saffron has been shown to yield good-quality mulberry leaf while generating additional income for farmers during the lean period when there are no saffron-related operations (Kaur *et al.,* 2002). Recent studies also suggest successful intercropping of mulberry with medicinal plants like *Aloe barbadense*, *Asparagus racemosus*, and *Acorus calamus* (Madhusudan *et al.,* 2015). Integrating field crops with mulberry in agroforestry systems is a way to increase productivity and net returns per unit area of land (Rajegowda *et al.,* 2020). Shashidhar *et al.* (2022) recently revealed that the cost of cultivating mulberry along with different field crops resulted in higher benefit-cost ratios in intercrops such as field bean, finger millet, and groundnut compared to sole crop mulberry. Rajegowda et al. (2020) suggested that intercropping mulberry with cowpea resulted in higher benefit-cost ratios due to increased soil fertility, higher leaf yield, cocoon yield, and additional income compared to other intercrops such as ragi and groundnut. Singhvi and Katiyar (2009) and Khan *et al.* (2015) tested the intercropping of mulberry with garlic, onion, carrot, and turmeric and reported that intercropping mulberry not only generated additional income through cocoon production but also from the intercrops. Mishra *et al.* (2009) found that the maximum yield of intercrops and net profit per hectare were obtained when mulberry was intercropped with cowpea using a spacing of 90 x 90 cm during June–August. It is clear from the above that IFS agricultural crops with mulberry cultivation enhance productivity, profitability, and nutrition security for the farmer and sustain soil productivity through there cycling of organic sources of nutrients from the enterprises involved.

**D. Seri-Forest Integrated Farming System**

The integration of agroforestry practices, specifically mulberry trees, offers several benefits in farm and agroforestry systems. These systems involve the inclusion of various trees, shrubs, and plants within farming landscapes to enhance nutrient cycling, soil organic matter, soil and water conservation, rural livelihood security, climate change mitigation, sustainable use of natural resources, and greening initiatives in India. Farm/ agroforestry systems consist of different components, with as many as 20 recognized systems in various agro-ecological regions. These systems meet the diverse requirements of farmers while providing hedge-rows/fencing to protect crops from wild animals and offering food and shelter to wildlife at the periphery of villages. This, in turn, reduces the intensity of human-wildlife conflicts, particularly with high-value cash crops grown near villages. Integrating sericulture (silk production) with agroforestry practices, particularly through the cultivation of mulberry trees, provides additional benefits. Mulberry trees serve as valuable components in agroforestry systems by providing shade, improving soil quality, preventing erosion, and acting as windbreaks. Mulberry cultivation not only supports silk production but also contributes to ecosystem stability and biodiversity conservation. It is interesting to note that wild herbivores have a strong preference for mulberry over other forages when presented together. However, elephants tend to show a non-preference for mulberry foliage, which could be due to the presence of unique chemical compounds in the leaves, such as morin and β-sitosterol that may deter elephants (Kumara and Yogendra, 2022). Additionally, the growth pattern of mulberry plants, including their rapid growth and resistance to damage, might contribute to their non-preference by elephants. In areas where conflicts between humans and elephants are frequent, cultivating mulberry in agroforestry systems can offer several advantages. Mulberry cultivation provides a perennial, fast-growing, and versatile plant with multiple uses. Its ease of cultivation and wide adaptability make it an attractive option. By integrating mulberry cultivation for sericulture or other purposes, communities can achieve livelihood sustainability while simultaneously preventing and mitigating human-elephant conflicts in forested regions. In conclusion, the integration of sericulture with agroforestry through the cultivation of mulberry trees not only supports silk production but also provides additional benefits such as ecosystem stability, biodiversity conservation, and conflict mitigation in human-wildlife interactions.

**E. Integrating silkworm rearing by products for sustainability**

Integrating Sericulture Byproducts for Sustainability (ISBS) is a crucial approach that recognizes the potential of byproducts generated in the sericulture industry. Waste management and utilization of these byproducts are essential for maximizing their value. The interconnection between various byproducts obtained during mulberry cultivation, rearing, and reeling in the sericulture process by implementing ISBS, it was discovered that high-quality compost can be produced using compost culture, significantly reducing the composting time. It has been recorded that around 12–15 tones of rearing waste are available per year from one hectare of mulberry garden. Using such rearing waste judiciously for in-situ composting (trenching and mulching) helps meet up to 50% of the mulberry nutrition annually (Kallimani *et al.,* 2014). The use of compost culture, a consortium of four microbial cultures (*Pleurotos, Phenerochetae, Trichoderma,* and *Pseudomonas),* further boosts the process of decomposition, particularly the lignin-degrading fungi (*Phenerochatae chrysosporium*) which accelerates the activity. It has been very well observed in farmer's fields that only 3–4 months are sufficient to degrade mulberry twigs with the use of compost culture, and without it, the duration is about 8–10 months. The mulberry compost is further supplemented with nitrogen-fixing (*Azatobactor, Azospirillum*) and phosphorus-solubilizing bacteria to formulate Bio-rich’ compost. Enrichment with micronutrients like Zn, S, Mg, Mn, gypsum, Bo, copper sulphate, wood ash, and concentrated cakes of pongamia and neem to formulate ‘Nutri-rich’. It is observed that application of such compost to mulberry gardens enhanced water holding capacity, leading to better nutrient utility and thus quality leaf production even under water stress conditions, particularly in rained mulberry growing areas of the Eastern Dry Zone in Karnataka. Similarly, various end products are generated at each and every stage of sericulture that can be utilized by vermicomposting, and the vermicompost thus produced can be used for the cultivation of various agricultural crops. In a study conducted by Kerutagi *et al.* in 2019, it was reported that the average income of farmers increased by 38.31 percent by adopting an integrated farming system involving vermicomposting as an integral enterprise.

**F. Seri-artisan integration for sustainability**

Some additional integrated programmes involving sericulture and other allied agri-enterprises laid emphasis on aspects of IFS and sericulture (Baishya *et al.,* 2004). The production of bio-crafts from pierced or cut cocoons has not only established its own market but has also provided valuable skills to rural youth and differently-abled individuals. Economically, the integration of sericulture byproducts has demonstrated higher benefit-to-cost ratios, ranging from 1:1.27 to 1:5.54, indicating enhanced use efficiency for sericulture farmers and entrepreneurs. This approach promotes the sustainable growth of the sericulture industry while benefiting both the environment and society as a whole.

**G. Sericulture and Poultry Integrated farming system**

                In India, sericulture is viewed as a subsidiary occupation by rural farmers. Moreover, the seasonal fluctuations compel the farmers to consider other alternatives. The broiler or poultry industry provides a good source of income to marginal farmers. Silkworm pupae are considered an excellent source of protein, fats, essential vitamins, and minerals (Longvah *et al.,* 2011). Thus, a mixture of silkworm larvae and pupae blended in appropriate proportions with other food materials can serve as excellent feed for poultry. Thus, sericulture in combination with poultry can be viewed as one of the most promising technologies for augmenting handsome income for farmers, as this combination opens avenues for small-scale and commercial agriculture businesses, and hence this type of diversification yields fruitful results (Prein, 2002). On the other hand, waste generated in poultry can be recycled to produce organic manure that can be applied as biofertilizer to boost the growth of mulberry plants, which in the long run helps the worms produce good cocoons, thus boosting the farmer‘s resources and income (Kumar *et al.,* 2012; AkliluNigussie, 2018).

**H. Seri-Pisi integrated farming system**

The integrated farming system of sericulture and pisciculture involves a harmonious combination of mulberry cultivation, sericulture activities, silk extraction, and fish farming. In this integrated approach, each component plays a crucial role: mulberry serves as the primary producer, silkworms act as the first consumers, and fish become the second consumers, directly benefiting from the silkworm. Recent research conducted by Sanjeev Kumar *et al.* (2012) demonstrated the effectiveness of this system, utilizing silkworm faeces, silkworm pupae, and wastewater in fish farming. Notably, trout fish fed with silkworm pupae meal reached a marketable weight of 250 g/fish in just 8–9 months, compared to 12–13 months when fed with traditional, more expensive department-supplied feed. This integrated system ensures improved fish growth without compromising survivability. The practice of combining aquaculture and mulberry trees near ponds has been extensively employed in China and has been well studied. This system involves incorporating silkworm droppings, waste pupae, and washings from silkworm trays into the fishponds. This increases the pond mud or humus, which serves as a valuable nutrient source for mulberry cultivation, contributing to the overall sustainability and productivity of the integrated system (Ruddle and Zhong, 1989; Zhong, 1995; Prein, 2002). By synergizing sericulture and pisciculture in this manner, this integrated farming approach presents a promising and environmentally friendly solution for enhancing agricultural productivity and resource utilization.

**I. Seri-fungi integrated farming system**

The Seri-Fungi integrated farming system combines sericulture (silk production) with mushroom cultivation, creating a symbiotic relationship between the two. In this system, the byproducts and waste materials from sericulture are utilized as inputs for mushroom cultivation, resulting in improved resource efficiency and economic returns. During sericulture, silkworm rearing generates substantial amounts of silkworm excreta, leftover mulberry leaves, and damaged cocoons. Instead of discarding these byproducts, they are repurposed as valuable inputs for mushroom cultivation. The nutrient-rich silkworm excreta, also known as silkworm castings, provide an excellent substrate for mushroom growth due to their high organic content and beneficial microorganisms. About 15 MT of sericulture waste, mostly mulberry shoots, is generated yearly from silkworm rearing (Das *et al.,* 1997), which is a good raw material source for an entrepreneur starting mushroom production in sericulture belt areas. This diverse and integrated utilization of mulberry also enables young entrepreneurs to get additional income from their small piece of land (Amelia *et al.,* 2020). The integration of mushroom cultivation with sericulture offers several advantages. Firstly, it helps in the efficient utilization of waste materials, reducing environmental pollution, and promoting sustainability. The sericulture byproducts serve as an affordable and readily available substrate for mushroom cultivation, eliminating the need for costly or resource-intensive inputs. Similarly, Cordyceps mushrooms are the most valuable naturally grown fungus on the surfaces of lepidopteron insects. These Himalayan fungi have high demand in the United States, with a price tag of US$ 2000 per kg in their purest form (Chugh *et al.,* 2022). Because of its scarcity and high medicinal value, artificial cultivation methods on a commercial scale have been developed (Garbyal *et al.,* 2004). In Korea, many cottage industries produce cordyceps in silkworm powder or pupae, which are further utilised as a dietary supplement or culinary ingredient to improve health (Hong et al., 2010). Since India produces approximately 139,162 MT of Mulberry, 18,660 MT of Tasar, and 5,782 MT of Muga fresh pupae annually, new entrepreneurs can take up cordyceps production as an integrated approach to enhance profitability (Anonymous, 2020). Furthermore, the integration of sericulture and mushroom cultivation can enhance the economic viability of farming systems. The sale of both silk and mushrooms can provide diversified income streams for farmers, increasing their overall profitability. By combining sericulture and mushroom cultivation, farmers can achieve enhanced productivity, reduced waste, and improved economic returns.

**J .Seri-Apiculture Integrated farming system**

The commensalism relationship of mulberry with humans is not only restricted to the production of foliage for silkworm rearing and livestock farming, but their floral products have also been efficiently utilized. Since mulberry and non-mulberry food plants have flowers, they are a rich source of pollen, which becomes a potent food source for honey bees ([Rijal](https://www.sciencedirect.com/science/article/pii/S1319562X21001054" \l "b0305) *[et al.,](https://www.sciencedirect.com/science/article/pii/S1319562X21001054" \l "b0305)* [2018](https://www.sciencedirect.com/science/article/pii/S1319562X21001054" \l "b0305)). Some of the intercultivation farming of mulberry and other crops gram, black gram, horse gram, soybean, and cowpea) serves as a good source of pollen for honey bees. Therefore, such integrated activities give immense scope for a businessman to take up beekeeping as a subsidiary source of income on the mulberry plantation.

**II. Conclusion**

In conclusion, integrating sericulture with various agricultural practices through Integrated Farming Systems (IFS) offers multifaceted benefits that encompass resource efficiency, sustainable agriculture, and diversified income sources for farmers and entrepreneurs. By establishing symbiotic relationships between sericulture and other agro-enterprises, such as livestock farming, horticulture, agroforestry, mushroom cultivation, and more, farmers can optimize resource utilization, reduce waste, enhance soil fertility, and increase overall productivity. These integrated approaches not only promote economic viability but also contribute to environmental conservation and rural livelihood sustainability. Embracing the concept of integrated farming systems presents a promising pathway towards a more resilient and prosperous agricultural landscape.

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