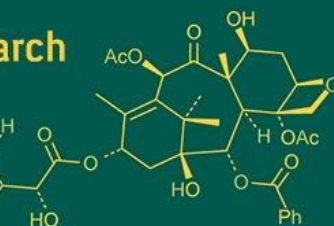


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Mulberry-based agroforestry: A nexus of nutrition, livestock integration, and environmental sustainability

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Abstract

Mulberry agroforestry systems represent a sustainable and versatile approach to land use, integrating food, fodder, and fibre production while addressing pressing challenges like food insecurity, environmental degradation, and rural poverty. This review explores the multifaceted role of mulberry (*Morus* spp.) in agroforestry, highlighting its adaptability, nutritional benefits, and economic potential. Mulberry's ability to thrive in diverse agro-climatic conditions, combined with its high biomass yield, makes it a vital component in integrated farming systems. Its contributions to soil health, carbon sequestration, and biodiversity enhancement establish its ecological significance. The cultivation of mulberry supports rural livelihoods through sericulture, which provides employment and income generation, particularly for smallholder farmers. Its nutrient-rich fruits and high-protein foliage offer direct and indirect solutions for food and nutritional security. Additionally, mulberry's role as a forage crop in silvipasture systems demonstrates its potential in sustainable livestock integration. Case studies illustrate its global applicability, with successful implementations in Asia, North America, and beyond. Despite its benefits, challenges such as limited awareness, land competition, and inadequate policy support hinder its widespread adoption. Addressing these issues requires targeted research, extension services, and policy interventions to promote sustainable practices. This review underscores the need for continued efforts to optimise mulberry-based agroforestry systems, ensuring their role in fostering climate resilience, enhancing rural economies, and achieving sustainable development goals.

Keywords: Mulberry agroforestry systems, sustainable land use, food, fodder, fibre production, food insecurity, environmental degradation, rural poverty

Introduction

Mulberry agroforestry represents a sustainable and innovative approach that integrates the cultivation of mulberry (*Morus* spp.) with various agricultural practices to optimise land use and productivity. This system supports the simultaneous production of food, fodder, and fibre, contributing significantly to economic stability, ecological balance, and rural development. As a fast-growing perennial species, mulberry has demonstrated its value in diverse agro-climatic conditions due to its adaptability, high biomass production, and nutritional benefits. Traditionally, mulberry has been central to farming systems in Asia, particularly in sericulture and livestock farming. Its foliage serves as a high-quality feed supplement for livestock, particularly in regions where forage resources are limited. The nutritional richness and digestibility of mulberry leaves position it as a sustainable alternative to conventional fodder crops (Singh and Makkar, 2000) [24]. Moreover, the economic importance of mulberry extends to fibre production, as its leaves are the sole food source for silkworms, which underpin the global silk industry (Ozturk *et al.*, 2023) [16].

The incorporation of mulberry into agroforestry systems yields multiple benefits, including enhanced land productivity, improved soil fertility, and carbon sequestration. Studies have shown the positive impact of agroforestry interventions on soil health and farm incomes, highlighting their potential to promote agricultural sustainability (Neupane and Thapa, 2001; Sarvade *et al.*, 2019) [14, 32]. Mulberry agroforestry also contributes to food security through fruit production, as mulberry fruits are a rich source of vitamins, minerals, and antioxidants, making them a valuable dietary component for both rural and urban populations. In the context of climate-resilient agriculture, mulberry agroforestry plays a pivotal role in addressing environmental challenges. Its ability to sequester carbon and thrive under varied environmental conditions makes it an essential crop

in mitigating climate change. Research by Varsha *et al.* (2019) ^[34] on high-density mulberry silvopasture systems underscores their significant role in carbon sequestration. Similarly, explored the potential of intercropping edible crops like colocasia with mulberry, demonstrating enhanced land-use efficiency and diversified farming opportunities. The versatility of mulberry extends to its integration into livestock systems, where it supports year-round forage production. Studies on the forage yield and carbon dynamics of mulberry fodder banks have highlighted their importance in maintaining consistent livestock feed supplies (John *et al.*, 2019) ^[10]. Furthermore, the management of tree fodder banks has been shown to improve both the quality and availability of livestock feed while contributing to carbon sequestration (Raj *et al.*, 2023) ^[18]. Despite these numerous advantages, the widespread adoption of mulberry agroforestry systems is constrained by challenges such as limited awareness, insufficient policy support, and competition for land resources. Addressing these barriers requires a coordinated effort that combines research, extension services, and policy reforms. Kabirizi and Ejobi (2006) ^[11] emphasised the importance of integrating indigenous knowledge with scientific advancements to fully realise the potential of mulberry-based systems.

This review provides an in-depth analysis of mulberry agroforestry, with a focus on its roles in food, fodder, and fibre production. By exploring its ecological, economic, and social dimensions, the review highlights how mulberry agroforestry can serve as a sustainable land-use strategy to tackle global challenges such as food insecurity, rural poverty, and climate change. The plant's deep-rooting system and drought resilience further enhance its suitability for diverse landscapes, including degraded areas. Its high protein content and digestibility make mulberry an indispensable feed resource in resource-constrained settings, underlining its value in sustainable agriculture.

Role of Mulberry in Agroforestry Systems

Agroforestry integrates woody perennials with arable crops, livestock, or fodder on the same piece of land, enabling more efficient resource utilisation compared to monocropping by diversifying structural and functional components (Fahad *et al.*, 2022) ^[7]. Including mulberry in agroforestry systems enhances land productivity and strengthens ecosystem resilience. Mulberry's ability to withstand drought and thrive on degraded soils makes it an ideal choice for resource-limited regions. Its deep-root system stabilises soil and facilitates water infiltration, which is essential for reducing erosion and improving groundwater recharge (Neupane and Thapa, 2001) ^[14]. Such traits make mulberry a valuable crop for sustainable agriculture. For foliage fodder purposes, mulberry plantations are suitable for black and lowland areas as well (Mathukia *et al.*, 2016) ^[12]. The plant produces approximately 25-30 t ha⁻¹ year⁻¹ of fresh leaf biomass, rich in protein (18-25% in DM) and featuring 75-85% *in vitro* DM digestibility (Ba *et al.*, 2005) ^[2]. Its leaves are also abundant in proteins, minerals such as calcium (Ca) and phosphorous (P), and metabolizable energy (Srivastava *et al.*, 2006) ^[26].

Compared to traditional forages, mulberry provides higher fodder yields in terms of digestible nutrients (Sanchez, 2000) ^[22]. Its foliage, comparable to alfalfa hay mix in digestible energy and crude protein values, is a protein-rich supplement that can be used fresh or dried in compound

feeds for high-yielding livestock (Dhillon *et al.*, 2023) ^[5]. As a supplemental feed, mulberry enhances milk protein and fat content and increases milk yields in cows and goats (Venkatesh *et al.*, 2015) ^[30]. In several regions, mulberry is also used as a substitute for concentrated cattle feed and serves as a primary feed source for sheep and goats (Bakshi and Wadhwa, 2007) ^[3].

Singh and Makkar (2000) ^[24] emphasised mulberry's role as a high-protein fodder source, especially in resource-constrained settings. Its rapid growth and capacity for frequent pruning ensure a consistent supply of biomass throughout the year. Additionally, its compatibility with intercropping enhances integrated farming systems, improving overall land-use efficiency. For example, intercropping mulberry with colocasia has been shown to boost both productivity and farmer income.

Mulberry's resilience to pests and diseases, combined with its low maintenance requirements, makes it a low-risk crop for smallholder farmers. Its leaf litter and organic matter enrich soil fertility, promoting healthy ecosystems for companion crops. Its adaptability to varied light and soil conditions broadens its applicability across diverse agricultural landscapes (Dibala *et al.*, 2021) ^[6]. Roberts (2017) ^[19] highlighted the potential of agroforestry systems, including mulberry, in temperate regions, demonstrating its flexibility and versatility.

Varsha *et al.* (2019) ^[27] compared forage productivity, quality, and carbon storage among monocultures of hybrid Napier grass, mulberry, and *Stylosanthes*, as well as mixed systems combining these fodders. While hybrid Napier monocultures delivered the highest forage dry matter yields, their fodder quality and carbon fixation were the lowest. In contrast, mulberry monocultures excelled in carbon fixation, although their forage yields were lower. Among the tested systems, intensive silvopasture combining hybrid Napier and mulberry trees emerged as the most promising option, balancing farmers' needs for high-quality forage and environmental sustainability through improved carbon storage and crude protein yields.

Food Security

Mulberry plays a vital role in enhancing food security by contributing to both direct and indirect nutritional resources. Its fruits are rich in essential nutrients such as vitamin C, iron, calcium, and antioxidants, which are beneficial for human health. These fruits are consumed fresh or processed into value-added products like juices, jams, and syrups, offering additional income opportunities for farmers.

The significance of mulberry in sericulture further amplifies its contribution to rural livelihoods and food security. Mulberry leaves serve as the exclusive food source for silkworms, supporting silk production, which is a major income-generating activity in many rural regions. The sericulture industry not only provides rural employment but also encourages women's participation in the workforce, fostering socio-economic progress (Ozturk *et al.*, 2023) ^[16].

Integrated farming systems that include mulberry alongside other crops have proven effective in boosting land productivity and diversifying income streams. For instance, the compatibility of cultivating colocasia under mulberry trees, where the improved microclimate enhanced colocasia yields. Choudhary *et al.* (2019) ^[4] emphasised that integrated farming systems improve resource use efficiency, aligning well with mulberry's role in such setups. Similarly,

Nutritional Benefits

Mulberry leaves exhibit a wide range of pharmacological properties, including antihypertensive, antidiabetic, bacteriostatic, antiviral, and antihyperlipidemic activities. These beneficial effects are attributed to the presence of amino acids, vitamins, quercetin, sugars, microelements, and volatile oils. The bioactive compounds in certain mulberry species have been shown to enhance lifespan, highlighting their potential health benefits (Venkatesh Kumar and Seema Chauhan, 2008) ^[29]. Additionally, a variety of biochemical compounds, such as Kuwanol, Albafuran, Hydroxymorcin, Albanol, *Morusin*, Moranoline, and Calystegine, can be extracted from the mulberry plant. These compounds play a critical role in the pharmaceutical industry, as noted by researchers (Andallu *et al.*, 2001; Singhal *et al.*, 2010) ^[1, 25]. The medicinal properties of mulberry make it a valuable resource for pharmaceutical research and industry, with roots, stems, leaves, flowers, bark, and fruits being utilised in herbal medicine for treating various conditions. Products derived from mulberry leaves, marketed under different names like no, wild pine, noni, mengkudu, and caribe, offer similar benefits and risks (Zeng *et al.*, 2016) ^[31].

According to Munir *et al.* (2018) ^[13], *Morus alba*, commonly known as white mulberry, is regarded as a medicinal and aromatic plant rich in essential oils, phenolic compounds, and biologically active substances. These properties make it effective in the treatment of several diseases, including cancer. Rich in vitamins C, K1, E, and essential minerals, white mulberry serves as an excellent ingredient for desserts, dairy products, shakes, tea, and beverages. Moreover, Muni *et al.* (2018) ^[16] highlighted its utility in addressing respiratory disorders, fever, and colds, further noting its role in enhancing immunity against diseases such as COVID-19.

Faseeha and Sadia (2020) ^[8] emphasised the importance of maintaining optimal nutritional status to combat COVID-19, highlighting the critical role of nutrition in bolstering the immune system. Mulberry not only offers medicinal benefits but also serves as a rich source of nutrition, making it a valuable asset in disease prevention and health maintenance. Its multifunctional nature positions it as a superior candidate for mitigating climate change impacts. By addressing diverse needs, mulberry has the potential to alleviate poverty at the farm level. Furthermore, its high water-use efficiency (WUE) makes it an effective crop for climate change mitigation. Comparative studies, such as Table 3, demonstrate that mulberry surpasses other plants in WUE, producing higher yields with the same amount of water, further solidifying its ecological and economic advantages.

Fodder Production and Livestock Integration

Mulberry is widely recognised as a highly valuable fodder crop due to its exceptional nutritional profile and palatability. The leaves are rich in protein, amino acids, and essential minerals, making them an excellent choice for enhancing livestock health and productivity. John *et al.* (2019) ^[10] evaluated mulberry fodder banks, concluding that these systems provide a sustainable and high-yielding forage source, adaptable to varying planting densities and harvest intervals. Kabirizi and Ejobi (2006) ^[11] also highlighted the potential of indigenous mulberry species as a feed option in intensive goat systems, which are critical for supporting smallholder livelihoods.

In silvipasture systems, mulberry plays a dual role by providing both shade and high-quality forage. This integration fosters a favourable environment for livestock while contributing to carbon sequestration. Varsha *et al.* (2019) ^[27] demonstrated that high-density mulberry silvipasture systems significantly enhance carbon storage, underscoring their environmental benefits. These systems are particularly beneficial in resource-constrained regions where commercial feed inputs are either expensive or unavailable. Mulberry's adaptability to diverse environmental conditions further enhances its role in livestock integration. Research by Dibala *et al.* (2021) ^[6] on red mulberry (*Morus rubra*) confirmed its potential as a reliable forage source under varied light gradients. Similarly, Salem *et al.* (2020) ^[21] underscored the importance of agroforestry systems in providing alternative animal feeds, reinforcing mulberry's critical role in sustainable livestock management.

Studies conducted with ruminants, including cattle, goats, and sheep, have shown high levels of dry matter (DM) intake and significant improvements in animal performance, such as weight gain and milk yield. Oviedo (1995) ^[15] compared mulberry foliage to commercial concentrate supplements in grazing Jersey x Criollo cows, finding comparable milk yields (13.2 and 13.6 kg/animal/day, respectively) at equivalent DM intake levels (1.0% of live weight). Both systems outperformed grazing-only systems, which yielded 11.3 kg/animal/day. While mulberry supplementation did not alter milk fat, protein, or total solids content, it significantly improved net economic benefits compared to concentrate feeds.

Rojas *et al.* (1994) ^[20] observed similar positive impacts in crossbred dairy goats weighing approximately 40 kg. Increasing mulberry supplementation from 1.0% to 2.6% of live weight on a DM basis resulted in milk yield increases from 2.0 to 2.5 kg/animal/day. Slight improvements were also noted in milk fat, protein, and total solids content. The study highlighted high DM intake levels and the additive effects of mulberry supplementation. Additionally, mulberry effectively substituted king grass as a primary forage source, further demonstrating its versatility and efficiency in livestock feeding systems.

Fibre and Economic Contributions

The economic significance of mulberry lies primarily in its pivotal role in the silk industry. Mulberry leaves are indispensable for silkworm rearing, which underpins silk production globally. Ozturk *et al.* (2023) ^[16] detailed how mulberry cultivation sustains rural employment and contributes to foreign exchange earnings through silk exports. The promotion of sustainable mulberry cultivation is essential for maintaining the economic stability of sericulture-dependent communities.

Beyond sericulture, mulberry agroforestry offers multiple income streams for farmers. The sale of fruits, leaves, and value-added products such as mulberry tea or dried leaves for medicinal use diversifies household incomes. Patnaik (2008) ^[17] highlighted mulberry's potential in animal production systems, showcasing its versatile applications. Hermansen *et al.* (2018) ^[9] provided guidelines for improving agroforestry systems, including fibre production, to bolster economic sustainability.

Environmental Benefits

Mulberry agroforestry systems contribute significantly to environmental sustainability by improving soil health, water conservation, and biodiversity. Neupane and Thapa (2001) ^[14] emphasised how mulberry's leaf litter enriches soil organic matter, enhancing fertility and structure. The plant's ability to stabilise soil and prevent erosion is particularly valuable in sloping or degraded lands.

Carbon sequestration is another key environmental benefit of mulberry agroforestry. Varsha *et al.* (2019) ^[27] reported that high-density mulberry systems effectively capture and store atmospheric carbon, aligning with global efforts to combat climate change. Additionally, mulberry-based agroforestry supports biodiversity by creating habitats for various flora and fauna, as well as enhancing ecosystem services such as pollination and pest control (Sivaranjani and Panwar, 2023) ^[26]. Studies on fodder trees for goats further support mulberry's ecological importance.

Challenges and Opportunities

While mulberry agroforestry offers numerous advantages, it is not without challenges. Land competition, lack of awareness, and limited research on optimised intercropping practices hinder its widespread adoption. Addressing these issues requires a multi-pronged approach, including policy support, capacity building, and investment in research and development. Kabirizi and Ejobi (2006) ^[11] emphasised the importance of integrating indigenous knowledge with scientific advancements to maximise the potential of mulberry-based systems.

Opportunities for expanding mulberry agroforestry include the development of climate-resilient cultivars, improved management practices, and enhanced market linkages for products like silk and mulberry fruits. Additionally, global initiatives promoting agroforestry, such as the FAO's Globally Important Agricultural Heritage Systems (GIAHS), provide a platform for showcasing successful mulberry-based models (Santoro *et al.*, 2020) ^[23].

Conclusion

Mulberry agroforestry represents a sustainable and multifunctional approach to land management, integrating food, fodder, and fibre production. Its ecological benefits, coupled with its economic and nutritional advantages, make it a valuable component of climate-smart agriculture. Future research should focus on optimising management practices, addressing challenges, and promoting awareness to unlock the full potential of mulberry agroforestry systems.

References

- Andallu B, Varadacharyulu N, Gopumadhavan S, Chandrasekhar N. Effect of mulberry (*Morus indica* L.) therapy on plasma and erythrocyte membrane lipids in patients with type 2 diabetes. *Clin Chim Acta*. 2001;314(1-2):47-53.
- Ba NX, Giang VD, Ngoan LD. Ensiling of mulberry foliage (*Morus alba*) and the nutritive value of mulberry foliage silage for goats in central Vietnam. *Livest Res Rural Dev*. 2005;17(1):1-10.
- Bakshi MPS, Wadhwa M. Tree leaves as complete feed for goat bucks. *Small Rumin Res*. 2007;69(1-3):74-78.
- Choudhary SK, AH RK, Gupta SK. Integrated farming system (IFS) is possible way out for double farmer's income. *J Pharmacogn Phytochem*. 2019;8(5S):282-289.
- Dhillon RS, Beniwal RS, Satpal, Kumari S. Tree fodder for nutritional security and sustainable feeding of livestock-A review. *Forage Res*. 2023;49(1):21-28.
- Dibala R, Jose S, Gold M, Kallenbach R, Knapp B. Initial performance of red mulberry (*Morus rubra* L.) under a light gradient: an overlooked alternative livestock forage? *Agrofor Syst*. 2021;1-12.
- Fahad S, Chavan SB, Chichaghare AR, Uthappa AR, Kumar M, Kakade V, *et al.* Agroforestry systems for soil health improvement and maintenance. *Sustainability*. 2022;14(22):14877.
- Faseeha A, Sadia M. How nutrition can help fight against COVID-19 pandemic. *Pak J Med Sci*. 2020;36(1):21-23.
- Hermansen JE, Bestman M, Westaway S, Grete A, Kongsted VB, Losada RM, *et al.* Guidelines for improved agroforestry systems for livestock production. *Agroforestry Systems*. 2018.
- John AR, Raj AK, Kunhamu TK, Anoop EV, Jamaludheen V. Forage yield and carbon dynamics of mulberry fodder banks under varying density and harvest interval in coconut garden. *Indian J Agrofor*. 2019;21(1):42-49.
- Kabirizi J, Ejobi F. Indigenous fodder trees and shrubs as feed resources for intensive goat production in Uganda. *Farmers Handbook*. 2006.
- Mathukia RK, Sagarka BK, Panara DM. Fodder production through agroforestry: a boon for profitable dairy farming. *Innovare J Agric Sci*. 2016;4(1):13-19.
- Munir A, Kher RA, Rehman R, Nisar S. Multipurpose white mulberry: A review. *Int J Chem Biochem Sci*. 2018;13:31-35.
- Neupane RP, Thapa GB. Impact of agroforestry intervention on soil fertility and farm income under the subsistence farming system of the middle hills, Nepal. *Agric Ecosyst Environ*. 2001;84(2):157-167.
- Oviedo JF. Morera (*Morus* sp.) enasocio con Poró (*Erythrina poeppigiana*) y comosuplemento para vacaslecherasenpastoreo [thesis]. Turrialba (C.R.): CATIE; 1995. 86 p.
- Ozturk M, Kamili AN, Altay V, Rohela GK. Economic Importance of Mulberry. In: *Mulberry: From Botany to Phytochemistry*. Cham: Springer Nature Switzerland; 2023. p. 149-179.
- Patnaik RK. Mulberry for animal production. Daya Books. 2008.
- Raj AK, Raj RM, Kunhamu TK, Jamaludheen V, Chichaghare AR. Management of tree fodder banks for quality forage production and carbon sequestration in humid tropical cropping systems—An overview. *Indian J Anim Sci*. 2023;93(1):10-22.
- Roberts E. Agroforestry for the Northeastern United States: research, practice, and possibilities. In: *Integrating Landscapes: Agroforestry for Biodiversity Conservation and Food Sovereignty*. Springer; 2017. p. 79-126.
- Rojas H, Benavides JE, Fuentes M. Producción de leche de cabrasalimentadas con pasto y suplementadas con altos niveles de Morera. In: Benavides JE, editor. *Árboles y arbustosforrajerosen América Central*. Vol II. Serie técnica, Informe técnico No. 236. Turrialba, C.R.: CATIE; 1994. p. 305-320.

21. Salem AZ, Kunst CR, Jose S. Alternative animal feeds from agroforestry plants. *Agrofor Syst.* 2020;94:1133-1138.
22. Sanchez MD. Mulberry: An exceptional forage available almost worldwide. *World Anim Rev.* 2000;93:1-21.
23. Santoro A, Venturi M, Bertani R, Agnoletti M. A review of the role of forests and agroforestry systems in the FAO Globally Important Agricultural Heritage Systems (GIAHS) programme. *Forests.* 2020;11(8):860.
24. Singh B, Makkar HP. The potential of mulberry foliage as a feed supplement in India. *FAO Anim Prod Health Pap.* 2000;139-156.
25. Singhal B, Varsha KM, Kurien EK, Bastin B, Kunhamu TK, Pradeep KP. Approaches to industrial exploitation of mulberry (*Morus* sp.) fruits. *J Fruit Ornament Plant Res.* 2010;18(1-2):83-99.
26. Sivaranjani S, Panwar VP. Carbon sequestration in agroforestry systems. In: *Agricultural Soil Sustainability and Carbon Management.* Academic Press; 2023. p. 207-227.
27. Srivastava S, Kapoor R, Thathola A, Srivastava RP. Nutritional quality of leaves of some genotypes of mulberry (*Morus alba*). *Int J Food Sci Nutr.* 2006;57:305-313.
28. Varsha KM, Raj AK, Kurien EK, Bastin B, Kunhamu TK, Pradeep KP. High density silvopasture systems for quality forage production and carbon sequestration in humid tropics of Southern India. *Agrofor Syst.* 2019;93:185-198.
29. Venkatesh KR, Chauhan S. Mulberry: life enhancer. *J Med Plants Res.* 2008;2(10):271-278.
30. Venkatesh KR, Chhatrapal G, Shobha N, Rohith LS. Use of mulberry leaves as supplementary food in cow and goat to improve milk production. *Int J Appl Res.* 2015;1:81-84.
31. Zeng Q, Yu B, Xu Z, Zhang H, Zhu X, Zhao L. Introduction trial of medicine mulberry (*Morus nigra*) in Chongqing. *Zhongguo Zhong yao za zhi = Zhongguozhongyaozazhi = China J Chin Mater Med.* 2016;41(8):1450-1455.
32. Sarvade S, Gautam DS, Upadhyay VB, Sahu RK, Shrivastava AK, Kaushal R, *et al.* Agroforestry and soil health: an overview. In: *Agroforestry for Climate Resilience and Rural Livelihood.* Jodhpur: Scientific Publishers India; 2019. p. 275-297.