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Cultivating debate: the dichotomy of trees in agroecosystems

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1 Introduction

Traditionally crop production has predominantly occurred in symbiosis with the environment. However, with the commencement of green revolution in late 60s, the emphasis shifted toward large open fields dedicated predominantly to monocropping, with the primary objective of augmenting crop productivity in the agriculture sector. Over time, the global populace grapples with a nexus of pressing environmental concerns, encompassing overexploitation of natural resources, biodiversity loss, land degradation, unsustainable agricultural practices, climate change, and heightened risks at the interface of environment and human health (Verma et al., 2023b). Amidst the current era of uncertainties, there has been a significant change in the perspective of researchers, farmers and policymakers by recognizing the extensive and consequential impacts that trees may have on agricultural environments. Nevertheless, there is a growing recognition of the multifaceted effects that trees can impart upon agricultural landscapes leading to a paradigm shift. The ongoing debate on incorporating trees in agroecosystems brings up important considerations pertaining to sustainability, biodiversity, and the delicate equilibrium between optimizing crop production and safeguarding the environment. Consequently, a burgeoning interest in examining and reassessing the significance of trees within agroecosystems.

2 Benefits of trees in agroecosystem

The trees in agroecosystems are posited as a potential strategy to sustain biodiversity and its concomitant ecosystem services in the agricultural areas. Globally over 40 per cent of agricultural lands have tree cover exceeding 10 per cent (Zomer et al., 2014), which is widespread among smallholder farmers and crucial for sustaining rural livelihoods. Simultaneously, incorporating trees in the farmlands is imperative for bolstering agroecosystem resilience and addressing ecological and biodiversity concerns. This integration serves as a crucial component in providing diverse ecosystem services through economically efficient land utilization, comparable to those observed in neighboring forests (Figure 1). This involves obtaining provisioning services from both trees (fruit, fodder, construction material, medicinal plants and fuelwood for cooking) and crop yields from the same piece of land, which ultimately contribute to their food and livelihood security (Sharma et al., 2023). Generally, trees on farmlands function as a metaphorical 'living savings account' for smallholder farmers, amenable to selective harvesting during periods of pronounced financial exigencies. Moreover, the trees on the farmland are known to provide various environmental services, including helping to moderate microclimatic

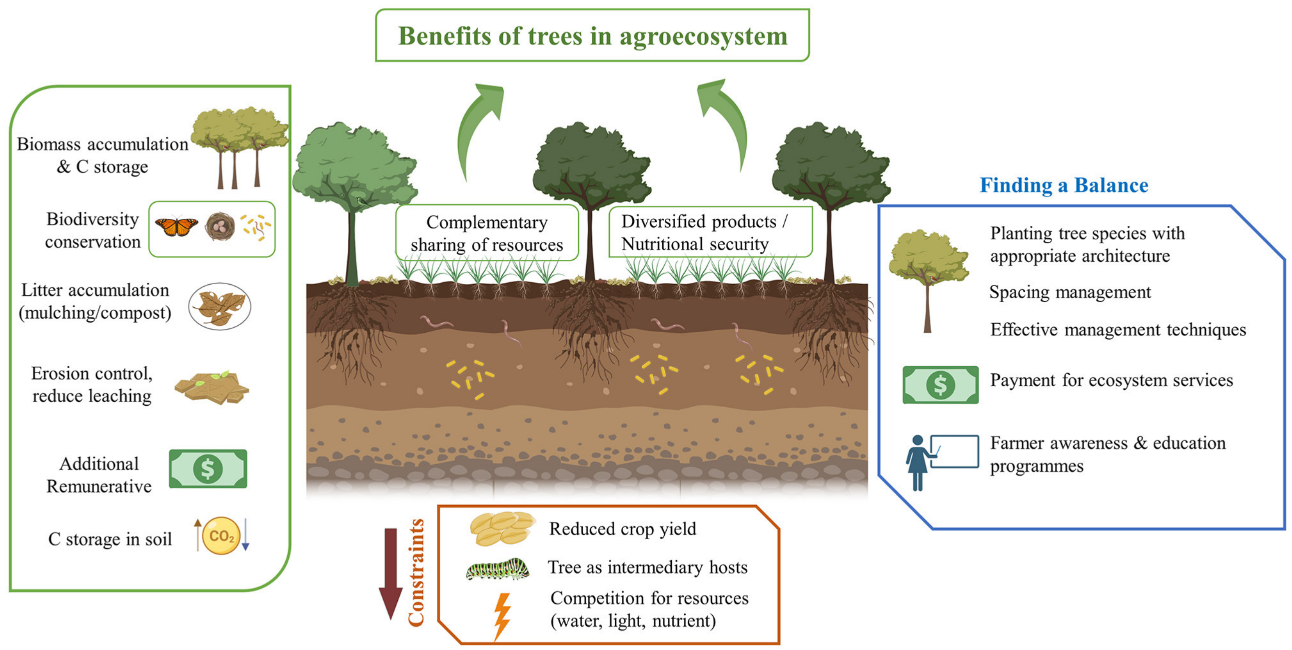

FIGURE 1
The benefits and constraints of trees in agroecosystem for attaining equilibrium to minimize competition and optimize the effective utilization of land for various ecosystem services.

fluctuations, resulting in more consistent environmental conditions for understory species and preventing heat-related strain (Ivezić et al., 2021), soil enrichment using leaf litter and better nutrient dynamics (Bhardwaj et al., 2023a,b; Sharma et al., 2023). Additionally trees also contribute to the reduction of crop pests and diseases incidences (Pumariño et al., 2015), reduction of soil erosion, pollination services, nitrogen-fixing (Miller et al., 2020), biodiversity conservation (Jose, 2012), regulating biogeochemical cycles (Mbow et al., 2014), climate change adaptation and mitigation through sequestrating carbon (Verma et al., 2023a,b), reducing emission of greenhouse gases (Kim et al., 2016) and reducing threats and enhancing resilience (Schoeneberger et al., 2012; Verma et al., 2021). For instance, planting trees on farmlands can decrease the amount of pesticides and nutrients that seep into groundwater aquifers by 60–90 per cent (Borin et al., 2005). In several African nations, trees grown on farms accounted for about 17 per cent of the annual gross revenue of households involved in tree cultivation (Miller et al., 2017). Simultaneously, trees can decrease vulnerability to external shocks, including those associated with financial constraints, market volatility, food scarcity, and climate change (Miller et al., 2020). Concurrently, the promotion of planting trees on the farmlands is also acknowledged by numerous as a vital strategy for the execution of forest restoration operations (Miller et al., 2017; Panwar et al., 2022), including a crucial role in attaining Sustainable Development Goals (SDGs) due to their support in various essential environmental aspects (Mbow et al., 2014). Overall, integrating trees into an agroecosystem is an innovative approach to enhancing sustainability and addressing climate change and biodiversity conservation, ultimately improving farmers' food and nutrition security.

3 Challenges and trade-offs

Planting trees on the farmlands has the potential to enhance conservation efforts compared to monocultural agriculture. However, to leverage this potential effectively, a nuanced consideration of specific methodologies is imperative. Given that substituting one tree ecosystem with another, such as replacing Dehesas [tree layer consists of an open landscape resembling a savannah, primarily characterized by the presence of Mediterranean evergreen oaks, including the holm oak (*Quercus ilex*)] with grazed Eucalyptus plantations, can result in a significant decrease in valuable species. Thus, meticulous planning of such systems becomes paramount to maximize their potential benefits (Nerlich et al., 2013), while emphasizing the need to avoid planting inappropriate tree species in unsuitable areas to prevent counterproductive outcomes. Moreover, challenges emerge in the form of the inherent competition between crops and trees for resources in agroecosystems, both in aerial and subterranean domains. Instances reveal a decline in annual yield of agricultural crops by up to 2.6 per cent in alley cropping during the initial 21 years of tree stand development, owing to trees becoming more competitive with age, resulting in a reduction in agricultural production (Ivezić et al., 2021). The competition for nutrients, water and light serves as the primary factors that regulate plant development and determine agricultural yields in tree-based systems. In addition, the trees found on agricultural fields may have negative impacts, such as allelopathy—a phenomenon characterized by the inhibition of neighboring plant germination caused by root exudates and leaf litter from trees (Garima et al., 2021). Further complexities arise with trees influencing pests within agroecosystems, either directly providing resources or altering microclimates and indirectly affecting pests by enhancing nutritional conditions or water availability for host plants (Pumariño et al., 2015). Therefore, the selected tree species must not function as pests in agriculture or as intermediary hosts for other pests. Somehow, farmers also exhibit reluctance to adopt agroforestry systems as a means of safeguarding against issues with their existing system, possibly due to the fact that planting trees entails substantial upfront costs, with the benefits being realized at a later stage. Unfortunately, the significant impact of trees on farms on the lives of farmers is frequently overlooked on international platforms, indicating a lack of government attention toward the "Cinderella species" that play a crucial role in providing rural families with a wide range of common goods especially in underdeveloped countries (Miller et al., 2020).

4 Finding a balance

In order to effectively find a balance between the trees and crops in agroecosystems (Figure 1), it is vital to adopt a comprehensive and site-specific approach. It optimizes the synergies between trees and crops while minimizing potential trade-offs, recognizing that the benefits trees bring, such as improved soil structure and biodiversity, need to be strategically balanced against potential competition for resources. The crux of effective tree cultivation is encapsulated in the meticulous implementation of the 5R approach, necessitating the selection of the appropriate tree species (Right tree), strategic placement in an optimal environment (Right Place), alignment with a specific purpose (Right purpose), temporal synchronization with the optimal season (Right time), and meticulous adherence to scientifically validated techniques (Right techniques). Thus, the first step should be to meticulously choose tree species that can meet local priorities and biophysical conditions while also taking into account the unique requirements of the crops. Given that no species can be classified as "bad," "good," or "perfect," it is crucial to discover the most appropriate combinations of trees and agricultural crops in order to achieve the numerous benefits of this system (Ollinaho and Kröger, 2021; Zhang et al., 2023). Since by selecting the tree species with appropriate architecture and implementing effective management techniques, it is possible to reduce the competition and optimize the use of growth resources, thereby facilitating climate-smart goals while attaining desired social and environmental advantages (Mbow et al., 2014). Nevertheless, it is crucial to bear in mind that appearances can be deceiving. Recently, there has been a surge of interest in fast-growing tree species in farmlands because of their capacity to fulfill industrial requirements and offer early remunerative. However, a 5-year-old poplar tree, which is a fast-growing species, will offer a much greater amount of shade in comparison to a slow-growing species like walnut (Ivezić et al., 2021). Undoubtedly, the inclusion of trees in agroecosystems offers a multitude of advantages, and countries are increasingly acknowledging their value. As an example, India's commitment to the Paris Agreement includes increasing tree and forest cover to one-third of its geographical area by 2030 to meet international obligations but also creates a substantial carbon sink, intending to absorb 2.5–3 billion t CO_2 equivalent (Panwar et al., 2022; Sharma et al., 2023). Simultaneously, it is crucial to foster awareness and education among farmers. Gaining knowledge about the environmental advantages of trees and offering rewards, such as payments for ecosystem services, for implementing sustainable tree-based systems can facilitate the transition from conventional farming practices to more environmentally robust alternative systems.

5 Conclusion

The debate surrounding the integration of trees in agroecosystems is intricate, touching upon environmental, economic, and social dimensions. Undoubtedly, the integration of trees into agroecosystems holds considerable potential to yield myriad benefits for farmers including addressing imperatives of food security and climate change mitigation. Nevertheless, it is imperative to acknowledge that the inadvertent selection of inappropriate tree species, including quality planting material, improper placement, and mismanagement can precipitate adverse consequences for farmers. Therefore, there exists a compelling need for the advocacy and promotion of the 5R approach to guide judicious decision-making in tree integration within agroecosystems and the seamless integration of these practices into the socio-economic fabric of rural communities. Striking the right balance between crop productivity and environmental sustainability requires collaborative efforts encompassing scientists, policymakers, and farmers. Consequently, in navigating the dichotomy of trees in agroecosystems, it is imperative to view it not as a binary perspective but as an opportunity to foster a resilient and harmonious coexistence between agriculture and the natural environment.

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References

Bhardwaj, D. R., Salve, A., Kumar, J., Kumar, A., Sharma, P., and Kumar, D. (2023a). Biomass production and carbon storage potential of agroforestry land use systems in high hills of north-western Himalaya: an approach towards natural based climatic solution. *Biomass Conv. Bioref.* doi: 10.1007/s13399-023-03952-0

Bhardwaj, D. R., Sharma, P., Kumar, D., Panwar, P., Kumar, A., Pala, N. A., et al. (2023b). "Carbon stock inventory and biomass production in different land use systems of Northwestern Himalaya," in *Climate Change in the Himalayas: Vulnerability and Resilience of Biodiversity and Forest Ecosystems*, ed. A. Kumar, W.D. Jong, M. Kumar, R. Pandey (London: Academic Press), 217–233. doi: 10.1016/B978-0-443-19415-3.00011-6

Borin, M., Vianello, M., Morari, F., and Zanin, G. (2005). Effectiveness of buffer strips in removing pollutants in runoff from a cultivated field in North-East Italy. *Agric. Ecosyst. Environ.* 105, 101–114. doi: 10.1016/j.agee.2004.05.011

Garima, D. R., Thakur, C. L., Kaushal, R., Sharma, P., Kumar, D., and Kumari, Y. (2021). Bamboo-based agroforestry system effects on soil fertility: ginger performance in the bamboo subcanopy in the Himalayas (India). *Agron. J.* 113, 2832–2845. doi: 10.1002/agj2.20684

Ivezić, V., Yu, Y., and Werf, W. V. D. (2021). Crop yields in European agroforestry systems: a meta-analysis. *Front. Sustain. Food Syst.* 5, 606631. doi: 10.3389/fsufs.2021.606631

Jose, S. (2012). Agroforestry for conserving and enhancing biodiversity. *Agroforest. Syst.* 85, 1–8. doi: 10.1007/s10457-012-9517-5

Kim, D. G., Kirschbaum, M. U., and Beedy, T. L. (2016). Carbon sequestration and net emissions of CH_4 and N_2O under agroforestry: synthesizing available data and suggestions for future studies. *Agric. Ecosyst. Environ.* 226, 65–78. doi: 10.1016/j.agee.2016.04.011

Mbow, C., van Noordwijk, M., Prabhu, R., and Simons, T. (2014). Knowledge gaps and research needs concerning agroforestry's contribution to sustainable development goals in Africa. *Curr. Opin. Environ. Sustain.* 6, 162–170. doi: 10.1016/j.cosust.2013.11.030

Miller, D. C., Muñoz-Mora, J. C., and Christiaensen, L. (2017). Prevalence, economic contribution, and determinants of trees on farms across Sub-Saharan Africa. *For. Policy Econ.* 84, 47–61. doi: 10.1016/j.forpol.2016.12.005

Miller, D. C., Muñoz-Mora, J. C., Rasmussen, L. V., and Zezza, A. (2020). Do trees on farms improve household well-being? Evidence from national panel data in Uganda. *Front. For. Glob. Change* 3, 101. doi: 10.3389/ffgc.2020.00101

Nerlich, K., Graeff-Hönninger, S., and Claupein, W. (2013). Agroforestry in Europe: a review of the disappearance of traditional systems and development of modern agroforestry practices, with emphasis on experiences in Germany. *Agroforest. Syst.* 87, 475–492. doi: 10.1007/s10457-012-9560-2

Ollinaho, O. I., and Kröger, M. (2021). Agroforestry transitions: the good, the bad and the ugly. *J. Rural Stud.* 82, 210–221. doi: 10.1016/j.jrurstud.2021.01.016

Panwar, P., Mahalingappa, D. G., Kaushal, R., Bhardwaj, D. R., Chakravarty, S., Shukla, G., et al. (2022). Biomass production and carbon sequestration potential of different agroforestry systems in India: a critical review. *Forests* 13, 1274. doi: 10.3390/f13081274

Pumariño, L., Sileshi, G. W., Gripenberg, S., Kaartinen, R., Barrios, E., Muchane, M. N., et al. (2015). Effects of agroforestry on pest, disease and weed control: a meta-analysis. *Basic. Appl. Ecol.* 16, 573–582. doi: 10.1016/j.baae.2015.08.006

Schoeneberger, M., Bentrup, G., De Gooijer, H., Soolanayakanahally, R., Sauer, T., Brandle, J., et al. (2012). Branching out: agroforestry as a climate change mitigation and adaptation tool for agriculture. *J. Soil Water Conserv.* 67, 128A—136A. doi: 10.2489/jswc.67.5.128A

Sharma, P., Bhardwaj, D. R., Singh, M. K., Nigam, R., Pala, N. A., Kumar, A., et al. (2023). Geospatial technology in agroforestry: status, prospects, and constraints. *Environ. Sci. Pollut. Res.* 30, 116459–116487. doi: 10.1007/s11356-022-20305-y

Verma, K., Sharma, P., Bhardwaj, D. R., Kumar, R., Kumar, N. M., and Singh, A. K. (2023a). "Land and environmental management through agriculture, forestry and other land use (AFOLU) system," in *Land and Environmental Management Through Forestry*, eds A. Raj, M. K. Jhariya, A. Banerjee, S. Nema and K. Bargali (Beverly: Scrivener Publishing), 247–271. doi: 10.1002/9781119910527.ch10

Verma, K., Sharma, P., Kumar, D., Vishwakarma, S. P., and Meena, N. K. (2021). Strategies sustainable management of agroforestry in climate change mitigation and adaptation. *Int. J. Curr. Microbiol. Appl. Sci.* 10, 2439–2449. doi: 10.20546/ijcmas.2021.1001.282

Verma, T., Bhardwaj, D. R., Sharma, U., Sharma, P., Kumar, D., and Kumar, A. (2023b). Agroforestry systems in the mid-hills of the north-western Himalaya: a sustainable pathway to improved soil health and climate resilience. *J. Environ. Manage.* 348, 119264. doi: 10.1016/j.jenvman.2023.119264

Zhang, W., Su, K., Wang, Q., Yang, L., Sun, W., Ranjitkar, S., et al. (2023). Agroforestry species selection for forest rehabilitation in the asia-pacific region: a meta-analysis on high-level taxonomy. *Forests* 14, 2045. doi: 10.3390/f14102045

Zomer, R. J., Trabucco, A., Coe, R., Place, F., van Noordwijk, M., and Xu, J. C. (2014). "Trees on farms: an update and reanalysis of agroforestry's global extent and socio-ecological characteristics," in *Working Paper 179* (Bogor: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program).