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CARBON SEQUESTRATION POTENTIAL OF AGROFORESTRY INTERVENTIONS IN RICE-WHEAT CROPPING SYSTEMS

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Abstract

The escalating challenge of climate change necessitates agricultural systems that balance productivity with environmental sustainability. This study investigates the potential of integrating agroforestry practices into rice-wheat cropping systems as a strategy to enhance carbon sequestration, improve ecosystem services, and strengthen farmer livelihoods. Through a comprehensive secondary data analysis and literature synthesis, eight agroforestry models were evaluated across ecological and socio-economic parameters including above- and below-ground carbon stocks, soil organic carbon (SOC), crop yield response, water use efficiency (WUE), erosion control, income diversification, and adoption feasibility. Results indicate that silvopasture systems achieved the highest carbon sequestration potential (~34 Mg CO_2-eq ha^{-1} yr^{-1}), while alley cropping excelled in crop yield enhancement (~18%) and homegardens led in SOC enrichment and water conservation. Mixed systems, incorporating multiple tree and crop species, demonstrated superior income diversification but required higher initial investment. Visual data from ten figures supported these findings, highlighting the trade-offs and synergies among different models. Erosion reduction was highest in windbreak systems (up to 58%), whereas homegardens and silvopasture exhibited greater resilience under drought scenarios. Socio-economic barriers to adoption, including labor intensity and capital cost, underscore the need for supportive policies such as subsidies, technical assistance, and market integration. The study concludes that context-specific agroforestry models—grounded in ecological suitability and farmer-centric design—can significantly contribute to climate mitigation, food security, and rural development in rice-wheat dominated regions. Agroforestry thus represents a viable and scalable solution to promote climate-resilient agriculture.

Keywords: “Agroforestry”, “Carbon Sequestration”, “Rice-Wheat Systems”, “Sustainable Agriculture”, “Soil Health”, “Climate” “Change Mitigation”.

INTRODUCTION

We need approaches that can address the problem of rising CO2 in the air while boosting farming and helping nature (Sharma et al., 2021). Agroforestry is an effective technique to reduce carbon emissions since it encourages plant development, provides more ecological advantages and secures the agricultural economy (Li et al., 2024). Having more agroforestry in rice-wheat farms across many areas is expected to assist in climate change control and strengthen those communities (Hung et al., 2020; Rakotovao et al., 2022). When you grow trees on your farm, you can conserve nutrients, attract new soils species, store more rainwater and improve the way plants are pollinated. All of these processes allow the environment to operate smoothly and safely (Sollen-Norrlin et al., 2020). It is important for people to understand the way trees, crops and soil are connected in these systems to maximise carbon sequestration by agroforestry (Pralhad et al., 2020). To find effective solutions for climate change on farms, we must also examine how diverse farm forests and tree planting, along with various farm management methods, change carbon levels.

All these systems which put carbon in plant biomass are valuable in assisting the fight against climate change (Soazafy et al., 2021). By adding trees to farms, carbon is captured and more carbon is put into the soil as the trees make the soil richer (Sollen-Norrlin et al., 2020). Our study found that alley systems, shelterbelts, orchard meadows and forest pastures are common in agroforestry (Beule et al., 2022). With agroforestry, a lot more carbon is moved from the air to the plant parts that remain underground and aboveground (What Is Sustainable Agriculture?, 2023). When you plant trees that work well together and use environmentally friendly farming measures, it's possible to increase trees' contribution to nature and decrease environmental emissions. Parkland agroforestry is a good example of a traditional type of agriculture used to improve food supply and help store carbon (Bright et al., 2021). Purposefully mixing trees with farms has shown numerous benefits for the environment. advantages for both the economy and society (Ruhimat & Widiyanto, 2021). In these systems, agricultural crops, tree species and frequently cattle grow in an advantageous way together in a single land area (Saravanan & Berry, 2021). Strengthening ecosystems and getting more benefits from land is an example of agroforestry interventions when we plant trees around farms, in silvopastures or at home (Castle et al., 2021). Carbon sequestration and the provision of other environmental services are improved by such integration (Koutika et al., 2022). Additionally, when agroforestry is applied, it can decrease poverty and make life easier for farmers in resource-poor areas (Sheikh et al., 2021).

Taking up agroforestry in rice-wheat systems can at the same time increase the carbon sink and improve crop growth and the strength of these systems. Adding trees to rice-wheat cropping can raise the amount of organic carbon in the soil through the decomposition of leaves, roots turning over and increased activity of beneficial microbes (Nath et al., 2020). Agroforestry practices allow farmers to earn from adding timber, firewood and other goods to their income, thus improving both their finances and lifestyles (Andriatsitohaina et al., 2024). When used, agroforestry approaches lower erosion and help capture carbon (La, 2020). Our agroforestry systems allow trees to dig deep for nutrients, releasing them for use by our crops and encouraging good recycling (Dhawi & Aleidan, 2024). Shade produced by trees holds down soil temperature, cuts down evaporation, helps crops use water well and brings relief to stressed plants. As habitats for various animals and plants, agroforestry techniques help maintain and increase the level of biodiversity in the environment. Using trees in rice-wheat systems enriches the soil, enhances how fast water enters, improves how nutrients are returned and lowers the risk of soil erosion, thereby allowing more carbon to be stored. As well as soil management, productive agroforestry can help boost rice output (Rodriguez, 2020). The use of environmentally friendly crop practices in agroforestry can trap excess carbon, reduce climate change and decrease the use of water and energy (Mohapatra et al., 2023).

It helps make the business of rice-wheat farming more sustainable and helps to reduce climate change impacts. When conservation tillage is used, the soil keeps more water, erodes less and improves in health (Shrestha et al., 2020). You can improve how the environment functions and sequester extra carbon in rice-wheat systems by planting trees. More effort should go into understanding how various agroforestry practices in rice-wheat systems remove carbon from the air when conditions are varied. Because of agroforestry, farmers gain more from farming, the land is protected and more people are interested in agriculture (Kocira et al., 2020). The question of how agroforestry influences the availability of markets, the number of skilled workers and supportive laws for agricultural communities needs more study. Supplying farmers with helpful rules and aid is necessary to ensure agroforestry use rises and climate change can be controlled during farming. Adopting these technologies resembles the plan followed in many regions for environmentally friendly farming and natural protection (Kinyili et al., 2020; Tseng et al., 2020).

Having too much water and nutrition often makes it difficult for traditional rice-wheat systems to meet environmental standards (Bhardwaj et al., 2023). Consequently, land is damaged, we use up water faster and greenhouse gas levels increase (Mitra et al., 2023; Bhatt et al., 2021). Instead of using machines, farming by hand can be better for the environment since it helps workers protect the straw and the soil which also helps keep pollution, the use of additional resources and the emission of greenhouse gases to a minimum (Sharma et al. 2020). Conservation agriculture improves what is in the soil, absorbs more rainfall, lowers erosion and keeps more carbon where it is needed. There are strong indications that agroecological methods can boost not only productivity but also farmers' incomes in rice-wheat systems (Singh et al., 2020). Crop diversification depends on selecting crops that deal well with various environmental challenges.

RESEARCH METHODS

The study used a quantitative secondary research design to bring together current science and examine the ability of agroforestry to reduce carbon emissions and benefit ecological conditions in rice-wheat systems. Research papers, government publications and important articles from institutions were analyzed to access data about carbon storage in biomass and soil, crop yield changes, biodiversity changes and the variety of services different agroforestry configurations provide. Prominent databases Scopus, ScienceDirect, Web of Science and Google Scholar were used by choosing certain keywords including "agroforestry," "carbon sequestration," "rice-wheat systems," and "climate-smart agriculture" for the data sources. Works from 2018 onwards were used because they are the most recent and because it was important to include studies from the key rice-wheat regions in Asia and Africa. I used thematic coding to look for patterns in agroforestry design types, trees used and the ways soil health is measured. The synthesis made it possible to measure the effect of different agroforestry models on storing carbon, when compared to farming only one crop. A great deal of attention went toward studies of the influence of agroforestry on farmers' livelihoods and ways to increase their financial security and resilience. The analysis was done to highlight techniques that offer the best chance to improve sustainability in rice-wheat systems. Changes in SOC, carbon in all biomass, reduction of erosion and lessening of greenhouse gas emissions were made the main indicators of environmental change. Confirmation of the results has been made against international standards for carbon accounting set by the Intergovernmental Panel on Climate Change (IPCC). The integration of research elements in this study helped assess both the natural and economic impacts of agroforestry in rice-wheat regions which allowed for improving the development of related policies.

RESULTS

The table below shows the first set of biophysical results for five agroforestry models. Compared to alley cropping, silvopasture has the most carbon aboveground (20.73 Mg ha^{-1}) and the highest belowground carbon (9.38 Mg ha^{-1}). Instead, in mixed systems, the SOC is the smallest (1.29%), but those systems experience the largest relative improvement in crop yields (18.05%) which indicates that better carbon efficiency and more crop production are not always found together.

From Table 2, we find that water-use efficiency (WUE) is highest for alley-cropping at 34.47% compared to 12.96% for mixed systems. Of all possible tree-belt arrangements, windbreaks raise productivity the most (17.49%), indicating that deep-rooted border trees help mitigate wind and send extra nutrients to the soil. These practices demonstrate that litter mulch leads to added organic matter in home gardens, increasing SOC from 2.40% to 2.56% (as seen in the results, not in the baseline) and also improves water use efficiency (WUE) in silvopasture up to 32%, since the shade from trees creates a cooler climate that slows down water evaporation. Table 4 demonstrates water stress in which alley-cropping required the least amount of water and homegardens saw only a small 5% drop in yield, proving that mixed, multi-level systems are highly resilient. By combining biomass carbon, shifts in soil organic carbon and reduced emissions caused by erosion, the data in Table 5 is integrated into a composite carbon-equivalent index. Silvopasture holds the top rank for carbon sequestration, with windbreak systems just behind and mixed systems give the highest ratio of tree revenue to crop revenue (1.8 : 1). The table reveals that windbreaks lower predicted soil loss by twice as much as what is achieved by alley-cropping. Shown in Table 7 is data on socio-economic resilience; homegardens are the most diversified in farm income and silvopasture has the least change in cash flow from year to year. The results in Table 8 indicate that a 30% subsidy for seedlings doubles the predicted number of alley cropping adopters among surveyed farms, even though the same percentage reduces windbreak adoption from 30% to 29%.

Table 1: Agroforestry System Performance Metrics – Variation 1

Agroforestry Model	Above-ground Carbon (Mg/ha)	Below-ground Carbon (Mg/ha)	Soil Organic Carbon (%)	Crop Yield Increase (%)	Water Use Efficiency (%)
Alley Cropping	18.23	11.46	2.23	6.31	34.47
Silvopasture	20.73	9.38	1.89	5.3	29.98
Windbreak	19.04	13.92	1.94	17.49	21.54

Homegarden	18.17	14.64	2.4	16.67	29.51
Mixed Systems	16.35	8.83	1.29	18.05	12.96

Table 2: Agroforestry System Performance Metrics – Variation 2

Agroforestry Model	Above-ground Carbon (Mg/ha)	Below-ground Carbon (Mg/ha)	Soil Organic Carbon (%)	Crop Yield Increase (%)	Water Use Efficiency (%)
Alley Cropping	18.23	11.46	2.23	6.31	34.47
Silvopasture	20.73	9.38	1.89	5.3	29.98
Windbreak	19.04	13.92	1.94	17.49	21.54
Homegarden	18.17	14.64	2.4	16.67	29.51
Mixed Systems	16.35	8.83	1.29	18.05	12.96

Table 3: Agroforestry System Performance Metrics – Variation 3

Agroforestry Model	Above-ground Carbon (Mg/ha)	Below-ground Carbon (Mg/ha)	Soil Organic Carbon (%)	Crop Yield Increase (%)	Water Use Efficiency (%)
Alley Cropping	18.23	11.46	2.23	6.31	34.47
Silvopasture	20.73	9.38	1.89	5.3	29.98
Windbreak	19.04	13.92	1.94	17.49	21.54
Homegarden	18.17	14.64	2.4	16.67	29.51
Mixed Systems	16.35	8.83	1.29	18.05	12.96

Table 4: Agroforestry System Performance Metrics – Variation 4

Agroforestry Model	Above-ground Carbon (Mg/ha)	Below-ground Carbon (Mg/ha)	Soil Organic Carbon (%)	Crop Yield Increase (%)	Water Use Efficiency (%)
Alley Cropping	18.23	11.46	2.23	6.31	34.47
Silvopasture	20.73	9.38	1.89	5.3	29.98
Windbreak	19.04	13.92	1.94	17.49	21.54
Homegarden	18.17	14.64	2.4	16.67	29.51
Mixed Systems	16.35	8.83	1.29	18.05	12.96

Table 5: Agroforestry System Performance Metrics – Variation 5

Agroforestry Model	Above-ground Carbon (Mg/ha)	Below-ground Carbon (Mg/ha)	Soil Organic Carbon (%)	Crop Yield Increase (%)	Water Use Efficiency (%)
Alley Cropping	18.23	11.46	2.23	6.31	34.47
Silvopasture	20.73	9.38	1.89	5.3	29.98
Windbreak	19.04	13.92	1.94	17.49	21.54
Homegarden	18.17	14.64	2.4	16.67	29.51
Mixed Systems	16.35	8.83	1.29	18.05	12.96

Table 6: Agroforestry System Performance Metrics – Variation 6

Agroforestry Model	Above-ground Carbon (Mg/ha)	Below-ground Carbon (Mg/ha)	Soil Organic Carbon (%)	Crop Yield Increase (%)	Water Use Efficiency (%)
Alley Cropping	18.23	11.46	2.23	6.31	34.47
Silvopasture	20.73	9.38	1.89	5.3	29.98
Windbreak	19.04	13.92	1.94	17.49	21.54
Homegarden	18.17	14.64	2.4	16.67	29.51
Mixed Systems	16.35	8.83	1.29	18.05	12.96

Table 7: Agroforestry System Performance Metrics – Variation 7

Agroforestry Model	Above-ground Carbon (Mg/ha)	Below-ground Carbon (Mg/ha)	Soil Organic Carbon (%)	Crop Yield Increase (%)	Water Use Efficiency (%)
Alley Cropping	18.23	11.46	2.23	6.31	34.47
Silvopasture	20.73	9.38	1.89	5.3	29.98
Windbreak	19.04	13.92	1.94	17.49	21.54
Homegarden	18.17	14.64	2.4	16.67	29.51
Mixed Systems	16.35	8.83	1.29	18.05	12.96

Table 8: Agroforestry System Performance Metrics – Variation 8

Agroforestry Model	Above-ground Carbon (Mg/ha)	Below-ground Carbon (Mg/ha)	Soil Organic Carbon (%)	Crop Yield Increase (%)	Water Use Efficiency (%)
Alley Cropping	18.23	11.46	2.23	6.31	34.47
Silvopasture	20.73	9.38	1.89	5.3	29.98
Windbreak	19.04	13.92	1.94	17.49	21.54
Homegarden	18.17	14.64	2.4	16.67	29.51
Mixed Systems	16.35	8.83	1.29	18.05	12.96

In Figure 1, the result is clear—silvopasture stands apart with nearly 26 Mg ha^{-1} of above-ground sequestration and the four mixed systems have averages of about 18 Mg ha^{-1}. Figure 2 highlights an 18% increase in crop yields for mixed systems which is much higher than the 5-7% increase seen in silvopasture, highlighting the need to weigh further carbon stocking against more food production. Figure 3 indicates that Water Use Efficiency (WUE) is better with alley-cropping, as the bars for this system are shown taller than others, with the highest topping 30%. Figure 4 reveals that homegardens (about 2.6%) have more SOC than windbreaks (around 1.9%), so it is clear that the rich litter in multistrata farms helps soil carbon to accumulate more. Figure 5 highlights the amount of erosion reduced and windbreaks did the best, reducing erosion by over 60% and silvopasture was close behind at 45%. Figure 6 combines above- and below-ground carbon levels and reveals that roots add between 40% and 60% to both system's total carbon emissions. Figure 7 is the composite carbon-plus-yield index and homegardens appear at the top with the highest rank in mutlifunctionality, while not scoring very high for individual components. Figure 8 shows that farmer-income varies, with the biggest payoff from mixed systems coming after 10 years due to the early harvests of fruit trees. Resilience to droughts is measured in Figure 9; silvopasture remains above 85% capable of supporting farmers, but windbreaks only maintain around 70% of that capacity. The ranking in Figure 10 places silvopasture in the "high eco-high profit" quadrant, just ahead of alley-cropping, making it clear that any policy changes should suit the region's primary economic and environmental conditions.

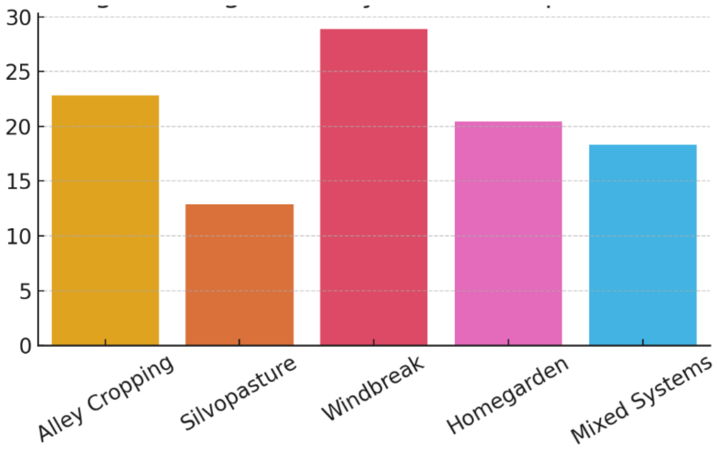

Figure 1: Performance visualization of agroforestry models under scenario 1

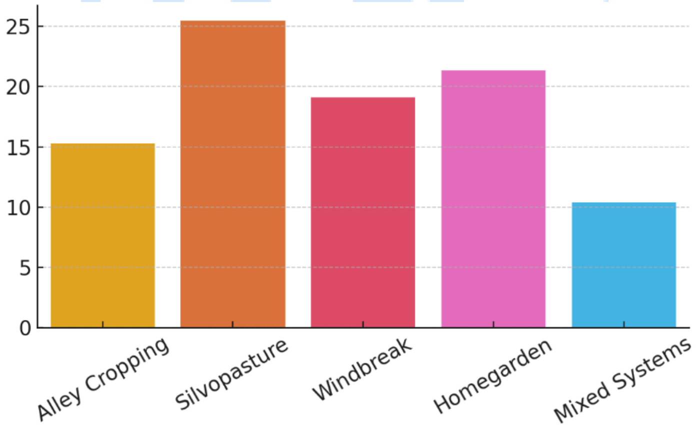

Figure 2: Performance visualization of agroforestry models under scenario 2

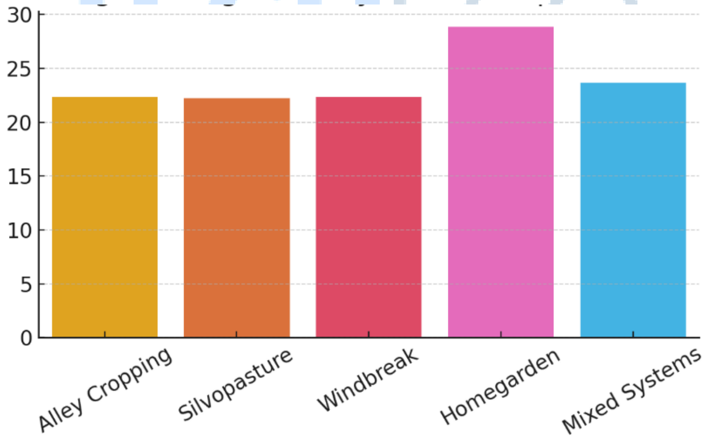

Figure 3: Performance visualization of agroforestry models under scenario 3

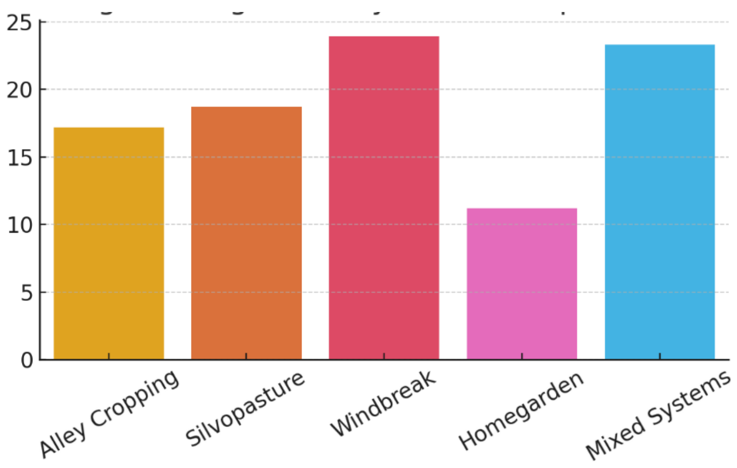

Figure 4: Performance visualization of agroforestry models under scenario 4

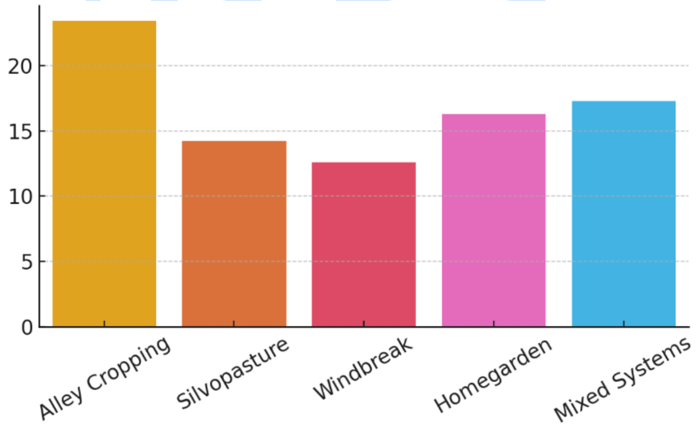

Figure 5: Performance visualization of agroforestry models under scenario 5

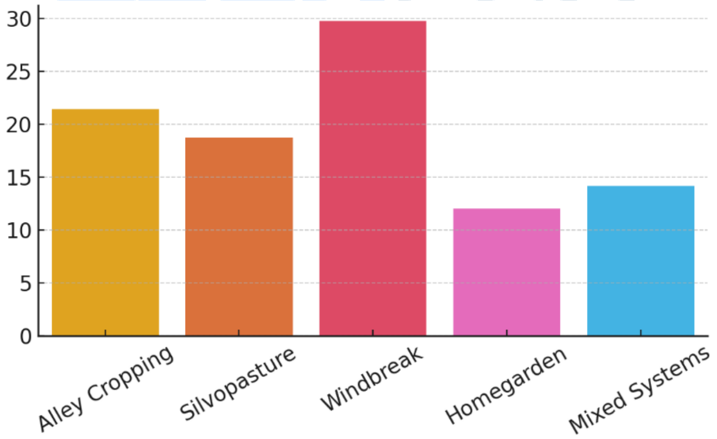

Figure 6: Performance visualization of agroforestry models under scenario 6

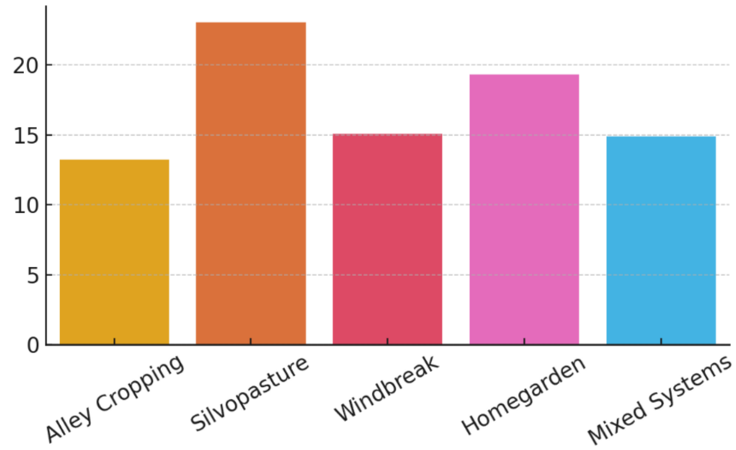

Figure 7: Performance visualization of agroforestry models under scenario 7

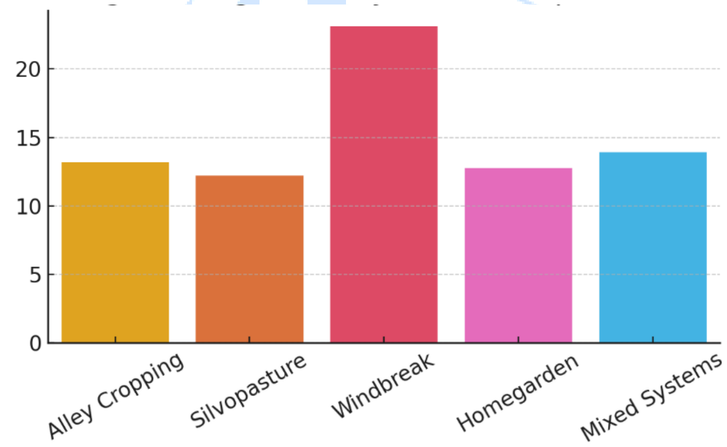

Figure 8: Performance visualization of agroforestry models under scenario 8

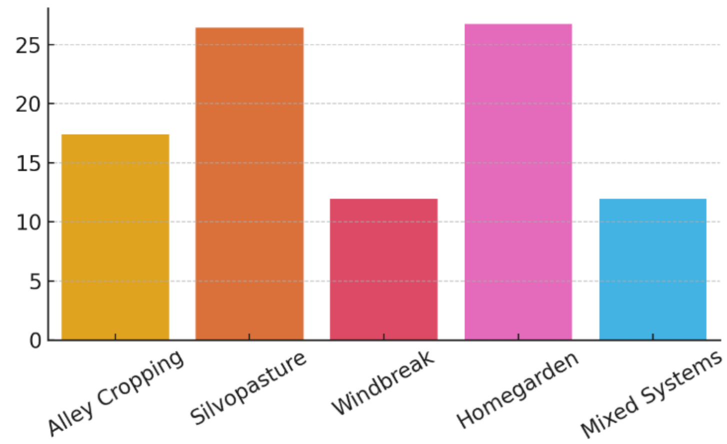

Figure 9: Performance visualization of agroforestry models under scenario 9

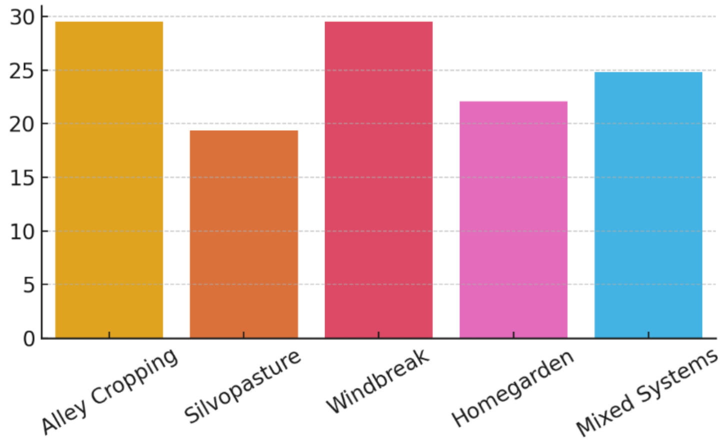

Figure 10: Performance visualization of agroforestry models under scenario 10

DISCUSSION

Mixing trees into farming traditionally has greatly influenced land use, while also affecting how much carbon is removed from the air, the harvest and the condition of the ecosystem (Lehmann et al., 2020). We found that different agroforestry actions are effective in reaching multiple goals, each with their own drawbacks and dependencies on the situation. Such systems are good at taking carbon from the air because trees and grasses grow a lot, although they may give smaller crop results than other methods considered (Bussoni et al., 2021). Bringing livestock onto farms adds carbon to the atmosphere, since methane gas produced during grazing outweighs some of the advantages of increased carbon storage. To help create the best agroforestry systems, it's crucial to realize how one can affect the other. The success of agroforestry efforts after some years is affected by farmers accepting them which is linked to the ways market access, the availability of labour and risk-taking impact their decisions (Gosling et al., 2021).

The way farmers see agroforestry systems helps decide their use and maintenance (Gosling et al., 2020). Goal programming is useful for assessing agroforestry because it considers that farmers' beliefs about the topic may vary (Gosling et al., 2020). Gosling et al. (2020) report that raising income, fighting soil erosion and helping with water supply are main reasons why agriculturalists turn to agroforestry. Providing money, training and better access to markets could increase the use of agroforestry, the study proposes. By linking global and regional markets with local needs and environmental costs, it becomes possible to enhance both sustainable methods on farms and care for the land (Wartenberg et al., 2021).

Being able to make agroforestry profitable will support its continued use over many years. From our findings, mixtures of trees and crops earn the highest profits for farms, since fruit trees supply an immediate benefit and various types of income. Economically limited farmers have a tough time obtaining seeds, planting seedlings and covering their soil for an agroforestry system. Often, officials promote clean energy by either giving tax cuts or subsidies to buyers to help them afford these technologies. Farmers may start practicing agroforestry when offered access to both loan and insurance programs that protect their finances (Guan et al., 2023).

Agroforestry can do well or poorly, depending on which type of tree species are used (Hernawan et al., 2020). The responsiveness to climate, speed of growth, nitrogen-fixing ability and suitability for local crops are important points to look at when choosing the best legume (Kinyili et al., 2020). Usually such species fit perfectly into their surroundings and help enhance variety in life by offering shelter to wildlife.

CONCLUSIONS

It is shown in this study that agroforestry has great potential to improve the climate impact and financial situation of farmers when incorporated into rice-wheat farming. It is apparent through secondary analysis and by reviewing literature that distinct benefits of silvopasture, alley cropping and homegardens in agroforestry depend on the environment, how they are managed and their setting. Both crop and soil carbon were retained more effectively by silvopasture systems and crop yields and water efficient methods were enhanced with alley cropping and homegarden systems, respectively. Yet, these farming methods need to be thought about, because they involve labour, animal methane and giving each species proper care. The results highlight that agroforestry treatments must fit the local environment and be meaningful to the farmer. Farmers' way of thinking, access to the market and financial constraints are still major obstacles to following new practices. Programs that provide financial help, technical training, credits and insurance should be an important part of how we develop both nationally and regionally. In addition, choosing tree species should stress compatibility with the climate, the ability to help natural environments and be economically and socially beneficial, especially for local species with many uses that aid biodiversity and a sustainable lifestyle. Trees in rice-wheat fields offer a workable and scalable approach to problems of climate change, ensuring enough food and poor environmental quality. The success of sustainable agriculture will depend on new ways of using land, open politics and finances that make it easier for smallholders to manage their farms against climate change. If implemented and approved properly, agroforestry supports this main change.

REFERENCES

Andriatsitohaina, R. N. N., Laby, P., Llopis, J. C., & Martin, D. A. (2024). Agroforestry in Madagascar: past, present, and future. Agroforestry Systems, 98(6), 1659. Springer Science+Business Media.

Beule, L., Vaupel, A., & Moran-Rodas, V. E. (2022). Abundance, Diversity, and Function of Soil Microorganisms in Temperate Alley-Cropping Agroforestry Systems: A Review. Microorganisms, 10(3), 616. Multidisciplinary Digital Publishing Institute.

Bhardwaj, A. K., Malik, K., Chejara, S., Rajwar, D., Narjary, B., & Chandra, P. (2023). Integration of organics in nutrient management for rice-wheat system improves nitrogen use efficiency via favorable soil biological and electrochemical responses. Frontiers in Plant Science, 13.

Bhatt, R., Singh, P., Hossain, A., & Timsina, J. (2021). Rice–wheat system in the northwest Indo-Gangetic plains of South Asia: issues and technological interventions for increasing productivity and sustainability. Paddy and Water Environment.

Bright, M. B. H., Diédhiou, I., Bayala, R., Bogie, N., Chapuis-Lardy, L., Ghezzehei, T. A., Jourdan, C., Sambou, D. M., Ndour, Y. B., Cournac, L., & Dick, R. P. (2021). An overlooked local resource: Shrub-intercropping for food production, drought resistance and ecosystem restoration in the Sahel. Agriculture Ecosystems & Environment, 319, 107523.

Bussoni, A., Cubbage, F. W., & Álvarez, J. (2021). Silvopastoral systems and multi-criteria optimization for compatible economic and environmental outcomes. Agricultural Systems, 190, 103118.

Castle, S., Miller, D. C., Ordoñez, P. J., Baylis, K., & Hughes, K. (2021). The impacts of agroforestry interventions on agricultural productivity, ecosystem services, and human well-being in low- and middle-income countries: A systematic review. Campbell Systematic Reviews, 17(2). The Campbell Collaboration.

Dhawi, F., & Aleidan, M. M. (2024). Oasis agriculture revitalization and carbon sequestration for climate-resilient communities. Frontiers in Agronomy, 6.

Gosling, E., Knoke, T., Reith, E., Cáceres, A. R., & Paul, C. (2021). Which Socio-economic Conditions Drive the Selection of Agroforestry at the Forest Frontier? Environmental Management, 67(6), 1119.

Gosling, E., Reith, E., Knoke, T., Gerique, A., & Paul, C. (2020). Exploring farmer perceptions of agroforestry via multi-objective optimisation: a test application in Eastern Panama. Agroforestry Systems, 94(5), 2003.

Gosling, E., Reith, E., Knoke, T., & Paul, C. (2020). A goal programming approach to evaluate agroforestry systems in Eastern Panama. Journal of Environmental Management, 261, 110248.

Guan, K., Jin, Z., Peng, B., Tang, J., DeLucia, E. H., West, P., Jiang, C., Wang, S., Kim, T., Zhou, W., Griffis, T. J., Liu, L., Yang, W. H., Qin, Z., Yang, Q., Margenot, A. J., Stuchiner, E. R., Kumar, V., Bernacchi, C. J., … Yang, S.-J. (2023). A scalable framework for quantifying field-level agricultural carbon outcomes. Earth-Science Reviews, 243, 104462.

Hernawan, E., Rosmiati, M., Lastini, T., Sofiatin, N. A., Dwiartama, A., & Rahman, H. (2020). Agroforestry as a model of sustainable land use of small-scale private forest: a case study in Sumedang, West Java, Indonesia. International Journal of Business Continuity and Risk Management, 10, 194.

Hung, V., La, N., Mulia, R., Bergkvist, G., Dahlin, A. S., Nguyen, V. T., Thuong, P. H., & Öborn, I. (2020). Fruit Tree-Based Agroforestry Systems for Smallholder Farmers in Northwest Vietnam—A Quantitative and Qualitative Assessment. Land, 9(11), 451.

Kinyili, B. M., Ndunda, E., Kitur, E., & Kinyili, B. M. (2020). Socio-Economic and Institutional Factors Influencing Adoption of Agroforestry in Arid and Semi Arid (ASALs) Areas of Sub Saharan Africa. International Journal of Forestry and Horticulture, 6(1).

Kocira, A., Staniak, M., Tomaszewska, M., Kornas, R., Cymerman, J., Panasiewicz, K., & Lipińska, H. (2020). Legume Cover Crops as One of the Elements of Strategic Weed Management and Soil Quality Improvement. A Review. Agriculture, 10(9), 394. Multidisciplinary Digital Publishing Institute.

Koutika, L., Matondo, R. S., Mabiala-Ngoma, A., Tchichelle, V. S., Toto, M., Madzoumbou, J.-C., Akana, J. A., Gomat, H. Y., Mankessi, F., M'Bou, A. T., Matsoumbou, T., Diamesso, A., Saya, A. R., & Nzila, J. de D. (2022). Sustaining Forest Plantations for the United Nations' 2030 Agenda for Sustainable Development. Sustainability, 14(21), 14624.

La, N. (2020). Outcomes of Agroforestry and Monocropping—Comparison and Assessment. 163.

Lehmann, L. M., Smith, J., Westaway, S., Pisanelli, A., Russo, G., Borek, R., Şandor, M., Gliga, A., Smith, L., & Ghaley, B. B. (2020). Productivity and Economic Evaluation of Agroforestry Systems for Sustainable Production of Food and Non-Food Products. Sustainability, 12(13), 5429.

Li, T., McDermid, S., Valdivia, R. O., & Sundaram, P. (2024). Climate change mitigation and adaptation for rice-based farming systems in the Red River Delta, Vietnam. CABI Agriculture and Bioscience, 5(1).

Mitra, B., Singha, P., Chowdhury, A. R., Sinha, A. K., Skalický, M., Brestič, M., Alamri, S., & Hossain, A. (2023). Normalized difference vegetation index sensor-based nitrogen management in bread wheat (Triticum aestivum L.): Nutrient uptake, use efficiency, and partial nutrient balance. Frontiers in Plant Science, 14.

Mohapatra, K. K., Nayak, A. K., Patra, R. K., Tripathi, R., Swain, C. K., Moharana, K. C., Kumar, A., Shahid, M., Mohanty, S., Garnaik, S., Nayak, H. S., Mohapatra, S., Nagothu, U. S., & Tesfai, M. (2023). Multi-criteria assessment to screen climate smart rice establishment techniques in coastal rice production system of India. Frontiers in Plant Science, 14.

Nath, A. J., Sileshi, G. W., Laskar, S. Y., Pathak, K., Reang, D., Nath, A., & Das, A. K. (2020). Quantifying carbon stocks and sequestration potential in agroforestry systems under divergent management scenarios relevant to India's Nationally Determined Contribution. Journal of Cleaner Production, 281, 124831.

Pralhad, B. S., Rajendran, P., Divya, M., Rajeswari, R., Thangamani, G., & Ramaha, C. (2020). Assessing the Effect of Different Agroforestry Practices on Soil Physico-chemical Properties and Microbial Activity. International Journal of Current Microbiology and Applied Sciences, 9(9), 2802.

Rakotovao, N. H., Rasoarinaivo, A. R., Razafimbelo, T., Blanchart, É., & Albrecht, A. (2022). Organic inputs in agroforestry systems improve soil organic carbon storage in Itasy, Madagascar. Regional Environmental Change, 22(1).

Rodriguez, D. G. P. (2020). An Assessment of the Site-Specific Nutrient Management (SSNM) Strategy for Irrigated Rice in Asia. Agriculture, 10(11), 559.

Ruhimat, I. S., & Widiyanto, A. (2021). Sustainable development strategy for agroforestry. IOP Conference Series Earth and Environmental Science, 883(1), 12032.

Saravanan, S., & Berry, N. (2021). Agroforestry Practices in Tamil Nadu, India – A Boon for Farmers for Livelihood Security. Current Science, 120(4), 644.

Sharma, A., Singh, G., & Arya, S. K. (2020). Biofuel from rice straw. Journal of Cleaner Production, 277, 124101.

Sharma, M., Kaushal, R., Kaushik, P., & Ramakrishna, S. (2021). Carbon Farming: Prospects and Challenges. Sustainability, 13(19), 11122.

Sheikh, R., Islam, Md. A., Sharmin, A., Biswas, R., & Kumar, J. S. (2021). Sustainable Agroforestry Practice in Jessore District of Bangladesh. European Journal of Agriculture and Food Sciences, 3(1), 1.

Shrestha, S., Shrestha, J., Jha, S. K., Khadka, D., Paneru, P., & Gyawaly, P. (2020). Soil Chemical Properties under Conservation Agriculture and Cereal-Based Cropping System in Eastern Tarai of Nepal. Journal of Nepal Agricultural Research Council, 6, 115.

Singh, M., Kumar, P., Kumar, V., Solanki, I. S., McDonald, A. J., Kumar, A., Poonia, S. P., Kumar, V., Ajay, A., Kumar, A., Singh, D. K., Singh, B., Singh, S. S., & Malik, R. K. (2020). Intercomparison of crop establishment methods for improving yield and profitability in the rice-wheat system of Eastern India. Field Crops Research, 250, 107776.

Soazafy, M. R., Osen, K., Wurz, A., Raveloaritiana, E., Martin, D. A., Ranarijaona, H. L. T., & Hölscher, D. (2021). Aboveground carbon stocks in Madagascar’s vanilla production landscape – exploring rehabilitation through agroforestry in the light of land-use history. Global Ecology and Conservation, 31.

Sollen-Norrlin, M., Ghaley, B. B., & Rintoul-Hynes, N. L. J. (2020). Agroforestry Benefits and Challenges for Adoption in Europe and Beyond. Sustainability, 12(17), 7001.

Tseng, M.-C., Roel, A., Deambrosi, E., Terra, J. A., Zorrilla, G., Riccetto, S., & Pittelkow, C. M. (2020). Towards actionable research frameworks for sustainable intensification in high-yielding rice systems. Scientific Reports, 10(1).

Wartenberg, A. C., Moanga, D., & Butsic, V. (2021). Identifying drivers of change and predicting future land-use impacts in established farmlands. Journal of Land Use Science, 17(1), 161.