Research Article

Agro-Silvopastoral System, Opportunities, Challenges and Future Prospects

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Abstract | The current study looked into the importance of agro-silvopastoral practices used by farming communities in Paharpur regions of District Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan. The goal of this study was to assess how well agroforestry systems enhance livelihoods by generating more money. This was one of a few studies on the use of agroforestry for livelihood and its importance to human welfare. The work was carried out to evaluate the agro-silvopastoral system as compared to the conventional agricultural crops. An area of one acre (8 kanals) was taken for practicing this model. 3 kanals were used for the plantation of tree species (Poplar and Sheesham), to increase the soil fertility and production of income for the household. 2 kanals were used for the growth of agricultural crops such as wheat (*Triticum aestivum*), to meet the basic needs of the local communities. The wheat was sown by broadcasting of seed. 2 kanals were used to grow the fodder crop such as Berseem (*Trifolium alexandrinum*). 1 kanal was used for livestock and poultry, to generate income through dairy and poultry products. The results showed that multifunctional agroforestry system yielded more than the agricultural crops through graphs and charts. This strategy supported sustainable land management and provides livestock farmers with a number of advantages. By enhancing the diet's nutritional value, it was found that this variety also promotes the health and productivity of livestock. The comparison of incomes generated by all the components of the agro-silvopastoral system were done and it was found to be the best strategy to generate more income as the compared to the conventional agriculture.

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Introduction

A sustainable agricultural production must address concerns like land degradation, food security, biodiversity loss, and climate change because agriculture is the largest economic sector in Asia and Africa. The most urgent issues in Asia and Africa are soil erosion, deforestation and land degradation caused by the growth of agriculture and pasture fields (Gupta *et al.*, 2023). Agroforestry is being promoted extensively

worldwide as a means of increasing production and diversification, because of its advantages in the economic, social, and environmental spheres (Ciaccia *et al*., 2021). Planting trees alongside annual crops helps farmers combat the effects of climate change and land degradation on agriculture (Leakey, 2020). Agroforestry is a potential approach for adapting to climate change that can help farmers and agricultural systems become more resilient to climate risk (Orji *et al*., 2022). Multifunctional land use system plays vital role in the production of both regional and international goods such as fuel wood, timber, fruit, and feed. It also assists numerous nations in achieving important goals for national development, particularly those pertaining to ending poverty, ensuring food security and maintaining the environment (Paudel and Shrestha, 2022). Smallholder agriculture in developing countries has agricultural yields that are more than twice as high as those of the local farming system as a whole. When the market for woody products grows, agroforestry effectively serves as a long-term beneficial investment and the farmer will begin to care for his trees (Zinngrebe *et al*., 2020). Agroforestry has been suggested as a solution to the environmental issues like land degradation, loss of biodiversity, soil fertility, deforestation, greenhouse gas emissions and threats to long-term supply of water (Do *et al*., 2020).

Multifunctional land use is necessary to satisfy the demands of a growing global population because it can produce fuel and food while also protecting the environment and biodiversity and being resilient to climate change (Specht *et al*., 2021). Agroforestry systems are capable of producing income and offering a variety of environmental resources. However, science has only recently started to examine these systems, their costs and advantages, as well as the intricate relationships that exist between their plant, animal and human components (Vera-Velez, 2020). Since agroforestry systems can improve smallholder farmers access to food, income and health, they are of utmost importance (Lacerda *et al*., 2020).

In silvopastoral systems, the quality and yield of the forages generated year-round determine the productivity of the animals. The addition of these tree byproducts to animal feed is essential for maintaining the output of cattle and poultry (Dagar and Gupta, 2020). Because trees have long been a crucial component of rural people's food security plans, agroforestry has a significant impact on the world's current and future levels of food security (IUCN, 2017). Depending on the agroecology, socioeconomic condition and sociocultural background of practitioners, the value of agroforestry may change (Iiyama *et al*., 2018). Agroforestry is a sustainable land management technique that incorporates intentional blending of an agricultural production in the lower story with a woody component (Santiago-Freijanes *et al*., 2021). Farmers frequently engage in agroforestry, but many do not see it as a distinctive and specific land use, l*et al*one accept such acknowledgment (Mosquera-Losada *et al*., 2020). As a result, it has the power to change things and presents a chance to improve organic farming's sustainability (Chattopadhyay *et al*., 2021). The loss of natural forests may be reduced by the production of trees for timber in wooded areas, but it may also be adversely affected by unfair exploitation (Kumar and Singh, 2020).

Materials and Methods

The work was carried out to evaluate the multifunctional agroforestry system (Agro-silvopastoral system) as compared to the conventional agricultural crops. An area of one acre (8 kanals) was taken for practicing this model. Site preparation was the first step; one ploughing was done with MB plow and 2-3 ploughing with harrow or cultivator. The land was leveled after every ploughing. The area was further divided into four compartments, to utilize each of these compartments for different functions.

First compartment

3 kanals were used for the plantation of tree species, to increase the soil fertility and production of income for the household. The pits were made in the selected area at 10 x 10 spacings for the plantation of tree seedlings. The seedlings of Poplar (*Populus deltoides*) and Sheesham (*Dalbergia sissoo*) were bought from the nursery and planted in the pits. The trees were irrigated at regular intervals throughout the study period to maintain their growth. The weeding was done after every 2 months to ensure the protection of the plants. The growth of the trees was measured for one year and their output at the rotation age was estimated according to the market rates and that income was divided per number of years. This has given us an idea about the annual yield of the trees. The seasonal vegetables were grown in between the plants to further benefit the cause. The rabi vegetables

were grown in September and collected in January. The growth rates and yield was calculated and the income was estimated by selling vegetables in the market.

Second compartment

2 kanals were used for the growth of agricultural crops such as wheat (*Triticum aestivum*), to meet the basic needs of the local communities. The wheat was sown by broadcasting of seed. The seed rate of wheat is 50kg per acre. The wheat was sown in November, as 15th of November is optimum time for the growth of wheat. The irrigation was done at regular intervals and a total of 5 s were provided throughout the crop season. Watering at just the right times is crucial for efficient wheat growing. Early irrigation for crops contributes to quicker and more even plant emergence, stronger crop establishment, and a greater yield per land area. The fertilizers such as DAP and Urea were used for the better growth of the crop and the weeding spray were also used. The crop was harvested in April through manual cutting because wheat turned golden yellow and fully reaped. The wheat was then threshed to separate the grain from the chaff with the help of threshing machine (thresher). The wheat grains were collected and stored in the jute bags. Total input and output costs were calculated and results were obtained through analysis.

Third compartment

2 kanals were used to grow the fodder crop such as Berseem (*Trifolium alexandrinum*) that is an annual clover cultivated mostly in irrigated sub-tropical regions, and used as leguminous crop, in order to enhance the livestock production and increase the income. The land was first irrigated and then seed was broadcasted. This crop was grown in October and the seed rate of Berseem is 1kg per kanal. Farmyard manure was used as fertilizer in this crop. This crop was used as fodder during the whole winter season. After two months when the crop was fully established then weekly data was collected by using fodder for livestock and selling in the market. This crop was repeatedly harvested throughout the season and thus contributed to the income. The seed of Berseem was collected in May for the next year.

Fourth compartment

1 kanal was used for livestock and poultry, to generate income through dairy and poultry products. The livestock and poultry products such as milk, eggs etc. were sold in the market and the annual yield was estimated. The purpose of this field oriented scientific study was to provide a multifunctional agroforestry system for the local communities that can generate more income than other agroforestry systems and help in raising the living standards of the community. The production of this one-acre multifunctional agroforestry model was compared with the production of one-acre agricultural crops and their statistical analysis was done to obtain the results.

Statistical analysis

The study was analyzed by applying basic descriptive statistics including mean values and standard deviations. Further, ANOVA (variance test) was performed to calculate the significance difference between production of one-acre multifunctional agroforestry model and the production of one-acre agricultural crops and how these characteristics may influence the farmer's adoption of agroforestry.

Results and Discussion

Most regions of the world have seen widespread use of agroforestry because it offers a variety of products, a means of subsistence, and ecosystem services (Fahad *et al*., 2022). It includes a broad variety of techniques, ranging from simple shifting farming to intricate home gardens, which are primarily used across the subcontinent (Smith *et al*., 2022). Agroforestry has helped smallholder farmers around the world become more resilient to climate change, by providing 20% more food variety in the traditional pattern and a five-fold increase in income in the commercial pattern (Panwar *et al*., 2022).

By incorporating trees with fodder crops and pasture areas, agroforestry can dramatically boost livestock productivity and forage availability. This strategy supports sustainable land management and provides livestock farmers with a number of advantages. Forage possibilities for cattle in agroforestry systems might include a variety of grasses, legumes, and shrubs. By enhancing the diet's nutritional value, this variety promotes the health and productivity of livestock. Agroforestry systems allow for the selection of trees based on their foliage, fruits, or pods, which provide nutrient-rich cattle fodder.

Silvopastoral systems allow cattle to graze under the shade of trees by combining pasture or fodder crops

with trees. The presence of trees in these settings provides animals with relief from heat stress and can lessen productivity losses caused by heat. Through leaf litter and root exudates, trees in agroforestry improve soil fertility by adding organic matter. In turn, this encourages the development of nourishing feed crops for animals. Agroforestry can aid in the retention of moisture in the soil, particularly during dry spells, increasing the amount of water available for fodder crops and enhancing their output. Some common combinations for the agroforestry system of land use being practiced are shown in Table 1.

Table 1: *Some common combinations for the agroforestry system of land use being practiced.*

Tree species	Agricultural crops
Poplars	Wheat, Maize, Turmeric, Sugar cane, Vegetable fodder
Eucalyptus	Wheal, Cotton, Sunflower, Turmeric
Semal	Maize, Sunflower, vegetables, fodder
Farash	Gram, Wheat, Tara Meera, Sarson
Sheesham	Turmeric, Wheat, Maize, Vegetables, Medicinal plant

Agroforestry trees can serve as windbreaks, shielding grazing areas from severe winds that could harm the productivity of cattle and fodder. Furthermore, trees contribute to the preservation of valuable topsoil for plant growth by reducing soil erosion. Perennial forage crops and tree-based fodder can both be included in agroforestry systems, ensuring a consistent source of food throughout the year, even during times of feed scarcity. In agroforestry, trees offer shade and cover for cattle, improving their quality of life, particularly in hot weather.

Agroforestry diversifies income sources for livestock farmers, as they can generate additional revenue from timber, fruits, and other tree products while supporting livestock rearing. Overall, agroforestry practices can lead to improved livestock productivity reduced feed costs, enhanced soil health, and better ecological resilience. Farmers who adopt agroforestry systems can create more sustainable and profitable livestock operations while contributing to environmental conservation and resource management. Proper planning, tree species selection, and management are essential for the success of agroforestry systems in promoting livestock productivity and forage availability. The data of every component of agro-silvopastoral system was recorded throughout the study and was compared with the agricultural crops. The first compartment consisted of 3 kanals in which tree species (Poplar and Sheesham) were planted along with the vegetables. The trees grown about 2 meters in height during the study time, at this rate they will reach their rotation age after 5 years. 48 plants were planted in 1 kanal at a spacing of 10 x 10 that is 144 plants in 3 kanals.

The rate of these plants was calculated according to the market rates which vary according to the demand of local market. The expenditure and income of the livestock products was calculated and the results were measured. The expenditure of livestock per animal is 7000-10000 rupees and the income is about 30000 rupees. Similarly monthly income of poultry is round about 1000 rupees and the expenditure is 300 rupees. The expense of the fodder crops was 5000 rupees and income is 15000-20000 rupees per kanal. The expense of the agricultural crops is shown in the Table 2.

Total income of wheat = Rs 15000 /Kanal
Total expenditure of wheat = Rs 4100/Kanal
Total saving/Kanal = Total Income – Total Expenditure
Total saving/Kanal = 15000 – 4100 = Rs 10900
Total saving/2 Kanal = 10900 x 2 = Rs 21800
Total saving/Acre (8 Kanal) = 10900 x 8 = Rs 87200
Total expenditure/Acre (8 Kanal) = 4100 x 8 = Rs 32800
Profit/Acre = 87200 – 32800 = Rs 54400

Table 2: *Table showing expense of wheat crop.*

Activities	Land unit	Expense
Tillage	01 kanal	1500
Wheat Seed	01 kanal	500
DAP	01 kanal	500
Urea	01 kanal	500
Harvesting	01 kanal	700
Watering	01 kanal	400
Total	01 kanal	4100

The annual income of the wheat is about 90000 rupees per acre while that of the plants is 300000 rupees per year. The vegetables yield about 50000 rupees while the income of livestock is 100000 rupees monthly. The income of poultry is 5000-10000 rupees and fodder crop is 20000 rupees per season, as shown in Figure 1.

The results showed that multifunctional agroforestry system yields more than the agricultural crops through graphs and charts. This strategy supports sustainable

land management and provides livestock farmers with a number of advantages. Forage possibilities for cattle in agroforestry systems might include a variety of grasses, legumes, and shrubs. By enhancing the diet's nutritional value, this variety also promotes the health and productivity of livestock. In conclusion of the study, the comparisons of incomes generated by all the components of the agro-silvopastoral system were done and it stands out to be the best strategy to generate more income as the compared to the conventional agriculture.

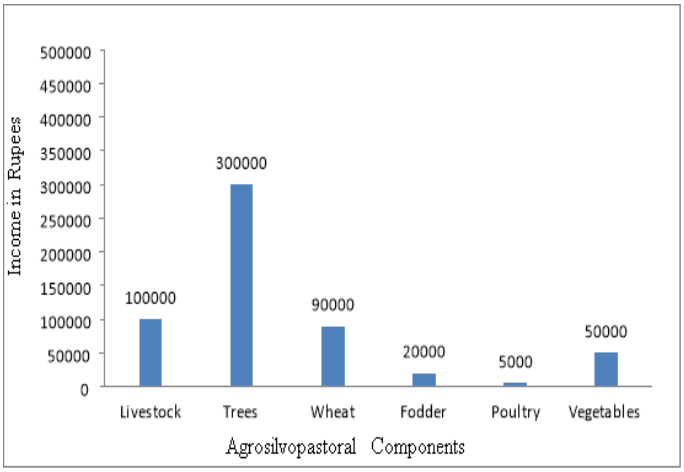

Figure 1: *Comparison of incomes of all components of Agro-silvopastoral system.*

The sparse forest resource has slowly depleted over time as a result of administrative, political, and bureaucratic failures, as well as flawed legislation, unsustainable policy, and total ignorance on the part of the populace, who rarely realize that environmental degradation is having a negative impact on all areas of development (Blaikie, 2016). According to the literature, planting on agricultural and marginal areas around the world has produced notable outcomes and made a significant contribution to closing the supply-demand imbalance. If farmers are obliged to plant trees anywhere in the globe, Pakistan's watersheds, plains, and deserts should be given top priority in order to restore the country's parched, dry, desolate, and devastated areas. The watersheds also require a vegetative cover in order to prevent reservoirs from silting up and flooding havoc.

Conclusions and Recommendations

Through its capacity to modify the microclimate, the integration of trees with agricultural crops with appropriate species selection and management approaches aids in improving the soil structure of degraded soil as well as the biological, chemical, and physical qualities of the soil. By enhancing infiltration and enhancing hydrologic functions through litter fall and canopy impacts, trees on farms increase water retention. Agroforestry improves soil quality by influencing the microbiological activity in the soil through the influence of the trees, organic matter deposition, the presence of root exudates, and the diverse litter quality.

Agroforestry systems minimize soil deterioration, lessen soil and nutrient erosion, and act as a buffer against the effects of rainfall. Because of its impacts on microclimate, nitrogen cycling, litter fall, and soil biota, agroforestry can restore soil-based ecosystem services in degraded soil and offer a feasible avenue for intensification to make agriculture more sustainable. The livelihoods of smallholders and the soil conditions are significantly impacted by climate-related unpredictability in the current context of climate change, which also increases disease risks and climate change vulnerability. Agroforestry systems are being pushed as more robust and sustainable farming methods on a worldwide scale.

The conclusion that agroforestry benefits the tree fanner both socially and economically has led to the suggestion of a few additional actions to further the cause of agroforestry. Making full use of the available land fertility at various depths, growing trees along with agriculture crops greatly increases the overall yield per unit of land. Agroforestry systems are an effective way to stop the degradation of the land and give rural households a source of income. However, in order for the adoption and empowerment of these systems to be effective in the long run, it should be taken into account technical and financial help due to the cost structure and the return period. As a crucial adaptation and mitigation tool against the negative consequences of climate change, agroforestry is becoming more and more important.

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Novelty Statement

The manuscript presents a comprehensive and pioneering examination of multifaceted land-use approach that integrates agricultural crops, forestry, and livestock on the same land. This study provides holistic evaluation of the system's potential benefits, such as enhanced biodiversity, improved soil health, and increased economic resilience for farmers.

Author's Contribution

Muhammad Ikram Ullah Malik: Performed the experiments, contributed materials, tools, Wrote the paper.
Aamir Saleem: Conceived and designed the experiments.
Lubna Ansari: Analyzed the data.
Arshad Mahmood Malik: Scrutiny of data.

Conflict of interest
The authors have declared no conflict of interest.

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