

Impacts of Agroforestry on Rural Communities

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Agroforestry can be used as an alternative way to tackle ecological crisis, while at the same time, sustaining crop production. This system integrates tree growing and crop cultivation and/or animal production on the same land management, based on spatial arrangement or temporal sequence. With such tree integration, agroforestry can preserve natural ecosystems through sustainable land management (including reforestation) and optimal resource utilization. Moreover, agroforestry can potentially mitigate climate change, as several practices within the system are found to improve carbon sequestration and therefore reducing greenhouse gas (GHG) emissions. Moreover, the system can promote biodiversity through the incorporation of different species of plants/crops which may provide homes for various wildlife. Apart from its positive impact on the environment, several studies have also highlighted the socio-economic benefits of agroforestry for rural communities. The implementation of a diverse agroecosystem including trees (timbers, fruits) and livestock might provide alternative incomes for the community promoting economic resilience. Furthermore, the system might improve household food security through diversified food sources. Thus, agroforestry might also become a solution for the existing socio-economic issues.

agroforestry

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environmental impacts

impact assessment

rural communities

climate mitigation

developing countries

1. Socio-Economic Impacts of Agroforestry

The distinction of agroforestry as compared to other land use systems lies in the inclusion of woody plants within the system. On the economic perspective, the adoption of such tree-based farming can improve economic resilience through product diversification ^[1]. The utilization of multipurpose trees, in particular, might improve the profitability of agroforestry as they can serve for various functions such as alternative incomes, sources for fodder or foods (i.e., wild edible fruits) during deficit periods among the rural communities ^[2]. Furthermore, some woods with higher economic value can provide additional incomes for the community apart from the earnings generated from annual crops. Research on teak-agroforestry (*Tectona grandis*) systems in Indonesia, for instance, can generate up to 12% of total household income despite its lower recycling time (due to slow growing period) ^[3]. Furthermore, a study on damar (*Agathis dammara*) agroforestry in Pesisir, West Sumatra, showed that the damar production yielded up to 50% of the total household income ^[4]. Additionally, the adoption of a coffee agroforestry in Wey-Besay Watershed, Lampung, contributed to more than 50% household income compared to only 12% from the conventional agriculture system (non-agroforestry system) ^[5]. Consideration, however, needs to be taken when comparing the economic benefits from different practices as the outcomes might be influenced by various aspects

such as type of trees included, environmental conditions (pest availability, weather conditions, etc.) and commodity price volatility.

Increased benefit-to-cost ratio can also be achieved through agroforestry. Some practices include cultivation of woody plants requiring low inputs (chemical fertilizers, pesticides, etc.), thus it can minimize the production costs and improve income gained by the farmers [6][7]. However, such an outcome might highly depend on the farmers' knowledge of the practice, particularly on how to make optimal plant/tree selection for their system. Some trees can grow better when they were cultivated along with their complementary crops. On the contrary, the wrong selection of tree or crop components can cause nutrient competition [8], which consequently reduce yield and therefore the profit gained by the farmers.

The implementation of agroforestry can also open up new job opportunities in rural areas for off-farm activities such as crop drying, wood cuttings, furniture making etc. [9]. Increased job opportunities might also benefit women as they can be directly involved in the production activities, which can improve gender equality in rural areas [10]. Furthermore, job absorption in the rural areas might prevent rural exodus [11][12] and therefore, can contribute to improved rural economy. Nevertheless, caution needs to be taken when creating industrial sites around the conservation area or near the primary forest as the risk of human encroachment to such protected areas might occur and can potentially damage the ecosystem [12].

Apart from generating income, agroforestry can also play a role in improving food security among the community near the forests. In this case, Ickowitz et al. [13] employed spatial data to elucidate micronutrient uptake among children between one to five years old in Indonesia. They found a correlation between agroforestry and increased consumption of legumes at the national level. Meanwhile, at regional level, their findings displayed a correlation between the presence of agroforestry and increased consumption of vitamin A-rich fruits and leafy vegetables. Furthermore, agroforestry systems were also associated with higher meat consumption particularly from those people adopting silvopastoral practice [13]. Increased volume of food productivity and diversity was also shown among the low-income farmers who had engaged in agroforestry training, indicating higher food availability following the implementation of agroforestry [14]. Evidence on the positive correlation between agroforestry adoption and food security among communities were also depicted by other studies, such as in several countries in Sub-Saharan Africa, South Asia and in Latin America [10][15][16].

Agroforestry might also stimulate socio-cultural activity among the adopters. For instance, farming communities can meet with each other and discuss the cultivation method, choice of tree species or crop varieties, fertilizer management and so on. A study conducted by Mungmachon [17] found that gathering was part of the culture among small forest communities in Thailand. They often discussed the problems they were facing and found solutions together. They began by collectively studying their problems, rediscovering traditional wisdom and existing knowledge, and then integrating new knowledge. By doing this, the community becomes more engaged and knowledgeable through peer-to-peer discussion and community participation. The summary of socio-economic impacts of agroforestry and their respective studies (references) on rural communities can be seen in **Table 1**.

Table 1. Summary of previous studies depicting socio-economic and environmental impacts of agroforestry for rural communities.

Aspect	Impact Description	Type of Impact	Reference
Economic	<ul style="list-style-type: none"> Improve economic resilience through diversified farming products and reduced crop losses 	Positive	[18][19]
	<ul style="list-style-type: none"> Open job opportunities in rural areas 	Positive	[9]
	<ul style="list-style-type: none"> Increase benefit to cost ratio 	Positive	[6][7]
	<ul style="list-style-type: none"> Reduced yield due to competition of sunlight, water and nutrients among introduced plants/crops 	Negative	[20]
	<ul style="list-style-type: none"> Speculative investment 	Negative	[12]
Social	<ul style="list-style-type: none"> Promote gender equality through empowerment of women 	Positive	[10]
	<ul style="list-style-type: none"> Improve household food security through food diversification 	Positive	[10][21]
	<ul style="list-style-type: none"> Development of cooperatives among the community 	Positive	[12]
	<ul style="list-style-type: none"> Prevent rural exodus 	Positive	[11]
	<ul style="list-style-type: none"> Improve cultural activity through community participation in developing innovations 	Positive	[22]
	<ul style="list-style-type: none"> Influx of migrants to conservation areas 	Negative	[12]
Environment	<ul style="list-style-type: none"> Prevent soil erosion through enhanced soil physical structure 	Positive	[23][24]
	<ul style="list-style-type: none"> Windbreak function to protect main crops 	Positive	[24]

Aspect	Impact Description	Type of Impact	Reference
	<ul style="list-style-type: none"> Enhance soil fertility through increased availability of nitrogen and carbon in soils 	Positive	[23][25]
	<ul style="list-style-type: none"> Prevent drought through improved water retention 	Positive	[26]
	<ul style="list-style-type: none"> Promote biodiversity and wildlife conservation 	Positive	[27]
	<ul style="list-style-type: none"> Maintain water cycle, sustaining water availability at the local level 	Positive	[26][28]
	<ul style="list-style-type: none"> Reduced biodiversity due to implementation of “industrial” agroforestry 	Negative	[12]
	<ul style="list-style-type: none"> Transformation of pristine forest (non-secondary) to agriculture which lead to, among others, biodiversity losses and transmission of disease to society 	Negative	[29]
	<ul style="list-style-type: none"> Risk of resource depletion including soil mining and water evaporation 	Negative	[20][30]

amendments [25]. This practice, however, can yield a different outcome depending on the quality of pruning materials available in the system. Plant residues have different C/N ratio which can affect their decomposability in soils. Consequently, the amount of nutrients released in the soil might vary between type of residues resulting in distinct soil chemical content [31], and therefore its impacts on crop growth. Different decomposition rate due to variation in C/N ratio can also influence soil carbon content (either increase or decrease), which may compromise the carbon sequestration capability of a particular agroforestry system as a whole [32][33].

The cultivation of different tree species in agroforestry system also improves biodiversity providing a habitat for the wildlife [34]. In addition, trees can also prevent soil erosion and landslides (in the higher slopes) due to the strong rooting system around the soil matrix [23][24]. The presence of trees in agroforestry systems can also change microclimatic conditions through shading which might reduce the sun radiation buffering the temperature around the farm [35]. Highly intensified solar radiation can hamper crop physiology and growth, hence incorporating trees through agroforestry can improve crop growth and subsequently, its yield [35][36]. Caution needs to be taken however, when selecting tree coverage, as overshading can significantly reduce the light penetration which can potentially reduce the growth of co-cultivated crops and increase disease emergence [37].

Another ecological benefit of agroforestry for the community is improved water conservation. Such ecosystem service might result from optimal water uptake by the integrated tree-crop system. A research that was done on an agroforestry system (maize-tree) in Kenya shows that during the dry season, only about 25% of the rain water was transpired from plant biomass, indicating the efficiency of the system in utilizing off-season rainfall (which accounts for 15–20% of the total annual rainfall). Meanwhile, the rest of the water remains in the soil layers even after the harvest period [38]. Improved organic carbon in agroforestry soils (as a result of organic amendment addition) can increase water retention and therefore prevent excessive evaporation or water runoff [39]. However, again, the choice of the tree species matters as water uptake might vary between plant species. Water uptake by plant roots is generated by the water potential difference between the soil and the atmosphere when leaf stomata are open and this depends on the root exploration capacity of a particular plant species [40].

In addition, a conducted trial showed that higher vegetation density (due to more biomass from trees/shrubs) positively correlates with the precipitation rates with reduced vegetation decreasing the rainfall. Such decline in precipitation might be attributed to the reduced evapotranspiration and increased light reflection to the atmosphere under less vegetation density [41]. Furthermore, analysis of the water cycle highlights the importance of managing tree cover to improve the quantity of rainfall [42][43]. Agroforestry, therefore, can be one of the strategies to alleviate drought in some arid areas and increase community resilience in the changing climate. Although promising, these studies were only performed at farm level and rely on data correlation or modeling. Hence, more studies need to be done to validate such findings covering different geographical locations. A brief summary of environmental impacts of agroforestry on rural communities and their respective studies (references) can be seen in **Table 1**.

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