SOIL & CROP SCIENCES | RESEARCH ARTICLE

*Mangifera indica (L.) tree as agroforestry component: Environmental and socio-economic roles in Abaya-Chamo catchments of the Southern Rift Valley of Ethiopia*

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**Abstract:** The integration of woody perennials into the agricultural ecosystem often has diversified environmental, economic and social benefits. *Mangifera indica*-based agroforestry system in southern rift valley is not investigated and scientifically documented well. The current study tried to investigate the environmental and socio-economic roles of the mango-based agroforestry system in the southern rift valley around the Abaya-Chamo catchment, especially in the Gamo Zone. Three kebeles (a small administrative unit in Ethiopia) were selected purposively based on the potential, and about 151 household heads were interviewed by questionnaires from May 2021 to July 2021. Household socio-economic data and environmental and socioeconomic roles of both mango and non-mango-based agroforestry practitioners were collected. Both key informant interview (KII) and focus group discussions (FGD) were also held. The collected data were analyzed by simple descriptive statistics in SPSS version 24 software. As a result, the interviewed respondents differed significantly (P < 0.05) in terms of agroforestry practices. It was confirmed that the mango-based agroforestry practitioners revealed that the soil fertility enhancement, reduction of crop damage by wind and amelioration of microclimate by shading for crop and livestock were of environmental importance mango-based agroforestry practitioners benefited more than non-mango-based agroforestry practitioners (P < 0.05). Whereas food/fruits, timber, traditional medicine, fuel-wood, pole and fodder were socio-economic roles of agroforestry. The mango-based agroforestry practitioners benefited from pole and food more than non-practitioners (P < 0.05). This indicates that the mango-based agroforestry of Abaya-Chamo catchments of the southern Rift valley of Ethiopia has potential for environmental and socio-economic advantages to the society. Elongated experimental research will help to optimize strategies for the management and sustainable utilization of this climate-smart agricultural system.

**Subjects:** Agriculture & Environmental Sciences; Conservation - Environment Studies; Biodiversity & Conservation; Ecology - Environment Studies

**Keywords:** Abaya-Chamo; Climate-smart agriculture; Kobo collect; mango orchard
1. Introduction

1.1. Background and justification
Agroforestry is a planned combination of trees and crops with or without livestock on the same land that is increasingly being recognized as a sustainable system to reconcile agricultural production (Catacutan et al., 2017; Hassan et al., 2016; Nair et al., 2021). In this system, there is ecological and economic interactions between the components (Alao et al., 2016; Atangana et al., 2014). The systems make a significant contribution toward reducing poverty and resource degradation in Africa. For instance, agroforestry technologies such as fruit trees can provide a more diverse farm income and reduce food insecurity (Thangata et al., 2002).

Fruit trees, grass and crops in agroforestry systems had higher productivity, higher profitability and earlier returns on investment than sole-crop fruit systems, but also higher initial investment costs (Do et al., 2020). A majority of fruit-based systems are found in the tropics and subtropics where fruit trees constitute an important component of agroforestry systems (Lauri et al., 2020). In Ethiopia, the fruit tree-based agroforestry system has a great role to play in livelihood improvement and it provides multiple contributions to household income and supplementary food for smallholder farmers (Adane et al., 2019).

Farmers in different parts of the tropics including Ethiopia traditionally integrate this fruit tree with other components of the so-called mango-based agroforestry system. This system (e.g., alley cropping) is an important component of agroforestry systems and is widely followed in many parts of the world (Mishra et al., 2020; Rana, 2022).

The southern rift valley around lake Abaya-Chamo catchment is known for fruit production specially Mangifera indica-based agroforestry (Gochera et al., 2021). The mango is claimed to be the most important fruit of the tropics and has been touted as the “king of all fruits”. The fruit contains almost all the known vitamins and many essential minerals. However, the dominant agroforestry systems in southern Ethiopia are enset-based, enset-coffee-based and fruit-coffee-based and chat-based (Mesele, 2013).

Even though the southern rift valley around Abaya-Chamo catchment, especially in the Gamo Zone the mango is the largest produced tropical fruit in the farmland as agroforestry, still fruit-based agroforestry system is not sufficiently investigated. So the current study tried to investigate the environmental and socio-economic roles of the mango-based agroforestry system in southern rift valley around the Abaya-Chamo catchment, especially in the Gamo Zone.

2. Materials and methods

2.1. Description of the study area
The study was carried out in the southern rift valley around the Abaya-Chamo catchment, especially in the Gamo zone in the Southern Nations, Nationalities, and Peoples’ Region of Ethiopia. According to the Gamo zone agriculture and natural resource development office (2021), the top mango fruit-producing potential areas in the Gamo zone were considered namely: Chano Mile, Lante and Kola Shelle. These potential areas are shown in the map below (Figure 1). The areas lie within the lowland agro-ecological zone at altitude ranges between 1200 m to 1285 m.a.s.l. The maximum mean annual rainfall of Chano Mille, Lante and Kola Shelle is 1000 mm and the minimum mean annual rainfall is 300 mm. The maximum and minimum mean annual temperature is 38°C and 14°C, respectively (Arba Minch meteorology service, 2021)

2.2. Sampling techniques and data collection method

2.2.1. Sampling techniques
Three kebeles were selected purposively based on the Mango fruit production potential in the Gamo zone (Gochera et al., 2021), namely, Lante, Chano mile and Kola Shelle. To determine the sample
distribution and the corresponding target population in the study area, the following formula will be used. To calculate a proportion with a 95% level of confidence and a margin of error of 8%, we obtain according to Cochran (1977). Formula $N = z^2(1-p)p/e^2$. Accordingly, 151 sample households were selected. During the survey, mango-based agroforestry practitioners and non-mango-based farm practitioners were identified with district and Kebele agricultural office experts. In addition, key informants and Focus group discussions were held. The KIs were model farmers, who lived there, for at least for continuous 30 years in the area, as recommended by the kebele agricultural office.

2.2.2. Data collection method
Both primary and secondary data were collected and used. Primary data were collected by structured and semi-structured questionnaires, key informant interviews, focus group discussion (FGD) and field observation. Secondary data were collected from different sources published and unpublished sources. The socio-economic and demographic characteristics of households (HHs); name, age, family size, level of education attended, land size, type of agroforestry practiced and the role of practiced agroforestry were gathered from the inspected HHs by kobo collect android application using smart mobile Tecno Camon 12 (Lakshminarasimhappa, 2022). Household heads were interviewed for both environmental and socioeconomic parameters pre-developed by the research team during KIIIs and FGD.

2.3. Data analysis
The quantitative data were analyzed using descriptive statistics. The results were presented using tables and figures. The qualitative data collected were narrated and summarized and used to substantiate and complement the collected data. Statistical Package for Social sciences (SPSS) software version 24 was used to analyze the data. The role of MBAFs among practitioners and non-practitioners was subjected to one-way ANOVA, and the mean differences were considered
significant at $P < 0.05$. Kruskal–Wallis $\chi^2$ tests to determine differences in interviewer responses to each variable and between MBAF practitioners and NMBAF practitioners were considered.

3. Results and discussions

3.1. Demographic characteristics of household in the study area
Household demographic features can influence species selection and the ecological and socio-economic roles of the agroforestry system. Out of 151 interviewed household heads, 121 were mango-based agroforestry practitioners (MBAF) and the rest 30 were non-mango-based agroforestry practitioners (NMBAF). Gender distribution indicates that 88% were male-headed whereas the remaining 12% were female-headed.

The age of MBAF practitioners indicated that 47.1% were in the range of 41–50, 27.3% were in the range of 31–40 and 19.8% were in the age of >50. The difference in age distribution was statistically significant ($P < 0.05$) for the age group from 31 to 50 (Table 1).

The education status of the respondents indicates that 44.4% had not received formal education, while the rest had education levels from elementary to degree level formal education. The education-level distribution of respondents was statistically significant ($P < 0.05$; Table 1).

The major livelihood activity for 91.4% of the respondents was farming and 1.3% was a civil servant. The livelihood activity difference between practitioners and among civil servants and others was statistically significant ($P < 0.05$). The marital status between practice and non-practitioners was statistically significant ($P < 0.05$). Of the interviewed respondents, 88.15 were married and the rest were single and widowed.

The household distribution of respondents was also significantly different for Practitioners and non-practitioners at statistically significant ($P < 0.05$; Table 1).

3.2. Environmental role of mango-based agroforestry systems (MBAFs)
Agroforestry plays an important role in environment mainly through maintaining the ecosystem (Table 2). With significant difference among the two land-use types ($P < 0.05$), the sampled respondents were asked about the parameters that indicate the environmental benefits of the agroforestry: soil fertility status, crop damage by wind, shade problem at a farm in hot weather, soil erosion risk and level of pest damage were considered in this study. Accordingly, about 34%, 27.3%, 26%, 12% and 0.7% of the respondents revealed that there is no damage, low damage, high damage and medium damage and very high damage (Table 2). This indicates the damage level is medium to no damage. Regarding the damage to crops by wind between MBAF practitioners and MBAF practitioners, 25.3%, 25.3%, 18%, 10.7% and 0.7% of the respondents reported

| Table 1. Respondents' demographic characteristics and their statistical tests |
|-------------------------------|-----------------|--------------|
| No.                          | Household characteristics | P-Value   |
| 1                            | Age of the household head | 0.027       |
| 2                            | Experience in the area | 0.337*      |
| 3                            | Sex of the HH head | 0.006       |
| 4                            | Education level of HH head | 0.192*     |
| 5                            | Major occupation of HH head | 0.00       |
| 6                            | Marital status | 0.005       |
| 7                            | Household size | 0.002       |
| 8                            | Farm size | 0.00        |

*Indicates that variables are significantly different at $P < 0.05$
Table 2. Environmental parameters and their significance level at $P < 0.05$

| No. | Parameter for environmental role | Agroforestry practitionership | Totaln (%) | $\chi^2$ | P-Value |
|-----|----------------------------------|-------------------------------|------------|--------|---------|
|     |                                  | NMBAF practitioner (%)        | MBAF (%)   |        |         |
| 1   | How do you rate damage to crops by the wind on the farm? | No damage 24(16.0) | 27(18.0) | 51(34.0) | 36.009 | 0.000* |
|     |                                  | low damage 3(2.0)             | 38(25.3)  | 41(27.3) |         |         |
|     |                                  | Medium damage 2(1.3)          | 16(10.7)  | 18(12.0) |         |         |
|     |                                  | High damage 1(0.7)            | 38(25.3)  | 39(26.0) |         |         |
|     |                                  | Very High damage 0(0.0)       | 1(0.7)    | 1(0.7)   |         |         |
| 2   | How do you rate the soil fertility status of the farm? | Not Fertile 17(11.3) | 8(5.3)    | 25(16.6) | 44.991 | 0.000* |
|     |                                  | Less Fertile 1(0.7)           | 29(19.2)  | 30(19.9) |         |         |
|     |                                  | Fertile 11(7.3)               | 80(53.0)  | 91(60.3) |         |         |
|     |                                  | Very Fertile 1(0.7)           | 4(2.6)    | 5(3.3)   |         |         |
| 3   | Is there a shade problem in your hot weather? | Yes 18(98.7) | 118(78.1) | 136(90.1) | 37.826 | 0.000* |
|     |                                  | No 3(2.0)                     | 12(7.9)   | 15(9.9)  |         |         |
| 4   | Rate the Soil Erosion Risk Level of the farm? | Very low 23(15.2) | 91(60.3)  | 114(75.5) | 4.755  | 0.313 |
|     |                                  | Low 6(4.0)                    | 12(7.9)   | 18(11.9) |         |         |
|     |                                  | Moderate 0(0.0)               | 3(2.0)    | 3(2.0)   |         |         |
|     |                                  | High 1(0.7)                   | 12(7.9)   | 13(8.6)  |         |         |
|     |                                  | Very High 0(0.0)              | 3(2.0)    | 3(2.0)   |         |         |
| 5   | Level of pest damage on the farm? | No damage 3(2.5)              | 17(14.4)  | 20(16.9) | 7.772  | 0.07  |
|     |                                  | Medium damage 3(2.5)          | 16(13.6)  | 19(16.1) |         |         |
|     |                                  | Low damage 3(2.5)             | 26(22.0)  | 29(24.6) |         |         |
|     |                                  | High damage 0(0.0)            | 50(42.4)  | 50(42.4) |         |         |

*Indicates that variables are significantly different at $P < 0.05$
that the level of damage to crops by the wind on the farm is a high damage, low damage, no damage, medium damage and very high damage, respectively. On the contrary, 16%, 2%, 1.3% and 0.7% of NMBAF practitioners reported that the level of crop damage by the wind is no damage, low damage, medium damage and high damage. The responses of two land-use type practitioners were significantly different (P < 0.05).

Researchers have witnessed the importance of agroforestry practices against crop damage from strong wind. For example, one of the most important functions is to reduce wind erosion and protect crops from wind damage windbreaks are a major component of and play an important role in agroforestry ecosystems (Yang et al., 2021). Integrating woody perennials in the agricultural system improves the efficiency of ecological and ecosystem services by increasing productivity and decreasing the damage to crops organically and by resulting in higher yields (Jo & Park, 2017; Mume & Workalemahu, 2021; Stigter et al., 2002). The role of agroforestry in wind damage control is due to the existence of potential woody species in agroforestry systems and the difference in wind damage between two land-use type practitioners could be due to the difference in a woody component.

Regarding the soil fertility status of their farms viewed it as 6.6%, 19.9%, 60.3% and 3.3% responded that their soil fertility status is “Not Fertile”, “Less Fertile”, “Fertile” and “Very Fertile”, respectively, in the study area. Similarly, 5.3%, 19.2%, 53.0% and 2.6% NMBAF practitioner responded their soil fertility status is “Not Fertile”, “Less Fertile”, “Fertile” and “Very Fertile”, respectively. About 11.3%, 0.7%, 7.3% and 10.7% NMBAF practitioner also stated their farms soil fertility status is “Not Fertile”, “Less Fertile”, “Fertile” and “Very Fertile”. The responses between the two land-use types of practitioners were significantly different (P < 0.05; Table 2).

The role of agroforestry in soil fertility enhancement has been reported by different scholars. This research can be supported by different reports from different corners of the world. For instance, (Rathore et al., 2013) recommended that 15 years of age of mango plantation for multiple outputs and good economic viability without impairing site fertility. (Kenfack Essoungong et al., 2020) reported the importance of Cocoa agroforestry systems for soil fertility management in Cameroon. Agroforestry increases the soil fertility status of the areas (Aragé, 2021). The soil fertility enhancing role reported by agroforestry might be due to the existence of agroforestry species that help in improving soil fertility and proximity to farmers for the management of the system in MBAF. The respondents with mango-based agroforestry perceived that their farming system has potential for soil fertility enhancement. This could be related to the less harvest from the system and moderate return to the soil. Respondents were also subjected to responses on the Soil Erosion Risk Level of their farm. Accordingly, 75.5%, 11.9%, 2.0%, 8.6% and 2.0% of all respondent in the area viewed “Very low, Low, Moderate, High, Very High” and 78.1%, 2.0%, 60.3%, 7.9%, 2.0%, 7.9% and 2.0% of MBAF practitioners viewed Very low, Low, Moderate, High, Very High and 15.2%, 4.0%, 0.0% and 0.7% NMBAF practitioners viewed “Very low, Low, Moderate, High, Very High”, respectively. The responses between the two land-use types of practitioners were significantly different (P < 0.05; Table 2).

Researchers have reported that woody perennials have the potential to reduce soil erosion in the farming system. The erosion reduction role of the agroforestry system of coffee (Coffee arabica) and mixed shade trees (Inga spp and Musa spp) in Northern Nicaragua was reported (Blanco Sepúlveda & Aguilar Carrillo, 2015). Agroforestry has the potential generally to conserve soil and water on the farm and nearby (Lundgren & Nair, 1985; Mou, 2011). The role of agroforestry in soil erosion risk control viewed by respondents might be due to the roots of woody species in agroforestry having the potential to control erosion risk in agroforestry settings. Another research witnessed the upscaling of sweet-orange-based agroforestry for the restoration of degraded shifting cultivated lands in North-East India for environmental sustainability (Sahoo et al., 2021). Generally, the role of MBAF was modeled and confirmed.
as it has helped for conversion of degraded land into productive land along with environmental security (Rathore et al., 2021). Hence, all the considered parameters except the risk of soil erosion have differed significantly between MBAF and NMBAF practitioners (P < 0.05; Table 2).

3.3. Socio-economic role of mango-based agroforestry systems (MBAFs)

Agroforestry practice in the study area has a lot of socio-economic roles to the community as indicated below in Figure 2. About 90.1% of the interviewed respondents stated that they got food, especially in the form of different fruits like mango, and citrus species, and 60.96% of the respondents stated that they got traditional medicine mainly for humans and cattle too. Forty-five per cent of respondents revealed as they got fuel wood from their farm. Other socio-economic roles; timber, pole and fodder, were informed by 11.96%, 27.2% and 12.6% of the respondents, respectively. In the case of agroforestry type, the respondents revealed significantly different only for food and pole (P < 0.05; Table 3). Mango-based agroforestry (MBAF) practitioners get significantly higher food and pole for construction than non-mango-based agroforestry (NMBAF) practitioner. The current research is in line with different reports about the importance of fruit tree-based agroforestry. For example, farmer’s livelihoods improved enormously by practicing agroforestry as they have more access to food, fodder and fuel wood which is reflected by greater access to livelihood capital (Hanif et al., 2018). By the proper implementation of agroforestry practices with proper tree-crop combination, farmers can improve their livelihood and socio-economic status (Ibrahim et al., 2011). Mango-based agroforestry in India also generates maximum employment for the society (Mishra et al., 2020). The significant difference between agroforestry practitioners for food could be due to agroforestry’s nature which is fruit-based and farmers’ focus on fruit-based perennials. In the case of pole for constriction, mango-based agroforestry practitioner experiences integrating trees for pole due to scarcity of woodlands to bushes and agriculture.

![Figure 2. The socio-economic role of agroforestry in the study area.](https://doi.org/10.1080/23311932.2022.2098587)

| Table 3. Socio-economic role of MBAF and NMBAF with statistical difference (P < 0.05) |
|---------------------------------|------------------|------------------|
| Socio-economic role          | AF practitioner ship | \( \chi^2 \)     | P-Value  |
| Food/fruits                  | 56.09             | 0.00*            |
| Pole                         | 7.48              | 0.05*            |
| Fodder                       | 0.52              | 0.47             |
| Traditional medicine         | 1.04              | 0.31             |
| Fuelwood                     | 0.48              | 0.79             |
| Timber                       | 1.86              | 0.17             |

*indicates that there is a statically significant difference between agroforestry types.
4. CONCLUSION

Agroforestry plays an important role in environmental and socio-economic roles mainly through maintaining the ecosystem. Agroforestry practitioners in the study area confirmed that mango-based agroforestry systems (MBAs) were used for soil fertility enhancement, the reduction of crop damage by wind, to ameliorate microclimate by shading crops and livestock at the farm in hot weather. This role of agroforestry practices was viewed as differently significant at $P < 0.05$.

In addition to environmental function, respondents confirmed the integrated Mangifera indica in their agricultural landscape has been used for socio-economic roles such as food/fruits, timber, traditional medicine, fuelwood, pole and fodder. Mangifera-based agroforestry practitioners got the food and pole for construction in significantly different amounts than Non-Mangifera-based agroforestry practitioners.

In general, mango-based agroforestry of Abaya-Chamo catchments of the southern Rift valley of Ethiopia has the potential for ecological and socio-economic merits for society. Further research on challenges, manangement practices and longitudinal experimental research on integrated mango-based agroforestry orchard with annual crops are needed to optimize strategies for sustainability of this green economy.

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