Int. j. adv. multidisc. res. stud. 2024; 4(5):239-245

Received: 17-07-2024
Accepted: 07-09-2024

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Assessing the Role of Agroforestry-Livelihood-Food Security Nexus in the Madhupur Sal Forest of Bangladesh

[1] SM Sanjida Tasnim Urmi, [2] SM Kamran Ashraf, [3] Md. Tanbheer Rana, [4] Saleha Khatun Ripta, [5] Sumaiya Binte Rahman Asha, [6] Mst. Sohela Afroz, [7] Kazi Kamrul Islam

[1, 2, 6, 7] Department of Agroforestry, Bangladesh Agricultural University, Mymensingh, Bangladesh
[3] Tropical and International Forestry, Georg-August-University, Göttingen, Bangladesh
[4] Department of Soil Science, Bangladesh Agricultural University, Mymensingh, Bangladesh

DOI: https://doi.org/10.62225/2583049X.2024.4.5.3223
Corresponding Author: **Kazi Kamrul Islam**

Abstract

Agroforestry practices play an inevitable role in reinforcing the livelihood of millions of small-scale farmers while ensuring sustainable food security throughout the world. The significance of practicing various strategies of agroforestry models in densely populated countries like Bangladesh is highly recognized according to livelihood functionalities. To achieve the sustainable goals of the United Nations, identifying potential agroforestry practices along with their impacts towards socio-economic, and ecological demands is crucial. Socio-economic interactions are highly influenced by livelihood improvement and assurance of food security for the participants. Madhupur Sal forest is one of the major sources of diversified combination agroforestry systems practiced by the people around it. Age, education, annual income, and agroforestry knowledge had a significant relationship with the farmers' opinions on socio-economic development through agroforestry practices. Sustainable livelihood capitals (Human, Social, Physical, Financial, and Natural) were improved in each model we determined, and agroforestry multi-functionally increased food security ensuring 94% yearly food sufficiency, and 6% sufficiency for two-thirds of the year according to the response variables. This study depicted various prospects for livelihood enhancement and food security concerning diverse agroforestry models.

Keywords: Livelihood, Food Security, Agroforestry Practices, Madhupur Sal Forest, Small Scale Farmer

Introduction

Agroforestry, the incorporation of trees into crops is a worldwide recognized practice to provide livelihood resilience while securing food security for the society (Quandt *et al*., 2019) [27]. It has been practiced as a potential solution for sustaining the livelihood of the beneficiaries as agroforestry is considered a sustainable form of land use that simultaneously improves farm productivity, and at the same time, ensures food security, sustainable development, biodiversity amelioration, and strengthens socio-cultural adaptations (Ahmed and Rahman 2000; Leakey *et al*., 2012; Roshetko *et al*., 2013) [1, 20, 32]. Bangladesh is an agriculture-based developing country in South Asia, with an area of 1,47,570 sq km. Of them, 13.36 million ha are land surface and 0.94 million ha are rivers and other inland water bodies (BBS, 2014) [2]. The country has only 17.08% (2.52 million ha) of total forestland, in which 15 protected National Parks (45,312.65 ha) together with 13 Wildlife Sanctuaries (223,648.68 ha) comprising 10.7% of total forest area (GOB, 2011) [6]. Madhupur Sal forest, one of the major forest resources of Bangladesh, has been governed by the Bangladeshi Forest Department since its independence to protect natural resources. Farmers dwelling in Madhupur Sal forest grow types of crops, especially pineapple (*Ananas comosus*), ginger (*Zingiber officinale*), papaya (*Carica papaya*), turmeric (*Curcuma longa*), banana (*Musa cavendish*), sweet gourd (*Cucurbita moschata*), taro (*Colocasia esculeata*), cassava (*Manihot esculenta*), etc. with a variety of trees like mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*), litchi (*Litchi chinensis*), plum (*Syzygium cumini*), etc. are the common fruit trees of cropland agroforestry, whereas sal (*Shorea robusta*), akasmoni (*Acacia auriculiformis*), breadfruit (*Artocarpus chama*), are the most common forest species. Once more, we can obtain fruits, fuel, timber, fodder, and fruits from trees (Rahman *et al*., 2009; Malekar *et al*., 2010; Rahman and Vacik, 2010; Rahman *et al*., 2019) [30, 21, 28, 29]. According to the studies, in 21 villages in and around the

Madhupur Sal forest (locally known as Madhupur Garh), there are roughly 50,000 households that depend directly or indirectly on forest resources, including around 20,000 ethnic minorities (Islam *et al*., 2013) [15]. Garo and Koch, two significant ethnic minorities living nearby, have been using these forests for centuries and depend entirely on them for survival (Islam and Sato, 2013) [12].

Various agroforestry models covering various components have been practiced by forest dwellers since the 1980s (Islam *et al*., 2015) [18] which improved socio-economic and ecological prospects. Agroforestry produced substantial economic outcomes (Rana, 2022; Rahman *et al*., 2018; Islam *et al*., 2008) [31, 27, 14] for small-scale farmers improving their livelihood (Hanif *et al*., 2018; Islam *et al*, 2022; Uddin and Chowhan, 2016; Nayek *et al*, 2014) [7, 23, 35, 24] and food security along with poverty reduction (Duffy *et al*., 2021; Sahoo and Wani, 2020; Tiwari, 2017; Waldron *et al*, 2017; Kiptot *et al*., 2014) [5, 33, 36, 19] throughout the world. In recent years, diversified research has been carried out in the Madhupur Sal forest of Bangladesh to observe various prospects of practiced agroforestry models, mainly focusing on economic outcomes, livelihood improvement of the communities, and biodiversity conservation. Very few studies focused on the food security of the inhabitants which is a crucial component of sustainable development due to adverse climatic changes relating to the livelihood reinforcement of the society at the same time. According to the research demand, the impacts of agroforestry on the livelihood of the farm owners and the relationship with sustainable food security were determined to broaden the research aspects for maintaining a balance among different components of the ecosystem.

Materials and Methods

Study site

Madhupur Sal forest is a tropical, moist, and deciduous forest located between $23^{0}50'$ to $24^{0}50'$ North longitude and $89^{0}54'$ to $90^{0}50'$ East longitude (Fig 1) comprising an area of 45565.18 acres of Bangladesh. The forest's soil is highly oxidized reddish-brown clay with moderate to strong acidic reactions characterized by low organic matter and fertility (Hoque *et al*., 2008) [10]. The area's mean annual rainfall and temperature ranges from 203-229 cm and 10-34˚C respectively (Hasan *et al.*, 2016).

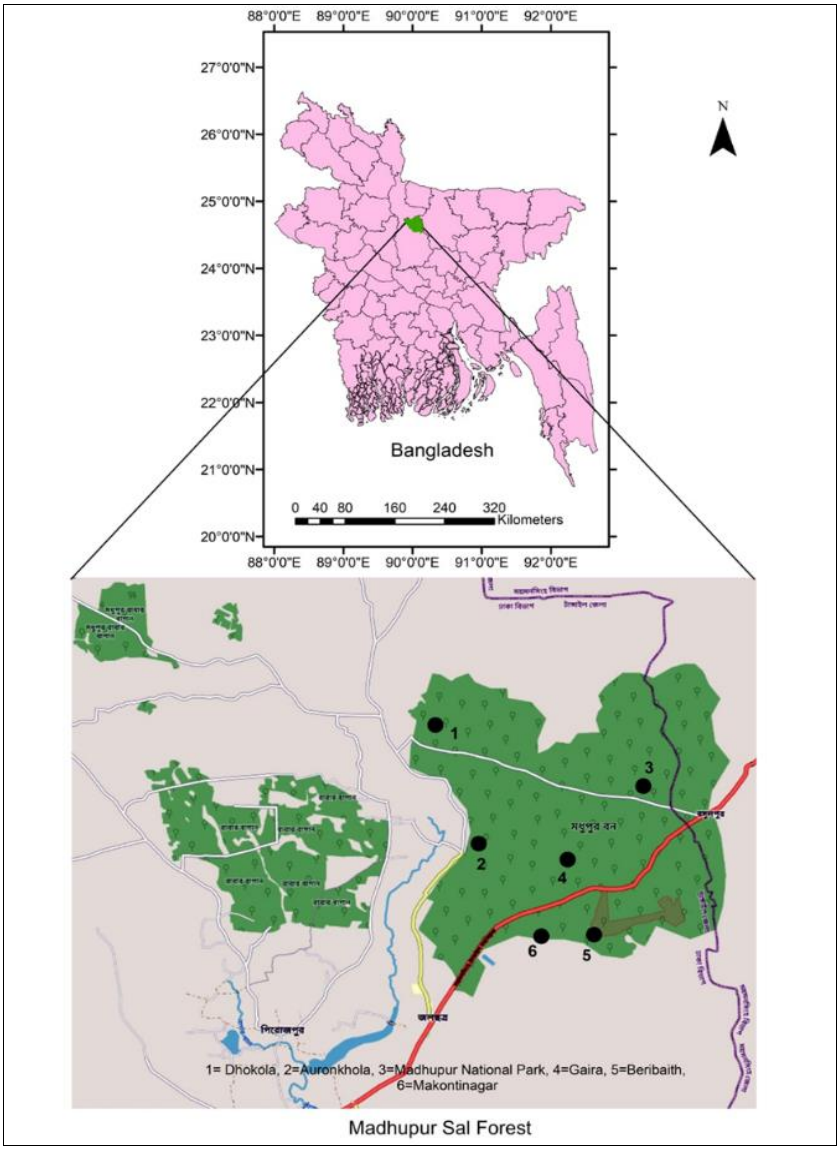

Fig 1: Study area map showing the selected villages of Madhupur Sal forest

Theoretical Framework

The livelihood of small-scale farmers is highly alleged through agroforestry worldwide (Hughes *et al*., 2020) [11] while maintaining the sustainable growth of ecosystem functions. We determined the potential impacts of agroforestry toward sustainable livelihood using the livelihood capital pentagon (human, social, natural, financial, and physical) of the Department for International Development (DFID). In our study, we evaluated the base strategies of the respondents using these livelihood capitals (Fig 3) through practical observation and interviewing farmers using a questionnaire.

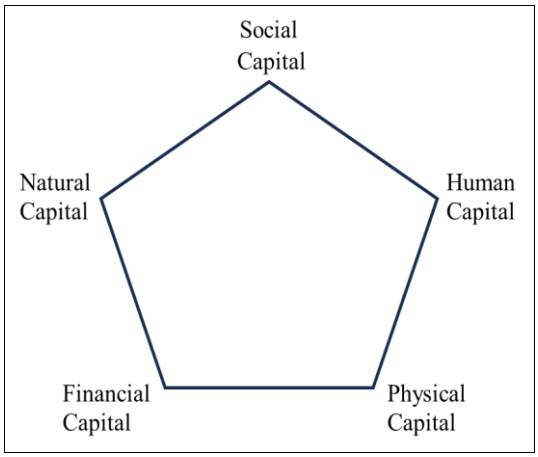

Fig 2: Livelihood assets pentagon of the respondents (Source: DFID, 2001)

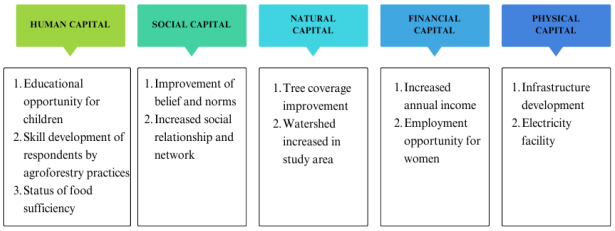

Fig 3: Selected parameters of the livelihood pentagon of respondents living in the forest

Data collection

Data was quantified concerning the information collected through interviews, focus group discussion, and practical observation. We randomly selected 140 respondents from randomly selected 7 villages among 21 total villages where we conducted our study from March to July 2023 according to our stipulated research plan. The following equations were used to perform the analysis:

Total income: total income was computed by multiplying the total yield of tree and crop species with the market price of the products.

Total income (USD) = Total yield (ton) x Market price (USD/kg) (1)

Net profit: net profit was determined by subtracting the total cost of tree and crop species from total income or gross income.

Net profit (USD) = Total income (USD) -Total cost (USD) (2)

Benefit-Cost Ratio (BCR): The benefit-cost ratio is the ratio of discounted benefit divided by the discounted cost. In this study, the BCR of different combinations of the selected agroforestry practices by

$$\text{Benefit-Cost Ratio (BCR)} = \frac{\sum_{i=0}^{n} B_t (1+i)t}{\sum_{i=0}^{n} C_t (1+i)t} \quad (3)$$

Where, B_t = Gross benefit in nth year, C_t = Total cost in nth year, t = Number of years (1, 2, 3,.....n), r = Interest (discount) rate (assuming 12%), the BCR greater than 1 indicates that the land-use system is profitable.

The analysis was then conducted using Microsoft Excel Software.

Results

Status of economic outcomes from selected agroforestry practices

Madhupur Sal forest consists of complex combinations of various types of components supporting the agroecological regime. Acacia (*Acacia auroculiformis*) proliferates, farmers frequently scatter acacia trees along the farmland boundaries or inside the cropland itself depending on the farms and it is being grown frequently along with Sal (*Shorea robusta*). Among different fruit-producing trees, mangoes, and jackfruits are commonly incorporated into the agroforestry fields according to the farmer's demand. Pineapple is mostly cultivated in Madhupur tracts (59% of total national production) with many suitable components. Mango and pineapple-based agroforestry produced the best outcomes (BCR = 1.89), whereas Acacia-Pineapple-Turmeric agroforestry practice yielded the lowest (BCR = 1.09) (Table 1).

Table 1: Benefit-cost ratio of different agroforestry practices

Agroforestry models	Cost of production	Net income	Benefit Cost Ratio
Acacia-Papaya-Pineapple	1932.85	2389.74	1.24
Acacia-Pineapple-Ginger	2134.31	3931.62	1.85
Acacia-Pineapple-Turmeric	1940.64	2111.16	1.09
Mango-Papaya-Pineapple	2194.78	2566.13	1.17
Acacia-Pineapple-Aroid	1608.59	3017.39	1.88
Mango-Pineapple	1602.47	3022.60	1.89
Jackfruit-Pineapple	1714.09	3051.35	1.79

*Total income of trees was calculated yearly (1 USD ≈ 110.42 BDT)

Impact on the livelihood of selected agroforestry practices

The results from the questionnaire survey and focus group discussion revealed that most farmers' skills (80%) from the selected farmers eventually improved through different agroforestry practices through receiving different training on agroforestry practices (Fig 4). The training encouraged the selected farmers to enhance their knowledge and skills in agroforestry practices, management, community development, and leadership development.

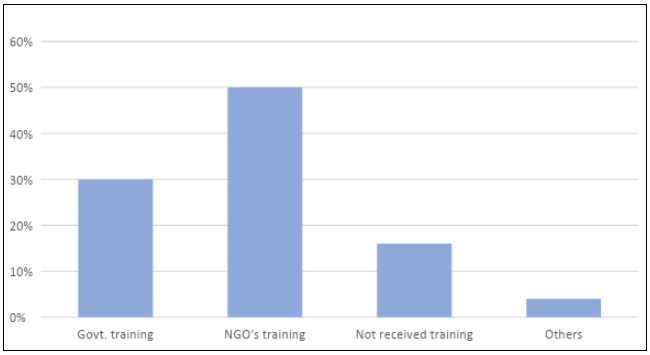

Fig 4: Skill development of respondents in agroforestry practices

The results showed that the educational opportunities for most of the children (92%) in different education levels were optimized whereas a minimal (8%) had unsatisfactory aspects (out of 50 respondents) (Fig 5).

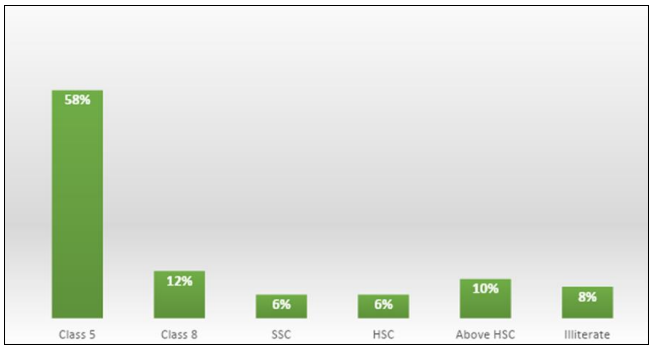

Fig 5: Education level of the respondents

Agroforestry practices produced flexibility for the farmers (70% out of total 50 respondents) to decide on consulting physicians, among those, 40% farmers usually consult with the nearest village physicians, and on the other hand 30% farmers consult with the specialized registered physicians. The rest of the respondents often take medicine through other sources (Fig 6).

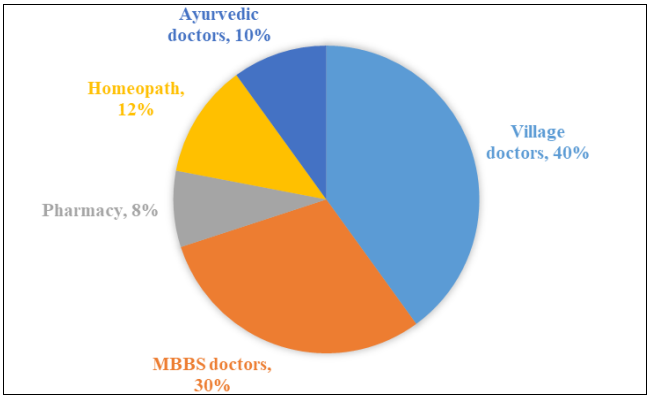

Fig 6: Medical treatment opportunities for the selected farmers

Agroforestry practices resulted in impacts on respondents' social relationships and networks, where the measurement scale (such as 4 very good, 3 good, 2 fair, 1 poor) of the study revealed that the respondents possessed a strongly positive relationship among themselves (Fig 7). Still, the participants had a poor relationship with the local forest department and local political parties. NGOs working in forest communities maintained a fair relationship with the farmers.

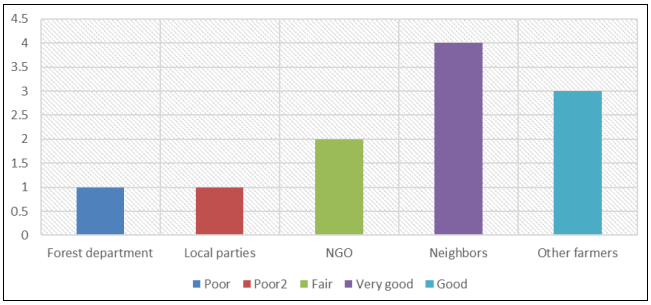

Fig 7: Relationship among the parties of the society

Farmers improved organizational participation after practicing different agroforestry practices that allowed them sustainable economic growth, where the most (70%) of respondents were involved in micro-credit organizations, 16% participated in NGOs, 10% were involved in village development committees, and 4% participated in local market committees (Fig 8).

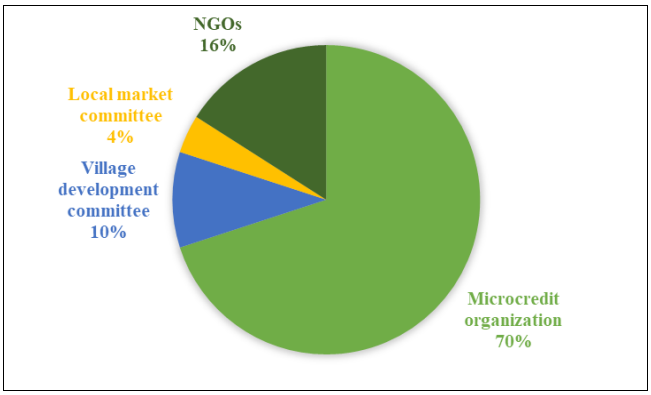

Fig 8: Organizational participation of the respondents practicing agroforestry

The number of trees increased (70%) after the introduction of agroforestry practices in the deforested areas in the Madhupur Sal forest. Shrub, herb, and climbers increased by 15%, 10%, and 5% respectively in the area (Fig 9).

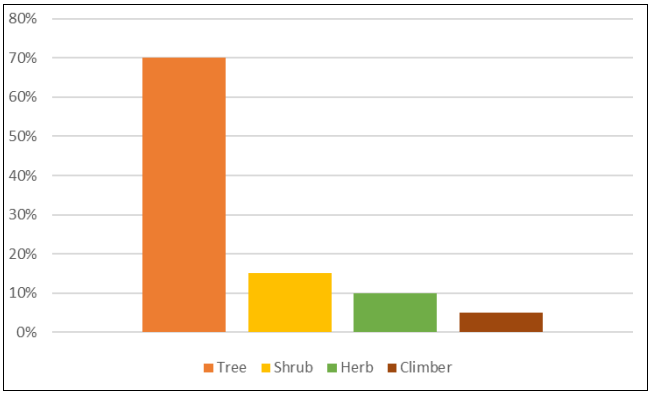

Fig 9: Improvement of vegetation through agroforestry

The results revealed that agroforestry practices have an impact on the income of the farmers which ultimately change their livelihood. Based on annual income from the agroforestry practices, farmers were classified into three groups, i.e., low income, medium income, and high income. The figure shows that (20%) of respondents earn 50000-60000 BDT, (30%) respondents earn more than 61000-100000 BDT, and (50%) earn above 100000 BDT from

agroforestry practices per year. The results indicate that most of the respondents had high incomes from agroforestry practices (Fig 10).

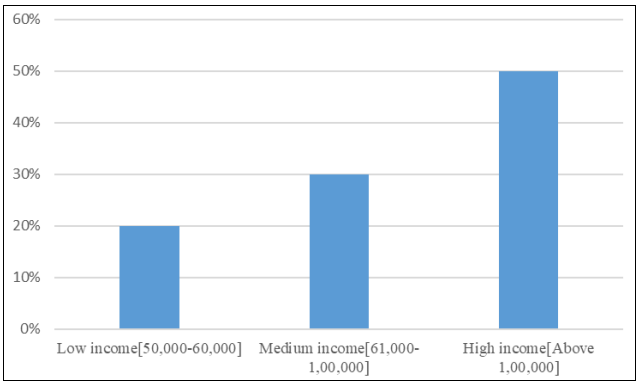

Fig 10: Annual income of the respondents from selected agroforestry practices

The majority of respondents (80%) have rural electricity, whereas 12% of respondents use solar electricity, and the rest (4%) do not use electricity. Most respondents had an electricity facility, indicating their improved living standards (Fig 11).

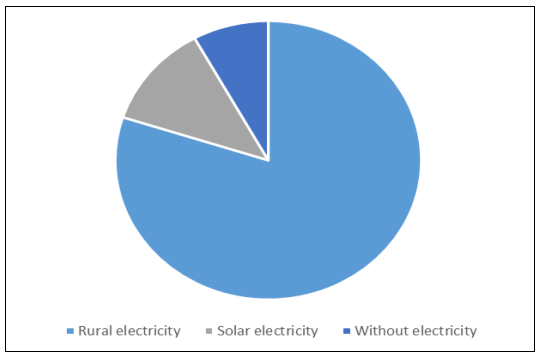

Fig 11: Energy dependencies of the beneficiaries of the agroforestry

Impact of agroforestry on food security

Agroforestry practices positively impacted farmers' food sufficiency and ethnic people's livelihood. It has been observed that most (94%) of the farmers have food sufficiency once introduced agroforestry. The result from the questionnaire survey stated that through agroforestry, food sufficiency of the poor farmer of the area was increased throughout the year (Fig 12).

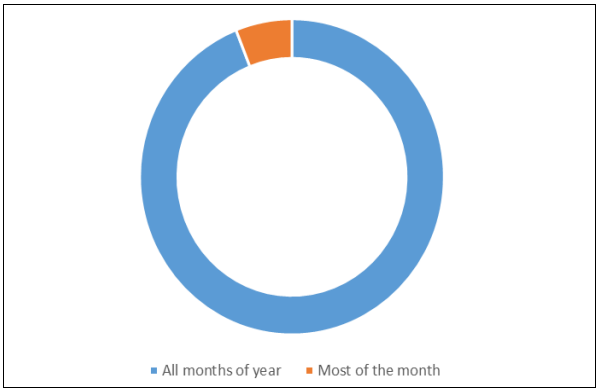

Fig 12: Food sufficiency of the farmers in a year

A clear insight into the food sufficiency of the farmers through monthly distribution showed that agroforestry ensured food security through sustainable management of resources. Farmers faced shortages of food only for one month, whereas in the rest of the months, food security was adjusted accordingly (Fig 13).

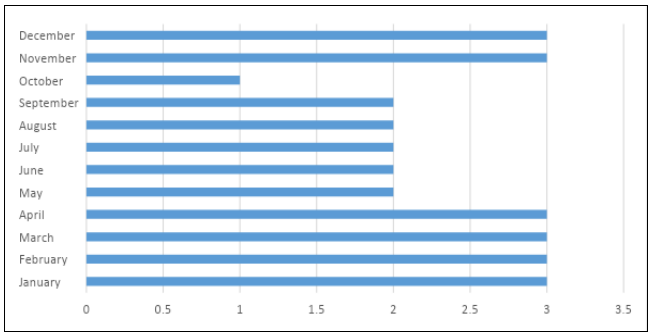

Fig 13: Monthly distribution of food sufficiency of the farmers (3 adequate, 2 inadequate, 1 shortage)

Discussion

Agroforestry, as a sustainable land management practice, has a prominent impact on combating the ecological crisis, ensuring the functionalities of a friendly ecosystem, fulfilling the socio-economic demands, and maintaining the balance (Mukhlis *et al*., 2022) [23]. We assessed the impacts of selected agroforestry practices on the livelihood and food security of the farmers. The study revealed that Acacia-Papaya-Pineapple, Acacia-Pineapple-Ginger, Acacia-Pineapple-Turmeric, Mango-Papaya-Pineapple, Acacia-Pineapple-Aroid, Mango-Pineapple, Jackfruit-Pineapple, based agroforestry resulted in improvement of economic outcomes which followed prior agroforestry combinations practiced in the Madhupur Sal forest (Islam *et. al*., 2021; Rana, 2022; Hasan *et al*., 2020; Hasan *et al*., 2008) [16, 31, 9, 8]. According to the DFID capitals, we justified the sustainability of farmers' livelihoods intending to identify the status and prospects resulting from the agroforestry practices. Initiation of agroforestry models in various lands led farmers to have structured training to maintain the productivity conducted by several parties, however, it was also revealed that participatory forestry in Madhupur Sal forest improved the farmer's attributes toward managed skills (Islam *et al*., 2010) [17]. We observed that the educational participation of the farmers, and availability of medical facilities augmented while agroforestry was introduced. Sustainable local livelihood was ensured by practicing agroforestry in Nepal (Pandit *et al*., 2014) [25]. Social relationships are attributed to the context of the participation of individuals in associated institutions, organizations, and other partners (World Bank, 2002) [37], social stakeholders' involvement is reinforced through agroforestry that ensures freedom for organizational involvement to the beneficiaries (Islam *et al*., 2022) [13]. Natural resources are one of the major factors determining sustainable management (Xiaoman *et al*., 2021) [38], agroforestry practices have increased the vegetation and water resources of the locality securing the marketing and trading of naturally obtained products. The annual income of the families related to agroforestry was improved allowing them the flexibility to extend expenditures accordingly. In Indonesia, farmers practicing agroforestry in state forests resulted in intensification from prior land use (Desmiwati,

2021) [3]. Our study found that agroforestry paved the opportunity for connecting to electric facilities that directly influenced the development of the infrastructures in the Sal Forest area. Agroforestry has the potential to provide food security and reduce poverty (Tiwari *et al.*, 2012) [34], it has been found that availability along with sufficiency of food to the respondents was secured in our study.

Conclusion

Agroforestry in Madhupur Sal forest positively changed the indicators of sustainable livelihood and food security of the farmers. Although a moderate enhancement of livelihood capital was determined, it showed the efficiency of improving the farmers' communities. The food sufficiency of the farmers was highly improved (90%) through agroforestry, which also helped to reduce the poverty margin of the area. The selected agroforestry practices demonstrated a direct effect on food security as well as the livelihood improvement of the farmers through increasing overall farm productivity, ensuring smooth cash flow, and developing socio-cultural infrastructure thus, the study can argue that those agroforestry practices can be more income generative and sustainable land-use practices.

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