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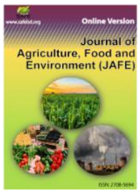

Original Article

Assessment of economic profitability and soil nutrient status of Eucalyptus and Gamar based agroforestry practices in the Madhupur Sal forest of Bangladesh

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Agroforestry, Eucalyptus, Gamar, Economic profitability, Soil nutrient status

ABSTRACT

The study was carried out in the Madhupur Sal forest of Bangladesh to assess the economic profitability and soil nutrient status of Eucalyptus and Gamar based agroforestry practices based on the data from July 2017 to September 2018. Four different agroforestry practices viz. Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Pineapple-Banana, Eucalyptus-Akashmoni-Turmeric-Banana, Gamar-Akashmoni-Acacia hybrid-Goraneem-Pineapple-Papaya-Banana and Gamar-Akashmoni-Acacia hybrid-Kalomegh along with their non-agroforestry practices (NAFPs) (except tree) having 0.2 ha plot area were selected through literature review, focus group discussion and practical observation. In order to calculate the economic profitability of respective agroforestry practices as well as NAFPs, data related to incurred cost, gross return, net return from tree and crop components, soil samples for chemical analysis were collected from each plot. The benefit-cost ratio (BCR) and land equivalent ratio (LER) for each of the selected agroforestry practices were determined. The results of the study showed that all the selected agroforestry practices were more profitable than their NAFPs. The net return, BCR, and LER (707110 Tk/ha, 3.87 and 1.76, respectively) indicated that the Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Banana-Pineapple based agroforestry practice was economically more profitable followed by Gamar-Akashmoni-Acacia hybrid-Goraneem-Pineapple-Papaya-Banana, Eucalyptus-Akashmoni-Turmeric-Banana, and Gamar-Akashmoni-Acacia hybrid-Kalomegh based agroforestry practices. Moreover, soil nutrient status like organic matter (%), total N (%), available P (ppm) and exchangeable K (meq/100g soil) of all of the selected agroforestry practices were mostly higher than their non-agroforestry practices. Therefore, it can be concluded that agroforestry practices are economically more profitable than the cultivation of their sole cropping systems which also helps to reduce the use of chemical fertilizer.

Introduction

Sal forests belong to the category 'Tropical Moist Deciduous Forest' mainly constitutes two parts; Madhupur Sal forest and Bhawal Sal forest. The Madhupur Sal forest is representing the major patches of Bangladesh Sal forests which are valuable in ecological as well as economic aspects that have been degraded due to destructive anthropogenic activities. About 50,000 established households which include ethnic minorities are dwelling in and around the 21 villages of the Madhupur Sal forest (Islam *et al*., 2013). Moreover, two-third (49748 ha) of the Madhupur forest area was deforested and subsequently encroached by the local people to practice commercial tree and/or crop cultivation (Muhammad *et al*., 2008; Islam *et al*., 2015). The nearby farmer of the Madhupur Garh area depends on agroforestry practices that play a critical function in supplying multiple choices and possibilities to improve farm production and profits and also offer productive and conservative features to the ecosystems (Alam *et al*., 2010). These local agroforestry production systems have developed both in private and forest department encroached land and also range from one any other in phrases of their economic and ecological performance as they have some advantages and drawbacks. Some researchers have noted the benefits of mango, banana, pineapple, lemon, jackfruit, and different seasonal crops cultivation along with agroforestry practices at the Madhupur Garh area (Safa, 2004; Hasan *et al*., 2008; Roy *et al*., 2011; Kibria and Saha, 2011; Rana, 2017). Moreover, in agroforestry practices, trees serve as insurance in case of sudden crop failure or to protect the crop against catastrophic climatic events and also provide additional income to the farmers. Within the array of benefits brought by agroforestry practice is particularly the tree component, an important element is the positive effect of trees on soil quality improvement and consequently benefits for crops. The majority of the local farmers do not have the scope to compare those potential agroforestry practices for further improvements with technological supports. Therefore, it is required to sort out different agroforestry practices, their benefits, and their effect in order to maintain sustainable development of the Madhupur Garh area.

Profit is one of the main data indicators to assess economic firm that can be regarded as a proper indicator for decision-making (Vahid *et al*., 2013). The farm profitability reflects the measuring of effects materialized in revenues with the efforts involved materialized in expenditure. Economic profit is the profitability measurement that calculates the number of revenues received from selling a product that exceeds opportunity costs incurred from using resources to make and sell these products. Economic profitability analysis combines the measurement of both profit margins (e.g. net profit margin and gross margin) and returns indicators (Persia *et al*., 2017).

Gmelina arborea, commonly known as Gamar, is an indigenous fast-growing tree species, used for timber, paper, and pulp making and other forest-based industries as with as fulfilling the domestic needs. In agroforestry practices, Gamar and some other crops such as gram, pea, and mustard along with mango tree species revealed a positive result in the content of economic profitability where Gamar and other species made more profitable returns than their monocropping systems (Kumar *et al*., 2017). Eucalyptus (*Eucalyptus camaldulensis*) is one of the most extensively planted trees in Bangladesh as well as in the world. Because of its fast-growing characteristics, this tree is extensively used for afforestation and reforestation in more than 58 countries. The potential of eucalyptus in Bangladesh is being capable to produce 3-4 times biomass and 6-8 times more stem wood on short rotations than the present forest species (Islam, 1986). Besides, this tree grows well on extinct sites in public forest areas and village forest areas for fuelwood and agroforestry intendeds. Eucalyptus tree species showed a positive net return in agroforestry practices where other crop species revealed a more return than the monocropping systems (De Souza *et al*., 2012).

Several findings were achieved on the overall productivity analysis of jackfruit, pineapple, lemon and banana-based agroforestry (Hasan *et al*., 2008; Kibria and Saha, 2011), mango based agroforestry (Rana, 2017), lemon based agroforestry (Raihan, 2018), akashmoni, jackfruit and litchi based agroforestry (Akter *et al.*, 2020) systems practiced in private or participatory programs in the Madhupur tract revealed that the agroforestry practice to be beneficial in terms of benefit-cost ratio analysis. But the research related to the economic profitability and soil nutrient status of agroforestry practices especially Eucalyptus and Gamar in the study area was negligible. As a result, considering the research gap it is necessary to assess the economic profitability of the said agroforestry practices with sustainable soil nutrient status at Madhupur Sal forest of Bangladesh.

Materials and Methods

Study area

The study was performed in the Madhupur Sal forest under Tangail and Mymensingh Forest Division (Figure 1).

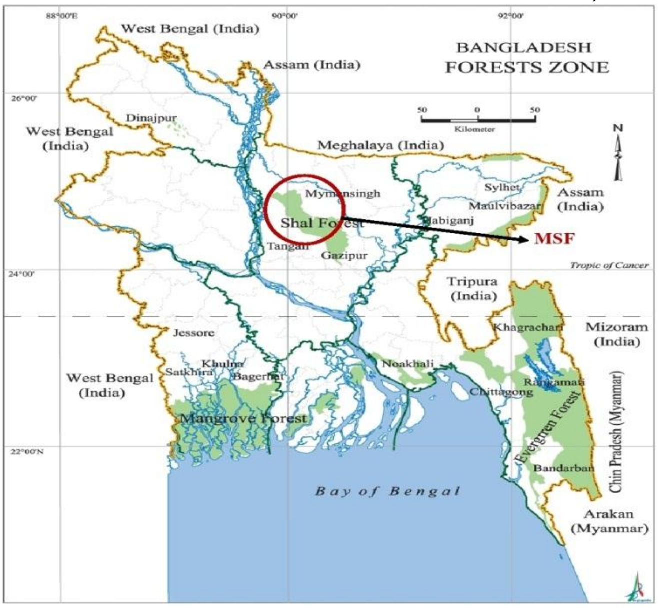


Figure 1. A map of Bangladesh forest showing Madhupur Sal Forest. (Source: Banglapedia, 2015)

Geographical description of the study area

The Madhupur Sal forest lies between 23º50' to 24°50' north latitude and 89°54' to 90°50' east longitude (Figure 1). The Madhupur Sal forest, popularly known as Madhupur Garh comprising an area 63,001.89 acre (45565.18 acres in Tangail and 17436.71 in Mymensingh districts) is located in the middle part of Bangladesh (Akter *et al.*, 2020). The topography of the area is characterized by plain land and low hills rising 3.0-4.5 m above the surrounding field. The soils of the areas are highly oxidized reddish-brown clay with moderate to strong acidic reaction characterized by low organic matter and low fertility (Alam, 1995). The annual rainfall ranges from 203-229 cm and the annual temperature ranges from 10-34°C. The humidity of the areas varies from 60 to 86% (Hasan *et al*., 2016).

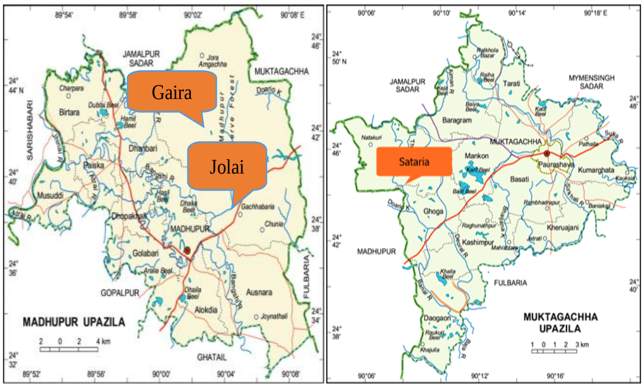
Vegetation of the study area

Sal (*Shorea robusta*) is the dominant species of the Madhupur Sal forest (Alam, 1995) and other associates like a mixture of Azuli (*Dillenia pentagyna*), Haritaki (*Terminalia chebula*), Koroi (*Albizzia spp.*), Jarul (*Lagerstroemia speciosa*), Jam (*Syzygium cumini*), Palash (*Butea monosperma*), etc. are present in this forest. Moreover, various exotic timber and fruit-bearing species like Akashmoni (*Acacia auriculiformis)*, Acacia hybrid (*Acacia spp.)*, Eucalyptus (*Eucalyptus spp.*), Teak (*Tectona grandis*), Mahogony (*Swietenia spp.*), Gamar (*Gmelina arborea*), Neem (*Azadirachta indica*), Goraneem (*Melia azedarach*), as well as Jackfruit (*Artocarpus heterophyllus*), Mango (*Mangifera indica*), Litchi (*Litchi chinensis*), Lemon (*Citrus spp*), and crops like Pineapple (*Ananas comosus)*, Papaya (*Carica papaya*), Banana (*Musa sapientum*), Turmeric (*Curcuma longa*), Ginger (*Zingiber officinale*), Aroid (*Colocasia alba*), Kalomegh (*Andrographis paniculata*), etc. are being planted and cultivated in different agroforestry and social forestry programs.

Specific study area and sampling design

The Madhupur Sal forest is mainly situated in two Upazila viz. Madhupur under Tangail and Muktagacha under Mymensingh district. Administratively, the Madhupur Sal forest consists of five ranges namely Rasulpur, Madhupur National

Park, Dokhla, Aronkhola, and Madhupur (Khan, 2009). The study was conducted in three villages viz. Gaira and Jolai of Madhupur Upazila under Tangail and Sataria under Muktagacha Upazila of Mymensingh district because agroforestry systems are abundant in this area (Figure 2). The study was carried out from July 2017 to September 2018. This study dealt with four agroforestry practices (all of them were timber-based agroforestry practices) (Table 1) with three replications having a 0.2 ha area for each sample plot along with a non-agroforestry plot (except tree) for each combination. The total numbers of plots were 24 of which 12 for Gamar and Eucalyptus based agroforestry practices and rest 12 for non-agroforestry practices. Due to time limitations, the study selected both established agroforestry and non-agroforestry practices in the study area.



A B

Figure 2. Map showing the selected villages of (A) Madhupur Upazila of Tangail and (B) Muktagacha Upazila of Mymensingh district.

Selection of agroforestry practices in the study area

Through literature review, secondary information, focus group discussion, and practical observation the following four Gamar and Eucalyptus based agroforestry practices (AFPs) along with their non-agroforestry practices (NAFPs) were selected for collecting data in the study area (Table 1).

Table 1. A list of selected agroforestry practices with their non-agroforestry practices.

Cropping systems	Agroforestry practices	Plot number
AFP's	Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Banana-Pineapple	3
	Eucalyptus-Akashmoni-Turmeric-Banana	3
	Gamar-Akashmoni-Acacia hybrid-Goraneem-Papaya-Pineapple-Banana	3
	Gamar-Akashmoni-Acacia hybrid-Kalomegh	3
NAFPs	Papaya-Ginger-Banana-Pineapple	3
	Turmeric-Banana	3
	Pineapple-Papaya-Banana	3
	Kalomegh	3
Total		**24**

Collection of data or samples from different agroforestry practices

From every selected plot, various tree-crop parameters and soil samples were collected in accordance with the requirement of the study. To analyze the economic profitability, various parameters viz. cost of production, income, net profit, benefit-cost ratio (BCR), and land equivalent ratio (LER) of the selected agroforestry practices all the connected data were collected during July 2017 to September 2018.

Collection of crop-related data

In order to calculate crop produce, the following parameters were collected from the sample plots-the number of fruits/plant, the weight of fruits /plant (kg), crop or fruit price (Tk/kg), cost of production (Tk/ha), crop yield (kg/ha) and income (Tk/ha).

Collection of tree-related data

The productivity of tree components was measured by collecting the following parameters-the number of trees/plot, timber price (Tk/cft), cost of production (Tk/ha), tree yield (Tk/ha), and income (Tk/ha).

Soil samples collection, preparation, and analysis

From each plot, five soil cores were taken randomly using an auger at 0-15 cm soil depth from different spots and kept them in a polythene bag with properly labeled. Then all of the soil cores were carried to the laboratory and make composite samples by mixing the collected soil cores from different locations of a particular field. The composite soil samples were kept on brown paper in the laboratory to allow them air dry. After that, the air-dried soil samples were processed and sieved through 20 mesh sieve and packed with a specific tag for laboratory analysis. Then the prepared soil samples were sent to the Soil Science Division, Soil Resource Development Institute (SRDI), Dhaka to analyze the nutrient status of the prepared soil samples. Soil pH was measured by using a Glass-electrode pH meter (WTW pH 522) at a soil-water ratio of 1:2. Organic carbon was determined by the wet oxidation method of Walkley and Black (1934). Total nitrogen was determined by the micro-Kjeldahl method (Jackson, 1958). Available P was extracted by the Molybdenum blue method of Bray and Kurtz using a spectrophotometer (Jackson, 1958). Exchangeable K was determined by the 1N NH_4OAc extract method using a flame photometer (Page *et al.*, 1989).

Analysis of economic profitability

Calculation of the total cost of production

The total cost of production was estimated by using the following formula:

TC= Input cost + Overhead cost

Where, TC= Total Costs of Production

Calculation of gross return

The gross return of the individual agroforestry practices was computed by adding crop return and tree return.

Gross return= Crop return + Return from tree products

Calculation of net profit

Net profits were estimated by using the following formula:

NR= GR - TC

Where,

NR= Net Return

GR= Gross Return

TC= Total Cost

Calculation of Benefit-Cost Ratio (BCR)

The benefit-cost ratio was estimated by using the following formula:

Benefit-Cost Ratio (BCR)= Gross benefit ÷ Cost

The BCR greater than 1 indicates that the land-use system is profitable.

Calculation of Land Equivalent Ratio (LER)

In agroforestry situations, LER was measured by using the following formula:

$$\textbf{LER}=\sum_{i=1}^{m}\frac{yi}{yii}$$

Where *yi* is the yield of "*i*" th component from a unit area of intercrop; *yii* is the yield of the same component grown as a sole crop over the same area, and $\frac{yi}{yii}$ is the relative yield of component *i*.

If LER=1, there is no advantage (i.e., neutral) to intercropping or agroforestry in comparison to sole cropping. If LER>1, indicate better use of resources or positive interaction between the components. If LER<1, indicate the competition i.e., negative interactions between the components.

Data analysis

Data on various parameters were collected, compiled, tabulated, and subjected to analysis. Before putting the obtained data in analyzing sheets, the data were scrutinized and edited. Then data were entered into the computer and analyzed by using MS Excel software.

Results and Discussion

Economic profitability of Eucalyptus and Gamar based selected AFPs

Cost of production of the selected agroforestry practices

The total input costs of the selected agroforestry practices were recorded from the period of July 2017 to September 2018 (Table 2). According to the result, the highest input cost (Tk. 279470) was required for the Gamar-Akashmoni-Acacia hybrid-Goraneem-Pineapple-Papaya-Banana based agroforestry practices followed by the Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Pineapple-Banana (Tk. 246605), Eucalyptus-Akashmoni-Turmeric-Banana (Tk. 134955) and Gamar-Akashmoni-Acacia hybrid-Kalomegh (Tk. 99125) based agroforestry practices respectively (Table 2). Akter *et al.* (2020) were also found such kind of cost of production from the five different timber and fruit tree-based agroforestry practices during 2017-2018 in the Madhupur Garh area and stated that the highest cost of production (180958 Tk/ha) from the Litchi-Pineapple-Papaya-Ginger-Banana based agroforestry practices and the followed cost of productions were Akashmoni-Ginger-Banana (138350 Tk/ha), Akashmoni-Turmeric-Banana (126052 Tk/ha), Akashmoni-Acacia hybrid-Gamar-Goraneem-Turmeric (97950 Tk/ha) and Jackfruit-Akashmoni-Turmeric-Aroid (95153 Tk/ha) respectively. The results from the study also revealed that the cost of production was higher during the first year for the initial cost of seedling establishment and the cost of production was relatively lower from the subsequent year. A similar result was also found by Raihan (2018) from the lemon-based agroforestry practices in the Madhupur Sal forest of Bangladesh and he revealed that the highest (183468 Tk/ha) cost of production was done for the Lemon-Litchi-Papaya-Banana based agroforestry practices and followed by Lemon-Mango-Pineapple-Papaya-Ginger (177090 Tk/ha), Lemon-Pineapple-Papaya-Banana-Aroid (171150 Tk/ha), Lemon-Pineapple-Papaya-Ginger (121935 Tk/ha) and Lemon-Mango-Turmeric-Red amaranth (102626 Tk/ha) respectively.

Gross return of selected agroforestry practices

The gross returns of the selected agroforestry practices were recorded during the time of July 2017 to September 2018 (Table 2). The result showed that the highest gross return (983735 Tk/ha) was obtained from the Gamar-Akashmoni-Acacia hybrid-Goraneem-Pineapple-Papaya-Banana based agroforestry practices and followed by the Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Pineapple-Banana (953715 Tk/ha), Eucalyptus-Akashmoni-Turmeric-Banana (308150 Tk/ha) and Gamar-Akashmoni-Acacia hybrid-Kalomegh (202900 Tk/ha) based agroforestry practices respectively (Table 2). A similar result was found with the findings of Nayak *et al.* (2014) where the highest gross return (525187.46 Tk/ha) was recorded under *Acacia mangium* with pineapple based agrisilvicultural (Tree-crop based) system as compared to other agrisilvicultural systems and sole crops in Bhubaneswar, India. Akter *et al.* (2020) studied on productivity analysis of timber and fruit tree-based agroforestry practices in the Madhupur Sal forest of Bangladesh and found that among the selected different timber tree-based agroforestry practices Akashmoni-Ginger-Banana based agroforestry combination obtained the highest (506883 Tk/ha) gross return during the year 2017-2018. Besides them, Hasan *et al*. (2008) conducted a survey to evaluate the agro-economic performance of the Jackfruit-Pineapple agroforestry system in the Madhupur tract of Bangladesh and they revealed that the cost was very high due to inputs during the initial year. The benefits derived from the jackfruit-pineapple agroforestry production system started in the second year of planting, which was 457449 Tk/ha and the benefit were increased with time.

Net return of selected agroforestry practices

Table 2 showed that among the selected agroforestry practices the highest (707110 Tk/ha) net return was found from the Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Pineapple-Banana based agroforestry followed by the Gamar-Akashmoni-Acacia hybrid-Goraneem-Pineapple-Papaya-Banana (704265 Tk/ha), Eucalyptus-Akashmoni-Turmeric-Banana (173195 Tk/ha) and Gamar-Akashmoni-Acacia hybrid-Kalomegh (103775 Tk/ha) respectively (Table 2). Akter *et al.* (2020) stated that among the selected different timber tree-based agroforestry practices Akashmoni-Ginger-Banana based agroforestry combination obtained the highest (368533 Tk/ha) net return followed by Akashmoni-Turmeric-Banana (232945 Tk/ha), Akashmoni-Acacia hybrid-Gamar-Goraneem-Turmeric (132591 Tk/ha) in the Madhupur Sal forest of Bangladesh. Dwivedi *et al.* (2007) found a similar outcome for poplar based agrisilvicultural system than a poplar and eucalyptus based band system in India. Nayak *et al.* (2014) obtained that the highest net return (301074.76 Tk/ha) was recorded under *Acacia mangium* with pineapple based agrisilvicultural (tree-crop based) system as compared to other agrisilvicultural systems and sole crops in Bhubaneswar, India. Raihan (2018) carried out a study on the assessment of the economic evaluation of lemon-based agroforestry practices in the Madhupur Sal forest and revealed that the highest net profit (460032 Tk/ha) was obtained from the Lemon-Litchi-Papaya-Banana based agroforestry practices and followed by Lemon-Pineapple-Papaya-Banana-Aroid (430400 Tk/ha), Lemon-Mango-Pineapple-Papaya-Ginger (388410 Tk/ha), Lemon-Pineapple-Papaya-Ginger (217935 Tk/ha) and Lemon-Mango-Turmeric-Red amaranth (167274 Tk/ha) respectively. He suggested that agroforestry practices were more profitable than sole cropping. Chakraborty *et al.* (2015) conducted an experiment in Jessore district of Bangladesh where they revealed that mean annual household profits of the cropland agroforestry (CAF) farmers were Tk. 190000 which was higher than that of the non-cropland agroforestry (NCAF) farmers (Tk. 105600).

Table 2. Profitability analysis of Eucalyptus and Gamar based selected AFPs in the Madhupur Sal forest area.

Agroforestry practices	Cost of production (Tk/ha)	Gross return (Tk/ha)	Net return (Tk/ha)	BCR	LER
Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Banana -Pineapple	246605	953715	707110	3.87	1.76
Eucalyptus-Akashmoni-Turmeric-Banana	134955	308150	173195	2.28	1.09
Gamar-Akashmoni-Goraneem-Acacia hybrid-Papaya-Pineapple-Banana	279470	983735	704265	3.52	1.63
Gamar-Akashmoni-Acacia hybrid-Kalomegh	99125	202900	103775	2.05	1.05

Benefit-Cost Ratio (BCR) of the selected agroforestry practices

The result showed that all the selected agroforestry practices, the benefit-cost ratio were greater than 1 which indicated that all of the selected agroforestry practices are profitable than their monocropping systems (Table 2). From the result, the highest BCR (3.87) was obtained from the Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Pineapple-Banana based agroforestry practices and followed by the Gamar-Akashmoni-Acacia hybrid-Goraneem-Pineapple-Papaya-Banana (3.52), Eucalyptus-Akashmoni-Turmeric-Banana (2.28) and Gamar-Akashmoni-Acacia hybrid-Kalomegh (2.05) respectively (Table 2). Akter *et al.* (2020) found that the highest (1.76) BCR was obtained from the Akashmoni-Ginger-Banana based agroforestry practices followed by the Litchi-Pineapple-Papaya-Ginger-Banana (1.69), Akashmoni-Turmeric-Banana (1.58), Akashmoni-Acacia hybrid-Gamar-Goraneem-Turmeric (1.58) and Jackfruit-Akashmoni-Turmeric-Aroid (1.53) respectively in the Madhupur Sal forest of Bangladesh. Bari *et al.* (2016) showed that maximum BCR (5.20) was found in the Litchi based agroforestry systems over sole cropping (4.38) and concluded that the cultivation of Bazra variety Napier fodder in the floor of Litchi orchard ensured higher revenue to the farmers compared to its sole cropping. The result was corroborated with the findings of Nayak *et al*. (2014) where the highest BCR (2.34) was recorded under *Acacia mangium* with pineapple based agrisilvicultural (tree-crop based) system as compared to other agrisilvicultural systems and sole crops in Bhubaneswar, India.

Land equivalent ratio (LER) of the selected agroforestry practices

From the result, the highest LER (1.76) was obtained from the Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Pineapple-Banana based agroforestry practices and followed by the Gamar-Akashmoni-Acacia hybrid-Goraneem-Pineapple-Papaya-Banana (1.63), Eucalyptus-Akashmoni-Turmeric-Banana (1.09) and Gamar-Akashmoni-Acacia hybrid-Kalomegh (1.05) respectively (Table 2). Akter *et al.* (2020) found that the highest (1.76) LER was obtained from the Akashmoni-Ginger-Banana based agroforestry practices and followed by the Litchi-Pineapple-Papaya-Ginger-Banana (1.69), Akashmoni-Turmeric-Banana (1.58), Akashmoni-Acacia hybrid-Gamar-Goraneem-Turmeric (1.58) and Jackfruit-Akashmoni-Turmeric-Aroid (1.53) respectively. Rana (2017) was also conducted a study to find out the economic evaluation of five mango based agroforestry practices in the Madhupur Sal forest of Bangladesh. From the study, he revealed that the highest (3.27) LER was obtained from the Mango-Pineapple-Ginger-Papaya-Banana-Turmeric based agroforestry practices and followed by the Mango-Pineapple-Ginger-Papaya-Banana (2.76), Mango-Turmeric-Papaya-Aroid (2.32), Mango-Lemon-Turmeric (1.93) and Mango-Pineapple (1.37) based agroforestry practices respectively and stated that the agroforestry practices was more profitable than the monocropping practices in the study area.

Economic profitability of Eucalyptus and Gamar based selected AFPs with their NAFPs

The result showed that the gross return, net profit, and BCR of Eucalyptus and Gamar based selected agroforestry practices were higher than their non-agroforestry practices (except mango tree) (Table 3). According to the results, it was obtained that the gross return and net profit of Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Pineapple-Banana, Gamar-Akashmoni-Acacia hybrid-Goraneem-Pineapple-Papaya-Banana, Eucalyptus-Akashmoni-Turmeric-Banana and Gamar-Akashmoni-Acacia hybrid-Kalomegh based agroforestry practices were Tk. 939965, 265650, 962485, 171400 respectively and Tk. 693360, 130695, 683015, 72275 respectively (Table 3). While the gross return and net return of non-agroforestry practices (except mango tree) i.e. Papaya-Ginger-Pineapple-Banana, Pineapple-Papaya-Banana, Turmeric-Banana and Kalomegh of the aforesaid agroforestry practices were Tk. 884965, 95650, 877485, 45400 and Tk. 623360, 20695, 598015, 11275 respectively (Table 3). According to the benefits-cost analysis, it has been found that all the selected Eucalyptus and Gamar based agroforestry practices obtained higher BCR compare to their non-agroforestry practices which clearly indicates that all the selected agroforestry practices were economically more profitable than their non-agroforestry practices (Table 3). The highest (3.54) benefit-cost ratio was recorded from coconut+guava based multistoried agroforestry which was higher than their sole cropping (1.65) observed by Bari and Rahim (2012). Rana (2010) calculated the Net Present Value (NPV) and Benefit-Cost Ratio (BCR) of the pineapple agroforestry practice were BDT 487010.79 and 5.35 respectively at 10% interest rate which indicated the farmer earned maximum profitability from the pineapple agroforestry practice in Madhupur Sal forest. Akter *et al.* (2020) studied on productivity analysis of timber and fruit tree-based agroforestry practices in the Madhupur Sal forest of Bangladesh and found that the selected agroforestry practices were more profitable than their non-agroforestry systems in terms of their total benefits, net profit and BCR. Dwivedi *et al.* (2007) found that B: C ratio (3.00) that was higher for poplar based agrisilviculture than poplar (2.84) and eucalyptus (2.68) based bund system.

Table 3. Comparison of economic profitability of Eucalyptus and Gamar based selected AFPs vs. NAFPs in the Madhupur Sal forest area.

Combination	Cropping systems	Gross return (Tk/ha)	Net return (Tk/ha)	BCR
Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Banana-Pineapple	AFPs	939965	693360	3.81
Papaya-Ginger-Banana-Pineapple	NAFPs	884965	623360	3.38
Eucalyptus-Akashmoni-Turmeric-Banana	AFPs	265650	130695	1.97
Turmeric-Banana	NAFPs	95650	20695	1.28
Gamar-Akashmoni-Goraneem-Acacia hybrid-Papaya-Pineapple-Banana	AFPs	962485	683015	3.44
Papaya-Pineapple-Banana	NAFPs	877485	598015	3.14
Gamar-Akashmoni-Acacia hybrid-Kalomegh	AFPs	171400	72275	1.73
Kalomegh	NAFPs	45400	11275	1.33

Soil nutrient status of Eucalyptus and Gamar based selected agroforestry practices

Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Pineapple-Banana based AFP

From the observed result, it has been found that during practicing Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Pineapple-Banana based agroforestry, soil pH, organic matter (OM) (%), total N (%), available P (ppm) and exchangeable K (meq/100g) were 4.65, 2.01, 0.095, 36.03 and 0.351 respectively (Table 4). While the combination of its non-agroforestry practice, the content of soil pH, OM (%), total N (%), available P (ppm), and exchangeable K (meq/100g) were 4.70, 2.58, 0.145, 37.45 and 0.372 respectively (Table 4). According to results, nutrient status like soil pH, OM (%), total N (%), available P (ppm) and exchangeable K (meq/100g) were higher in the agroforestry field due to tree leaf litterfall, the addition of banana and pineapple leaves after harvesting which conserves soil moisture as well as organic matter. Akter *et al.* (2020) found a similar result that soil nutrient status like OM (%), total N (%), available P and exchangeable K of timber and fruit tree based all of the selected agroforestry practices were higher than their non-agroforestry systems which are very supportive to the findings.

Eucalyptus-Akashmoni-Turmeric-Banana based AFP

The result showed that the soil chemical properties like organic matter (%), total N (%), and available P (ppm) were higher in that field where practicing Eucalyptus-Akashmoni-Turmeric-Banana based agroforestry compare to its non-agroforestry combination in the study area (Table 4). On the other hand, soil pH and exchangeable K (meq/100g) were 4.38 and 0.217 relatively lower than that of 4.86 and 0.362 respectively found in the non-agroforestry practice field (Table 4). Akter *et al.* (2020) found that OM (%), total N (%), available P and exchangeable K were higher in Akashmoni based agroforestry combination except for soil pH which was high in its non-agroforestry combination in the Madhupur Sal forest of Bangladesh.

Gamar-Akashmoni-AH-Goraneem-Pineapple-Papaya-Banana based AFP

From Table 4, it has been observed that soil pH, soil organic matter (%), total N (%), available P and exchangeable K (meq/100g) were 4.96, 2.88, 0.195, 32.62 and 0.860 respectively in Gamar-Akashmoni-Acacia hybrid-Goraneem-Pineapple-Papaya-Banana based agroforestry practice. While the soil pH, soil organic matter (%), total N (%), available P, and exchangeable K (meq/100g) of its non-agroforestry combination were 5.15, 2.72, 0.168, 38.85 and 0.827 respectively (Table 4). The results indicate that soil organic matter (%), total N (%), and exchangeable K (meq/100g) were higher in agroforestry filed but soil pH and available P (ppm) were higher in the non-agroforestry field (Table 4). Kibria and Saha (2011) found that soil pH, organic matter, total nitrogen, available phosphorus, and potassium showed variation among the different agroforestry land-use systems in Madhupur Sal forest of Bangladesh.

Gamar-Akashmoni-Acacia hybrid-Kalomegh based AFP

From the result, it has been found that soil pH, organic matter (OM) (%), total N (%), available P (ppm) and exchangeable K (meq/100g) contents in Gamar-Akashmoni-Acacia hybrid-Kalomegh based agroforestry practice were 4.48, 2.01, 0.095, 52.62 and 0.382 respectively (Table 4). On the other hand, soil pH, organic matter (%), total N (%), available P and exchangeable K (meq/100g) of its non-agroforestry combination were 4.53, 2.35, 0.106, 13-21 and 0.351 respectively (Table 4). The result of the study indicates that only available P (ppm) and exchangeable K (meq/100g) status in soils were higher in agroforestry plot but soil pH, OM (%) and total N (%) were higher in the non-agroforestry plot (Table 4). A similar result was observed by Chowdhury (2004) found that organic matter, soil pH decreased with the conversion of natural forest into another land use.

Table 4. Soil nutrient status of selected Eucalyptus and Gamar based AFPs along with their NAFPs in the study area

Combinations	Cropping system	pH	OM (%)	N (%)	P (ppm)	K (meq/100g)
Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Banana-Pineapple	AFPs	4.70	2.58	0.145	37.45	0.372
Papaya-Ginger-Banana-Pineapple	NAFPs	4.65	2.01	0.095	36.03	0.351
Eucalyptus-Akashmoni-Turmeric-Banana	AFPs	4.38	2.60	0.151	33.89	0.217
Turmeric-Banana	NAFPs	4.86	2.01	0.100	21.40	0.362
Gamar-Akashmoni-Acacia hybrid-Goraneem-Papaya-Pineapple-Banana	AFPs	4.96	2.88	0.195	32.62	0.860
Papaya-Pineapple-Banana	NAFPs	5.15	2.72	0.168	38.85	0.827
Gamar-Akashmoni-Acacia hybrid-Kalomegh	AFPs	4.48	2.01	0.095	52.62	0.382
Kalomegh	NAFPs	4.53	2.35	0.106	13.21	0.351

Conclusion

Among the selected agroforestry practices, Eucalyptus-Akashmoni-Teak-Papaya-Ginger-Pineapple-Banana based agroforestry practice was economically more profitable followed by Gamar-Akashmoni-Acacia hybrid-Goraneem-Pineapple-Papaya-Banana> Eucalyptus-Akashmoni-Turmeric-Banana> Gamar-Akashmoni-Acacia hybrid-Kalomegh based agroforestry practices in the study area. Moreover, soil nutrient status like organic matter (%), total N (%), available P and exchangeable K of all of the selected agroforestry practices were more or less higher than their non-agroforestry systems which clearly indicate that through different agroforestry practices fertility status of soils also improved due to efficient utilization of nutrients and addition of organic matter into the soil. Therefore, it can be concluded that agroforestry practices are more economically profitable than the cultivation of their non-agroforestry systems which also helps to reduce the use of synthetic fertilizer.

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