Productivity analysis of timber and fruit tree-based agroforestry practices in Madhupur Sal forest, Bangladesh

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ABSTRACT

In developing countries, different agroforestry systems have been promoted as a pathway to increase household incomes and to generate environmental benefits that are well suited to poor farmers. Thus, a study was carried out in the Madhupur Sal forest of Bangladesh to find out the suitable agroforestry systems based on their productivity. Five agroforestry practices namely Akashmoni tree with Ginger and Banana crops, Akashmoni tree with Turmeric and Banana crops, Akashmoni, Acacia Hybrid, Ghoraneem, and Gamar trees with Turmeric crops, Jackfruit and Akashmoni trees with Turmeric and Aroid crops, and Litchi tree with Pineapple, Ginger, Papaya and Banana crops were randomly selected. The non-agroforestry systems (NAFs) for each of the aforesaid practices were also selected. The study showed that all the selected agroforestry practices were more profitable than their NAFs. The net profit indicated that Litchi- Pineapple- Ginger- Papaya- Banana based agroforestry practice was financially more profitable than the other practices while the benefit-cost ratio (BCR) and land equivalent ratio (LER) were higher (3.66 and 1.76 respectively) in Akashmoni- Ginger- Banana agroforestry practice than in Litchi- Pineapple- Ginger- Papaya- Banana, Akashmoni- Turmeric- Banana, Akashmoni- Acacia Hybrid- Ghoraneem- Gamar- Turmeric, Jackfruit- Akashmoni- Turmeric- Aroid based practices. Even though Litchi- Pineapple- Ginger- Papaya- Banana based agroforestry practice gave higher net profit, the cost required for this practice was much higher. On the other hand, soil pH and content of organic matter, total nitrogen, phosphorus, and potassium in soil of all of the selected agroforestry practices showed higher values than their NAFs. Soil fertility status showed that Akashmoni- Ginger- Banana based agroforestry practice was more fertile as compared to other land uses. The findings revealed that integrated agroforestry systems are more productive than monoculture or NAFs. Both economical and ecological point of view, Akashmoni- Ginger- Banana based agroforestry practice was more suitable than the other practices in the Madhupur Sal forest of Bangladesh.

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Introduction

The degradation of natural resources, especially the land and forest of Bangladesh has become a matter of serious concern because the enormous population of the country (FAO, 1999). Deforestation is nothing but a prime cause of soil erosion and land degradation (Barbier, 1998). Under such conditions, it is needed to identify the alternate systems that sustainably increase productivity as well as conserve natural resources therein by combining trees and crops like agroforestry system. Agroforestry, a land-use system featured by growing different species of woody perennials in association with field crops, is a suitable land-use system specifically for degraded areas. It controls soil erosion, reverses environmental degradation through biological interactions of trees and crops and increases income from farmland (Sanchez, 1994; Garity, 2004). Being a land-use system, agroforestry has been notably considered as an effective and low-cost method as it does help to minimize the process of degradation associated with land cultivation and also for its retention of the ecosystem (Vergara and Nicomedes, 1987).

During the last decades, different agroforestry systems have been promoted in developing countries as a means to increase household incomes and to generate environmental benefits that are well suited to poor farmers (Franzel et al., 2004).

Bangladesh was rich in forest resources but with the pace of population explosion rapid degradation takes place in its forest reserves. In Bangladesh, Sal forests cover an area of about 120,000 ha which accounts for about 0.81% of the total land and 7.5% forest coverage (BFD, 2017). The Sal forest mainly constitutes two parts; the Madhupur Sal forest and the Bhawal Sal forest area. The Madhupur Sal forest is popularly known as Madhupur Garh. Recent statistics showed that about 50,000 forest-dependent people including ethnic minorities are living in and around the 21 villages of the Madhupur Sal forest area mostly rely on agroforestry practices which offer multiple alternatives and opportunities to improve farm production and income.
and also providing productive and conservative functions to the ecosystems (Alam et al., 2010; Islam et al., 2013). The agroforestry programs at the Madhupur Sal forest area contributed more than 46% of the forest dependents people’s household income (Islam et al., 2013).

In the Madhupur Sal forest area, the most important crop and tree products those are mostly preferred by the farmers of different agroforestry practices are pineapple, ginger, aroid, turmeric, banana, papaya and poles, pulpwood and firewood as these trees are mostly short-rotation species (Islam et al., 2013; Kibria and Saha, 2011). Farmer-led agroforestry production systems to this forest have already been provided food, timber, fodder, firewood, fruit, construction materials and another small scale enterprise (Alam et al., 2010; Hossain et al., 2015; Muhammad et al., 2005). But the majority of the local farmers do not have the scope to compare those local potential agroforestry practices for further improvements with technological supports. Therefore, it is required to know about different agroforestry practices, their benefits and their effect on natural resources to maintain sustainable development of this forest. Nevertheless, it is important for policymakers to know which agroforestry systems better serve to income and improve the livelihood of rural people. Unfortunately, there is lacking such kind of research in the Madhupur Garh area. Therefore, this research work was carried to analyze the productivity of timber and fruit tree-based agroforestry practices in the Madhupur Sal forest area.

Materials and Methods

The study area

The study was performed in the Madhupur Sal forest under the Tangail and Mymensingh Forest Division which is popularly known as the Madhupur Tract or Garh. The tract lies between 23°50’ to 24°50’ North latitude and 89°54’ to 90°50’ East longitude (Fig. 1). Recent statistics of the local Madhupur forest office state that the total area of this forest is about 63,001.89 acre (45565.18 acre in Tangail and 17436.71 in Mymensingh districts) acres comprising five ranges namely National Park, Dokhola, Aronkhola, Madhupur and Rasulpur (Local Forest Department, 2018). The tract consists of Pleistocene terraces and recent alluvial floodplain. It occupies the central part of the Ganges- Brahmaputra-Meghna Delta. During the dry season, the soil is compact and hard, but melts with the rainfall and becomes soft and tenacious. The soils of the areas are highly oxidized reddish brown clay with moderate to strong acidic reaction (Alam, 1995).

Location and sampling design

The study was conducted in four villages’ viz. Gaira, JoIoy and Magontinagar of Madhupur Upazila under Tangail district and Sataria under Muktagacha Upazila of Mymensig district (Fig. 2). This study dealt with five agroforestry practices having 0.2 ha area for each sample plot along with a non-agroforestry system (except tree) for each combination.

Selected agroforestry practices in the study area

In the Madhupur Sal forest, five existing timber and fruit tree-based agroforestry practices were selected by baseline survey, practical observation, consulting with local people etc. A list of the selected existing agroforestry practices are-

1. Akashmoni (Acacia auriculiformis)- Ginger (Zingiber officinale)- Banana (Musa sapientum)
2. Akashmoni (Acacia auriculiformis)- Turmeric (Curcuma longa)- Banana (Musa sapientum)
3. Akashmoni (Acacia auriculiformis)- Acacia hybrid (Acacia spp.)-Gamar (Gmelina arborea)- Goraneem (Melia azedarach)- Turmeric (Curcuma longa)
4. Jackfruit (Artocarpus heterophyllus)- Akashmoni (Acacia auriculiformis)- Turmeric (Curcuma longa)- Aroid (Colocasia esculenta)
5. Litchi (Litchi chinensis)- Pineapple (Ananas comosus)- Papaya (Carica papaya)- Ginger (Zingiber officinale)- Banana (Musa sapientum)

Collection of data for productivity analysis

Productivity is commonly defined as a ratio between the output volume and the volume of inputs. In other words, it considers a key source of economic growth and competitiveness and, as such, is basic statistical information for many international comparisons and country performance assessments (Krugman, 1994). Under agroforestry systems, productivity considers the production and fertility of the land. A questionnaire survey, interview, and practical observation method were used to gather data regarding different agroforestry land-use information and physical yield data for productivity analysis viz. cost of production, income, Benefit-Cost Ratio (BCR), Land Equivalent Ratio (LER), as well as soil fertility. For the vegetative survey, measuring tape and Sunto clinometer were used for different measurements. At the same time, soil samples were also collected from the selected plots to find out the impact of agroforestry practices on resource conservation especially the nutrient status of the soil.

Data collection

In order to calculate crop produce, different parameters like number of fruits /plant, weight of fruits /plant (kg), crop or fruit price (Tk/kg), cost of production (Tk/ha), crop yield (kg/ha), income (Tk/ha) were collected from the sample plots. For analyzing the productivity of tree components, parameters like number of trees /plot, bole diameter (cm), bole height (ft), timber price (Tk/ctf), cost of production (Tk/ha), tree yield (kg/ha and cft/ha), income (Tk/ha) were gathered from the selected plots.
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Fig. 1. Forest map of Bangladesh showing Madhupur Sal Forests (MSF) (Islam et al., 2015)

Fig. 2. Map showing the selected villages of (A) Madhupur Upazila of Tangail district and (B) Muktagacha Upazila of Mymensingh district (Banglapedia, 2015)
Soil sample collection, preparation and analysis

A total of 25 (5 in each agroforestry practice) plots in existing agroforestry land uses and 25 plots (10 m × 10 m Quadrat plot) in non-agroforestry practices were established to collect the soil sample. From each quadrat plot, five soil cores were taken and mixed to make a composite sample. Then the soil samples were air-dried, processed and sieved through 20 mesh sieves and packed with a specific tag for laboratory analysis. The chemical analysis of soil samples was done in the Humboldt Soil Testing Laboratory, Department of Soils Science, Bangladesh Agricultural University, Mymensingh. Soil pH was measured by using 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 1N NH₄OAc extract method using flame photometer (Page et al., 1989).

Calculation of production cost

The cost includes land preparation cost, labor cost, seed/seedling cost and, intercultural operation and maintenance cost (fertilizer, pesticide, weeding, etc) related to the production.

Calculation of total income

Benefits received by farmers include agricultural outputs, price of fruits, pruning materials used and sold as fuel and timber both from thinning and final harvest. Benefits obtained from the timber species are accounted as average income per year as the research was carried out for two years. Total income can be computed by multiplying total yield of tree and crop species with their market price.

Total income (Tk) = Total yield (t/ha) × Market price (Tk/kg)

It is mentionable that in case of timber species the yield and income related information were collected from the farmers and the volume of the standing trees were also measured as following method: Volume = πr²h (cft)

Where, \( r \)= radius (cm) and \( h \)= height (ft)

Income of tree products (Tk/ha) = Volume (cft/ha) × Price per unit (Tk/cft)

Calculation of Benefit-Cost Ratio (BCR)

The benefit-cost ratio (BCR), which indicates the rate of return per unit of cost, was calculated using the following formula (Islam et al., 2004):

Benefit-cost ratio (BCR) = Gross income / Total cost of production

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

Calculation of Land Equivalent Ratio (LER)

Land equivalent ratio (LER) is derived from its indication of relative land requirements for intercrops versus monocultures. It helps to find the relative performance of a component of a crop combination compared to the sole stands of that species (Mead and Willey, 1980).

LER can be expressed as:

\[
LER = \frac{C_i}{C_s} + \frac{T_i}{T_s}
\]

Where, \( C_i \) is crop yield under agroforestry, \( C_s \) is crop yield under sole cropping, \( T_i \) is tree yield under agroforestry, and \( T_s \) is tree yield under sole cropping.

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 tree and crop components. If \( LER<1 \), indicate the competition i.e., negative interactions between the tree and crop components.

In this study, the LER was calculated considering some deviation of the mentioned equation. Where, the LER was the ratio of the yield obtained from agroforestry plots to the yield of the non-agroforestry systems (Absence of tree species).

Statistical analysis

The obtained data were scrutinized and edited before putting the data in analyzing sheets. Then data were entered into the computer and analyzed by using MS excel software and ANOVA technique with the help of Statistix 10 to examine the variation of the results for different practices.

Results and Discussion

Economic performance of the selected agroforestry (AF) practices

Akashmoni-Ginger-Banana based AF practice

Income from the sale of different products and all costs were assessed to analysis the economic aspect of the study. However, the BCR and LER are the common indicators of economical performance as both cost and return components are counted here. The results revealed that the total cost incurred for the cultivation of 1 ha land during the study period was Tk 138350 (Table 1). On the contrary, the benefit recorded from this practice was Tk 506883 where banana contributed about 45% of the total income. However, income received from its non-agroforestry system (NAFs) was Tk 402584 (Table 6). The BCR and LER analysis clearly indicated that this land-use system was more profitable than the NAFs (BCR 3.66 and LER 1.76 in Akashmoni-Ginger-Banana based agroforestry practice where BCR 2.92 in
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NAFs) (Tables 1 and 6). The result was corroborated with the findings of Nayak et al. (2014) where the highest gross return (Tk 525187.46/ha), net return (Tk 301074.76/ha) and BCR (2.34) were recorded under Acacia mangium with pineapple based agrosilvicultural (Tree-crop based) system as compared to other agrosilvicultural systems and sole crops in Bhubaneswar, India. Similar result was observed by Kumari and Madan (2016) where they found that the yield performance of four perennial medicinal plants—Glycyrrhiza glabra, Asparagus racemosus, Aloe-vera, and Tinospora cordifolia (0.37 t/ha, 1.8 t/ha, 14.5 t/ha, and 14.76 t/ha, respectively) under Poplar based agroforestry systems was better compare to the sole cropping in Odisha, India.

Table 1. Economic performance of Akashmoni-Ginger-Banana based agroforestry practice

| Year | Production Cost (Tk/ha) | Income (Tk/ha) | BCR | LER |
|------|------------------------|----------------|-----|-----|
| 2017 | 96240                  | 257905         | 3.66 | 1.76 |
| 2018 | 42110                  | 248978         | 3.66 | 1.76 |
| Total| 138350                 | 506883         |      |      |

Note: Taka (Tk) Bangladesh local currency, 1 USD= 85 TK

Akashmoni-Turmeric-Banana based AF practice

The economic analysis stated that the total cost incurred for this practice was Tk 124552 where the initial cost was the highest of Tk 82216 in the year 2017 which was reduced in the next year of production (Table 2). According to the yield analysis, total income calculated for Akashmoni-Turmeric-Banana based agroforestry practice was Tk 358997 while the total income of its NAFs (absence of tree) was Tk 281132 (Table 6). On the other hand, the results of BCR and LER clearly indicated that this land-use system was more profitable than the NAFs (BCR 2.88 and LER 1.58 in Akashmoni-Turmeric-Banana based agroforestry practice where BCR 2.36 in NAFs) (Table 2 and Table 6). Dwivedi et al. (2007) found a similar outcome for poplar based agrosilvicultural system in India. The results were corroborated by Jaimini et al. (2006) where higher fodder yield of 4.95 t/ha was obtained from below the tree canopy followed by between tree rows of 4.03 t/ha and the lowest forage yield was 3.87 t/ha observed in sole dhaman grass (Cenchrus ciliaris) in the absence of Prosopis cineraria in Gujarat, India.

Table 2. Economic performance of Akashmoni-Turmeric-Banana based agroforestry practice

| Year | Production Cost (Tk/ha) | Income (Tk/ha) | BCR | LER |
|------|------------------------|----------------|-----|-----|
| 2017 | 82216                  | 141810         | 2.88 | 1.58 |
| 2018 | 42336                  | 217187         | 2.88 | 1.58 |
| Total| 124552                 | 358997         |      |      |

Akashmoni-Acacia hybrid-Gamar-Goraneem-Turmeric based AF practice

Under this agroforestry practice, the production cost measured for the cultivation of 1 ha land at the time of the study was Tk 97950. While the benefit recorded from this practice was Tk 230541 where about 36% of the total income received from non-woody components (Turmeric) (Table 3). On the contrary, the benefit obtained from its non-agroforestry system (NAFs) was Tk 117843 (Table 6). The BCR (2.35) and LER (1.58) clearly indicated that this practice was profitable while the BCR of its NAFs was 1.99 (Table 3 and Table 6). The result was supported with the findings of Alam et al. (2010) where they indicated that the agroforestry production system in the Madhupur Garh was more profitable than the cultivation of the agricultural crop. Similar findings were found by Rahangdale et al. (2014) where they recorded the highest average monetary return of Tk 25024.51ha⁻¹ from bamboo based agrosilvicultural system compared to sole crops, which gave Tk 11663.19 ha⁻¹. In agroforestry system, the highest financial return of Gamar (Tk 86836.68 of total boundary plants), papaya (Tk 1118941.53 ha⁻¹), pea (Tk 34843.2 ha⁻¹), gram (Tk 73631.25 ha⁻¹), and Indian mustard (Tk 18492.6 ha⁻¹) whereas in sole plantation, the financial yield of Gamar (Tk 25473.14 of total boundary plants), papaya (Tk 964020.19 ha⁻¹), pea (Tk 33462.8 ha⁻¹), gram (Tk 60803.05 ha⁻¹), and Indian mustard (Tk 17368.05 ha⁻¹) in Jharkhand, India (Kumar, 2012).

Table 3. Economic performance of Akashmoni-Acacia hybrid-Gamar-Goraneem-Turmeric based agroforestry practice

| Year | Production Cost (Tk/ha) | Income (Tk/ha) | BCR | LER |
|------|------------------------|----------------|-----|-----|
| 2017 | 67862                  | 54160          | 2.35 | 1.58 |
| 2018 | 30088                  | 176381         |      |      |
| Total| 97950                  | 230541         |      |      |

Jackfruit- Akashmoni-Turmeric-Aroid based AF practice

From the results, the incurred cost of production for this practice was Tk 95153, while the benefit earned was Tk 212071 during the study period (Table 4). Moreover, the BCR and LER calculated for this land-use system were 2.23 and 1.53 which revealed that this practice was profitable for the farmers in the study area (Table 4). In the case of its NAFs, the total income and BCR were Tk 161309 and 1.95 (Table 6). Rahman et al. (2018) found higher net return, BCR and LER from jackfruit based agroforestry system were BDT 557863, 4.56 and 2.17, respectively than their sole cropping systems in Narsingdi district of Bangladesh. Similar findings were also recorded by Hasan et al. (2008) in jackfruit based agroforestry systems in the Madhupur Garh which were very supportive to the present findings.
Table 5. Economic performance of Litchi-Pineapple-Papaya-Ginger-Banana based agroforestry practice

| Year | Production Cost (Tk/ha) | Income (Tk/ha) | BCR | LER |
|------|------------------------|----------------|-----|-----|
| 2017 | 119891                 | 279087         |     |     |
| 2018 | 61067                  | 313826         |     |     |
| Total| 180958                 | 592913         |     |     |

According to the result, it was found that all the selected agroforestry combinations were more profitable than their NAFs in terms of their total benefits (Table 6).

According to the BCR and LER analysis, it had been found that Akashmoni-Ginger-Banana based agroforestry practice was the most profitable having BCR of 3.66 and LER 1.76 followed by Litchi-Pineapple-Papaya-Ginger-Banana, Akashmoni-Turmeric-Banana, Akashmoni-Acacia Hybrid-Gamar-Ghoraneem-Turmeric, Jackfruit-Akashmoni-Turmeric-Aroid based agroforestry practices (Table 6).

Table 5. Economic performance of Jackfruit-Akashmoni-Turmeric-Aroid based agroforestry practice

| Year | Production Cost (Tk/ha) | Income (Tk/ha) | BCR | LER |
|------|------------------------|----------------|-----|-----|
| 2017 | 64859                  | 87857          | 2.23| 1.53|
| 2018 | 30294                  | 124214         |     |     |
| Total| 95153                  | 212071         |     |     |

The Net Present Value (NPV) and Benefit-Cost Ratio (BCR) of the pineapple based agroforestry systems in the Madhupur Sal forest were Tk 487010.79 and 5.35 respectively (Rana, 2010).

According to the result the total cost incurred for this practice was Tk 180958. On the contrary, the benefit received from this practice was Tk 592913 (Table 5) whereas income received from its non-agroforestry system (NAFs) was Tk 535108 (Table 6). In BCR and LER analysis, it was observed that this agroforestry practice was much more profitable than its NAFs (BCR and LER of Litchi-Pineapple-Papaya-Ginger-Banana based agroforestry practice were 3.28 and 1.69, respectively while BCR for its NAFs was 2.99) (Table 5 and Table 6). The highest benefit-cost ratio (3.54) was recorded from coconut with guava based multistoried agroforestry which was higher than their sole cropping (1.65) (Bari and Rahim, 2012). Litchi based agroforestry system ensured a higher return and more sustainable than sole cropping system (Hanif et al., 2010).

Comparison of the selected agroforestry practices with their NAFs

Table 4. Economic performance of different cropping systems

| Cropping Systems                      | Total Production Cost (Tk/ha) | Gross return (Tk/ha) | Net profit (Tk/ha) | BCR  |
|---------------------------------------|-------------------------------|----------------------|--------------------|------|
| Akashmoni-Ginger-Banana               | 138350                        | 506883               | 368533             | 3.66 |
| NAFs                                  | 137630                        | 402584               | 264954             | 2.92 |
| Akashmoni-Turmeric-Banana             | 126052                        | 358997               | 232945             | 2.88 |
| NAFs                                  | 119265                        | 281132               | 161867             | 2.36 |
| Akashmoni-Acacia hybrid-Gamar-Ghoraneem-Turmeric | 97950                       | 230541               | 132591             | 2.35 |
| NAFs                                  | 58975                         | 117843               | 58868              | 1.99 |
| Jackfruit-Akashmoni-Turmeric-Aroid    | 95153                         | 212071               | 116918             | 2.23 |
| NAFs                                  | 82475                         | 161309               | 78834              | 1.95 |
| Litchi-Pineapple-Papaya-Ginger-Banana | 180958                        | 592913               | 411955             | 3.28 |
| NAFs                                  | 178560                        | 535108               | 356548             | 2.99 |

Note: NAFs= Non agroforestry system

Table 6. Economic performances of different cropping systems

| Cropping Systems                      | Total Production Cost (Tk/ha) | Gross return (Tk/ha) | Net profit (Tk/ha) | BCR  |
|---------------------------------------|-------------------------------|----------------------|--------------------|------|
| Akashmoni-Ginger-Banana               | 138350                        | 506883               | 368533             | 3.66 |
| NAFs                                  | 137630                        | 402584               | 264954             | 2.92 |
| Akashmoni-Turmeric-Banana             | 126052                        | 358997               | 232945             | 2.88 |
| NAFs                                  | 119265                        | 281132               | 161867             | 2.36 |
| Akashmoni-Acacia hybrid-Gamar-Ghoraneem-Turmeric | 97950                       | 230541               | 132591             | 2.35 |
| NAFs                                  | 58975                         | 117843               | 58868              | 1.99 |
| Jackfruit-Akashmoni-Turmeric-Aroid    | 95153                         | 212071               | 116918             | 2.23 |
| NAFs                                  | 82475                         | 161309               | 78834              | 1.95 |
| Litchi-Pineapple-Papaya-Ginger-Banana | 180958                        | 592913               | 411955             | 3.28 |
| NAFs                                  | 178560                        | 535108               | 356548             | 2.99 |

Note: NAFs= Non agroforestry system

Table 7. Effect of different cropping systems on soil properties in the Madhupur Sal forest area

| Cropping Systems                      | pH   | OM (%) | Total N (%) | P (ppm) | K (meq/100g) |
|---------------------------------------|------|--------|-------------|---------|--------------|
| Akashmoni-Ginger-Banana               | 4.77 | 2.69   | 0.16        | 42.74   | 0.32         |
| NAFs                                  | 4.71 | 2.43   | 0.13        | 15.54   | 0.29         |
| Akashmoni-Turmeric-Banana             | 4.38 | 2.60   | 0.15        | 33.89   | 0.29         |
| NAFs                                  | 4.86 | 2.01   | 0.10        | 21.40   | 0.26         |
| Akashmoni-Acacia hybrid-Gamar-Ghoraneem-Turmeric | 4.77 | 2.58   | 0.15        | 30.89   | 0.27         |
| NAFs                                  | 4.56 | 2.35   | 0.11        | 19.01   | 0.19         |
| Jackfruit- Akashmoni- Turmeric-Aroid  | 4.75 | 2.55   | 0.15        | 23.01   | 0.24         |
| NAFs                                  | 4.72 | 2.46   | 0.14        | 22.99   | 0.18         |
| Litchi-Pineapple-Papaya-Ginger-Banana | 4.58 | 2.52   | 0.14        | 32.00   | 0.31         |
| NAFs                                  | 4.76 | 2.24   | 0.12        | 29.87   | 0.28         |
Similar findings were observed by Alam et al. (2010), Dwivedi et al. (2007), and Hanif et al. (2015) in which it was concluded that agroforestry systems were economically more profitable compare to their sole cropping systems. Hasan et al. (2008), Hanif et al. (2010) and Rana (2010) also showed the similar types of results in their researches and all of the scientists argued that that agroforestry is a profitable land-use system.

Soil fertility status of the cropping systems

Chemical analysis of the soil samples showed that soil fertility status was improved under the selected agroforestry practices compare to their NAFs (Table 7). From the results, it was recorded that organic matter, total N, available P, exchangeable K content of the selected agroforestry practices were higher than the non-agroforestry systems in the absence of trees. But in the case of Akashmoni with Ginger and Banana based agroforestry practice, all values of the soil properties were higher than the other agroforestry practices. The result indicated that all the agroforestry practices improved soil fertility status as well as conserve natural resources in the Madhupur Sal forest. Kibria and Saha (2011) reported that pineapple agroforestry was more fertile than rest of other agroforestry systems in the Madhupur Sal area. Soil fertility increased from mono-crop to agroforestry soils, observed by Gupta et al. (2009). Improvements of soil characters after practicing bamboo based agroforestry were found by Shannughavel et al. (2000). Similar trends were also recorded by Hasan et al. (2005); Rahman (2006). Pandey et al. (2002) recorded the soil properties like organic carbon, available N, P and k under neem plantations were 0.11 %, 38.90 kg ha⁻¹, 5.14 kg ha⁻¹ and 62.55 kg ha⁻¹ respectively, which were much more higher over control plots (without tree).

Conclusion

In the economic view point, the Akashmoni with Ginger and Banana based agroforestry is much more profitable than the other agroforestry practices. The result also indicates that soil nutrients under different agroforestry practices are utilized more efficiently in comparison to the non-agroforestry systems. All of the selected agroforestry practices are more profitable than their non-agroforestry systems in the economic and ecological points of view. Through agroforestry, farmers can get their food, fuelwood, fodder, timber as well as could increase their income from the same unit of land. So, poor farmers in different areas of our country could improve their livelihood with the conservation of natural resources by adopting these sustainable production systems rather than traditional monoculture. In addition, tree coverage of the country could be raised through practicing different agroforestry systems, which helps to reduce the deforestation problems. Therefore, it is plausible to advocate for the promotion of timber and fruit tree-based agroforestry practices as it requires comparatively low investment, helps to improve soil properties and provides continuous benefits throughout the year.

References

Alam, M., Furukawa, Y. and Harada, K. 2010. Agroforestry as a sustainable land use option in degraded tropical forests: a study from Bangladesh. Environment Development and Sustainability, 12: 147-158. https://doi.org/10.1007/s10668-009-9186-3

Alam, M. K. 1995. Diversity in the woody flora of Sal forests of Bangladesh. Bangladesh Journal of Forest Science, 24(1): 41-52.

Bangladesh Forest Department, 2017. Land and Forest area. Official website of Bangladesh Forest Department (BFD), Government of Bangladesh. URL: http://www.bforest.gov.bd/act.php. Banglapedia, 2015. National Encyclopedia of Bangladesh. http://en.banglapedia.org.

Barbier, E. B. 1998. The economics of land degradation and rural poverty linkages in Africa. UNU/INRA annual lectures on natural resource conservation and management in Africa, November 1998, Accra, Ghana.

Bari, M. S. and Rahim, M. A. 2012. Economic evaluation and yield performance of some medicinal plants in coconut-based multistoried agroforestry systems. The Agriculturists, 10(1): 71-80. https://doi.org/10.3329/agric.v10i1.11067

Dwivedi, R. P., Kareemulla, K., Singh, R., Rizvi, R. H. and Chauhan, J. 2007. Socio-economic analysis of agroforestry systems in Western Uttar Pradesh. Indian Research Journal of Extension Education, 7(4&3): 18-22.

FAO. 1999. Poverty Alleviation and food security in Asia. Rap Publication, Food Agriculture Organization of the United Nation, Rome, Italy.

Franzel, S., Denning, G. L., Lillesø, J. P. B. and Mercado, A. R. J. 2004. Scaling up the impact of agroforestry: lessons from three sites in Africa and Asia. Agroforestry System, 61(1-3): 329-344. https://doi.org/10.1023/B:AGFO.0000029008.71743.2d

Garity, D. P. 2004. Agroforestry and the achievement of the Millennium Development Goals. Agroforestry System, 61: 5-17. https://doi.org/10.1007/978-94-017-2424-1_1

Gupta, N., Kuikal, S. S., Bawa, S. S. and Dhaliwal, G. S. 2009. Soil organic carbon and aggregation under poplar based agroforestry system in relation to tree age and soil type. Agroforestry System, 76: 27-35. https://doi.org/10.1007/978-90-481-3323-9_3

Hanif, M. A., Amin, M. H. A., Bari, M. S., Ali, M. S. and Uddin, M. N. 2010. Performance of okra under litchi based agroforestry system. Journal of Agroforestry and Environment, 4(2): 137-139.

Hasan, M. K., Ahmed, M. M. and Miah, M. G. 2005. Agro-Economic Performance of Jackfruit-Pineapple Agroforestry System at Kapasia in Gazipur district. Journal of Agriculture and Rural Development, 6(1&2): 147-156. https://doi.org/10.3329/jard.v6i1.1672

Hasan, M. K., Ahmed, M. M. and Miah, M. G. 2008. Agro economic performance of jackfruit-pineapple agroforestry system in Madhupur Tract. Journal of Agriculture & Rural Development, 6: 147-156. https://doi.org/10.3329/jard.v6i1.1672

Islam, K. K., Rahman, G. M. M., Fujitara, T. and Sato, N. 2013. People’s participation in forest conservation and livelihoods improvement: experience from a forestry project in...
Islam, M. S., Sattar, M. A., Rahman, M. M., Qayum, M. A., Alam, M. S. and Mustafi, A. 2004. Krishi Projekti Hartoi (Handbook on Agro-technology), 3rd Ed. Bangladesh Agricultural Research Institute, Gazipur- 1701, Bangladesh.

Islam, K. K., Jose, S., Tani, M., Hyakumura, K., Krott, M. and Sato, N. 2015. Does actor power impede outcomes in participatory agroforestry approach? Evidence from Sal forests area, Bangladesh. Agroforestry Systems, 89(3). https://doi.org/10.1007/s10457-015-9822-x

Jackson, M. L. 1958. Soil Chemical Analysis. Prentic Hall Inc. Engle Wood Clitis, N.J, USA

Jainini, S. N., Patel, J. M. and Patel, S. B. 2006. Khejri (Prosopis cineraria) based silvipastoral system for dry land areas of North Gujarat. Indian Journal of Forestry, 29(2): 129-130.

Kibria, M. G. and Saha, N. 2011. Analysis of existing agroforestry practices in Madhupur Sal forest: an assessment based on ecological and economic perspectives. Journal of Forestry Research, 22(4): 533-542. https://doi.org/10.1007/s11676-011-0196-2

Krugman, P. 1994. The Age of Diminishing Expectations. Defining and Measuring Productivity. (http://www.oecd.org/std/productivity-stats/40526851.pdf)

Kumar, S. 2012. Studies on growth performance and economic evaluation of Gamar (Gmelina arborea roxb.) based agroforestry system in East Singbhum district in Jharkhand. M.S. Thesis, Department of Silviculture and Agroforestry, Birsa Agricultural University, Ranchi, Jharkhand.

Kumari, B. and Madan, V. K. 2016. Performance of perennial medicinal crops in Poplar based three-tier agroforestry system. Indian Forester, 142(11): 1109-1116.

Mead, R. and Willey, R. W. 1980. The concept of "Land Equivalent Ratio" and advantages in yields from intercropping. Experimental Agriculture, 16: 217-228. https://doi.org/10.1017/S0014479700010978

Muhammed, N., Koike, M., Haque, F. and Miah, M. D. 2005. Quantitative assessment of people-oriented forest land in Bangladesh: A case study in the Tangail Forest Division. A presentation on people oriented forest in Forest Policy Laboratory, Shinshu University, 8304 Minamimimowa, 399-4598 Nagano, Japan.

Nayak, M. R., Behera, L. K., Mishra, P. J. and Bhola, N. 2014. Economics and yield performance of some short duration fruit and medicinal crops under agrosilvicultrual system in rainfed uplands of Odisha. Journal of Applied and Natural Science, 6 (1): 274-278. https://doi.org/10.31018/jans.v6i1.414

Page, A. L., Miller, R. H. and Keeny, D. R. 1989. Methods of soil analysis. American Society of Agronomy, 2(2):36

Pandey, A. K., Solanki, K. R. and Gupta, V. K. 2002. Impact of Neem (Azadirachta indica A. Juss) plantation under Agroforestry system on soil properties in semiarid Region of India. Journal of Agroforestry, 4(2): 109 - 112.

Rahangdale, C. P., Pathak, N. N. and Koshla, L. 2014. Impact of bamboo species on growth and yield attributes of Kharif crops under agroforestry system in wasteland condition of the central India. International Journal of Agroforestry and Silviculture, 1(3): 31-36.

Rahman, A., Rahman, M. A., Miah, M. G., Hoque, A. and Rahman, M. 2018. Productivity and profitability of jackfruit-eggplant agroforestry system in the terrace ecosystem of Bangladesh. Turkish Journal of Agriculture, Food Science and Technology, 6(2): 124-129. https://doi.org/10.24892/turjaf.v6i2.124-129.1330

Rahman, G. M. M., Wadud, M. A., Shahjahan, M. and Jewel, K. N. A. 2014. Fruit tree based agroforestry practices in Charland farming system. Journal of Agroforestry and Environment, 8(1): 1-6.

Rahman, M. M. 2006. Soil Properties and Vegetative Study of Lachawara National Park. Dissertation, Department of Forestry and Environmental Science, Shahjalal University of Science and Technology, Sylhet, Bangladesh.

Rahman, S. A., Imam, M. H., Wachira, S. W., Farhana, K. M., Torres, B. and Kabir, M. H. 2017. Land use patterns and the scale of adoption of agroforestry in the rural landscapes of Padma floodplain in Bangladesh. Forests, Trees and Livelihoods, 18: 193-207. https://doi.org/10.1080/14728028.2008.9752629

Rana, M. P. 2010. Pineapple agroforestry practice in Madhupur Sal (Shorea robusta) forest: a sustainable way to forest conservation and livelihood security. International Information System for the Agricultural Science and Technology, 1701, Bangladesh.

Sanchez, P. A. 1994. Alternative to slash and burn: A pragmatic approach for mitigating tropical deforestation. In: J.R. Andrdson (ed), Agricultural technology: policy issues for the international community. Wallingford: CAB International, pp. 451-479.

Shanmughavel, P., Peddappaiah, R. S. and Muthukumar, T. 2000. Litter production and nutrient return in Bambusa bambos plantation. Journal of Sustainable Forestry, 11(3):71-82 https://doi.org/10.1300/J091v11n03_04

Vergara, N. T. and Nicomedes, D. B. 1987. Agroforestry in the humid tropics: its protective and ameliorative roles to enhance productivity and sustainability. Honolulu, Hawaii USA: Environment and Policy Institute, East West Center.

Walkley, A., and Black, I. A. 1934. The determination of organic carbon and total nitrogen of soils. Soil Science, 37, 29-38. https://doi.org/10.1097/00010694-193401000-00003