A SEMINAR PAPER ON

EXISTING AGROFORESTRY SYSTEMS FOR BETTER LIVELIHOOD IN MAJOR ECOSYSTEM OF BANGLADESH

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Existing Agroforestry Systems for Better Livelihood in Major Ecosystem of Bangladesh [1]

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ABSTRACT

Bangladesh is one of the most densely populated countries in the world where 1015 persons are living per square kilometer. The per capita land area is decreasing at an alarming rate due to increasing population. The availability of land has been declined from 0.19 ha in 1961 to 0.101 ha in 1992 and now the country is claimed to have the lowest per capita arable land of 0.02 ha. Per capita land area is decreasing and demand for food, fuel wood, fodder, timber poles etc. is increasing. Since there is neither scope for expanding forest area nor sole grain crop area, the country has to develop combined production system integrating trees and crops which is now being called agroforestry. Agroforestry is an integral part of the rural livelihood systems for centuries in Bangladesh and plays a key role in providing household food and energy, security, income and employment generation, investment opportunities and environmental protection. Both traditional and modern Agroforestry systems are practiced in Bangladesh. Agroforestry systems have been contributing to the livelihood of the rural households of Bangladesh through providing diversified products. BCR and LER value found higher in case of Agroforestry practices compare to sole cropping. Agroforestry provided better eco-system services. So agroforestry has a vital role for improving livelihood in Bangladesh. It provides multiple products, services and year round income generation.

Key words: Traditional agroforestry, Modern agroforestry, Multiple products

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CHAPTER I

INTRODUCTION

Bangladesh is one of the most densely populated countries in the world where 1015 persons are living per square kilometer (BBS, 2013). The per capita land area is decreasing at an alarming rate due to increasing population (Hossain and Bari, 1996). This availability of land has been declined from 0.19 ha in 1961 to 0.101 ha in 1992 and now the country is claimed to have the lowest per capita arable land of 0.02 ha (Iqbal *et al.,* 2002).

To feed this over increasing population, agricultural land needs to be intensified. The productive capacity of our agricultural land is low due to poor soil health. In fact, rising population pressure and urbanization coupled with land degradation, soil salinization and global warming causing food and nutritional insecurity of Bangladesh. Because of the increasing environmental hazards and demand for food, timber, fuel wood, fodder, fruits and poles etc. production of multiple products from the same land management unit is urgently needed. Multiple productions from homesteads and croplands are indispensable for a country like Bangladesh where the population growth rate is very high and faster than its agricultural growth rate. Since there is neither scope for expanding forest area nor sole grain crop area, the country has to develop combined production system integrating trees and crops which is now being called agroforestry.

Agroforestry is an integral part of the rural livelihood systems for centuries in Bangladesh and plays a key role in providing household food and energy security, income and employment generation, investment opportunities and environmental protection (Miah *et al.,* 2002). The integration of trees, agricultural crops, and/or animals into an agroforestry system has the potential to enhance soil fertility, reduce erosion, improve water quality, enhance biodiversity, increase aesthetics, and sequester carbon (Garrity *et al*., 1992). Moreover, tree plantations improve soil physical, chemical and biological properties through accretion and decomposition of organic matter through litter fall, and roots decay. Deep and extensive root systems of trees enable them to absorb substantial quantities of nutrients below the rooting zone of crops and transfer them to surface soil (Hartemink *et al*., 1996; Allen *et al*., 2004).

Various traditional and modern agroforestry systems are practiced in different ecosystems of Bangladesh. Although agroforestry systems are prevailed throughout the country, specific agroforestry systems are found in specific ecosystems due to variations in topography, soil, water and climatic reasons as well as socio-economic settings. Many of the practices such as Jackfruit based system in Madhupur Tract, Date palm and Pulmyra palm based system in Faridpur and Jessore areas, Mango based system in Rajshahi region etc. are well suited on the smallholdings of Bangladesh characterized by sub-optimal management and subsistence farming conditions (Miah, *et al.,* 2001). Burmese grape based agroforestry systems are also found as economically viable practice in some areas of terrace ecosystem (Alam, 2004). The modern agroforestry systems like cropland agroforestry, alley cropping and forest farming in north-west part of Bangladesh and Windbreaks or Shelterbelts and forest farming east-south part of Bangladesh are well practiced.

These traditional and modern agroforestry systems have been contributing to the livelihood systems of the rural households of Bangladesh for centuries through providing diversified products (Abedin and Quddus, 1990; Akter *et al*., 1990).

Many people are now rediscovering agroforestry as a way to address food security, resource conservation, and habitat restoration, while building local economic capacity. Even a small "forest island" of food trees and shrubs can provide a significant amount of food for a family, with excess to share with friends or sell at a local farmer's market.

Considering the above perspective, the study was undertaken with the following objectives.

- ☐ To review some dominant agroforestry systems in different ecosystems of Bangladesh
- ☐ To know the role of agroforestry for better livelihood in Bangladesh

CHAPTER II

MATERIALS AND METHODS

This seminar paper is completely a review paper. During the preparation of this manuscript various books, journals, proceedings, articles, report etc. related to the topic have been revealed that were available in the library of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), Bangladesh Agricultural Research Council (BARC) and Soil Resource Development Institute (SRDI) and have been compiled systematically and chronologically to enrich this paper. Internet searching have also been conducted. All the information and data collected from the secondary sources and presented in its present form.

CHAPTER III

RESULTS AND DISCUSSION

AGROFORESTRY: DEFINITION AND TYPES

Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence (Figure 1). In agroforestry systems there are both ecological and economical interactions between the different components (Lundgren and Raintree, 1982).

Agroforestry is the most effective land use system for climate change adaptation and livelihood improvement and is recognized worldwide as the best productive system and provide food, fodder, fuel-wood and services. It implies that, agroforestry provide for food security, employment and income generation (Miah and Ahmed, 2003).

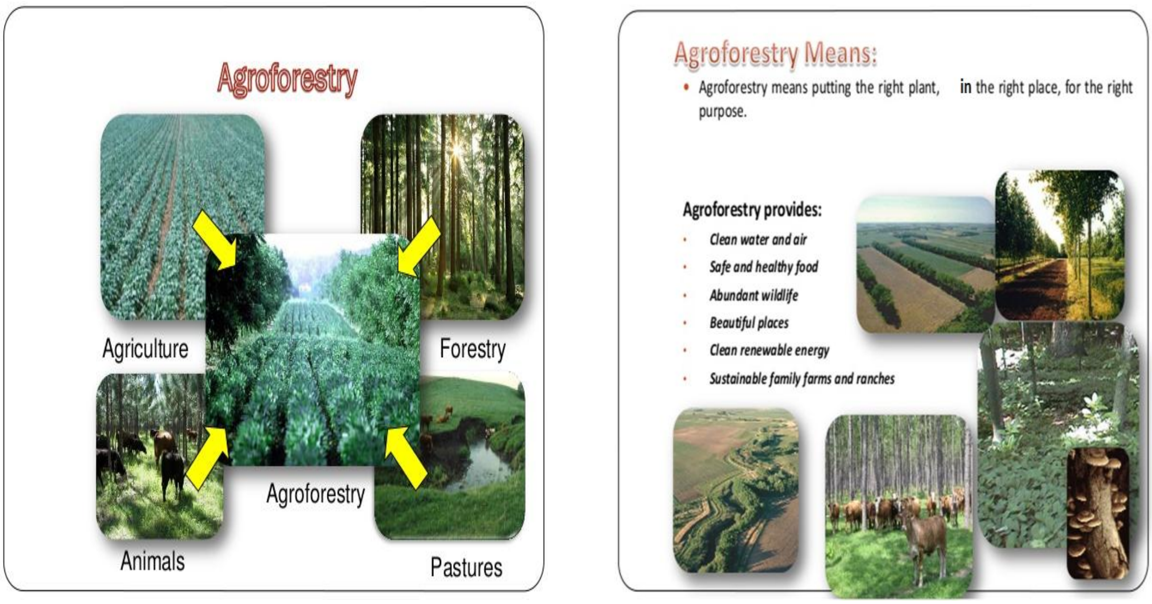

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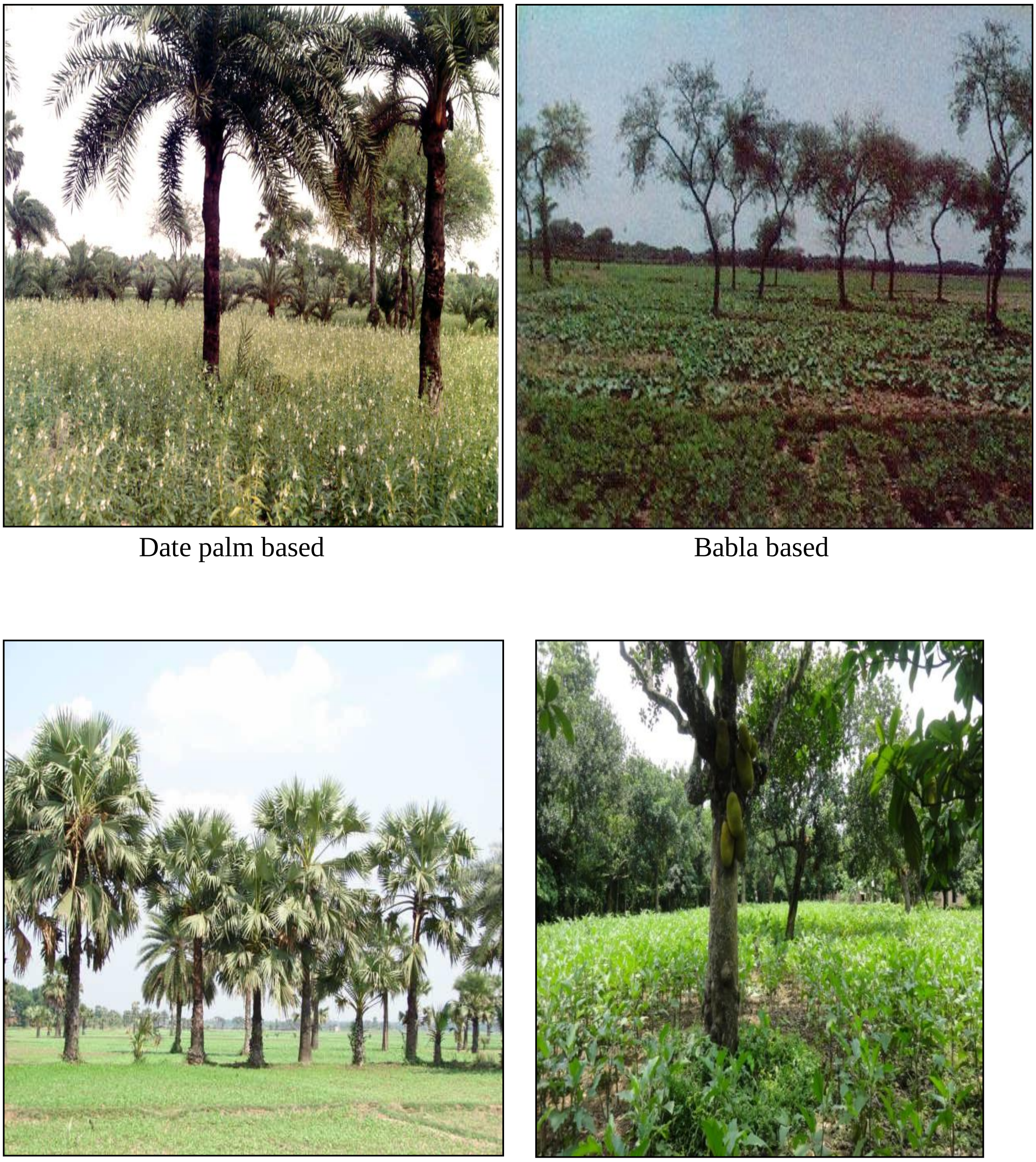
Figure 1. Agroforestry systems

A. Traditional agroforestry system in Bangladesh



Date palm based

Babla based

Palmyra palm based

Jackfruit based

Figure 2. Traditional agroforestry system (Source: Miah, *et al*., 2001).

B. Modern agroforestry system in Bangladesh

Cropland agroforestry

Alley cropping

Riparian buffer strip

Forest farmin

Riparian buffer strip

Windbreak/shelterbelt

Figure 3. Modern agroforestry system (Source: Miah. *et al*., 2001).

Figure 4. Monitoring visit to BSMRAU component by project personnel of BARC (Source: Miah, *et al*., 2001).

Performance crops under agroforestry system

Crop land agroforestry

Chakraborty *et. al.*, (2015) stated that, cropland agroforestry (CAF) is a land based production system that is directly related to food security, employment, income opportunities and environmental issues (Fig. 5). CAF also plays a vital role in rural socio-economic

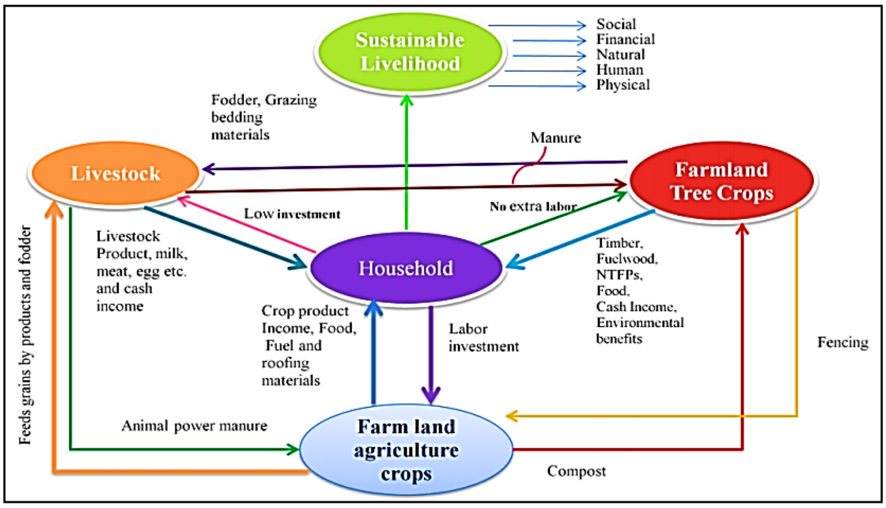


Figure 5. Contribution of cropland agroforestry (CAF) on sustainable livelihood (Source: Chakraborty *et. al.*, 2015)

development as well as poverty reduction. Likewise, CAF practice increases yield and services of per unit agro-forest area. At present, people are practicing various CAF practices all over the country (Aktar *et. al.*, 1992). It is also intensively practiced in Jessore district (Hasanuzzaman *et. al.*, 2014).

Jackfruit based agroforestry system

The performance of jackfruit tree as upper story component was evaluated before and after transformation of agroforestry. The diameter at breast height (DBH) after transformation of agroforestry was not significantly changed showing only 2.4% increase. However, fruit bearing trees increased remarkably (57.1%) after the transformation. In addition, agroforestry system resulted in the greater number of fruits per tree with smaller fruit size, and length. Finally, the transformation of agroforestry system increased yield of jackfruit by 32.7% compared to sole system (Table 1).

Table 1. Performance of jackfruit trees in both monoculture and agroforestry system in terrace ecosystem of Bangladesh

Parameter	Year		Change (%)
	Before upscaling (sole)	After upscaling (agroforestry)	
DBH (cm)	24.0(±3.65)	24.6(±3.57)	2.4
Fruit bearing tree (%)	60.9(±2.44)	95.7(±2.86)	57.1
Fruit weight (kg)	16.3(±0.32)	12.7(±0.54)	-22.1
Fruit length (cm)	38.2(±2.04)	31.6(±1.43)	-17.3
Fruit width (cm)	76.3(±3.29)	60.3(±2.40)	-21.0
No. of fruits per tree	30.7(±4.21)	52.3(±3.98)	70.3
Total yield (kg tree^{-1})	499.1(±1.38)	662.1(±2.18)	32.7

(Source: Miah *et al*. 2017)

Performance of papaya as middle story crop

As middle story crop, yield of papaya in agroforestry system was lower compared to that of monocrop in both the years (Fig. 6). Papaya yield was reduced by 39.2% in agroforestry system compared to traditional monoculture plantation. In the study, year to year variability in the yield of papaya was insignificant (P > 0.05).

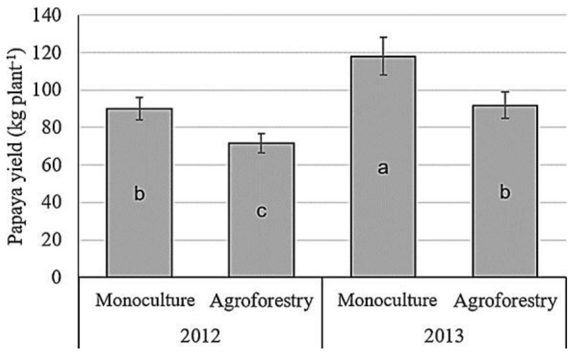


Figure 6. Fruit yield of papaya as monoculture and agroforestry crop in jackfruit based multistory agroforestry system during 2012 and 2013 (Source: Miah *et al*. 2017).

Performance of eggplant as lower story crop

The monocrop and agroforestry system showed significant ($P < 0.05$) differences in eggplant yield during both the years (Fig. 7). The eggplant grown as sole crop gave remarkably high fruit yield in both the years, but in the second year, it was much higher than first year. Between the systems, yield of eggplant reduced significantly ($P < 0.05$) when grown in association with papaya and jackfruit in the multistoried system. The yield of eggplant did not vary significantly in both the years when grown only with jackfruit tree. Significantly highest (1.60 kg/plant) and lowest (0.61 kg/plant) yields were recorded as sole crop in 2013 and as multistoried crop in 2012, respectively.

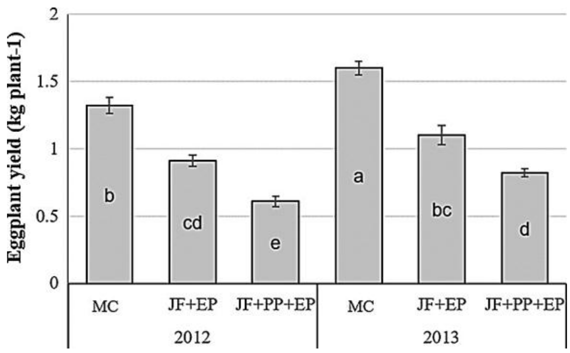


Figure 7. Fruit yield of eggplant as monoculture and agroforestry crop in jackfruit based multistory agroforestry system during 2012 and 2013 (Source: Miah *et al*. 2017).

Benefit–cost ratio and land equivalent ratio

The BCR (Table 2) reveals that multistoried agroforestry system based on jackfruit–papaya–eggplant had the highest BCR followed by that of jackfruit–eggplant agroforestry system. There was remarkable increase in BCR from 2012 to 2013 indicating better establishment of the under storied jackfruit and eggplant in the second year. The sole system involving either papaya or eggplant performed poorly giving lower BCR. However, BCR increased when eggplant is cultivated as under-storied crop followed by that of papaya. The result indicates that the multistoried agroforestry system was economically profitable over the sole cropping.

Similarly, land equivalent ratio (LER) remarkably increased in agroforestry systems compared to that in sole cropping in both the years. The jackfruit–papaya– eggplant (2.58) multistoried system exhibited the highest LER followed by jackfruit–eggplant (1.82) and jackfruit–papaya (1.77) systems. However, the LER remained almost unchanged for jackfruit–eggplants system in both the years.

Table 2. Benefit-cost ratio (BCR) and land equivalent ration (LER) of different agroforestry systems and sole during 2012 and 2013

System	Benefit-cost ratio (BCR)		Land equivalent ratio (LER)	
	2012	2013	2012	2013
Jackfruit-papaya	3.64 b	4.80 b	1.76 b	1.78 b
Jackfruit-eggplant	4.63 b	5.26 a	1.82 b	1.82 b
Jackfruit-papaya-eggplant	5.32a	5.62 a	2.58 a	2.60 a
Sole papaya	3.35 c	4.52 b	-	-
Sole eggplant	3.98 c	4.42 b	-	-

(Source: Miah, *et al*., 2017)

Ber based agroforestry system

Ten years old two ber orchards were selected for experimentation. The spacing of ber trees was 7 m × 7 m, and the population of ber tree was 204/ha. The ber trees were headed back just after harvesting of fruits. Different vegetables were grown after the heavy pruning of ber trees. In the first orchard, okra followed by red amaranth and mukhikachu were grown separately keeping one control plot. In second orchard, sponge gourd and sponge gourd + mukhikachu were grown separately keeping one control plot. Performance of okra in ber based agroforestry system was slightly lower (8.0 tha^{-1}) than sole cropping (10.0 t. ha^{-1}) and the yield reduction was 20%. Similar pattern of change in yield of mukhikachu was found in association with ber tree. The yield reduction was recorded 28.3% in ber+ mukhikachu based agroforestry system compared to sole cropping. While the yield of sponge gourd in agroforestry system was slightly higher (24.7 t.ha^{-1}) than sole cropping (20.01 t.ha^{-1}) and the yield improvement was 23.4%.The increasing trend of the yield of red amaranth was also recorded in ber based agroforestry system and the yield was increased by 14.2% as compared to sole cropping. The yield increment of sponge gourd in sponge gourd + mukhikachu (mixed cropping) + ber was 22.4%, while the yield reduction of mukhikachu in this association was 75.2% as compared to sole cropping. This severe yield reduction of mukhikachu was due to heaviest shade provided by ber tree and middletoried sponge gourd vegetable. Yield performance of ber tree in agroforestry system was better than sole cropping irrespective of vegetable combination. The highest yield of ber was recorded in ber + mukhikachu based agroforestry system (13.3 t.ha^{-1}), which was almost similar to that of ber + okra-red amaranth based system (13.2 t.ha^{-1}). For these two systems, there was one control plot (sole), where the yield of this control ber plot was 9.24 tha^{-1}. The finding revealed that ber yield was increased by 43.9 and 42.9% in mukhikachu and okra-red amaranth based agroforestry systems, respectively. The yield of ber in sponge gourd based agroforestry system was 12 tha^{-1}, while in sponge gourd + mukhikachu based agroforestry system, the yield of ber was 11.5 t.ha^{-1}. The yield of ber fruit in control plot was 8.4 tha^{-1}. Therefore, the yield of ber tree was increased by 42.8 and 36.9% in ber + sponge gourd and ber + sponge gourd + mukhikachu based agroforestry systems, respectively. Calculation of LER showed that the highest LER(3.37) was in ber + mukhikachu based agroforestry system followed by ber +sponge gourd + mukhikachu based agroforestry system (Table 3).

Table 3. Yield and LER for vegetables in ber based agroforestry system

Vegetables	**Yield of vegetables(t ha^{-1})**			**Yield of ber (t ha^{-1})**			**LER**
	AF	Sole	Change (%)	AF	Sole	Change (%)	
Okra	8	10	-20	13.2	9.24	+42.9	2.15
Red amaranth	4	3.5	+14				
Mukkhikachu	11.11	15.5	-28.3	13.3	9.24	+43.9	3.37
Sponge gourd	24.7	20.01	+23.4	12	8.40	+42.8	2.66
Sponge gourd	24.5	20.01	+22.4	11.5	8.40	+36.9	2.73
Mukkhikachu	2.1	8.5	-75.2				

(Source: Wadud, M. A. 1999)

Financial analysis was done for each system through calculating Benefit Cost Ratio (BCR) and net return (NR). All these four combinations of vegetables with ber tree gave higher BCR and NR than sole ber cultivation, while, sole production of all these vegetables gave much lower BCR and NR than sole ber cultivation. Among the systems, the highest BCR as well as NR was recorded for ber + sponge gourd system and the values were 10.40 and 1281618Tk ha^{-1}, respectively. The second highest BCR (9.88) was recorded for ber + okra – red amaranth system, while, the second highest NR (1255076 Tkha^{-1}) was achieved in ber + sponge gourd+ mukhikachu system (Table 4).

Table 4. BCR for vegetables in ber based agroforestry system

System	**Gross income (Tk ha^{-1})**	**Cost (Tk ha^{-1})**	**Net return (Tk ha^{-1})**	**BCR**
Ber + okra – Red amaranth	1236400	125132	1111268	9.88
Ber + mukhikachu	1162975	122007	1040968	9.53
Ber + sponge gourd	1418000	136382	1281618	10.40
Ber + sponge gourd+ mukhikachu	1401750	146674	1255076	9.56
Okra – red amaranth	252500	109178	143322	2.31
Mukhikachu	193750	103552	90198	1.87
Sponge gourd	400200	105250	294950	3.80
Sole ber	646800	91132	555668	7.10

Prices were used @ 12.5, 20.0, 15, 20.0 and 77.0 Tk Kg^{-1}, respectively, for mukhikachu, okra, red amaranth, sponge gourd and ber.

(Source: Wadud, M. A. 1999)

Coconut-Litchi based agroforestry

Equivalent yield and land equivalent ratio

The performance of agroforestry system (AF) was evaluated on the basis of equivalent yield. The equivalent yields of coconut, litchi, sweet orange, and pineapple was markedly influenced by multi-layered fruit garden (Table 5). The result showed that AF gave higher coconut, litchi, sweet orange and pineapple equivalent yields than that of their corresponding sole crop yields (Rahman *et. al.,* 2014). The land equivalent ratio (LER) was used to assess the performance of an intercrop relative to the corresponding sole crop. If the value of LER is more than one (1.00) it indicates a total yield advantage of growing intercrops over sole crops, since the index denotes how much land would be required for growing sole crops to obtain the same yields of each component as was obtained in AF (inter crop condition). The highest LER value (2.6) was obtained from AF (Table 5) which might be due to maximum complementary use of different growth resources in multi -storey fruit gardening.

Table 5**.** Equivalent yield and land equivalent ratio of different fruit crops as sole and their combination in agroforestry system.

Treatments	**Coconut equivalent yield (no./ha/yr)**	**Litchi equivalent yield (no./ha/yr)**	**Malta equivalent yield (kg/ha/yr)**	**Pineapple equivalent yield (no./ha/yr)**	**Land equivalent ratio (LER)**
Fruit crop in AF	2,12,277	1,57,710	53,109	5,35,313	2.6
Coconut (sole)	20,000	-	-	-	1.0
Litchi (sole)	-	1,04,297	-	-	1.0
Malta (sole)	-	-	51,339		1.0
Pineapple (sole)	-	-	-	55,500	1.0

AF = Agroforestry (Source: Rahman *et. al.*, 2014)

Cost–return analysis

The highest gross return in multi-storey garden was obtained from sweet orange (TK. 6,07,256.79/ha/yr) followed by pineapple (TK. 3,40,277.78/ha/yr) and coconut (TK. 2,65, 625.00/ha/yr) and the lowest from litchi (TK. 2,49,375.00/ha/yr) (Table 6). The maximum gross return was recorded from AF (TK. 14,62,534.57/ha/yr) which was followed by sweet orange (TK.11,06,875.00/ha/yr) (Table 7). The AF gave the highest gross margin (TK. 12,47,085.19/ha/yr) followed by sweet orange (TK 9,04,687.44/ha/yr) and the lowest from litchi (TK. 88,836.81/ha/yr). The maximum BCR of 6.89 was also recorded in AF followed by sweet orange sole (5.47) and coconut sole (3.46). In an earlier study Hasan *et al.* (2008) stated that benefit cost ratio (1.51), net present value and internal rate of return clearly indicated the profit ability of Jackfruit-pineapple agroforestry production system. The benefit cost ratio indicated that if a farmer invests Tk. 100, he would get Tk.151 which was inconsonant with present investigation.

Table 6. Gross return from different fruit crops in agroforestry system and from sole fruit garden.

Fruit crop	Gross return in AF (Tk./ha/yr)	Total gross return in sole crop (Tk./ha/yr)
Coconut	2,65,625.00	4,00,000.00
Litchi	2,49,375.00	2,08,593.75
Malta	6,07,256.79	11,06,875.00
Pineapple	3,40,277.78	3,64,583.33
Total	14,62,534.57	-

(Source: Rahman *et. al.*, 2014)

Table 7. Cost-return analyses of different fruit crops as sole and their combination in agroforestry system.

Treatment	Gross return (Tk./ha /yr)	Total variable cost (Tk./ha/yr)	Gross margin (Tk./ha/yr)	Benefit-cost ratio (BCR)
Fruit crop combination (AF)	14,62,534.57	2,15,451.38	12,47,083.19	6.79
Coconut (sole)	4,00,000.00	1,15,520.83	2,84,479.16	3.46
Litchi (sole)	2,08,593.75	1,19,756.94	88,836.81	1.74
Sweet orange (sole)	11,06,875.00	2,02,187.56	9,04,687.44	5.47
Pineapple (sole)	3,64,583.33	2,07,673.61	1,56,909.72	1.76

(Source: Rahman *et. al.*, 2014)

Note: Coconut fruit (nut): Tk. 20/piece, Litchi: Tk. 200/100 pieces, Sweet orange: Tk. 80/kg from AF, Sweet orange: Tk. 70/kg from sole, Pineapple: Tk. 7/piece, AF = Agroforestry system

Cotton-aonla based agroforestry

Seed cotton yield

There was a significant effect of different agroforestry systems and open field in recording seed cotton yield (Figure 8). Open field produced the highest seed cotton yield (2393 kg ha $^{-1}$ and 2395 kg ha $^{-1}$ in 2009-2010 and2010-2011, respectively). Significantly, the lowest seed

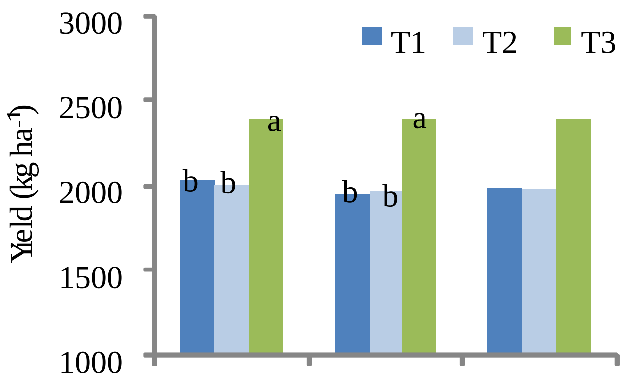


Figure 8. Yield performance of cotton in aonla based multistoried agroforestry system during 2009-2010 and 2010-2011 (Source: Mortuza *et. al.*, 2014)

cotton yield (2004 kg ha $^{-1}$ and 1965 kg ha $^{-1}$ in 2009-2010 and 2010-2011, respectively) was recorded in Aonla + Carambola-Lemon + cotton agroforestry system which was insignificantly followed by Aonla + cotton agroforestry system in both growing seasons. The seed yield of cotton varied greatly for different varieties of cotton (Figure 9). The highest seed cotton yield (2392 kg ha $^{-1}$ and 2362 kg ha $^{-1}$ in 2009-2010 and 2010-2011, respectively) was found in CB 10 cotton variety which was statistically superior to the rest of the varieties.

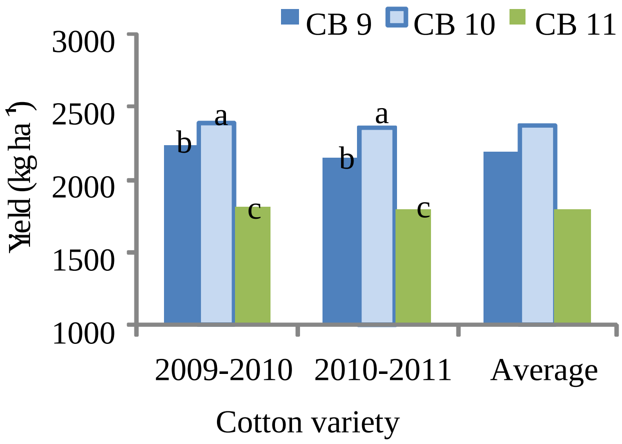


Figure 9. Yield performance of cotton varieties in aonla based agroforestry system during 2009-2010 and 20102011 crop season (Mortuza *et. al.*, 2014).

This might be due to the genetic potentiality to be exploited for higher yield of cotton. The lowest yield of cotton (1807 kg ha $^{-1}$ and 1803 kg ha $^{-1}$ in 2009-2010 and 2010-2011, respectively) was obtained by CB 11 cotton variety. The highest seed cotton yield of CB 10 was associated with its better yield component like number of bolls per plants. However, CB 10 is a medium in plant height and higher number of bolls per plant might have attributed to enhance its higher seed cotton yield (Mortuza *et. al.*, 2014).

Interaction effect showed significant variation in seed cotton yield of different cotton varieties for different agroforestry systems and open field (Table 8). Significantly, the highest seed cotton yield (2725 kg ha^{-1} and 2740 kg ha^{-1} in 2009-2010 and 2010-2011, respectively) was produced in CB 10 at open field condition which was followed by T_3V_1 treatment combination. However, significantly the lowest seed cotton yield (1723 kg ha^{-1} and 1749 kg ha^{-1} in 20092010 and 2010-2011, respectively) was recorded in CB 11 in + Carambola-Lemon +cotton agroforestry system in both growing seasons. The study revealed that agroforestry systems had a strong influence on seed cotton yield. Similar results were observed by Bashir (2002) and Reza (2005) in mungbean. Lower yield in shaded conditions in cotton was reported by Dunlap (1945).

Table 8. Interaction effect of agroforestry systems and varieties of cotton on single boll weight and yield of cotton (kg ha^{-1}) during 2009-2010 and 2010-2011 crop seasons

Treatment Combination	Single boll weight (g boll^{-1}) and yield of cotton (kg ha^{-1})				
	Single boll weight (g boll^{-1})		Yield (kg ha^{-1})		Average Yield (kg ha^{-1})
	2009-2010	2010-2011	2009-2010	2010-2011	
T_1V_1	4.86 b	4.88 b	2098 cd	1925 d	2011.5
T_1V_2	4.71 de	4.76 cd	2234 c	2144 c	2189
T_1V_3	4.67 e	4.65 d	1756 e	1774 e	1765
T_2V_1	4.86 b	4.88 bc	2073 cd	1946 d	2009.5
T_2V_2	4.70 de	4.79 bc	2216 c	2200 c	2208
T_2V_3	4.68 e	4.67 d	1723 e	1749 e	1736
T_3V_1	5.01 a	5.02 a	2511 b	2559 b	2535
T_3V_2	4.77 cd	4.85 bc	2725 a	2742 a	2733.5
T_3V_3	4.80 bc	4.68 d	1942 d	1886 d	1914
CV (%)	0.81	0.82	3.11	4.78	

In a column, means followed by same letter (s) are not statistically different by DMRT.

T_1 = Aonla + Cotton, T_2 = Aonla + Carambola- Lemon + Cotton, T_3 = Open Field, V_1 = CB-9, V_2 = CB-10 and V_3 = CB-11.

(Mortuza *et. al.*, 2014).

Litchi-okra based agroforestry

Yield Contributing Parameters of Okra as Influenced by Litchi Tree (Hanif *et. al.*, 2010). Number of fruits plant-1 was also influenced by the over storey multipurpose tree species (Table 9). Significantly, the highest number of fruit plant-1(8.50) was recorded in T1 (sole cropping of hybrid okra variety) and the lowest number of fruit per plant-1 (4.25) was observed in T6 (Litchi + Local okra variety). Lower number of fruits per plant under relatively more and prolonged shaded conditions was probably due to poor photosynthetic capacity of plants. The decreasing photosynthetic capacity of shaded plants was attributed due to both stomata and mesophyll cell properties (Wolff, 1990). The present results are in support of Rahman (2006) who found the highest number of fruits per plant in open field when eggplant grown as multistoried system. Consequently, the highest fruit length (14.25 cm) was recorded in sole cropping of okra (T1) which was statistically similar with T4 (13.75 cm) and the lowest fruit length (11.75 cm) was observed in T6 (Litchi + Local okra variety). Similar result was also reported by Rahman (2006) on performance of cane and eggplant in multistoried agroforestry system. On the other hand, the highest fruit girth (7.43 cm) was recorded in T1 which was statistically similar with T4 (7.365 cm) and T3 (7.335 cm) and the lowest fruit length (6.37 cm) was observed in T6 (Table 9). The lower fruit girth under heavy shade may be associated with the lower mobilization of reserve assimilation to reproductive organ. Similar finding in caseof okra and eggplant was also reported by Wadud (1999) and Rahman (2006), respectively. Apparently, fruit weight plant-1, single fruit weight and dry weight were maximum (159.72 g, 18.79 g and 10.25 g) in sole cropping of okra hybrid variety while minimum (66.29 g, 15.61 g and 8.95 g) fruit weight plant-1, single fruit weight and dry weight were recorded in Litchi + Local okra variety. Reduced dry matter of plants and fruits was also reported by Fawusi (1985). Yield of Okra as Influenced by Litchi Tree: Fruit yield (t ha-1) of okra significantly varied under Litchi based agroforsetry system. Significantly, the highest yield (10.24 t ha-1) was found in sole cropping of okra hybrid variety that was followed by (7.685 t ha-1) in T2 (sole cropping of BARI-1 variety). The lowest yield (4.24 t ha-1) was found in T6 (Litchi + Local okra variety). The present results are in support of the findings of Sivan (1984) where 40% yield reduction was noticed when okra was intercropped with taro. However, the less light was not as deleterious in case of okra as was experimented by Singh (1997) with 65% shading to normal light. Similar result was also reported by Rahman (2006).

Table 9. Yield contributing parameters and yield of okra as influenced by litchi based agroforestry system

Treatment	Fruit weight (g) plant^{-1}	Single fruit weight (g)	Dry weight of fruits (g)	Yield (t ha^{-1})
T1	159.27a	18.79a	10.25a	10.24a
T2	119.90b	16.13b	9.15b	7.68b
T3	104.01c	16.13b	9.15b	5.28d
T4	119.90b	16.33b	9.65c	6.65c
T5	104.01c	16.33b	9.65c	5.12e
T6	66.29d	15.61b	8.95c	4.240f
Level of Sig.	**	**	**	**

** 1% level of significance * 5% level of significance MAP=Month after planting

(Source: Hanif *et. al.,* 2010)

Soil enrichment

The role of agroforestry in enhancing and maintaining long-term soil productivity and sustainability has been well documented. The incorporation of trees and crops that are able to biologically fix nitrogen is fairly common in tropical agroforestry systems. Non N-fixing trees can also enhance soil physical, chemical and biological properties by adding significant amount of above and belowground organic matter and releasing and recycling nutrients in agroforestry systems. A large body of literature, comprised of both original research and synthesis articles, has described the effects of agroforestry on soils in the tropics (Nair and Latt 1997; Young

1997; Buck *et al.*, 1998; Schroth and Sinclair 2003). Similar accounts are relatively few in the temperate literature; however, the role of woody perennials, both N-fixing and non-fixing, in improving the soil chemical, physical and biological properties has become the subject of investigations in the last decade (Jose *et al.*, 2004). For example, Seiter *et al.*, (1995) demonstrated the use of N-fixing red alder (*Alnus rubra*) in a maize alley cropping system in Oregon. The authors observed, using an 15N injection technique, that 32–58% of the total N in maize was obtained from N fixed by red alder and that nitrogen transfer increased with decreasing distance between the trees and crops.

Improvement of soil fertility is one of the major objectives of the agroforestry practices. The findings of the respondents (88%) observed soil fertility improvement and reduction of soil erosion that were the main aspects of soil conservation through practicing agroforestry by addition of organic matter and requirement of less inorganic fertilizers opined by the respondents through benchmark study during 2014 complited by the department of agroforestry and environment, BSMRAU, Gazipur (Figure 10).

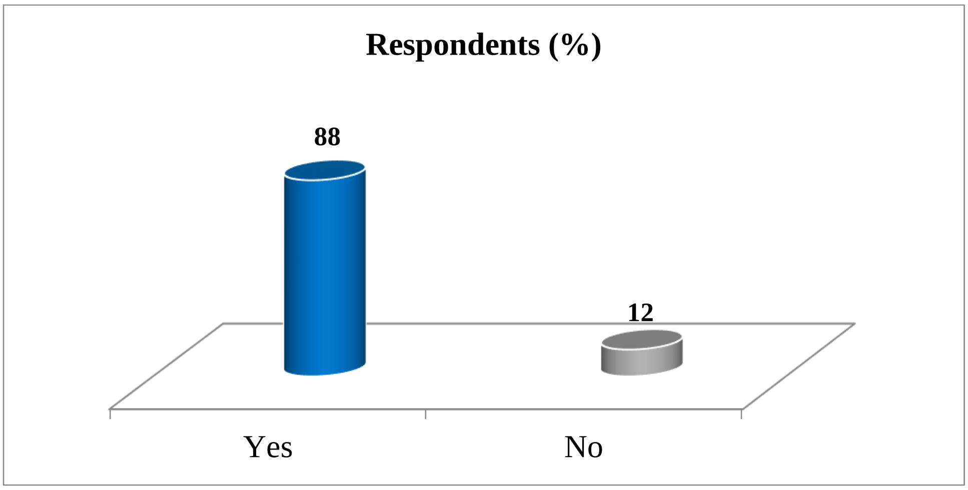


Figure 10. Improvement of soil fertility in agroforestry practices in the study area (Source: Miah *et. al.*, 2014)

Top soil (0-15 cm) samples before and after experimentation were collected to analyze and understand the changes occurred due to agroforestry practices. It was observed that all the studied parameters were changed in a positive direction after the experimentation over the initial values. The changes in soil chemical properties after two years of experimentation have been presented in Table. 10.

Table 10. Soil properties changes in agroforestry system under terrace ecosystem of Bangladesh

Parameter	Before experimentation (2011)	After experimentation (2013)	% Change
Soil pH	4.54	4.62	1.76
Nitrogen (%)	0.072	0.081	12.5
Organic carbon (%)	0.59	0.61	3.38
Organic matter (%)	1.01	1.05	3.96
Available P (ppm)	3.77	4.23	12.20
Available S (ppm)	9.03	10.17	12.62
Ca (meq/100g)	2.08	2.27	9.13
Mg (meq/100g)	0.44	0.46	4.55
K (meq/100g)	0.51	0.52	1.96

(Source: Miah *et. al.*, 2014)

Agroforestry for biodiversity conservation

Ecosystems and species important in sustaining human life and the health of our planet are disappearing at an alarming rate. Consequently, the need for immediate action to design effective strategies to conserve biodiversity is receiving considerable attention worldwide. Scientists and policy makers are becoming increasingly aware of the role agroforestry plays in conserving biological diversity in both tropical and temperate regions of the world. The mechanisms by which agroforestry systems contribute to biodiversity have been examined by various authors (e.g. Schroth *et al.* 2004; McNeely 2004; Harvey *et al.* 2006). In general, agroforestry plays five major roles in conserving biodiversity: (1)agroforestry provides habitat for species that can tolerate a certain level of disturbance; (2) agroforestry helps preserve germplasm of sensitive species;(3) agroforestry helps reduce the rates of conversion of natural habitat by providing a more productive, sustainable alternative to traditional agricultural systems that may involve clearing natural habitats; (4)agroforestry provides connectivity by creating corridors between habitat remnants which may support the integrity of these remnants and the conservation of area-sensitive floral and faunal species; and (5agroforestry helps conserve biological diversity by providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat. Designing and managing an agroforestry system with conservation goals would require working within the overall landscape context and adopting less intensive cultural practices to achieve the maximum benefits.

It is widely believed that agroforestry has the potentiality to retain good environment as service function. Likewise, a significant number of respondents (91%) opined that they were getting environmental benefits from agroforestry practices through benchmark study during 2014 complited by the department of agroforestry and environment, BSMRAU, Gazipur (Figure 11). Soil moisture availability to the under-storied crops was the major benefit of the agroforestry, while sufficient rainfall, required less irrigation, shade during high sunlight and cool weather were other benefits.

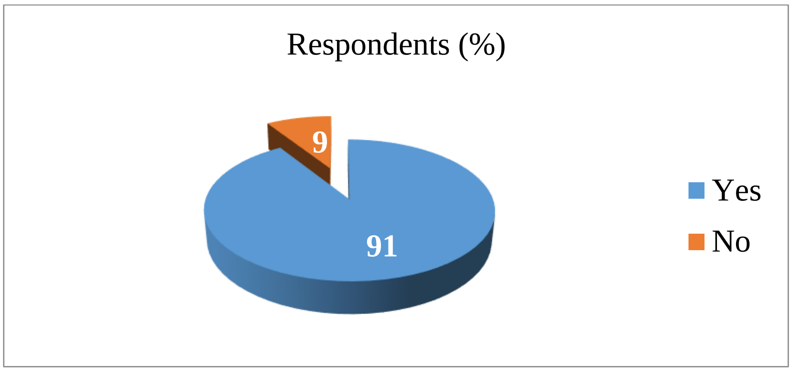


Figure 11. Environmental benefit from agroforestry practices in the study area (Source: Miah *et. al.*, 2014)**.**

Agroforestry on sustainable agricultural development

Whether agroforestry play a role on sustainable agriculture development, we counted farmer's opinion and presented in Figure 12. The computed scores of the opinion of the farmers on the effect of agroforestry on sustainable agricultural development were found to be ranged from 34 to 99 against the possible ranged from 0 to 104. Based on these scores, farmers were classified into three categories. About 70 percent of the farmers belonged to "highly positive effect" category, 18.33 percent to "moderately positive effect" and rest 11.67 percent to "less positive effect" category. This result indicates that more than 85 percent of the farmers given their opinion that agroforestry practices increase agricultural development through sustain production.

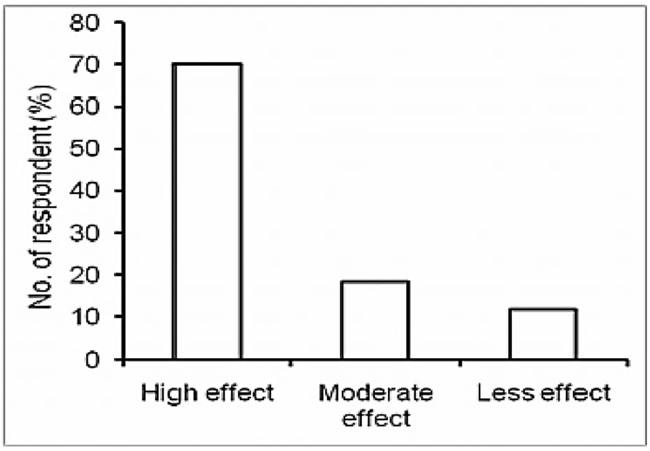


Figure 12: Farmer's opinion on the effects of agroforestry on sustainable agricultural development (Source: Jahan *et. al.*, 2012)

CHAPTER IV

CONCLUSION

- ❖ Different types of agroforestry systems are practiced in different regions of Bangladesh. Some traditional agroforestry systems- jackfruit based agroforestry system, date palm based agroforestry system, Palmira palm based agroforestry system, babla based agroforestry systems are practiced widely. Alley cropping and crop land agroforestry, windbreak and shelterbelt are the modern agroforestry that are practiced widely

- ❖ Agroforestry systems contribute a lot to improved livelihood by providing better yield of products (food grains, fruits, fodder, fuel wood), services like clean air, fresh water, conserving soil and generating year round income from the same land management unit. BCR and LER showed significant positive value that indicate potentiality of production system of agroforestry.

CHAPTER V

RECOMMENDATION

- Intensive research programme should be taken to identify both crop and tree species that are compatible in agroforestry systems for different ecosystem of Bangladesh.

- Agroforestry practitioner should be trained enough so that they have the capability to select the right plant in the right place for agroforestry practices to harvest maximum benefits from the agroforestry systems.

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