Competitive Research Grant (CRG)

Sub-Project Completion Report

on

Rice-based agroforestry in Bangladesh-status and opportunities for sustainable land use system and combating future climate change challenges

Project Duration

April 2017 to September 2018

Bangabandhu Sheikh Mujibur Rahman Agricultural University
Gazipur 1706

Submitted to
Project Implementation Unit-BARC, NATP 2
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

September 2018

Acronyms

BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
BCR	=	Benefit-cost ratio
BSMRAU	=	Bangabandhu Sheikh Mujibur Rahman Agricultural University
CDM	=	Clean Development Mechanism
Co-PI	=	Co-Principal Investigator
CRG	=	Competitive Research Grant
GDP	=	Gross domestic product
GIS	=	Geographic Information System
GoB	=	Government of Bangladesh
GPS	=	Global Positioning System
LER	=	Land Equivalent Ratio
NATP	=	National Agricultural Technology Program
PI	=	Principal Investigator
PIU	=	Project Implementation Unit

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Executive Summary

The crops that grow for food need specific climatic conditions to get better performance in terms of economic yield. A changing climate would have both beneficial and harmful effects on the crops. Keeping the above points in mind, this study was designed to investigate the impacts of practicing agroforestry systems on land use, productivity and profitability under changing climate; documentation of rice-based agroforestry practices; and formulation of policy and guideline for promotion of agroforestry in different agroecosystems of Bangladesh. Three districts, namely Rajshahi, DinajpurandChapinawabgonjwere selected as the study sites. One hundred fifty sample farms, 50 from each district, were selected randomly for data collection. MS Excel and SPSS computer programs were used for data processing, analysis and preparing graphs and tables. GPS data were collected from all the study sites for satellite image analysis and accuracy assessment. Several discussion meetings in each location and consultation with the relevant personnels of government organizations working in the study areas were arranged for data validation. The research team visited the study areas several times for monitoring and collecting necessary information. In all study areas,agroforestrycoverageis not remarkablecompare to non-agroforestry system evidenced by remotesensingtechnology.Remote sensing-based acreage of agroforestry showed that an area of 486 ha (2.16%), 2212 ha (7.79%) and 1301 ha (6.52%) were under agroforestry at Bochaganjupazilla, Baghaupazilla and Nacholoeupazilla, respectively.

In the study areas, several rice-based agroforestry systems have been identified and evaluated. Farmers were getting a substantial amount of income from mango trees as it is well managed in agroforestry systems. Their annual income and desired yield were increased from rice-based agroforestry in all the study areas. Year-round income, working opportunity and women participation showed increasing trend in all study sites. Maximum respondents opined that soil health improved due to agroforestry practices. Farmers usually cultivate potato, mustard and wheat in mango-based agroforestry systems along with rice. They also opined that some assistances like training, financial help, improved technology etc. are needed in all study areas. The highest BCR was recorded in Dinajpur (4.88), which was followed byRajshahi (4.63) and Chapainawabgonj (4.35). The lowest BCR was noted in non-agroforestry systems. Likely, LER was higher in rice-based agroforestry systems than non-agroforestry system in all study areas. The highest LER was noted in Dinajpur (2.58) in rice based agroforestry system followed by Chapainawabgonj (2.18) and Rajshahi (2.03). Based on the findings, it is suggested to develop a future policy and planning related to rice-based agroforestry in Bangladesh. It will ensure sustainable agricultural production under climate change scenario.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. **Title of the CRG sub-project: Rice-based agroforestry in Bangladesh – status and opportunities for sustainable land use system and combating future climate change challenges**

2. **Implementing organization:** Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur 1706

3. **Name and full address with phone, cell,and E-mail of PI/Co-PI (s):**

Principal Investigator:	**Dr. Tofayel Ahamed** Professor Department of Agroforestry and Environment, BSMRAU, Gazipur 1706 Cell No.: 01556322553, Fax: 9205333 E-mail: tofayela@gmail.com
Co-Principal Investigator:	**Dr. Hasan Mohammad Abdullah** Assstant Professor Department of Agroforestry and Environment, BSMRAU, Gazipur 1706 Cell No.: 01767695926 E-mail: hasan.abdullah@bsmrau.edu.bd

4. **Sub-project budget (Tk):** 2203255.00

   4.1 Total:

   4.2 Revised (if any):

5. **Duration of the sub-project:**

   5.1 Start date (based on LoA signed)**:** May 2017

   5.2 End date**:** 30 September 2018

6. **Justification of undertaking the sub-project:**

   Population throughout the world is increasing rapidly and the rate of increase is very high in developing countries like Bangladesh. Bangladesh is a small deltaic country with a large population of 161 million and the growth rate is 1.37%, per annum with cultivable land of 8.44 million ha (BBS, 2011). To feed thisever-increasing population, agricultural land needs to be intensified. The productive capacity of agricultural land is low due to poor soil health and intensive cropping. As

a part of development works, housing facilities for the increased population, new industries, and infrastructures are building up at the cost of shrinking this cultivable land. The high population growth and the poor socio-economic conditions, which are typical in Bangladesh, are forcing farmers to intensify their farming practices. Due to intensive cultivation, soil fertility is reducing rapidly and consequently reducing the crop yield. Intensive cultivation is also associated with the use of high inputs, particularly the chemical fertilizers. As a result, the natural soil ecosystem has rapidly degrading and farm agro-ecosystem is losing its integrity and health as well as polluting the environment. The organic matter content which is an indicator of soil health is depleted to less than the critical value of 1 percent (Hossain and Kashem, 1997) in most of the areas (about 60%) of cultivable land during the last 20-25 years.

To address the issue of crop environment and crop productivity, the different farming practices like organic farming, ecological farming,and regenerative agriculture are now the subject of discussion. The current climatic events such as increased atmospheric temperature, erratic behavior of rainfall, frequent drought, flood, and salinity have been rendering profound impacts on Bangladesh's natural resources and their productivity as a whole. Considering a steady decreasing trend of cultivable area in Bangladesh, still rice covers about 81% of the total cropped area and production has increased manifold during the last two decades. However, this production trend is under severe threats. Rather, most of the rice and currently many farmers are reluctant to grow rice because of climatic risks (especially temperature and rainfall) and low-profitmargin.

Globally as well as regionally, agroforestry is considered as a viable system that increases crop productivity by maintaining high-level organic matter in the soil. In Bangladesh, many farmers have started to grow trees particularly fruit and fast-growing timber trees in rice and other crop fields either boundary or inside the fields of different agroecosystem especially vulnerable climatic areas such as northwest areas. There is apprehension or strong debates that if the current trend of expansion of those agroforestry systems occurs, there would be a sever debate for the land-use system or crop production resulting food crisis. The pressing need for the country especially for agroforesters/agriculturists is to do an in-depth assessment of the services of agroforestry systems, their suitability and

sustainability in terms of land-use, production, environment, and livelihoods. Both traditional and systematic agroforestry practices are being found in different parts of Bangladesh since a few decades. Recently rice based agroforestry practices are being expanded especially in the north and North West regions of Bangladesh using various fruit and timber species. Unfortunately, no comprehensive study or document has been done or reported on the benefit, success, opportunity, and limitation of the traditional and new agroforestry systems and practice.

7. **Sub-project goal:** Sustainable rice based agroforestry system to combat climate change

- Sub-project objective (s): Documentation of rice-based agroforestry practices in the northwest region of Bangladesh
- Analysis of the impacts of practicing agroforestry systems in terms of land use, productivity and profitability under climate change,
- Formulation of policy and guidelines for the promotion of agroforestry in different ecosystems.

8. **Sub-project Objectives:**

- Documentation of rice based agroforestry practices in the northwest region of Bangladesh
- Analysis of the impacts of practicing agroforestry systems in terms of land use, productivity and profitability under climate change,
- Formulation of policy and guidelines for promotion of agroforestry in different ecosystems.

9. **Implementing location (s):**Rajshahi, DinajpurandChapinawabgonj districts

10. **Methodology in brief:**

A benchmark survey was conducted from September 2017 to December 2017 through field survey, discussion meetings and institutional consultations to document the existing traditional and new agroforestry.

10.1 Study Area

The study has been conducted at three locations namely Rajshahi, Dinajpur and Chapinawabgonj districts. The study areas are shown in Table 1 and Figure 1

Table 1. Study areas under different study locations

Region	District	Upazila
North-west region of Bangladesh	Dinajpur	Bochagonj
	Rajshahi	Charghat
	Chapinawabgonj	Nachol

10.2 Primary Survey

Before conducting a questionnaire survey, field visits were done in all study areas to get the idea and to know field situation about traditional and rice-based agroforestry practices and other necessary information.

10.3 Survey

Fifty sample farms from each location were selected randomly for data collection. The questionnaire survey was done to know the demography, socio-economic conditions, agroforestry practices and livelihood activities of the respondents. Moreover, detail production practices for both tree and crop components, growth and yield of crops and tree species, environmental changes, cost of all inputs and outputs were also recorded using the same questionnaire. A pretested and then a structured questionnaire were used to collect information (Appendix 1).

10.3.1 Personnel: The Principal Investigator (PI), Co-PI, three graduate students and three field assistants were involved in the survey process.

10.3.2 Problem encountered: During the survey, there was heavy rain in all the locations. Thus, road communication was sometimes difficult. The problemwas also faced in getting time/appointment of the farmers.

10.4 Discussion Meeting

Several discussion meetings were arranged in each location for validation and consultation with the experienced farmers, and relevant personnel of Government, Non-government and private organizations working in the study areas.

10.5 Institutional Consultation

Different institutional consultations were held with the concerned researchers of the Research Organizations, Universities, and Non-government organizations (NGOs) with a view of selecting the best production system for the region

10.6 GIS and Remote Sensing information

GIS and remote sensing based assessment were done using Sentinel-2 imagery. GPS data were collected for satellite image analysis and accuracy assessment. Object-based classification, techniques were triedin getting good classification/results.

Procedure for Agroforestry classification in Nachole, Bagha, and Bochaganj

10.7 Site selection

At the very beginning of the agroforestry classification; three upazilla's from three separate districts were selected based on the agroforestry area availability and dispersion rate in those respected areas. The selected upazillas were Bochaganj from Dinajpur, Bagha from Rajshahi and Nachole from Chapainawabganj district.

10.8Satellite selection

Sentinel-2 optical satellite image was selected for the agroforestry classification as it provides global coverage of land surfaces with a 10m spatial resolution for free of cost. It can detect agroforestry area even in small scale. In case of low spatial resolution like 30m in Landsat satellite, it is difficult to separate agroforestry from crop land due to the similar nature of their vegetation.

10.9 Satellite image download

Sentinel-2 optical satellite imagery were downloaded from Sentinel Scientific Data Hub. Image form the month of December and January were selected as the cloud disturbance was least. Furthermore most of the agricultural crops were harvested so agroforestry areas were easily separated from the other land use and land cover classes.

Satellite image preprocessing

After downloading satellite images several processes was done before agroforestry classification to make sure better classification. A python based script Sen2Cor was used for atmospheric correction and cloud masking. It also provides some additional functions such as aerosol optical thickness-, Water Vapor-, scene classification maps and quality indicators for cloud and snow probabilities.

10.10 Satellite image clipping

After correction, images were clipped using shape file of respective areas.

10.11 Satellite image segmentation

Image segmentation was carried out using eCognition developer. eCognition is a powerful development environment for object-based image analysis. It is used in earth sciences to develop rule sets for the automatic analysis of remote sensing data such as satellite images. All the images were segmented using a scale parameter of 25 with 0.10 shape and 0.70 compactness in the composition of homogeneity criteria. After segmentation images were again clipped using the same shape file to cut out the unnecessary area of the images generates due to the segmentation process.

10.12 Satellite image classification

The segmented satellite image was loaded into ArcMap 10.4. Google earth image was used as a base map to identify and mark the agroforestry area. All the agroforestry area were merged together and named as agroforestry class which was later exported into a new shape file. Rest of the area of the image was merged together and named as non-agroforestry class.
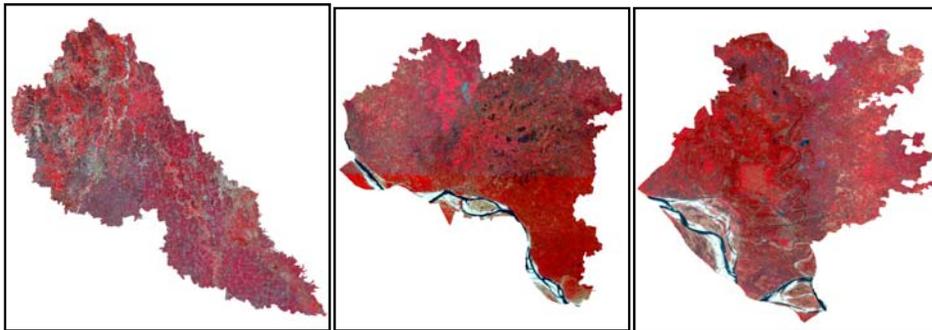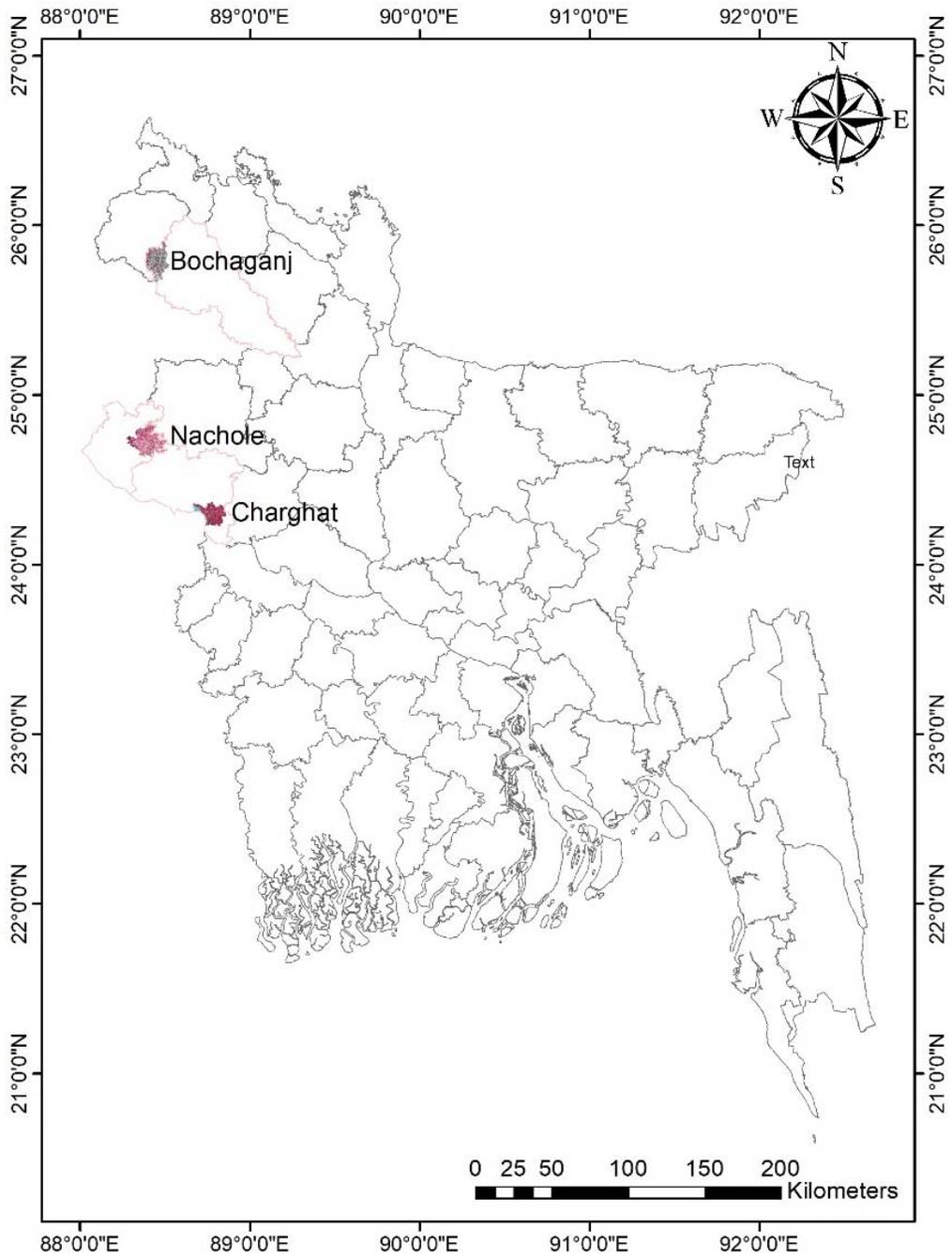
Dinajpur   Rajshahi   Chapainwabgonj

Figure 1. Study area map of Sentinel-2 image.

10.13 Land Equivalent Ratio (LER)

The comparative advantages of land use through agroforestry and traditional farming wasevaluated calculating LER as follows:

LER = Xi/Xs + Yi/Ys

Where X and Y are the component crops in intercrop (i) or sole crop (s).

10.14Cost-Benefit Analysis

Cost-benefit analysis of production technology was done by estimating on-site and off-site costs and benefits of the crop, fruit tree, land,and environmental variables.

Benefit-cost ratio is the ratio of gross returns with a total cost of productions. It was calculated by the following formula –

Gross return (Tk. ha^{-1}year^{-1})
Benefit-cost ratio = _____
Total cost of Production (Tk. ha^{-1}year^{-1})

10.15 Analysis of the information /data

Different graphs and table are formed by using SPSS and MS Excel computer software programme.

10.16 Review of Literature

Bangladesh has an agrarian economy,and its agriculture contributes 18.6% of the country'sGDP and employs around 45% of the total work force. The performance of the agriculture sector has an overwhelming impact on major macroeconomic indicators like poverty alleviation, human resource development, employment generation,and food security. However, the agriculture sector is vulnerable to impacts of climate change (Xenarios et al., 2013). Agroforestry can play an important role in mitigating climate change impacts in agriculture, as the tree has the inherent capacity to withstand drought, salinity,and flooding. The actual aim of

farmers and government institutions behind agroforestry was improving rural livelihood and meeting various needs, viz.

Food, fuel, timber, the fodder of the farmers.However,in the recentera of climate change, agroforestry became economicallyand ecologically very attractive tool for mitigating the harmful effect of GHGs. Since the Kyoto Protocol allowed industrialized countries with a GHG reductioncommitment so as to invest in mitigationprojects in the developing and least developed countries under the Clean Development Mechanism (CDM),and there is an attractiveopportunity for major practitioners of agroforestry, especially the resource-poor farmers (Nair et al., 2009).

Agroforestry is often considered a cost-effective strategy for climate change mitigation. Agroforestry systems store carbon in the soils and woody biomass, and these also reduce greenhouse gas emissions from soils. Majority of the agroforestry systems have the potential to sequester carbon, which may vary according to tree species (Prasad et al., 2012; Rajendran et al., 2003) In Khybri et al., 1992) three different tree species were studied for their suppressing effects on rice yield. The study showed that the tree species with the largest suppressing effect on rice yield was also the species with the widestcanopy(Khybriet al.,1992), which that shade is a decisive property of agroforestry trees.

Figure 2. Showing the GPS data collection (top left), mango based rice agroforestry at early growth stage (top right), questioner survey (bottom right), and mango based rice agroforestry at late growth stage (bottom left)

11. Results and discussion

11.1 Agroforestry coverage:

Bochaganj, Dinajpur

The total area of Bochaganjupazilla was 22481 ha. Among which 486 ha was agroforestry, this was only 2.16% of whole area (Fig. 3 and Table 3).

Figure 3. Agroforestry map of Bochaganjupazilla.

Table.3. Bochaganjupazilla agroforestry area statistics.

Categories	Areas (ha)	Percentage
Agroforestry	486	2.16%
Non- agroforestry	21995	97.84%
Total areas	22481	100%

Nachole, ChapaiNawabganj

The total area of Nacholoeupazilla was 28368 ha. Among which 2212 ha was

agroforestry, this was only 7.79% of whole area. Most of its agroforestry was mango

orchard based that is pretty common in western part of Bangladesh (Fig. 4 and Table 4).
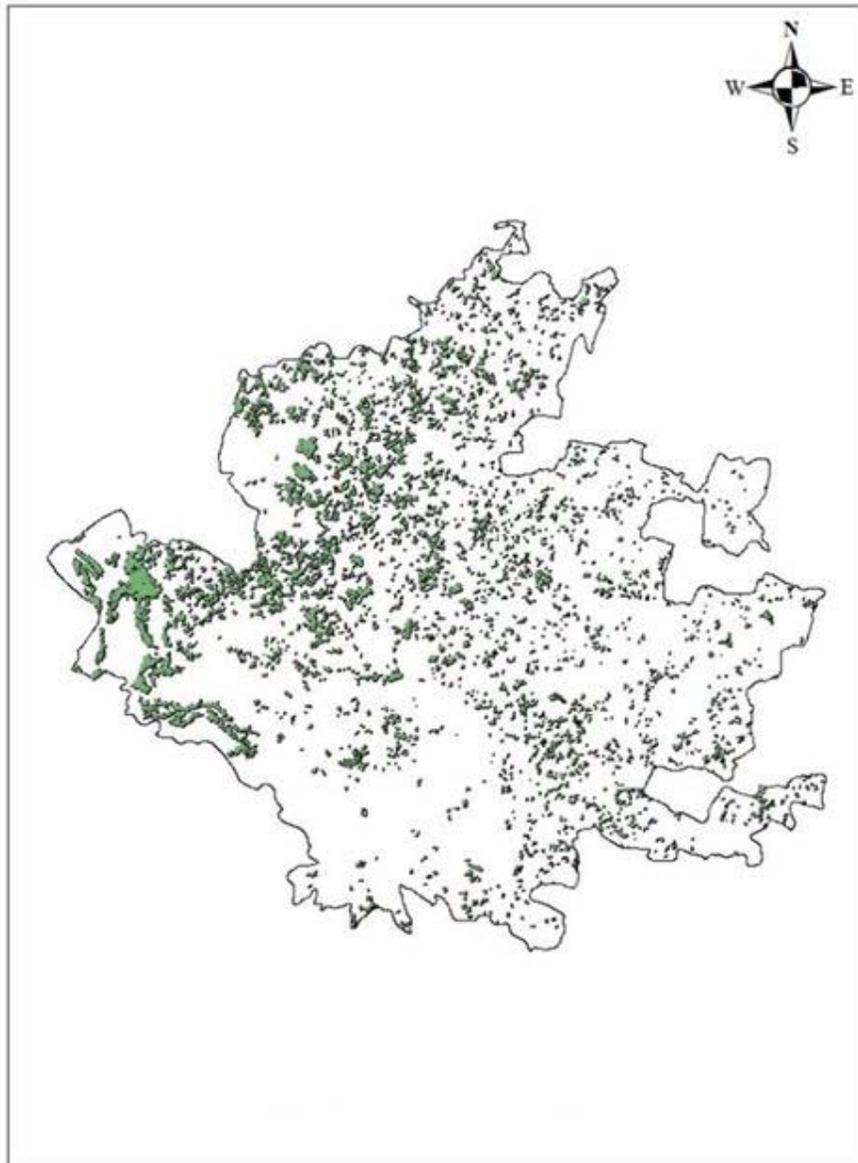
Figure 4. Agroforestry map of Nacholeupazilla.

Table.4: Nacholeupazilla agroforestry area statistics

Categories	Areas (ha)	Percentage
Agroforestry	2212	7.79%
Non- agroforestry	26456	92.21%
Total areas	28368	100%

Bagha, Rajshahi

The total area of Baghaupazilla was 19951 ha. Among which 1301 ha was agroforestry, this was only 6.52% of whole area. Mango orchard based agroforestry is pretty common in that part of Bangladesh (Fig. 5 and Table 5).
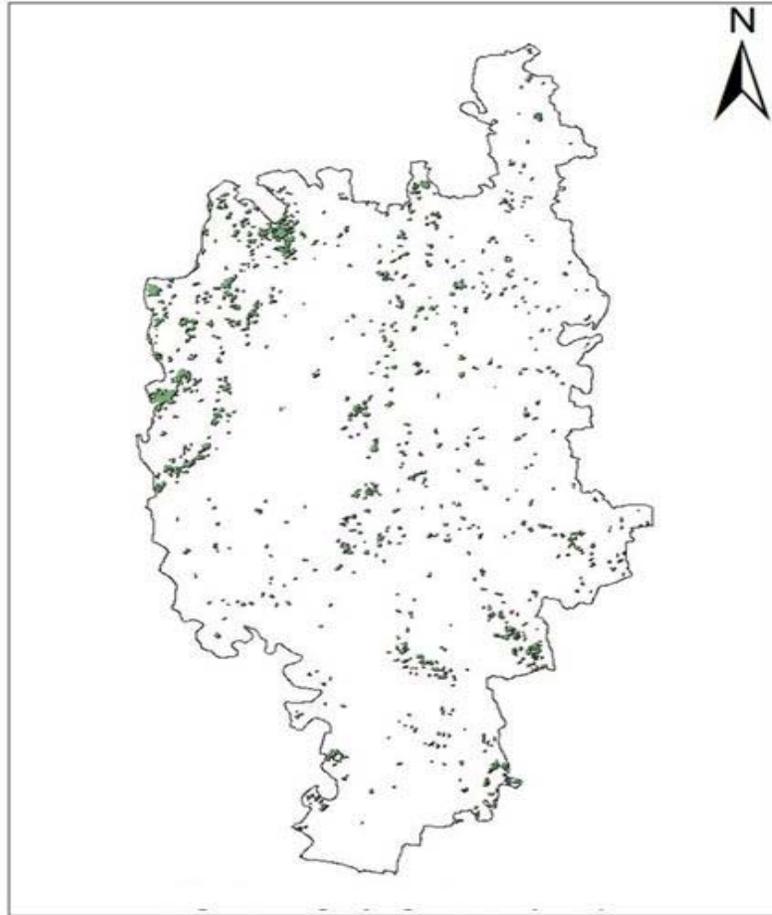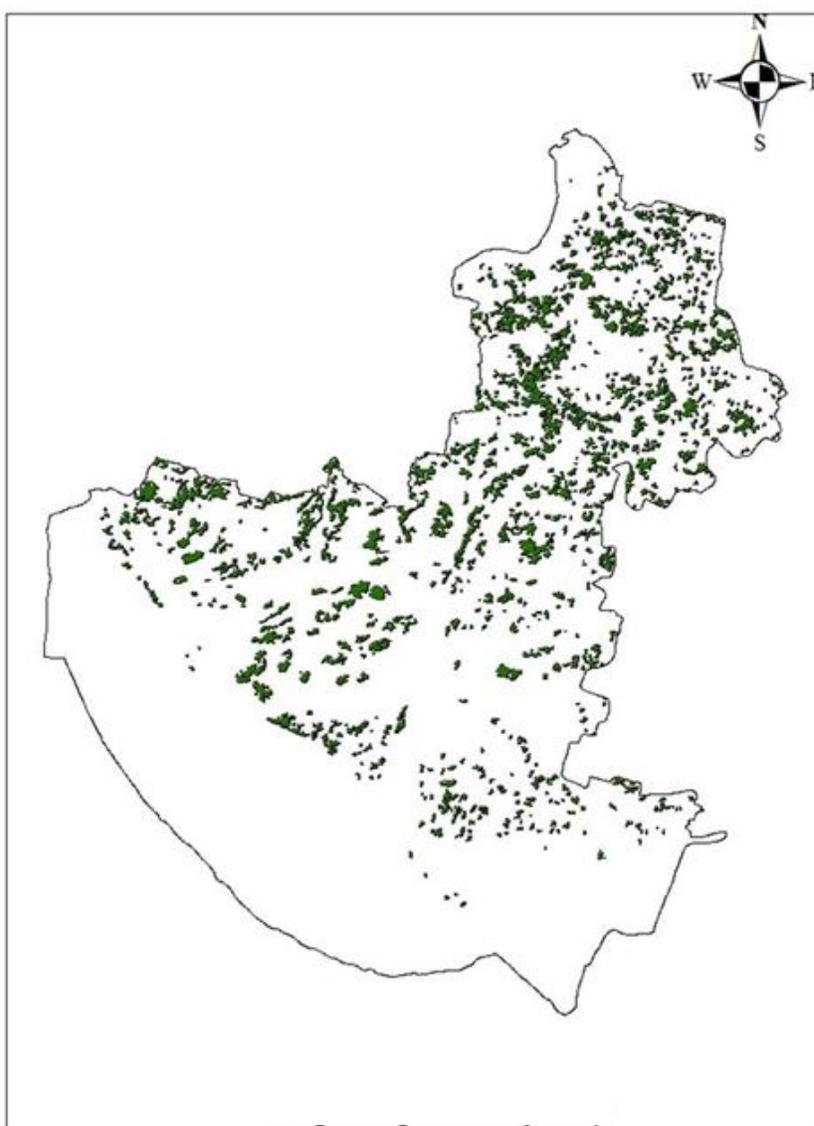

Figure 5. Agroforestry map of Baghaupazilla.

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Table 5: Baghaupazilla agroforestry area statistics

Categories	Areas (ha)	Percentage
Agroforestry	1301	6.52%
Non- agroforestry	18650	93.47%
Total areas	19951	100%

11.1 Demography of the respondents

11.1.1 Age

The respondents were categorized into three age groups,i.e., less than 35 years (young aged), 35 to 50 years (middleaged) and above 50 years (old aged). In Dinajpur, 42% of the respondents were middleaged followed by old aged (38%) and young aged (20%). On the other hand, in Rajshahi, 58% of the respondents (58%) were middleagedwhich was followed by old aged group (24%) and young aged (18).In Chapainawabgonj, the highest was in middleaged group (68%) while the young aged and old aged groups were similar (Fig. 6).
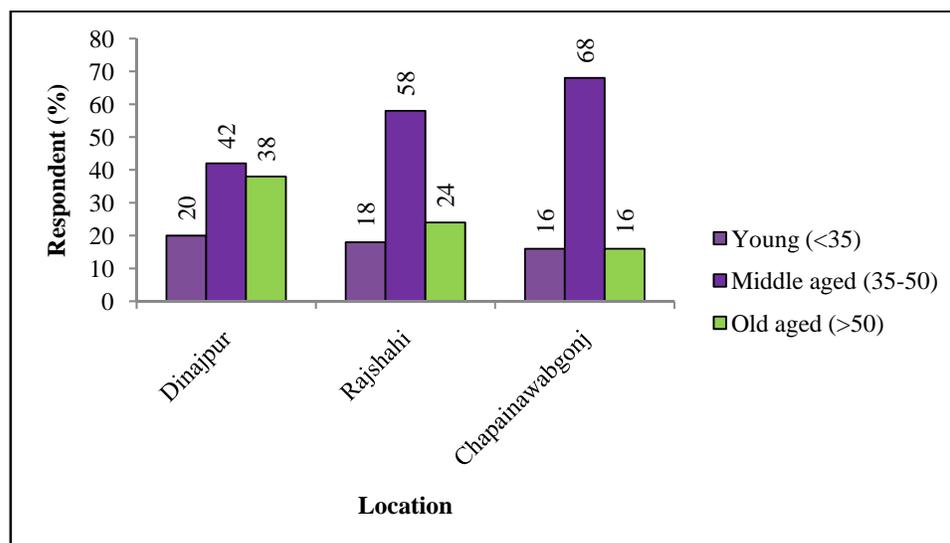
Figure 6. Distribution of the respondents according to their age.

11.1.2 Family size

To know the family size of the respondents, family size was classified into total family member, male, female and children number. In three study areas, total family member was around 6. Male and female status were similarly followed by children. Near about one children were found in each family in each study area (Fig. 7).
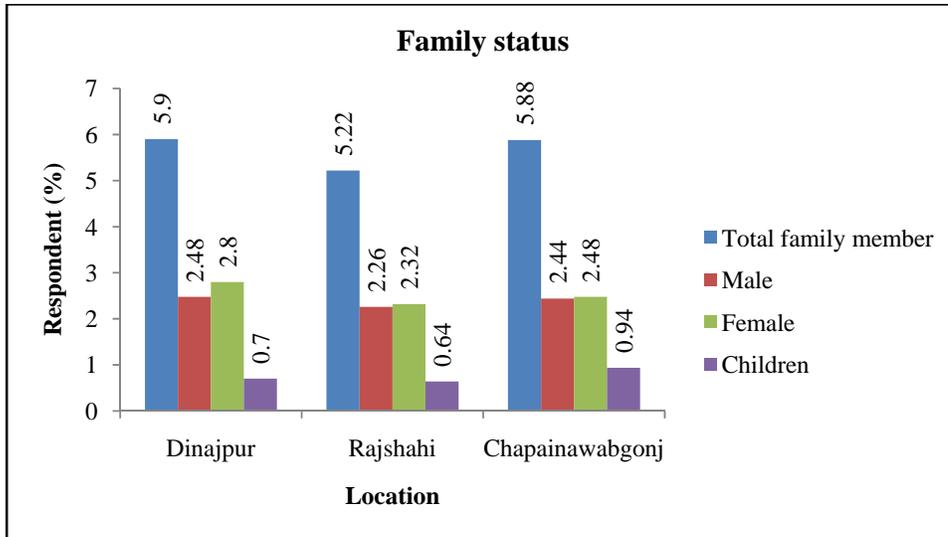
Figure 7. Distribution of the respondent according to their family size.

Figure 8. Showing the rice-based agroforestry practice in Bochagonj (Dinajpur).

11.1.3 Occupation

Agriculture was the major occupation in all the study areas, which was 48, 56 and 34% in Dinajpur, Rajshahi and Chapainawbgonj, respectively (Fig. 9). On the other hand, agriculture+businesswas 28, 40 and 50% in Dinajpur, Rajshahi and Chapainawbgonj, respectively and agriculture+service was8, 2 and 14% in Dinajpur, Rajshahi,and Chapainawbgonj, respectively.
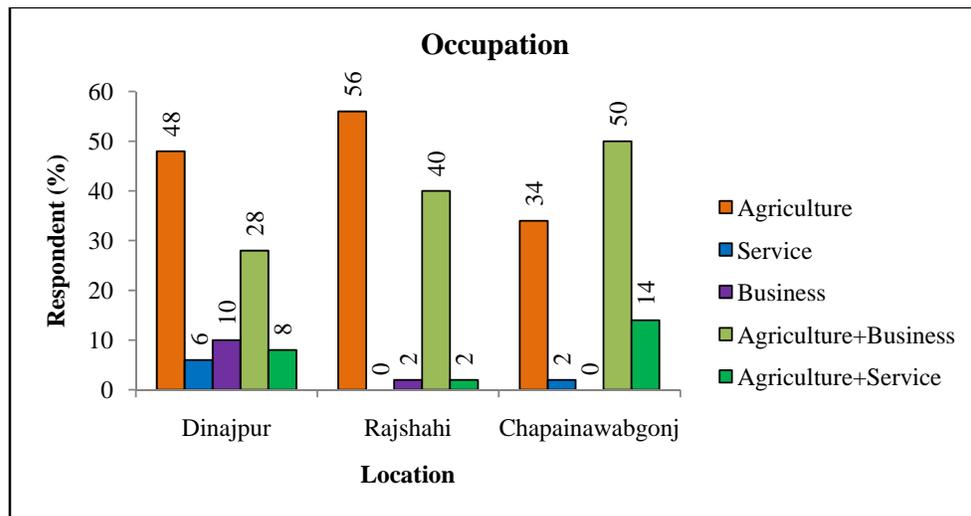
Figure 9. Distribution of the respondent according to their occupation.

11.1.4 Educational level

Education develops the mental and physiological ability of a person to understand, decide and adopt new ideas and practices. It also helps farmers increase their power of observation and decision-making ability. The widely used educational class of the rural people was used in the study,i.e., illiterate (no education), primary education, secondary education, higher secondary education, bachelor and above level.About 14, 26 and 14% of the respondents had primary (1-5) level of education whereas 32, 18 and 22% of the respondents had secondary (6-10) and 6,10 and 12% of the respondents had higher secondary (10-12) level of education in Dinajpur, Rahshahi and Chapainawabgonj, respectively. However, 32, 42 and 38% of the respondents had no education. Also,the degree level of education found in all study areas was not remarkable(Fig. 10).
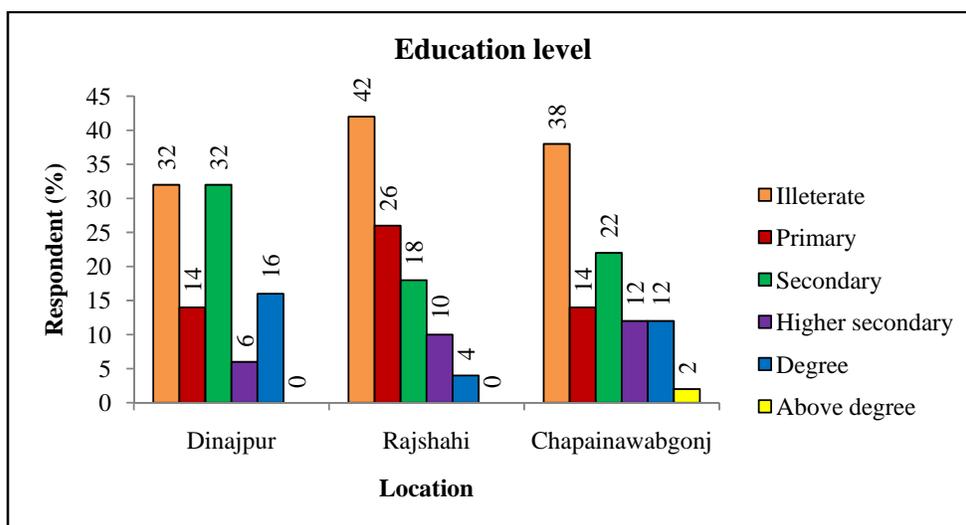
Figure 10. Distribution of the respondent according to their education level.

11.1.5 Active family member per family

Familyis defined as a group of individuals living together, taking meals unitedly and live under the control of one person as its head. It includes husband, wife, sons, daughters, brothers, sisters and parents,etc. Most of the respondents in all study areas opinedthat they had near about two active persons involved in other work (Fig. 11).
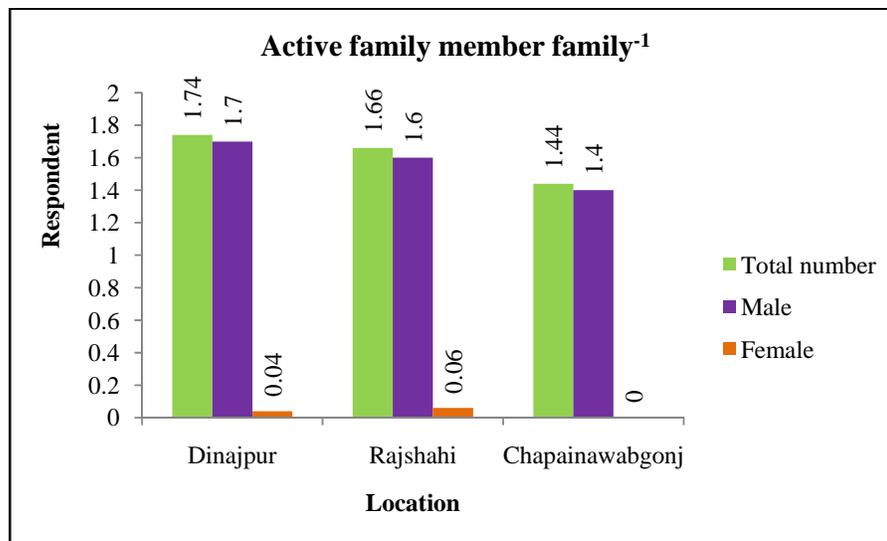
Figure 11. Active family member per family in the study area.

11.2 Livelihood and Socioeconomics

The current livelihood activities and socio-economic status of the respondents of all the study areas have been examined in this study.

11.2.1 Landuse

Agriculture was thesignificantly dominant landuse pattern in Dinajpur(413.62 decimal/farm), Rajshahi(291.24 decimal/farm) and Chapainawbgonj (343.514decimal/farm) followed by agroforestry. Orchardwas also found in all three study areas,and it was dominant in Rajshahi (87.71 decimal) followed by Dinajpur (41.18 decimal) and Chapainawbgonj (35.38 decimal). A similar trend of variation in the homestead area was observed,and the corresponding values for Dinajpur, Rajshahi,andChapainawbgonj were 30.88, 29.74 and 26.68 decimal, respectively (Fig. 12).
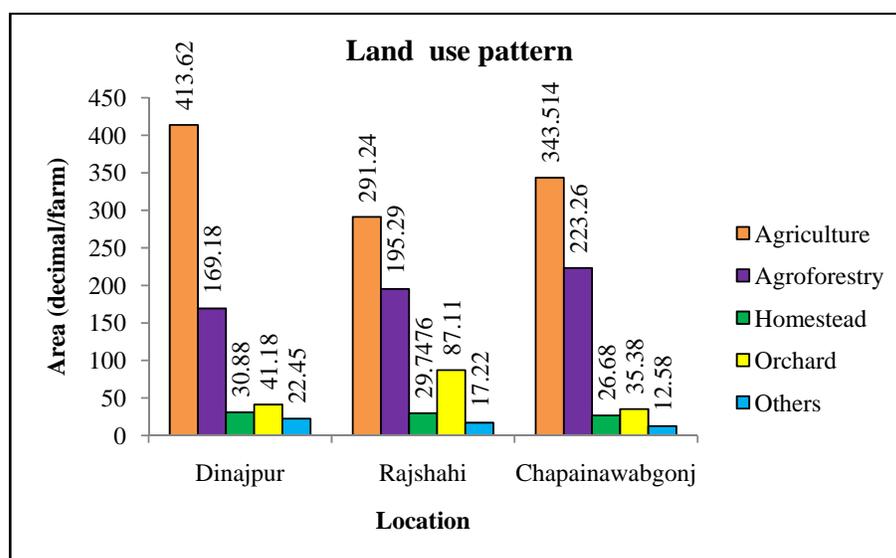
Figure 12. Distribution of the respondent according to their land use pattern.

11.2.2 Rice cultivation

Rice is the staple food of about 135 million people of Bangladesh. It provides nearly 48% of rural employment, about two-third of total calorie supply and about one-half of the total protein intake of an average person in the country. Rice sector contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh. The respondents were asked about the length of rice cultivation with the orchard. Maximum respondents opined that they cultivated rice with orchard from eight years in Rajshahi followed byChapainawbgonj, and Dinajpur, respectively (Fig. 13).
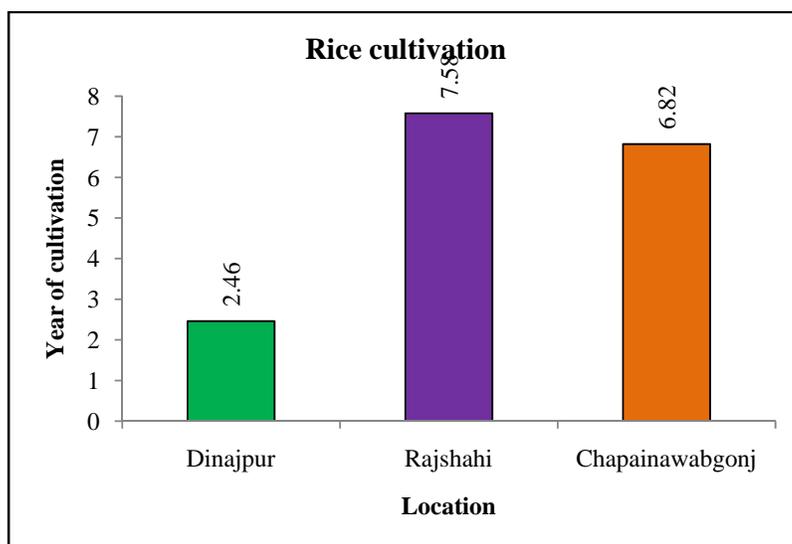
Figure 13. Rice cultivation period with orchard.

11.2.4 Motivation on agroforestry system

Respondents were asked about first time motivation in agroforestry and it was observed that most of the respondents in Dinajpur (78.2%), Rajshahi (61.6%) and Chapainawbgonj (66.2%) were convinced to practice agroforestry through neighbor, while 17.3, 30.8 and 26.4% respondents were self-motivated in Dinajpur, Rajshahi andChapainawbgonj, respectively(Fig. 14).
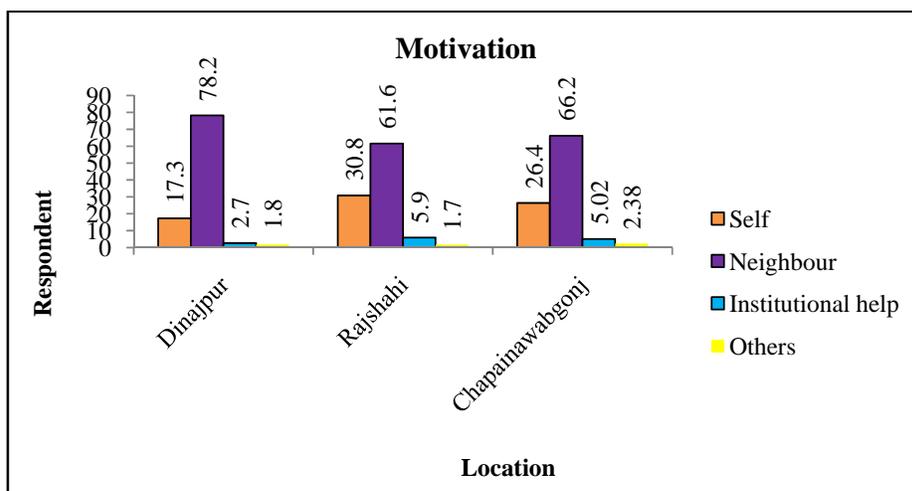
Figure 14. Motivation in practicing agroforestry of the respondents.

11.2.5 Women participation

From the study, it was noted that the highest percent (78%) of woman was participating in the production system in Dinajpur, which was followed by Chapainawbgonj (68%) and Rajshahi (60%) (Fig. 15). Since farming was found

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profitable in Dinajpur, both men and women were actively participating in various production activities.

Women Participation
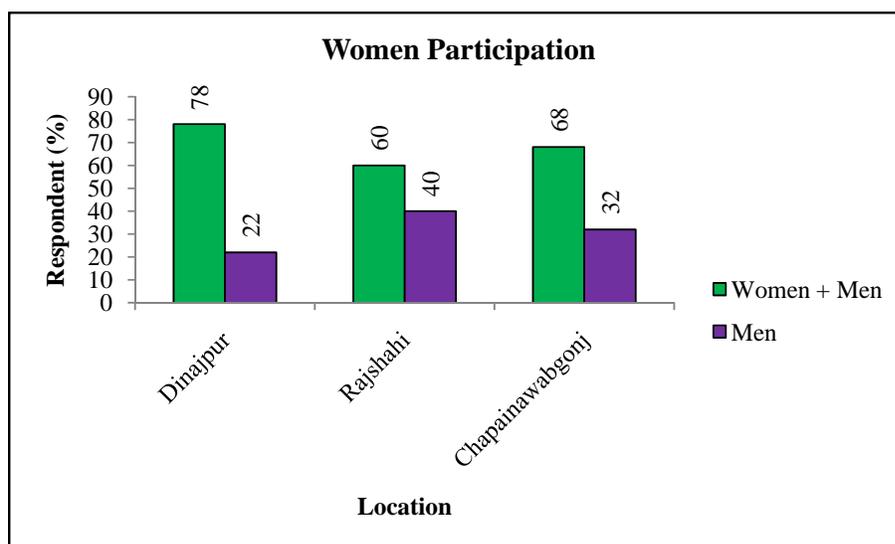
Figure 15. Women participation in an agricultural production system.

10.2.5 Management practices followed by women in a production system

Different management practices were followed by the women in all study area. Among different management practices, it was notedthat most of the respondent were involved in rice harvesting (56%) and rice planting (52) in Dinajpur. On the other hand, rice planting and other activities were dominant in Rajshahi,andChapainawbgonj followed by rice harvesting, weeding and thrashing (Fig. 16).
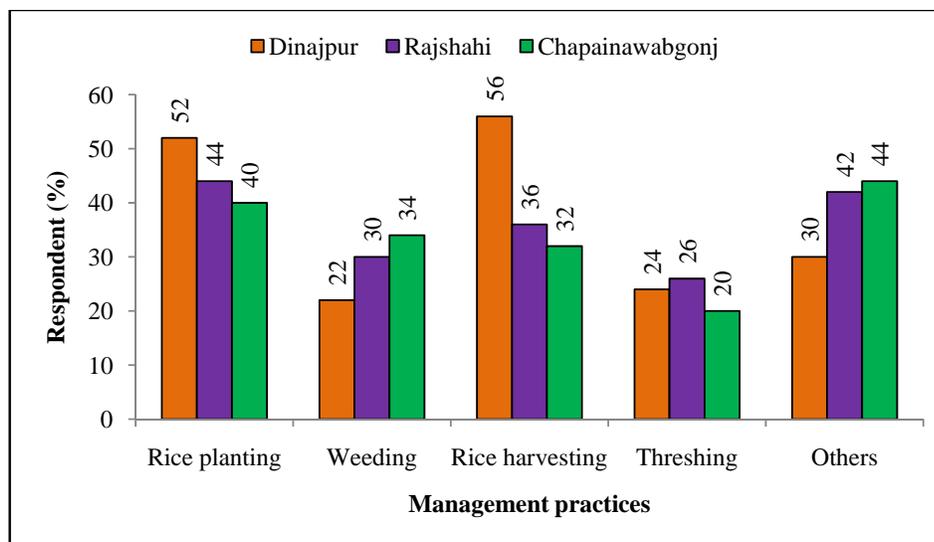
Figure 16. Different management practices followed by women in the production system.

11.3 Estimation of income and expenditure

11.3.1 Source of income

Annual income of the respondents varied remarkably among the study areas (Table 5), where the highest income was foundfrom agroforestry in Rajshahi (Tk 2,25,760.00)followed by agricultural crops in Dinajpur (Tk 2,02,580.00) and Chapainawbgonj (Tk179960.00). Among different sources, service, business, crops, fruit tree, forest tree, livestock,poultry contribute a lot to the annual income.In Dinajpur, crops play a vital role in annual income, which wasTk202580.00. Agroforestrypracticesalso contributed to the annual income (Tk135640.00, 225760.00 and 179960.00in Dinajpur, Rajshahi,andChapainawbgonj, respectively) substantially.

Table 5. Source of average annual income (Tk) of the respondents (Per family) in the study area

Sl. No.	Source	Income (Tk)		
		Dinajpur	Rajshahi	Chapainawabgonj
1	Agroforestry	135640.00	225760.00	179960.00
2	Fruit tree	43500.00	52080.00	51300.00
3	Timber tree/Forest tree	40000.00	42000.00	38500.00
4	Agricultural crops	202580.00	126560.00	154140.00
5	Livestock and poultry	26320.00	35900.00	22820.00
6	Service	165000.00	158000.00	135000.00
7	Business	85000.00	90000.00	120000.00
8	Others	111260.00	110560.00	194200.00

11.3.2 Expenditure

Annual expenditure also varied among the study areas where maximum expenditure in food was noted in Chapainawbgonj (Tk 181680.00) followed by Dinajpur (Tk126680.00) and Rajshahi (Tk172460.00). The major sectors of expenditure were food, education, medication, social program,and other activities in the study areas (Table 6).

Table 6. Average annual expenditure (Tk) of the respondents (Per family) in the study area

Sl. No.	Item	Expenditure (Tk)		
		Dinajpur	Rajshahi	Chapainawabgonj
1	Food	126680.00	172460.00	181680.00
2	Education	20900.00	18180.00	16300.00
3	Medication	15580.00	14160.00	14360.00
4	Social program	12560.00	9460.00	9280.00
5	Others	14480.00	24560.00	15120.00

11.4 Agroforestry systems

11.4.1 Agroforestry practice

Agroforestry were practiced by agood number of respondentsin order to establishe a permanent orchard in all the study areas. It was more dominant in Chapainawbgonj (94%) followed by Rajshahi (90%) and Dinajpur (84%). Although crop and orchard+crop (agroforestry) were observed in all the study areas (Fig. 17).
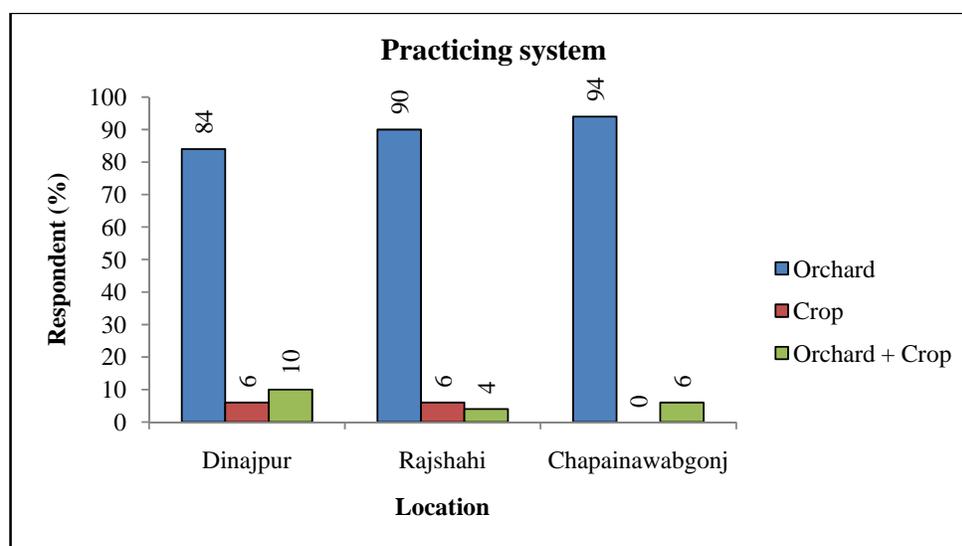
Figure 17. Distribution of the respondent according to practicing type.

11.4.2Cropping pattern

Cropping patternin agroforestry systems variedwidely among the study areas (Fig. 18). However, rice-based systems dominated in all the study areas. In Dinajpur,rice based agroforestry systems dominated, while it was the same in Rajshahi and Chapainawbgonj site. In Rajshahi, Rice+Wheat+Mustardagroforestry system was the most dominant (40%) agroforestry practice. In Chapainawbgonj, Rice+Wheat was

the most frequent (38%) practice.Figure 16 also revealed that different crops are cultivated with rice in the study areas.
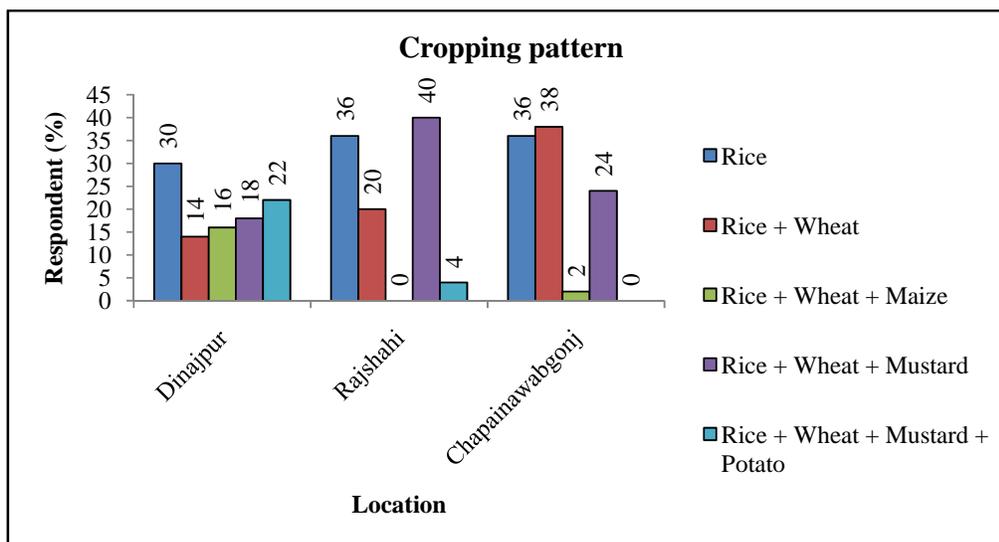
Figure 18. Distribution of the respondent according to their cropping pattern.

11.4.3 Fruit tree plantation system

Farmers are planting fruit trees on their field in different ways. Most of the respondents of all study areas, planted fruit trees in their whole field followed by aile and aile+field. Planting of mango trees in the field was highest in Rajshahi (88%) followed by Dinajpur (82%) and Chapainawbgonj(76%), respectively (Fig. 19).
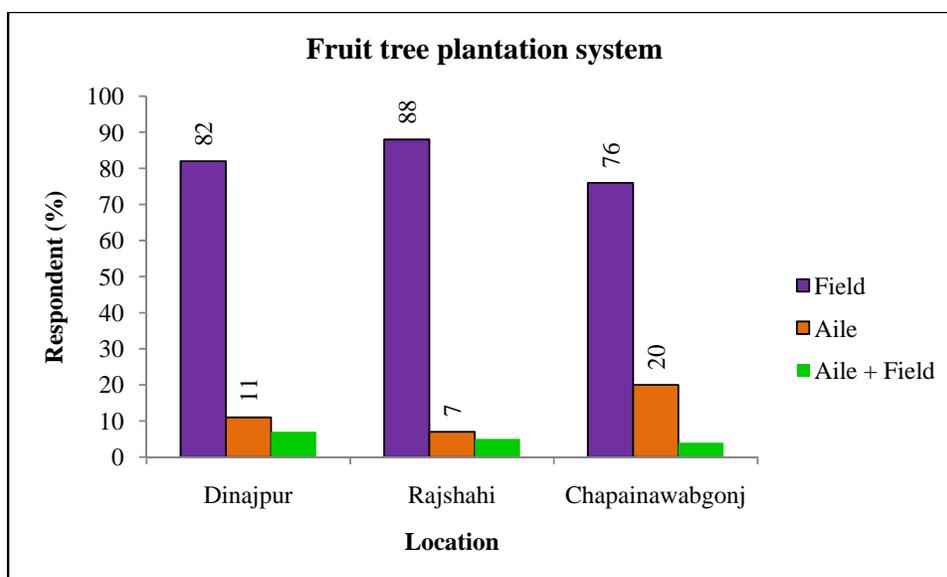
Figure 19. Fruit tree plantation system by the respondents in the study area.

11.4.4 Age of practicing rice under mango orchard

The practicing time of rice in the field with mango orchard depending on the type of orchard and it was varied from 6 to 16 years(Fig.20). In Chapainawbgonj and Rajshahi, most of the respondents arepracticing riceunder mango since 15.08 years and 11.9 years, respectively.
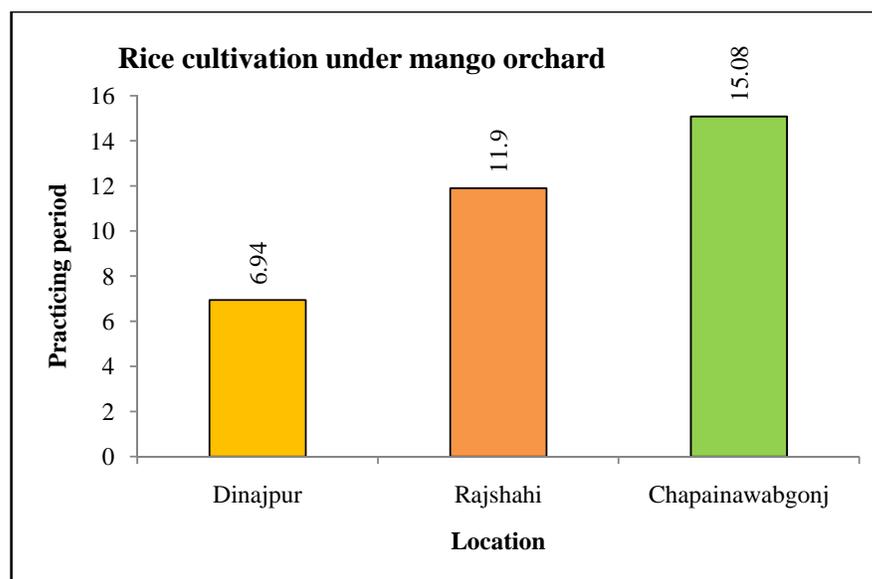
Figure 20. Age of practicing rice under mango orchard in the study area.

11.4.5Reason for rice cultivation in fruit orchard

Respondents were asked about rice cultivation in fruit orchard and it was observed that most of the respondents in Dinajpur (82%), Rajshahi (66%) and Chapainawbgonj (60%) were cultivating rice in fruit orchard to get more profit, while 8, 22 and 32% of the respondents were obtained more profit in Dinajpur, Rajshahi and Chapainawbgonj, respectively (Fig. 21).
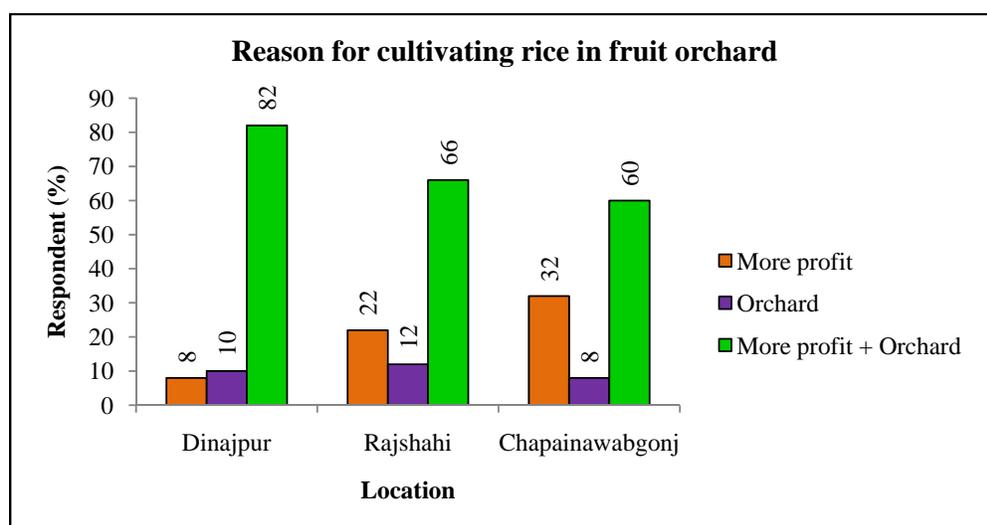
Figure 21. Reason for rice cultivation in a fruit orchard in the study area.

11.4.5 Suitable crop species

Most of the respondents (88, 92 and 90% in Dinajpur, Rajshahi,andChapainawbgonj, respectively) opined that rice is the most suitable crop species in mango based system. Respondents in Dinajpuralso opined that wheat, mustard, potato,andblack gram are also suitable for mango orchard. In Rajshahi, wheat was found suitable crop (70%) followed bysesame, grass pea, lentil, pea, potato,and vegetables. However, respondents in Chapainawbgonj opined thatwheat as suitable crop followed by, mustard, black gram,sesame, grass pea, lentil,andpea for fruit-basedagroforestry systems (Table 7).

Table 7. Suitable crops for fruit-based orchard practicing system opined by the respondents

Sl. No.	Crops	Respondents Opinion (%)		
		Dinajpur	Rajshahi	Chapainawabgonj
1	Rice	88	92	90
2	Wheat	62	70	66
3	Mustard	60	-	54
4	Potato	58	14	-
5	Black gram	28	-	24
6	Lentil	-	42	48
7	Sesame	-	54	28
8	Pea	-	40	30
9	Grass pea	-	44	42
10	Vegetables	-	4	-

11.4.6 Non-suitable crop

In Dinajpur, most of the respondents opined maize (84%) as most non-suitable crop followed by sugarcane (80%) and jute (30%). In Rajshahi, sugarcane (80%) and maize (60%) were the top two non-suitable crops as opined by the respondents. On the other hand, in Chapainawabgonj, jute was top non-suitable crop (74%) for fruit-based system followed by sugarcane (62%), maize (56%) and onion (30%) (Table 5).

Table 8. Nonsuitable crops for fruit-based orchard practicing system opined by the respondents

Sl. No.	Crops	Respondents Opinion (%)		
		Dinajpur	Rajshahi	Chapainawabgonj
1	Jute	30	28	74
2	Maize	84	60	56
3	Sugarcane	80	80	62
4	Onion	-	-	30

11.5 Land resource utilization

Respondents were asked about the maximum utilization of their land resource and it was observed that most of the respondents in Dinajpur (88%), Rajshahi (90%) and Chapainawbgonj (92%) were utilizing their land with agroforestry practices, while 12, 10 and 8% of the respondents were not utilized in Dinajpur, Rajshahi,andChapainawbgonj, respectively(Fig. 22).
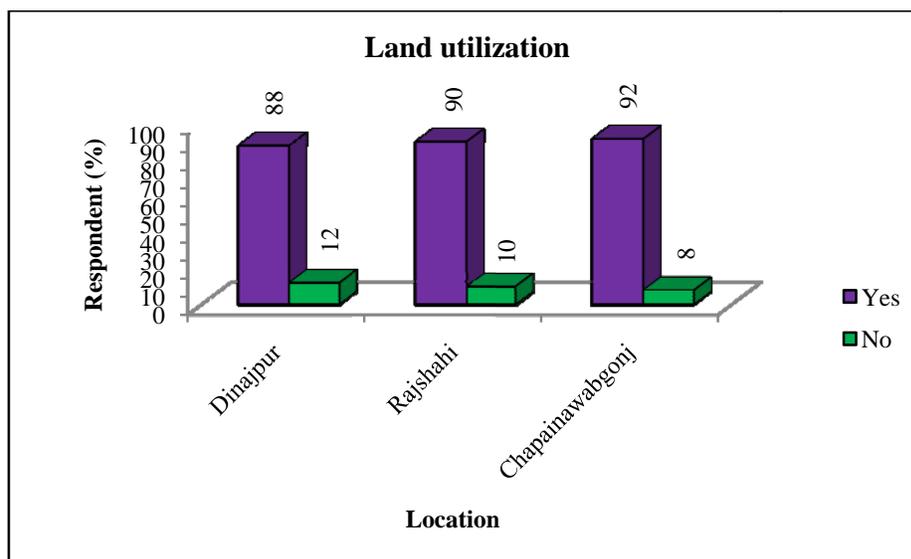
Figure 22. Maximum utilization of the land resource by rice-basedagroforestry system.

11.6 Soil fertility improvement through agroforestry system

Improvement of soil fertility is one of the major benefits of any agroforestry practice. Respondents of the study area have been practicing agroforestry since 10-15 years. So, they could realize the improvement of soil fertility through agroforestry practice. The study revealed that most of the respondents in Dinajpur (70%), Rajshahi (52%) and Chapainawbgonj (62%) were expressed that soil fertility was improved by practicing agroforestry (Fig. 23). Litter fall from tree increased the soil organic matter.The tree also uptake the leached soil nutrients of the top soil layer by its root and also conserve it against wash out from the field. Thus, agroforestry help increasessoil fertility.
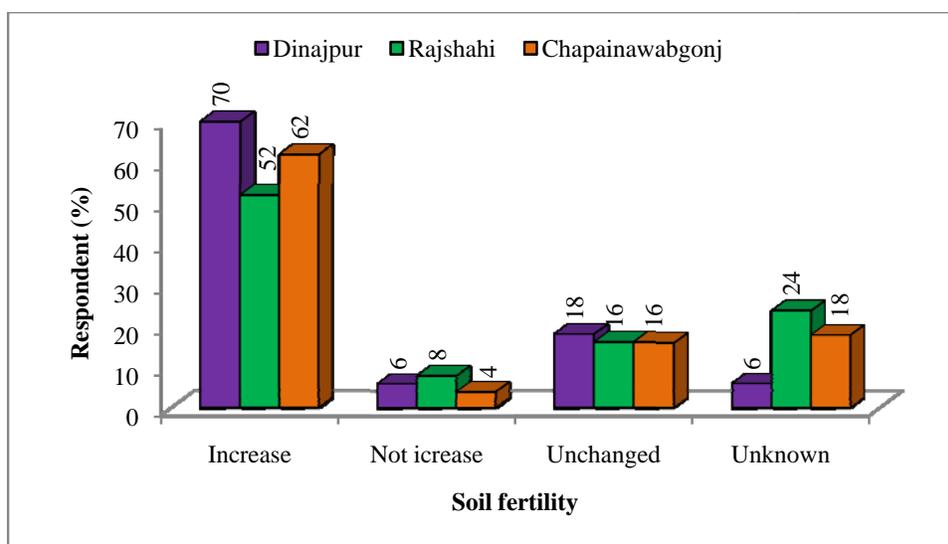
Figure 23. Improvement of soil by practicing agroforestry system.

11.7 Management practice

Different management practice is needed for higher productivity and profitability. Respondents of all study sitesoppined that they need different management practice for a combined production system.

11.7.1Management practice for fruit orchard

Respondents were asked about different management practices for orchard, among the management practices,irrigation in Dinajpur (42%)whereas insecticide/ pesticide control with irrigation in Rajshahi (36%) and provides in Chapainawbgonj (46%), respectively (Table 9) as opined by the respondents.

Table 9. Different management practices for orchard within rice production

Sl. No.	Management practices	Respondents Opinion (%)		
		Dinajpur	Rajshahi	Chapainawabgonj
1	Irrigation	42	36	30
2	Fertilizer	6	4	0
3	Insecticide/pesticide	14	36	46

11.7.2 Management practice for rice production

Respondents were asked about different management practices for rice production, among the management practices, it was observed that irrigation, in all study areas, was top most management practice for rice production opined by the all respondents.On the other hand, fertilizer application was the second mostimportant manaagement practice followed by desease and insect and weed control in all study areas(Table 10).

Table 10. Different management practices for rice production within the orchard

Sl. No.	Management practices	Respondents Opinion (%)		
		Dinajpur	Rajshahi	Chapainawabgonj
1	Irrigation	100	100	100
2	Fertilizer	92	84	90
3	Insecticide/pesticide	88	90	82
4	Weeding	76	94	86
5	Others	56	40	52

11.7.3 Special management practice for fruit orchard

Different special management practices are needed in the orchard for higher productivity and profitability. Among thespecialmanagement practices, it was observed that modern technology and good management practicewas top mostspecial management practice for orchardas oppined by most of the respondents in all study areas.On the other hand, judicious use of fertilizer and pesticideswas the second most important management practice followed by earthing up(Table 11).

Table 11. Special management practice for orchard within rice production

Sl. No.	Sector	Respondents Opinion (%)		
		Dinajpur	Rajshahi	Chapainawabgonj
1	Modern technology and good management practice	74	82	80

2	Judicious use of fertilizer and pesticides	36	32	38
3	Earthing up tree base	44	40	38
4	Same management practice	16	20	26
5	No need special care	32	36	30

11.7.4Special management practice for rice production

There are needed some different special management practices for rice production in the orchard for higher productivity and profitability. Most of the respondentsopined that, disease control was the main probleminall study areas. On the other hand, the secondtop mostmanagement practicewas the same management practicein all study areas,and they said that, no need anyspecial management practices for rice production (Table 12).

Table 12. Special management practice for orchard within rice production

Sl. No.	Sector	Respondents Opinion (%)		
		Dinajpur	Rajshahi	Chapainawabgonj
1	Control diseases	42	36	30
2	Control insect infestation	6	4	0
3	Need intensive care	14	36	46
4	More use of water and fertilizer	16	4	2
5	Same management practice	22	20	22

11.8 Desired yield from agroforestry

The respondents who were practicing agroforestry opined differently on getting the desired yield from the production system. Most of the respondents, in all study areas, were getting the desired crop yield (Fig. 24). Respondents ofDinajpur (86%), Rajshahi (92%),and Chapainawbgonj (96%) have been practicing agroforestry systematically with different high yielding rice varieties.
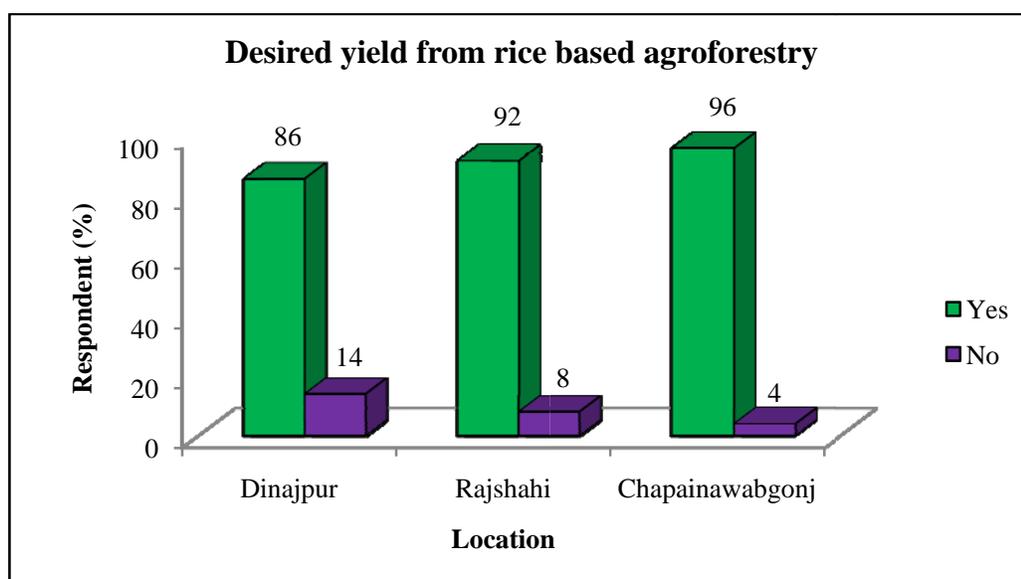
Figure 24. Distribution of the respondent in getting the desired yield from their
orchard.

10.9 Year-round crop cultivation

To increase the productivity of agroforestry systems, year-round crop cultivation
within the orchard is needed. In the study area, respondents spontaneously grow
different crops withfruit tree orchard in which year-round employment opportunity
and income generation are created. They planted different types of the crop with
rice-basedagroforestry system (Table 13).

Table 13. Year-round crop cultivation within the orchard in different study location

Location	Kharif-I (April-June)	Kharif-II (July-October)	Rabi (November-March)
Dinajpur	Agroforestry/Maze Jute	Rice	Potato/Mustard/Wheat Sweetgourd
Rajshahi	Agroforestry /Jute/Sesame /Turmeric/Aroid	Rice	Potato/Mustard/Wheat/Sweetgourd/Lentil/Checkpea
Chapainawabgonj	Agroforestry /Jute/Sesame	Rice	Potato/Mustard/Wheat/ Lentil/Checkpea/Rice

11.10 Cultivating rice and mango variety

Agroforestry practice is a diversified production system. In the study area, farmers
cultivate different high yielding transplanted rice variety. Incase of mango, more or
less the same variety was practicing by the farmers (Table 14).

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Table 14. Cultivating variety of rice and mango in different study locations

Dinajpur		Rajshahi		Chapainawabgonj	
Rice	Mango	Rice	Mango	Rice	Mango
Gutisarna	Amrapali	Gutisarna	Amrapali	Gutisarna	Amrapali
Lalsarna	Harivanga	Lalsarna	Fazli	Lalsarna	Fazli
BRRIdhan28	Fazli	BRRIdhan11	Langra	Sadasarna	Langra
BR29	Ashini	BRRIdhan33	Ashini	Sumonsaran	Ashini
Hybrid sumon	Himsagar	BR29	Himsagar	BRRIdhan28	Himsagar
Ranjit	Lakhanvog	Binadhan-7	Lakhanvog	BRRIdhan51	Lakhanvog
	Local		Totapari	Bandhan-7	Mohonvog
	Surjamukhi		Local		Khirshapat
					Surjamukhi
					Local

11.11 Yieldof rice and mango

Yield depends on availability of the required quantity of water; mineral nutrients; quantity, quality and duration of light; temperature;area of growing space and genetic set up of the plants. In multiple cropping systems, the individual yield may decrease,butthe totaloverall yield increase. In rice based agroforestry system, the highest rice production was recorded in Chapainawabgonj (5.11 ton ha^{-1}) followed by Dinajpur(5.04 ton ha^{-1}) and Rajshahi (4.80 ton ha^{-1}), respectively. On the other hand, the highest mango yield was recorded in Rajshahi (10.36 ton ha^{-1}) followed by Chapainawabgonj (10.02 ton ha^{-1}) and Dinajpur(9.45 ton ha^{-1}), respectively(Table 15).

Table 15. Yield of rice and mango in mango based agroforestry system

Location	Yield (ton ha^{-1})	
	Boro Rice	Mango
Dinajpur	5.04	9.45
Rajshahi	4.80	10.36
Chapainawabgonj	5.11	10.02

11.12 Crop loss

Respondent farmers opined that crop yield loss varied depending on the type of fruit tree and rice varieties used in agroforestry systems (Table 16). In rice, the maximum crop yield loss was observed in Rajshahi(35%) when crops were grown in association with mango, followed by Chapainawabgonj (25%) and Dinajpur(20%), respectively. In the case of mango, yield loss was more than 25% in

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Chapainawabgonj when mangowasgrown in association with ricefollowed by Rajshahi(20%). In Dinajpur, yield loss was not much(15%) in rice-based agroforestry systems.

Table 16. Average crop yield loss (%) in rice-based agroforestry systems in the study areas opined by the respondent

Location	Average yield loss (%) opined by the respondents	
	Rice	Mango
Dinajpur	20	15
Rajshahi	35	20
Chapainawabgonj	25	25

11.13 Overall yield advantage

Most of the respondents who practiced agroforestry were aware ofthe overall benefit of the system. Farmers` opinion regarding the overall benefit from agroforestry systems for all study areas have been presented in Figure 25. In Dinajpur, respondents got the maximum overall benefit (22.86%) from rice-based agroforestry system. InRajshahi, rice-based agroforestry system wasfound intensiveand farmers have been getting profit from that system. On the contrary, rice-based agroforestry system was found in Chapainawabgonj, and the respondents were getting overall good profit from this system. Therefore, overall profit was relatively higher in Chapainawabgonj (33.2%) compared to other study areas.
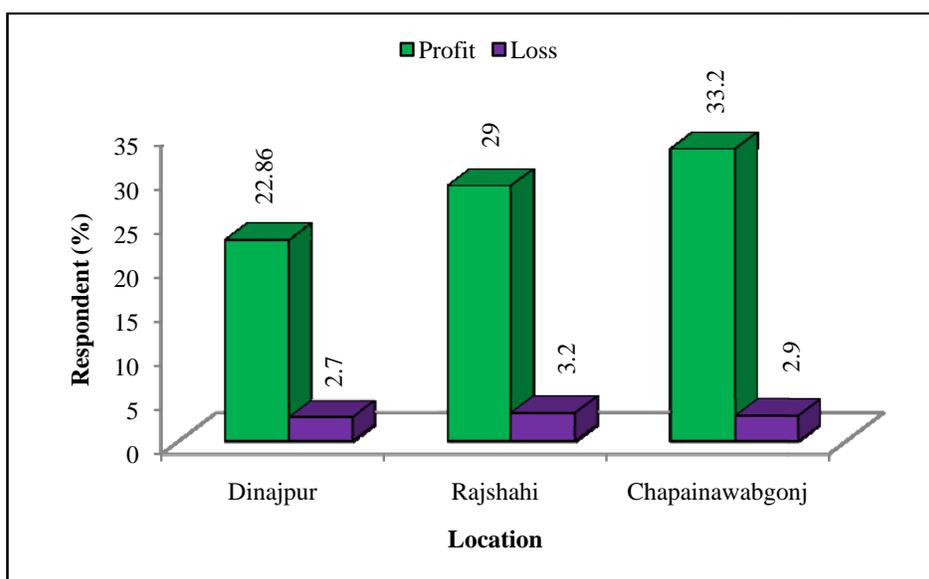
Figure 25. Total profit or loss for rice-based agroforestry system.

Figure 26. Showing the rice-based Agroforestry practice in Nachol(Chapinawabgonj).

11.14 Suggestion

Respondents provided some suggestions to increase the productivity of rice-basedagroforestry systems, which are presented in Table 17. In Dinajpur, most of the respondents (88%) suggested that financial helpand training on various aspects would be very helpful to increase productivity and income followed by use of quality planting materialand shade tolerant rice variety(78%), planting of improved fruit variety(70%) and use of modern technology (64%). On the other hand, in Rajshahiand Chapainawabgonjuse of shade-tolerant rice variety was suggested by the majority of the respondents to increase agroforestry productivity and income. Use of improved fruit variety, use of modern technology, good management

practice,use of quality planting material,financial help and trainingwere also suggested by a good number of respondents inRajshahi and Chapainawabgonj sites.

Table 17. Suggestion to increase productivity and income ofrice-based agroforestry system

Sl. No.	Sector	Respondents Opinion (%)		
		Dinajpur	Rajshahi	Chapainawabgonj
1	Use of shade tolerant rice variety	78	80	74
2	Planting of improved fruit variety	70	78	70
3	Good management practice	58	36	50
4	Use of modern technology	64	54	64
5	Use of quality planting material	78	34	24
6	Financial help	88	68	74
7	Training	88	66	70
8	No comment	12	4	8

11.15 Advantage of rice-basedagroforestry

Some important points especially advantages of rice-based agroforestry were expressed by the respondents for all the study areas (Table 18). In Dinajpur, 78% of respondents opined that getting higher income and year-round productionwas the main advantage. Higher yield, year-round working opportunity,maximum use of land, efficient use of water,less fertilizer requirement,efficient use of fertilizer andincrease soil fertilitywere some other advantages inDinajpur area. In Rajshahi, higher yield (58%) and year-round working opportunity (58%) were two major advantages, while higher income and year-round production were some other advantages. In Chapainawabgonj, 72% respondents identified higher income and year-round working opportunityas the top most advantages of rice-basedagroforestry system followed by year-round production (66%) and higher yield (60%), respectively.

Table 18. Advantages of rice-based agroforestry practices opined by the respondents

Sl. No.	Advantages	Respondents Opinion (%)		
		Dinajpur	Rajshahi	Chapainawabgonj
1	Higher income	78	56	72
2	Year round production	78	56	66
3	Higher yield	74	58	60
4	Year-round working opportunity	72	58	72
5	Maximum use of land	62	34	30
6	Efficient use of water	58	34	44

7	Less fertilizer required	68	36	40
8	Efficient use of fertilizer	60	56	52
9	Increase soil fertility	54	42	56

11.16 Disadvantage of rice-basedagroforestry

Although rice based agroforestry is a profitable and environmentally sound land use system, but in the eyes of the respondents, it has some disadvantages too. In Dinajpur, most of the respondents (82%) reported that higher incidence of insect,and diseasewas a major disadvantages, followed by lack of skilled labor (72%), shade to the crop (62%),lack of shade tolerant variety (60%) and higher primary cost (56%).In Rajshahi and Chapainawabgonj, higher incidence of pest, insect,and diseasewere the major disadvantages of rice-basedagroforestry systems (Table 19).

Table 19. Disadvantages of rice based agroforestry opined by the respondents

Sl. No.	Disadvantages	Respondents Opinion (%)		
		Dinajpur	Rajshahi	Chapainawabgonj
1	Higher primary cost	56	58	42
2	Higher incidence of pest, insect and disease	82	72	78
3	Need skilled labor	72	76	72
4	Shade to the crop	62	58	44
5	The lower yield of rice	42	46	48
6	Lack of shade tolerant variety	60	38	40
7	Water scarcity	40	34	10

11.17 Economic benefit and land use

11.17.1Benefit-cost ratio (BCR)

To know the economic performance and land use in rice-based agroforestry system over sole cropping, benefit-cost ratio (BCR) and the land equivalent ratio (LER) have been calculated and presented in Table 20 and Table 21. Benefit-cost ratio was higher in rice-based agroforestry system as compared to the non-agroforestry system in all aspects and systems. The highest BCR was recorded in Dinajpur (4.88) which was followed byRajshahi (4.63) and Chapainawabgonj (4.35). The result revealed that rice-based agroforestry system was economically profitable than the non-agroforestry system.

Table 20. Benefit-cost ratio (BCR) of rice-based agroforestry and non-agroforestry

System	Benefit-cost ratio (BCR)		
	Dinajpur	Rajshahi	Chapainawabgonj
Rice-based Agroforestry	4.88	4.63	4.35
Non Agroforestry	3.12	2.87	2.91

11.17.2Land equivalent ratio (LER)

LER was higher in rice-based agroforestry systems than the non-agroforestry system in all study areas. The highest LER was noted in Dinajpur (2.58) in rice-based agroforestry system followed by Chapainawabgonj (2.18) and Rajshahi (2.03) study areas, respectively(Table 18).

Table 21. Land equivalent ration (LER) of rice-based agroforestry and non-agroforestry system

System	Land equivalent ratio (LER)		
	Dinajpur	Rajshahi	Chapainawabgonj
Rice-based Agroforestry	2.58	2.03	2.18
Non-Agroforestry	1.00	1.00	1.00

12. Research highlight/findings:The research highlights of the project have been briefly summarized below:

o Rice based agroforestry systems, practices, benefits and constraints in all study areas (Dinajpur, Rajshahi and Chapainawabgonj) were identified through formal and informal surveys.

o The major agroforestry systems were mango orchard with sporadic understory crops in Dinajpur, Rajshahi and Chapainawabgonj, respectively. However, farmers are getting desired yield by practicing agroforestry system as compared to non-agroforestry system.

o The major constraints were high cost of production, skilled labor crisis and high incidence of diseases and pests. Specifically, lack of availability of irrigation was also a severe problem in all study areas.

o Scientific management packages including good planting materials for trees and crops; training, financial help, disease and pest managements were suggested to make the systems sustainable and high productive.

o Mango yield was increased remarkably in rice based agroforestry system due to benefits received from fertilizer and irrigation management for lower

storied crops, while lower-storied yields were reduced due to competition for resources among the components. Introduction of agroforestry practice made the system more viable and economically profitable. The LER for agroforestry systems were 2.58, 2.03 and 2.18; and the corresponding values for BCR were 4.88, 4.63 and 4.35 in Dinajpur, Rajshahi and Chapainawabgonj, respectively.

o The newly established rice based systems have not reached to their economic productivity stage. These newly developed fruit tree based agroforestry systems will reach to the reproductive stage within a couple of years and then farmers could get significant yield, income and ecosystem services.

o From GIS based study, more non-agroforestry area have been identified for improving the existing practices and developing new systems for all the study regions.

13. Reference:

Hossain, S.B. and M.A. Kashem. 1997. Management combat declining soil fertility in Bangladesh. Key note paper. Proceeding of the 6th Biennial Conference of the Bangladesh Society of Agronomy.Held on 29 July 1997.pp: 22-39.

Khybri, M., Gupta, R., Ram, S., &Tomar, H. (1992). Crop yields of rice and wheat grown in rotation as intercrops with 3 tree species in the outer hills of western Himalaya. Agroforestry Systems, 17(3), 193-204. Doi: 10.1007/BF00054147

Nair P K R, Kumar B M and Nair V D. 2009. Agroforestry as a strategy for carbon sequestration. Journal of Plant Nutrition and Soil Science 172: 10–23.

Prasad J V N S, Srinivas K, Srinivasarao C, Ramesh C,Venkatravamma K and Venkateswarlu B. 2012. Biomass productivity and carbon stocks of farm

forestry and agroforestry systems of leucaena and eucalyptus in Andhra Pradesh, India. Current Science 103(5): 536–40.

Rajendran, K., Gunasekaran, T. andDevaraj.P., 2003,Performance of teak and rice in the Agri-silvicultural system inSouthern TamilNadu. Range Management and Agroforestry,24: 74-76.

Xenarios SH, Polatidis NU, Sekhar BJC, ManiruzzamanMd, Sarker GW (2013) Alleviating climate change impacts in rural Bangladesh through efficient agricultural interventions. Rice Clima.

B. Implementation Position

1. **Procurement:**

Description of equipment and capital items	PP Target		Achievement		Remarks
	Phy (#)	Fin (Tk)	Phy (#)	Fin (Tk)	
(a) Office equipment	4	1,00,000	4	1,19,500	
(b) Lab &field equipment	2	95,000	4	74,000	
(c) Other capital items					

2. **Establishment/renovation facilities: Not Applicable**

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	

3. **Training/study tour/ seminar/workshop/conference organized: Not Applicable**

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training					
(b) Workshop					

C. Financial and physical progress

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Contractual staff salary	824,255.00	824,255.00	649,875.00	174,380.00	78.84	
B. Field research/lab expenses and supplies	416,000.00	416,000.00	139,050.00	276,950.00	33.43	
C. Operating expenses	323,000.00	323,000.00	230,767.00	6534.00	97.25	
D. Vehicle hire and fuel, oil & maintenance	300,000.00	300,000.00	224,400.00	37,324.00	85.74	
E. Training/workshop/ seminar etc.	-	-	-	-	-	

F. Publications and printing	95,000.00	95,000.00	-	95,000.00	0	
G. Miscellaneous	50,000.00	50,000.00	47,987.00	2013.00	95.97	
H. Capital expenses	195,000.00	195,000.00	194,000.00	-	100	
Total	**2,203,255.00**	**2,203,255.00**	**1,486,079.00**	**592,201.00**		

D. Achievement of Sub-project by objectives: (Tangible form)

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output(i.e. product obtained, visible, measurable)	Outcome(short term effect of the research)

E. Materials Development/Publication made under the Sub-project: Under Process

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.			
Journal publication			
Information development			
Other publications, if any			

F. Technology/Knowledge generation/Policy Support (as applied):

i.   Generation of technology (Commodity & Non-commodity)

In general farmers do not take much care of their orchard,

ii.   **Generation of new knowledge that help in developing more technology in future**

Since different crops are grown in association with mango orchard, it creates favorable environment and improve ecosystem services, more crops needed to be tested. This finding will be helpful for other fruit orchards in other locations of the country.

iii.   Technology transferred that help increased agricultural productivity and farmers' income

In this study, farmers were encouraged to use quality planting materials, use of balance fertilizer, way of management of pest and disease. Therefore, total production and income of the farmers have been increased. Income will be higher when the orchard will be optimum fruiting stage

iv.   Policy Support

The finding of the study opinion of the farmers, extension agent, NGO personnel were incorporated with will help policy maker for the development of rice based agroforestry systems.

G. Information regarding Desk and Field Monitoring

    i)   **Desk Monitoring:**
           Research team meeting was held every month where the progress of the project was discussed and action plan was prepared.

    ii)   **Field Monitoring (time& No. of visit, Team visit and output):**
           Prof. Dr. Abiar Rahman, Department of Agroforestry and Environment visited the study site and gave valuable suggestions to the farmers and research team.
           Dr. Hasan Md. Abdullah, Co-PI of the project visited several times of the project sites.
           Professor Tofayel Ahamed, PI of the project visited the field in regular interval with research team and closely monitored the progress of work.

I. Lesson Learned/Challenges (if any)

Mango based agroforestry systems are getting popularity in north-western part of the country and become a popular land use system that contributing much to economy of farming community of the region.

J. Challenges (if any)
- Heavy rainfall during the rice growing season restricts the rice production.
- Lack of labour availability during crop establishment and harvesting seasons.
- Lack of quality planting materials
- High price of labor and input cost

Signature of the Principal Investigator   Counter signature of the Head of the

Date ………………………….   organization/authorized representative

                                                 Date ………………………….

Seal   Seal