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Competitive Research Grant

Sub-Project Completion Report

on

Up-scaling of Multistorey Agroforestry System for Diversified Production, High Income and Ecosystem Services

Project Duration

May2017 to September2018

Dept. of Agroforestry and Environment
Bangabandhu Sheikh Mujibur Rahman Agricultural University
Gazipur 1706, Bangladesh

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

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Acronyms

%N	Nitrogen Percentage
AEZ	Agro-ecological Zone
BCR	Benefit-Cost Ratio
BSMRAU	Bangabandhu Sheikh Mujibur Rahman Agricultural University
DAS	Days after Sowing
DAT	Days after Transplanting
DBH	Diameter at Breast Height
i.e.	That is
LER	Land Equivalent Ratio
MAFS	Multistorey Agroforestry System
MOC	Mustard Oil Cake
PAR	Photosynthetically Active Radiation
RCBD	Randomized Complete Block Design
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
TOC	Total Organic Carbon

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Executive Summary

Agroforestry is a time old practice in Bangladesh, currently jackfruit (*Artocarpusheterophyllus*Lam.) based agroforestry is predominantly found in the terrace ecosystem where different crops are grown beneath the jackfruit tree. There are scope for further improvement in production and soil fertility management of jackfruit orchards. The present study is aimed to assess the productivity, profitability and ecosystem services of jackfruit based agroforestry system after up-scaling from a traditional jackfruit orchard with the goal of income generation and productivity increment by maintaining farm environment. In this system, jackfruit trees have been kept as top–storey crop, while papaya and different types of vegetables including spices are being grown as middle– and lower–storey crops, respectively. However, before going through field experimentation, a benchmark survey was conducted from June 2017 to July 2017 on thirty respondents in four village sunder Belabo and Shibpur upazillas of Narsingdi district, representing the terrace ecosystem of Bangladesh to get primary information from the farmers on existing agroforestry practices. The benchmark information indicate that the peoples are interested to practice agroforestry systems but irrigation and labor paucity including lack of technical knowledge severely deprived them to engage in agroforestry. Based on the outcomes of benchmark survey, fifteen jackfruit orchards were selected for transformation into multistorey agroforestry systems (MAFS), which presume to be a promising approach to boost agricultural yield through improving farm environment.

Crops like aroid, ginger, turmeric, cabbage, and chili were planted at 1, 2, 3, and 4m distance from jackfruit tree base, while bottle gourd, bitter gourd, and sweet gourd were grown in orientation basis such as north, south, east and west direction around the jackfruit tree. Nonetheless, all of the above-mentioned test crops were grown and reared as under-storey, papaya as border crop as well as middle-storey, and jackfruit as upper-storey from September 2017 to August 2018. Higher yields of ginger and turmeric were recorded at 2, 3 and 4m distance from the tree base, while reduced yield was noted at 1m distance as compared to that of sole ginger and turmeric fields. In case of cabbage, yield reduction was 56.06% at 1m distance from tree base relative to sole cabbage. Chilli yield was reduced by only 0.92% at 4m distance, although 32% yield reduction was recorded at 1m distance from tree base compared to sole chilli fields. In case of bottle gourd, bitter gourd, and sweet gourd, the highest yield reduction by 40.75, 56.16, and 50.61%, respectively, was recorded in MAFS in comparison to that of sole-cropping systems. On an average, papaya yield was reduced by 26.83% in MAFS as compared to that of sole papaya field. Interestingly, jackfruit yield was enhanced by 62.73, 7.92, 24.74, 12.78, and 54.96% in aroid and bitter gourd, turmeric and bottle gourd, ginger and sweet gourd, chilli and cabbage based MAFS than sole jackfruit orchard.

Benefit cost ratio (BCR) was 30.67, 31.57, 51.42, 32.71, 10.59, 27.39, 5.40, and 4.17% higher in aroid, ginger, turmeric, cabbage, chilli, bitter gourd, sweet gourd and bottle gourd associated MAFS, respectively, than respective sole cropping system. Aroid-papaya-jackfruit system gave the highest LER (2.72) followed by bitter gourd-papaya-jackfruit (2.62), while the lowest was recorded in bottle gourd-papaya-jackfruit system (2.17).

Microclimates like soil moisture, soil temperature, and PAR was relatively favorable in MAFS than open field. Nonetheless, increasing trend of soil moisture, while decreasing trends of temperature and PAR were recorded in MAFS in compared to sole cropping system. The highest litter fallw as recorded in the month of February in cabbage-papaya-jackfruit based systems, while the lowest litter fall was noticed in the month of August in chilli-papaya-jackfruit field. However, dropping leaf litter amount is intimately associated with tree age and ground area and one kg of leaf litter might add 10.40 and 90.15g of N and organic matter, respectively, into the soil. It is fascinating to note that soil chemical properties like soil-pH, N, organic carbon, and organic matter increased substantially in MAFS in compared to that of open field. Therefore, jackfruit orchards may be transformed into MAFS for higher production, income and ecosystem services.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. Title of the CRG sub-project: **Up-scaling of Multistorey Agroforestry System for Diversified Production, High Income and Ecosystem Services**

2. Implementing organization: Dept. of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh.

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

Principal Investigator	Dr. Md. Abiar Rahman; Professor, Department of Agroforestry and Environment, BSMRAU, Gazipur 1706. Tel: 9205310-14 Extn. 2196; Cell No.: 01552-495452, Fax: 9205333, E-mail: abiar@bsmrau.edu.bd; abiarbd@yahoo.com
Co-Principal Investigators	Dr. Satya Ranjan Saha; Professor, Department of Agroforestry and Environment, BSMRAU, Gazipur 1706. Tel: 9205310-14 Extn. 2037; Cell No.: 01712541000, Fax: 9205333, E-mail: satyasaha1960@yahoo.com

4. Sub-project budget (Tk):

Total: 23,53,125 (Twenty-three lakh fifty-three thousand one hundred twenty-five taka only)

Revised (if any):

5. Duration of the sub-project:

Start date (based on LoA signed) : May 2017

End date : 30 September 2018

6 Justification of undertaking the sub-project:

Bangladesh is one of the most densely populated countries in the world where more than 1090 persons are living per square kilometer (BBS, 2017). The per capita land area is decreasing at an alarming rate due to increasing population. With the increase of population, the areas under field crops and the forests are decreasing constantly resulting imbalance in food and energy security, and causing a number of environmental hazards in different ecosystems.

Because of increasing environmental hazards and demand for food, timber, fuel wood, fodder, fruits etc., production of multiple products from the same land management unit are 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. Agroforestry system having multipurpose tree plantation helps to increase soil fertility, supplies fuel wood, creates employment and improved socio-economic condition of the farmers (Alam, 2004). Moreover, agroforestry systems provide multiple products including fruits, vegetables, cereals, fuel wood, fodder etc. to contribute in livelihoods of the households.

Multistorey agroforestry system (MAFS) improves close and efficient nutrient cycling systems through high rates of nutrient turnover, improves soil structure, enhancement of microbial biomass, plant residues, biodegraded products and improving biological nitrogen fixation in the soil compare to conventional agricultural systems (Araujo et al., 2012; Li et al., 2016). It is worthy to mention that tree based intercropping systems also promotes diverse soil microbes and arbuscular mycorrhizal (AM) communities which play pivotal role in the retrieval of microbial functions as well as keep the soil free from periodic disturbance. The recovering ability of microbial biomass after disturbance helps in maintaining agroecosystem functions and services. In addition, trees in MAFS accelerate understory growth by reducing incident solar radiation, air and soil temperature along with reduced wind velocity while improving water status, gas exchange and water use efficiency in compared to sole cropping system (Bayala et al., 2008).

In Bangladesh, agroforestry is an integral part of the rural livelihood systems for centuries 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). Various traditional and systematic agroforestry systems are found in different ecosystems of Bangladesh. Although agroforestry systems prevail throughout the country, various patterns of agroforestry systems are found across the ecosystems due to variations in topography, soil, water and climatic advantages.

Traditionally, farmers of the Madhupur Tract have been practicing different types of agroforestry systems from time immemorial. The agroforestry systems in terrace ecosystem have become an integral part of the rural livelihood systems for centuries and play key role in up-scaling their socioeconomic status through providing multifaceted benefits.

The boundaries between terrace ecosystem and the adjoining areas are generally sharp and well defined. Undulating red soil is the main ecological feature of the zone. This terrace ecosystem's soils, covering 8% of country's total soil area, are diverse, ranging from deep reddish-brown, friable, well-drained clay loams to grey, poorly-drained silty top soils over clay on level highlands. This zone is enriched with high floral diversity.

Among the different systems, Jackfruit based agroforestry system is the most dominant one. Khan (2007) identified a large number of major and minor traditional and new agroforestry systems in terrace ecosystem of Bangladesh, where jackfruit-turmeric/ginger, jackfruit-brinjal and jackfruit-chili were identified as top-ranked systems, which are practiced widely. Latkon based agroforestry systems are also found as economically viable practice in some areas of terrace ecosystem (Alam, 2004). Besides, some fruit and timber tree based systems are also newly developed in this region without following any scientific silvicultural and agronomic management practices.

Nowadays, several modern agroforestry production systems based on both fruit and timber species have been practiced by the farmers (Miah and Hussain, 2005). Among the different newly emerged agroforestry systems, *Zizyphus auritiana* (jujube), *Psidium guajava* (guava), dwarf *Magnifera indica* (mango) and *Litchi chinensis* (litchi) based systems are expanding rapidly without following scientific basis.

However, both traditional and newly introduced agroforestry systems are not being practiced scientifically. Therefore, the potential benefits of agroforestry are still remaining untapped. Although some research activities on modern agroforestry practices have been done, it is not sufficient to expand the new systems. To get economic and environmental advantages of agroforestry practices, it is needed to record the nature, types of interactions among the components, resource use, practices, performances, yields as well as economic and environmental benefits of the suitable agroforestry practices through survey and monitoring.

Available baseline information shows that, in general, practitioners do not manage the jackfruit orchards systematically, as a result, low productivity and benefit are found. In a recent study on agroforestry at different agro-ecosystems showed that Jackfruit based agroforestry system in the Terrace ecosystem gave better production and higher income. In the Terrace ecosystem, jackfruit orchard was transformed into MAFS by keeping jackfruit tree as upper-story, introducing papaya as middle-story and seasonal vegetables such as brinjal, bottle gourd and ash gourd as lower-story crop. A better farm environment in terms of soil moisture and temperature was maintained in MAFS than sole practice. Light availability was reduced by about 49% and 38% at middle- and lower-story, respectively, indicating low competition for light among the components. Due to better management, jackfruit yield was increased by 33%, while lower-story yield decreased by about 30% due to competition for light, water and nutrient. We found BCR about 5 in MAFS over sole practice. In the previous study, we emphasized on production. In this proposed study we shall evaluate ecosystem services such as improvement of soil environment, biomass output, land use efficiency and overall production. More new crop combinations will be evaluated in this project to find out compatible tree-crop system. In Bangladesh, ecosystem services in an agroforestry system has not been investigated systematically. We hypothesize that since three components will be grown simultaneously and sequentially, the overall production, services and functions would give high benefits to the farmers. Using the present and previous findings, a model will be developed.

7 Sub-project goal: Income generation and productivity increment by maintaining farm environment through agroforestry

8 Sub-project objective (s):

- To expand the multistorey agroforestry system (MAFS) with the introduction of middle- and lower-story crops in a jackfruit orchard for increasing diversified products.
- To evaluate the economic and land-use performances of MAFS and compare with the conventional practices.
- To investigate the ecosystem services in terms of microclimatic modifications and system dynamics of the MAFS.

9 Implementing location (s): Narsingdi district

10 Methodology in brief:

Location and Time of the Study

The study was conducted in farmer's field (On-Farm) from May 2017 to August 2018 in Belabo and Shibpur upazila under Narsingdi district, which were an ideal location of central terrace ecosystem in Bangladesh (Fig. 1). The experimental site is situated at about 56 km and 7 km away from the capital city Dhaka and Narsingdi city, respectively. The study site is located on the 23º 29´ North latitude and 90º10´ East longitude.

Fig. 1. Map showing Belabo and Shibpur upazila under Narsingdi District (Study area).

Benchmark survey

A benchmark survey was conducted from June 2017 to July 2017 to know the demography, socio-economic conditions 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 pre-tested and structured interview schedule was used to collect data from the randomly selected 30 farmers.

Preparation of interview schedule: The interview schedule was designed to obtain relevant information according to the objectives of the study. The interview schedule was pre-tested with limited respondents.

Sampling technique: Considering the limitation regarding time and money, a simple random sampling technique was followed. Four villages under Belabo and Shibpur upazilas under Narsingdi district were selected. From the selected four villages, 30 respondents were selected comprising at least six from each of Kumartek, Moishertek, Abdulanagar and Lakhpur villages.

Method of data collection: Direct interview method was followed with the respondents for data collection. Three researchers collected the necessary information during the study period using the interview schedule. Appointments with the respondents were made in advance through a local assistant. This helped the researchers to have a friendly orientation with the respondents.

Analysis of the questionnaire information /data: After collection of data, every interview schedule was critically evaluated to confirm that every question was replied properly or not. All the collected benchmark survey data were summarized, scrutinized, coded and recorded in Statistical Package for Social Science (SPSS) computer software.

On-farm experimentation

Soil properties of the study area: The soils of the study area made it an ideal hotspot for the diversified fruit productions, namely jackfruit and latkan and belonging to Madhupur Tract (Agro-ecological Zone, 28) and classified as shallow red-brown under Inceptisol soil category according to USDA Soil Taxonomy (Brammer 1971; Shaheed 1984). The land topography is characterized by upland and closely associated narrow-valleys, popularly alluded to as *Chala* and *Baid*, respectively. However, the soil of the study area is dark grey in color and acidic in nature including low-organic matter and poor fertility levels. It is worth mentioning that the soils of the study plots in the dry season having poor water holding capacity, while in the rainy season it became sticky due to its clay-loam nature.

Climatic conditions: The climate of the area is characterized by humid tropics with three distinct seasons namely, the monsoons or rainy season (June to October), the winter or the dry season (November to February), and the pre-monsoon or hot season (March to May). The average annual rainfall is 2050 mm with the relative humidity of 60–70%. More than 80% of rainfall occurs during monsoon. Most of the rainfall occurs during June-July (more than 407 mm), while the least in December. The temperature varies from a maximum of 34.2ºC to a minimum of 12.6ºC with an average annual variation of 9.8ºC. May is the warmest (28.9ºC) and January is the coldest (19.1ºC) month in a year.

Selecting of jackfruit orchard and conversion to multistorey agroforestry: Established jackfruit orchards between the age of 10 to 38 were selected to convert in the multistorey agroforestry system (MAFS) in order to assess the yield and economic performances of aroid (local var. *Gaitta*), turmeric (local var. *Danna*), ginger (local var. *Kalinjira*), chili (hybrid var. *Jhillick*), bottle gourd (hybrid var. *Diana*), sweet gourd (hybrid var. *Sonia*), bitter gourd (hybrid var. *green bangla*, cabbage var. ATLAS 70 as lower-storied-crops. Papaya (hybrid var. *Top lady*) was planted in borderline to maximize the land use and get more profit. In general, this multistoried system comprised of existing jackfruit trees as top-storey, papaya (*Carica papaya* L.) as middle-storey, and different seasonal crops as under-storey. Although jackfruit plants were not planted in a systematic manner, it had enough space to grow under-storied-crops. Unfortunately, farmers of the study area kept it fallow, therefore, we aimed to utilize this space for maximizing land productivity as well as provide year-round economic returns. Plants having medium-canopy have been selected to the transformation of MAFS so that the light can be passed to the ground, and lower-storey crops could be successfully grown. Since the jackfruit tree is already established, therefore, plot size might not be even and varied between 20 to 42m^2.

Land preparation: Based on previous experiments and ground-truth information, 15 jackfruit trees were selected for experimentation on 29 March 2017. The lands were prepared by ploughing and cross-ploughing with power tiller followed by laddering until good tilth were obtained on 1st April, 2017. Manually the weeds and stubbles were removed from the field and bigger clods were broken into small pieces, and thereafter, pulverized and leveled uniformly. Similar procedures were followed for land preparation during each cropping season.

Sowing of aroid, turmeric and ginger: Seed-tubers of aroid were planted on 3rd April 2017 by maintaining spacing at 50-30 cm^2 (r-r and p-p), whereas, turmeric and ginger were planted at a spacing of 45-25 cm^2 and 40-25 cm^2 (r-r and p-p), respectively with a depth of 6 to 7 cm. However, fertilizers were applied based on fertilizer recommendation guide, 2012 as follows-

Name of the manure and fertilizer	Name of the crops		
	Aroid	Turmeric	Ginger
Cowdung (Kg/ha)	5000	5000	5000
Urea (Kg/ha)	150	200	200
TSP (Kg/ha)	100	150	150
MoP (Kg/ha)	120	150	150

The full doses of TSP, MP, and cow dung were applied at the time of final land preparation. Urea was applied in two equal splits at 60 and 90 days after sowing of aroid. In case of turmeric and ginger total dose of urea were applied in three equal splits at 60, 90 and 120 days after sowing.

Transplanting of Bottle gourd, Bitter gourd, Sweet gourd and Cabbage: Land was prepared on 25 September 2017. The land was prepared well by disking followed by harrowing and laddering until a good tilth was obtained. Clods were broken and weeds and stables of the previous crops were collected and removed from the field during land preparation. The plots were prepared and leveled according to the design and layout. The plants of bottle gourd, bitter gourd, and sweet gourd were fertilized with the following manure and fertilizer doses-

Manure and fertilizer	Dose (ha^{-1})	Dose (pit^{-1})
Cow-dung	10 ton	10 Kg
Urea	250 Kg	220 g
TSP	182 Kg	450 g
MOP	162 Kg	210 g

Cow-dung, Urea, TSP and MOP were applied as basal doses @10 Kg, 220 g, 450 g, 210 g per pit, respectively during final pit preparation. Rest of the urea and MP were applied in the field @ 150 g and 100g, respectively, in 15-day alternate as top dressing from sowing to final harvest.

Cabbage plots were fertilized with N, P and K at the rates of 115, 26 and 100 Kg ha^{-1}, respectively. Full dose of TSP was applied during the final land preparation. Urea and MP were applied in two equal splits at 15 and 45 days after transplanting.

Chilli seedlings were transplanted into the main field at a spacing of 60 cm×60 cm. The plots of chilli were fertilized by followings fertilizers doses as follows-

Manures and Fertilizers	Dose per hectare	Basal application	Applied as top-dressing		
			1st Installment at 30 DAT	2nd installment at 60 DAT	3rd installment at 90 DAT
Cowdung	10 ton	10 ton	-	-	-
Mustard oil cake	250 kg	150 kg	-	100 kg	-
Urea	250 kg	100 kg	50 kg	50 kg	50 kg
TSP	200 kg	200 kg	-	-	-
MoP	150 kg	60 kg	30 kg	30 kg	30 kg

Seedling raising and transplanting of Papaya: Papaya seeds were sown in polybag on 2nd May, 2018. Seeds were sown at a depth of 2 cm and covered with a fine layer of soil followed by light watering by water can as and when necessary. Healthy 35-day-old plants of Papaya were transplanted into the experimental field on 7th June 2017. Pits for papaya having size of 1.5ft x 1.5ft x 1.5ft (L×W×H) have been prepared on 24th May 2017 and papaya seedlings were transplanted around the boarder of jackfruit canopy at a distance of 1.5m. The soils of the pits have been prepared by intermixing of soils, cow dung and fertilizers following the guideline of fertilizers recommendation guide, 2012. The soils intermixed again at five days' interval for better decomposition of mixed materials. The pits were fertilized by following fertilizer doses:

Manures and Fertilizers	Dose per hectare (kg)	Dose per pit	Applied in pit as basal dose	Applied as top-dressing		
				1st Installment at 40 DAT	2nd installment at 80 DAT	3rd installment at 120 DAT
Cowdung	12500	5 kg	5 kg	-	-	-
Mustard oil cake	250	100 g	50 g	-	50 g	-
Urea	500	200 g	-	50 g	50 g	100 g
TSP	300	120 g	120 g	-	-	-
MoP	400	160 g	80 g	20 g	20 g	40 g
Boron	10	4 g	4 g	-	-	-
Zinc Sulphate	12.5	5 g	-	5 g	-	-

Intercultural operation

Gap Filling: Very few seedlings have been damaged and died after transplanting and replaced these by new seedlings from the same stock.

Weeding: The plants were kept under careful observation. Weeding was done during cropping period for different crops depending upon intensity of weeds for proper growth and development.

Earthling up: Two times earthling up was done by taking the soil from the space between the rows in aroid, turmeric, ginger and chilli depending upon their growth stages.

Irrigation: Irrigation was given by observing the soil moisture condition. Plants were irrigated as and when needed.

Sticking in Papaya and Chilli: Sticking was done in papaya and chilli to prevent lodging.

Pest Control: Some seedlings were attacked by virus. Affected plants were uprooted and burnt immediately. Malathion 57 EC was applied at the rate of 2 ml lit^{-1} for virus vector control each 25-day interval. Dithene M 45 was also applied at the rate of 2 g lit^{-1} for protection against fungal disease. Poison bait and sex pheromone were also used to reduce the infestation of insects.

Percent increase and decrease were calculated based on following equation

Percent increase = [(Values in agroforestry treatment - values in control conditions) /values in control conditions]* 100

Percent reduction = [(values in control conditions - values in agroforestry treatment) /values in control treatment]* 100

Experimental design and treatments

The experiment was conducted in randomized complete block design (RCBD) with three replications. The experiment was conducted at different farms (at least three farms for each crop), which were considered as blocks. Each jackfruit tree was considered as a unit plot for a single replication. Field size of each replication were not uniform due to different canopy size and shape of jackfruit trees. However, vine type plants like-bottle gourd, sweet gourd, and bitter gourd were planted in north, south, east and west directions, whereas, other crops like-aroid, ginger, turmeric, cabbage, and chilli were planted in distant regimes like 1, 2, 3, and 4m from the base of the tree. Each of the crops were planted as mono-crop to represent control fields.

11 Results and Discussion:

11.1 Benchmark survey results

Demography of the respondents

The socioeconomic characteristics of the respondent's included age, family size, occupation, years of schooling, which are presented in Table 1.

Age of the respondents: The age of the respondents ranged from 18 to 64 years with an average of 43.03 and standard deviation of 9.45. Based on their age, the respondents were classified into three categories as young (less than 35 years), middle–aged (35–50 years) and old–aged (over 50 years) as suggested by Haider (2010). The number and percentage distribution of farmers according to their age group have been shown in Table 1. It is revealed that the majority of the respondents were in the middle age category (43.33%) followed by old age (30.00%) and young age (26.67%). This finding is adequate to the national statistics indicating that the selected respondents were typical respondents of the country.

Table 1. Distribution of the respondent according to their socio-economic characteristics

Characters	**Unit**	**Categories**	**Respondents' opinion**			
			Frequency	**Percent**	**Mean**	**SD**
Age	**Actual year**	**Young aged (<35)**	8	26.67	43.03(±0.06)	9.45
		Middle aged (35-50)	13	43.33		
		Old aged (>50)	9	30		
		Total	30	100		
Family size	**Number**	**Small family (≤4)**	10	33.33	4.73(±0.03)	2.17
		Medium family (5-8)	15	50.00		
		Large family (>8)	5	8.34		
		Total	30	100		
Occupation	**Number**	**Agriculture**	18	60	1.52(±0.02)	0.83
		Service	4	13.33		
		Business	6	20		
		Others	2	6.67		
		Total	30	100		
Education	**Year of schooling**	**No schooling**	5	16.67	0.82(±0.02)	0.76
		Primary (1-5)	8	26.67		
		Secondary (6-10)	15	50		
		Above secondary (>10)	2	6.67		
		Total	30	100		

Family size of the respondents: Family size was assessed on the basis of the total number of members in a family. It ranged from 2 to 11 members with an average of 4.73 members per family, which was very much related to the current average family size of Bangladesh. The average household size in Bangladesh was 4.66 (HIES, 2010) and 4.35 (BBS, 2012) persons per family in 2004 and 2011, respectively. The highest proportion of the respondents had medium family size (50%) whereas, 33.33% and 8.34% of the respondents had small and large family size, respectively (Table 1). Data presented in the Table 1 indicated that 50% of the respondents were in medium size family, which was also a representative of typical family size in Bangladesh. In Bangladesh, it is very common to live together with parents and with brothers and sisters and some time with relatives (Joint family) (MoEF, 2001). It was noted that the percentage of joint families was higher in large farm categories. This might be one of the reasons for larger family size in large farm categories.

Occupation of the respondents: In the rural area of Bangladesh, maximum numbers of the population depend on agriculture. A small portion of the population is engaged in business while some earn their livelihood from service in the local area or elsewhere. The occupations of the respondents were categorized into four groups (Table 1). Among the four occupations of the respondent's agriculture (60%) was the major occupation of the total respondents, which was followed by service (13.33%), business (20%) and others (6.67%).

Education level of the respondents: The level of education of the respondents was categorized into four groups i.e. illiterate (no schooling), primary level (class I-V), secondary level (class VI-X) and above secondary level (college and university). The level of education of the respondents ranged from illiterate (no schooling) to above secondary with the mean and the standard deviation of 0.82 and 0.76 respectively. About 26.67% of the respondents had primary level education, whereas 50 and 6.67% of the respondents had secondary and above secondary level education, respectively. However, 16.67% of the respondents had no education.

Land use: Among different land-use patterns in the study area, the orchard of jackfruit tree was significantly dominant (1.32 ha) followed by agriculture land (0.42 ha), agroforestry (0.25 ha), homestead (0.14 ha) and others (0.03) (Fig. 2). The data indicate that agroforestry is being practiced in small scale means that the orchards are not being used for crop production. The orchards might be a good production unit if crops are grown in association with the trees.

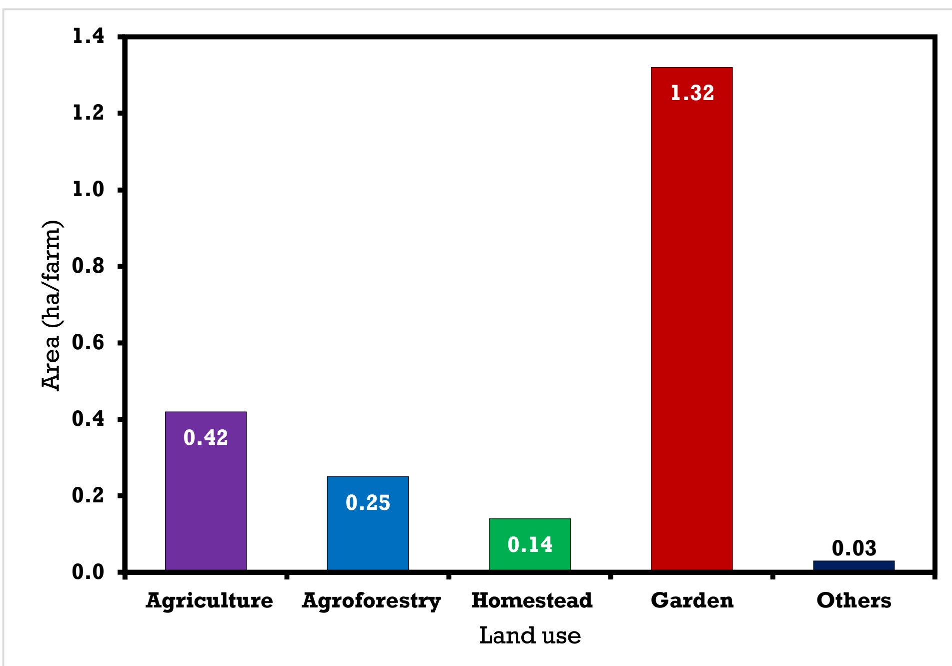

Fig. 2. Landuse pattern in the study area.

Land resource utilization for cropping: Figure 3 indicates the pattern of land resource utilization for crop production in the study area. It was noted that the respondents used their land resources throughout the year with some remarkable variations among the seasons. In the study area, Kharif-1 was the most important cropping season (94.00%) followed by Kharif-2 (79.00%) and Robi (52.00%). It was found that irrigation water was a big problem, particularly during the dry season. Therefore, the crop cultivation was less in Robi season compared to other seasons.

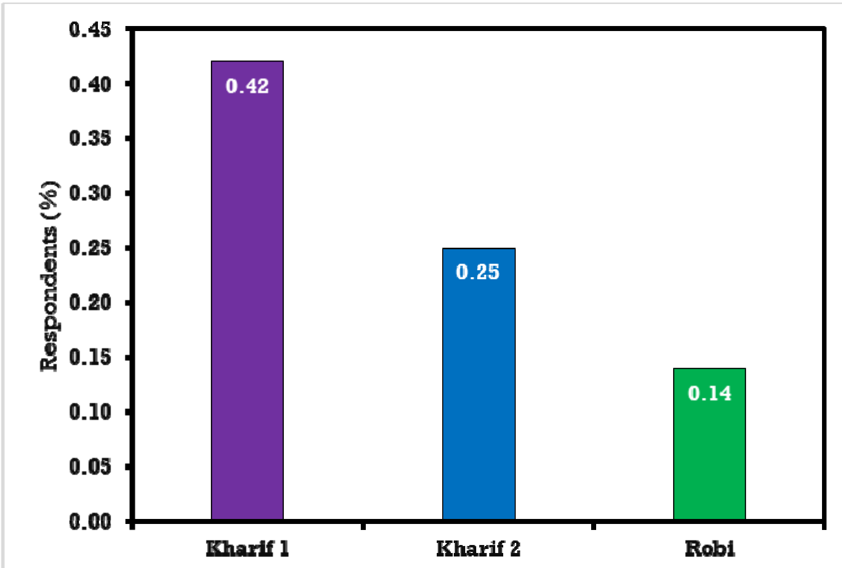

Fig. 3. Distribution of the respondents according to the seasonal pattern of crop production.

Training received on agroforestry or crop production: Status of training was recorded to know the knowledge level of the respondents on crop production. The findings revealed that most of the respondents (74%) did not get any training in the study area, while 26% respondents opined that they had training on crop production (Fig. 4).

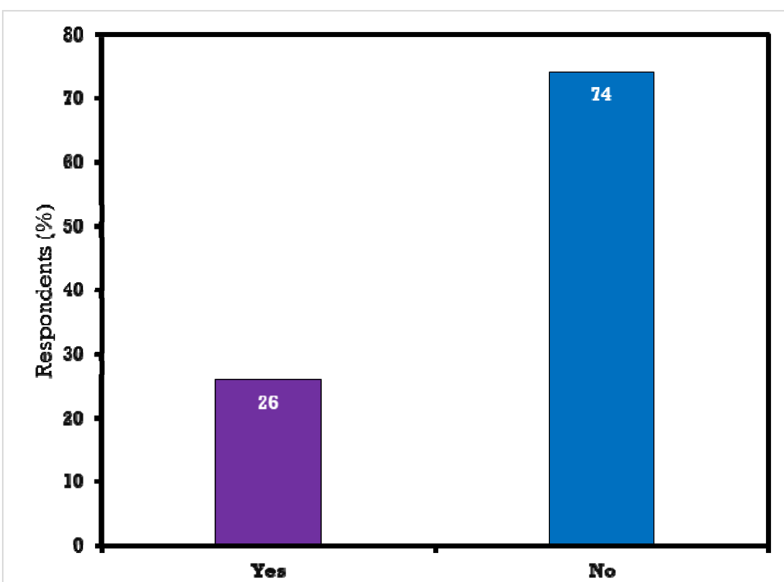

Fig. 4. Distribution of the respondents according to the training received on crop production.

Woman participation: The study revealed that about 62% of women did not participate in the production system, whereas 38% women were participating in the production system in the study area (Fig. 5). Since farming was found profitable in the study area, both men and women have been actively participating in various production systems. However, there is still ample scope to engage the woman in the production system that might have ensured high production and income generation at the household level.

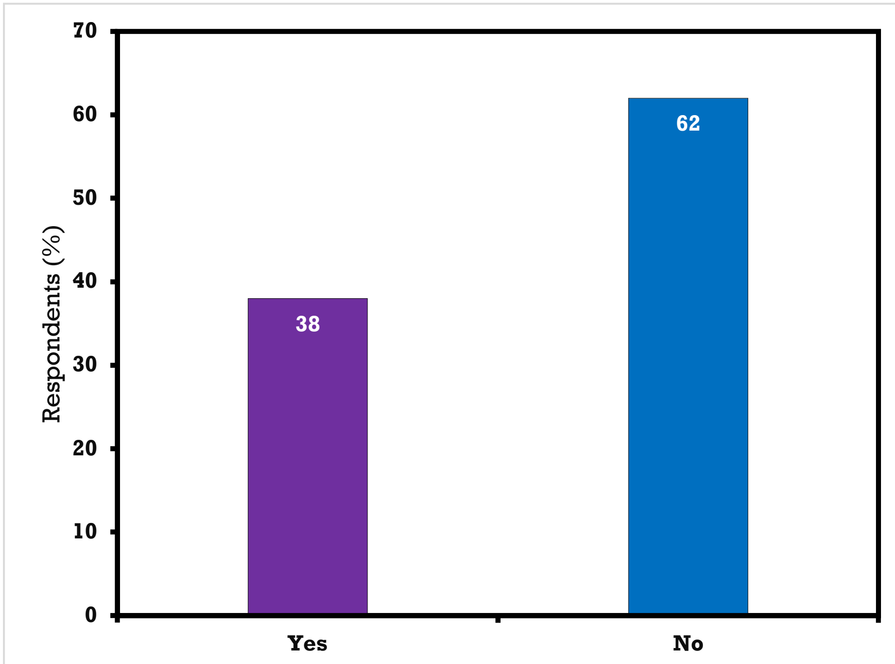

Fig. 5. Women participation in agroforestry practices.

Price level: More than 68% respondents opined that they were getting the desired price of their products, while more than 32% respondent did not get the desired price in the study area (Fig. 6). However, the study area is one of the high potential areas for vegetable production in Bangladesh. Due to good transportation facility with Dhaka and Narsingdi city, the price was quite better than other potentials areas. Although many farmers were satisfied with the price of the products, they were not satisfied with their production level.

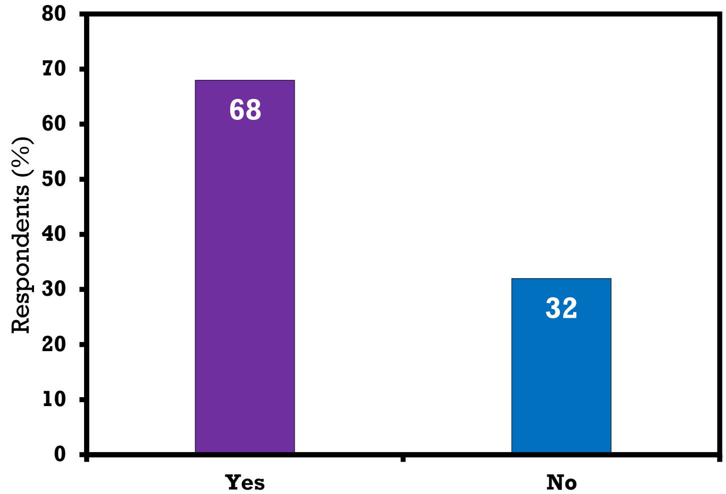

Fig. 6. Distribution of the respondents according to getting desired price of their farm commodities.

Estimation source of income: The annual income of the respondents varied remarkably in the study area (Table 2). Among different income sources, service, business, agricultural crop, fruit tree, forest tree, livestock and poultry and agroforestry contributed a lot to the annual income of the respondents. In the study area, fruit trees played a vital role in annual income, which was Tk 154175 followed by business (Tk. 124444), agricultural (Tk. 110363), service crop (Tk. 50223), forest tree (Tk. 11000), livestock and poulty (Tk. 17150) and agroforestry (Tk. 25608), respectively. However, income from other sources (Tk. 14106) was not at the desirable level, which might be due to low management parctices and lack of appropriate technologies.

Table 2. Source of annual income (Tk) of the respondent in study area

Sl. No.	Source	Income (Tk.)	Rank
1	Fruit tree	154175	1
2	Business	124444	2
3	Agricultural	110363	3
4	Service crop	50233	4
5	Forest tree	11000	5
6	Livestock and poultry	17150	6
7	Agroforestry	25608	7
8	Others	14106	8

Agroforestry systems

Dominant agroforestry system: Agroforestry systems widely varied in the study area (Table 3). Jackfruit based system was found dominant, where Jackfruit +Turmeric was the most frequent (50%) practice followed by Jackfruit + Ginger (16%), Jackfruit + Aroid (14%), Jackfruit + Eggplant (12%) and Jackfruit + Burmese Grape + Eggplant (8%). Table 3 also revealed that multistorey agroforestry systems were found in small scale.

Table 3. Dominant agroforestry systems in the study area

Sl. No.	Existing agroforestry systems	Respondent (%)	Rank
1	Jackfruit +Turmeric	50	1
2	Jackfruit + Ginger	18	2
3	Jackfruit + Aroid	14	3
4	Jackfruit + Eggplant	12	3
5	Jackfruit + Burmese Grape + Eggplant	6	4

Motivation on adopting agroforestry: Respondents were asked about first-time motivation in agroforestry and it was observed that most of the respondents (88%) learned it from the neighbour, while 12% respondents were self-motivated in the study area (Fig. 7).

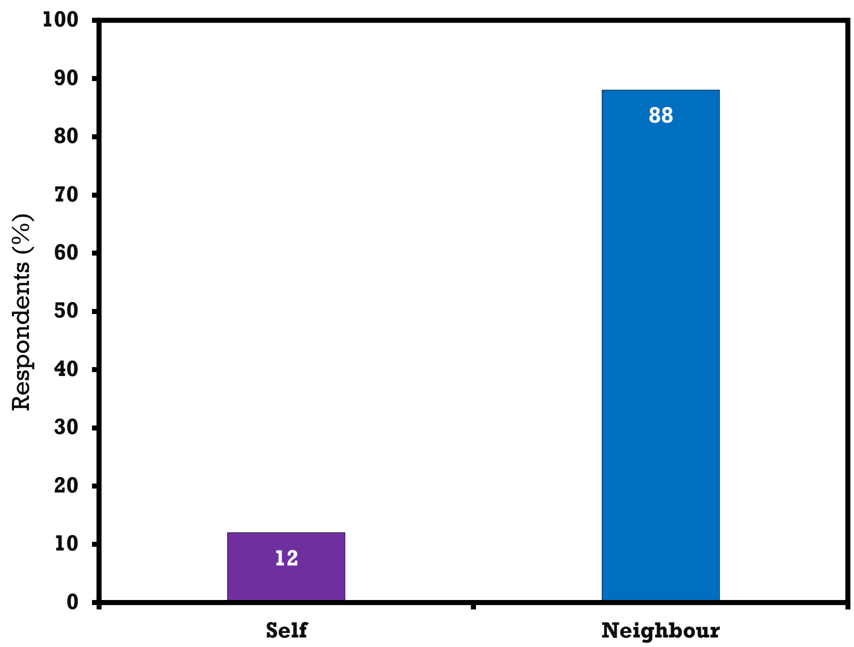

Fig. 7. Distribution of the respondent according to motivation in practicing agroforestry.

Desired yield from agroforestry: The respondents who were practicing agroforestry opined differently on getting the desired yield from the production system (Fig. 8). Most of the respondents (71%) reported that they were not getting desired crop yield as because they had been practicing mostly in a traditional way and did not manage the systems properly. However, 29% of the respondents opined that they were getting desired crop yield because of practicing agroforestry systematically with different fruit tree (Lemon, Malta,Guava, jackfruit, Burmease grape etc.).

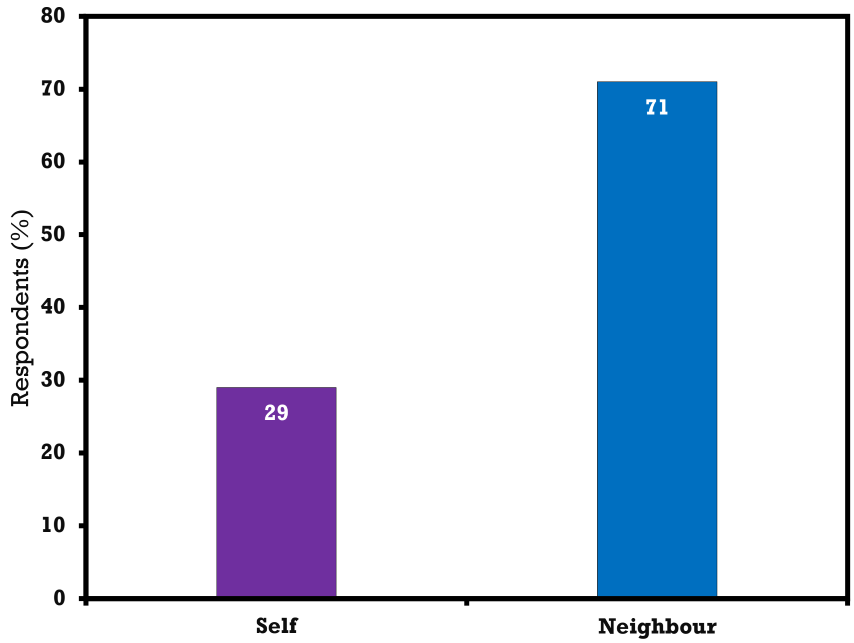

Fig. 8. Distribution of the respondent in getting desired yield from agroforestry.

Reason for not getting desired yield: A number of reasons had been identified behind not getting desired yield (Table 4). Among those, lack of irrigation facilities (51.13%) was the major reason followed by infestation of insect and diseases (42%), lack of modern technology i.e. spatial arrangement, proper combination of crops, suitable desing of agroforestry practice etc. (37.32%), fruit dropping (30.65%), lacks of improved management practices (28.30%), lack of good variety (26.13%), lack of judicious use of pesticides (13.14%) and vertebrate pests (7%) were opined by the farmers for not getting desired yield.

Table 4. Reason for not getting desired yield from agroforestry in study areas opined by respondent

Sl. No.	Reason	Respondent (%)	Rank
1	Lack of irrigation facilities	51.13	1
2	Infestation of insects and diseases	42.00	2
3	Lack of modern technology	37.32	3
4	Fruit dropping	30.65	4
5	Lack of improved management practices	28.30	5
6	Lack of good variety	26.13	5
7	Lack of judicious use of pesticides	13.14	6
8	Vertebrate pests	7.00	7

Suitable crop species: Most of the respondents opined that turmeric (74.56%) was the most suitable species for agroforestry practice. Aroid under Jackfruit trees was also widely found as most profitable crop, next to turmeric by 70% respondents, while ginger (56.33%), eggplant (40.66%), papaya (23%), bottle gourd (19.25%), chili (15.66%), bitter gourd (11.29%), yard-long bean (9.33%), lemon (9.33%) and okra (5.66%) were also reported as suitable crops (Table 5). This finding is also good agreement with Michon et al., 1983).

Table 5. Suitable crops for agroforestry systems in study areas

Sl. No.	Crop	Respondent (%)	Rank
1	Turmeric	74.56	1
2	Aroid	70.00	2
3	Ginger	56.33	3
4	Egg plant	40.66	4
5	Papaya	23.00	5
6	Bottle gourd	19.25	6
7	Chili	15.66	7
8	Bitter gourd	11.29	8
9	Yard long bean	9.33	9
10	Lemon	9.33	9
11	Okra	5.66	10

Overall yield advantage: In the study area, mostly Jackfruit based agroforestry system was identified as the good one, where farmers were getting benefit from this practice. Moreover, some multistorey agroforestry systems were identified as profitable systems in the study area. Among the systems, Jackfruit + Burmese grape + Turmeric was the most beneficial system (45%) followed by Jackfruit + Turmeric (38%), Jackfruit + Ginger (33%), Jackfruit + Burmese grape + Aroid (32.57%), Jackfruit + Egg plant (30.36%), Jackfruit + Burmese grape + Egg plant (30.33%), Burmese grape + Ginger (24%) and Jackfruit + Gourd (21%). Therefore, overall benefit was relatively higher in Jackfruit + Burmese grape + Turmeric compared to other multistorey agroforestry systems (Table 6).

Table 6. Overall yield advantage from agroforestry pactice in study site

Sl. No.	Agroforestry practice	Overall, benefit (%)	Rank
1		45.00	1
2	Jackfruit + Turmeric	38.00	2
3	Jackfruit + Ginger	33.00	3
4	Jackfruit + Burmese grape + Aroid	32.57	4
5	Jackfruit + Egg plant	30.36	5
6	Jackfruit + Burmese grape + Egg plant	30.33	6
7	Burmese grape + Ginger	24.00	7
8	Jackfruit + Gourd	21.00	8

Management practice: In the study area, most of the respondents (92%) opined that they did not do much management practices, while 8% of the respondents opined that they used to do intensive management practice in agroforestry system (Fig. 9). This might be due to lack of training and awaremess.

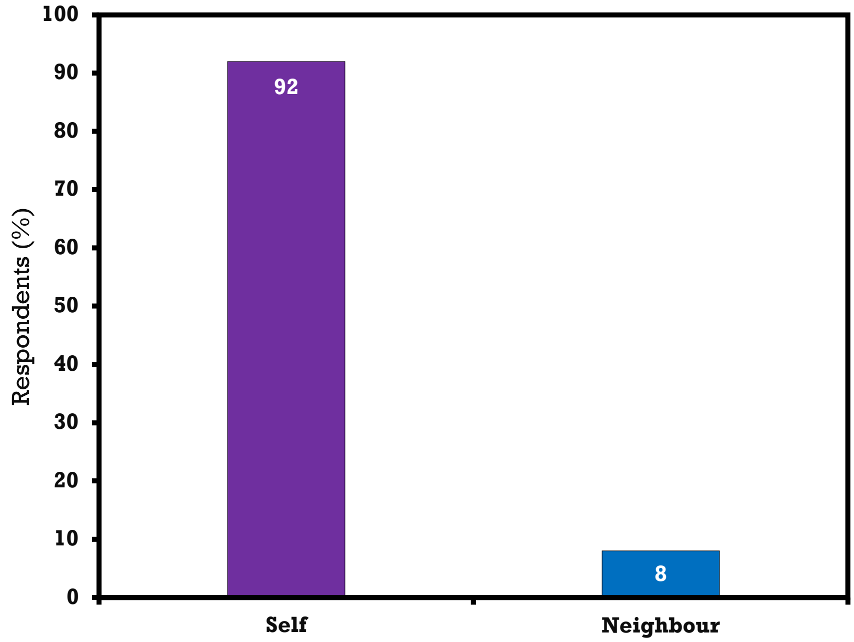

Fig. 9. Opinion of the respondents on management practcie followed in agroforestry systems.

Soil fertility improvement through agroforestry system: Improvement of soil fertility is one of the major objectives of the agroforestry practices. Most of the respondents (87%) opined that soil fertility improvement and reduction of soil erosion were the main aspects of soil conservation through practicing agroforestry by addition of organic matter. On the other hand, 13% respondents opined that the soil fertility did not improve due to the practice of agroforestry (Fig. 10).

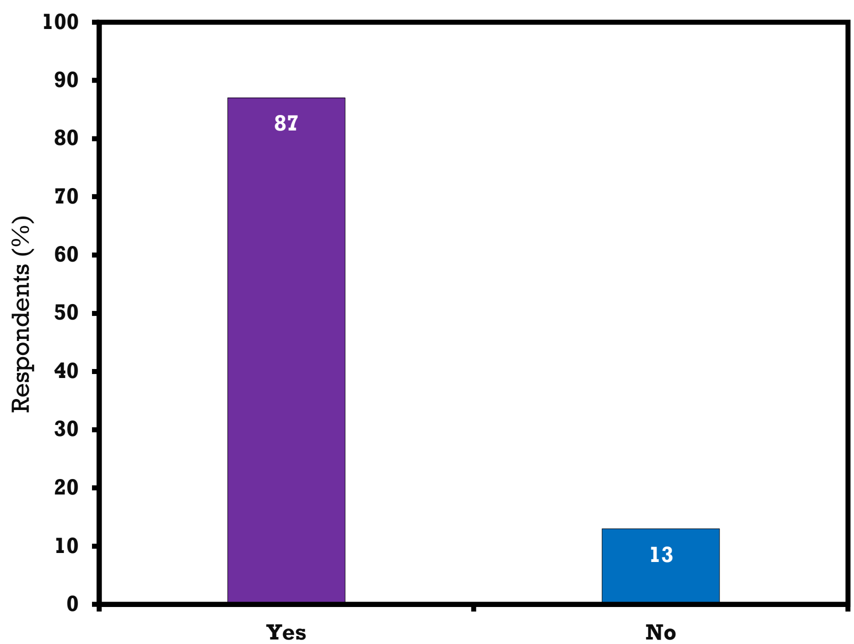

Fig. 10. Distribution of the respondents according to improvement of soil fertility due to agroforestry practice.

Environmental benefit: It is widely believed that agroforestry has the potentiality to retain good environment as the service function. Likewise, a significant number of respondents (90%) opined that they were getting environmental benefits from agroforestry practices. 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 was other benefits. Rest of the respondents (10%) did not have experience any environmental benefit from agroforestry practices (Fig. 11).

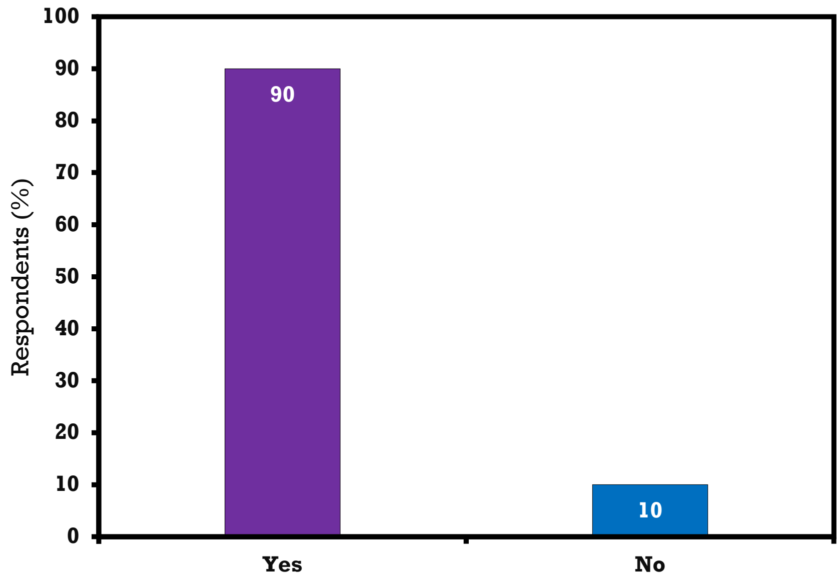

Fig. 11. Distribution of the respondents according to getting environmental benefit from agroforestry practices.

Assistance needed: Respondents identified some issues where they needed assistance to increase the productivity of agroforestry system. Assistance in providing training (70%) was the most important issue as opined by the respondents followed by supply of quality seed and Irrigation (41.67%), pesticide (40%), quality planting materials (35%), technology (28.33%), financial support (22%), agricultural inputs (15%) and soil test (10.00%) (Table 7).

Table 7. Assistance need to increase the productivity of agroforestry practices in study area

Sl. No.	Sector	Respondent (%)	Rank
1	Training	70.00	1
2	Quality seed	41.67	2
3	Irrigation	41.67	2
4	Pesticides	40.00	3
5	Quality planting materials	35.00	4
6	Technology	28.33	5
7	Financial support	22.00	6
8	Agricultural inputs	15.00	7
9	Soil test	10.00	8

Problem: Respondents reported various problems in practicing agroforestry in the study area. Among different problems, availability of irrigation was the major one (70.34%) followed by disease (60.67%). Insect infestation (42.67%) and Immature fruit and leaf dropping (20.65%) were some other problems also reported by the respondents in the study area (Table 8).

Table 8. Problems encounterd by the respondents in the study area

Sl. No.	Problem	Respondent (%)	Rank
1	Availability of irrigation	70.34	1
2	Disease	60.67	2
3	Insect infestation	42.67	3
4	Immature fruit and leaf dropping	20.65	4

Advantage of agroforestry: Advantages of agroforestry were expressed by the respondents in the study area that are presented in Table 9. Year round production (67%) and higher income (65%) were two major advantages, while the supply of fuel (51.60%), less fertilizer requirement (9.34%) and increase soil fertility (8.34%) were some other advantages.

Table 9. Advantages of practicing agroforestry systems in study area

Sl. No.	Advantage	Respondent (%)	Rank
1	Year round production	67.00	1
2	Higher income	65.00	2
3	Fuel supply	51.60	3
4	Less fertilizer required	9.34	4
5	Increase soil fertility	8.34	5

Plate: Benchmark survey


Plate: Selection of fields

11.2 Performance of field crops in multistory agroforestry system (MAFS)

Aroid: Plant height of aroid varied significantly in agroforestry system in comparison to that of non-agroforestry system. However, aroid plant height was enhanced by 21.81, 19.34, 12.69 and 5.64%, respectively at 1, 2, 3, and 4m distance from the tree base, when equated with sole aroid field. In contrast, number of leaves was reduced by 11.35, 11.14, 10.48, and 4.80%, respectively, and number of suckers per hill was attenuated by 34.71, 31.65, 27.52, and 22.12%, respectively at 1, 2, 3, and 4m distance from the tree base in comparison to that of non-agroforestry field as a control. Yield-contributing features of aroid also reduced in agroforestry systems compared to sole aroid field. Nonetheless, distant regimes of 1, 2, 3, and 4m from tree base caused notable reduction in corm weight (26.34, 18.27, 11.96 and 9.25%, respectively), cormel number per hill (43.30, 35.77, 29.23 and 18.66%, respectively), total cormel weight per hill (43.06, 40.73, 31.33, 27.02%, respectively), cormel yield (43.09, 40.76, 31.32, and 27.07%, respectively), and corm yield (26.42, 18.23, 11.87, and 9.20%, respectively) relative to that of sole aroid field.

Plate: Performances of aroids

Table 10. Effects of multistorey agroforestry system (MAFS) on plant height, leaves number per plant, suckers number per hill including yield-contributing attributes of aroids

Treatment	Plant height at 130 DAS (cm)	Number of leaves per plant at 130 DAS	Number of suckers per hill during harvest	Individual corm wt. (g)	Number of cormel per hill	Total cormel weight per hill (g)	Cormel yield (ton ha^{-1})	Corm yield (ton ha^{-1})
1m	116.23±1.55a (+21.81)	4.06±0.03b (-11.35)	3.63±0.14c (-34.71)	73.48±2.12d (-26.34)	11.00±0.62d (-43.30)	160.58±3.57c (-43.06)	9.63±0.21c (-43.09)	4.40±0.12d (-26.42)
2m	113.87±1.69a (+19.34)	4.07±0.04b (-11.14)	3.80±0.17c (-31.65)	81.53±2.19c (-18.27)	12.46±0.70cd (-35.77)	167.15±4.92c (-40.73)	10.02±0.29c (-40.76)	4.89±0.13c (-18.23)
3m	107.53±2.23b (+12.69)	4.10±0.05b (-10.48)	4.03±0.08bc (-27.52)	87.83±1.79b (-11.96)	13.73±0.61c (-29.23)	193.67±9.04b (-31.33)	11.62±0.54b (-31.32)	5.27±0.10b (-11.87)
4m	100.80±1.30c (+5.64)	4.36±0.12ab (-4.80)	4.33±0.14b (-22.12)	90.53±1.59b (-9.25)	15.78±0.59b (-18.66)	205.80±5.03b (-27.02)	12.34±0.30b (-27.07)	5.43±0.09b (-9.20)
Sole aroid	95.42±1.43c	4.58±0.13a	5.56±0.12a	99.76±3.01a	19.40±0.70a	282.01±3.99a	16.92±0.23a	5.98±0.18a

Values are means ± standard errors (n = 3). Values in parentheses indicate percent change of the respective parameters. Different alphabetical letters as superscripted above standard errors within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) ($P < 0.05$).

Ginger: Irrespective of different distance, the plant height of ginger increased gradually with increasing days after sowing (DAS). However, the highest relative value of plant height was observed at 1m distance by 22.81% followed by 2m (by 18.90%) and 3m (by 12.42%) at 210th DAS, in comparison to that of ginger field as a control. The relative plant height at 4m distance were not significant enough as compared to that of sole ginger field. The number of tillers, rhizome weight per hill and yield of ginger augmented by 11.27, 35.10 and 34.78%, respectively at a distance of 4m from the tree base relative to that of sole ginger plot. However enhanced rhizome weight per hill as well as yield per ha was also noted in 2m (9.66 and 10.23%, respectively) and 3m (27.37 and 27.91%, respectively) distance away from tree base, in compared to sole ginger field. Regrettably, reduced number of tiller by 17.17 and 3.21% were recorded at 1, and 2m distance, correspondingly, from the base of the tree in comparison to that of non-agroforestry ginger field as a control, with the exception of highest relative tiller number (4.50%) at 3m.

Table 11. Plant height and yield-contributing characters of ginger in agroforestry and sole-ginger system

Treatments	Plant height at 210 days (cm)	Number of tillers per hill	Rhizome weight per hill (g)	Yield (ton ha^{-1})
1m	66.33 ±3.15a (+22.81)	9.55 ±0.29b (-17.17)	60.46 ±2.42d (-19.85)	5.74± 0.23d (-19.49)
2m	64.22 ±2.85a (+18.90)	11.16 ±0.72ab (-3.21)	82.72 ±1.62b (+9.66)	7.86± 0.15b (+10.23)
3m	60.72 ±3.36b (+12.42)	12.05 ±0.82ab (+4.50)	96.08 ±2.76a (+27.37)	9.12± 0.26a (+27.91)
4m	57.89 ±2.30b (+7.18)	12.83 ±0.78a (+11.27)	101.19±1.33a (+35.10)	9.61± 0.12a (+34.78)
Sole ginger	54.01 ±2.45c	11.53 ±0.24ab	75.43 ±2.64c	7.13± 0.25c

Values are means ± standard errors (*n* = 3). Values in parentheses indicate percentage change of the respective parameters. Different alphabetical letters as superscripted above standard errors within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) (P < 0.05).

Plate: Performances of ginger

Turmeric: Irrespective of distant regimes, progressive increment of turmeric plant height was observed with increasing days after sowing (DAS). Nevertheless, utmost enhancement of plant height was observed at 1m distance by 14.61%, followed by 2m (by 9.47%) and 3m (6.74%) on 210th DAS, as compared with that of sole turmeric as a control. The relative plant height at 4m distance were not significant enough in comparison to that of non-agroforestry turmeric field. In comparison to that of non-agroforestry field, increasing rate of tiller number by 4.47 and 2.87%, rhizome weight by 6.15, 14.66 and 14.91%, and yield by 6.83, 15.41 and 15.80% were found in correspond to 2, 3, and 4m distance, respectively from tree base, with the exception of relatively lowest number of tiller (0.64%) at 2m distance. However, these parameters were reduced by 16.69, 1.17 and 0.64%, respectively at 1m distance from the base of the tree as compared to mono-crop field.

Table 12. Plant height and yield-contributing characters of turmeric in agroforestry and sole turmeric field

Treatments	Plant height at 210 DAS (cm)	Number of tillers per hill	Rhizome wt. per hill (g)	Yield (ton/ha)
1m	111.55 ±5.54a (+14.61)	2.61 ±0.52a (-19.92)	114.77 ±2.25c (-1.17)	10.17 ± 0.18c (-0.78)
2m	106.55 ±4.16b (+9.47)	3.11 ±0.11a (-0.64)	123.27 ±3.49b (+6.15)	10.95 ±0.30b (+6.83)
3m	103.89 ±4.30c (+6.74)	3.27 ±0.14a (+4.47)	133.16 ±4.96a (+14.66)	11.83 ±0.44a (+15.41)
4m	101.78 ±4.89c (+4.57)	3.22 ±0.11a (+2.87)	133.44 ±4.06a (+14.91)	11.87 ±0.36a (+15.80)
Sole turmeric	97.33 ±4.79d	3.13 ±0.08a	116.13 ±2.17c	10.25 ±0.24c

Values are means ± standard errors (*n* = 3). Values in parentheses indicate percent change of the respective parameters. Different alphabetical letters as superscripted above standard errors within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) ($P < 0.05$).

Plate: Performances of turmeric

Cabbage: To assess the influence of different distances from the tree base of MAFS on the growth performance of cabbage was evaluated by examining several growth-related parameters (Table 13). The fresh weight of plant was reduced by 50.78, 41.42, 40.78, and 36.90%, while the noticeable enhancement (17.28, 11.26, 6.34, and 4.48%, respectively) was recorded in number of outer leaves, in response to different distant regimes (1, 2, 3, and 4m, respectively, away from the tree base), in comparison to sole cropping systems. However, different distances (1, 2, 3, and 4m, respectively) from the tree base resulted in a significant reduction of leaf weight (42.61, 38.31, 37.97, 34.93%, respectively), leaf length (9.41, 8.23, 7.05, 5.88%, respectively), and leaf width (26.25, 21.25, 20.00, 16.25%, respectively) compared to non-agroforestry plots. To assess the yield response of cabbage, different yield contributing characters were recorded. In comparison to sole cropping system, significant reduction of head weight (55.64, 43.28, 41.26, 36.75%, respectively), head length (34.71, 26.74, 22.99, 20.73%, respectively), head width (20.39, 13.86, 13.53, 10.27%, respectively), and yields (56.05, 43.76, 41.74, 37.28%, respectively) was recorded at 1, 2, 3 and 4m distance from the tree base.

Plate: Performances of cabbage

Table 13. Effect of jackfruit based MAFS on different morphological and yield contributing characters of cabbage

Distance from tree base	Fresh weight of plant (g)	Number of outer leaves	Single Leaf weight (g)	Leaf length (cm)	Leaf width (cm)	Head weight (g)	Head length (cm)	Head width (cm)	Yield (ton ha^{-1})
1m	914.70±12.78c (-50.78)	20.33±0.76a (+17.28)	14.63±0.36c (-42.61)	25.66±0.33c (-9.41)	19.70±0.33d (-26.25)	606.70±10.34c (-55.64)	14.17±0.34c (-34.71)	8.13±0.18c (-20.39)	21.65±0.37c (-56.05)
2m	1088.70±111.12bc (-41.42)	19.28±0.61ab (+11.26)	15.72±1.03bc (-38.31)	26.00±0.57bc (-8.23)	21.00±0.58c (-21.25)	775.70±96.39bc (-43.28)	15.90±0.92b (-26.74)	8.80±0.32b (-13.86)	27.69±3.43bc (-43.76)
3m	1100.70±85.23bc (-40.78)	18.43±0.47bc (+6.34)	15.81±0.97bc (-37.97)	26.33±0.70bc (-7.05)	21.33±0.33c (-20.00)	803.33±74.50b (-41.26)	16.71±0.58b (-22.99)	8.83±0.37b (-13.53)	28.68±2.66b (-41.74)
4m	1172.70±88.10b (-36.90)	18.11±0.29cd (+4.48)	16.58±0.99b (-34.93)	26.70±0.33b (-5.88)	22.33±0.33b (-16.25)	865.00±77.59b (-36.75)	17.20±0.52b (-20.73)	9.17±0.33b (-10.27)	30.88±2.78b (-37.28)
Sole cabbage	1858.70±14.63a	17.33±0.33d	25.49±1.36a	28.33±0.33a	26.70±0.33a	1367.70±20.43a	21.70±0.26a	10.21±0.04a	49.23±0.73a

Values are means ± standard errors (*n* = 3). Values in parentheses indicate percent change of the respective parameters. Different alphabetical letters as superscripted above standard errors within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) ($P < 0.05$).

Chilli: Plant height of chilli increased progressively with increasing days after transplanting (DAT). Initially after 30 DAT, plant height did not vary significantly in terms of distance regimes. Irrespective of DAT, relatively highest increments of plant height were obtained at 1 and 2 m distant regimes compared to 2 and 3 m distances, when cumulatively equated with that of monocrop field (Fig. 12). However, plant height was noticeable enhanced by 11 and 10% at day 45th, 20 and 13% at day 60th, 20 and 16% at day 75th, 17 and 13% at day 90th, 18 and 14% at day 105th, 21 and 15% at day 120th, 22 and 17% at day 135th, and 22 and 17% at day 150th in respect of 1 and 2m distances from tree base, respectively, in compassion to that of non-agroforestry field.

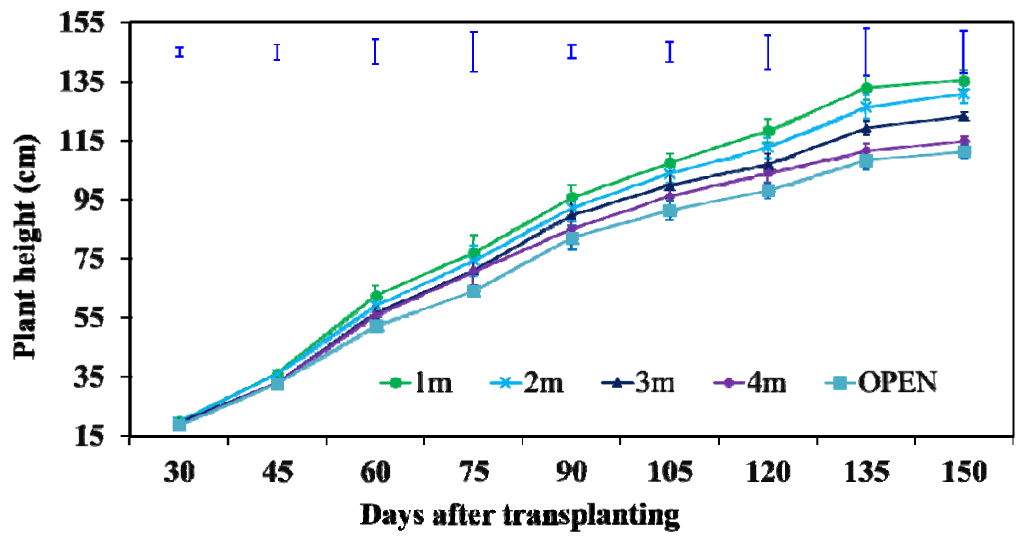

Fig. 12. Plant height of chilli at different measurement periods in agroforestry and monocrop field. Vertical bars indicate ± LSD. DAT, days after transplanting.

To appraise the morphological and yield performance of chilli, we have determined different features that acts as a key driving force to influence yields like-number of-branches and fruit, fruit length and width, and fruit weight. Nevertheless, different distant regimes from the base of the tree have strong influence on chilli yield. Distance from the tree base at 1, 2, 3, and 4m, respectively reduced the primary branches of chilli by 20, 20, 12, and 10% and secondary branches by 12, 7, 9 and 2%, relative to that of non-agroforestry field. In comparison with that of monocrop field, number of fruits reduced by 32, 19, 5, and 1% respectively, in 1, 2, 3, and 4m distance from tree base. The individual fruit weight reduced by 0.43 and 1% in correspond to 2 and 3m distance, respectively from the tree base, with the exception of same fruit weight at 1m and increased fruit weight (0.21%) at 4m distance. Intriguingly, fruit length was enhanced by 0.62, 0.37 and 0.12% and fruit width by 2.57, 2.10 and 2.03%, respectively, in response to 1, 2, 3, and 4m distance from the tree base, when compared with sole cropping plots, with the exception of low fruit length (0.24%) at 2m and same fruit diameter at 1m distance. All of these features lead to dropped fresh yield per plant by 32, 19, 6 and 0.92%, respectively at 1, 2, 3, and 4m distance from the tree base as compared with that of non-agroforestry field as a control.

Table 14: Morphological and yield-contributing characters of chilli in agroforestry and sole cropping system

Treatment	Primary Branches	Secondary Branches	No. of Fruit	Single Fruit Weight (g)	Fruit Length (cm)	Fruit Diameter (mm)	Fresh yield per plant (g)	Yield (ton ha^{-1})
1m	5.70±0.22b (-20.39)	19.70±0.51c (-12.48)	163.33±0.08d (32)	4.55±0.04a	8.08± 0.36a (+0.62)	12.80±0.20a	742.5 ±0.53d (-32.45)	20.56 ±0.30d (-32.50)
2m	5.72±0.30b (-20.11)	20.83±0.60bc (-7.46)	195.67±0.04c (19)	4.53 ±0.02a (-0.43)	8.01 ±0.30a (-0.24)	13.13±0.17a (+2.57)	893.2 ±1.42c (-18.79)	24.73 ±0.82c (-18.81)
3m	6.33±0.39b (-11.59)	20.53±0.59bc (-8.79)	229.00±0.07b (5)	4.52±0.04a (-1.00)	8.06 ±0.25a (+0.37)	13.07± 0.14a (+2.10)	1035.4 ±1.17b (-5.78)	28.68 ±0.67b (-5.84)
4m	6.44±0.24ab (-10.05)	21.97±0.17ab (-2.39)	238.67±0.08a (1)	4.56 ±0.04a (+0.21)	8.04 ±0.20a (+0.12)	13.06± 0.12a (+2.03)	1089.7 ±1.84a (-0.92)	30.17 ±1.06a (-0.95)
Sole chilli	7.16±0.08a	22.51±0.57a	241.00±0.05a	4.55±0.03a	8.03 ±0.30a	12.80± 0.17a	1099.9 ±0.97a	30.46±0.56a

Values are means ± standard errors (n = 3). Values in parentheses indicate percent change of the respective parameters. Different alphabetical letters as superscripted above standard errors within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) (P < 0.05).

Plate: Performances of chilli

Bottle gourd: To evaluate the growth performance of bottle gourd, different parameters were studied that has been presented in Table 15. In respect to non-agroforestry field as control, agroforestry practices caused remarkable decrease in fruit length (18.12, 18.23, 8.38, and 16.11%, respectively), fruit diameter (13.65, 16.28, 13.04, and 15.24%, respectively), number of fruits per plant (20.05, 25.79, 14.31, and 17.13%, respectively), individual fruit weight (13.88, 20.55, 7.22, and 14.44%, respectively), fruit yield in single plant (31.17, 40.75, 20.40, and 29.17%, respectively), and fruit yield in ha (31.16, 40.75, 20.42 and 29.17%, respectively) in east, north, south and west direction, respectively, in comparison to that of mono-crop field condition.

Table 15. Growth and yield attributes of bottle gourd in jackfruit-based agroforestry system and open plot

Orientation	Fruit length (cm)	Fruit diameter (cm)	Number of fruits per plant	Individual fruit weight (kg)	Fruit yield per plant (kg)	Yield (t/ha)
East	28.60±0.52 c (18.12)	14.16±0.23 b (13.65)	9.33±0.33bc (20.05)	1.55±0.04bc (13.88)	14.44±0.25 c (31.17)	23.83±0.42 c (31.16)
North	28.56±0.54 c (18.23)	13.73±0.08 b (16.28)	8.66±0.33c (25.79)	1.43±0.02c (20.55)	12.43±0.32 d (40.75)	20.51±0.53 d (40.75)
South	32.00±1.19 b (8.38)	14.26±0.41 b (13.04)	10.00±0.05 b (14.31)	1.67±0.04ab (7.22)	16.70±0.43 b (20.40)	27.55±0.72 b (20.42)
West	29.30±0.46 c (16.11)	13.90±0.20 b (15.24)	9.67±0.33bc (17.13)	1.54±0.04bc (14.44)	14.86±0.41 c (29.17)	24.52±0.68 c (29.17)
Sole bottle gourd	34.93±0.71 a	16.40±0.52 a	11.67±0.33 a	1.80±0.02a	20.98±0.39 a	34.62±0.65 a

Values are means ± standard errors (*n* = 3). Values in parentheses indicate percent reduction of the respective parameters. Different alphabetical letters as superscripted above standard errors within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) (*P* < 0.05).

Plate: Performances of bottle gourd

Bitter gourd: Bitter gourd performance was evaluated by analyzing various parameters that has been presented in Table 16. Yield contributing characters of bitter gourd varied remarkably in non-agroforestry field and agroforestry practices. With respect to monocrop field, agroforestry practices led to noticeable reduction in fruit length (21.81, 11.20, 22.75, and 6.67%, respectively), fruit diameter (16.53, 15.73, 17.33, and 12%, respectively), number of fruits per plant (32.11, 23.44, 28.40, and 23.44%, respectively), individual fruit weight (35.89, 14.52, 25.00, and 13.39%, respectively), fruit yield in single plant (56.52, 34.42, 46.01, and 33.69%, respectively) and fruit yield per ha (56.16, 34.32, 46.01, and 33.44%, respectively) in east, north, south and west direction, respectively.

Table. 16. Yield characters of bitter gourd grown in MAFS and open field

Orientation	Fruit length (cm)	Fruit diameter (cm)	Number of fruits per plant	Individual fruit weight (g)	Fruit yield per plant (kg)	Yield (t/ha)
East	13.26±0.29d (21.81)	3.13±0.08b (16.53)	18.33±0.88c (32.11)	65.57±4.50d (35.89)	1.20±1.42c (56.52)	5.44±0.64c (56.16)
North	15.06±0.59c (11.20)	3.16±0.08b (15.73)	20.67±1.33b (23.44)	87.43±2.56b (14.52)	1.81±1.59b (34.42)	8.15±0.71b (34.32)
South	13.10±0.10d (22.75)	3.10±0.11b (17.33)	19.33±0.88bc (28.40)	76.70±2.96c (25.00)	1.49±1.26c (46.01)	6.70±0.55c (46.01)
West	15.83±0.43b (6.67)	3.30±0.05b (12)	20.67±0.88b (23.44)	88.57±3.86b (13.39)	1.83±1.52b (33.69)	8.26±0.68b (33.44)
Sole bitter gourd	16.96±0.17a	3.75±0.08a	27.00±1.15a	102.27±1.13a	2.76±1.10a	12.41±0.49a

Values are means ± standard errors (*n* = 3). Values in parentheses indicate percent reduction of the respective parameters. Different alphabetical letters as superscripted above standard errors within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) ($P < 0.05$).


Plate: Performances of bitter gourd

Sweet gourd: Growth performance of sweet gourd was evaluated by assessing various parameters has been presented in Table 17. In comparison to mono cropping condition, agroforestry practices led to decrease in fruit length (18.91, 20.63, 5.93, and 17.08%, respectively), fruit diameter (12.21, 13.08, 6.11, and 10.43%, respectively), number of fruits per plant (38.14, 38.14, 23.86, and 28.57%, respectively), individual fruit weight (16.02, 20.44, 6.63, and 15.47%, respectively), fruit yield in single plant (44.04, 50.59, 28.57, and 40.17%, respectively), and fruit yield per ha (43.98, 50.61, 28.54 and 40.11, respectively) in east, north, south and west direction, respectively.

Table 17. Yield and yield contributing attributes of sweet gourd in jackfruit based MAFS and open plot

Orientation	**Fruit length (cm)**	**Fruit diameter (cm)**	**Number of fruits per plant**	**Individual fruit weight (kg)**	**Fruit yield per plant (kg)**	**Yield (t/ha)**
East	16.00±0.26b (18.91)	25.16±0.36b (12.21)	4.33±0.33b (38.14)	1.52±0.04bc (16.02)	7.09±0.58c (44.04)	14.19±1.16c (43.98)
North	15.66±0.53b (20.63)	24.91±0.65b (13.08)	4.33±0.33b (38.14)	1.44±0.07c (20.44)	6.26±0.50c (50.59)	12.51±1.00c (50.61)
South	18.56±0.49a (5.93)	26.91±0.60ab (6.11)	5.33±0.33b (23.86)	1.69±0.02ab (6.63)	9.05±0.72b (28.57)	18.10±1.45b (28.54)
West	16.36±0.49b (17.08)_	25.67±0.50b (10.43)	5.00±0.57b (28.57)	1.53±0.07bc (15.47)	7.58±0.54bc (40.17)	15.17±1.09bc (40.11)
Sole sweet gourd	19.73±0.29a	28.66±1.22a	7.00±0.57a	1.81±0.04a	12.67±0.74a	25.33±1.00a

Values are means ± standard errors (*n* = 3). Values in parentheses indicate percent reduction of the respective parameters. Different alphabetical letters as superscripted above standard errors within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) ($P < 0.05$).

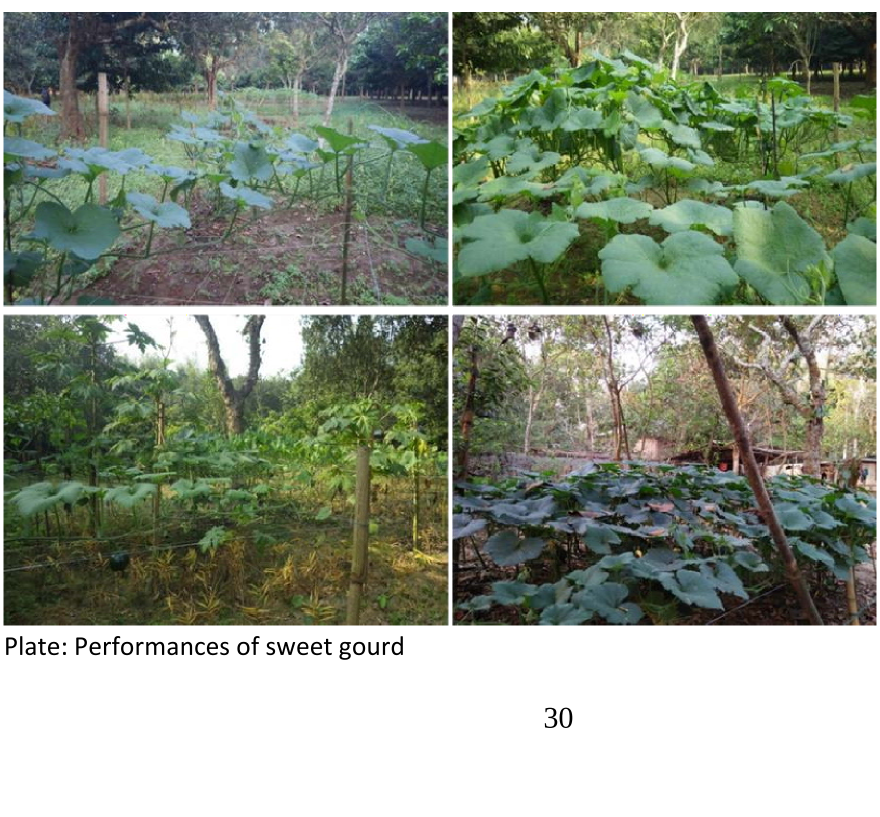

Plate: Performances of sweet gourd

Papaya: Jackfruit based MAFS had a negative effect on yield-contributing features of papaya. Nevertheless, managed jackfruit orchard in association with aroid, turmeric, ginger, chilli and cabbage resulted in a decreased number of-fruits per plant (25.39, 28.96, 26.78, 18.57, and 15.10%, respectively), -fruit weight (3.57, 3.52, 1.53, 1.79, and 2.15%, respectively), -fruit length (11.98, 11.79, 5.18, 6.60, and 7.26%, respectively) and fruit diameter (5.81, 5.53, 4.40, 4.75, and 5.46%, respectively) as well as -yield per plant (28.80, 31.46, 27.86, 19.99, and 16.92%, respectively) in comparison to that of non-regulated open field. It is worth to mention that higher number of papaya plants can be amassed in one hectare of open filed in comparison to that of agroforestry practices due to spacing factor, which lead to massive yield reduction by 56.22, 58.29, 56.14, 51.33, and 49.47%, respectively in aroid, turmeric, ginger, chilli, and cabbage- amalgamated jackfruit orchard.

Table 18. Yield and yield contributing attributes of papaya in different crop-associated MAFS and open field

Parameter	Jackfruit-Aroid-Bitter gourd-Papaya	Jackfruit-Turmeric-Bottle gourd-Papaya	Jackfruit-Ginger-Sweet gourd-Papaya	Jackfruit-Chilli-Papaya	Jackfruit-Cabbage-Papaya	Sole Papaya
Number of fruits per plant	21.53± 0.54cd (25.39)	20.50±0.64d (28.96)	21.13±0.88cd (26.78)	23.50±0.52bc (18.57)	24.50±0.60b (15.10)	28.86± 0.92a
Single fruit weight of papaya (g)	687.50± 9.08b (3.57)	687.83±4.73b (3.52)	702.03±1.41ab (1.53)	700.17±4.14ab (1.79)	697.57±3.44ab (2.15)	712.97±7.16a
Length of fruit (cm)	18.66± 0.68b (11.98)	18.70±0.70b (11.79)	20.10±0.17ab (5.18)	19.80±0.17ab (6.60)	19.66±0.21ab (7.26)	21.20± 0.55a
Diameter of fruit (mm)	134.03± 1.53b (5.81)	134.43±1.57b (5.53)	136.03±1.1b (4.40)	135.53±0.84b (4.75)	134.53±1.39b (5.46)	142.3± 2.51a
Yield per plant (kg)	14.80± 0.39c (28.80)	14.09±0.48c (31.46)	14.83±0.60c (27.86)	16.45±0.35b (19.99)	17.08±0.35b (16.92)	20.56± 0.45a
Yield (ton/ha)	22.20± 0.58bc (56.22)	21.15±0.72c (58.29)	22.24±0.90bc (56.14)	24.68±0.53b (51.33)	25.62±0.52b (49.47)	50.71± 1.16a

Values are means ± standard errors (n = 3). Values in parentheses indicate percent reduction of the respective parameters. Different alphabetical letters as superscripted above standard errors within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) (P < 0.05).

Plate: Performances of papaya

Jackfruit: We evaluated several growth and yield-attributing characters of jackfruit both in the open field and under the MAFS in order to appraise the profitability of jackfruit. Since the experiment was performed in the already established jackfruit orchard, therefore, it encompasses different ages of tree in between the range of 10 to 36, which had greater influence on DBH and canopy area. However, external inputs like fertilizers, irrigated water and crop residues in MAFS helps to boost jackfruit yield-contributing characters, regardless in considering the age, DBH and canopy area. Associated intercultural operation in different crop fields like aroid, turmeric, ginger, chilli and cabbage enhanced the number of fruits per plant by 113.75, 113.65, 99.89, 51.60, and 82.73%, respectively in comparison to that of open field with no management practices. In contrast, individual fruit weight showed the opposite trend and reduced by 13.54, 48.48, 38.14, 14.17, and 19.95%, respectively, in the jackfruit orchard with the association of aroid, turmeric, ginger, chilli and cabbage. However, length of fruit increased by 3.78% and 9.02%, respectively in aroid- and cabbage-included jackfruit field, while turmeric, ginger and chilli-association resulted in 17.28, 3.27, and 8.60% reduction in compared to unmanaged open field as a control. On the other hand, diameter of fruits reduced by 17.62, 39.35, 35.87, 28.95 and 6.62%, respectively, in aroid, turmeric, ginger, chilli and cabbage-associated jackfruit orchard, when compared with the open non-supervised field. Interestingly, in comparison to that of open field, fruit yield boosted by 62.73, 7.92, 19.83, 12.78, and 54.96%, respectively in managed jackfruit orchard in association with aroid, turmeric, ginger, chilli and cabbage.

Plate: Performances of jackfruit

Table 19. Morphological, yield and yield contributing attributes of jackfruit in different crop-associated agroforestry systems

Parameter	Jackfruit-Aroid-Papaya	Jackfruit-Turmeric-Papaya	Jackfruit-Ginger-Papaya	Jackfruit-Chilli-Papaya	Jackfruit- Cabbage-Papaya	Open field
Age	26.66±7.69a	22.33±5.61a	20.33±6.44a	18.00±3.21a	22.00±6.81a	30.00±5.51a
DBH (cm)	41.66±10.11a	33.667±4.67a	31.66±4.98a	26.33±0.33a	34.66±8.75a	40.66±6.57a
Canopy Volume (m^3)	456.09±164.64a	374.42±123.27a	279.18±158.19a	183.91±23.94a	308.06±109.45a	512.35±44.16a
Number of fruits per tree	20.67± 6.23a (+113.75)	20.66±3.53a (+113.65)	19.33±3.28a (+99.89)	14.66±3.38a (+51.60)	17.67±8.22a (+82.73)	9.67±.88a
Single fruit weight of Jackfruit (g)	9.70±3.55a (-13.54)	5.78±0.78a (-48.48)	6.94±1.30a (-38.14)	9.63±3.15a (-14.17)	9.38±1.95a (-19.95)	11.22±1.43a
Length of fruit (cm)	42.20±2.65a (+3.78)	33.63±4.23a (-17.28)	39.33±4.48a (-3.27)	37.16±2.20a (-8.60)	44.33±2.62a (+9.02)	40.66±3.38a
Diameter of fruit (cm)	30.33±3.63a (-17.62)	22.33±3.84a (-39.35)	23.61±2.98a (-35.87)	26.16±3.34a (-28.95)	34.38±7.94a (-6.62)	36.82±6.88a
Yield per tree (kg)	173.25±37.58a (+62.73)	114.90±12.11a (+7.92)	132.80±24.42a (+19.83)	120.07±9.50a (+12.78)	164.98±83.17a (+54.96)	106.46±9.34a
Yield (ton/ha)	17.32±3.75a	11.49±1.21a	13.27±2.43a	12.00±0.94a	16.50±8.31a	10.64±0.93a

Values are means ± standard errors (n = 3). Values in parentheses indicate percent change of the respective parameters. Different alphabetical letters as superscripted above standard errors within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) ($P < 0.05$).

Economic and Land Use Performances of MAFS

To know the economic performance and land use in different crop-associated agroforestry systems over sole cropping, benefit cost ratio (BCR) and land equivalent ratio (LER) have been calculated. Proper management of jackfruit based MAFS improved the BCR significantly in comparison to that of non-agroforestry systems. Nevertheless, regular inspection and intercultural operation in aroid, ginger, turmeric, cabbage, chilli, bitter gourd, sweet gourd, and bottle gourd-associated jackfruit field elevated the BCR by 31.48, 31.57, 51.42, 32.71, 10.59, 27.39, 5.40, and 4.17%, respectively relative to that of sole cropping system. Amongst the different crop-associated jackfruit based MAFS, aroids-papaya-jackfruit system provide the highest LER (2.72) followed by bitter gourd-papaya-jackfruit (2.62), while the lowest was recorded in bottle gourd-papaya-jackfruit system (2.17).

Table 20. Economic and land use performance of Jackfruit based MAFS in comparison to mono-cropping system

System	Total Cost (TK/ha)	Gross Income (TK/ha)	Net return (TK/ha)	BCR	% increase of BCR	LER
Aroid + Papaya + Jackfruit	310962	664320	353358	2.13	31.48%	2.72
Ginger + Papaya + Jackfruit	420024	931260	511236	2.21	50.34%	2.81
Turmeric + Papaya + Jackfruit	349964	743700	393736	2.12	51.42%	2.57
Cabbage + Papaya + Jackfruit	314211	675820	361609	2.15	32.71%	2.60
Chilli + Papaya + Jackfruit	455625	1061230	605605	2.33	10.95%	2.47
Bitter Gourd + Papaya + Jackfruit	355782	662500	306718	1.86	27.39%	2.62
Sweet Gourd + Papaya + Jackfruit	335181	653924	318743	1.95	5.40 %	2.27
Bottle Gourd + Papaya + Jackfruit	350033	700200	350167	2.00	4.17%	2.17
Sole Aroid	160345	262040	101695	1.63	-	-
Sole Ginger	290407	427800	137393	1.47	-	-
Sole Turmeric	220347	307500	87153	1.40	-	-
Sole Cabbage	178594	288780	110186	1.62	-	-
Sole Chilli	333008	700580	367572	2.10	-	-
Sole Bitter Gourd	212165	310250	98085	1.46	-	-
Sole Sweet Gourd	191564	354620	163056	1.85	-	-
Sole Bottle Gourd	216416	415440	199024	1.92	-	-
Sole Papaya	343234	709940	366706	2.07	-	-
Sole Jackfruit	-	-	110200	-	-	-

Ecosystem service assessment in terms of microclimate modification and litterfall

The Multistoried agroforestry system had greater influence on the microclimate modification as evident in lower temperature and higher moisture. Nevertheless, in comparison to that of sole cropping system as control, MAFS reduce the soil temperature in turmeric (8.88, 7.29, 5.88, and 5.67%, respectively), ginger (7.76, 5.95, 4.64, and 3.76%, respectively), cabbage (13.25, 11.13, 9.82, 7.20%, respectively), chilli (12.13, 9.81, 8.58, and 6.44%, respectively) and aroid (8.11, 8.03, 6.78, and 5.28%, respectively) field at 1, 2, 3 and 4m distances, respectively, from the base of the tree. In contrast, soil moisture was enhanced by 23.85, 26.26, 23.31, 13.60, and 9.57% at 1m, 8.99, 24.86, 25.57, 16.69, and 23.74% at 2m, 4.79, 11.00, 9.26, 6.40, and 24.83% at 3m and 8.49, 19.02, 18.52, 12.97, and 12.96% at 4m in respect to turmeric, ginger, cabbage, chili, and aroid-associated MAFs, respectively. However, photosynthetically active radiation was increased with increasing distances from the tree base. In comparison to that of mono-crop field PAR, highest light interception was perceived at 4m by 30.37, 28.61, 38.10, 31.25 and 22.14%; followed by 3m by 20.26, 18.18, 31.11, 23.77 and 19.17%, while the lowest was recorded at 1m by 14.83, 13.03, 24.31, 16.91 and 14.45% in turmeric, ginger, cabbage, chilli and aroid-associated MAFs system (Fig. 13).

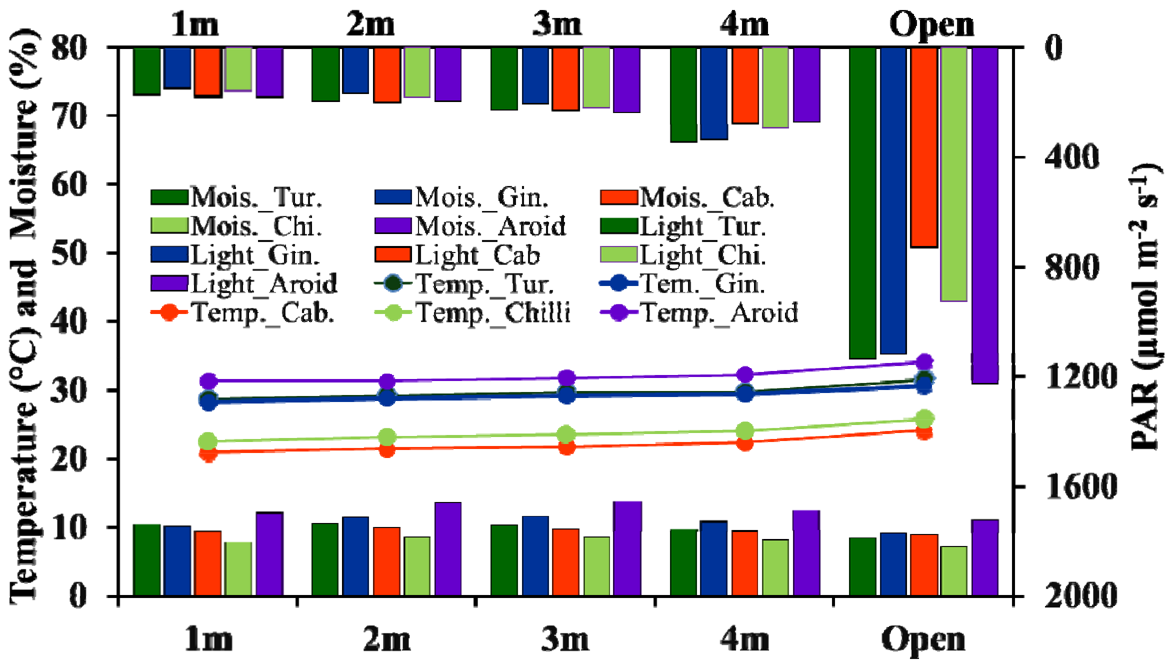

Fig. 13. Soil temperature, soil moisture and photosynthetically active radiation status in turmeric, ginger, cabbage, chilli and aroid-associated agroforestry system as well as mono-cropping system at different distant regimes amid the experimental period.

Since, we converted the existing jackfruit orchard to multistorey agroforestry systems, therefore, microclimates like-soil moisture, soil temperature and PAR was irregularly found at different orientation in response to sunlight inclination. However, relative to that of monocrop field, soil temperature was reduced by 11.25, 7.34, 9.22 and 9.67% in bottle gourd field, 14.63, 10.47, 10.94, and 7.27% in sweet gourd field, 11.12, 11.45, 17.59, and 6.80% in bitter gourd field in north, south, east and west orientation, respectively. In contrast, at north, south, east and west orientation, soil moisture was enhanced by 15.79, 7.56, 10.27, and 11.57%, respectively in bottle gourd, 18.42, 12.65, 13.43, and 11.99%, respectively in sweet gourd, and 16.10, 12.81, 20.52, and 8.84%, respectively in bitter gourd-associated MAFS, when compared with non-agroforestry field as an open plot. Nevertheless, percent light interception varied significantly in agroforestry practices in comparison to that of sole cropping PAR. Percent light interception in bottle gourd field was reduced by 39.54, 31.41, 52.86 and 37.31%, in sweet gourd field by 35.46, 48.05, 27.75, and 26.33%, and in bitter gourd field by 34.67, 29.85, 25.77, and 40.87% at north, south, east and west orientation, respectively, when compared with monocrop control field (Fig. 14).

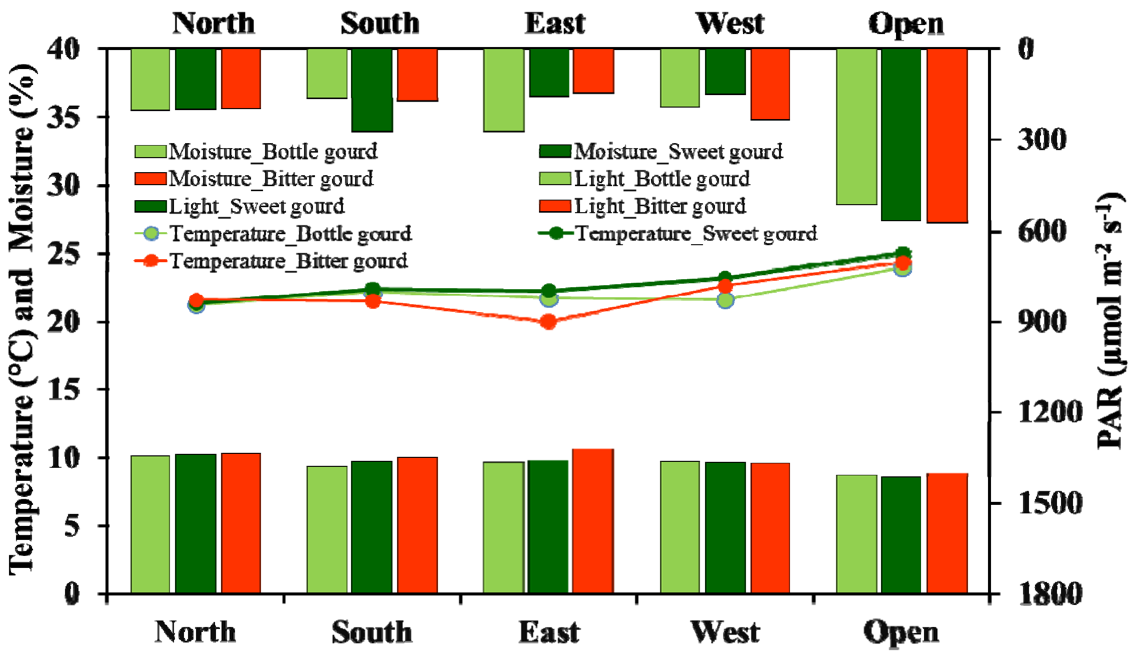

Fig. 14. Soil temperature, soil moisture and photosynthetically active radiation status in bottle gourd, sweet gourd, and bitter gourd-associated agroforestry system as well as mono-cropping system at different orientation regimes amid the experimental period.

Relationship between crop yields with photosynthetically active radiation

In order to find the association between crop yields with PAR, regression analysis was carried out. Linear relationships between ginger, turmeric and chilli yields with PAR represents weak-moderate association, while cabbage and aroid indicates strong association, and evident by r^2=0.018, 0.162, 0.436, 0.975, and 0.905, respectively. The regression line showed that ginger and turmeric yield was reduced by 0.0005 and 0.0008 t/ha in response to per unit changes of PAR, while cabbage, chilli and aroid yield was enhanced by 0.044, 0.007, and 0.006 ton ha^{-1}, respectively, with respect to per unit enhancement of PAR (Fig. 15).

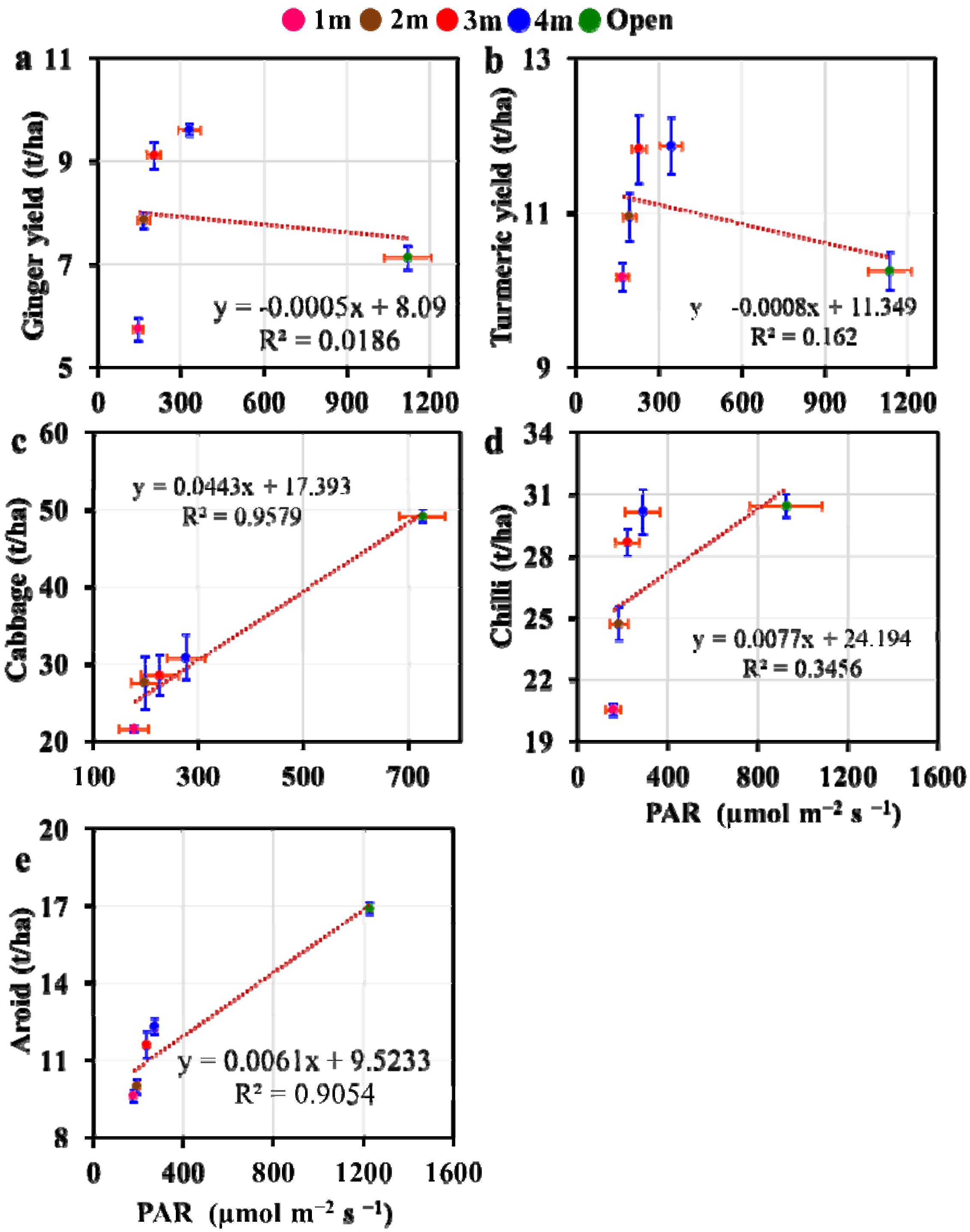

Fig. 15. Linear relationship of (a) ginger yield with PAR, (b) turmeric yield with PAR, (c) cabbage yield with PAR, (d) chilli yield with PAR, and (e) aroid yield with PAR in different distant regimes from the base of the tree. Vertical and horizontal bars indicate standard errors of three independent replications (*n*=3).

Vine type plant yield of-bitter gourd, bottle gourd, and sweet gourd were strongly and positively influenced by PAR and it was manifested by r^2 values of 0.91, 0.62, and 0.90, respectively. However, per unit changes of PAR resulted in 0.014, 0.029 and 0.027t enhancement of bitter gourd, bottle gourd, and sweet gourd yield, respectively.

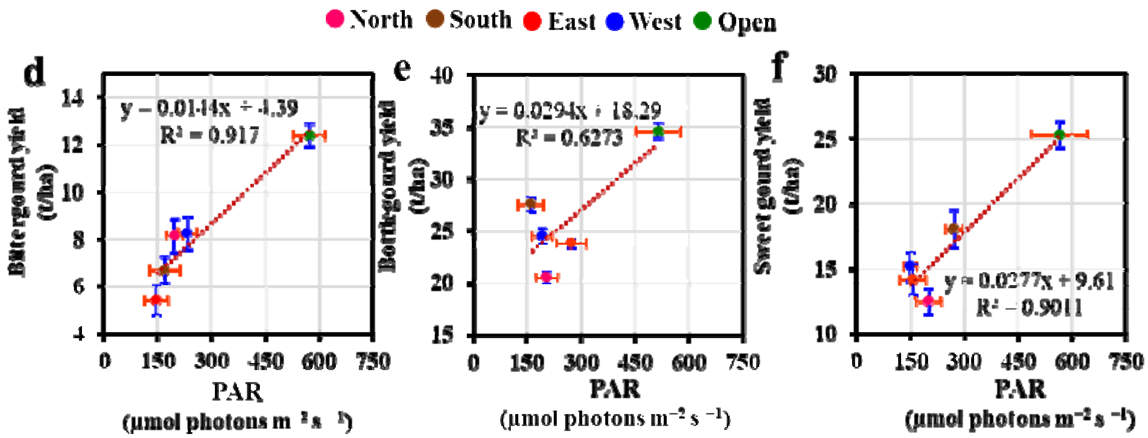

Fig. 16. Linear relationship of (a) bitter gourd yield with PAR, (b) bottle gourd yield with PAR, and (c) sweet gourd yield with PAR in different orientation regimes from the base of the tree. Vertical and horizontal bars indicate standard errors of three independent replications (*n*=3).

Litterfall in jackfruit based MAFS

During the experimental period, highest litterfall (3.64 kg) was obtained in the month of February, while lowest (0.99 kg) was recorded in August. Amongst five cropping patterns amid the experimental tenure, highest leaf litter (26.16 kg) was dropped in cabbage-papaya-jackfruit plot followed by aroid-bitter gourd-papaya-jackfruit combination, while the lowest litterfall (16.64 kg) was recorded in chilli-papaya-jackfruit fields (Fig. 17).

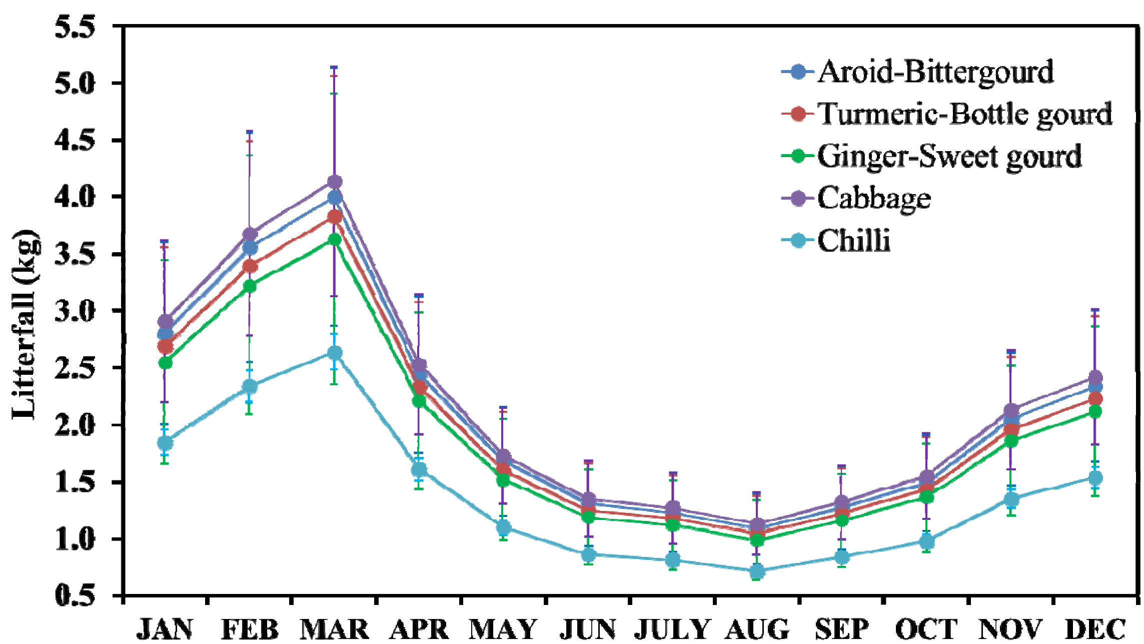

Fig. 17. Leaf litter accumulation in different crop-associated agroforestry systems.

Relationship amongst ground area, canopy area, age, litterfall and leaf nutrients

Ground area was intimately correlated with age, canopy volume and litter fall, and was apparent by higher r^2 values of 0.57, 0.60, and 1.00, respectively. Nevertheless, ground area has been increased by 2.98 and 0.09 m^2 in response to per unit changes of age and canopy volume, respectively. On the other hand, per unit changes of ground area increased the litterfall by 0.30 kg. It is worth to mention that N, OC, and OM content in the leaves of jackfruit were strongly and positively associated (r^2=1) with litter fall and per unit changes of litterfall might add 10.40, 52.41, and 90.15g of N, OC, and OM, respectively, to the soil (Fig. 18).

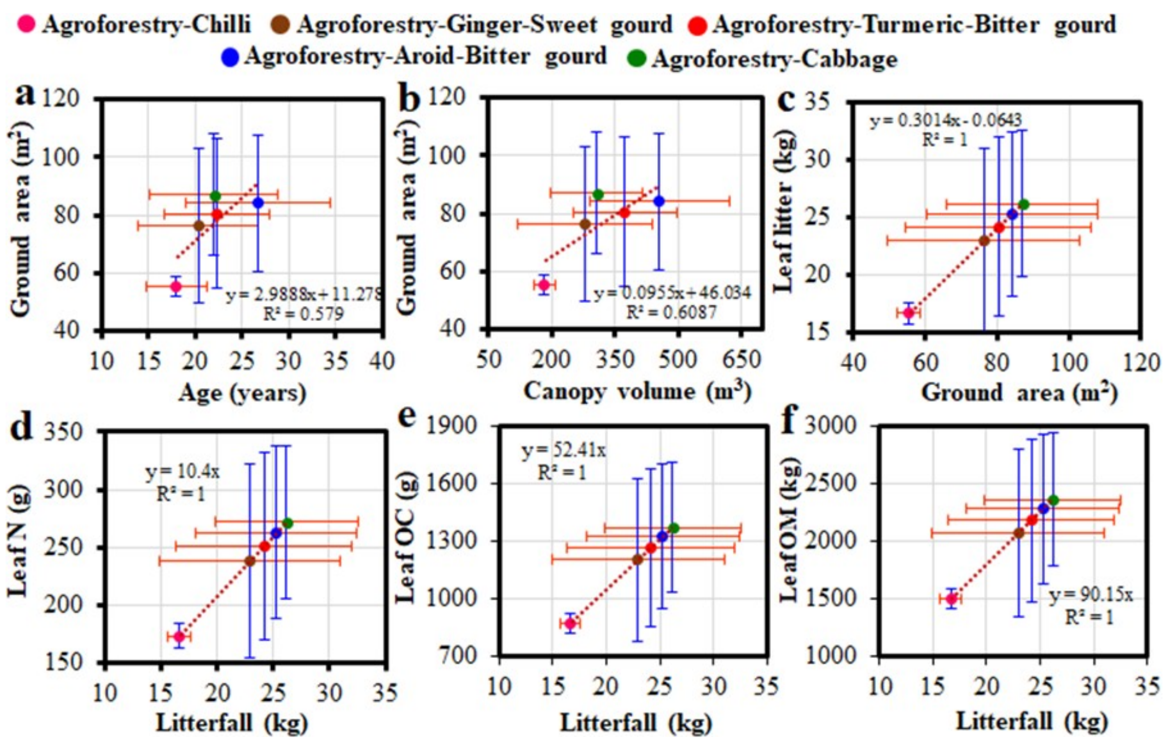

Fig. 18. Linear relationship of (a) ground area with age, (b) ground area with canopy volume, and (c) litterfall with ground area, (d) leaf N with litterfall, (e) leaf OC with litterfall, and (f) leaf OM with litterfall in different crop-associated agroforestry systems. Vertical and horizontal bars indicate standard errors of three independent replications (*n*=3).

Soil chemical properties

It was evident after field experimentation that jackfruit based-multistoried agroforestry systems influenced greatly to augment soil chemical properties in compared to sole cropping field. With respect to initial un-regulated monocrop field, soil pH was enhanced by 6.47, 5.96, 19.65, 8.50 and 9.86%, respectively in aroid, cabbage, turmeric-bottle gourd, chili, and ginger-sweet gourd-associated MAFS, while 5.66, 1.39, 12.17, 4.77 and 0.94% enhancement was recorded in respective monocrop field after experimentation. Nevertheless, pH of the soil of aroid, cabbage, turmeric-bottle gourd, chilli, and ginger- ackfruit orchard before transformation to MAFs. Similarly, soil organic matter (SOC) was also elevated in aroid (20.96%), cabbage (33.57%), turmeric-bottle gourd (22.84%), chilli (7.22%), and ginger-sweet gourd (13.47%)-associated MAFs as well as in respective monocrop field by 9.82, 8.74, 15.87, 3.97 and 8.26%, respectively, when compared to un-managed open field. SOC was also raised by 14.22, 21.11, 19.03, 3.12, 7.05, in the above-mentioned crop-associated agroforestry systems, respectively, relative to the soil of initial jackfruit orchard. A significant increase in the content of N and organic matter (OM) was also recorded in aroid (19.04 and 21.00%, respectively), cabbage (33.33 and 34.00%, respectively), turmeric-bottle gourd (22.35 and 23%, respectively), chilli (18.66 and 7.20%, respectively), and ginger-sweet gourd (18.18 and 13.00%, respectively)-associated MAFs over mono-cropped field, while enhanced of N (9.52, 6.41, 18.82, 9.33, and 10.38, respectively) and organic matter (9.80, 8.70, 16, 4.00, and 8.3, respectively) content was also recorded in respective monocrop field after experimentation. In compared to the soil of jackfruit orchard before converting to MAFS, soil N and OM was also increased in aroid (16.27 and 14.00%, respectively), cabbage (25.30 and 21.00%, respectively), turmeric-bottle gourd (15.55 and 19.00%, respectively), chilli (5.95 and 3.1%, respectively), and ginger-sweet gourd (2.24 and 7.1%, respectively)-associated MAFS after experimentation (Fig. 19).

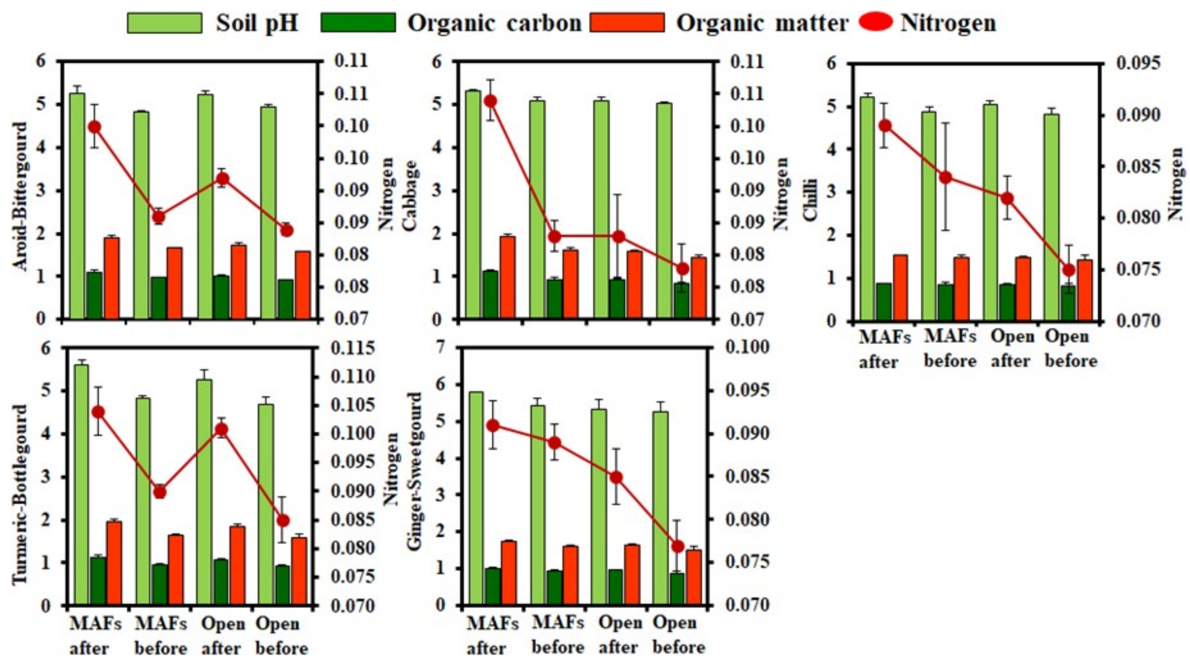

Fig. 19. Effect of Jackfruit based MAFS on the status of soil-pH, nitrogen, organic carbon and organic matter.

12. Research highlights/ findings:

- To get fruits, fuelwood, timber and various agricultural products as well as to bring back equilibrium in the ecosystem, the establishment of multi-layered cropping systems in the orchard is inevitable.
- The agroforestry techniques may be applied in the orchards of Jackfruit in central terrace ecosystem of Bangladesh.
- However, based on the field experiment regarding crop performances, it could be concluded that the growth performance of some crops might be declined.
- The findings of the study revealed that the yields papaya, aroid, chilli, cabbage, bitter gourd, bottle gourd and sweet gourd were reduced by 26.83, 32.58, 15.06, 43.20, 43.16, 30.25 and 40.75%, respectively, in MAFS than their respective sole cropping systems. On the other hand the yield of turmeric, ginger and jackfruit were increased by 8.19, 14.10 and 32.30%, respectively, in MAFS than sole cropping systems.
- Among the different crop-associated jackfruit based MAFS, turmeric-papaya-jackfruit provide highest BCR (51.42%) followed by cabbage-papaya-jackfruit (32.71%), while the lowest BCR was obtained in bottle gourd-papaya-jackfruit orchard (4.17%), when compared to un-managed open field.
- All of the crop-associated jackfruit based MAFS augment total N, organic carbon, organic matter and pH of soil, in compared to open unsupervised field.
- The jackfruit orchards and jackfruit-based agroforestry practices could be transformed into MAFS through introducing middle- and lower-story crops, preferably shade tolerant plants with proper management practices. This technique would be a sustainable production system for farmers as at least three components are grown together. If one component fails, other components may substitute. Moreover, jackfruit orchards will be more productive that will sustain the system.
- Similar study should be conducted with other middle- and lower-storey crops in other agroecosystems of Bangladesh.

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B. Implementation Position

1. Procurement:

Description of equipment and capital items	PP Target		Achievement		Remarks
	Phy (#)	Fin (Tk)	Phy (#)	Fin (Tk)	
(a) Office equipment	Desktop (1) Printer (1) Camera (1)	60,000 20,000 25,000	Desktop (1) Printer (1) Camera (1)	60,000 20,000 25,000	
(b) Lab &field equipment	Quantum PAR meter microbial sensor (1) Portable pH meter (1) Soil moisture and temperature meters (1) Mini Anemometer (1)	1,00,000 20,000 70,000 40,000	Quantum PAR meter microbial sensor (1) Portable pH meter (1) Soil moisture and temperature meters (1) Mini Anemometer (1)	1,00,000 20,000 70,000 40,000	
(c) Other capital items	Computer Table	5,000	Computer Table	5,000	

2. Establishment/renovation facilities:

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	
Water supply renovation and Balance repair			40,000	40,000	

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	738970	679489	676860	2629	92%	Fund shortage
B. Field research/lab expenses and supplies	704155	704155	704155	0	100%	
C. Operating expenses	205000	202735	202735	0	100%	
D. Vehicle hire and fuel, oil & maintenance	200000	200000	200000	0	100%	
E. Training/workshop/seminar etc.	0	0	0	0	100%	
F. Publications and printing	95000	15000	15000	0	16%	Fund shortage
G. Miscellaneous	50000	49805	49805	0	100%	
H. Capital expenses	360000	360000	360000	0	100%	
Total	**2353125**	**2211184**	**2208555**	**2629**		

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)
To expand the multistory agroforestry system (MAFS) with the introduction of middle- and lower-story crops in a jackfruit orchard for increasing diversified products	Benchmark survey Field experimentation by jackfruit orchards to multistorey agroforestry system (MAFS)	30 farmers were interviewed and they now understand that agroforestry can be practiced in jackfruit orchards. On-Farm experimentation was done on 15 farmers' fields and now they know that MAFS can ensure higher overall yields.	The benchmark information indicate that the peoples are interested to practice agroforestry systems but irrigation and labor paucity including lack of technical knowledge severely deprived them to engage in agroforestry. The agroforestry techniques may be applied in the orchards of Jackfruit in central terrace ecosystem of Bangladesh. Based on the field experiment regarding crop performances, it showed that the growth performance of understory crops was inhibited in MAFS. Most of the understory crops and middle-storey crops were inhibited in MAFS. However, jackfruit, ginger and turmeric yields were enhanced in MAFS.
To evaluate the economic and land-use performances of MAFS and compare with the conventional practices	Field experimentation by jackfruit orchards to multistorey agroforestry system (MAFS)	Farmers accepted the MAFS as they got higher income and overall production.	Higher benefit cost ratio (BCR) and land equivalent ration (LER) indicate that jackfruit based MAFS is more potential than conventional farming.
To investigate the ecosystem services in terms of microclimatic modifications and system dynamics of the MAFS	Field experimentation by jackfruit orchards to multistorey agroforestry system (MAFS). Laboratory analysis for soil and leaf samples	Two MS thesis have been produced. Two journal papers will be published.	Microclimates like soil moisture, soil temperature, and PAR was relatively favorable in MAFS than open field. Nonetheless, increasing trend of soil moisture, while decreasing trends of temperature and PAR were recorded in MAFS in compared to sole cropping system. Litterfall helps to improve soil fertility in MAFS.

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

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.		2 MS Thesis	Productivity, profitability and microclimatic modification in jackfruit based agroforestry system. Performance of different vegetable and spice crops in jackfruit based multistory agroforestry system.
Journal publication	4		Under process
Information development		1	Local Newspaper (The Daily Narsingdir Kagoj)
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 jackfruit orchards and sporadically they grow few crops. Therefore, they do not get real benefits from the orchards. The findings of this project have proved that the jackfruit orchards can be brought under agroforestry system and up-scaling for year-round production, high income and useful benefits. A productive multistorey agroforestry system (MAFS) model has been generated through this project.

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

Since various crops are grown together at different strata, it also creases favorable farm environment and improves ecosystem services. More middle-storey and lower-storey crops need to be tested. This model will be helpful for the other fruit orchards in different locations of Bangladesh.

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

In this study, jackfruit orchards were transformed to multistorey agroforestry system (MAFS) where jackfruit trees were kept as top-storey crop, papaya was introduced as middle-storey crop and different vegetable and spices crops were tested as lower-storey crops. Farmers got multiple products from the same land at the same time. Therefore, the total production and income of the farmers have increased remarkably. Higher BCR and LER also confirm the increased system productivity and farmer's income.

iv. Policy Support

The baseline information and findings of the On-Farm research may help policy makers, researchers and development workers for the improvement of 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.
- Weekly lab seminar was arranged with the MS students where the research progress was discussed.

ii) Field Monitoring (time& No. of visit, Team visit and output):

- Prof. Tofayel Ahamed, Treasurer of BSMRAU visited field once. He participated in a Field Day as Chief Guest and gave valuables suggestions to the farmers and research team.
- Prof. Dr. Satya Ranjan Saha, Co-PI of the project visited 7 times to the fields and each time he discussed with farmers and researchers including MS students and gave suggestions.
- Prof. Dr. Md. Abiar Rahman, PI of the project visited the fields every month along with the research team and closely monitored the field activities and other progresses.
- About 100 BS Agriculture students visited the research field as a part of their study tour. They have gathered practical knowledge from the visit.

I. Lesson Learned/Challenges (if any)

i) To get fruits, fuelwood, timber and various agricultural products as well as to bring back equilibrium in the ecosystem, the establishment of multi-layered cropping systems in the orchard is inevitable.

ii) The agroforestry practices can be improved by proper care and management practice, more research activity, cooperative and extension services etc., and replace low economic value crops by high economic value crops.

iii) Tree-crop interaction is important. Therefore, in-depth research works should be done to address the tree-crop interactions for improving the systems.

J. Challenges (if any)

- Heavy rainfall during rainy season restricts the crop production especially papaya.
- Lack of labor availability due to peak season of Burmese grape collection and marketing.
- Poor communication facilities.
- Hedgehog-induced crop damages.
- Some crops were stolen.
- Slow release of funds.

Signature of the Principal Investigator Date ……………………….. Seal	Counter signature of the Head of the organization/authorized representative Date ……………………….. Seal

Other Activities

Field day for the farmers

Field visit by BS (3rd Year) Agriculture Students of BSMRAU

Publicity

দৈনিক নরসিংদীর কাগজ

সত্যের সাথে সমান্তরাল

THE DAILY NARSINGDIR KAGAJ

শারদীয় দুর্গোৎসব সুষ্ঠুভাবে পালনে মতবিনিময় সভা অনুষ্ঠিত

দুর্গোৎসবকে ঘিরে কোন ধরনের অপ্রীতিকর ঘটনা সহ্য করা হবেনা

নরসিংদীর বিভিন্ন মহল্লায় অবৈধ গ্যাস সংযোগ ॥ প্রশাসন নিরব

দুর্নীতি বিরোধী চিত্রাংকন, রচনা প্রতিযোগিতা

আমরা একটি দুর্নীতি মুক্ত সমাজ গড়ে

দেড় শত ভিটেবাড়ী মেঘনা গর্ভে বিলীন

চানপুর ইউনিয়নের কালিকাপুর গ্রামে নতুন করে ভাঙ্গন শুরু

দীর্ঘ ৭ মাস পর নিহত মাদরাসা ছাত্রের কঙ্কাল উদ্ধার

শারদীয় দুর্গোৎসব উপলক্ষে নরসিংদী পুলিশের উদ্যোগে মতবিনিময়

করিমপুরে পুকা নিধনের ওষুধ খেয়ে দুই সহোদরের মৃত্যু

উদ্যোগে যক্ষা রোগ মতবিনিময় সভা

মাধবদী এসপি. ইনস্টিটিউশন পরিচালনা পরিষদের নির্বাচন শান্তি পূর্ণভাবে সম্পূর্ণ

বাস প্রাইভেটকার মুখোমুখী সংঘর্ষে নিহত ২, আহত ৩

বেলাবতে বঙ্গবন্ধু শেখ মুজিবুর রহমান কৃষি বিশ্ববিদ্যালয়ের মাঠ দিবস পালিত

দুলাল সরকারঃ গত শনিবার লাখপুরে বঙ্গবন্ধু শেখ মুজিবুর রহমান কৃষি বিশ্ববিদ্যালয়ের কৃষিবনায়ন ও পরিবেশ বিভাগের 'বহুমুখী উৎপাদন' অধিক আয় ও ইকোসিস্টেম সেবা প্রদানের নিমিত্তে বহুস্তর বিশিষ্ট কৃষিবনায়ন পদ্ধতির মনোন্নয়ন' শীর্ষক প্রকল্পের মাঠ দিবস পালিত হয়।

এতে উপস্থিত ছিলেন উক্ত বিভাগের অধ্যাপক ড. মো: আবিয়ার রহমান, অধ্যাপক ড. সত্য রঞ্জন সাহা, অধ্যাপক মো: তোফায়েল আহমেদ, জয়নগর ইউপি চেয়ারম্যান মো: নাজমুল হোসেন নান্নুসহ স্থানীয় কৃষকবৃন্দ এবং উক্ত বিশ্ব বিদ্যালয়ের ছাত্র-ছাত্রীবৃন্দ। প্রকল্পের অর্থায়ন করছে বাংলাদেশ কৃষি গবেষণা কাউন্সিলের জাতীয় কৃষি প্রশিক্ষণ কর্মসূচী পর্যায় মাঠ দিবসে কৃষকদের উদ্দেশ্যে বহুস্তর বিশিষ্ট কৃষিবনায়ন পদ্ধতির উৎপাদনশীলতা নিয়ে আলোচনা করা হয় এবং গবেষণা মাঠ প্রদর্শন করানো হয়। উক্ত পদ্ধতি অনুসারে বিজ্ঞানসম্মতভাবে চাষ করলে একই জমিতে বিভিন্ন ধরনের ফসল উৎপাদন করে কৃষক অধিক লাভবান হতে পারবে।