CHAPTER 1

INTRODUCTION

A total of 805 million people are undernourished worldwide (FAO *et al*., 2014). The need to produce food to feed the ever increasing population occupies a top priority in the agenda of many countries specially in the developing countries of the world (FAO, 2013). Globally food production systems are facing increasing challenges to meet the growing demands of a population expected to reach 9 billion people by 2050 (Vinceti *et al*., 2013). Despite advances in agricultural production globally, approximately one billion people are still chronically hungry, two billion people regularly experience periods of food insecurity and just over a third of humans are affected by micronutrient deficiencies (Girard *et al*., 2012). A household or individual who spends over 70% of one's total income on food is said to be poor and food insecure. Therefore, food security is of paramount importance (Ndaeyo, 2007). Food security is a situation that exists when all people, at all times have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2013). Individuals who are food secure do not live in hunger or fear of starvation. Food insecurity, on the other hand, is a situation of "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways" (USDA, 2013). Forests and trees can be conceptualized within food security dimensions as their availability contributes to direct food consumption, indirect income increase ability of individuals to purchase foods (CIFOR, 2014). It has been estimated that approximately 1.2-1.5 billion people are forest dependent (Chao, 2012 and Agrawal *et al*., 2013). Forests cover 31% of global land uses and only 30% of this is used in production of wood and non-timber forest products (NTFPs) that contributes to food systems of rural households (FAO, 2010). It is

also increasingly recognized that food from forests provides micronutrients and contributes to dietary diversity, thereby supporting a shift away from calorific intake as the primary metric for food security, towards a broader understanding of nutritionally-balanced diets (FAO, 2013). Forests provide not only food items, they are also critically important for providing fuel for cooking. In developing countries, 2.4 billion households still use conventional biofuels (firewood, charcoal, crop-residues and cattle dung) for cooking and heating (Modi et al., 2005). To feed the population of 9 Billion people by 2050, the food production needs to increase by 70% (Sharma et al, 2016). According to Young (1989), considering high population growth rates, increasing poverty levels and scarcity of land, the need for technologies that would boost food production including crops and animals, forest and wood products as well as sustaining the use of land cannot be over emphasized. The international concern is to find alternative farming systems that are ecologically and economically sustainable and culturally acceptable by the farmers. Agroforestry is one such an alternative. Agroforestry is a sustainable agricultural system being widely promoted all over the world, especially in Sub-Saharan Africa (Thangata *et al.*, 2002). Several development experts have recommended agro-forestry as a new solution to rural development needs (Rocheleau *et al.*, 1989). Agroforestry has a large and important role to play in improving present and future food security worldwide. Agroforestry is the practice and science of the interface and interactions between agriculture and forestry, involving farmers, livestock, trees and forests at multiple scales" (ICRAF, 2013). Throughout the world many farmers have long recognition on the importance of trees and they almost invariably incorporate trees in production systems in areas where they have lived for an extended period of time (Sène, 1985 and Hoskins, M. 1990). Agroforestry systems with agriculture crops, trees and livestock farms generate wide range of social and environment benefits to 1.2 billion people for enhancing

food production (Jamnadass *et al.* 2013). The roles of forests and trees uses are increasingly recognized as critically important for foods and income sources of large rural population in Bangladesh (Miah *et al.* 2012; Rahman *et al.* 2014). In the last two decades, Bangladesh has increased national capacity for securing food access of large population (GoB, 2013). Though level of poverty and number of hungry people declined, food security still remains challenge due to population growth and limited land for cultivation. Agriculture practices cover 60% of land uses and provide essential foods to two-third of population in Bangladesh. But, lack of crop diversification or dietary diversity hinders availability of micro-nutrient rich foods (GoB, 2013). Some woody species also provide diversified outputs for smallholder farmers in the form of fuel wood and poles. In some cases, agroforestry technologies such as fruit trees can provide a more diverse farm income and reduce food insecurity (Thangata *et.al*, 2002). However agroforestry supports food and nutritional security through the direct provision of food, by raising farmers' incomes and providing fuel for cooking, and through various ecosystem services.

OBJECTIVES OF THE STUDY

- To explore the food insecure and undernourished people in the world,
- To evaluate the contribution of agroforestry system in food production and income generation for food security.

CHAPTER 2
MATERIALS AND METHOD

This seminar paper is exclusively a review paper so all of the information has been collected from the secondary sources. During preparation of this paper, I went through various relevant books, journals, reports, publications etc. Findings related to my topic have been reviewed with the help of the library facilities of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU). I have also searched related internet web sites to collect information. I got valuable suggestion and information from my major professor and course instructors. After collecting all the available information, I myself compiled and prepared this seminar paper.

CHAPTER 3

REVIEW OF FINDINGS

3.1 Food security

Food security is a situation that exists when all people, at all times have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2011). Individuals who are food secure do not live in hunger or fear of starvation. Food insecurity, on the other hand, is a situation of "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways" (USDA, 2013). Both population growth and prevailing undernourishment are highly localized in Asia (65.6%) and Africa (29.8%) (FAO *et al.,* 2015).

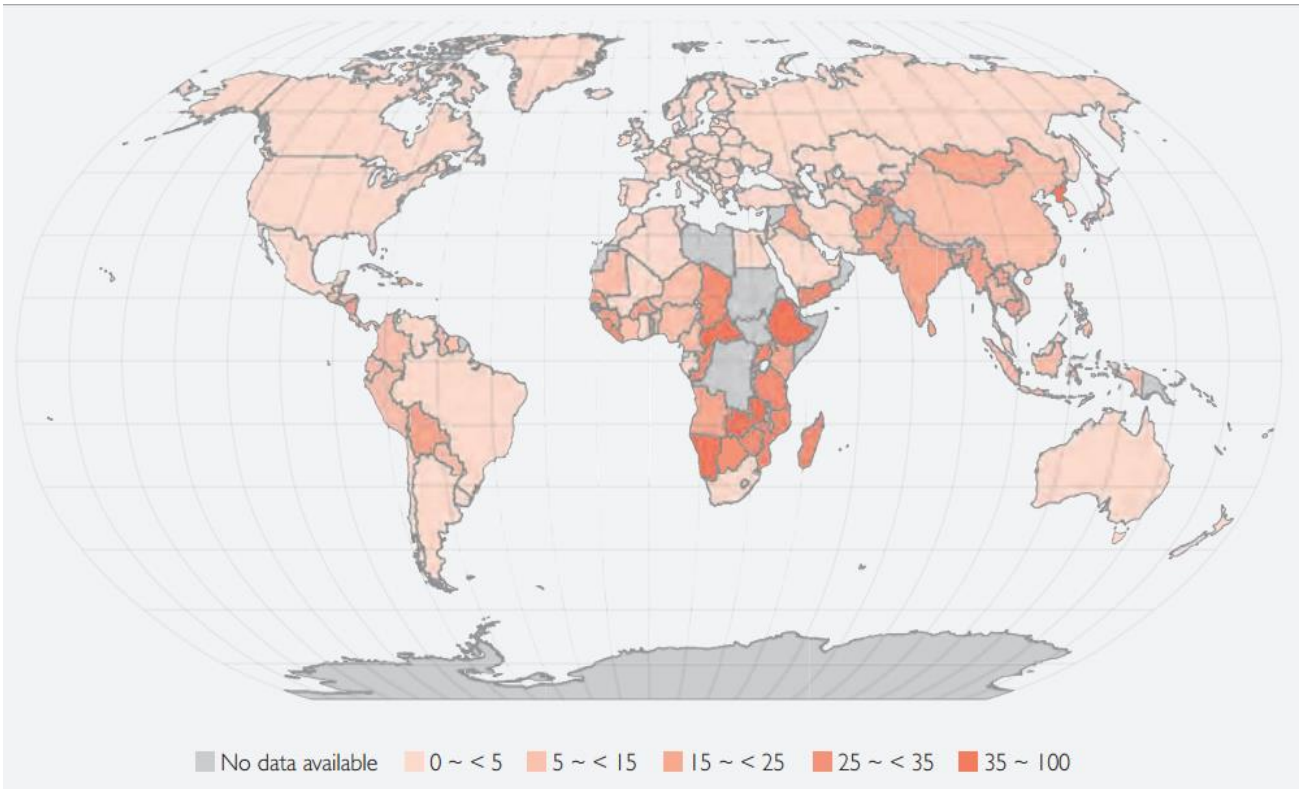


Figure 1(a): Prevalence of undernourished people (percent, 2012-14). **Source**: FAO, 2014b.

FAO, 2009 reported that the number of undernourished people is higher in Asia and the Pacific region (566.2 million), in terms of percentage the prevalence is clearly higher in sub-Saharan Africa. This generally shows that out of its total population of 716.3 million, sub-Saharan Africa has a greater proportion of hungry people (212.3 million), accounting for 29.64% of its total population

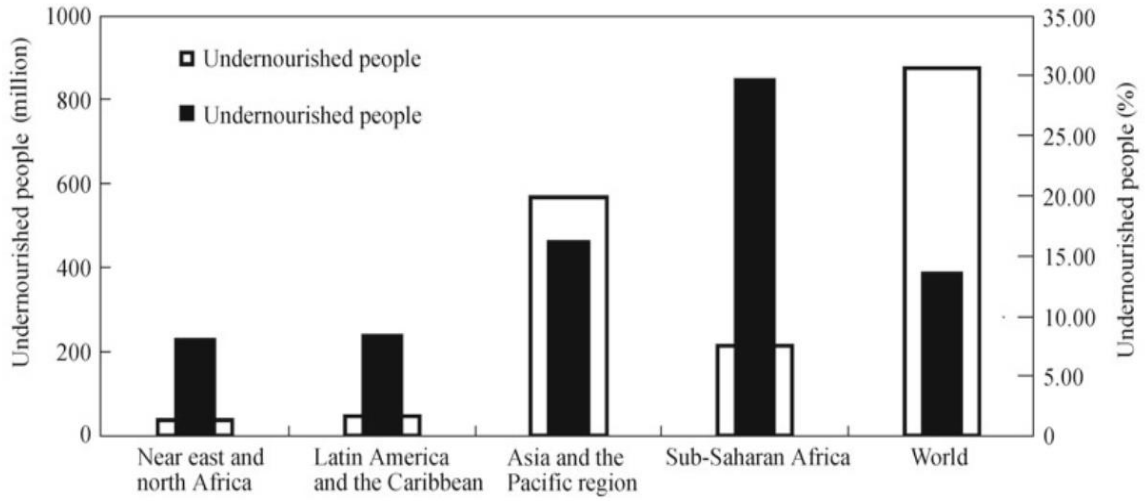


Figure 1(b): Prevalence of undernourishment in Asia and the Pacific region and other regions of the world in the year 2004 to 2006. Source: FAO, 2009

The four pillars of food security are availability, access, utilization, and stability". (FAO, 2009)

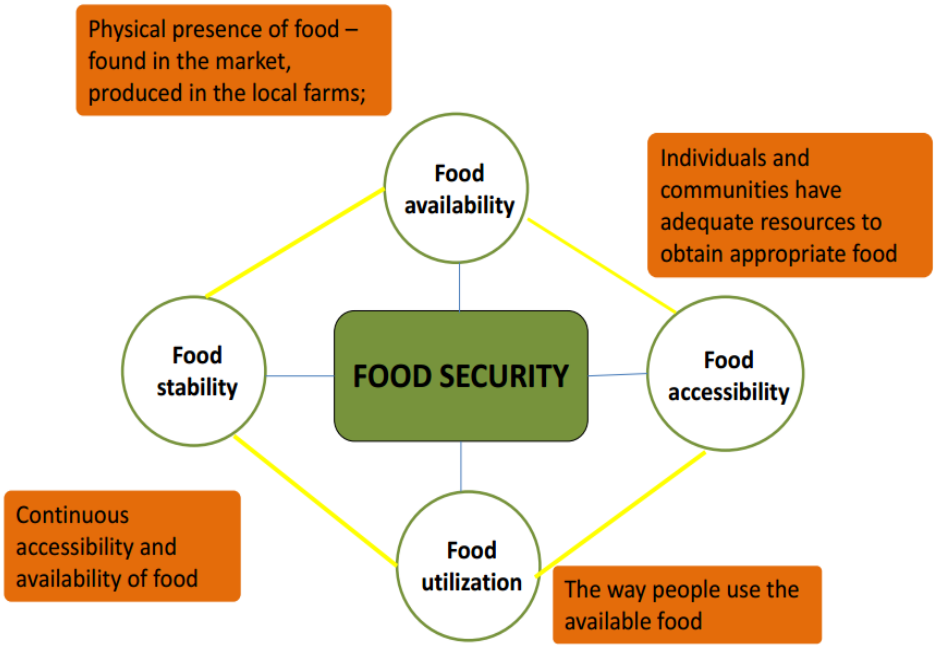
Food Availability: The existence and supply of sufficient amount of food ready for consumption for all individuals in the household, country and region, via production, distribution, exchange of food (FAO, 2013).

Food Accessibility: This refers to the capabilities of region, locality, households and/or individuals within those households, with respect to sufficient access to resources, and rights to acquire sufficient amounts and quality of food. Drivers of food access are household resources,

food prices, food preferences and socio-political factors such as discrimination and gender inequality (Pieters *et al.*, 2013).

Food Utilization: It denotes the ability of an individual to use food in a way that all physiological requirements are satisfied.

Food Stability: continuous availability and accessibility of food. The fourth pillar, stability, refers to the duration of the three other dimensions for long periods of time (FAO, 2009).



Source: FAO, 2014.

Figure 2: Pillars of food security

3.2 Agroforestry

Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components (Lundgren and Raintree, 1982). According to World Agroforestry Centre agroforestry, Agroforestry is the inclusion of trees in farming systems and their management in rural landscapes to enhance productivity, profitability, diversity and ecosystem sustainability (ICRAF, 2013). Followings agroforestry systems are practiced throughout the world-

- Taungya system
- shifting cultivation
- Alley cropping
- Homestead agroforestry system
- Multistory agroforestry
- Multispecies tree gardens
- Silvopastoral System
- Agrosilvopastoral System

Possible impacts of Agroforestry

Following impacts of agroforestry are listed by Chundawat and Gautam, 1999 -

- Controlling poverty through increased income by higher production of agroforestry products for home consumption and market.
- Food security by restoring farm soil fertility for food crops and production of fruits, vegetables, nuts and edible oils.
- Reducing deforestation and pressure on forest by providing fuel wood grown on farms.
- Increasing buffering capacity of farmers against the effects of global climate change on-farm tree crops and tree cover.
- Improving soil health of the farm through ameliorated micro-climate and nutrition level.
- Augmenting accessibility to medicinal trees for cure of common and complex diseases.

3.3 Agroforestry in Food and Nutritional Security:

Woody perennial based production systems, such as agroforestry, have the potential to meet the food security of people. Farmers depend more on annual crops, the small and marginal farmers in the tropics have long been practicing agroforestry to meet their food, fodder and fuel requirements (Kumar, 2006). Agroforestry can provide new and useful solutions to many of the adverse consequences of human land use, including increased diversification of agricultural production system, increased yield of crops and livestock , increased the farmers' income and ensure food security (Adekunle and Bakare, 2004). Table 1 shows the direct and indirect roles of forest and tree based production system in food security.

Table 1. The direct and indirect roles of forest and tree based system for food security

<table>
<tr><td colspan="4">FOREST-TREE-LANDSCAPE CONTINUUM</td></tr>
<tr><td>Managed forests</td><td>Shifting cultivation</td><td>Agroforestry</td><td>Single species tree crop production</td></tr>
<tr><td colspan="4">  </td></tr>
<tr><td colspan="2">DIRECT ROLES</td><td colspan="2">INDIRECT ROLES</td></tr>
<tr><td colspan="2">➢ Dietary diversity, quality & quantity
Food provisioning:
Fruits & vegetables
Nuts and palm
Mushrooms
Fodder and forage
Animal source foods (rabbit, fish, insects etc.).

➢ Livelihood safety nets
Food in times of seasonal and other scarcities, nutritional composition
wood fuel for cooking.</td><td colspan="2">➢ Tree products for income generation
Tree crops, wood products,
Other NTFPs and AFTPs.

➢ Ecosystem services
Provision of genetic resources
pollination
microclimatic regulation
habitat provisioning
soil formation
erosion control
nutrient cycling
pest regulation</td></tr>
</table>

source: Vira *et al.*, 2015.

Asinwa *et al.,* (2012) conducted a survey on the economics of some forest fruit trees and found out that harvesting, processing and marketing of products from economic forest trees plays an

important role in food security, employment and income generation. Table 2 shows the number of important agroforestry species in different region of the world.

Table 2. The number of tree species in the Agroforestree Database mentioned as providing tree functions of importance to smallholders for promoting food and nutritional security

function	Region			
	Africa	South America	Southeast Asia	Total (regions)
Human food	295 (54)	119 (43)	225 (49)	639 (50)
Animal fodder	295 (55)	96 (45)	191 (47)	582 (50)
Soil improvement	194 (51)	73 (45)	154 (45)	421 (48)
Fuel	357 (53)	126 (42)	249 (47)	732 (49)
Total (functions)	1141 (53)	414 (43)	819 (47)	2374 (49)

Note: The percentage of references to indigenous species is given in brackets. **Source:** FAO, 2013

A study in Philippines by Landicho *et al*., (2016) found that agroforestry system secure highest score 7.01 in food security that's mean high level of food security over other land use system (Table 3).

Table 3. Food security score by farming system in Philippines

Indication of food security	Base score	Mean score			
		Mono cropping	Relay cropping	Multiple cropping	agroforestry
Food availability	2	1.76	1.74	1.77	1.82
Food stability	2	1.18	1.13	1.31	1.46
Food accessibility	2	1.73	1.76	1.85	183
Food utilization	2	1.96	1.81	1.89	1.90
Food security score*	8	6.63	6.44	6.82	7.01

*sum of the mean scores of the four indicators Source: Landicho *et al.*, 2016

*7.00 – 8.00 (highl evel of food security) 6.00-6.99 (moderate level of food security), 5.00 – 5.99 (low level of food security) and <5.00 (food insecure).

3.3.1 Nutritional contribution of fruit tree based agroforestry system:

A study in terrace ecosystem in Bangladesh found that jackfruit-pineapple orchard has great contribution on family nutrition (Table 4). The contribution of jackfruit-pineapple orchard for a farm family in recommended dietary allowance of energy, protein, vitamin A, thiamin, riboflavin, niacin, vitamin C, calcium and iron was 13, 11, 70, 15, 15, 25, 9, 144, 16 and 33%, respectively during cropping season. It revealed that daily requirement of vitamin C can fully satisfied solely by jackfruit-pineapple (Hasan *et al.,* 2008).

Table 4. Nutritional contribution from jackfruit-pineapple orchard in the recommended dietary allowance (per family per day)

Fruits	Energy (kcal)	Protein (mg)	Vit A (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Vit C (mg)	Ca (mg)	Iron (mg)
Jackfruit	1234	26.6	2450	0.42	1.82	5.6	98	280	7
Pineapple	585	9	900	0.9	0.45	4.5	180	195	12
Total	1819	35.6	3350	1.32	2.27	10.1	278	475	19
RDA	14200	334	4815	9	9	118	193	2889	58
% of RDA	13	11	70	15	25	9	144	16	33

RDA= Recommended Dietary Allowance for average family size. **Source:** Hasan *et al.,* 2008

3.3.2 Homestead agroforestry system supports food and nutrition:

Home garden' (HG) is a complex sustainable land use system (Marambe *et al.,* 2012), which generally combines multiple farming components, i.e., annual and perennial crops, trees, shrubs, livestock and fishery. The flow of goods and services from the HG not only provides the household needs and employment support, but also environmental services similar to those of natural forests as a result of being a mixed farming system consisting of fruits, vegetables, trees and animals. Gautam *et al*. (2004) reported that in India Agroforestry homegarden contributed 60% of the household's total fruit and vegetable consumption, in Philippines, twenty percentage (20%) of the foods consumed by families are produced in the homegarden whereas in Vietnam

51% of their produce is used by household members. Small animals such as rabbits, poultry and bees can be associated with the garden for animal protein intake and vitamins. A survey in Medinipur District of West Bengal reported that homegarden contributed significantly in providing the consumption needs of vegetables, meat and eggs of the households (Table 5).

Table 5. Household average annual consumption and contribution of HG for different food items in West Bengal of India

Crops	Food obtained from				
	Total quantity (kg)	Homegarden (%)	Other farm area (own cultivations) (%)	Gifts (%)	Purchased (%)
Rice	13553.17	0.12	67.05	0.07	32.75
Finger millet	446.66	0	98.88	0	1.11
Wheat	1274.66	4.97	4.90	2.2	87.93
Other cereals	3964.75	0	85.05	0	14.95
Total cereals	19239.25	0.42	67.38	0.2	32.01
Vegetables	6011.06	31.04	46.38	0.35	22.23
Leafy vegetables	1283.33	22.38	25.57	0.47	51.58
Total vegetables	7294.40	29.52	42.72	0.37	27.4
Meat	446.50	28.59	0	0	71.41
Eggs (number)	2698	31.69	0	0	68.31

Source: Jana *et al.*, 2015

In home garden or agroforestry systems, tree fruits are increasingly cultivated for securing food and nutrition sources during crisis period of a year when adequate access to food is not possible (Rahman *et al.*, 2012). Homestead garden provide approximate amount of nutrients during

different periods of the year (Table 6). A total of 233,000 kcal, 24,500 mg protein, 257,000 lg vitamin A, 70,400 mg vitamin C, 79,300 mg calcium, 153,000 mg phosphorus and 13,100 mg iron were obtained in a year. Table 6 shows that developed homestead garden provides significant amount of vegetable, i.e. 630.14 g/person/day as consumed by the household that contains 638.36 kcal against the minimum requirement of 200 gm per person/day.

Table 6. Month wise food (in kg) and nutrition supply (‘000) per capita from homestead agroforestry garden

Periods	Vegetables	Home consumption (kg/yr)	Energy (kcal)	Vit. A (µg)	Vit. C (mg)	Protein (mg)	Ca (mg)	P (mg)	Iron (mg)
Jan-Feb	Tomato	15	5.25	28.8	4.65	0.285	3	5.40	0.27
Feb-Mar	Cauliflower	25	5.75	7.50	14.0	1.47	8.25	26.7	10.0
Nov-May	Cowpea	40	19.2	4.80	5.60	1.40	28.8	23.6	1.00
Dec-Mar	Brinjal	37	12.9	27.4	4.44	5.18	6.67	17.4	0.14
Jun-Sep	Okra	31	10.8	16.1	4.03	0.59	20.5	17.4	0.11
Mar-Apr	Tuber crops	14	60.2	119	0.49	10.4	1.04	40.3	0.41
Jul-Aug	Cucumber	15	2.25	00	1.05	0.10	1.50	3.75	0.15
Aug-Sep	Bitter gourd	31	18.6	39.0	27.3	0.62	7.13	11.8	0.62
Dec-Feb	Chilli	8	2.32	14.0	8.88	0.23	2.40	6.40	0.35
Nov-Feb	Mushroom	14	96.0	00	00	4.25	0.01	0.03	0.02
Jan-Dec	total	230	233	257	70.4	24.5	79.3	153	13.1

Tuber crop includes *Discoria*, Yam, *Tapioca* and *Colocasia* **Source:** Singh *et al.*, 2016

They are also sources of mineral nutrients for improving household nutritional security especially for at-risk populations (e.g., women and children). As little or no chemical inputs are used, the produce from agroforestry is also expected to be of superior quality (Shankar *et al,* 1998).

3.3.3 Contribution of agroforestry to health:

Many trees are cultivated to provide medicines from bark, leaves, roots, etc., which are sold to support incomes and are used for self-treatment, supporting the health of communities (Muriuki *et al*., 2012). The diverse products harvested in agroforestry systems particularly fresh vegetables and fruits are a major source of dietary minerals. This is especially important for women and children because there is a poor access to healthcare facilities in Bangladeshi society. More than 80% of household members were found to depend on medicinal plants for their primary medical needs in Padma floodplain of northern Bangladesh (Rahman *et al.*, 2012).

3.4 Agroforestry for higher production and income to support access to food:

Agroforestry provide a greater contribution of the total income of farmers per year. Agroforestry can help attain both increase of income and the provision of direct access to edible nutritious products for the households (Jamnadaas *et al.*, 2013). Natural forests and agro-forestry systems generate plant and animal foods in rural areas of Bangladesh. Bamboo shoots, different fruits, nuts and vegetables are major plant based foods (Miah *et al.* 2012; Zohora 2011). Also relying on the income received from a single commodity crop leads to food insecurity as the payments will be one-off, delayed or unpredictable (Jamnadaas *et al*, 2013). On the other hand, agroforestry systems with multiple crops will help to avoid risks of food insecurities as they provide not only variety of tree commodities but also local food trees, vegetables and even edible fungi and mostly profits gained are superior than monoculture systems (Kumar, 2006 and Pushpakumara *et al*, 2012). A study in Jessore showed that sesame was most profitable agricultural crop in the agroforestry practice and the Benefit-Cost Ratio (BCR) was 6.20 which meant that by investing Tk. 1.00 the farmers got return back Tk. 6.20 for sesame species. Pea, jute, wheat and Aus rice were next most profitable agricultural crops (table

7). In terms of production (per unit land), jute and Aus rice were maximum but these were not profitable as sesame or pea which production were not so high (Islam *et al.,* 2013).

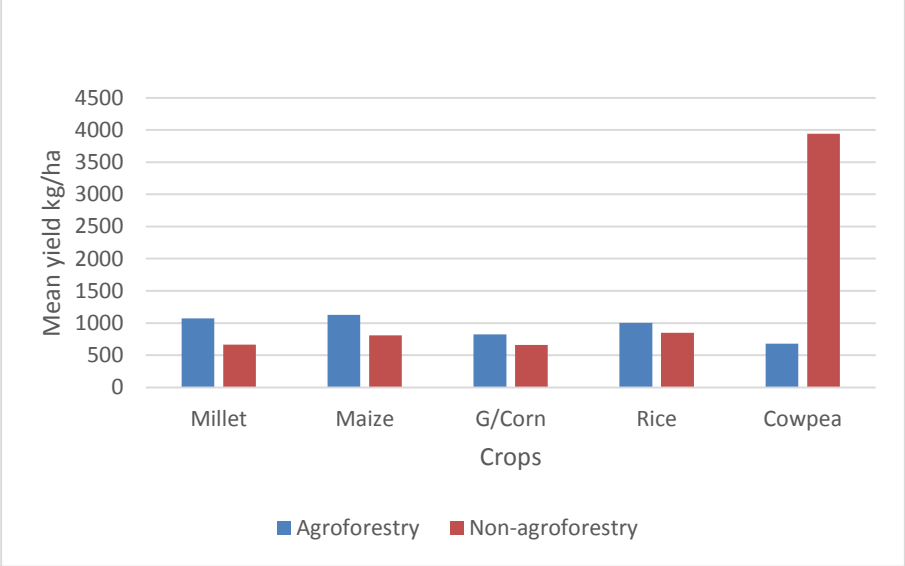
Table 7. Production of some major agricultural crops in agroforestry practice in Jessore district of Bangladesh

Name of the crops	Production per bigha (kg)	Investment per bigha (tk)	Profit per bigha (tk)	Net return (kg)	Benefit – Cost Ratio (BCR)
Rice (Aus)	500	1400	2600	1200	1.86
Wheat	450	1200	2400	1200	2.00
Jute	500	1300	3700	2400	2.85
Pea	260	1500	4220	2720	2.81
Sesame	240	600	3720	3120	6.20

Source: Islam *et al*., 2013

This study revealed that the people of that region choose mahagony for their excellent growth performance and high timber value, Jackfruit and mango for food and timber value. The production performance of coconut and betel nut in this study area was considerably satisfied. The prevalence of date palm tree in this region was considered as the highest in Bangladesh. Most of the date palm molasses was produced in this region. Good production of date palm molasses and juice contributed handsome amount of money to the local people of this region. Moreover, the other species such as guava, blackberry, lemon, wood apple, palm, litchi, etc. were also used significantly for their nutrition and timber value. Timber grown mostly for long-term savings, if households need large amounts of cash then the wood is cut down. Commercialize livestock farmers as savings for the future. Many households keep cattle that are regularly sold or redeemed for cash and food as part of their normal activities yearly (Tiwari *et al*., 2017). Fuelwood and charcoal also plays a significant role in the food and nutritional security as they produce energy and generate high income in spite of introduction of modern energy sources. It is

also noted that agroforestry practitioners spent less on fuelwood, rely less on natural fuelwood sources, and they require less time for fuelwood collection. Adequate access to cooking fuel will make people more flexible in their diets preferably better nutritional foods which require more energy to prepare (Jamnadaas *et al*., 2013). Another study in Nigeria found that the higher yields obtained from agroforestry system than non-agroforestry farmland. Crops grown in the sampled farmers' farmlands in the agroforestry and non-agroforestry farmlands are shown in figure 3. This findings showed that the yield of agricultural crops were significantly different with higher yield for agroforestry farmlands compared to non-agroforestry farmland. The higher yields of crops obtained from agroforestry farmlands could be as the influence of the agroforestry practices to soil organic matter, nutrient cycling, soil fertility, soil organisms, weeds and pests control (Nguyen *et al.* 2013).



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

Figure 3. Crop production on agroforestry and non-agroforestry plots in Nigeria.

Homestead agroforestry implies the intimate association of multipurpose trees and shrubs with annuals and perennial crops and invariably livestock within the compound of individuals with the

whole crop-tree-animal unit being managed by family labor (Ajah *et al.*, 2013). Multipurpose trees (MPTs) provide various type of non-timber forest products (NTFPs). Table 8 shows the role of NTFPs obtained from different forest species in rural livelihood was remarkable.

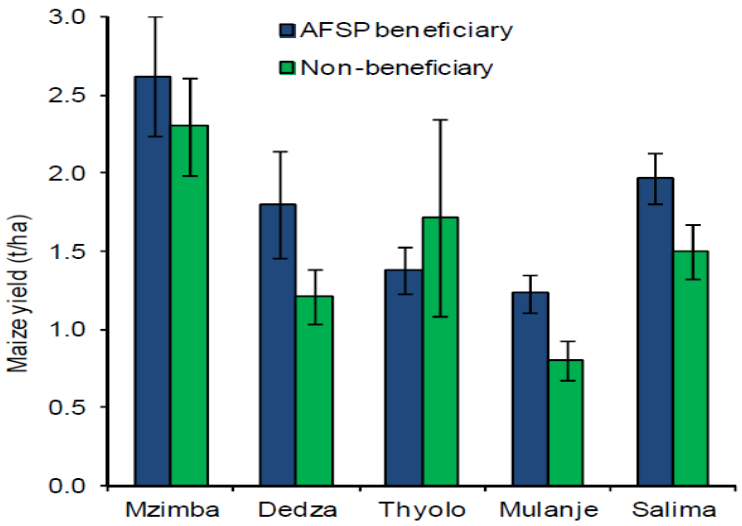
Table 8. A wide range of other studies have also indicated an important role of NTFPs in supporting rural people's livelihood

Reference	**Location**	**Land use type**	**%household income**
Shackleton *et al.* (2007)	South Africa	Natural forest	20
Appiah et al. (2007)	Ghana	Natural forest	38
Kamanga *et al.* (2009)	Malawi	Forest, farmland	15
Babulo *et al*. (2009)	Northern Ethiopia	Natural forest	27
Yemiru *et al.* (2010)	Southern Ethiopia	Forest (participatory management)	53P,23W
FAO (2011)	Sahel	Parkland, savannah woodland	80
Bwalya (2013)	Zambia	Natural forest	32
Adam and pretzsch (2010)	Sudan	savannah woodland	54
Ingram *et al.* (2012)	Congo Basin	Natural forest	47
Kar and Jacobson (2012)	Bangladesh	Forest adjacent hilly area	16 P, 9 W
FAO (2011)	mozambique	Natural forest	30
Heubach *et al.* (2011)	Northern Benin	Natural forest	39

Note: The range of contribution between poorer (P) and wealthier (W) groups. Values normally expressed in terms of environmental income. **Source:** Vira *et al.*, 2015

Farmers in Malawi have recognized that low soil fertility is a major constraint on their ability to produce food. To address this through the planting of leguminous tree and shrubs, ICRAF implemented the Malawi Agroforestry Food Security Program, which between 2007 and 2011 reached about 180,000 farmers. An external review of the program in five districts surveyed 283 households that were beneficiaries (participants in the program) and 200 that were not. Maize

yield in four districts out of five districts were on average higher for beneficiaries than for non-beneficiaries participants (Figure 4).



Source: Dawson *et al.,* 2011.

Figure 4: Maize yields in five districts in Malawi with and without the intervention of the Agroforestry Food Security Program, based on 283 beneficiaries and 200 non-beneficiaries.

3.4.1 Multistory agroforestry for higher production:

In multistory agroforestry system (MAFS), rural people utilize their homesteads and fruit orchards for multi-strata cropping that includes various types of tree resources (such as trees, shrubs, herbs) and rearing livestock. Farmers grow diverse species in three to seven layers where generally the lowest layer is comprised of shade tolerant species (e.g. pineapple, turmeric, ginger), the lower-middle layer by medium sized trees (e.g. banana, olive, papaya etc.), the upper-middle layer by medium-tall fruit trees (e.g. jackfruit, mango, litchi etc.), and the highest layer by tall trees (e.g. palmyra palm, coconut etc.) (Miah & Husain, 2009). A study in terrace ecosystem in Bangladesh found that performance of jackfruit is superior in agroforestry system than monoculture (table 9).

Table 9. Performance of jackfruit trees in both monoculture and agroforestry system in terrace ecosystem of Bangladesh

Parameter	Jackfruit as monoculture	Jackfruit as agroforestry	Change (%)
Fruit bearing tree (%)*	60.9 (±2.44)	95.7 (±2.86)	57.1
No. of fruits per tree*	30.7 (±4.21)	52.3 (±3.98)	70.3
Fruit weight (kg)	16.3 (±0.32)	12.7 (±0.54)	-22.1
Total yield (kg/tree)*	499.1 (±1.38)	662.1 (±2.18)	32.7

Values in parenthesis indicate the standard error (±SE) **Source:** Miah *et al.,* 2017
* Significant at the 0.05 probability level.

Miah *et al.,* 2017 reported that jackfruit based multistory agroforestry system provides higher benefit cost ratio (BCR) and land equivalent ratio (LER) over monoculture in terrace ecosystem in Bangladesh (table 10).

Table 10: Benefit–cost ratio (BCR) and land equivalent ratio (LER) of different agroforestry systems and monoculture during 2013 in Bangladesh

System	Total cost (BDT/ha)	Benefit–cost ratio (BCR) a	Land equivalent ratio (LER)
Jackfruit–papaya	111,763	4.80b	1.78b
Jackfruit–eggplant	88,772	5.26a	1.82b
Jackfruit–papaya–eggplant	200,036	5.62a	2.60a
Monoculture (sole papaya)	111,263	4.52b	1
Monoculture (sole eggplant)	88,272	4.42b	1

a= Within columns, means followed by the same letter are not significantly different according to LSD (0.05). S**ource:** Miah *et al.,* 2017

Monocultures also reduce resilience to shocks such as drought, flood and, often (although not always), the outbreak of pests and diseases (FAO, 2012). Mixed agroforestry regimes can help to avoid many of the negative effects described above by combining tree commodities in diverse production systems with locally important food trees, staple crops, vegetables and edible fungi – such as shade coffee and shade cocoa systems (Jagoret *et al*., 2011) – which increase or at least do not decrease commodity yields and profitability (Clough *et al*., 2011).

3.4.2 Agroforestry for ecosystem services

Agroforestry trees provide important ecosystem services, including soil, spring, stream and watershed protection, animal and plant biodiversity conservation, and carbon sequestration and storage, all of which ultimately affect food and nutritional security. Trees can modify the microclimate for garden crops under harsh climate and support climbing plants such as yam (Muriuki *et al*., 2012). In western Kenya, subsistence farmers practicing agroforestry (e.g. for soil erosion control, improving soil fertility and fuelwood provision) identify more coping strategies when exposed to climate-related hazards than those who do not (Neufeldt, 2012). A diversity of trees in farmland and neighboring natural forest fragments, where present, supports populations of pollinator species such as insects and birds that are essential for many crops (Garibaldi *et al*., 2013). Many fruit tree species that are important as human foods rely on insect pollinators for their production, while diverse farms that provide an alternative habitat for pollinator communities can support the regeneration of food plants in neighboring forest (Klein *et al*., 2007).

CHAPTER 4

CONCLUSION

Based on these finding, agroforestry system plays a vital role in achieving global food security especially in African, South and South East Asian countries as agroforestry meets the all dimensions of food security. Forests and tree based farming system supports food security and nutrition in a number of ways, through direct provision of food, increased crop production, increased crop diversity (with different crop duration) which ensures multiple produce throughout the year, interactions of the crop components promote nutrient cycling, and finally through ecological services (e.g. erosion control potentials of crop components, supportive technologies) help improve soil condition and crop production. The contributions of forests to global food supply may be negligible, but throughout the world quality of the foods is more important in the local food systems. Agroforestry practices contribute to food production even in the face of economic recession and land degradation. Proper agroforestry practice may be the best solution to food and nutrition security in developing and non-developed country. Hence, global focus on the use of agroforestry as a tool to achieve food security should be increased and refined due to its ample positive social and environmental benefits. So Programs or policies should put emphasis specially on the use of fruit tree-based agroforestry system for achieving food and nutrition security.

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