A Seminar Paper on

Homestead Agroforestry: A Path to Climate-Smart Land Use

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Homestead Agroforestry: A Path to Climate-Smart Land Use[1]

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ABSTRACT

Homestead agroforestry is a multi-strata integrated production system that integrates the cultivation of trees, crops, livestock, and occasionally fish to give millions of households in developing nations access to chances for work and revenue generating. Furthermore, it provides a strong ecological foundation for higher crop and animal yield, more consistent economic returns, and improved biodiversity preservation. This review investigates the concept and significance of homestead agroforests, as well as their potential benefits for climate change adaptation and mitigation. Climate change is affecting crop yields, livestock productivity, and food security in significant ways. Climate-smart agriculture seeks to promote more sustainable agricultural practices that reduce greenhouse gas emissions, build resilience to climate change, and increase agricultural productivity in order to address these challenges. Homestead agroforestry is a climate-smart land use system that can address all three pillars of climate-smart agriculture by increasing productivity, assisting with adaptation, and assisting with mitigation. Trees sequester carbon via photosynthesis and reduce emissions via shading and cooling, and agroforestry systems can reduce emissions by improving soil health and reducing the need for synthetic fertilizers. As a result, homestead agroforestry has enormous potential to mitigate the effects of climate change, sequester atmospheric carbon, and provide livelihood security while contributing to food security. It provides an opportunity for developing-country smallholder farmers to adopt sustainable land use practices that benefit both people and the environment.

Key words: homestead agroforestry, climate change, adaptation, carbon sequestration and food security

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Chapter 1

INTRODUCTION

Homestead agroforestry is a multi-strata integrated production system that combines all farming components (tree, crop, livestock, and occasionally fish) and provides food security, employment, and income generation opportunities to millions of households (Miah & Ahmed, 2003). It has the potential to provide a solid ecological foundation for increased crop and animal productivity, more consistent economic returns, and increased biodiversity (Amatya, 2022). In Bangladesh, people in rural and semi-urban areas grow and maintain a diverse range of plants in their homes. They have purposefully grown these plants for generations to meet household needs such as fuel wood, timber, fruit, and vegetables, as well as for revenue and environmental improvement (Abdula, 2021). Due to the rapid deforestation of the country's forests, these homestead forests are regarded as a major source of forest products. Homestead agroforestry is also gaining popularity as a tool for reducing poverty and increasing farmers' food self-sufficiency. Agroforestry farming systems support an estimated 1.2 billion people, primarily in developing countries (Zomer *et al*., 2016).

Bangladesh is situated at the intersection of two geographical regions that are in conflict with each other - the Bay of Bengal to the south and the Himalayas to the north. Bangladesh has now begun to feel the effects of climate change, with longer food periods and more frequent cyclones, droughts, and earthquakes wreaking havoc on the country's agriculture and land, as well as challenges to water resources, occupational dislocations, food, health, energy, and finally urban planning, all of which are manifesting themselves more immensely in Bangladesh's coastal region (Jahan *et al*., 2022). Climate change is a pressing issue in today's world and a major contributor to global warming. The increase in the amount of greenhouse gases (GHG) in the atmosphere, primarily carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), traps infrared radiation and prevents it from escaping into space, causes global warming (Ram *et al*., 2016). Agriculture, which is a crucial industry for many economies, is already suffering serious effects from climate change. Crop yields, animal output, and food security are all being impacted by changes in temperature, precipitation, and extreme weather events. Moreover, agriculture considerably increases the amount of greenhouse gas emissions that cause climate change (Frank et al., 2017). Climate smart agriculture seeks to promote more sustainable agricultural practices that reduce greenhouse gas emissions, increase resilience to climate change, and increase agricultural productivity in order to address these challenges (FAO, 2013). Farmers can help mitigate climate change while also improving their own livelihoods and contributing to food security by implementing practices like agroforestry, conservation agriculture, and improved water and soil management (Lipper *et al*., 2014). Agro-forest ecosystems, which are thought to play an important role in climate change, can be managed to absorb CO2 through photosynthesis and store carbon in biomass and soil (Watson *et al.*, 2000). In addition to providing livelihood security, it plays an important role in reducing vulnerability, increasing the resilience of farming systems, and buffering households against climate-related risk (Amatya, 2022). Homestead agroforestry, which integrates tree production with crop and animal production, is thought to have a higher carbon sequestration potential than pastures or field crops (Nair *et al*., 2009). It also helps to reduce carbon emissions from burning fossil fuels while relieving pressure on existing agroforestry systems by producing fuel wood and maintaining carbon stocks (Mattsson *et al*., 2013). Carbon sequestration in homestead agroforestry is permanent because, unlike other practices, complete biomass removal does not occur (Nath *et al*., 2014). Reducing Emissions from Deforestation and Forest Degradation (REDD) practices are one of the approaches that can help mitigate the effects of climate change and sequester atmospheric carbon (Amatya, 2022). Homestead agroforestry can meet all three pillars of Climate Smart Agriculture (CSA).Firstly, it can boost productivity by providing households with a variety of food, fuel, and income. According to research, homestead agroforestry systems can increase crop yields, improve soil fertility and nutrient cycling, and provide habitat for beneficial insects that control pests (Garrity *et al*., 2010). Secondly, Homestead agroforestry can help with adaptation by providing a variety of benefits that boost resilience to climate change, such as soil conservation, water retention, and biodiversity preservation.Trees can also provide shade and windbreaks, which can help reduce the effects of extreme weather events (Garrity *et al*., 2010). Finally, Homestead agroforestry can help with mitigation by sequestering carbon in trees and soil and reducing greenhouse gas emissions from agricultural activities. Trees can sequester carbon through photosynthesis and reduce emissions through shading and cooling (Lipper *et al*., 2014). Agroforestry systems can also help to reduce greenhouse gas emissions by improving soil health and reducing the need for synthetic fertilizers, which are a major source of greenhouse gas emissions (Lipper *et al*., 2014; FAO, 2013).

By considering the above situations, this review paper is made to satisfy the following objectives:

- To describe the concept and importance of homestead agroforestry
- To find out the opportunities of homestead agroforestry as a climate-smart land use system

Chapter 2

MATERIALS AND METHODS

This seminar paper is exclusively a review paper. Therefore, all the information were collected from secondary sources with a view to prepare this paper. Various relevant books and journals, which were available in the library of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) and Bangladesh Agricultural Research Institute (BARI), were used for the preparation of this paper. For collecting recent information internet browsing was also be practiced. Good suggestions, valuable information and kind consideration from my honourable major professor, course instructors and other resources personnel were taken to enrich this paper. After collecting necessary information, it has compiled and arranged chronologically for better understanding and clarification.

Chapter 3

REVIEW OF FINDINGS

3.1. Climate change and climate-smart agriculture

Climate change is the shift in weather patterns caused primarily by greenhouse gas emissions from natural systems and human activities. Anthropogenic activities have so far caused about 1.0 °C of global warming above pre-industrial levels, and this is expected to rise to 1.5 °C between 2030 and 2052 if current emission rates continue. According to the 2013 IPCC report, climate change has the potential to affect all four dimensions of food security through its effects on agricultural production and rural household incomes, food prices and markets, and many other parts of the food system (e.g., storage, food quality, and safety). Climate-smart agriculture (CSA) is an approach that seeks to promote sustainable agricultural practices that reduce greenhouse gas emissions, build resilience to climate change, and increase agricultural productivity. It is essential for achieving food security and meeting the challenges of climate change (Lipper *et al*., 2014). Homestead agroforestry, which involves mixing trees and crops on small pieces of land close to homes, is a type of CSA that has showed promise in Bangladesh. Many benefits, including enhanced yields, better soil fertility, and increased climatic resistance, can be obtained from homestead agroforestry. It supports climate-smart agriculture, aids in mitigation and adaptation, and ensures food security.

3.2. Definitions, concept, and importance of homestead agroforestry practice

Agroforestry is a traditional and sustainable land-use system that includes the deliberate integration of a woody perennial with an agricultural crop as an understory. Homestead agroforestry, also known as homestead gardening or homestead production system, refers to the integrated production of crops, trees, and/or livestock in the home and its surroundings. Homestead agroforestry, a common form of multistory agroforestry, includes mixed plantings of annual, tree crops, and pasture around the habitat area (Parihaar *et al*; 2015). Farmers grow trees with multiple uses in their backyard gardens, including those for flowers, fruits, trees, fish, agricultural crops, and cattle. Homestead systems in Bangladesh provide approximately 70% of the country's fruit, 40% of its vegetables, 70% of its timber, and 90% of its firewood and bamboo needs. (Abdula, 2021). Because agricultural land is scarce, adopting homestead agroforestry practices may be a viable option for farmers seeking to ensure their survival and achieve both food and income security.

Characteristics of a home garden (Mitchell & Hanstad, 2004) list five intrinsic characteristics of home gardens: 1) are close to the residence; 2) have a diverse plant population; 3) production is supplemental rather than the primary source of family consumption and income; 4) occupy a small area; and 5) are a production system that the poor can easily enter at some level.

Table 1. The key characteristics of a typical home garden

Characteristic	General practice
Species density	High
Species type	Staples, vegetables, fruits, medicinal plants
Production objective	Home Consumption
Labor source Family	(women, elderly, children)
Harvest frequency	Daily, seasonal
Labor requirements	Part-time
Space utilization	Horizontal and vertical
Location	Horizontal and vertical
Cropping pattern	Irregular and row
Technology	Simple hand tools
Input-cost	Low
Distribution	Rural and urban areas
Skills	Gardening and horticultural skills
Assistance	None or minor

Source:(Niñez, 1987)

3.3. Multilayered homestead garden production systems

Homestead may be a life boat for survival of the landless, marginal and small farmers who do not have any resource other than their homestead and own labor. To make homegarden more productive we can utilize its space both horizontally and vertically all the year round through suitable vegetables and tree species which will help to upscale nutritional status as well as eradicate poverty. (**Table 2**) stated the following possible layers may develop at suitable micro-sites with good access to light.

Table 2. Multi-layered homegarden production system

Layers	Type of plants	Name of the plants	Possible average height (at mature stage)
1st	Mostly creeper type plants such as	Thunkuni, Pudina, Kangkong, red amaranth, radish, brinjal, tomato Chilli,	Up to 1 meter

	creepers, leafy vegetables, tuber crops	Ginger, Turmeric, Aroids/Taro, Lalshak, Napashak, Palongshak, Cabbage, Radish, Carrot, Coriander, Aloe vera, Pineapple	
2nd	Saplings, Small size trees, plants and climbers which are grown as understorey in the homesteads; all vine /climber types of vegetables grown in trellis	Country beans, Indian spinach, sweet gourd, white/ash gourd/bottle gourd/ridge gourd/bitter gourd, cucumber, snake gourd, Shotomuli, Gondovaduli, Telakucha, Yums or other climber type vegetables/spices Okra, papaya, Karamcha, Citrus, Guava dwarf variety, Basak, Dalim	Up to 3 meters
3rd	Small sized fruit and timber trees	Bel, Golab jam, Litchi (dwarf), Kamranga, Lotkon, Jujube, Olive, Dewa, Amloki, Haritaki, Bohera, Babla,	Up to 10 meters
4th	Trees with medium sizes of height	Amra, Ghoraneem, Arjun, Jackfruit, Mango Koroi, Betelnut, Ipil Ipil, Shimul, Kadam,	Up to 20 meters
5th	Trees in uppermost storey	Eucalyptus, Coconut-tall variety, Jam, Palmyra palm, Tetul, Debdaru, Rajkoroi	Above 20 meters

Source: Miah and Hussain, 2010

3.4. Homestead microsites

Homestead microsites i.e., approach road, front yard, home yard, back yard and boundary.

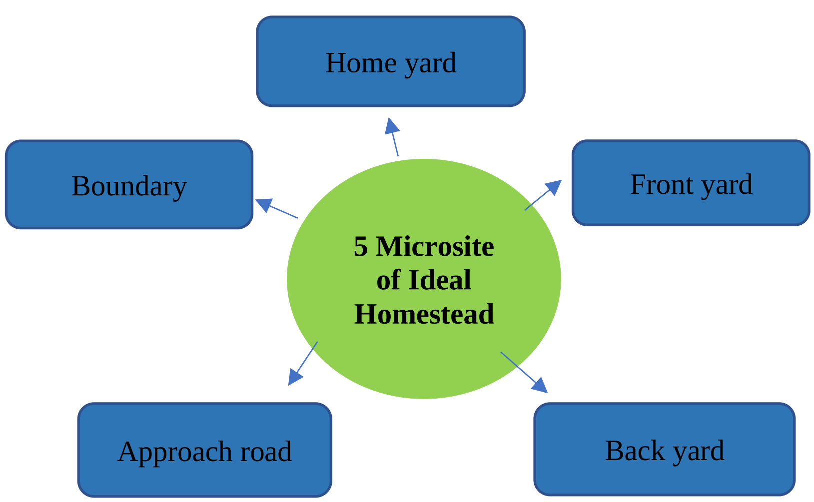

Fig 1. Microsites of ideal homestead

All homesteads are not comprised of all five microsites or units. Therefore, area of each microsite compared to total homestead area vary with homesteads (Anjum *et al*., 2016).

The study found that the majority of approach roads (90.9%) covered a maximum of 33% of the total household area. For 34-66% of households, about 7.3% had approach roads, while for 67-100% of households, the proportion decreased to approximately 1.8%. In terms of front yards, 84.5% were found to cover 33% of the total household area, with 14.5% falling within the 34-66% range and only 0.9% within the 67-100% range. Similarly, 48.2% of home yards accounted for up to 33% of the total household area, with 47.3% falling within the 34-66% range and 4.5% within the 67-100% range. Regarding backyards, 66.4% covered up to 33% of the total household area, with 30.9% falling within the 34-66% range and 2.7% within the 67-100% range. Around 30.9% of back yards were located within a 34- 66% household area, with 2.7% located within a 67-100% area. The majority of the boundaries (76.4%) were within 0 -33% of the total household area. Nearly one-fourth (23.6%) of the boundaries were within 34 - 66% of the household area. Within the 67-100% household area, no boundaries were discovered.

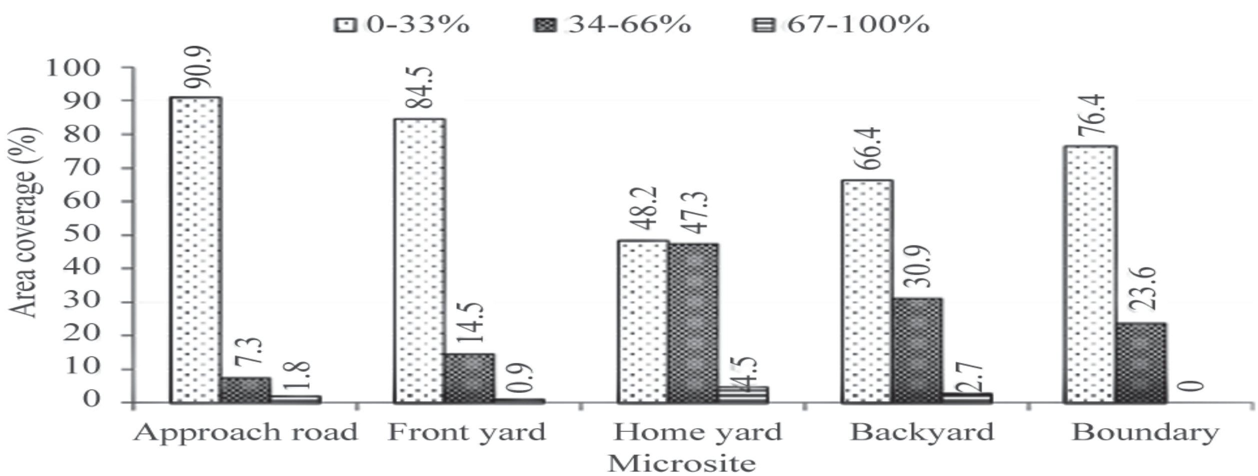

Fig. 2. Distribution of area coverage of different microsites in total homestead area (Anjum *et al*., 2016).

Not all microsites contained the same balance of species, as some species performed much better in certain microsites than others. Table 3 shows the species that performed particularly well in each microsite. Mango was the most dominant high-performing species in the approach road, accounting for 15.37% of the species present, followed by jackfruit at 12.83%, banana at 10.29%, palm at 9.02%, and pineapple also at 9.02%. In the front yard, jackfruit was the most dominant high-performing species at 25.73%, followed by mango at 19.61%, banana at 6.23%, coconut at 4.08%, and jujube also at 4.08%. In the home yard, mango performed the best among all species at 12.01%, followed by jackfruit at 11.09%, papaya at 8.35%, jujube also at 8.35%, and blackberry at 5.6%. In the back yard, mango was the most dominant high-performing species at 12.78%, followed by jackfruit at 11.63%, banana at 10.48%, and coconut at 8.18%. Jackfruit was the best performing species among the boundary species at 14.47%, followed by mango at 9.26%, betel nut also at 9.26%, teak also at 9.26%, and coconut at 7.6%. Other species, including guava, litchi, wood apple, date palm, betel nut, palm, pineapple, and teak, were found in varying numbers across different microsites.

Table 3. Highly performing species in different microsites

Highly performed species	Approach road		Front yard		Home yard		Back yard		Boundary	
	Percent	Rank	Percent	Rank	Percent	Rank	Percent	Rank	Percent	Rank
Mango	15.37	1	19.61	2	12.01	1	12.78	1	9.26	2
Jackfruit	12.83	2	25.73	1	11.09	2	11.63	2	14.47	1
Banana	10.29	3	6.23	3	4.58	5	10.48	3	5.2	5
Coconut	3.81	6	4.08	4	2.75	7	8.18	4	7.6	3
Guava	-	-	2.04	6	3.66	6	4.6	7	2.6	7
Blackberry	2.54	7	-	-	5.6	4	-	-	-	-
Papaya	-	-	2.04	6	8.35	3	4.6	7	3.9	6
Jujube	1.27	8	4.08	4	8.35	3	2.3	9	-	-
Litchi	-	-	2.04	6	3.66	6	2.3	9	-	-
Wood apple	-	-	2.04	6	3.66	6	2.3	9	3.9	6
Date palm	1.27	8	2.04	6	0.92	9	-	-	6.51	4
Betel nut	2.54	7	-	-	2.75	7	7.03	5	9.26	2
Palm	9.02	4	1.02	7	-	-	3.45	8	5.21	5
Pineapple	9.02	4	6.23	3	-	-	-	-	-	-
Teak	2.54	7	2.04	6	-	-	-	-	9.26	2
Durba grass	5.07	5	1.0	7	1.83	8	1.15	10	5.2	5

Source: (Anjum *et al*., 2016).

3.5. Importance of homestead agroforestry

Homestead agroforestry systems are most appropriate for resource poor farmers. They can earn immediate benefits from crops while waiting for long term benefits from trees. s. A unique combination of different species of fruit, timber and biomass yielding trees can generate high amount of earnings for the farmers (Middendorp *et al*., 2018). Most of the trees in homestead agro forestry system to be traditional varieties with less production potential. So, there is much scope to improve productivity of the system both in the homesteads and in the fields by replacing the existing tree species/varieties with the improved ones, planting trees in planned ways, using suitable tree-crop combination and by improving management practices (Hussain *et al*., 2015). Homestead forests can help increase rural households' climate-relevant adaptive capacity by providing diverse production potential of food, timber, fuelwood, fodder, and non-timber forest products (NTFPs) (Mattsson *et al*., 2015; Nath *et al.*, 2015). These forest ecosystems also help with conservation and improvement of soil and water quality, as well as reduction, and removal of carbon dioxide (CO_2) emissions (Alessandro and Marta 2012). Homestead agroforestry that integrates tree production with crop and animal production is believed to have a higher potential to sequester carbon than pastures or field crops (Nair *et al.*, 2009). It also helps to reduce carbon emissions from fossil-fuel burning through fuel wood production and conservation of carbon stocks in existing natural forests by alleviating pressure on these forests (Kumar *et al.*, 2004).

Table 4. Importance of homestead components

Materials	Description	Benefits
Trees	Deliberately planted and managed trees	Shade, erosion control, nutrient cycling, wind protection, timber, fuelwood, fruits, nuts
Crops	Annual and/or perennial crops selected for compatibility with tree species	Food, income, soil health, biodiversity, pest management
Livestock	Animals such as chickens, goats, or pigs	Weed control, pest management, income, food, soil health
Soil Health	Improved soil health through increased organic matter content, reduced erosion, and enhanced nutrient cycling	Increased crop yields, reduced soil degradation, improved water retention and infiltration
Multiple Benefits	Food production, income generation, biodiversity conservation, carbon sequestration, and water filtration	Enhanced ecosystem resilience, increased household food security, and income, reduced greenhouse gas emissions

Source: (Garrity *et al*.,2010, Nair,1993)

3.6. Importance of homestead agroforestry for uplifting the status of women

Women, the vulnerable group of the society and half of the country's population, have a great opportunity for self-employment in the income-generation activities through the practice of vegetable and fruit production in the homestead (Miah & Hussain, 2010).In many cultures, women play an important role in food production but at times their worth is somewhat undermined. They are also active in home gardening, though their involvement in the home garden tends to be determined by socio-cultural norms (Mitchell & Hanstad, 2004). In most scenarios women's contribution to household food production is immense, but this does not imply that home gardening is predominantly a female activity. Women's participation and responsibilities in home gardening varies across cultures, including land preparation, planting, weeding, harvesting, and marketing (Moreno-Black *et al*., 1996). Despite the significant role that women play in the production and management of homesteads, there is still a vast opportunity for improvement in their knowledge and skills. Empowering women with the necessary skills and knowledge will enable them to more actively and meaningfully participate in homestead production activities, thereby enhancing overall productivity.

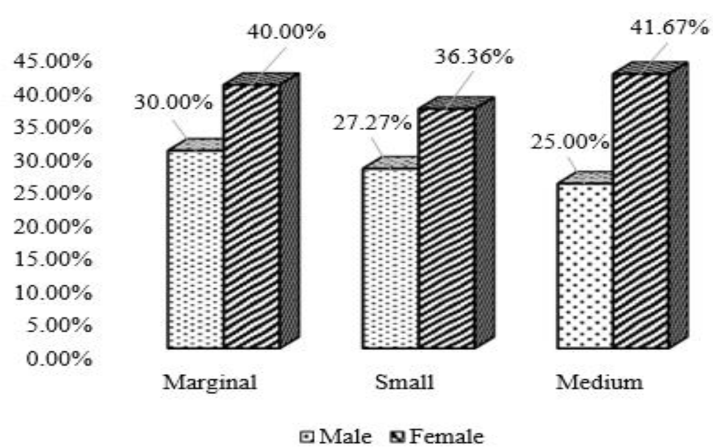

Fig. 3. Women participation on homestead vegetable production (Zohora *et al*., 2022)

3.7. Opportunities of homestead agroforestry as a climate-smart land use system

Climate-smart agriculture (CSA) is an approach to agriculture that aims to increase food security and improve resilience to climate change while also reducing greenhouse gas emissions (FAO, 2013; Gómez-Baggethun *et al*., 2010)). It involves implementing sustainable farming practices that can increase yields and reduce vulnerability to weather-related shocks.

The three main pillars of CSA are:

- Increasing agricultural productivity and incomes
- Adapting and building resilience to climate change
- Reducing and/or removing greenhouse gas emissions, where possible.

Homestead is a key example of how CSA can be implemented at the household level. In homestead agroforestry, trees can provide shade and soil fertility, crops can provide food and income, and livestock can provide manure and other products. This approach can help increase food security and income, reduce the risk of crop failure due to weather-related events, and contribute to reducing greenhouse gas emissions.

3.8. Adaptation role of homestead agroforestry

Adaptation to climate change involves taking measures to mitigate the negative impacts of changes in the climate on human health and well-being, while also leveraging the potential benefits that the climatic environment offers. It is an important strategy for minimizing the detrimental effects of climate change and involves making adjustments to practices, processes, or structures within systems to cope with both anticipated and observed changes in the climate (Termeern *et al*., 2017). Adaptation to climate change requires monitoring and anticipating change, as well as taking actions to avoid negative consequences and capitalize on potential benefits. Climate change adaptation necessitates combining scientific knowledge with indigenous knowledge and practices (Keenan, 2015).

3.8.1. To maximize homestead agroforestry resources for enhancing adaptive and resilience capacity of community people

To establish a "Green Zone" in vulnerable communities affected by climate change, an integrated approach can be taken. This involves planting and nurturing species of plants that are productive and can tolerate extreme climates, including the native vegetation that promotes an elevated mood and has a ditch structure. Fruit trees, timber trees, herbs, shrubs, plants, vegetables, pond fisheries, agrosilviculture, and animal husbandry can all be incorporated in this approach. The goal is to create a self-sustaining ecosystem that provides food, income, and environmental benefits to the community while promoting resilience to climate change (Abdula, 2021). The villagers' preferences for different plant species are driven by a range of factors, such as their economic benefits and their impact on the environment. Through their local knowledge, they have learned that planting light canopy fruit species near their dwellings and large canopy taller trees along their boundaries serves both productive and protective purposes. This means that they choose certain plants for their ability to provide food and other economic benefits, as well as for their ability to provide shade and protect against wind and other environmental factors. Overall, the villagers' choices are informed by a deep understanding of the benefits and functions of different plant species in their local environment (Nath *et al*., 2015). Boundary trees are used as a means to protect trees and homes located downwind by acting as a wind barrier. Residents of villages can take regular and intensive care of trees located near homes and use them to protect fruits from theft. To reduce the extent of damage caused by cyclones, residents build homes at the center of their homestead land and surround them with trees. This approach helps to provide an additional layer of protection against the destructive effects of cyclones (Baas & Ramamasy, 2008).

3.9. Climate change mitigation in the homestead agroforestry practice

According to Ussiri *et al*., (2017), climate change mitigation refers to human intervention aimed at reducing greenhouse gas (GHG) sources or enhancing GHG sinks. Agroforestry activities can be an appropriate means of achieving this by increasing biotic carbon storage, reducing GHG emissions from operations, and producing biomass as a substitute for fossil fuels (Abbas *et al*., 2017). One way to achieve this is by reducing fossil fuel consumption, thereby decreasing GHG emissions. Another approach involves maintaining or increasing vegetation cover to enhance carbon sequestration, which helps to reduce GHG concentrations in the atmosphere. Tropical homestead forests, also known as home gardens and homestead agroforestry, have the potential to sequester carbon and thus mitigate the impacts of climate change (Kumar, 2011).

3.9.1. Choice of Species for mitigation of natural hazards from climate change

Natural disasters such as seasonal cyclones, tidal storms, and sea water surges are becoming more common, causing property damage, soil erosion, salinity intrusion, and vegetation damage (Nath *et al.*, 2015). As a result of the permanent flooding of a number of homestead agroforestry areas, the locals worry that it will become more challenging to survive. Because of their strong root systems that protect them from uprooting during cyclones (72%), sturdy stems that do not break easily (68%), and lightweight, low canopy that reduces wind load on trees (55%), these species have a high survival rate (85%), preventing wind damage to homes (Abdula, 2021). When wind hits trees, its speed decreases, reducing the destructive force of strong wind. Trees with a taproot or enough branch roots can withstand strong winds (Haq *et al.*, 2012).

3.9.2. Potential role of homesteads in carbon sequestration to mitigate climate change

The carbon sequestered within agroforestry systems may have a positive impact on the global GHG balance. Most tree species in homestead are slow growing and long lived. They can also form a large canopy volume with a high total car-bon accumulation (Harvey *et al.,* 2010). Whole tree harvest is uncommon in the management of this type of system; thus, the carbon sequestered stays there over a long period of time and critical role in climate change mitigation. It has been reported that forest carbon stock can be estimated as 50% (dry mass basis) of above ground Biomass (Behera *et al*., 2017)**.** Homestead forests thus possess the potential to sequestrate a considerable quantity of carbon (Nath *et al.*, 2015). However, the structural variation in a forest (e.g., tree height, diameter at breast height DBH, density, basal area BA, and species diversity) affects the C dynamics(Jahan *et al*., 2016). The average aboveground standing stocks of carbon in home gardens ranged from 16 to 36 Mg/ha (Kumar, 2011). Homestead agroforestry have high potentials to carbon sequestration than others strategies. When compare with altitude, the tree biomass C stock was higher in the high and medium altitude than in the low altitude homestead agro forests, The C in fallen litter biomass decreased with increasing (Behera *et al*., 2017)**.**

Table 5: Carbon stocks (Mg C ha^{-1}) of tree biomass (above ground and living roots) and litterfall

Homestead forests	Tree biomass C stock (Mg C ha^{-1})	C stock of litterfall (Mg C ha^{-1})
Low altitude	28.69 ± 3.56^{a}	0.04 ± 0.01^{a}
Medium altitude	39.34 ± 4.87^{a}	0.03 ± 0.01^{a}
High altitude	42.50 ± 6.43^{a}	0.03 ± 0.00^{a}
Mean	36.35 ± 2.88	0.03 ± 0.01

Source: (Baul *et al*., 2021)

Carbon stocks (Mg C ha−1) of tree biomass (above ground and living roots) and litterfall in the homestead forests sampled across three altitudes. ± represents the standard error of the mean. Same alphabet in different rows indicates the insignificant difference among the different altitude homestead forests ($p \leq 0.05$). The tree biomass C stock was higher in the high and medium altitude than in the low altitude homestead forests, though the difference among the altitudes was not significant ($p \leq 0.05$) (Table 5). The C in fallen litter biomass decreased with increasing altitude (Table 5).

3.10. Role of homestead agroforestry food and income security

The dietary intake of four micronutrients viz., vitamin A, iron, folic acid, and calcium in particular play a pivotal role in growth, physical and cognitive development. Dietary imbalance and unavailability of micro-nutrients are among the major factors responsible for poor nutritional outcomes. High consumption of cereals, but low intake of edible oils, vegetables and fish results in a low level of absorption of micro-nutrients and a high level of anemia and other ailments. In Bangladesh, most of the cultivable land are used for cereal grains production, so homestead area plays great role in fruit and vegetables production and these meet our daily requirement of all nutrition

Table 6: Homestead vegetable production, income and BCR

Types of farmers	Total production (kg/year)	Total production Cost (USD)	Total Ownuse (kg)	Total Distribution (kg)	Total Sale (kg)	Total income (USD)	BCR
Marginal	25,514	1468.54	3,420	1,818	20,208	4708.80	2.21
Small	39,445	4406.79	6,080	2,281	30,600	8852.21	1.01
Medium	63,732	6923.54	8,450	4,142	51,840	19267.67	1.78

Source: (Zohora *et al*., 2022)

From (Table 6) it has been shown that marginal, small and medium farmers produced 25,514 kg, 39,445 kg and 63,732 kg vegetables per year where their Benefit Cost Ratio (BCR) was 2.21, 1.01 and 1.78 respectively. Most of the farmers sell their vegetables directly to the local mark, village market as well as district market. That's why they can not only earn more profit than wholesaler farmers but also avoid market syndicates.

3.11. Challenges and Constraints of Homestead Agroforestry

Limited land availability: In many regions, the availability of land suitable for agroforestry is limited, and this can be a significant constraint on the adoption and success of homestead agroforestry systems (Salam *et al*.,2000) .The shortage of land can lead to overcrowding and competition for resources, which can reduce the effectiveness of agroforestry practices.

Lack of knowledge and awareness: A lack of knowledge and awareness about agroforestry practices and their benefits can be a significant challenge to the adoption and success of homestead agroforestry systems (Gebru *et al*., 2019). Without adequate education and training, farmers may not be aware of the potential benefits of agroforestry, and may not know how to effectively implement agroforestry practices (Kiptot *et al*., 2006)

Limited access to resources: The lack of access to resources such as seeds, equipment, and credit can be a significant constraint on the adoption and success of homestead agroforestry systems (Kiptot & Franzel, 2012). Without adequate resources, farmers may not be able to effectively implement agroforestry practices or may not have the means to invest in the long-term benefits of agroforestry.

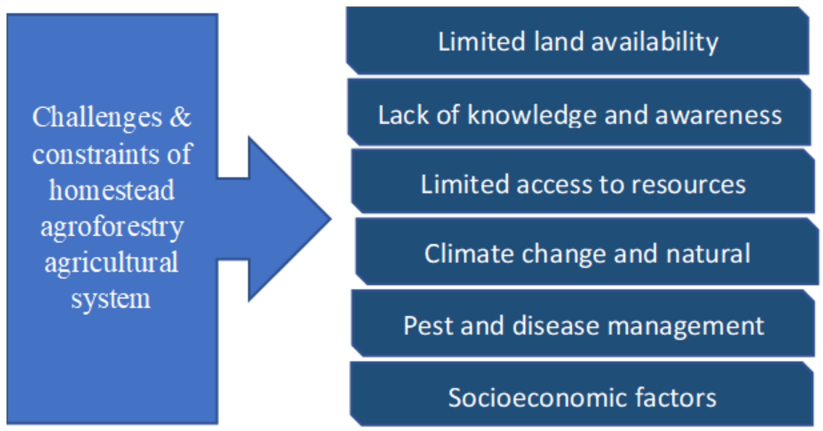

Fig.4. Challenges and Constraints of Homestead Agroforestry

Climate change and natural disasters: Climate change and natural disasters such as droughts, floods, and storms can have significant impacts on homestead agroforestry systems, including the loss of crops and damage to infrastructure (De Zoysa & Inoue, 2020). These impacts can reduce the effectiveness of agroforestry practices and make it more difficult for farmers to achieve food and income security.

Pest and disease management: Pests and diseases can have a significant impact on the success of homestead agroforestry systems, particularly when crops and trees are intercropped (Rao *et al*., 2004). Effective pest and disease management strategies are essential for the success of agroforestry practices.

Socioeconomic factors: Socioeconomic factors such as gender, education, and income can have a significant impact on the adoption and success of homestead agroforestry systems (Gebru *et al*., 2019). For example, women may have limited access to resources and may face cultural barriers to participating in agroforestry activities. Addressing these socioeconomic factors is essential to promoting the adoption and success of homestead agroforestry systems.

Chapter 4

CONCLUSION

Homestead agroforestry presents a comprehensive approach to address the interrelated challenges of climate change, food and nutrition security, and income security. By integrating trees and crops on small-scale farms, this system promotes sustainable land management practices that mitigate climate change effects, improve soil health, water retention, and carbon sequestration.

In terms of food and nutrition security, homestead agroforestry offers a diversified and nutritious food supply, which can supplement and improve the household diet. The system can provide fruits, vegetables, and grains, as well as animal protein, and thus enhance the nutritional status of local communities. The integration of trees can also increase the resilience of the food system to climatic shocks and reduce the risk of crop failure.

Moreover, homestead agroforestry can contribute to income security by generating multiple income streams from the sale of crops, fruits, timber, and other value-added activities. This can improve the profitability of farming activities, reduce production costs, and create employment opportunities, particularly for women and youth, who often have limited access to formal employment.

In conclusion, homestead agroforestry presents a promising approach to building more resilient and sustainable food systems that address the interrelated challenges of climate change, food and nutrition security, and income security. With appropriate support and investment, this system can contribute to improving the livelihoods and well-being of small-scale farmers and rural communities, while promoting environmental sustainability and resilience.

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