Khulna University
Life Science School
Forestry and Wood Technology Discipline

Author(s): Md. Nurul Alam

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Supervisor(s): Md. Sharif Hasan Limon, Forestry and Wood Technology Discipline, Khulna University

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Md. Nurul Alam

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Life Science School
Khulna University
Khulna – 9208
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Supervisor

02.02.14

Md. Sharif Hasan Limon

Associate Professor,

Forestry and Wood Technology Discipline,

Khulna University, Khulna,

Khulna-9208.

Prepared by

02.02.2014

Md. Nurul Alam

Roll No. MS-100519

Forestry and Wood Technology Discipline,

Khulna University, Khulna,

Khulna-9208.

Dedicated to

My beloved parents

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Abstract

The Forest Department of Bangladesh initiated agroforestry program for the poor people in order to multiple use their gher land or agriculture land. This study explores the performance of trees in Gherland agroforestry. Seedling survival is estimated from living status e.g. live or death. Height of seedlings was measured from root collar to the base of the newest leaf of the terminal shoot by measuring tape. Collar diameter was measured using digital slide calipers.

Farmers prefer to Mahgony, Akashmini, Neem for their basic need of bole, timber. Fruit trees (Kul, Coconut, Guava, Mango and Lemon) also prefers to immediate return of nutrient. Mango (*Mangifera indica*), Star apple *(Syzygium samarengense)*, Guava (*Psidium guajava)*, Lime *(Citrus limon)*, Neem (*Azadirachta indica)*, Coconut (*Cocos nucifera)* showed the highest performance whose survival rate were 100% and it was followed by Mahgony (*Swietenia macrophylla*), Akasmoni (*Acacia auriculiformis)* and 81%, 72%, respectively.

Height increment contribution percentage of Akashmoni, Mahagony, Guava, Neem, Mango, Star apple, Kul, lime was showed respectively 22.49%, 15.32%, 13.83%, 48.34%, 17.71%, 24.93%, 30.44% and 26.91%. Diameter increment contribution percentage was about 19.80%, 18.62%, 17.01%, 44.54%, 25.15%, 26.66% and 24.23% respectively.

There was significant difference between height increment in growing season and height increment in dry season ($p < 0.05$).

The average height increment of Neem (*Azadirachta indica)* is more than others species. Mango (*Mangifera indica*) was the lowest height growth performance. The average diameter increment of Neem (*Azadirachta indica)* is more than others species. Mango (*Mangifera indica*) was showed the lowest diameter increment among the others species. Height increment contribution and diameter increment contribution of Neem (*Azadirachta indica)* are showed the best growth performance in gher dikes. So Neem (*Azadirachta indica)* is suitable species for gher dike plantation. Survival rate and growth performance is satisfactory in the study area.

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CHAPTER ONE

INTRODUCTION

1.1 Problem Statement

Agroforestry (AF) is a sustainable management system for land that increases overall production, combines agricultural crops, tree crops and forest plants of animals simultaneously or sequentially and applies management practices that are compatible with the cultural patterns of the local people (Bene et al, 1997). If Agroforestry practices in gher (fish and shrimp/prawn shallow ponds) land area, this is called Gher land agroforestry. Gherland Agroforestry is one of the important sustainable land management techniques involving a combination of different agricultural crops, timber and fruit trees, fish and Shrimp practices, termed as aquasilviculture.

The forestry situation in Bangladesh reveals a dismal picture. Bangladesh has about 17 per cent of forestland but the actual tree covered area is estimated at about 8.6 per cent (Forestry Master Plan, 1992). This has made the country as a whole ecologically critical. The forests of south-western part of Bangladesh are also subjected to tremendous pressure of increasing population for their livelihood demands of both land and forest products. In this connection, agroforestry (AF) practice in this region has immense potentialities to address the problem by providing its multi-dimensional products and services. Gher -based Agroforestry (GAF) practice is a traditional land use system in the south-western part of the country (i.e., coastal ecosystem).

The different ghers, ponds, tanks, agricultural lands and other fallow lands can be utilized to grow suitable tree species for fuel, fodder and small timber and agricultural crops. Domestic animals can also be incorporated into these land-use systems wherever possible. Introduction of fodder trees in these potential land-uses is an important issue for this fodder deficient area. Therefore, improved gherland agroforestry (GAF) practices and technologies can be helpful in ensuring food security for the rural people and domestic animals along with other perceived environmental and social benefits. GAF is a type of land use system that helps in mitigating present land use problem as well as provides income and employment for sustainable livelihood.

AF practice increases yield and services of per unit area through crop diversification. Assuming sustainability of the area more yield is expected from the different crop

combinations, such as food, fodder, timber, etc. if ever there will be a failure in one crop, the other crops would supplement the deficit. Services like protection to soil erosion, improvement of soil fertility, amelioration of the microclimate, colorful scenery, shelterbelts, etc. are obtained from this practice with the cultural patterns of the local communities by providing the necessary assets of their livelihood (Zabala, 1990).

The present study aims to find out the potentiality and growth performance of trees for improvement of GAF in terms of its productivity, profitability, adaptability and sustainability in Khulna and Satkhira districts.

1.2 Objective of the study

- To study the survival and growth of timber and fruit trees planted in Gher dikes.

CHAPTER TWO

LITERATURE REVIEW

2.1 Concept & definitions of agroforestry:

Agroforestry(AF) is the art and science of growing woody and non-woody together on the same unit of land for range of benefits. Agroforestry is the use of land for a combination of agriculture and forestry. In other word, the practice of growing tree crops or some other fast growing trees along with the main crops. Agroforestry is one of the important sustainable land management techniques, involving a combination of different agricultural, horticultural, forestry and livestock practices. Sometimes it is closely related to community forestry and homestead forestry (Hasanuzzaman, 2009).

According to Nair (1990), agroforestry is a land-use system that involves socially and ecologically acceptable integration of trees with agricultural crops and/or animals, simultaneously or sequentially, top get increased total productivity of plant and animal in a sustainable manner from a unit of farm land, especially under conditions of low level of technological inputs and marginal lands.

Agroforestry is a form of multiple cropping which satisfies three basic conditions: 1) three exists at least two plant species that interact biologically, 2) at least one of the plant species is a woody perennial and 3) at least one of the plant species is managed for forage, annual or perennial crop production.
Agroforestry has been recognized as a strategy for rural poverty alleviation through combined production of trees and crops and many other produces that help in generating income and employment including environmental amelioration (BARC, 1994).

Therefore, AF provides environmental, economic and social benefits to the community (Chundawat and Gautam, 1993) which ultimately reflects the sustainable livelihood strategies of the local people. AF is the only land use system which can engender those daily essential products of the local people. AF is such a practice which can satisfy needs of the poor within short period of time by its multidimensional productive nature. The different ghers (fish and shrimp shallow ponds)/other ponds/tanks, rivers, agricultural lands and other fallow lands can be utilized under agroforetry. Domestic animals can also be incorporated into these land-use systems wherever possible. So, appropriate agroforestry practices can be helpful in ensuring food security for the rural people and the country as a whole.

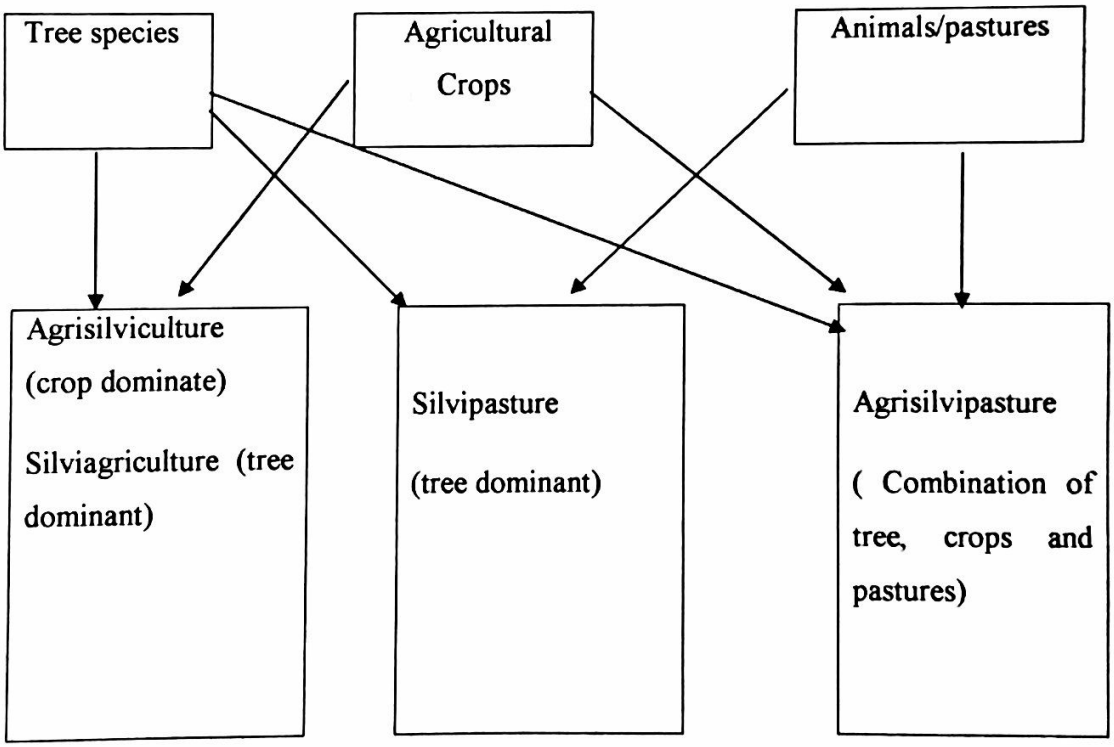
2.1.1 Common Characteristics of Agroforestry practices:

- Multiple plant components at least one of which must be a woody perennial component of the system both ecological and economical.
- A high level of interaction (economic and biophysical) between the woody and non-woody components.
- Usually multiple output products often of different categories (e.g. food, fodder, fuel wood) with protection of resources.
- The most simple Agroforestry system is more complex, ecological and economically than a mono-cropping system (Hasanuzzaman, 2009).

2.1.2 Components of Agroforestry:

There are three major components in Agroforestry system, these are: (According to Nair)

i) Tree or woody perennials ii) Agricultural Crops iii) Animals/pastures



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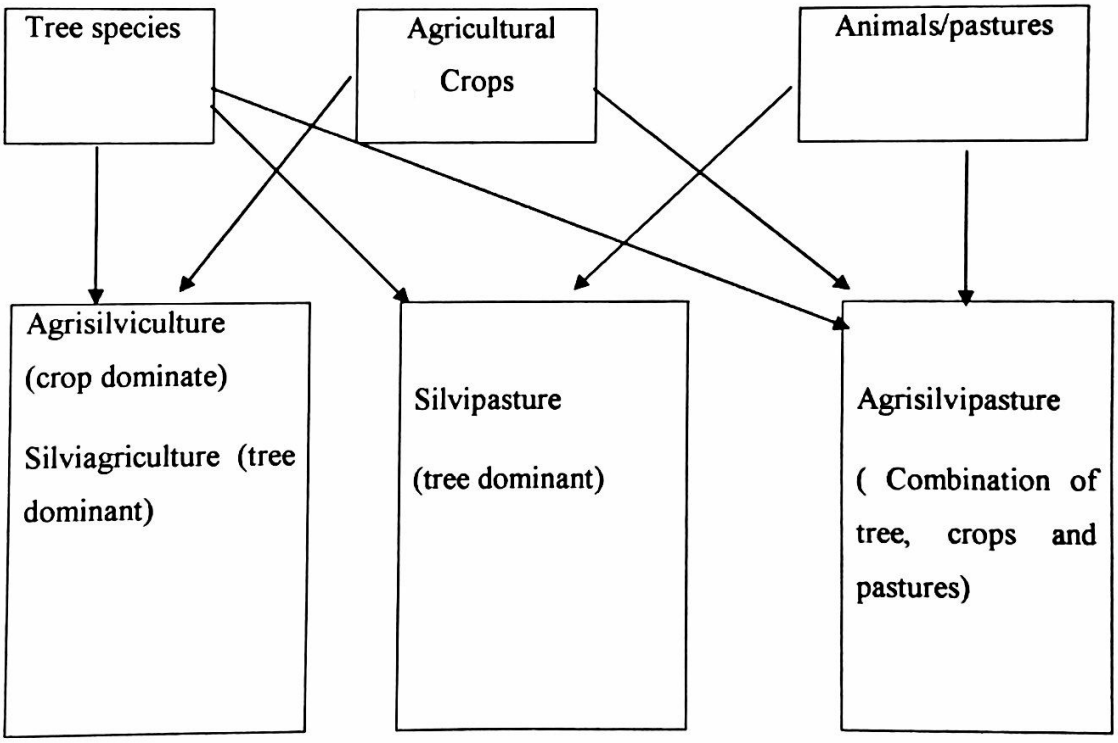


2.1.3 Benefits of Agroforestry:

The reasons behind adoption of agroforestry through adding trees in the croplands with agricultural crops vary with grower's views, perception, necessity, etc. From the farmers view point the objectives of growing trees in the croplands or gherland includes of increase the total land productivity, widen the range of produce and thus spread risk and preserve their livelihood and survival by conserving resources (Nair, 1991). According to Conway (1984) the socio-economic objectives of growing trees in the croplands are based on productivity, stability, and sustainability.

The following benefits are generalizations that are not likely to apply to all AF

2.1.3.1 Biological benefits of Agro forestry:

Increased space utilization:

Increased utilization of the above and below ground environment should result in an increase of total biomass production potential. The planting of crops that differ in light requirements root development, and height allows for more efficient use of solar radiation soil moisture and nutrients. Trees are generally thought to be able to extract nutrient from greater volumes of soil than do annual crops. However this assumption is based on little quantitative information for tropical tree species (Halle et al., 1978).

Potential reduction of soil erosion:

Soil erosion risks can be reduced by a reduction in rainfall erosivity by a multistoried canopy. Agro forestry practices can include three or more canopy layers, which can contribute to reduce soil erosion risk by combined effects of tree canopy, ground cover of annual crops or pasture grasses, legume and shrubs and surface little layer. The time of initiation, the duration and the density of the canopy or ground covers are the critical factors in the effectiveness of agro forestry practices in reducing erosion risks. Stems and surface roots also play a significant role in erosion reduction by reducing the velocity and therefore the erosive of surface runoff. Agro forestry practices can enhance above ground canopy and soil surface condition that reduce erosion risks. (Lundgren and Nair, 1987).

Reduction in microclimate extremes:

Temperature and moisture extremes are modified under tree canopies. The tree canopies shield the soil surface from solar radiation during daylight hours and serve to reduce heat losses at night thereby narrowing the amplitude the of daily temperature variation (Vergara,1983).

Reduced risk of complete crop failure:

Plant diversity can reduce the risk of total crop failure because the risk of losses from pest infestation or climatic stress is spread among many species. There is considerable evidence that the combination of crops in intercropping systems provide an insurance factor in which one crop may compensate for the loss in a pest damage crop (Harwood, 1979).

Physical support for herbaceous climbers:

The tree component can provide support for climber such as black pepper, vanilla, yams, and the like. This can be significant economic value where tree stems are substituted for expensive poles or support that need to be replaced periodically (Vergara,1983).

Positive use of shade:

Some crops such as coffee and cacao benefit from the provision of shade. This is particularly true under soil condition that are not very favorable, when rainfall is excessive and when temperature are too extreme. Multi storied system with nitrogen fixing tree species are used in many parts of the world to provide shade for plantation crop (Vergara, 1983).

2.1.3.2 Economic and social benefits of Agro forestry

Increased income opportunities:

Opportunities for earning greater income per hectare per year using or intensifying agro forestry practices have been documented by a number of authors (Gupta, 1979, 1983; Stoler, 1978). Another general advantage is year round distribution of employment and income rather than more highly seasonal income from annual mono-cropping.

Variety of products and services:

A variety of products can be produced from the same piece of land. Products might include food, firewood, poles, craft wood, fodder, fertilizer, medicinal products and so on. Services might include shade for shade tolerant or for human or comfort windbreak or ornament.

Potential for improved human nutrition:

the wide diversity of crops in agro forestry systems can provide a correspondingly wide range of edible plants for human consumption (Conclin, 1957). Tree species and shrubs that are cultivated in agro forestry systems can provide important sources of vitamins and other nutrients during period of seasonal shortage (Okafore, 1981).

Reduced establishment costs:

The cost of establishing long term tree crops can be reduced when trees and other crops are established together (Haufe, 1977).

Improved distribution of labor:

Labor requirements may be more evenly distributed over a long period time. This is because the labor requirements of the various components in mixed or multiple cropping patterns of most agro forestry practices may occur at different times of the year.

2.1.3.3 Intangible benefits of agroforestry

Agroforestry helps carbon storage

Agroforestry plantings can sequester substantial carbon (Watson 2000), but it is important to understand the opportunities of climate change mitigation activities in the context of multiple spatial scales. Agroforestry can be used to link forest fragments and other critical habitat as part of a broad landscape management strategy that enables species to migrate for population genetics reasons and in response to climate change. Trees and shrubs planted in shelterbelts can store carbon in their shoots and roots, while protecting soils and crops and providing biodiversity and habitat for wildlife (Pandey 2002). The biodiversity in agroforestry system is usually superior to conventional agricultural systems. It also has the potential to help reduce climate change since trees take up and store carbon at a faster rate than crops do and carbon storage time in timber is much greater than that of agricultural residues (Wikipedia, 2010).

Agroforestry maintain ecosystems

Forest activity at a specific site needs to be integrated into a broader land-use context that considers the management of land and water resources as regional units (Miller 1996). Agroforestry plantings can help add structural and functional diversity to landscapes and, if strategically located, they can help restore many ecological functions (Olson et al. 2000). While agroforests are typically less diverse than native forest, they do contain a significant number of plant and animal species. This diversity can, in time, provide ecological resilience and contribute to the maintenance of beneficial ecological functions (Lefroy et al, 1999,). Similar to plantation forests, agroforests can help relieve some of the pressure to harvest native forests.

Agroforestry protect biological diversity

Agroforestry provides ways of augmenting the supply of forest habitat and providing greater landscape connectivity. Where croplands occupy most of the landscape, linear riparian forest buffers and field shelterbelts can be essential for maintaining plant and animal biodiversity, especially under a changing climate scenario. Agroforestry adds plant and animal biodiversity to landscapes that might otherwise contain only monocultures of agricultural crops (Noble and Dirzo 1997, Guo 2000).

Freemark (2002) demonstrated the important role of farmland habitat for the conservation of plant species in Eastern Canada. In the Great Plains region of the United States, where cropland occupies most of the landscape, linear riparian zones and field shelterbelts were argued to play essential roles in maintaining biodiversity (Guo 2000, Brandle et al. 1992). In Central and South America, shaded coffee plantations integrate leguminous, fruit, fuelwood, and fodder trees (Beer 2001). These systems have been documented to contain over 100 plant species per field and support up to 180 bird species (Michon and de Foresta 1990, Altieri 1991, Thrupp 1997). In mature complex multi-strata agroforestry systems of Indonesia, plant diversity was in the order of 300 species per hactor, while bird diversity was found to be 50 percent that in the original rainforest. In addition, almost all mammal species were still present at some level in these agroforestry systems (Thrupp, 1997)

2.1.4 Common Agroforestry practices of Bangladesh:

2.1.4.1 Cropland Agroforestry

The system which is practiced in croplands by introducing woody vegetation with the annual crops in spatial or temporal sequences to get benefits from the both crops is known as cropland agroforestry. Generally, trees are grown naturally in croplands and sometimes these are intentionally planted on the crop fields. These systems are primarily used for managing lands classified as agricultural lands. The Cropland Agroforestry systems aim at production of enough food grains, timber, fodder, firewood and other products. The agricultural systems require heavy inputs and the production cannot be increased beyond certain limits. The trees can provide further opportunity to increase production. The Cropland Agroforestry practices are closer to agricultural practices in comparison to silviculture. The trees are grown on agricultural land for security against adverse climatic factors, supplementing agricultural income and increasing the total productivity of the agricultural lands. The Cropland Agroforestry systems are more productive and sustainable than pure agricultural system (Chowdhury M. K. and M.A. Sattar, 1992).

Different types of cropland agroforestry models were found in our country on the basis of arrangement of components:

a) Boundary plantation (hedgerows)

Boundary plantations combine perennial, preferably leguminous trees or shrubs, grown around an arable crop. During the cropping phase the trees are pruned and the pruning's used as green manure or mulch for the arable crop to improve the organic matter status of the soil and to provide nutrients, particularly nitrogen. Boundary plantations as windbreaks also protect crops. Commonly used trees are prickly acacia (*Acacia nilotica*), betel-nut (*Araca catachu*), eucalypt (*Eucalyptus brassiana*) and rose wood (*Dalbergia sissoo*). Eucalypt and rose wood are fast growing trees with high timber values; prickly acacia and betel-nut also have high commercial values. In boundary plantation , trees are planted all along the boundary of the agroforestry plot in one, two or three rows depends on the size and shape of the plot, the interior of the plot is left blank for growing agricultural crop (Chowdhury M. K. and M.A. Sattar, 1992).

b) Alley cropping (hedgerows intercropping)

This model is the most popular and is widely accepted in the study area. Annual crops are grown between rows of trees or shrubs. Multipurpose species – here, usually Mango (*Mangifera indica*) trees are planted in rows. Paddy (*Oryza sativa*), wheat (*Triticum aestivum*), sugarcane (*Saccharum officinarum*), papaya (Carica papaya), banana (*Musa species*), ginger (*Zingiber officinale*), turmeric (*Curcuma domestica*) and different types of vegetables are intercropped with the mango trees to provide a cash flow particularly in the early years after the mangoes have been planted but have yet to yield. Paddy, wheat, sugarcane, papaya and banana are intercropped in the early years (first 12 years), and then the shade tolerant ginger, turmeric and vegetables are commonly planted later (Chowdhury M. K. and M.A. Sattar, 1992).

c) Intercropping

This model is widely practiced in different regions of Bangladesh. Here also multipurpose tree species like Mahagony, Mango, Raintree etc. intercropped with annual crops in a systematic way. Crops yields under the trees are generally reported to be higher than in the open field and this has been attributed to various factors that contribute to micro sited enrichment by the trees (Nair, 1993).

d) Random plantation

Here, trees are planted randomly or scattered on farmlands with annual crops. No systematic pattern followed here.

e) Mixed practices

This model is combination of alley cropping and boundary plantation. In the study area usually Mango (*Mangifera indica*), Lichu (*Litchi chinensis*), Kanthal (*Artocarpus heterophyllus*) trees are planted in alleys with annual crops & other tree species like Mahagoni, Ipil-ipil, Neem, Sissoo, Tal, Khejur etc. planted along the boundary to protect the main crops .Here boundary trees act as a live fences (Chowdhury M. K. and M.A. Sattar, 1992).

2.1.4.2 Based on the Nature of the Composition, there also present different types of agroforestry models in our country.

Agro-silvicultural System

Nair (1985), noted that the term Agrosilvicultural system refers to the use of land for the production of agricultural and forest crops, either simultaneously or alternately E.g. intercropping of forest plantation with agricultural crops, growing tree crops with forest trees.

Silvopastoral System

Silvopastoral system refers to a land management system in which forests are managed for the production of wood, as well as, for rearing of domestic animals e.g, and forests with grasses.

Agrosilvopastoral System

Agrosilvopastoral system is the combination of agrosilvicultural and silvopastoral system, e.g. forest with agricultural crops and grazing lands.

2.2 Performance of tree species in Common Agroforestry practices of Bangladesh:

There are different types of agroforestry practices in our country. The performance of tree species in common agroforestry practices are satisfactory. Date palm is planted along the farm boundaries and in the field to tap juice for molasses making. During the taping season 200-250 liters of juice and 25-30 kg molasses can be obtained from each tree (Abedin and Quddus, 1991; Bhuiyan, 1994)

Mango based agroforestry system is particularly popular in the Rajshahi, Chapai nawabgonj, Kushtia and Meherpur regions. The lateritic, high land soils of these and other similar situations have special preferences for Mango trees, which is planted as Alley cropping and Mixed plantation as well as in-field plantations like an orchard with intercropping of agricultural crops.

Palmyra palm, locally called tal are also grown in plantation patterns more or less similar to date palm. Here also juice tapping is the main economic product sought for, although fruits of female plants are preserved and consumed as green or ripens fruits. Juice is obtained from the

inflorescence of both male and female plants. About 20-25% more juice and Ghur are secured than date palm. The mature stem provides durable construction timber (Abedin and Quddus 1991; Bhuiyan, 1994).

Pine apple based agroforestry system is more productive system which is available in the district of the greater Dhaka, Tangail and Mymensing (Bhuiyan, 1994).

Jack fruit based agroforestry system is particularly popular in the Bhawl and Modhupur tracts regions of greater Dhaka and Mymensing as well as Tangail districts. This system is also more productive than monocroping system (Bunyan, 1994).

Lichu based agroforestry system is particularly popular in the Kushtia, Chuadanga, Meherpur and Rajshahi regions, Lichu trees are planted as both Alley cropping and Mixed plantation as well as in-field plantations like an orchard with intercropping of agricultural crops.

In the Barind tract and also in the high land situations of greater Kushtia and Jessore district in particular, farmers usually retains or plant 50-60 Babla trees/hac in sugar cane field. It has no negative impact upon the production of sugar cane. Peasant has a peculiar belief that it (babla) helps increase the yield of sugar cane (Bhuiyan, 1994).

Table #1: Tree species used in agroforestry practices in Bangladesh

Serial no.	Name of species	Types of agroforestry	Region	Growth/ productivity
1	Date palm (*Phoneix sylvestris*)	Alley cropping and Mixed plantation	Jessore	
2	Mango (*Mangifera indica*)	Alley cropping and Mixed plantation	Rajshahi, Chapai Nawabgonj, Kushtia and Meherpur regions	
3	Palmyra palm (*Borassus flabellifer*)	Boundary cropping	Jessore, Kushtia	
4	Jack fruit (*Artocarpus heterophyllus*)	Boundary and intercropping of agricultural crops	Bhawl and Modhupur	
5	Lichu	Alley cropping and	Kushtia,	

	(*Lichi cinensis*)	Mixed plantation	Chuadanga, Meherpur and Rajshahi	
6	Babla (*Acacia nilotica*)	Boundary plantation	greater Kushtia and Jessore district	
7	Sissoo (*Dalbergia sissoo*)	Boundary plantation	greater Kushtia and Jessore district	
8	Eucalyptus *(Eucalyptus brassiana)*	Boundary plantation	Comilla	
9	Mahagony (*Swietenia macrophylla*)	Alley and boundary	All region	
10	Neem *(Azadirachta indica)*	Homestead agroforestry	All region	
11	Lemon (*Cytrus spp*)	Mixed plantation	Mymensingh, Kushtia, Satkhira	
12	**Guava** (*Psidium guajava*)	Mixed plantation	All region	
13	Kul (*Zizyphus jujuba*)	Mixed plantation	Jessore, Kushtia, Mymensingh	

2.3 Factors influence tree selection in agroforestry:

The following criteria of a tree are very important for tree selection in agroforestry. (According to different authors)

- ✓ Low crown diameter to bole diameter ratio. If large crown then pruning, lopping, pollarding and coppicing should be done.
- ✓ Deep tap root system thus it can take nutrient and water from lower surface of soil and small lateral root system.
- ✓ Having a small lateral root, the species should be survived when the root will be pruned by ploughing.
- ✓ The leaf should not be toxic and the leaf should be decomposed with the soil thus the annual crops can be up taken organic matter.
- ✓ The species should be N_2 fixing and capable of giving timber, food, medicine etc to the local people.
- ✓ The species should be suitable with the particular site.
- ✓ Planting stock availability.
- ✓ Self pruning properties and tolerance of slide shade.
- ✓ Market availability for the product.

2.3.1 Survival and growth

Survival means that has remained as a relic of an earlier time, the continued existence of those forms of animal and plant life best suited to their environment. Seedling survivality are estimated from living status e.g. live or death. Growth means gradually increasing or development of any things. Tree growth means biomass increment of a particular time. Survival rate and growth performance are very importance for tree selection in agroforestry. Because of root system, crown diameter depends on its growth performance. The growth patterns of trees have important implications for resource capture and use, and hence the extent of inter-specific competition and compatibility within specific environments and systems.

2.3.2 Products and services

Since agroforestry is basically the combination of crops and forest, it therefore enables more crops to be cultivated on the same piece of land. Furthermore, since agroforestry should naturally involve two or more species of crops and sometimes combined with animals, the practice would therefore enable the cultivation of many more species, than would be the case with conventional cropping, and forestry. So there are different types of products and services in agroforestry. From the study, all respondents in Dumuria site produce aquatic products as well as vegetables. Very few of them extract fuel wood, pole and timber as most of them have little deficiency of tree based tangible benefits but they have more demand on tree based intangible benefits like environmental service and medicinal plants. So gher with medicinal plant and agricultural crops may be a solution of the above phenomena. Most of the respondents in Kaligonj site produce aquatic products but there is a great opportunity to utilize their gher dike for annuals crops like Vegetables , and tree products like fodder, fuel woods, fruits etc production sequentially or simultaneous.

2.3.3 Constraints in Developing Agroforestry of Bangladesh

Land and tree tenure problems are common problem in all types of public land agroforestry interventions. None of the agroforestry projects had adequate research back up to develop an appropriate system as well as management package for the module adopted and to tailor the module itself, if needed. Lack of farmers knowledge about improved management of trees and agricultural crops (training) is a common constraint for agroforestry system. Scarcity of quality planting materials was reported as the most important constraint for improving the economic productivity of the tradition homestead agroforestry system in Bangladesh. Damage by animals is a major problem for agroforestry plantation. In homesteads, goats and cattle often damage seedlings. Protection problems are also common in strip-side agroforestry. Except the FD's efforts to introduce agroforestry systems to recover encroached forest lands, there is no declared policy on agroforestry research and development) (Abedin and Quddus, 1988. Knowledge gap in agroforestry standard module and species selection is one of the important constraints for improving agroforestry in Bangladesh. Sometimes forestry professionals are lacking of agronomic and sociological knowledge to agroforestry production system. Irrigation facility in the prime is limiting factor for all season cultivation (Bhuiyan, 1994). Scarcity of land, lack of forestry professionals with shortage of other staff, lack of marketing facility, etc are also vital Constraints in developing agroforestry. The propaganda on agroforestry is not satisfied in our country. People's negative attitude toward NGOs also hinders the system's mobility.

2.4 Gherland: a dominant aquaculture base land use

Aquasilviculture - An agroforestry system that combines trees with the raising of aquatic animals (Huxley and, Houten H, 1997). Aqua-Silviculture -coming from the Greek word, "aqua" means water and "silvos" means tree and is an aquasilviculture -management strategy which combines and harmonizes fishery production and vegetation. Again "Aquasilviculture is a multiple use system that promotes a harmonious co-existence between fishery and tree species in a semi-enclosed system while providing coastal protection and maintenance to the ecosystem". (Baconguis,1991). Through the consideration of ecological and socioeconomic importance of the ecosystem, the culture of fishes in cases in fresh water is both compatible with environment and amenable to small-scale family level operations (Troell, 2009).

In a gherland there have high wide dikes, so there have more scope to cultivate agricultural crops. Tree, agricultural crops and fish are combinely cultivated in a same management unit in a same time. So farmers can get more benefit from the gherland agroforestry practices.

2.4.1 Gherland of south western part of Bangladesh

Gher is synonymously used as fish farm in Bangladesh especially in the south west part of the country. If gher is modified rice field having high wide dikes and a canal inside the periphery of the dikes that retains water during the dry season. At the early stage of gher farming most of the farmers cultivated prawn in monoculture ponds, but recently the farmers commonly grow fish with prawn. In addition to this, rice, vegetables and fruit trees are also grown under the integrated gher farming at this coastal ecosystem (Barmon et al., 2004). Rice-prawn culture in the southwest of Bangladesh is an indigenous technique developed solely by farmers. In Bangladesh, two types of gher farming are operated; one is brackish water based shrimp culture and another is fresh water based rice-prawn culture. Shrimp gher farming is large in size and scale, and needs saline water, whereas prawn gher farming is comparatively small in size and scale, and need fresh water (Barmon et al., 2004).

Brackish water aquaculture, also known as coastal aquaculture, is a rapidly expanding farming activity and plays an important role in the overall fisheries development effort in Bangladesh. Marine and estuarine shrimp, fish and crabs are the farm products. *Bagda* shrimp (black tiger shrimp, *penaeus monodon*) is the primary target culture species, while fish, heterogeneous shrimp and crabs are the by-products. The open brackish water fish landing in Bangladesh are generally categorized together with marine landings. The brackish water

culture fisheries generally deal with black tiger shrimp, the main target commodity for high value of frozen food form in Bangladesh.

Though brackish water shrimp is highly preferred to the farmer for highest profit than any other mono-crop. It required 2-3 month saline water for one crop but for double crop it requires year round saline water, which though increase shrimp yield but greatly hamper fresh water rice production. They demand at least a single deep boring machine for each union; so that they can continue their farm activities during drought season otherwise they have to wait for rain water that is also uncertain. Supplemental pumping could significantly increase productivity here, but it is not used. Brackish water organism may be classified into two categories resident and migratory. Brackish- water aquaculture in Bangladesh however, has not yet developed as total system dealing with production of finfish and shellfish for domestic consumption and for export maintaining a sound ecological balance. (Banglapedia, 2010).

Prior to the Rice-prawn gher (RPG) farming, the southwest region experienced a period of severe environmental change during 1960s and 1980s because of the construction of embankments and polders that caused permanent waterlog and increased saline intrusion and the farmers were not able to produce any agricultural crops (Kendrick, 1994). After the introduction of RPG farming system, the cropping patterns have changed. Now the farmers are producing prawn and Modern Varieties (MV) paddy in the RPG farming system throughout the year.

Cultivating rice and fish together has been a 2000-year-old tradition in some parts of Southeast Asia. However, this beneficial cultivation system was gradually abandoned due to population pressures, decreasing stocks of wild fish and the "Green Revolution" which emphasized high-input monoculture using high-yield rice varieties, pesticides, and herbicides (which are toxic to fish) (IDRC,1998). Fish farming in rice fields can be broadly classified as concurrent (integrated) and rotational (alternate). In the concurrent system, rice and fish are grown together, while in the rotational system they are grown alternately. In general, the concurrent rice-fish culture system is practiced in plain-lands and medium lowlands, while the rotational system is performed in deeply flooded lowlands. Two types of rice crops are cultivated in the concurrent system: IRRI and Aman. Farmers cultivate IRRI rice during the dry season from January to April, and the monsoon season Aman rice during June to October. The Aman rice culture takes place in either deep or flooded water conditions with fish, and

with a fish culture period of around 4 months. In the rotational system, farmers produce fish during the monsoon. Fish fingerlings are stocked in May to June and are harvested primarily from November to December, a culture period of around 5 to 8 months. Rotational farmers avoid cultivation of Aman rice with fish due to high water levels. On the other hand, farmers avoid fish culture with Boro rice because of water scarcity and lower availability of fingerlings.

During growth period, the farmers give supplementary feed to the prawn. Traditionally, only mud snail meat was used as prawn feed, but nowadays farmers use a wide range of homemade and commercial supplementary feeds. Carp fish fingerlings are released into gher in May/June and cultured for nine months as long as sufficient water is retain in gher. Usually, no specific supplementary feed is provided for the fish. Native fish species are favored over species which are generally cultured like the common carp, tilapia and silver carp.

2.4.2 Potential of tree component in gherland

The country is facing the problems of fast growing population, low rate of development, depletion of the natural resource base, natural calamities and environmental degradation. Less and less available resources are unable to meet the demands of multiplying development problems. Agriculture is the mainstay of the economy where 80% people live in the villages and are dependent on agriculture. So to accelerate development mission it prior need to develop socio-economic condition of villagers still below poverty level that is acute problem. Agriculture land is being reduced to meet the rapidly growing demand for non-agricultural needs. There is an immediate need for innovative land use practices for maximizing output and income from the limited resource. Aquasilviculture is considered to be a very significant tool for optimizing land use, maximizing output and integrating the production of crops, woody perennial, fish, fodder and livestock into farming system.

Adoption of sustainable land use systems and practices can be a very effective way of achieving the overall development objectives. Practice of GAF is one of the most effective ways for a sustainable conservation and utilization of the land. As a land use practice, aquasilviculture that combines integrated trees, agricultural crops-rice mainly with aquatic organism like shrimp-fish polyculture by this taking care of the best land use, soil fertility and farmer's needs for food, fuel, timber and fodder. It simultaneously helps to sustain rural economy and environment. Many village people are now able to afford household needs very

easily than any time before. It augments the food crops and the tree resources. Depletion of forest and tree resource is leading to environmental degradation and pauperization of the rural economy. Practice of integrated aquasilviculture can help in a very important way to ameliorate the environment and rural economy of Bangladesh.

In rural areas of poorer countries, agronomy, water management, aquaculture and wild aquatic resource harvesting are often physically and functionally integrated. Thus aquasilviculture is an integral and indivisible part of the management of forest and aquatic resources. From the farmer's perspective, GAF can be a way to increase crop yields and the diversity of products grown, but an additional benefit is the creation of a carbon sink that removes carbon dioxide from the atmosphere, and therefore has implications for climatic change. In inland and coastal areas, improved aquatic resources management, including aquasilviculture into existing farming systems, therefore, has the potential to enhance livelihoods, but considerable effort is required to include local people and support their management to sustainable development.

CHAPTER THREE
METHODOLOGY

3.1 Materials and Methods

The study was conducted at Dumuria upazilla in Khulna district in Bangladesh during the period from November 2011 to March 2013. A semi-structured questionnaire was used for detailed baseline information collection. About 39 gherland farmers from Dumuria (Khulna) upazila were interviewed for baseline information of gherland morphology, tree and crop species, productivity, socio-economic status of owners/farmers, local demand for tree products and services, perception on the influence of trees on fish production, livestock, response of planting trees, dike stability, gher management strategies, presence of trees in gher, inundation of dike, sustainability of gher practices etc.

3.2 Selection of the study area

Within 10 upazilla of Khulna district in Bangladesh, Dumuria was selected purposively for the study. The criterion for selecting the site was availability and a large area where has no plant. Farmers are used the land as a gher land. They have practiced aqua culture in their gher and also have cultivated agricultural crops in the gher dikes. Information on this aspect was collected by interviewing the respondents as per questionnaire. Initially, about 6 gher were selected at Moikhali village from Raja union in Dumuria upazilla to plant tree species for the study purpose.

3.3 General Description of the study area

3.3.1 Geography

Dumuria is an upazilla of Khulna district in the division of Khulna, Bangladesh Dumuria is located between 22°39' and 22°56' north latitudes and between 89°15' and 89°32' east longitudes. and it has 71909 units of house hold and total area 454.23 km². Dumuria has 14 Unions/Wards, 189 Mauzas/Mahallas, and 240 villages. It is bounded by Monirampur, Abhaynagor and Phultala upazilla on the north, Baitaghata and Paikgaccha upazilla on the south, Khanjahan Ali, Khalishpur and Sonadanga thanas and Baitaghata upazilla on the east, Tala and Keshobpur upazilla on the west. Main rivers are Shibsa and Shengrail: Beel Dakatia is notable (Source: BBS, 2011).

Fig. 1: Administrative Map of Dumuria Upazilla in Khulna district (LGED, 2011).

3.3.2. Demographics

Dumuria has a population of 317342. Males constitute are 50.12% of the population, and females 49.88%, Muslim 56.97%, Hindu 42.83%, Christian 0.01%, Buddhist 0.01%, and others 0.09%. Dumuria has an average literacy rate of 52.6% (7+ years), and the national average of 51.8% literate. (Source: BBS, 2011).

3.3.3. Main occupations

Agriculture 46.29%, Agricultural labourer 16.77%, wage labourer 4.09%, commerce 12.85%, industry 2.01%, transport 3.24%, service 4.66% and others 10.08% (Banglapedia, 2011).

3.3.4 Land use pattern & cultivation system

Land use: Total cultivable land 31,340 hectares, fallow land 3240 hectares; single crop 36.52%, double crop 33.82%, treble crop 29.66%. Land control Among the peasants 20% are landless, 28% small, 32% intermediate, and 0.8% rich; cultivable land per head 0.12 hectares. (Banglapedia, 2011).

Rice, Jute, Pulses, Oilseeds, Wheat, Sugarcane & vegetables are the important crops of the upazilla. So, the economy of the upazilla is based on agriculture, nursery raising, gardening & business. Among paddy-crops Aus, Aman &IRRI rice is the main. Cropping patterns follow the rainfall. This is particularly true for rice, which has three distinct crops. The Rabi season is dry & extends from late October to late March. Irrigated Boro rice is grown in season. Non-irrigated crops include wheat, potatoes & oilseeds. About a third of the cultivated land is used in this season. Aus & Aman paddy can sometimes be planted on the same land. Agriculture & homestead activities are relatively uniform throughout the upazilla (Banglapedia 2011).

2.3.4.1 Common feature of gherland

The most of the land of southwestern part of Bangladesh are occupied by gher. The feature of gherland is varied from site to site. The common feature of gherland which observed during our study period are given in below-

There are two types of gherland of our study area. Those are -

1. Gher with fish: There practices only fish cultivation. Farmers are not practices agricultural crops or others.
2. Gher with fish and agricultural crops: Farmers cultivates combindly fish and agricultural crops.

Rice-prawn culture in the southwest of Bangladesh is a common feature. In our study area, two types of gher farming are operated; one is brackish water based shrimp culture and another is fresh water based rice-prawn culture.

Different types of GAF practice in our study area

a) Rice + Fish
b) Rice + Fish + Coconut tree
c) Rice + Fish + Vegetables (annual crops)
d) Rice + Fish + Mango tree
e) Rice + Fish + kul (Zizyphus spp.)
f) Rice + Fish + tree species
g) Rice + Fish + Vegetables+ trees

2.2.4.2 Productivity of gherland production system

The main products of gherland are prawn, shrimp and white fish. In additional, farmers also practice different agricultural crops.

Farmers cultivate different agricultural crops in different season.

Table # 2: Seasonal products variation in Dumuria, 2011

Season	Pattern
Apr to Oct	Prawn+ Lady's finger+ White fish
All years	White fish + Banana
May to December	Spone gourd + gourd + Brinjal
October to March	Tomato
January to May	Paddy + Pumpkin

Table # 3: Seasonal products variation in Dumuria, 2012

Season	Pattern
Apr to Oct	Prawn+ Lady's finger+ White fish+ Asparagus bean+ Bean
All years	White fish + Banana+ Basil+ Papaya
May to December	Spone gourd + gourd + Brinjal
October to March	Tomato+ Kohlrabi+ Balsam apple+ Green pepper
January to May	Paddy + Pumpkin

3.3.5 Climatic condition: rainfall & temperature

Rainfall is heavy and humidity high (80%) due to the proximity of the Bay of Bengal. About 80% of the rainfall in the monsoon, this lasts from June to October. Mean annual rainfall varies from about 1,800-2790 (mm) at Dumuria Upazilla. There is a six-month dry season during which evapo-transpiration exceeds precipitation. Conditions are most saline in February-April, the depletion of soil moisture being coupled with reduced freshwater flow from upstream. (Banglapedia, 2011).

Temperatures rise from daily minimam of 10-11 degrees Celsius in winter to a maximum of about 36 degrees Celsius in April and May exceeds 35 degrees Celsius in the monsoon. Storms are common in April to May and October-November and may develop into cyclones, usually accompanied by tidal waves of up to 7.5 meter (m) high (Christensen). (Banglapedia, 2011).

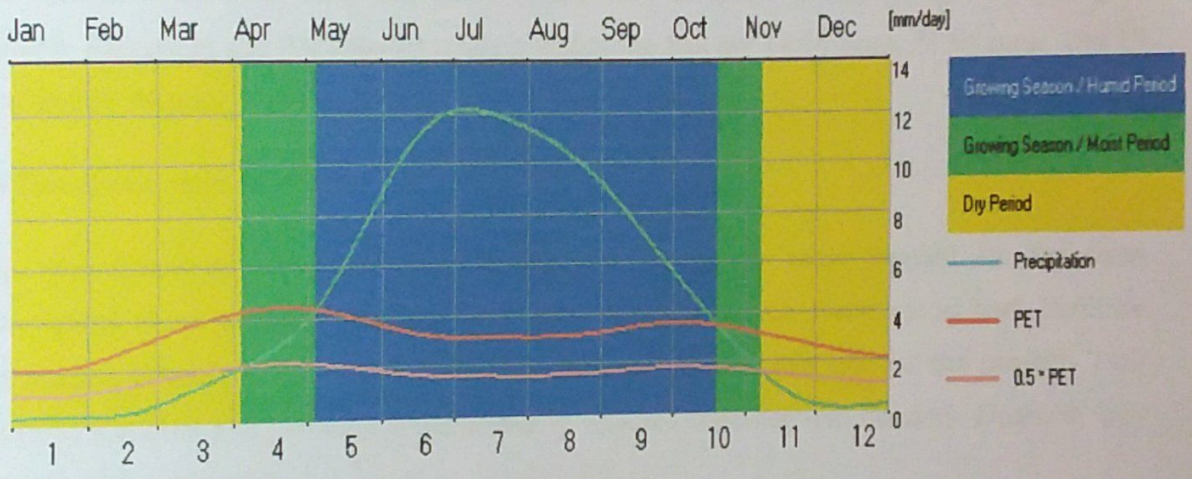


Fig. 2: Growing and Dry period of the study site.

3.3.6 Soil condition

3.3.6.1 Soil pH

Soil pH is the indicator weather the soil is acidic or basic. It is very essential for plant growth as the availability of plant nutrients is considerably affected by soil pH. Calcium, potassium, magnesium and sodium are alkaline elements, which are lost with increasing acidity whereas phosphorous is more available in acidic soil conditions. Acidity can also induce deficiencies of micronutrients such as molybdenum, copper and boron. So determination of soil pH is necessary before plantation. The soil pH of the study sites was analyzed in Soil Science Lab of Khulna University. The average soil pH was found 7.21 of the studied area.

3.3.6.2 Soil salinity

Salinity effects soil properties, water quality, and plant growth. So, it is necessary to measure the salt content in soil before any agroforestry practices. The easiest method of estimating the amount of salt in a soil or water sample is to measure the electrical conductivity (EC) of a solution. The collected composite soil samples were preserved in freeze. After then it was air dried and prepared for EC measurement. The soil salinity (EC) is 0.36 m S/cm of the study site.

3.3.6.3 Soil Chemical analysis

Soil Chemical component such as Nitrozen, Sulphur, Potassium and Phosphorus are very important for plant growth. These are essential component of the proteins that build cell material and plant tissue. In addition, it is necessary for the function of other essential biochemical agents, including chlorophyll (which makes photosynthesis possible), many enzymes (which help organisms carry out biochemical processes and assimilate nutrients), and nucleic acids such as DNA, RNA (which are involved in reproduction). Nitrogen, Sulphur, Patassium and Phosphorus content within the soil are 14.56 ppm, 71.04 ppm, 194.19 ppm and 10.94 ppm of the study site.

3.4 Reconnaissance Survey:

The reconnaissance survey was conducted by the survey team headed by Principal Investigator along with Co-principal Investigators and Research Assistant in both Satkhira and Khulna District in July 2011 in order to find out the suitable site for the project. Two upazillas Kaligonj and Dumuria were primarily selected from the two districts. Dumuria was selected of the study site.

3.5 Tree Plantation:

The gher of six interested farmer from the respondents of each study site was selected for plantation. Plantation species was selected on the basis of baseline survey, where respondents showed their species preference. In Dumuria upazila gher dikes were planted with tree seedlings of Akashmoni, Mahagany, Neem, Koroi, Guava,Coconut, Lime, Mango, Star apple and kul.

3.6 Determination of Survival Rate

Survival means a thing that has remained as a relic of an earlier time, the continued existence of those forms of animal and plant life best suited to their environment. Seedling survivality are estimated from living status e.g. live or death.

3.7 Growth Measurements

In order to know the growth performance of the seedlings height and diameter were taken as growth parameters as a non-destructive measurement. Height of seedlings was measured from root collar to the base of the newest leaf of the terminal shoot. Diameter was measured using digital slide calipers. Two measurements were taken perpendicular to each other, one measurement was taken North-South direction and another measurement was taken East-West direction. The two measurements were averaged to get diameter at the base. The growth data were taken at define interval. Non-destructive measurement are used for determine of growth performance. So biomass is not determined.

3.8 Data Processing and Analysis

Seedling survival is estimated from living status e.g. live or death. Height of seedlings was measured from root collar to the base of the newest leaf of the terminal shoot by measuring tape. Collar diameter was measured using digital slide calipers.

At first, the collected data was reviewed and then discarded of the unnecessary part of the data. Data normality test carried out with SAS (Statistical Analysis Software). The data were analyzed using MS Excel. Paired t test was done by using SPSS (Statistical package for social science), Version-16 to observe the variation of growth for two seasons.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter describes the empirical findings of the research. First of all, the outcomes as regard to the survival rate and growth performance of planting tree in gherland will be discussed. Secondly, the probable factors that might responsible for survival and growth will be discussed.

4.1 Results

4.1.1 Tree species preferred by the farmers

Thirty nine gherland farmers from Dumuria (Khulna) upazila were asked for their preference about tree species to assess potentiality of tree planting in the gher dikes. Most of the respondents who are in favour of planting trees in the dike preferred Mahagony (*Swietenia macrophylla*) (100%) and Akashmoni (*Acacia auriculiformis)* (89%), Neem (*Azadirachta indica)* (23%), Coconut (*Cocos nucifera)* (38%), Kul (*Zizyphus mauritiana)* (31%), Lemon *(Citrus limon*)(10%), Guava (*Psidium guajava)* (33%), Jackfruit(*Artocarpus heterophyllus*) (31%), Mango (*Mangifera indica*) (26%), Eucalyptus *(Eucalyptus camaldulensis)* and Ipil-ipil (*Leucaena leucocephala*) (23%) etc.

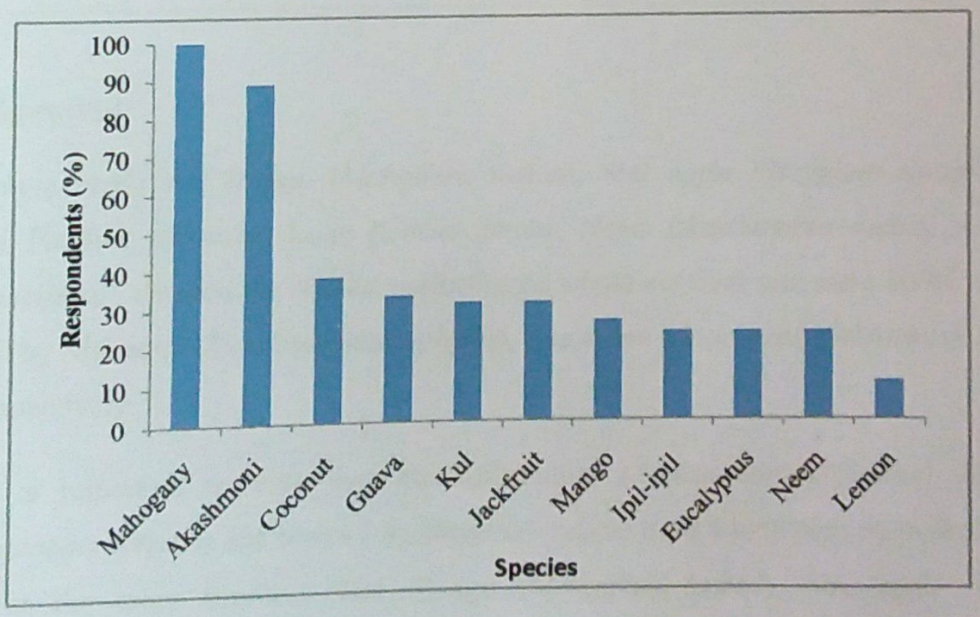


Fig. 3: Interest shown in tree species by the respondents in Dumuria.

Table #4: Woody species used in Gherland agroforestry practices in the study site. (According to farmers preference)

Name of species	Scientific name
Mahagony	*Swietenia macrophylla*
Neem	*Azadirachta indica*
Akashmoni	*Acacia auriculiformis*

Table # 5: Fruit species used in Gherland agroforestry practices in the study site. (According to farmers preference)

Local Name	English name	Scientific name
Am	Mango	*Mangifera indica*
Boroi	Plum	*Zizyphus mauritiana*
Payara	Guava	*Psidium guajava*
Jamrul	Star Apple	*Syzygium samarengense*
Lebu	Lemon	*Citrus limon*
Narikel	Coconut	*Cocos nucifera*
Safeda	Sapodilla	*Manilkara achras*
Superi	Betel nut	*Areca catechu*

4.1.2 Survival

In Dumuria study site Mango (*Mangifera indica*), Star apple *(Syzygium samarengense)*, Guava (*Psidium guajava)*, Lime *(Citrus limon)*, Neem (*Azadirachta indica)*, Coconut (*Cocos nucifera)* showed the highest performance whose survival rate were 100% and it was followed by Mahgony (*Swietenia macrophylla*), Akasmoni (*Acacia auriculiformis)* and 81%, 72%, respectively.

Here it is important to note that the Akashmoni (*Acacia auriculiformis)*, Mahagony (*Swietenia macrophylla*) and Neem (*Azadirachta indica)* trees which planted in the study site at late in the rainy season. But Mango (*Mangifera indica*), Star apple *(Syzygium samarengense)*, Guava (*Psidium guajava)*, Lime *(Citrus limon)*, Coconut (*Cocos nucifera)* are planted at early in the rainy season.

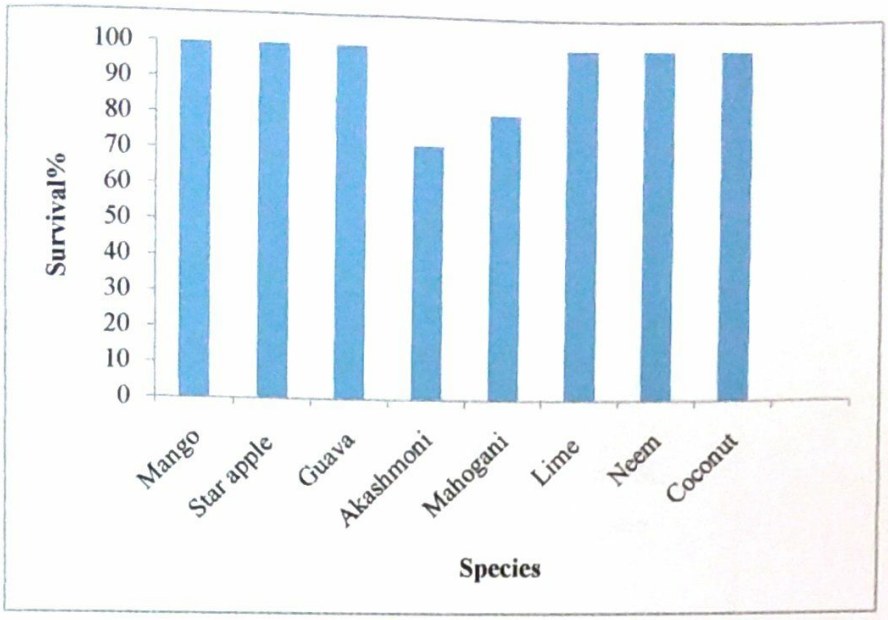
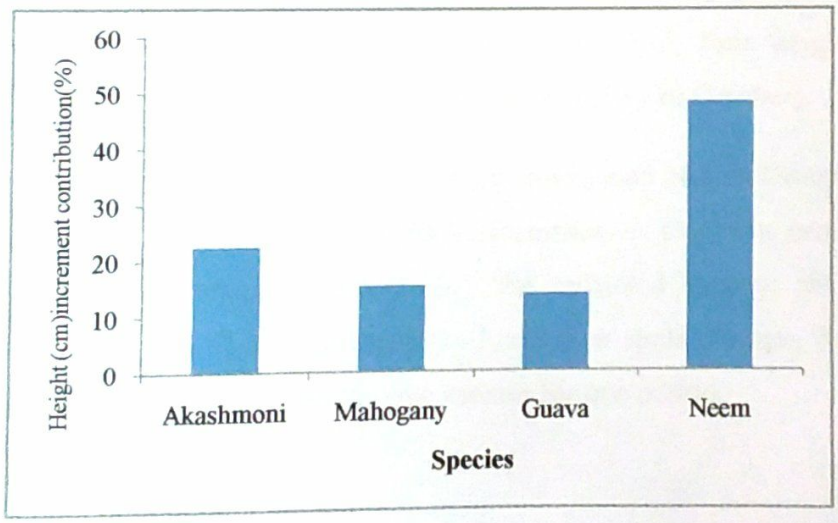


Fig. 4: Survival rate of tree seedlings in the study site.

4.1.3 Growth Performance

Height increment (cm) contribution (%) of different species



Height (cm) increment contribution (%) of different species

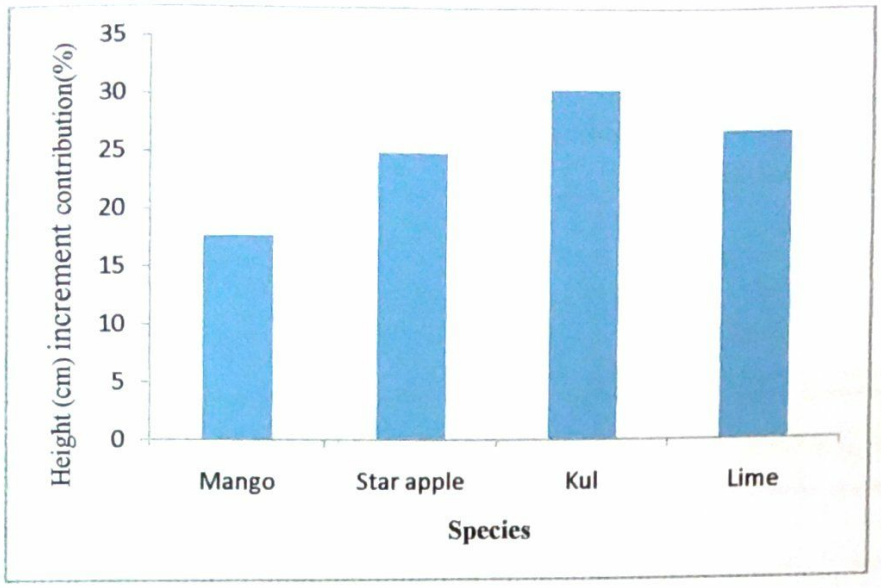


Fig. 5: Height increment (cm) of different species.

Height increment contribution percentage of different species (Akashmoni, Mahagony, Guava, Neem, Mango, Star apple, Kul, lime) are showed above the bar chart. Height increment contribution percentage of Akashmoni, Mahagony, Guava, Neen are shown for two season (Dry season/ Off season (November to April) and Growing season (July to October)). But in case of Mango, Star apple, Kul, lime height increment contribution percentages are shown for only growing season (July to October).

Among the planted tree seedlings, Neem performed best in Dumuria during two periods of time. The order of height growth performance in Dumuria can be arranged as Neem > Akashmoni> Mahagony> guava. But the replanted species, the order of height growth performance can be arranged as Kul> Lime>Star apple>Mango. Kul showed the best height growth performance among the tree species for one period.

4.1.3.1 Periodic Height Increment

Table #6: Paired t test: Height (cm) increment of Akashmoni, Mahagony, Guava, Neem for two seasons

Species		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Akashmoni	Pair 1 Height increment(Nov to Apr)-Height increment(Jul to Oct)	3.79787	52.04663	5.36820	-6.86231	14.45805	.707	93	.481
Mahagony	Pair 1 Height increment(Nov to Apr)-Height increment(Jul to Oct)	-1.64981E2	35.28403	3.08278	-171.07983	-158.88200	53.517	130	.000
Guava	Pair 1 Height increment(Nov to Apr)-Height increment(Jul to Oct)	-4.19828E1	31.78850	5.90298	-54.07446	-29.89106	7.112	28	.000
Neem	Pair 1 Height increment(Nov to Apr)-Height increment(Jul to Oct)	-1.99167E2	113.89366	46.49689	-318.69074	-79.64260	4.283	5	.008

The paired t test table shown that in case of height increment of Akashmoni, probability was greater than 0.05. So there was no significant difference between height increment in growing season and height increment in dry season. There was significant difference between height increment in growing season and height increment in dry season of Neem, Mahagony and Guava ($P<0.05$). Pruning was done in several times in study period to get sun light for the agricultural crops. So height increment was different in case of Akashmoni and others species in the study period.

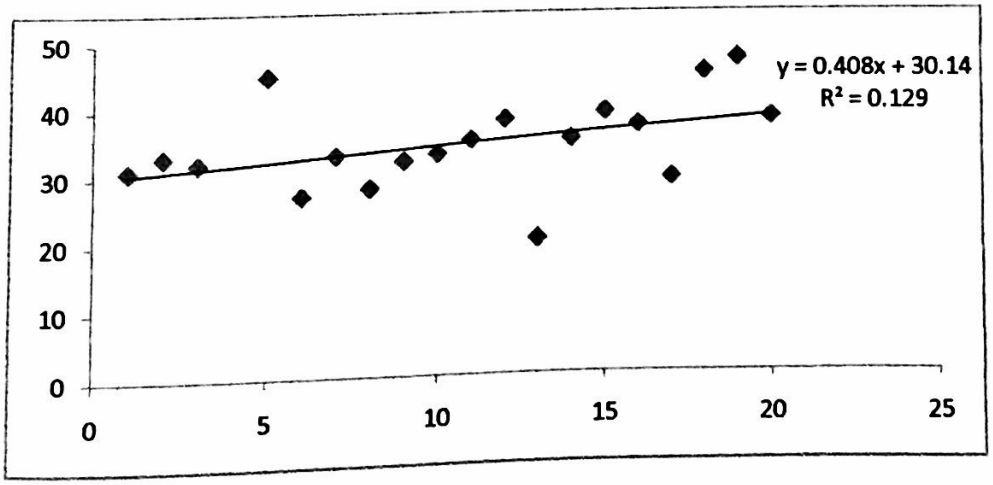
Table # 7: Paired t test: Diameter (mm) increment of Akashmoni, Mahagony, Guava, Neem for two seasons

Species		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Akashmoni	Pair 1 Diameter increment(Nov to Apr)- Diameter increment(Jul to Oct)	-3.52372	7.99187	.82430	-5.16062	-1.88683	4.275	93	.000
Mahagony	Pair1 Diameter increment(Nov to Apr)- Diameter increment(Jul to Oct)	-9.42599	6.69807	.58521	-10.58377	-8.26822	16.107	130	.000
Guava	Pair 1 Diameter increment(Nov to Apr)- Diameter increment(Jul to Oct)	-8.93810	8.01478	1.48831	-11.98676	-5.88945	6.006	28	.000
Neem	Pair 1 Diameter increment(Nov to Apr)- Diameter increment(Jul to Oct)	-3.61193E1	11.31304	4.61853	-47.99165	-24.24702	7.821	5	.001

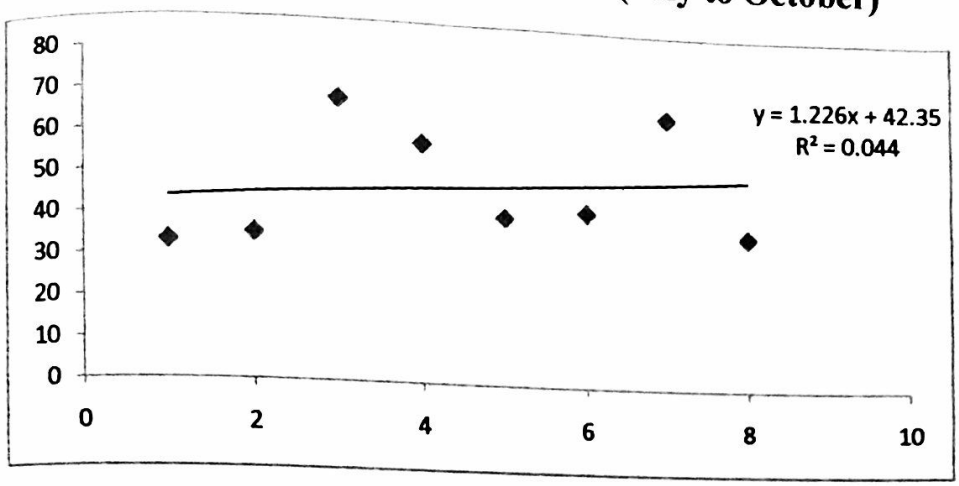
In case of diameter increment, probability was less than 0.05. So there was significant difference between diameter increment in growing season and diameter increment in dry season of Akashmoni, Neem, Mahagony and Guava.

4.1.3.2Height increment (cm) of Mango, Star apple, Kul and Lime

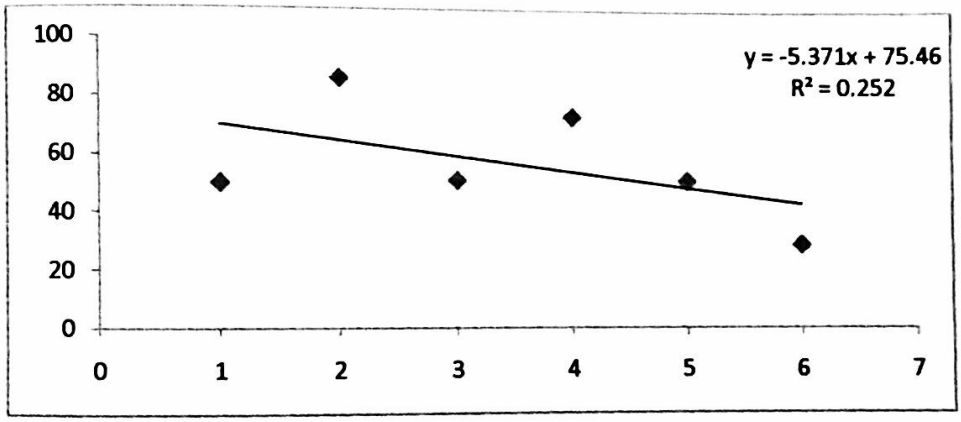
Mango (Height) in Growing season (July to October)



Star apple (Height) in Growing season (July to October)



Kul (Height) in Growing season (July to October)



Lime (Height) in Growing season (July to October)

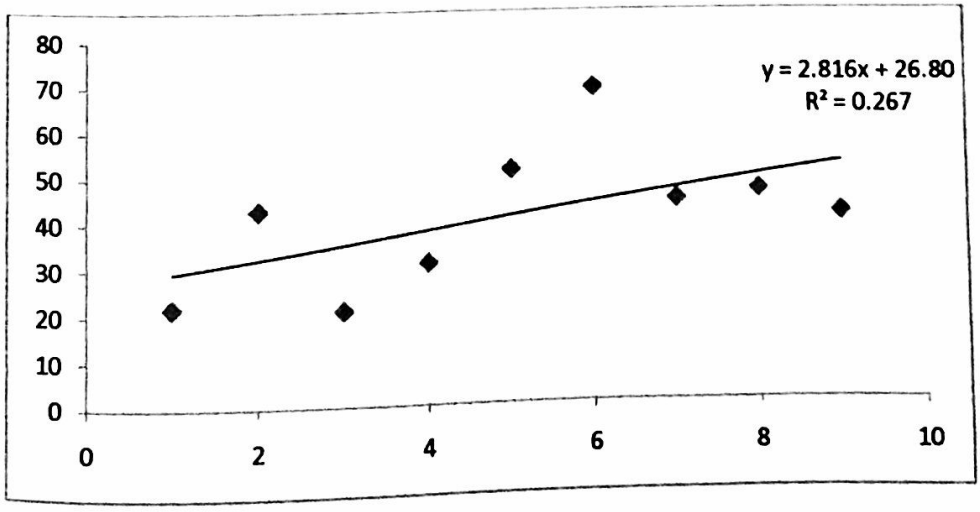
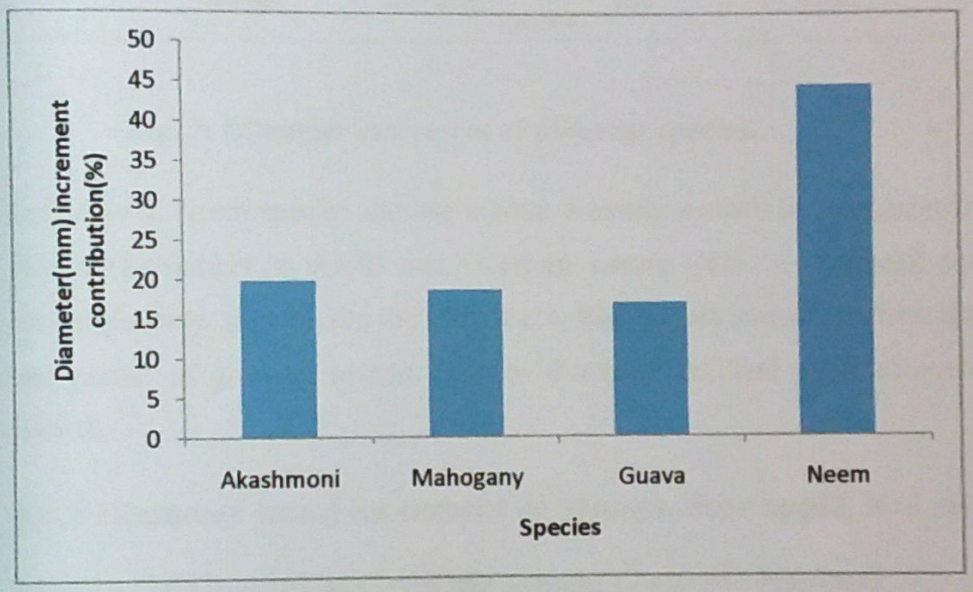


Fig. 6: Height increment in different growing season.

From the above linear equations, the height increment of Mango, kul and Lime has no significant differences among the time series increment of the species. Because of, R^2 value is greater than 0.05. But height increment of Star apple has significant difference among the time series increment of the species (R^2 is less than 0.05).

From the linear line in a scatter plot of the data, the height increment of Mango, Star apple and lime has showed positive increment throughout the months. But height increment of Kul has not showed positive increment throughout the months. Pruning was done in several times in study period to get sun light for the agricultural crops. So height increment was different in case of Kul and others species in the study period.

4.1.4 Diameter (mm) increment contribution (%) of different species



Diameter (mm) increment contribution (%) of different species

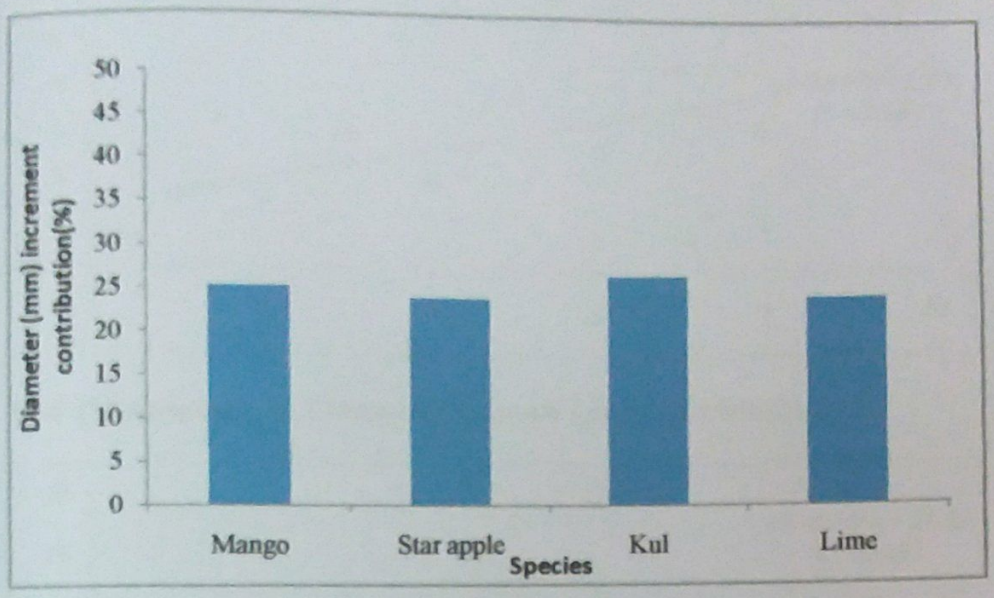
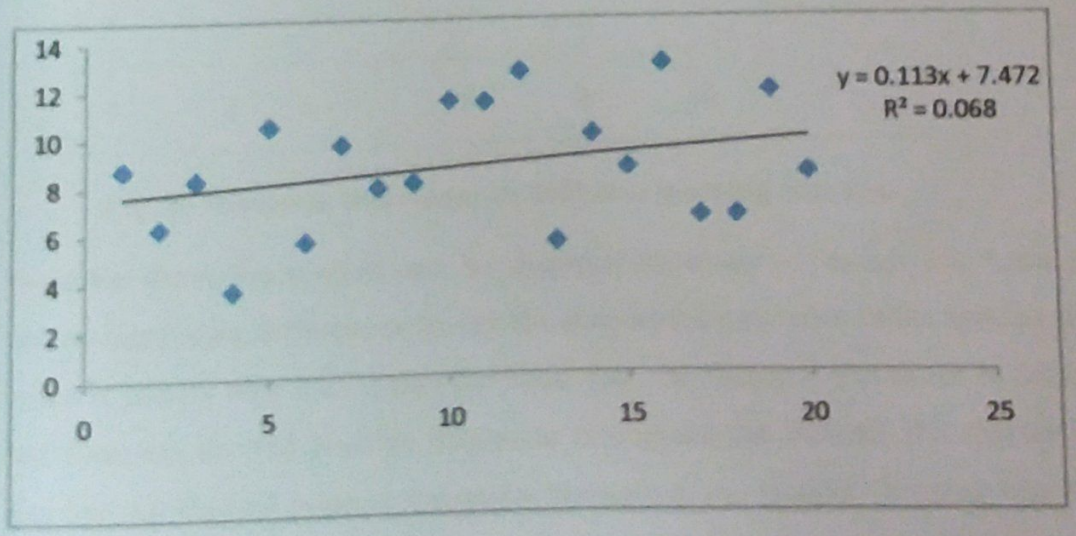


Fig. 7: Diameter increment of different species.

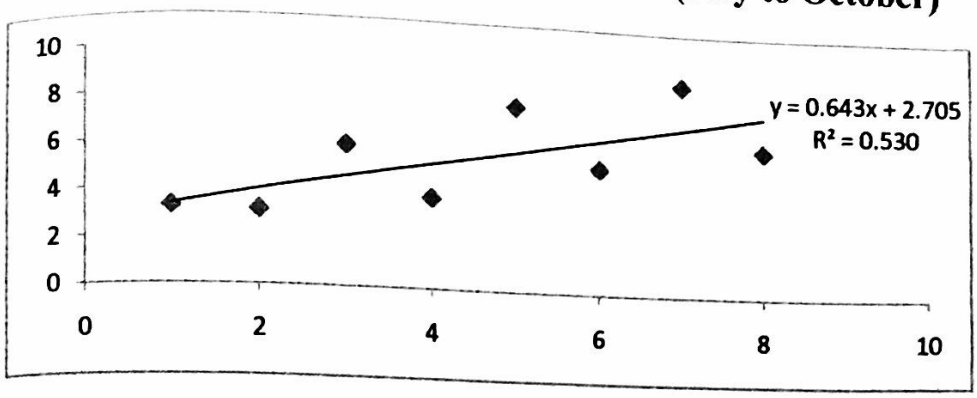
In Dumuria, Neem species showed highest diameter growth for two periods (Dry season/ Off season (November to April) and Growing season (July to October)) and Guava showed lowest diameter growth. On the other hand, Kul species showed highest diameter growth for one period of growing season (July to October) and Star apple showed lowest diameter growth.

4.1.5 Diameter (mm) increment of Mango, Star apple, Kul and Lime

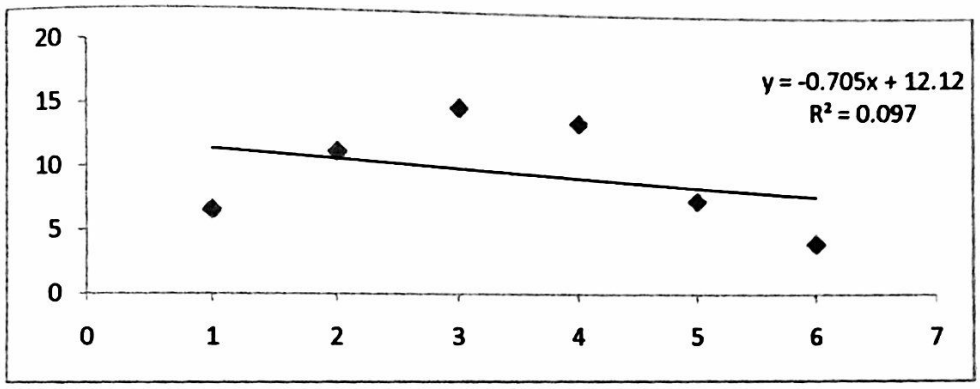
Mango (Diameter) in Growing season (July to October)



Star apple (Diameter) in Growing season (July to October)



Kul (Diameter) in Growing season (July to October)



Lime (Diameter) in Growing season (July to October)

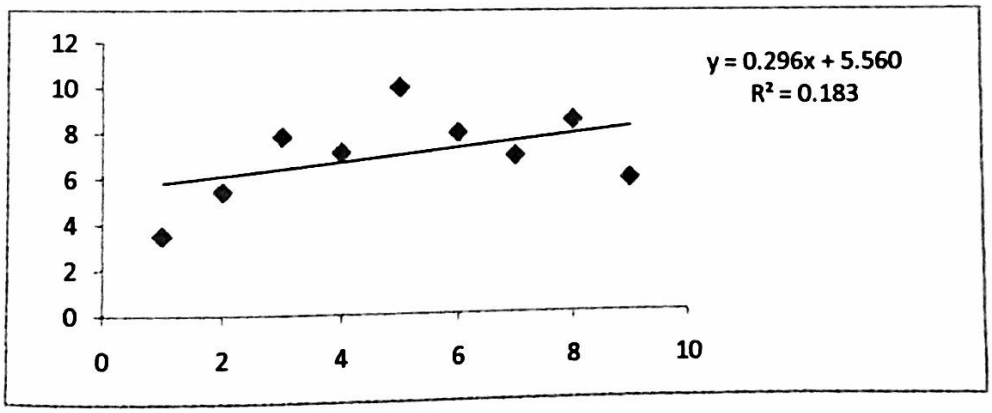


Fig. 8: Diameter increment in different growing seasons.

From the above linear equations, the diameter increment of Mango, kul, Lime and Star apple has no significant differences among the time series increment of the species. Because of, R^2 value is greater than 0.05. From the linear line, the diameter increment of Mango, Star apple and lime has showed positive increment throughout the months. But diameter increment of Kul has not showed positive increment throughout the months. Pruning was done in several times in study period to get sun light for the agricultural crops. So diameter increment was different in case of Kul and others species in the study period.

4.1.6 Height increment (cm) of Akashmoni, Mahagony, Guava, Neem, Mango, Star apple, Kul and Lime

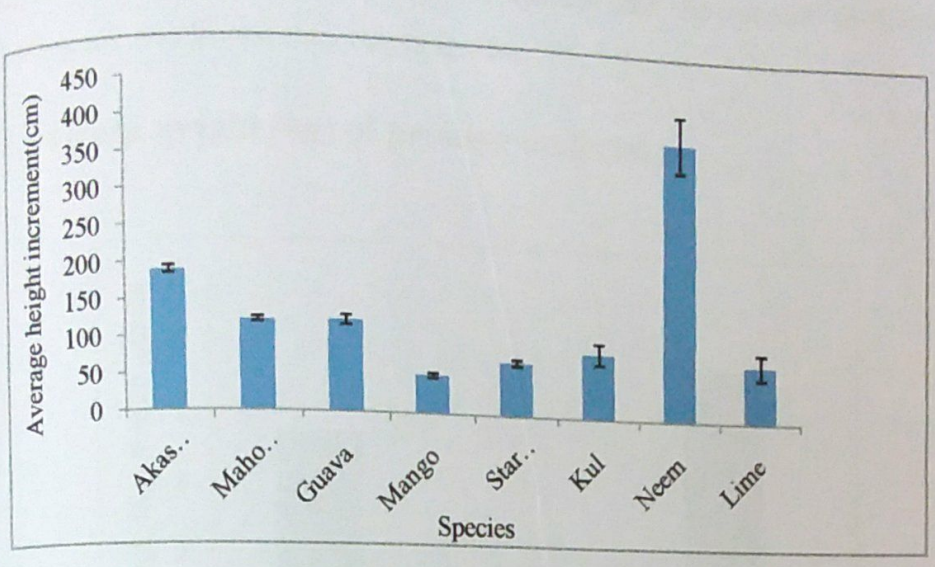


Fig.9: Height increment (cm) of different species.

The average height increment of Neem is the most of others species. But Neem was shown the highest error bar (Positively or negatively error in estimation). So variable of height increment is more in case of Neem. Mango was the lowest height growth performance. Mango and Mahagony were shown the lowest error bar among the others species. So variable of height increment of Mango and Mahagony is not more than other species.

4.1.7Average diameter increment (mm) of Akashmoni, Mahagony, Guava, Neem, Mango, Star apple, Kul and Lime

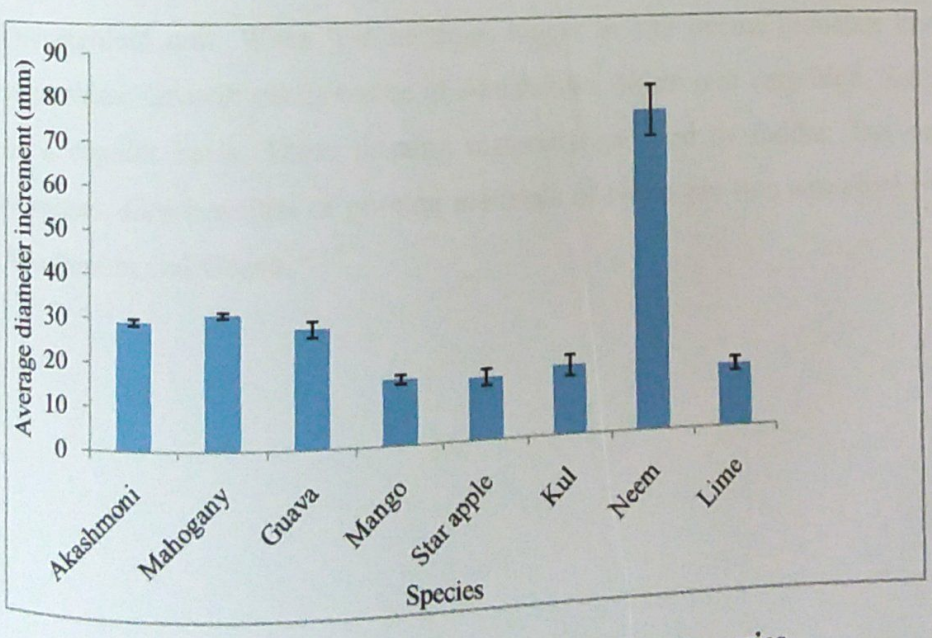


Fig. 10: Diameter increment (mm) of different species.

The average diameter increment of Neem is more than other species. The variable of diameter increment of Neem is also more than other species. Mango was shown the lowest diameter increment among the others species. But the variable of diameter increment of Mahagony was lowest than others species.

4.2 Green weight (kg) of pruning material

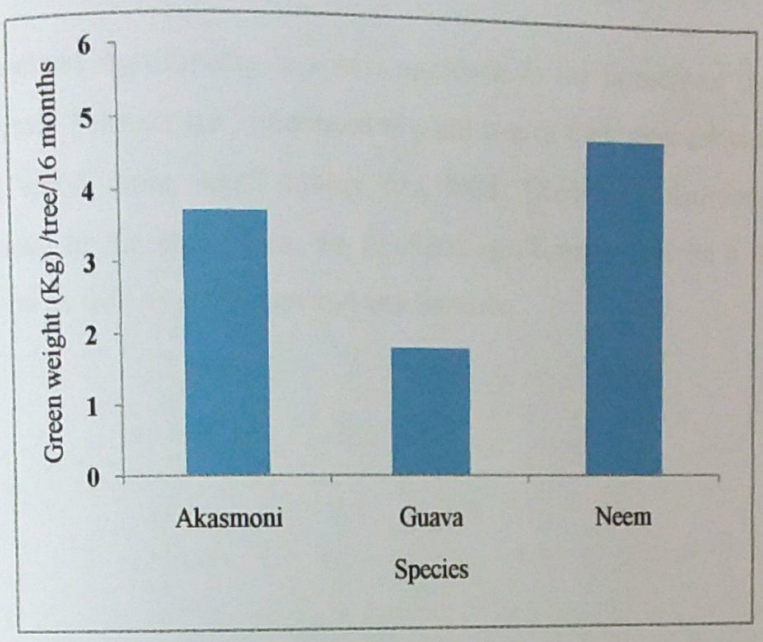


Fig. 11: Green weight of pruning materials.

Pruning (removal of parts of a plant, such as branches, buds, or roots) is essential in agroforestry system as both agricultural crops and forest tree species are cultured in the same management unit. When tree becomes bigger in size excess branches create shade on the vegetables. Growth performance of Akashmoni, Neem was very high. So pruning was done on a regular basis. These pruning materials are used as fodder, fuel and green manure purposes. Green weight of pruning materials of Neem per tree was more of the two species, Akashmoni and Guava.

CHAPTER FIVE

CONCLUSION

GAF is one of the important sustainable land management techniques involving a combination of different agricultural crops, timber and fruit trees, fish and Shrimp practices, termed as aquasilviculture. GAF is a type of land use systems that helps in mitigating present land use problem as well as provides income and employment for sustainable livelihood.

The Gherland Agroforestry is a new approach to the farmers of the south western part of Bangladesh. Farmers are interested to plant tree in their gher dikes to fulfill the basic needs of fuel wood, bole, small timber and food. Growth performance and survival rate is satisfactory in the study area. So gherland agroforestry can be a good practice for better livelihood as well as environmental amelioration.

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APPENDIX

Appendix 1: Local and Scientific names of Annual crops that practiced in GAF

Local name	English name	Family name	Scientific name
Tomato	Tomato	Solanaceae	*Solanum lycopersicum)*
Shasa	Cucumber	Cucumbritaceae	*Cucumis sativus Linn.*
Begoon	Brinjal	Solanaceae	*Solanum melongena L.*
Kochu	Arum	Araceae	*Calocasia esculenta (L.) Schott*
Dharosh	Lady's finger	Malvaeae	*Hibiscus esculentus (L.) Moench.*
Morich	Green pepper	Solanaceae	*Capsicum frutecans Linn.*
Ada	Zinger	Zingiberaceae	*Zingiber officinale Rosc.*
Holud	Turmeric	Zingiberaceae	*Curcuma longa Linn.*
Kumra	Pumpkin	Cucumbritaceae	*Cucumbrita maxima Duch.*
Puishak	Basil	Basellaceae	*Baselle alba Linn.*
Olkochu	Arum	Cucumbritaceae	*Amorphophallus campanulatus Bl.*
Carolla	Balsam apple	Cucumbritaceae	*Momordica charantea Linn.*
Kakrol	Teasle gourd	Cucurbitaceae	*Momordica cochinchinensis*
Bandhakopi	Cabbage	Cruciferae	*Brassica oleracea var capitata*
Lau	Bottle gourd	Cucurbitaceae	*Lagenaria siceraria*
Papay	Green papaya	Caricaceae	*Carica papaya*
Sheem	Bean	Leguminoseae	*Lablab niger*
Barbati	String bean	Leguminoseae	*Vigna sesquipedalis*
Mula	Radish	Cruciferae	*Raphanus sativus*
Phulkopi	Cauliflower	Cruciferae	*Brassica oleracea*
Kola	Banana	Musaceae	*Musa acuminata*

Appendix 2: Local and Scientific names of Food crops that practiced in GAF

Local name	English name	Family name	Scientific name
Dhan	Paddy	Poaceae	*Oryza sativa*

Apendix 3: Height and Diameter increment of Akashmoni in growing and off season

	Growing season		Off season	
Species	Height	Diameter	Height	Diameter
Akashmoni	60	16.74	129	24.025
Akashmoni	69	14.055	100	
Akashmoni	143	13.01	137	21.605
Akashmoni	138	14.8	101	17.315
Akashmoni	72	14.765	101	14.43
Akashmoni	104	12.535	57	12.05
Akashmoni	118	9.87	125	18.115
Akashmoni	105	8.15	118	18.96
Akashmoni	121	16.625	80	12.645
Akashmoni	52	26.41	45	4.49
Akashmoni	115	22.57	89	10.835
Akashmoni	132	22.18	115	13.46
Akashmoni	177	17.1	123	12.945
Akashmoni	100	20.035	100	13.305
Akashmoni	104	25.825	65	6.67
Akashmoni	88	16.33	65	11.745
Akashmoni	123	8.18	120	15.395
Akashmoni			115	17.005
Akashmoni	155	29.73	98	22.99
Akashmoni	87	28.525	55	6.865
Akashmoni	158	18.395	97	12.9
Akashmoni	158	26.86	85	18.15
Akashmoni	103	11.975	79	12.24
Akashmoni	97	10.315	74	16.005
Akashmoni	130	10.905	60	10.345
Akashmoni		20.835	121	12.485
Akashmoni	74	18.875	142	12.33
Akashmoni	57	17.48	105	9.815
Akashmoni	87	19.685	120	11.455
Akashmoni	65	13.735	95	11.075
Akashmoni	83	15.3	125	13.45
Akashmoni	60	17.195	108	10.865
Akashmoni	85	21.25	135	11.53
Akashmoni	63	21.345	135	13.015
Akashmoni	90	22.505	80	10.8
Akashmoni	60	15.125	140	12.845
Akashmoni	97	11.595	140	12.42
Akashmoni	60	11.96	97	11.595
Akashmoni	97	21.585	112	14.375
Akashmoni	97	10.595	120	13.315
Akashmoni	74	8.55	113	16.6

Akashmoni	63	8.61	135	18.59
Akashmoni	78	23.83	75	18.57
Akashmoni	154	27.625	124	12.71
Akashmoni	129	16.585	54	13.21
Akashmoni	55	18.58	142	19.18
Akashmoni	71	11.88	99	15.425
Akashmoni	76	19.34	100	13.815
Akashmoni	121	13.695	61	12.095
Akashmoni	141	15.22	85	9.06
Akashmoni	42	19.56	73	12.28
Akashmoni	72	28.95	73	17.835
Akashmoni	48	13.505	90	9.215
Akashmoni	86	11.5	37	5.54
Akashmoni	98	21.795	65	9.405
Akashmoni	19		93	8.87
Akashmoni	97	21.29	45	6.96
Akashmoni	94	17.995	86	7.805
Akashmoni	54		95	8.32
Akashmoni	121		53	7.92
Akashmoni			99	11.185
Akashmoni	29		79	7.85
Akashmoni	114	20.76	98	10.735
Akashmoni	99	16.69	91	16.205
Akashmoni	89	16.155	118	6.805
Akashmoni	153	9.13	45	4.27
Akashmoni	87	13.17	74	5.27
Akashmoni	43	11.59	84	8.72
Akashmoni	52	9.67	88	7.2
Akashmoni	63	11.53	92	7.845
Akashmoni	31	14.065	62	6.925
Akashmoni	55	11.59	90	6.575
Akashmoni	48	17.95	90	11.07
Akashmoni	23	9.215	103	10.27
Akashmoni	77	14.005	96	11.3
Akashmoni	58	20.92	63	6.975
Akashmoni	93	20.695	66	8.36
Akashmoni	98	13.3	110	8.77
Akashmoni	91	19.205	77	6.455
Akashmoni	75	15.515	76	7.195
Akashmoni	47	21.21	80	6.955
Akashmoni	90	7.9	130	17.245
Akashmoni	50	15.4	105	21.17
Akashmoni	58	16.43	142	17.005
Akashmoni	51	5.56	90	13.67

Akashmoni	36	10.305	111	12.68
Akashmoni	160	25.55	21	8.29
Akashmoni	68	21.335	85	17.66
Akashmoni	135	15.3	50	8.085
Akashmoni	80	23.99	42	11.7
Akashmoni	43	12.26	114	22.46
Akashmoni	63	22.015	137	19.78
Akashmoni	143	10.9	32	19.595
Akashmoni		23.68	128	18.825
Akashmoni	75	11.735	94	12.67

Apendix 4: Height and Diameter increment of Mahagony in growing and off season

	Growing season		Off season	
Species	Height	Diameter	Height	Diameter
Mahagony	57	21.825	30	11.555
Mahagony	103	13.4	36	11.005
Mahagony	73	18.82	12	7.18
Mahagony	124	21.75	38	13.24
Mahagony	108	20.53	46	5.745
Mahagony	96	19.43	45	14.115
Mahagony	117	22.92	36	12.005
Mahagony	90	23.805	17	1.03
Mahagony	101	21.065	21	5.655
Mahagony	123	19.695	19	8.64
Mahagony	137	24.85	60	12.5
Mahagony	132	28.545	25	15.82
Mahagony	85	28.275	67	14.64
Mahagony	68	22.765	55	9.205
Mahagony	87	18.57	10	7.77
Mahagony	152	28.005	43	13.745
Mahagony	102	21.06	18	10.755
Mahagony	116	24.085	55	13.8
Mahagony	135	28.765	29	12.945
Mahagony	112	26.185	27	10.265
Mahagony	103	22.655	26	7.37
Mahagony	53	32.14	35	11.795
Mahagony	112	15.68	22	11.445
Mahagony	87	17.615	34	11.65
Mahagony	177	28.59	20	12.885
Mahagony	88	17.205	5	10.495
Mahagony	86	17.915	6	3.79

Mahagony	89	13.875	35	11.74
Mahagony	102	14.85	14	11.625
Mahagony	74	12.48	18	11.47
Mahagony	145	25.735	60	11.39
Mahagony	118	19.695	9	4.555
Mahagony	96	18.555	40	11.235
Mahagony	51	11.435	15	10.115
Mahagony	89	15.74	15	7.135
Mahagony	83	19.08	13	8.28
Mahagony	104	20.865	28	12.755
Mahagony	122	24.835	20	11.2
Mahagony	110	19.735	9	9.055
Mahagony	131	25.045	26	15.35
Mahagony	140	29.075	2	3.125
Mahagony	13	24.455	36	10.89
Mahagony	90	18.95	24	12.445
Mahagony	72	18.745	7	6.06
Mahagony	125	24.76	6	9.545
Mahagony	87	25.06	22	5.68
Mahagony	69	26.075	22	10.145
Mahagony	14	2.565	21	10.44
Mahagony	63	4.705	7	5.205
Mahagony	63	23.225	29	8.27
Mahagony	25	1.4	6	4.26
Mahagony	42	1.61	7	4.715
Mahagony	86	16.095	5	9.09
Mahagony	61	12.725	23	11.55
Mahagony	8	5.57	12	9.61
Mahagony	39	3.945	18	5.515
Mahagony	74	14.485	55	5.495
Mahagony	26	4.695	14	5.96
Mahagony	90	13.665	11	11.42
Mahagony	74	12.55	7	9.26
Mahagony	58	7.81	35	10.78
Mahagony	93	16.9	11	10.01
Mahagony	50	16.06	48	11.495
Mahagony	71	19.765	17	6.7
Mahagony	107	22.05	32	9.495
Mahagony	61	18.35	9	9.34
Mahagony	87	18.335	16	11.755
Mahagony	98	19.01	15	11.33
Mahagony	91	22.07	8	10.875
Mahagony	128	27.68	39	8.905
Mahagony	50	15.96	49	312.24

Mahagony	129	25.29	111	7.76
Mahagony	127	23.77	16	12.245
Mahagony	76	28.025	36	10.39
Mahagony	81	19.235	37	13.36
Mahagony	100	19.815	26	9.99
Mahagony	83	15.59	50	17.06
Mahagony	103	22.475	29	11.97
Mahagony	110	18.045	25	11.885
Mahagony	43	20.94	32	9.715
Mahagony	54	14.735	27	11.12
Mahagony	38	24.195	33	10.095
Mahagony	1	16.76	58	13.875
Mahagony	53	14.615	27	10.685
Mahagony	40	21.3	40	7.34
Mahagony	78	29.91	18	6.2
Mahagony	109	30.495	25	8.47
Mahagony	68	26.095	26	11.095
Mahagony	136	30.925	19	7.275
Mahagony	70	23.495	44	10.895
Mahagony	89	27.365	35	8.3
Mahagony	75	17.66	27	11.52
Mahagony	77	19.415	17	5.165
Mahagony	74	23.005	51	12.525
Mahagony	135	18.285	20	8.77
Mahagony	77	15.945	50	11.05
Mahagony	124	17.31	6	9.995
Mahagony	113	19.115	27	11.085
Mahagony	133	20.065	34	12.51
Mahagony	141	18.365	26	10.2
Mahagony	111	19.69	22	10.995
Mahagony	113	26.32	26	11.915
Mahagony	118	21.02	29	13.575
Mahagony	98	11.715	30	5.1
Mahagony	108	27.12	73	15.225
Mahagony	139	24.225	39	13.585
Mahagony	110	20.68	11	6.18
Mahagony	151	26.295	32	13.82
Mahagony	111	18.335	29	14.05
Mahagony	93	23.555	43	15.22
Mahagony	80	18.015	17	8.39
Mahagony	73	21.535	13.5	11.135
Mahagony	47	12.18	26	13.735
Mahagony	42	4.55	38	13.005
Mahagony	57	21.27	64	13.16

Mahagony	37	20.575	50	9.955
Mahagony	29	19.185	37	8.98
Mahagony	162	31.6	17	10.615
Mahagony	68	15.56	60	15.985
Mahagony	113	19.39	32	15.33
Mahagony	74	17.125	15	10.765
Mahagony	78	26.86	20	6.955
Mahagony	111	19.675	35	12.76
Mahagony	74	22.82	48	11.25
Mahagony	78	16.47	45	11.07
Mahagony	98	17.155	25	16.685
Mahagony	77	13.295	27	13.46
Mahagony	89	20.85	4	5.84
Mahagony	106	28.69	37	13.075
Mahagony	102	27.65	35	5.45
Mahagony	93	21.17	62	20.06

Apendix 5: Height and Diameter increment of Guava in growing and off season

	Growing season		Off season	
Species	Height	Diameter	Height	Diameter
Guava	103	19.725	73	12.115
Guava	127	24.065	42	11.86
Guava	81	31.99	40	10.7
Guava	53	10.745	23	5.715
Guava	57	9.965	13	6.57
Guava	123	24.34	16	6.75
Guava	48	21.335	28	9.955
Guava	82	23.005	20	3.16
Guava	125	26.38	16	2.235
Guava	108	26.125	19	2.42
Guava	48	4.325	43	4.28
Guava	43	7.865	30	4.94
Guava	45	5.115	37	4.5
Guava	21	0.415	30	5.13
Guava	65	1.525	24	6.04
Guava	78	17.13	76	12.53
Guava	77	19.135	48	12.48
Guava	75	16.145	18	11.32
Guava	108	24.545	41	13.46
Guava	132	19.44	38	13.245
Guava	99	18.995	52	16.045

Guava	65	23.755	61	13.985
Guava	82	23.665	42	9.91
Guava	41	12.72	33.5	3.58
Guava	55	28.915	22	7.22
Guava	72	13.255	29	11.8
Guava	109	17.525	65	14.33
Guava	102	23.81	53	10.255
Guava	85	22.225	59	12.445

Apendix 6: Height and Diameter increment of Am in growing and off season

	Growing season		Off season	
Species	Height	Diameter	Height	Diameter
Am	31	8.725	8	3.405
Am	33	6.27	47	9.885
Am	32	8.235	20	8.2
Am	45	10.445	6	6.93
Am	27	5.61	19	0.725
Am	33	9.6125	21	12.0975
Am	28	7.785	14	4.455
Am	32	7.975	25	4.74
Am	33	11.41	27	0.085
Am	35	11.35	35	5.915
Am	38	12.61	23	10.94
Am	20	5.425	17	6.415
Am	35	9.925	16	8.855
Am	39	8.505	17	3.73
Am	37	12.885	32	8.765
Am	29	6.455	26	7.555
Am	45	6.475	18	10.635
Am	47	11.695	15	4.875
Am	38	8.245	9	6.215

Apendix 7: Height and Diameter increment of Jamrul in growing and off season

	Growing season		Off season	
Species	Height	Diameter	Height	Diameter
Jamrul	33	3.24	62	15.405
Jamrul	35	3.125	59	17.095
Jamrul	68	5.925	83	12.46
Jamrul	58	3.83	76	14.205
Jamrul	41	7.85	68	10.56
Jamrul	43	5.38	83	14.52
Jamrul	67	9.085	90	23.59
Jamrul	38	6.36	72	7

Apendix 8: Height and Diameter increment of Kul in growing and off season

	Growing season		Off season	
Species	Height	Diameter	Height	Diameter
kul	50	6.59	32	7.635
kul	86	11.24	14	11.09
Kul	51	14.775	100	3.055
Kul	73	13.675	8	7.545
Kul	51	7.53	0	1.86
Kul (R)	29	4.095	49	6.81

Apendix 9: Height and Diameter increment of Neem in growing and off season

	Growing season		Off season	
Species	Height	Diameter	Height	Diameter
Neem	397	71.441	20	15.935
Neem	350	56.92	145	35.245
Neem	348	57.22	61	21.505
Neem	193	45	89	12.97
Neem	181	41.97	91	10.46
Neem	209	50.85	77	10.57

Apendix 10: Height and Diameter increment of Lebu in growing and off season

	Growing season		Off season	
Species	Height	Diameter	Height	Diameter
Lebu	43	5.45	11	4.765
Lebu	21	7.855	25	8.005
Lebu	22	3.53	5	4.795
Lebu	31	7.165	27	14.335
lebu	51	10.005	20	4.235
Lebu	69	7.985	31	9.74
Lebu	44	6.955	133	8.41
Lebu(R)	46	8.525	102	3.095
Lebu(R)	41	5.915		