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AGROFORESTRY RESEARCH TECHNIQUES

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Bangladesh Forest Research Institute, Chittagong
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FOREWORD

Agroforestry is an age-old practice in Bangladesh. However, research and development efforts in agroforestry have been initiated only in recent years. Agroforestry is recognized as an effective means of rural poverty alleviation and environment amelioration. Bangladesh, being a densely populated country, needs development of agroforestry for sustained agricultural production to cater to the basic needs of ever-increasing population for food, wood and shelter. A well-concerted agroforestry research program, therefore, is necessary for sustained agricultural production and environmental amelioration.

It is imperative to train dedicated researchers on proper scientific knowledge and technical skills necessary to conduct meaningful research. With this view in mind, the training workshop organized at the Bangladesh Forest Research Institute for researchers, development and extension professionals was a timely step taken by the organizers.

BARC-Winrock International Agroforestry and Participatory Forestry Support Program deserves special appreciation for publishing the proceedings of the training workshop which is expected to be a useful guide to identification of research needs and preparation of meaningful research projects on agroforestry in future.

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ABOUT THE WORKSHOP

Introduction

A well-concerted agroforestry research program in Bangladesh is necessary to find solutions to the chronic problems of food, wood, and environmental degradation. These problems are generated by ever-increasing population pressure on a very limited land and catastrophic natural calamities like droughts, floods and cyclones. Many indigenous agroforestry systems have been in practice in the country. Information is meager about these management aspects, productivity, sustainability and ecological adaptiveness in the specific sites where these are practiced. The main objective, therefore, of an agroforestry research program is to generate data and information essential for and relevant to providing proper guidance to farmers in improving their techniques and capabilities to increase productivity, enhance sustainability, and attain ecological stability on their farm units. The major research needs are: (1) development of guidelines to evaluate or assess the present indigenous agroforestry practices; (2) development of technologies to improve productivity of the existing agroforestry systems; and (3) evaluation of the socio-economic and environmental effects.

To pursue and attain the objectives and meet the major research needs in agroforestry, it is important to train dedicated researchers to equip them with scientific knowledge and technical skills necessary to conduct meaningful researches. A training workshop was, therefore, organized at Bangladesh Forest Research Institute to train research, development and extension professionals in agroforestry research techniques.

The objectives of the training workshop were to:

1. acquaint the participants with basic knowledge and skills in conducting research in agroforestry;

2. stimulate and encourage the participants to identify research needs in agroforestry and prepare meaningful research projects;

3. encourage inter-disciplinary cooperation, inter-personal as well as inter-organizational linkages among workers and institutions concerned with forest production and rural development.

Course Description

The training workshop covered agroforestry systems, data collection techniques; statistical techniques applicable to agroforestry research; and preparation of research proposals.

The participants

The workshop included lectures and field trip for diagnosis and design (D&D) exercise from 26 January to 6 February 1991, and one month interval for literature survey and

field visits to plan appropriate agroforestry research projects. The participants were grouped in four groups, and each group developed an implementable properly-designed agroforestry research project on the basis of agroforestry research needs in their duty stations.

The participants were professionals having bachelor's degree in forestry or agriculture or in related discipline. A list of participants is appended in appendix E. The resource persons were experienced national and international agroforestry practioners or policy planners from BFRI, IFCU, FD and BARC.

The lecture notes distributed during the training workshop by the resource persons are compiled in this proceedings for facilitating other professionals who did not participate in the workshop.

The Editors

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THE NEED FOR AGROFORESTRY IN BANGLADESH

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Introduction

Bangladesh is one of the most densely populated countries of the world with a population density of about 800 per square kilometer. Well over 1000 people live per square kilometer, making land the most valued commodity. More than 60 million people are functionally landless possessing less than 0.2 ha of agricultural land. The population growth rate during the Third Five-Year Plan was 2.2 percent against the target of 1.8. Due to rapidly-growing population, there is a tremendous pressure on land for the basic needs. Consequently, forest land is being encroached for agriculture, aquaculture and homestead. About 73,000 ha of forest land has been lost for these purposes. The annual deforestation rate is estimated to be 8000 ha.

Rural poverty and deforestation in Bangladesh are critical and interrelated problems. The problems are accelerated by over-population, land scarcity and natural disasters. Of the total forest area, less than half is covered with trees, and some areas (such as USF) are virtually devoid of trees. Deforestation and encroachment of forest land for other uses has been highest in the plain land shal forests stretching from Dinajpur to Mymensingh, Tangail and Dhaka Districts. Within 80 kilometer radius of Dhaka, forest lands are being rapidly converted to industrial sites, dairy and poultry farms, and residential areas.

Agroforestry and Poverty Alleviation

Agroforestry is a land use system which facilitates spatial and temporal arrangement for the production of trees, crops and livestock on a given unit of land to maximize productivity and sustainability of the land. In recent years agroforestry has emerged as a strategy to alleviate rural poverty and forest depletion. The practice is appropriate for resource-poor farmers because they can get immediate returns from agricultural crops and accrue long-term benefits from trees.

Importance of Agroforestry

The importance of trees grown under agroforestry system cannot be over-emphasized. Trees provide environmental protection, building materials, energy, shade and beauty, and food for both human beings and livestock. At present trees are being removed at a

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faster rate than they are being replaced. The demand for wood and other tree products, is increasing with the increase of population pressure. In the past land was not scarce. The population of the country was in equilibrium with the environment. People could leave their land fallow to avoid stress over the land resources for some years for rejuvenation.

Monocropping and continuous farming in the same land can seriously degrade the soil through loss of nutrients and increase in soil erosion. Fertilizers help compensate for the lost nutrients. However, chemical fertilizers are often expensive for small farmers, and natural fertilizers are usually not available in sufficient quantitites as these are either used as fuel or thatching material.

Agroforestry is a land use system that can be used by the rural poor to meet many of their needs. Homestead garden is the best example. Trees and shrubs planted in a homestead are a ready and constant source of wood products such as timber, pole and fuelwood. Trees may also be used for soil stabilization and improvement(often through nitrogen fixing) as well as other benefits. The benefits are discussed below:

How Crops Benefit From Tree

(a) Nutrients are added to the soil by trees in the following ways:

i. Nitrogen fixation: Microorganisms (bacteria and fungi) in root nodules of trees/shrubs fix nitrogen in a form that crops can use.

ii. Green leaf manure: Leaf litter from trees provid nutrients and organic matter for the soil. When the leaves fall from the trees or cut and incorporated, they decompose and release humus and minerals to the soil. In a process called **"Nutrient Pumping"** roots of trees carry valuable minerals from deep below the soil surface to the leaves, and eventually these minerals come back to the food crops rooting zone of the soil.

iii. Root decomposition: Regular coppicing of the trees causes a portion of roots of trees to die back. As they decompose, they add organic matter to the soil.

(b) Trees increase soil-water retention through:

i. Organic matter: Like a sponge, organic matter added to the soil by the trees (leaf litter, roots) increases the soil's ability to absorb and retain water.

ii. Windbreaks: Between and during cropping seasons, trees act as windbreaks reducing the rates of evaporation caused by high and dry winds.

iii. Shade: Between cropping seasons, tree crowns shade the bare soil, thus lowering surface evaporation losses. Of course, the wrong trees (especially those with spreading and shallow roots) can also deplete soil moisture, and thus harm shallow-rooted annual crops nearby.

(c) Trees reduce the rate of soil erosion in many ways:

i. The roots hold the soil together. This is specially valuable when trees are planted along the contours of a hillside.

ii. Leaf litter on the soil surface, as well as the protection by the tree crown, lessen the force with which raindrops strike the soil. As a result larger volume of water can soak into the ground, and less soil is carried away by run-off.

iii. Windbreak provided by the trees reduces the wind speed across the crop field, thus lowering the bulk of soil blown away and moisture removed.

iv. Trees/shrubs planted in hedges along contours act as physical structure and thus reduce soil erosion.

(d) Tress reduce weed infestation thus:

i. As the tree crowns are allowed to grow between cropping seasons, the shade from the crowns suppresses weed growth.

ii. The absence of fallow land in an agroforestry system prevent a build-up of weed population, and the tree hedgerows act as a barrier against weed seeds blown into the crop field.

How Trees Benefit From Intercropping With Crops

Tree seedlings planted with crops have high survival and growth rates because they receive the same attention which is given to the crops.

a. They are fenced and/or watched, thus protected from grazing livestock and wild animals.

b. They are weeded along with the crops.

c. They make use of fertilizers that move below the level of crop roots.

d. Some crops act as nurse crop for the tree seedlings.

How Livestock Benefit From Agroforestry

Many tree species supply nutritious, often protein-rich fodder for livestock (e.g. *Leucaena leucocephala*). The tree products, such as leaves, twigs and pods can be used in increasing outputs from their animals.

During dry periods, when feed for livestock is scarce, trees continue to produce fodder. A farmer who has a continuous supply of nutritious fodder will have healthier animals year round than a farmer whose animals are well-fed only during the rainy season.

There are two methods for providing livestock with fodder from intercropped agroforestry species:

- "Cut-and-carry" : The fodder from the trees/shrubs is harvested and brought to the livestock.
- Letting the livestock graze on the trees/shrubs after harvesting the crops.
- Weeds and tree/shrub wildings are controlled by the browse, and the manure of the livestock helps increase soil fertility.
- Livestock benefit from the shade and favourable browsing conditions beneath the trees.

Agroforestry in Ecological Balance and Food Production

Through agroforestry systems, tree cover outside the conventional forest land is increased thereby restoring ecological balance affected by extremely low percentage of forest cover. At the same time through agroforestry practices agricultural crops are grown along with trees which help in substantial increase of the country's food production goal. The principal beneficiaries of agroforestry systems are rural poor. Agroforestry systems ensure multiple uses of the scarce land resource of the country.

Traditional Agroforestry Systems of Bangladesh

Agroforestry has been practiced for centuries in Bangladesh. Trees and shrubs grown in and around homesteads are a ready and constant source of wood products. Homestead trees provide over 80% of all wood consumed in Bangladesh. In crop fields or along

their borders, trees can help maintain or enhance soil productivity, as well as provide multiple products and benefits.

In all agro-ecological zones, trees, crops, livestock and fish are integrated in the homestead production system. In some areas, particularly on rainfed agricultural highland, trees are intentionally planted or retained by farmers, either along field borders or directly in the fields. A more recent focus involves agroforestry development with landless families on denuded forest land, khas land, and marginal land such as strips along roads, railways and ponds.

According to farming systems concept the entire farm and the household is the integral unit for production and consumption. Usually, no land is allocated on a farm for growing purely tree. Instead, trees are mixed with other components to form the agroforestry subsystem.

Agroforestry Research and Development

To improve existing agroforestry systems and test alternative interventions, appropriate research and development is urgently needed. Based on the potential and availability of land, and the scope for improving productivity and benefits through agroforestry, priority areas for research and development have been identified:

High Priority Areas	Lower Priority Areas
Rural homesteads	Khas land
Degraded/encroached forest land	Marginal land
Agricultural highland	Community land

Participatory agroforestry development requires innovative approaches to training, research and extension. In response, the Government of Bangladesh has initiated a number of programs. There is a growing consensus among the senior policy makers that government alone cannot solve the pressing problems of rural poverty and deforestation. Participation of all kinds of change agents and particularly the people must be ensured to make agroforestry economically and ecologically sustainable.

AGROFORESTRY SITUATION IN BANGLADESH AND RESEARCH NEEDS

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1.0 Introduction

Agroforestry, the joint production of trees, crops and/or livestock, has long been practiced by farmers in Bangladesh. In all agro-ecological zones, trees, vegetable crops, livestock and fish are integrated into the homestead production systems, where women play a predominant role. In some areas, particularly on rainfed cropland, trees are intentionally planted or retained along the borders of, or even directly in the crop fields.

A more recent focus in Bangladesh involves agroforestry development with landless families on (1) nonstocked public forest land, (2) revenue khas land and (3) marginal land, such as strips along roads and railways.

Both government agencies and non-governmental organizations (NGO's) are undertaking agroforestry research and development activities.

2.0 Status of Current Efforts

The following 10 subsections summarize the status of current efforts in agroforestry coordination (BARC), research (BARI, BFRI, BLRI, BAU, SDC) and development (Forest Department, BRAC, Proshika, Betagi-Pomora). Other agroforestry research and extension efforts are being carried out by government agencies, universities and NGOs.

2.1 Bangladesh Agricultural Research Council

Agroforestry Working Group : The lack of an institutional base has been identified as one of the major gaps in agroforestry research. In Bangladesh no research institute has an Agroforestry Research Division. The task force on agroforestry and participatory forestry and participants at the "1988 National Workshop on Homestead Plantation and Agroforestry" recommended the creation of an Agroforestry Working Group (AWG) to address coordination needs. The AWG was first convened by BARC in July 1989.

Presently, the AWG includes representatives from Bangladesh Agricultural Research Council (BARC). Bangladesh Agricultural Research Institute (BARI), Bangladesh Forest Research Institute (BFRI), Bangladesh Livestock Research Institute (BLRI), Forest Department (FD), Department of Agricultural Extension (DAE), Bangladesh Agricultural

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University (BAU), Institute of Forestry at Chittagong University (IFCU), Bangladesh Rural Advancement Committee (BRAC), Proshika and Swiss Development Cooperation (SDC):

Farming Systems Research: The National Coordinated Farming Systems Research Program (NCFSRP) was launched in July 1985. BARC provides overall coordination and seven of its member institutions are involved in the program. These are : BARI (9 FSR sites), Bangladesh Jute Research Institute (2), Sugarcane Research Institute (1), BLRI (1) and BFRI (1). The 19 FSR sites are situated in several agro-ecological zones.

Surveys have been conducted on different farming system components, such as crops, livestock and homesteads. In most FSR sites, fisheries and agroforestry surveys have also been completed. The surveys suggest great scope for improving fruit tree varieties as well as management practices on homesteads.

BARC coordinates training activities, program and progress reviews, field monitoring of on-going activities, and dissemination of technology under NCFSRP.

2.2 Bangladesh Agricultural Research Institute (BARI)

Besides the central role in implementing the NCFSRP, BARI/ OFRD has been active in several initiatives related to agroforestry research. These include the following activities:

* **"Women and homestead utilization system"**, is an inter-divisional project in which lady scientists of BARI conducted case studies on homesteads near FSR sites.

* **"Women's contribution to homestead agricultural production systems in Bangladesh"**, is a project undertaken in collaboration with BARD. It is supported by the Ford Foundation through Women's Desk of the Agriculture at BARD.

* **"Household fuel situation, homegardens and agroforestry practices at six agro-ecologically different locations of Bangladesh"**, is a survey conducted at Patuakhali, Jessore, Rangpur, Rajshahi, Ishurdi and Tangail.

* **Surveys on date palm, palmyra palm and babla in the low-rainfall Ganges Floodplain of western Bangladesh,** are conducted to understand the species distribution, tree-crop interactions, different uses and crafts/ cottage industries supported by tree products.

* **A national workshop on "Homestead Plantations and Agroforestry in Bangladesh,"** was organized by OFRD in collaboration with the FAO Regional Wood Energy Development Program and Winrock International. The workshop was held at BARI, Joydebpur on 17-19 July 1988.

Under the rubric of "agroforestry systems and household fuel management", On-farm Research division of BARI started 4 research initiatives during 1988-89 and during 1989-90. These 22 experiments are listed in annex A.

Most of this work is concentrated in the Barind Tract (Rajshahi and Bogra) and the Ganges Floodplain (Jessore, Ishurdi and Pabna), two areas of relatively low rainfall (Table 1). Most research is carried out within the farming systems framework; 18 of the 22 experiments are on FSR sites. Therefore, the work focuses on agroforestry interactions on homesteads and crop land.

Studies on the tree-crop interaction in an agroforestry module are being conducted on forest land in Dinajpur by Nowabganj multilocation trial (MLT) site of BARI. One experiment seeks to determine the effects of four different tree species (*Eucalyptus camaldulensis, Leucaena leucocephala, Dalbergia sissoo and Acacia auriculiformis*) on agricultural intercropsin the agroforestry farms established by the Forest Department's Community Forestry Project. A second experiment tests different cropping patterns to determine suitability with agroforestry and compatibility with farmers' requirements.

Table 1. Location and focus of BARI/OFRD agroforestry experiments

	Number of Experiments focussed on			
Location	Homestead	Cropland	Forest land	Other
Rajshahi	1	2	-	-
Bogra	2	1	-	-
Jessore	2	3	-	-
Ishurdi	1	2	-	-
Pabna	-	1	-	-
Jamalpur	2	1	-	-
Tangail	1	-	-	1*
Dinajpur	1	-	1	-
Rangpur	1	-	-	-
Total	10	10	1	1

* Introduction of improved *chula* (cookstove)

2.3. Bangladesh Forest Research Institute (BFRI)

BFRI is currently conducting four projects with agroforestry orientations:

1. "Agroforestry Research in Government Forest Land and Marginal Land" is a five-year (1989-1991) project that seeks to test (1) different agroforestry cropping systems on government forest land in Chittagong, Cox's Bazar and Gazipur and (2) composite planting patterns for roadside and canalside marginal lands.

2. The Bandarbans (Chittagong Hill Tracts) FSR site is run by BFRI as part of the NCFSRP. BFRI is expected to (1) conduct a baseline survey on existing tree cover by farm size and income group, (2) develop suitable tree planting models on BFRI and FSR sites, (3) develop improved multipurpose tree species and (4) assess costs, benefits and impact on farmers.

3. "Planting of medicinal plants and cane under trees in plantations" is a research effort designed to (1) test different plants that can be grown under big trees, (2) develop techniques for multiple landuse, (3) popularize the underplanting concept among farmers and the Forest Department and (4) determine the economic feasibility of underplanting non-timber crops.

4. Socio-economic studies of the agroforestry settlements at Betagi and Pomora have been undertaken by BFRI.The study on the Pomora Community Forest Project will continue up to 1990 and explore the integration of poultry and betel leaf production as well as community marketing mechanisms for agroforestry products.

2.4 Bangladesh Livestock Research Institute

BLRI's agroforestry research focuses on fodder production and utilization. At the BLRI Farm in Savar and substation at Narikel Chari near Cox's Bazar, experiments are being conducted on grass, legume and tree fodder species. BLRI systematically evaluate indigenous and exotic fodder species and multiply desirable seed and planting material to meet the demands of livestock extension programs.

The following completed and on-going agroforestry and fodder production experiments have been initiated at the Savar farm:

A. Completed projects:

1. Comparative production on maize forage (*Zea mays*) with Ipil-Ipil for fodder and firewood (*Leucaena leucocephala* cv. peruvian) as hedgerow intercrop cut at different heights and different planting methods.

2. Chemical composition of tree leaves.

3. Digestibilities and production trials with tree leaves.

4. Clipping potentiality of *Desmanthus virgatus* as fodder.

B. On-going projects:

1. Comparative production trial of mungbean (*Vigna mungo*) and paragrass (*Brachiaria mutica*) in the intercropping of maize (*Zea mays*) and early established Ipil-Ipil *(Leucaena leucocephala* cv. peruvian).

2. Screening of seven high yielding shrub legumes of tropical genus for forage and fuel biomass.

3. Effect of different cutting heights on the forage clippings of Dhaincha (*Sesbania aculeata*) in hedgerows.

4. Performance evaluation of native and exotic trees for fodder and fuel bio-mass.

5. Nutritive evaluation of different tree leaves.

6. Productive potentials of maize in the established hedgerows of Ipil-Ipil

7. Intercropping potentiality of pigeon pea (*Cajanus cajan*) and Sunhemp (*Crotolaria* spp.) with cowpea (*Vigna unguiculta*) and Centrosema (*Centrosema pubescence*).

2.5 Bangladesh Agricultural University (BAU)

BAU's Farming Systems Research and Development Program (FSRDP) is responsible for two FSR sites in Mymensingh district: Kazirshimla (highland) and Noagaon (low-lying haor land). The FSRDP team is multidisciplinary and includes a component on agroforestry and biomass production, with five experiments at the Kazirshimla site and four at Noagaon.

At Kazirshimla, the agroforestry research work is as follows:

1. "Plantation of fast-growing trees for timber and fuel production" tests several species and involves 20 households at the FSR site. Technical advice and seedlings are provided by the Forest Department (DFO) in Mymensingh.

2. "Plantation of pigeon pea around banana orchards" is designed to use pigeon pea for dual purposes: as a live fence to protect banana orchards; and to produce fuel and edible pulses. Five orchards are included in this experiment.

3. "Relay transplanting of dhaincha in boro rice fields" explores the introduction of dhaincha as a green manure crop in areas where farmers practice a fallow-transplanted aman rice-boro rice cropping cycle. Dhaincha seedlings or stem cuttings are transplanted after ear emergence in boro rice fields and act as a relay crop that replaces the fallow period. *Sesbania aculenta*, a local root-nodulated species, and *S. rostrata*, a stem-nodulated species native to Africa, are used in the trials, which also include replications of the traditional cropping cycle as control.

4. "Plantation of ipil-ipil for fodder and biomass production" monitors *Leucaena* growth on the homesteads of five cooperating farmers.

5. "Monitoring existing biomass production and management of fuel" samples 10 households every fortnight to gather data on biomass production, collection and management.

At the Noagaon site, four agroforestry-related experiments are conducted:

1. "Utilization of fallow lands by growing fodder crops and *Sesbania*" involves five farmers and a 50 square metre plot for each study crop: maize, napier grass, para grass, cowpea, ipil-ipil and *Sesbania*. For *Sesbania*, leaf and stem parts are sun-dried and stored.

2. "Performance of bera, babla and selected water-logged plant species on homestead slopes" tests many tree species for their ability to withstand flooding and prevent erosion of homestead slopes during the monsoon. Contour planting and suitable grass species are also used to stabilize the homestead slopes.

3. "Performance of *Sesbania* transplanted in rice fields as a relay crop" is similar to experiment # 3 at Kazirshimla.

4. "Monitoring the existing pattern of biomass fuel production and utilization" is similar to experiment # 5 at Kazirshimla.

2.6 Forest Department

Since 1982, the Community Forestry Project has initiated a range of reforestation activities in northwestern Bangladesh. With Asian Development Bank funding and FAO technical assistance, the Forest Department has implemented social forestry training, block plantations, roadside tree planting, homestead seedling distribution, and agroforestry.

The most innovative activity has been the establishment of 120 hectares of agroforestry demonstration farms on nonstocked public forest land, where plots of 0.4 to 1.2 hectares in size have been allocated on an annual renewable basis to landless families. A "benefit-sharing" scheme was developed whereby the participating farmers receive all agricultural crops and intermediate tree products (branches, fodder, fruit) and 50% of tree harvests, with the other half going to the Forest Department.

The original "agroforestry modules" were designed by a short-term FAO consultant and were essentially silvi- horticultural combinations. Participating farmers found these models unacceptable as the cropping alleys were too narrow for the use of draft animals and cereal crops were not included. With this feedback, the project introduced a new module in 1986, with 10 meter alleys for crop cultivation between bands of two rows of trees and gaps at the end of tree rows to facilitate passage of draft animals.

This design is liked well by the farmers and has developed into a very productive system. Growth rates for the tree species *Eucalyptus camaldulensis, Acacia auriculiformis, Dalbergia sisso, Leucaena leucocephala and Cassia siamea* are visibly higher in agroforestry plots than in block plantations of the same species. The agroforestry trees benefit from fertilizer, irrigation and weeding that the farmer applies on the crops in the adjacent alleys. In 1987, the project also experimented with a module of 14-meter cropping alleys between bands of four rows of trees.

The Upazila Banayan and Nursery Prokalpa is a follow up project that includes a target of 3,200 hectares of agroforestry to be established over the next four years in the Dhaka-Tangail- Mymensingh shal (*Shorea robusta*) forest zone. The agroforestry design and models will be site-specific and utilize the experience gained in the prior project (Ali 1989).

A pilot project is planned in which the Forest Department will implement 120 hectares of pilot agroforestry demonstrations in the central shal forest plains in collaboration with NGO-affiliated landless groups. Different models will be designed, using a participatory approach, and successful models can be replicated in the Upazila Bonyon Project. This pilot project is awaiting final approval of the Government.

An ICRAF diagnosis and design (D&D) exercise was carried out at Mouchak shal forest site in Feb-March 1990. ICRAF scientists collaborated with Forest Department, BARI, BARC and BFRI, Proshika and BRAC staff on that exercise, produced an agroforestry design for an ICRAF training course held in Bangladesh in 1991.

2.7 Bangladesh Rural Advancement Committee (BRAC)

BRAC's social forestry and agroforestry programme has ecological, economic and social objectives and includes the following components (BRAC 1989):

1. **Homestead plantation:** Since 1977, BRAC has been distributing sedlings of fruit trees and multipurpose trees to group members to plant in their homesteads. These seedlings were collected from the Forest Department and other government nurseries and sold to group members at subsidized rates.

2. **Tree nurseries:** Since 1988, BRAC has emphasized tree nursery development and provided training and credit to group members for this purpose. Seedlings produced are sold back to BRAC for distribution in social forestry and agroforestry programs. Currently, BRAC has established 57 nurseries in 18 Area Offices, with an annual production of about 300,000 seedlings, mostly of fruit trees and mulberry plants. There were also 28 nurseries operated by group members themselves prior to BRAC's nursery establishment efforts.

3. **Roadside plantation:** Since 1980, BRAC has assisted group members by obtaining roadside leases, on a renewable basis, from local administrative authorities. Various tree species are used, including mulberry (for the sericulture program), ipil-ipil (for livestock and poultry programs), fruit trees and fuelwood species.

4. **Mulberry plantation:** In addition to roadside planting of mulberry, 46 acres of mulberry tree plantation and 18 acres of mulberry bush plantation have been established. Survival rate is about 55% and well over 600,000 mulberry seedlings have been planted by the end of 1989.

5. **Agroforestry action research:** BRAC is involved in two agroforestry research activities. The first is a survey designed and conducted on 180 homesteads throughout Manikganj Upazila. BRAC group members were interviewed on their homesteads and the spatial distribution of the trees was mapped. The purpose was to determine how three major variables (homestead size, gender of household head, and elevation) affect species selection and management practices, benefits obtained from trees, and the homesteaders' attitudes toward tree planting. The final survey report will be available soon and the findings will be shared in a workshop with a range of participants.

   The second activity is to design and establish agroforestry demonstrations on a 10.6-acre hill purchased by BRAC in the Garo Hills of Sherpur district. Using rapid rural appraisal techniques and a participatory approach with group members, the demonstration areas are being developed since 1990 to serve as models for khas land agroforestry development in the Sherpur region, where group members have applied for leases on 600 acres of collectorate khas land.

6. **Studies:** BRAC has also commissioned two studies. First is a study undertaken by a Bangladeshi intern in the Yale Forestry School Bangladeshi intern in 1989 on the feasibility of providing credit by BRAC to landless groups for nursery

establishment. Second is a comprehensive review of the forestry sector by BRAC's Research and Evaluation Division.

2.8 Proshika

Among NGO's, Proshika has the most extensive social forestry training activities. It has developed a week-long training module that has been presented about 30 times to some 750 participants from Proshika and other NGO's. Proshika has considerable experience in roadside agroforestry, homestead agroforestry and nursery development, shal forest protection and action research.

Roadside agroforestry: Proshika initiated roadside agro- forestry in 1985 in Sirajganj ADC through a process of cooperation among Proshika, the Forest Department and other agencies. Training, seed and seedlings were provided by the Forest Department. Proshika provided the pigeon pea (arhor) seed. Considerable assistance also came from various other departments at the upazila level for obtaining roadside leases, protecting seedlings, and providing information to the local people.

For this activity, 17 organized groups leased 14 miles of upazila roads for a five year period. In a village called "Italy", two male groups interplanted arhor and babla trees on one mile of roadside. They earned a net income of Tk. 10,300 from selling Arhor pulses and fuelwood.

In 1987, three hundred groups obtained leases along 220 miles of local council roads in 25 ADC's. Three types of problems have been encountered: access to roadside, protection of seedlings and attitudes of adjacent landowners. These problems can be overcome if the rural poor are well-organized, and if good relations exist with upazila and union officials. Roadside agroforestry requires training in nursery development, plantation techniques and protection. Not much capital input is required. Seeds are collected by the groups or purchased with their own savings.

Homestead agroforestry and nursery development: The homestead is a productive resource that even most landless families own; only 5% of the landless in Bangladesh does not own homesteads. The cultivation of trees, shrubs and vegetables as well as the postharvest processing of crops and fuels are done on the homestead. Major nutritional needs of the people are met by the vegetables grown on the homestead.

Proshika group members are involved in tree plantation and nursery development, along with vegetable cultivation on their small homesteads. Group members gain economic benefits from these activities. Group members develop nurseries of both tree and vegetable seedlings, with their own savings or with credit assistance from Proshika. Seedlings from these nurseries are purchased by other group members and villagers. Seedlings are also used by the groups for roadside agroforestry.

The production of tree and vegetable seedlings has been steadily increasing. In 1981 group members produced 987,200 seedlings; in 1988 this production increased to 1,985,000 seedlings. The local demand for seedlings is much higher than that being produced by the groups. Given this high demand, Proshika's present Five-Year Plan has emphasized nursery development; 3,000 nurseries will be established by groups during the plan period.

Shal forest protection: The Proshika experience in protecting forest resources is an example of alternative forest management in Bangladesh. Group members in Kaliakoir and Mirzapur ADC's are at present protecting about 150 hectares of degraded shal forests.

In the Sreepur-Kaliakoir-Mirzapur area, most of the Proshika group members were previously landless daily wage-earners. In the past, many of the group members were part of the deforestation problem. They were often hired by rich people to fell trees from the shal forests. In 1985 Proshika provided training workshops to discuss causes of deforestation and to heighten environmental awareness among group members. Through this process, the groups realized that they were directly contributing to environmental degradation of the shal forests.

In response, some groups have taken the initiative to protect nearby shal forests. In each protection area, a Village Coordination Committee organizes the protection work, which involves rotating patrols of group members. Proshika would like to develop a collaborative program with the Forest Department, whereby group members could help protect areas of existing forests and also participate in agroforestry activities on non-stocked forest lands, in exchange of certain usufruct rights.

Agroforestry trials: Proshika has already documented, on a preliminary basis, more than 9,500 acres of "seasonally fallow" forest land where Proshika groups live in Sreepur, Kaliakoir and Mirzapur ADCs. This information was derived through interviews with Proshika groups in villages near shal forest lands. Much of this "seasonally fallow" forest land has been cleared only recently and is used for a single rainfed crop of broadcast aus rice. Through agroforestry, partial tree cover can be restored some of these areas, and landless participants would derive immediate benefits from agricultural intercropping.

Agroforestry interventions would also serve as **buffer zones** to the nearby protected areas of shal forest. Fuelwood produced in agroforestry plots would meet part of the local demand and lessen pressures on the remaining shal forest for fuelwood collection.

The agroforestry design would be based on the needs of the participating groups as well as site-specific biophysical conditions. As these would be pilot trials, different agroforestry arrangements should be tested.

Proshika has submitted a proposal to the Forest Department to collaborate on shal forest protection and agroforestry activities on a pilot basis. This arrangement would include technical assistance from the Forest Department, training and credit from Proshika, labor contributions from participating groups, and benefit-sharing of trees.

Action research: Proshika has identified five purposes for conducting action research: (1) monitoring; (2) process documentation; (3) agroforestry species selection; (4) agroforestry systems design; and (5) environment and poverty linkages, and impact of environmental degradation on women.

2.9 Swiss Development Cooperation (SDC)

The concern of the SDC for village and farm forestry in Bangladesh is related to rural energy. In 1986 a consultancy study established the action research approach for the SDC intervention called "Village and Farm Forestry in Bangladesh". The first field trials were planted in May 1987.

An Agroforestry Coordinator at SDC, Dhaka provides program management. He is assisted by two field supervisors -- one at Natore and one at Dinajpur. The action research is carried out through several "primary contact partners" -- usually NGO's already established in the field -- and is focused on northern Bangladesh, where serious fuelwood deficit exists. At present, nine organizations (eight NGOs and the Bangladesh Agricultural University) and over 500 cooperating farmers are associated with the research work. The Forest Department and DAE provide some technical support, training and seedlings.

SDC decided to intervene on privately-owned land, which generally has less complex land and tree tenure than on government or community lands. The main objective of the action research is to determine the acceptability of intensifying the number and management of trees on homesteads and cropland in northern Bangladesh. Secondary objectives are to determine the desirability and adaptability of different species, their effects on field crops, any incremental benefits, and optimal agroforestry production models and requirements.

Models for in-field trials are followed, and individual tree records are kept to monitor growth and products obtained from the trees. For each model three different tree species and planting times are employed. The most common species used are : *Eucalyptus camaldulensis, Acacia nilotica and Leucaena leucocephala*; a variety of other local and exotic species is also being tried.

The action research includes the testing of different tree planting technologies, tree management practices, utilization of agroforestry products, monitoring and evaluation, and data analysis. Individual tree records are maintained for data on survival, growth, yields and effects on agricultural crops. Farmer acceptability of in-field tree

planting appears to increase with time as long as there is no reduction in the yields of rice and other associated crops (SDC 1989).

2.10 Betagi and Pomora Agroforestry Settlements

Betagi and Pomora are two settlements in Rangunia Upazila, Chittagong District. Betagi is on hilly khas land administered by the Assistant Commissioner (Land); Pomora is on Protected Forest under the Forest Department's jurisdiction. The dense forests of this area have been illegally felled by timber contractors. Most of the prior tree plantation efforts have failed as a result of illicit felling. Many of the hills are now co-opted by local elites as grazing land for their cattle. Landlessness and encroachment are endemic problems.

In 1979, seventy-two landless families settled in Betagi; later in 1980, another 96 families settled in Pomora. The number of families have increased to 83 in Betagi and 126 in Pomora.

The critical institutional arrangement for this effort was securing the land from the government despite stiff opposition from the local elites. Eventually, this was achieved with support from the Deputy Commissioner and local administrative officials, and each family was allocated a 4-acre plot, on a 5-year verbal lease basis. In 1988 each Betagi family was given a permanent land deed, with certain restrictions, by Begum Ershad, the President's wife on behalf of GOB. The then tenurial situation in Pomora is still on a verbal basis.

In Betagi and Pomora, small loans of Taka 1,000-5,000 ($30- 160) per family were provided by the local Krishi Bank for land development. Following Grameen Bank procedures, the families were divided into small groups, with each group taking responsibility for loan repayments. The loan recovery rate has been about 70-75%.

An agroforestry system was developed with vegetables, fruit trees and timber species. Crops of short-rotation (vegetables), medium-rotation (papaya, banana, pineapple, lemon and others) and long-rotation (jackfruit, mango, coconut and timber species) were used. Lemon has emerged as the most important revenue-earning produce. In Betagi, healthy natural regeneration of *Albizia* spp. and other trees is now abundant, especially on the upper portions of the hillsides. In Pomora, however, the plots appear to be less developed and with less tree cover.

The settlement scheme and agroforestry practices have provided the previously landless families with some degree of stability and security. In addition to subsistence needs, income is generated from the sale of fruits (particularly citrus), fuelwood, and thatching material. In time, timber revenues will be realized.

While these earlier studies provided some important preliminary information, they relied on "snapshot" data collected during short periods in the field. The absence of

baseline information on the settlers (e.g., pre-Betagi income and social status) and the two areas (e.g., maps on land ownership and use patterns) makes it difficult to compare changes over time and the magnitude of the impacts.

The dearth of solid empirical data on social forestry experiences in Bangladesh is not unique to Betagi-Pomora. To make any valid comparisons between the array of social forestry approaches implemented by government, NGOs and local communities, one must know how each effort has affected (1) the social and economic condition of the participants and (2) the ecological and land-use situation of the area concerned.

An in-depth collaborative study on Betagi-Pomora is needed to document and evaluate the processes leading to the present social, economic and land-use conditions and to learn lessons from these dynamic, evolutionary processes. These lessons could provide insights on how this type of agroforestry settlements can be replicated on barren land in the Chittagong Hills, the Garo Hills and other similar areas.

Research Needs

The draft agroforestry plan identifies specific research needs for the highest priority areas: rural homesteads, agricultural highland and degraded forest land. These should form the central thrust of agroforestry research activities over the next five years.

Homestead agroforestry research needs:

* diagnosing existing homestead agroforestry systems, and designing improvements based on household needs and resources

* identifying fast-growing fruit trees, MPTS and nitrogen-fixing trees suitable for homesteads in different agro-ecological zones

* determining proper tree management, homestead cultivation practices, and spatial arrangements to maximize production and income, especially on small homesteads

* conducting socio-economic research on homestead systems, with particular focus on gender roles and problems

* developing appropriate small-scale nursery techniques for homestead production, utilizing no- or low-cost inputs available to the household (e.g., organic fertilizers, green manure, water hyacinth mulch)

Crop land agroforestry research needs:

* monitoring and diagnosis of the existing crop land agroforestry systems, especially those in the lower rainfall zones to better understand problems and design potential remedies

* developing silvo-pastoral modules for existing jackfruit, shishu and mango orchards in the High Ganges River Floodplain

* determining optimum spatial arrangements of babla, shishu and jackfruit in different crop land situations

* testing different combinations of field border (*ail*) planting of trees, hedgerows, live fences etc.

* determining appropriate management practices (pruning, lopping, pollarding) for in-field trees to reduce negative effects on crops

* experimenting with the use of *Sesbania* (local species and *S. rostrata*) as a fast-growing MPTS for fuel and green manure: planting cuttings as a relay crop in rice systems; hedgerow intercropping with rice

Forest land agroforestry research needs:

* testing different cropping patterns in agroforestry modules establishing in the shal forest zone; of particular importance are suitable winter (rabi) crops for no or limited irrigation facilities

* measuring tree-crop interactions over time; and developing dynamic cropping patterns in response to evolving site conditions (e.g., using more shade- tolerant crops as trees mature)

* monitoring and evaluating total agroforestry production, inputs and outputs, and ecological impact

* determining optimal plot size and configuration to maximize agroforestry production, based on land availability, site variables (e.g., irrigation potential), and labor availability of participating households

* testing more local species for their compatibility and value in agroforestry modules

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RAPID RURAL APPRAISAL IN AGROFORESTRY RESEARCH

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Introduction

Agroforestry (AF), an old landuse practice with a new name, needs extensive research anchored on the felt needs and problems of beneficiaries. By a holistic definition, agroforestry means a sustainable land management system which increases the overall yield of the land, combines the production of crops (including tree crops), and forest plants and/or animals simultaneously or sequentially on the same unit of land, and applies management practices that are compatible with the cultural practices of the local population (King and Chandler, 1978). So AF is a complex land use technology intimately associated with factors like structural description (trees, crops and/or animal combination), production objectives (sustained yield) and socio-economic objectives (cultural practices of local community) which encompasses myriads of problems and needs of the local community. Community appraisal to acquire knowledge of these needs and problems is pivotal in designing any agroforestry project. Community appraisal is a method of assessing or evaluating a proposed project community (Rabanol 1985). The main objectives of community appraisal are: to analyze a target community in terms of the critical bio-techno-physical, socio- economic and cultural factors bearing on possible constraints and/or potentialities for AF project. In the recent past, Rapid Rural Appraisal (RRA) has got recognition as a rapid and effective technique for community appraisal in various rural development projects like FSR/E, Health, Irrigation and so on. RRA can play a vital role in designing. implementing, monitoring and evaluation of an effective and efficient AF project.

Evolution of RRA Technology

Over the last 10-15 years, field researchers have begun to develop and refine their methods for the purpose of collecting more accurate and more effective data in a timely and cost- effective manner. In the late 1970's, good deal of enthusiasm was generated for the use of RRA for improving the cost- effectiveness, timeliness and quality of rural development-related research (Grandstaff et al. 1987). The lengthy, complex and inflexible traditional research methods have failed to provide necessary information in time which jeopardized the implementation of rural development projects.

Again, information gathered by quick survey suffered from a number of biases. Example of such biases include primarily visiting research sites that were close to urban centers, talking only to village elites, giving only where projects were accepted and

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traveling only where roads were good or only making visits during more favourable seasons (Grandstaff et al. 1987). These considerations played an important role in the emergence of RRA. Many questions have been raised on RRA's concepts, legitimacy and applicability in different situations. There is a debate about RRA whether it is a methodology with a distinct conceptual approach or just a collection of tools and techniques. Certainly it relies on a large and growing collection of tools and techniques, many of which are not new but were instead adopted from many different fields, such as anthropology, geography, psychology and journalism.

RRA, an emerging new methodology, is a distinctive "process of learning about rural conditions in an intensive, iterative, interactive and expeditious manner" (Kaen 1987). Molnar (1989) defines, "RRA as a tool-kit designed to reduce biases in gathering and analyzing information under a time constraint." In effect, RRA is a creative package of social science tools for information gathering and for the dissemination of findings in a digestible form for use by planners, project staff, local people and government officials." RRA provides a wide range of techniques which have in common the objectives of quickly acquiring critical information about or from an area during one or more visit (Conway 1987). RRA provides a timely and cost-effective way to learn about characteristics, opportunities and constraints of the local situation that may affect implementation of the project.

Variations on RRA are known by a number of other names (Sondes, informal agricultural survey, exploratory survey, and so on) and are practiced in slightly different forms in various parts of the world. The "diagnosis and design" (D&D) approach used by ICRAF can also be considered as a form of RRA.

Principles of RRA

As an evolving research methodology RRA is based upon following core principles:

A. Triangulation:For most RRA, the major dimensions should be triangulated to improve accuracy: (1) team composition, (2) units of observation; and (3) research methods.

B. Exploratory and Highly Iterative Research: The sooner inappropriate hypothesis can be abandoned or reformulated based on new information, the faster one learns. RRA is designed to be highly iterative so that this can take place. For example, semi-structured interviewing is normally one of the principal methods used, because it enables researchers to rapidly change questions, interviews and directions as new information appears.

C. Rapid and Progressive Learning: The conduction of an RRA frequently results in as many new questions as answers. The new questions and new insights usually allow researchers to move more directly toward an understanding of real

problems and their solution. Rapid learning means that delays and distractions in the RRA work must be minimized.

D. Substantial Use of Indigenous Knowledge: RRA is carried out as close to the source as possible. Farmers' perceptions and understanding of resource situation and problems are important to learn and comprehend because solutions must be viable and acceptable in the local context and because local inhabitants possess extensive knowledge about their resource settings.

E. Interdisciplinary Approach and Teamwork: The overall complexity of the total rural system cannot be studied by a specialist in any single discipline to adequately understand the factors. A small team of researchers representing different disciplines works in RRA to better understand the rural situation. RRA engages multi- disciplinary team of researchers in intensive interaction, both among themselves and with informants/respondents from outside the research community.

F. Flexibility and Use of Conscious Judgment: An important principle in RRA is not just to plan the work but also to 'work the plan' in a flexible manner that allows creativity and modification where appropriate. To benefit from flexibility, RRA team relies upon evaluation and conscious judgment to make effective and appropriate decisions.

Conceptual model for factors influencing methodological development in RRA is given in figure 1.

RRA Methodology

RRA will continue to be a viable methodology for learning about rural conditions. It should also be envisioned that the methodology will evolve as rural development efforts continue and rural conditions change world-wide. Two things under A and B below are attributed in the range of RRA methodology:

A. Major categories of RRA activities:

1. Preparatory Work: Before field work, multidisciplinary team is selected for collection and examination of existing information (Appendix B). This includes published and unpublished reports, maps, aerial photographs environmental and social data and so on. The duration of preparatory work is 1-2 days.

2. Field Study: Field study can be done by one or many visit(s) to the project area. Fieldwork always involves various consciously chosen forms of researcher-villager interaction, including but not limited to extensive semi-structured interviewing. Observation and frequent meeting of team members occur during field study. The team will be divided into groups of two members

alternately interchanged. Every evening, there should be an interaction/interchange of information/ideas among RRA team members. The overall goal of the team during RRA should proceed with gradual convergence and agreement on problems and constraints and important issues. Field study continues for 3-14 days. Field studies/assessment needed for RRA is annexed in Appendix-C.

3. Completing the RRA: Throughout the course of RRA, team members should participate in discussion and analysis which are aimed at reaching consensus on what has been learned and what is still unclear. The results of RRA recorded by preparation of report may be supplemented by audiovisual material when appropriate. Analysis, interpretation and report preparation can usually be completed in 2-4 weeks (Appendix-D).

B. Methods, Tools and Techniques:

RRA involves deliberate selection and combination of a number of research methods, tools and techniques to suit particular research needs.

Research Methods:

(1) Semi-structured interview; Indigenous knowledge
(2) Direct observation
(3) Use of (proxy) indicators
(4) Use of time and space, and logic schematics
(5) Use of maps
(6) Aerial photographs
(7) Simple direct measuring tools
(8) Interview guide
(9) Key informants.

Tools and techniques: A large variety of specific tools and techniques has been employed in RRA work.

1. Organizational techniques: Interview protocols, selection of respondents, focus group; ways of handling interview introduction, setting and contexts;

2. Schematic tools: Crop calender, sketch map, cross-sectional diagram, labour schedule, decision tree, folk taxonomy and family structure diagram;

3. Measuring and recording tools: Camera, videocamera, measuring tape, immersion gauge, scale and range-finder;

4. Interviewing techniques: Probing, the 'six helpers (who what-where-when-why-how'), and non-leading questions; and

5. Observational techniques: Field walks, transacts and spending time in central places.

Application of RRA

1. Explore, identify and diagnose rural situations, problems or issues;

2. Design, implement, monitor, and evaluate program, projects and development actions;

3. Help develop, extend and transfer technology;

4. Assist in policy formulation and decision making;

5. Respond to emergencies and disasters, and

6. Improve, supplement or complement other types of research.

Shortcomings of RRA

1. Quick appraisals can be seriously misleading. Specially when there is a concern with poorer people, RRA will merely mean that appraisers spend less time in the field, and the poor remain as in the past unseen and unheard.

2. Since the RRA collects only limited quantifiable data, since the sample is an opportunity sample, purposively chosen and not a random sample, its future use for project evaluation is limited.

3. RRA often neglects existing information

4. Comes up with preconceived solutions

5. The biases of rural development tourism are:

   (i) Spatial bias-urban, roadside, etc.
   (ii) Project bias
   (iii) Personal bias
   (iv) Professional bias
   (v) Diplomatic bias
   (vi) Dry season bias

6. Failure to learn from project participants or beneficiaries often happens in RRA.

RRA and Agroforestry

Large number of rural people depend on forest land but dependence patterns are not well-understood and generally have not been taken into account in management. RRA techniques are now being adopted in Indonesia to analyze and understand both formal and non-formal dependence patterns of rural communities located on or around state forest lands. RRA deems particularly suited to this, given the magnitude of the situation. Using sketch maps, land use transacts, aerial photograph, graphic tables and flowcharts, in combination with semi-structural interviewing, researchers are able to analyze dependence pattern with respect to land zone, seasonal patterns, and social factors such as social grouping, socio-economic status, gender roles and tenure status.

The U.S. Agency for International Development (USAID) in Dhaka, Bangladesh, has also used RRA to improve project design with respect to the Homestead Agroforestry Project. This project would initially involve several hundred homesteads in technology testing, and promising technologies would then be expanded to include several million homesteads throughout the country. Thus, it was crucial to have a very concrete sense of what the proposed project was about. A two-day intensive look at trees and bamboos, watching how people used them and asking questions resulted in a better understanding of what homesteads were and what research should be undertaken. A related RRA application was a more open-ended study of Homestead Agroforestry Project. There had been a general feeling that the project should be concerned with fuelwood supply in particular, and perhaps, with building material and fodder. A five-day visit to, and interviewing in, two eastern districts of Bangladesh confirmed that fuelwood acquisition was a very important issue; villagers were spending much time for collecting fuelwood. There were a number of other issues that needed to be examined. In addition, a range of other useful information on relationships between households and homestead holdings and on how households use their economic base was also obtained. This allowed for adjustments in project design and consideration of appropriate research issues for the project. Although these examples of RRA application in Bangladesh relate to project design, it was also clear that RRA or something like it would additionally be needed in implementation and evaluation stages.

Conclusion

In designing an agroforestry project, RRA can be the most rapid and cost-effective technology, and can effectively and efficiently be adopted. It has the potential to make the researchers able to analyze the needs and aspiration of the rural people and the problems of agroforestry farms to direct/formulate an action program for development.

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INTRODUCTION TO AGROFORESTRY SYSTEMS

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Agroforestry is a collective name for land-use systems and technologies in which woody perennials are deliberately combined on the same land management unit with herbaceous crops and/or animals, either in some form of spatial arrangement or temporal sequence.

In agroforestry the words like "system", "sub-system" and "practice" are commonly used. Let us define these.

System refers to a group of physical components i.e. an assemblage of objects, connected or related in a manner so as to form and/or act as a unit. This is from the viewpoint of an analysis. Example of this is an ecosystem which consists of living organisms and their non-living environment with which they are inseparably related. In land use terms, a system refers to a type of land-use specific to an area and described according to its biotechnical composition and arrangement, level of technical management of socio-economic features. Examples of these systems, which usually clearly portray the basic nature of the system are : rice production system, subsistence agricultural systems, plantation crop system, mixed cropping systems, maize-wheat rotation system, livestock production system, commercial timber production systems and so on. Each one of these has various sub-divisions and forms. These common land use systems of agriculture and forestry are mostly oriented to the production of specific commodity (or groups of similar commodities), hence in land use literature, commodity-orientation has evolved as the first consideration of the systems nomenclature. The terms "agroforestry system" corresponds to specific or generalized agroforestry land utilization types (the basis for defining and demarcating the various such systems being not only biological or technical but also economic or social).

Sub-system indicates a lower-order hierarchy of the system. A system is composed of various sub-systems or compartments, each with definable boundaries, though being unable to exist independently. In agroforestry, a sub-system refers to a part of system with a more restricted role, content and complexity than the system itself. Depending on the criteria used for defining or designating the system, the types of sub-systems can also vary.

For example, an agri-silvicultural system can have several types of sub-system according to the type and arrangement of its constituent components. A sub-system produces a defined "basic need" as its major output so that there can be a food sub-system, an energy sub-system, a shelter sub-system, a cash sub-system and so on.

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Practice in agroforestry denotes a specific land management operation of an agroforestry nature on a farm or other management unit. Such practices are involved in the constitution and maintenance of an agroforestry system. These practices include the arrangement of components in space and time vis-a-vis the major functions of the tree components. Examples of agroforestry practices are alley cropping (hedgerow intercropping), boundary planting of trees, trees and shrubs as shelter-belts and windbreaks, use of woody perennials in soil conservation, tree gardens, woodlots on agricultural land etc. Any of these practices becomes an agroforestry system when it is developed or spread to an extent in a specific locality so as to form a definite land utilization type in that area.

Hierarchically, the system, the **sub-system** and **practice** form different levels of organization of the components i.e. a system consists of several sub-systems and each sub-system consists of several practices.

Agroforestry Production Systems

The basic elements or components of an agroforestry as a land use system managed by man are : trees (woody perennial), the herbaceous (agricultural crops including pasture species), and the animals (livestock, fish, bees etc.). When these elements are harmoniously arranged in space or time, it forms a specific system in which the woody component can serve as either productive, protective or service-oriented. This lead to the simple and straight forward classification of agroforestry system which are:

1. Agri-silvicultural system : Agricultural crops and trees including shrubs/vines/fruit trees are grown in time and space;

2. Silvipastoral system : Pasture/animals/trees;

3. Agri-silvipastoral system : Crops/pasture/animals and trees are produced in the same unit of land;

4. Multipurpose tree production system : Trees are regenerated and managed for wood, leaves, fruit, bark, sap etc;

5. Aqua-silvicultural systems : Trees and fish;

6. Others: apiculture with trees.

1. Agri-silvisultural System

This system combines the production of agricultural crops and forest trees in a given unit of land. The crop combinations are either arranged or grown at a particular period and/or

arranged in space. The various subsystems and practices in agri-silviculture include swidden or shifting cultivation where improved fallow species are used; taungya system where agricultural crops and forest crops are planted at interlapping period; home-gardens where a multistoried combinations of multispecies plants exist; shade trees for commercial plantation crops; agroforestry fuelwood production; shelter-belts and windbreaks on crop field (border tree plantation) etc. Some common practices will be described and modules will be presented. It would not just be possible to present and discuss the variants of agri-silvicultural systems because these are numerous.

1.1 Swiddening or Shifting Cultivation

This is the oldest form of agri-silvicultural system, dating back to the beginning of human transition from the hunting-and-gathering phase to the plant domestication and cultivation system of livelihood. The practice is called in many different names differing from one country to another. In Bangladesh and India, it is called jhum or jhumming; in the Philippines, it is called kaingin or kaingin-making etc. Whichever country in the tropics it is practiced, the procedure is more or less similar.

The primary forest or secondary forest or vegetation of secondary succession is clear-felled, dried and burnt for planting and for returning the nutrients trapped in the forest biomass or the soil to be used by the food crops. Cropping (agricultural crops, such as sweet potato, rice, maize, banana, papaya, vegetable etc.) lasts for about two to three years, after which the land is left over a longer period (eight to ten years) to forest fallow in order to rejuvenate the soil and to prepare it for the next cycle of burning and cropping. In most cases, horticultural crops like jackfruit, avocado, mango etc. are planted. Initially, in most cases, where the area is in hilly land or sloping, the soil is not ploughed so as not to disturb the top soil. However, since most soils in the tropics are fragile and nutrients are easily lost in leaching, the sustainability of production in swiddened areas cannot be maintained for an indefinite period. This is the reason why, after two or three years, the farmer is forced to leave farming because the area becomes unproductive. In areas where soil conditions are more or less stable, swiddening becomes a permanent agroforestry production system. Also, for reasons where there are no more land to move, the farmer convert the area into another form of agroforestry system such as silvi-horticultural one, where more permanent or semi-permanent crops such as coconut, jack-fruit, mango, litchii etc. are planted (Figure 1).

Swiddening or shifting cultivation has been generally condemned on two counts: firstly, with intensive cultivation and shortening fallow periods, it is responsible for degrading the land or ecological degradation; secondly, it destroys valuable resources in the shape of forest trees which are simply cut and burnt and not put to any use. Ecologically, it is an acceptable system of land management under low population density and high availability of primary or secondary (logged- over) forests for the purpose of clearing, although economically, it only creates a low income, local subsistence economy with little surplus.

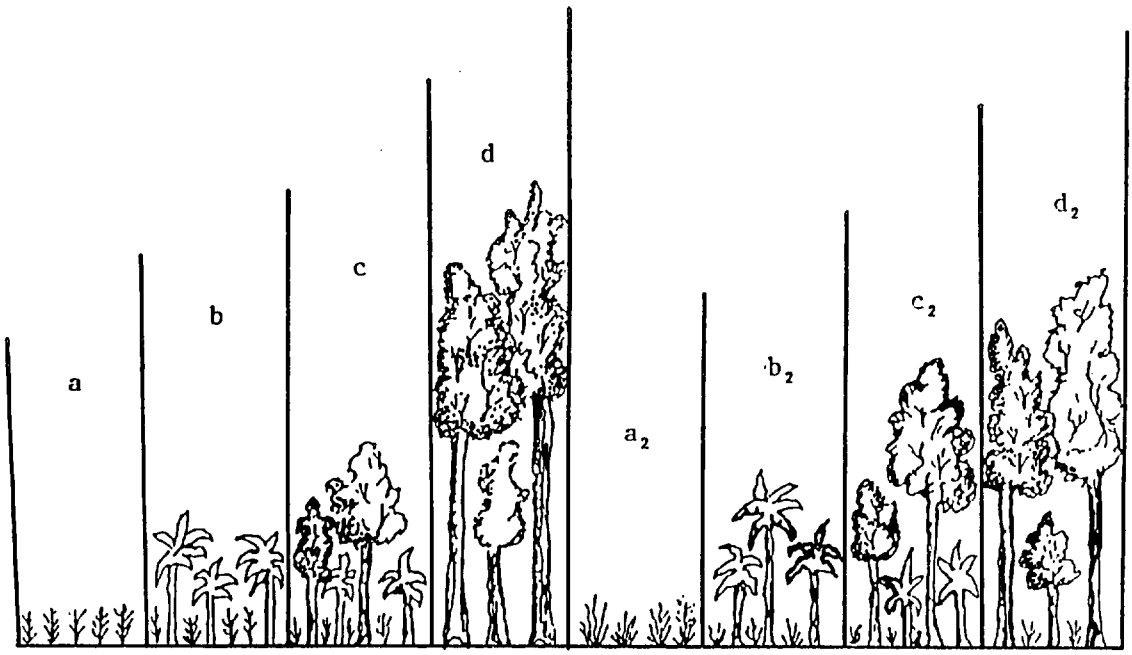


Figure 1. An illustration of a typical swiddening cycle

a = 1st to 2nd year, agricultural crops, such as rice, corn, sweet potato etc. are planted

b= 3rd to 4th year, tuber crops like taro, and banana, some fruit trees are being planted

c = 5th year, the area is dominated by saplings of forest trees interspersed with bananas and fruit trees

d = 6th year, and thereafter, trees and shrubs cover the area. This is the fallow period which may last for 5-7 years.

a_2 = The beginning of the next cycle: the area is again cleared, cultivated with agricultural crops, and similar pattern of cropping made except the area for cultivation that may still be covered with scattered fruit trees.

1.2 Taungya Systems

This is a method of establishing forest crops in temporary combination with agricultural crops. Agricultural cropping is confined to the period which ends with the casting of dense lateral shade or closing of the canopy of the forest crops. The farmers tend the forest crops and may also be required to plant it. They usually receive use of the land in return for this labor.

The system begins with the clear-felling and burning of either the remains of a recently exploited forest or of the secondary growth. Some tree species may be marked for retention for their value or for shade. In most cases, the first agricultural crops are planted one or two year(s) before the tree crop, in other cases, they are planted with or after the tree crop. The actual time of the year for planting both types of crops is regulated by the rainfall of the area concerned. Where agricultural planting precedes forest planting, the objectives are to provide an incentive to the farmers to clear the land, to allow them to cultivate the area at its highest level of fertility, during a period when they are not burdened by the necessity of caring for the forest crop, and to ensure that the land is properly cleared before the forest crop is introduced. When the two crops are planted simultaneously, the trees will experience an initial boost in growth from the burnt vegetable matter, and the farmers will give more attention to weeding and tending of the trees at the same time as their own crops. When their field crops start giving returns, the tree crops also benefits from the intensive cultural practices that they adopt for their agricultural crops.

One or two year's cultivation without any forest crop is often permitted in any new area in which the method is being introduced, or in which a good deal of work is found necessary in getting the area ready for planting. This is often done in the drier areas in order to get the soil in good condition as there is little or no burn, and in these circumstances, it is only after the first two or three years that the best crops are obtained. Seen from the purely forestry angle, delay is obviously to be avoided as the tree crop loses the great benefit of the favourable soil and growth conditions of the first season after clearing and burning, and the weeds get a start; it also lengthens the period of exposure of the soil, which is often harmful, especially in dry areas.

1.3 Home-gardens

This is the most popular and common agroforestry system in much of Asia, particularly exemplified by the "pekarangan" in Java and the coconut-based Philippine polyculture.

1.3.1 The Javanese home-gardens

The two most common agroforestry systems in Java are:

(1) Kebun-talun (rotation system between mixed garden and tree plantation) : A traditional system that increases overall production and serves multiple functions by sequentially combining agricultural crops with tree crops.

(2) Pekarangan (home-garden intercropping system) : A traditional village-based system that provides both subsistence and commercial products and serves multiple functions by simultaneously combining agricultural crops with tree crops and animals.

The Kebun-talun system usually consists of three stages: (a) Kebun, (b) Kebun campuran, and (c) talun. Each stage serves different functions. Kebun is the first stage and is usually planted with a mixture of animal crops. This state has a high economic value since most of the crops are sold for cash. After two years, tree seedlings begin to grow in the field, and there is less space for annual crops. The kebun gradually evolves into a kebun-campuran where annuals are mixed with half-grown perennials. The economic value of this stage is not that high but it has a high biophysical value as it promotes soil and water conservation. After harvesting the annuals, the field is usually abandoned for two to three years to allow becoming dominated by perennials. This stage is known as talun, the climax stage in the kebun talun system. The talun has both economic and biophysical values.

The pekarangan is a home-garden with a mixture of annual crops, perennial crops and animals on the land surrounding a house. It is an integrated system with definite boundaries that serve a variety of economic, biophysical and socio-cultural functions for the owner. A kebun-talun is converted into a homegarden when a house is built upon it. Instead of clearing the trees to cultivate field crops as in kebun-talun, the homegarden trees are kept as a permanent source of shade for the house and the area around it, and field crops in the home-garden are planted continuously beneath the trees (Figure 2).

1.3.2 Coconut-based polyculture in the Philippines

The mainstay in this system is the coconut tree occupying the uppermost tier from where nuts are harvested every four months. At the first one meter layer are vegetables (e.g. egg plant, tomato, peanut etc.) planted between rows of pineapples. At the second layer are banana, papaya, coffee and cacoa; the third layer is composed of fruit trees, such as *Lansium domesticum*, chico (*Achras sapota*) and guava. In some instances, the third layer could be of leguminous shade trees, such as *Gliricidia sepium* and *Leucaena leucocephala* on the base of which black pepper (*Pepperonnia nigra*) is planted. The fourth layer is occupied by the coconut. In such a mixture of crops arranged in rows, the farmer is provided with food and cash throughout the year. This particular system has been a traditional practice in most fertile soil areas in the province of Batangas and Albay

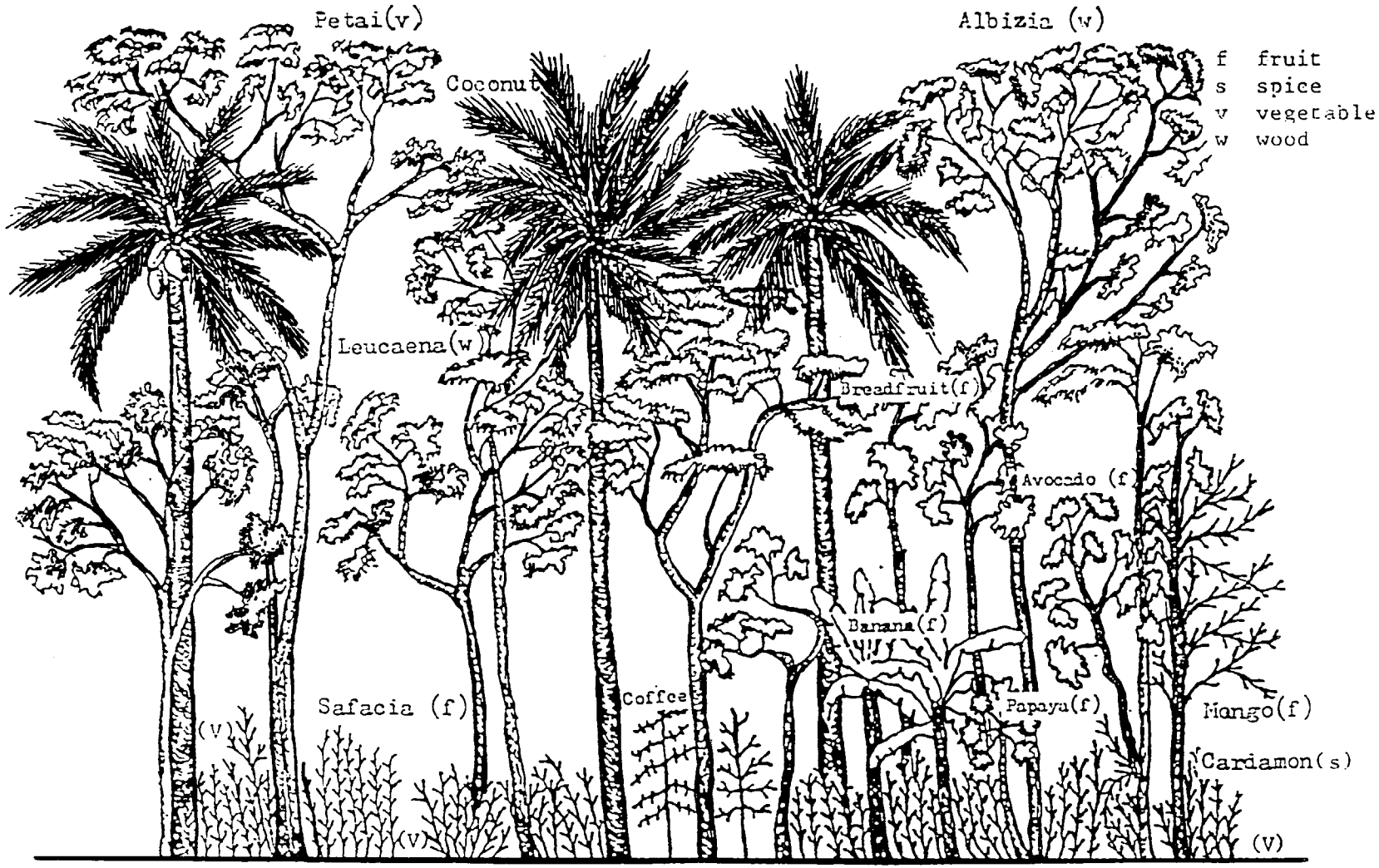


Fig.2. Strucyure of a typical home-garden (pekarangan) in Indonesia

where periodic eruptions of taal and Mayon volcanoes, respectively, have added ashes to the soil.

The coconut trees are widely spaced, about 12 meters by 12 meters, and in between these spaces, different mixtures of crops are planted. Growing of selected vegetable crops are dependent on the season on which such crops are adapted. For example, peanuts are grown toward the end of the rainy season, followed by tomato, and then eggplant, leguminous beans etc. The planting of peanuts and leguminous beans further enriches the soil with the decomposition of the vegetative parts of these plants.

In most backyards in the Barios of the Philippines, home-gardens similar to that in Java are being practiced.

1.4 Border-tree or Interstitial Tree Planting System

In most plains, where there are no problems of soil erosion and run-off, protective trees are not required and thus there is no intercropping; instead trees are planted along the border of the area. Fast-growing, multipurpose trees are planted along borders; they are lopped off periodically for fuelwood, and their leaves are also harvested and used as fodder or as green manure. In addition, normal littering serves as green fertilizer for the food crops.

The planting of trees in interstitial locations within farms, along farm boundaries and internal borders, or along roadsides, water courses, and on waste or under-utilized lands in the general landscape, offers a special opportunity for supplementary production. Planting at these locations, almost regardless of the biological competitiveness of the trees, may be undertaken with no opportunity cost. For example, in the densely-settled farming community in the sub-humid mid-lands of Kenya, pathways, water courses, farm boundaries, and internal borders - were fully utilized for planting of appropriate trees and shrubs. Some 50 percent of the fuelwood and 40 percent of the fodder requirements of the households in the area could be supplied by these hedgerows, with very little competition with existing agricultural land use practices.

Another frequent reason for border planting is the need for permanent posts around the farms or home-gardens. Live trees used as posts do not require frequent replacements like the untreated cut poles that decay rapidly under humid tropical conditions. And if prices of wire fences that need to be strong between posts become prohibitive, farmers can plant closely spaced trees that themselves serve as a fence or hedgerow.

Border tree planting can help eliminate the problem of land dispute or boundary disputes for trees that are taken as legal markers. In some instances, planting of trees may lead to problems with neighbours. To solve this, one may plant only valuable fruit or fodder trees and allow the neighbors to take the share of the produce that extends into or falls on their property. Another approach is to plant only trees of less or no value at

all. A tree which can be utilized for fuelwood in case of emergency would be preferable, although a tree which is useless is a unique legal boundary mark.

1.5 Alternate-Rows or Alternate-Strips or Alley Cropping System

This system is the most appropriate in sloping grounds or hilly lands, where most of government agroforestry projects are earmarked for migrant farmers, because the land is prone to degradation which needs either conservation or rehabilitation. Rows or strips of trees planted close to each other to form contour hedge rows are most effective vegetative means to stabilize or conserve soils on slopes. Moreover, if the trees selected are capable of fixing nitrogen and are able to regenerate by coppicing, they could serve as a steady source of organic fertilizer to rejuvenate a degraded site.

A modification of this system is terracing the contour and trees are planted near the outer edge of the terraced benches to serve as windbreak and/or erosion control (to stabilize the soil). Strips of agricultural crops are grown along the terraced benches. This system is exemplified by the the Mindanao Baptist Rural Life Center, in Davao del Sur, Philippines.

In the SALT system, contour lines are first located and marked, spaced at about 6 to 10 meters. (The space between contours will depend on the degree of slope. The steeper the slope the closer is the space between contour lines). Once the contour lines are marked, a one meter strips are plowed and harrowed, then planted with double rows of ipil-ipil (Leucaena leucocephala) or *Gliricidia sepium*. These are allowed to grow 4 to 5 meters tall at which time it will form a dense hedgerow. Cultivation can even proceed before the ipil-ipil trees reached the desired height by plowing alternate contours because the unplowed will hold the soil in place. When the ipil- ipil is fully grown, cultivation proceeds in every strip.

The land between the thick rows of ipil-ipil is called strip. It is in these strips that the crops are planted. Permanent crops may be planted during planting ipil-ipil rows (Figure 3) at chosen contour lines and inter-space. When permanent crops, such as coffee, citrus, cacoa, bananas and other crops of about the same height are planted, the soil is not plowed, and only ring weeding is used to protect the plants from excess weeds and grasses until the ipil-ipil trees are large enough to hold the soil so that cultivation can be started. Tall trees are planted at the bottom of the hill and short ones at the top. Permanent crops are usually planted in every third strip.

Between the strips of permanent crops, short-term as well as medium-term crops that can provide food and good income are planted. Suggested crops are pineapple, ginger, taro, castor beans or mung beans, sweet potato, peanuts, watermelon, sorghum, corn, rice etc. To avoid shading which will result in poor harvest, short plants are always planted away from tall plants. Once a month the continuously growing ipil-ipil is cut down to about one meter, and the leaves and twigs are piled at the base of the crops to provide organic fertilizer and conserve water moisture as mulch before decomposition.

Non-permanent or cash crops are rotated. A good way of rotating is to plant grains (rice, corn etc.) where ipil-ipil was planted previously and vice versa. This practice helps maintain the fertility and good condition of the soil. Other management practices in crop growing like weeding, pest and insect control are also done regularly.

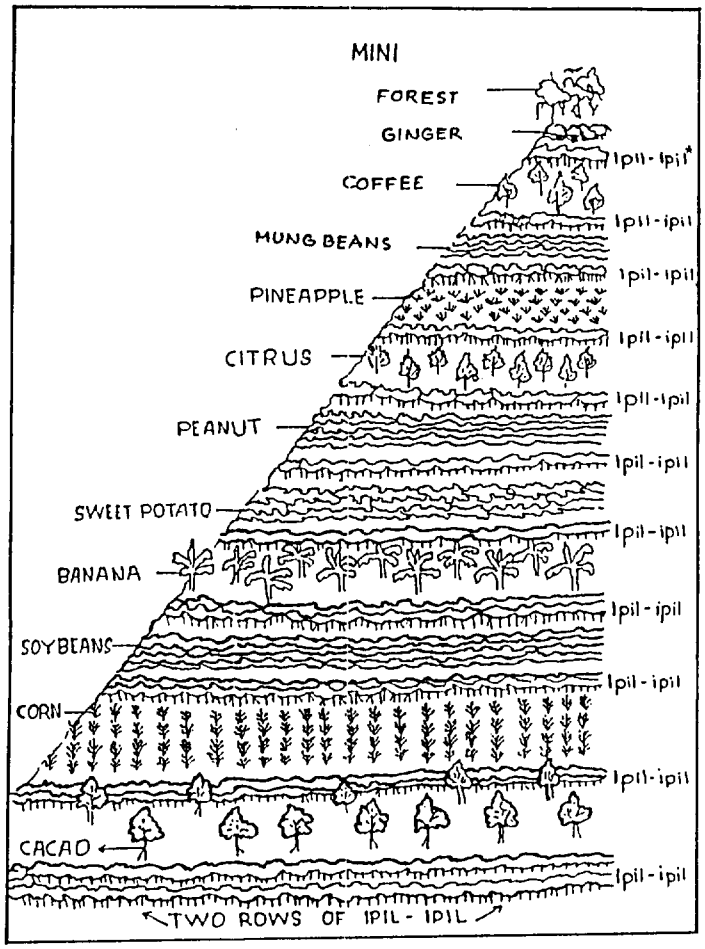


Figure 3. Hilly land when properly "SALT-ed."

* The composition of the farm will be:

25% ipil-ipil planted in double lines on contour spaced at 4-6 meters apart. Other leguminous trees, hedges and shrubs that copice fast are also recommended as alternative to ipil-ipil;

25% permanent crops planted in every third strips; 55% non- permanent crops planted between strips of permanent crops. All food crops are only suggestive.

The key to sustainability of this system is the maintenance of the stability of the soil in a sloping ground. Soil erosion is controlled by the double thick rows of ipil-ipil and the natural terraces are formed along the contour lines of the hill. As farming goes on in the sloping land, the straws, stalks, twigs, branches, leaves, rocks and stones are gathered and piled at the base of the rows of ipil-ipil. By doing this regularly as the years go by, strong, permanent, naturally green and beautiful terraces are maintained where precious soil is anchored on a right place. When this soil piled-up, it is spread through the strips where cultivation of cash crops is done.

1.6 Silvi-Agronomic Production System

This is a zonal agroforestry where agronomic crops are planted between spaces of trees like ipil-ipil. The ipil-ipil trees provides partial shade and enriches the soil from its litters and nitrogen fixation. An example of this is the planting of ginger/turmeric and vegetables in-between the rows of ipil-ipil or *Albizia procera.*

Ipil-ipil is planted at a spacing of 4 meters between strips, 2 meters between rows and 1.5 meters along the rows (Figure 4). The vegetables are planted at the same time with the ipil-ipil, during the first year or during the first planting season. Whatever be the selected/chosen vegetables species, leguminous beans must be one of them. During harvest, vegetable residues should be left on the ground or soil to decay, then incorporated into the soil when the land is prepared for planting the ginger/turmeric.

The ginger and/or turmeric are interplanted between the strips of ipil-ipil, especially on the mound or furrows which are prepared by plowing or hoeing the soil to form the mound or the furrows. Planting is done after the vegetables are harvested or when ipil-ipil trees are about one year old and are capable of providing shade. Three (3) ridges/furrows, about 60-70 cm apart along the ridges are made and mulched as in the germination bed. The leaves of ginger/turmeric dry gradually when the rootstocks become mature and then lie dormant in the soil if not harvested. It is during this period that harvesting is done. After this harvest, the ipil-ipil trees are top-pruned (pollarded) leaving a stump of about 1.0 meter. The branches and stump are collected for fuelwood but the leaves are spread on the soil surface of the ridges or furrows to dry, then incorporated into the soil when the furrows are again prepared for the planting of the next crops of vegetables or ginger/turmeric.

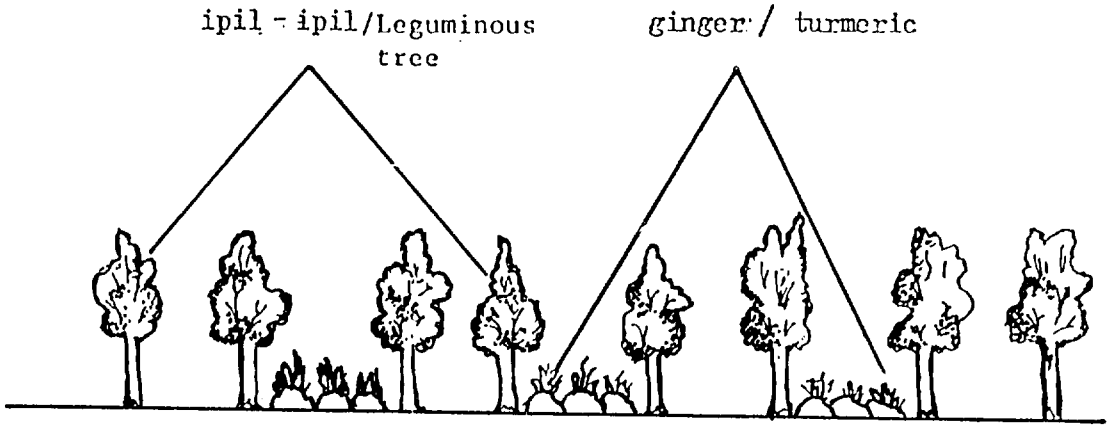
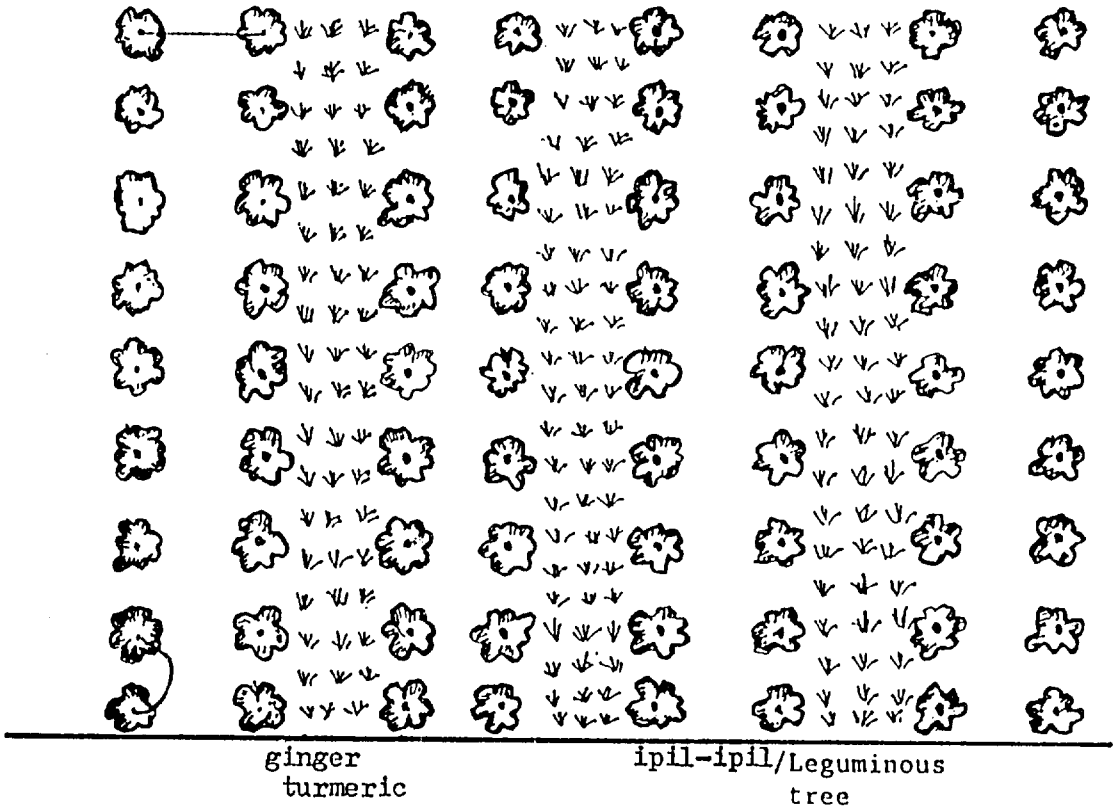


Figure 4a. Illustration showing tree-crop system



b. Planting lay-out

Figure 4b. Illustration showing planting lay-out

1.7 Silvi-Horticultural System

Forest trees, usually ipil-ipil, *Gliricidia sepium, Samanea saman* etc., are used as shade trees or nurse trees to plantation crops such as lemon, coffee, tea, and cacoa. Usually, the forest trees, such as *Albizia falcataria* or giant ipil-ipil which are light-crowned and where sunlight can penetrate through the crown are planted at a wider spacing of about 8 to 10 meters, and coffee/cacoa trees are planted at a spacing of 3 m X 4 m. There are several variations on the kind of plantation crops and forest trees which could be harmoniously planted together. In Bangladesh, litchi, lemon, papaya, banana, and pineapple can be planted in-between or under the shade of ipil-ipil and *Sesbania* species. In exposed areas, windbreak of *Acacia mangium, Sweitenia macrophylla, A. auriculiformis* and *A. nilotica* are planted at the side or sides of the plantation which are likely directions of wind-paths.

For silvi-horticultural module involving *A. mangium*, large-leaf mahogany as windbreak, ipil-ipil and *Sesbania* spp. as source of green manure, pineapples, papaya and banana as fruit crops are the best combinations. The planting scheme is presented in Figure 5a and 5b.

2.0 Silvo-Pastoral System

This particular system includes animal production in which multipurpose woody perennials provide the fodder (protein bank) or functions as living fences around grazing land or are retained as commercial shade/browse/fruit trees in pasture lands, integrated production of animals and wood products (in natural forests or in plantations) etc.

2.1 Protein Bank Systems

Fodder trees are planted in rows or in groves in the pasture to serve as source of supplementary feed or protein for livestock, especially during summer when most grasses are withered due to lack of moisture. Example of some fodder trees are *Leucaena leucocephala, Sesbania grandiflora, Albizia procera, Acacia nilotica, Samanea saman,* etc. The trees are allowed to grow to a size when it can withstand lopping and pruning before gathering of leaves and twigs is done. In some cases, livestock may be allowed to browse on the fodder trees.

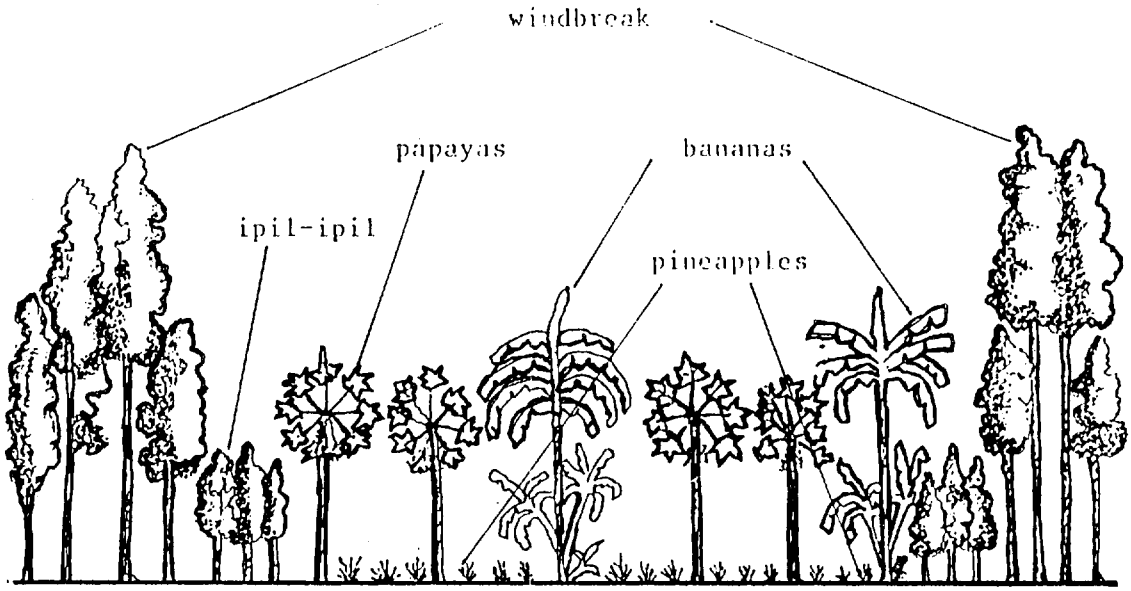


Figure 5a. Illustration of silvi-horticultural module

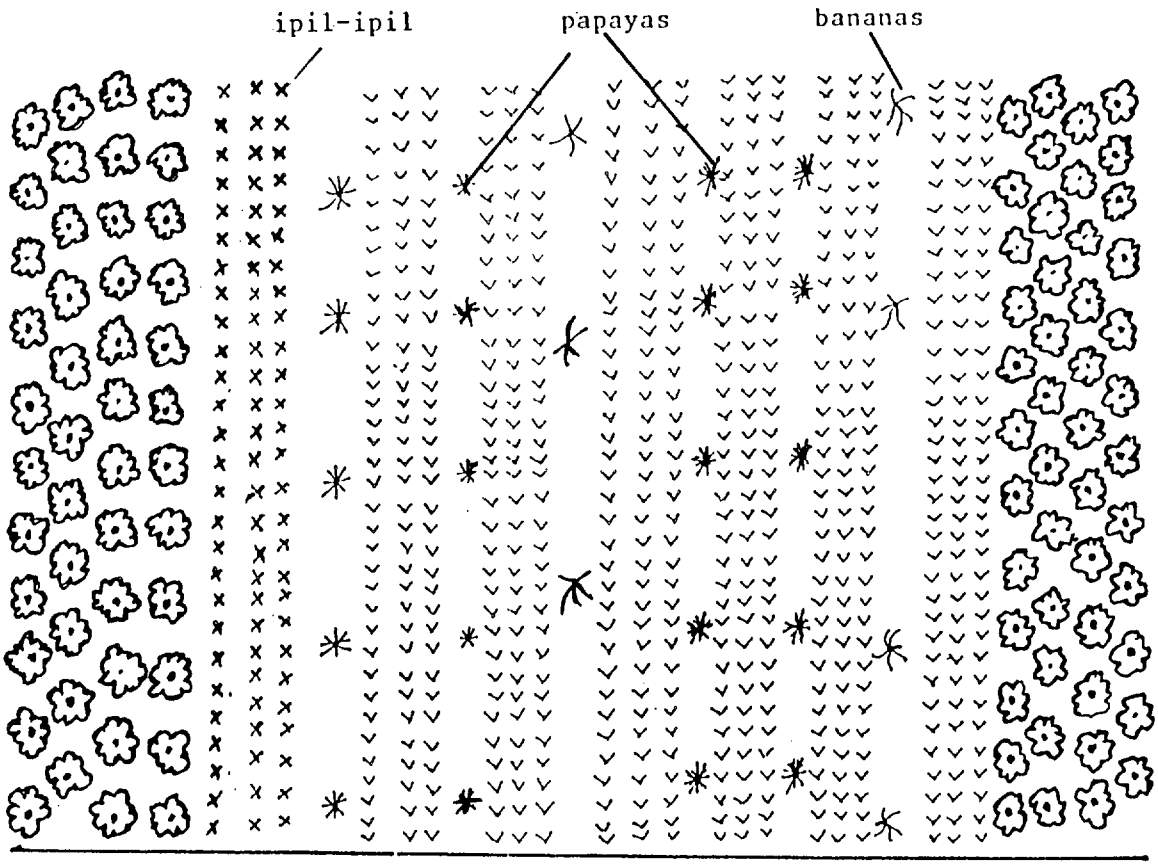


Figure 5b. Planting scheme of silvi-horticultural module

The multipurpose trees are also planted along the perimeter of the grazing area or as border plants between grazing compartments to serve as living fence and to restrict grazing, to minimize over-grazing in a given pasture. Trees contribute both to production of fuelwood and feed, and to minimizing soil erosion.

2.2 Commercial Fruit Trees-Livestock System

Livestock seek shelter under the shade of trees during the summer months. The animals usually graze in the early morning hours and late afternoon when it is not that hot. During the hot period of the day, they like to rest under cool shade of trees. Shade trees, therefore, are part of the pasture management. Instead of planting trees without any potential use, fruit trees, such as mango, cashew nut (*Anacardium occidentale*), rambutan (*Nephelium lappaceum*), litchii, jackfruit, citrus etc. are planted at wide spacing, wider than the normal spacing in the fruit orchard. The wide space between the fruit trees are maintained for high-yielding forage grasses and legumes to supplement or compliment the native grasses. The number of animals or livestock allowed to graze in the area is determined by computing the carrying capacity.

In this system, the role of the trees is to provide shade and shelter to the livestock.

2.3 Browse Trees - Livestock System

Livestock (goats and sheep) are both browser and grazer, utilizing leaves and twigs of shrubs or brushes, and leaves of grasses and leguminous forage. A typical example of this system is found in the Mediterranean region. Usually, goats and other livestock species are allowed to graze in natural forest. To lessen pressure on the forest and to provide an alternative feed source, the natural brush-lands constitute an important resource for all kinds of livestock, especially goats.

2.4 Integrated Wood - Livestock Production System

In recent years, a farming system that has received attention both in temperate and in tropical countries is the grazing of cattle either in natural forests or in plantation. Because of the relatively long-term returns from forest, the attempts to raise cattle have important implications as follows:

- Provided that cattle are not introduced in early stages of planting and, therefore, do not damage young seedlings or growing trees, they keep down weeds and reduce costs of weed control.

- Cattle provide a secondary financial return prior to harvest of trees, apart from the occasional sale of thinned trees.

- In tropical areas the shade offered by the forest creates a better environment for livestock than open space, particularly by reducing heat stress, provided that suitable pasture species are found to grow under conditions of reduced light.

- Grazing under the forest or plantation reduces fire risk by the removal through grazing of inflammable debris.

2.5 Plantation - Livestock Production

When livestock is integrated with forest plantation development and management, the first and foremost consideration would be that related to the silvicultural aspects of the trees, such as choice of species, spacing and treatment of the stand. The timing of initial grazing (the first time to allow animals in the plantation) is of critical importance, and of course, the number of animals (carrying capacity) and the length of time the animals are allowed to graze within a given grazing period, must also be given due consideration and attention. Of equal importance is the choice of forage species to be introduced to either replace or augment the low-yielding and less palatable native forage species. Such species must be capable of producing optimum forage under the partial shade of the trees.

2.5.1 Applicability of the system to Bangladesh

Beef and mutton are major components of a Bangladeshi diet. Almost everywhere cattle and goats are being allowed to graze, often leading to the over-grazing of an area due to scarcity of forage. And yet, the already established tree plantation offers a possibility for cattle grazing if they could be thinned, and allows light penetration to the forest floor to stimulate the growth of grasses, herbs and brushes. These thinnings can be sold as fuelwood which is also a much-demanded commodity for household energy use or brick-making. In this manner, the Forest Department can realize an early income from the plantation. The village people can benefit from livestock grazing under the plantation. Dung of the animals will serve as organic fertilizer, which will enhance the growth of the remaining trees.

In case of new plantation development, the species to be planted must possess potential of multiple uses and be capable of enriching the soil. At suitable ages, those trees can be the sources of fodder for the cattle and goats. Portions of the branches are lopped, and the leaves are given to the livestock in the barn. With wider spacing, forage grasses and legumes can be planted between the interspaces, and once established, regulated grazing can be allowed.

2.6 Natural Forest - Livestock Production

Livestock grazing under a natural forest is an age-old practice in the temperate countries as well as in some tropical forests. For instance, in the United States cattle and sheep are

allowed to graze inside the pine forests. In Australia, cattle and sheep graze under the natural eucalypt forests, which are developed in association with several browse species. In the Philippines, the Ifugaos and Igorots have long been dependent on the natural forest of *Pinus kesiya* as grazing ground for their cattle and goats. When grazing is done under the coniferous forest, it reduces fire risk by compacting the litter and hastening decomposition.

In the Mediterranean, the forests are rich in plant species partly because of the light-tolerance of the dominant tree species, and partly because of their mismanagement in the past. These forests have relatively open crowns. This permits the growth of a lush under-story consisting of both herbaceous and woody species. The woody plants are mostly evergreen, which means that green leaves and twigs are available throughout the year. As a result, Mediterranean forests constitute an important year-round source of feed for livestock.

3.0 Agri-silvi-Pastoral System

This is an agroforestry production system which includes the harmonious combination of tree-livestock-crop mix in home-gardens or homesteads; woody hedgerows for browse, mulch, and green manure as well as for soil conservation; and spatial arrangement of crops, trees and livestock in pasture. These are the most common practices under the agri-silvi-pastoral systems.

3.1 Tree-Livestock-Crop Mix System

As discussed earlier, a home-garden has multistoried composition of different vegetations, such as trees (forest and fruit), ornamental and agronomic crops. Animals become a component when they are raised within the backyard of the house and derive a portion of their feed from the fodder trees growing in the home-gardens.

Another scheme that belongs to this category is grazing of livestock and production of crops in plantation such as coconut. This is very popular in the Philippines. Several shade-tolerant agronomic crops (annuals) are raised under the coconut plantation. After the fruits of these agronomic crops are harvested, livestock are allowed to graze on the remnants.

In Malaysia, both cattle and sheep are known to thrive well under the rubber plantation. In this system, creeping legumes serve dual purposes, initially as cover crops in the establishment phase of rubber, and later as forage to the cattle or other ruminants when the rubber is mature.

In western Samoa, during the first two or three years after establishing the plantation, when there are still enough aerial space for sunlight penetration, vegetables and root crops are planted in the interspaces of trees. After this period, growing of agronomic crops becomes unprofitable because of the decline in production due to

shading of trees. Instead, tolerant grasses are allowed to grow, then cattle grazing follows.

3.2 Woody Hedgerows - Livestock - Crop System

Fooder trees are planted around the perimeter of the farm or in strips at different portions of the land to serve as hedgerows and windbreak. Agronomic crops are planted in the wide open spaces such as in sugarcane, peanuts, cereals, vegetables etc. Livestock are kept in the barn, and residues of the agronomic crops and leaves of the fooder trees are fed to the animals. After harvesting the crops, these livestock are also allowed to graze on the farm.

3.3 Spatial Arrangement of Trees - Crops - Livestock

An example of this system is the growing of ipil-ipil in rows and in between rows/strips of corn or of other cereal crops or vegetables. Trees such as *Sesbania bispinosa, Albizia procera, Cajanus* etc., which are sources of fodder are planted in some portions of the farm to serve as shelter-belt or windbreak, and also as source of fodder for livestock. At spaces in the farm where it is not profitable to grow agronomic crops, high-yielding grasses such as Guinea grass (*Paspalum maximum*) or Napier grasses and leguminous forages are planted and subjected to moderate grazing.

4.0 Aqua-Silvicultural System

This is a system of land use wherein forest trees and agricultural crops are integrated into one area in combination with some aquatic crops like fish, snails (particularly the golden snail), some water fowl and other aquatic food resources. Some vegetable plants can also be grown. To illustrate how this system can be worked out, the following module, appropriate for Bangladesh and other tropical countries, is presented:

4.1 Aqua-Silvicultural Module

(1) Cropping components:

(a) Forest crops - Ipil-ipil, Eucalyptus
(b) Agricultural crops - bananas, water aram, waterbend weed

(c) Aquatic crops - fish, snails

(2) Land preparation/improvements etc.:

(a) The inner side/banks of the farm pond is excavated to a suitable angle-of-repose so that cave-in shall be avoided and also dug to the desired depth.

(b) The band or mound of earth surrounding in pond is properly thumped to minimize slip or soil creep erosion.

(c) The boundaries of the surrounding land are surveyed and delimited for each land use pattern (forest or agriculture), and the soil is tested.

(d) Prepare planting plan, planting schemes for the different land use patterns and determine the quantity of planting material needed for each crop (based on spacing etc.)

(3) Plan implementation:

In accordance with the plan of activities, plant the forest crop and agricultural crops following the planting scheme and the planting techniques prescribed (traditional or improved). The fish or aquatic crop component shall also be introduced following the detailed instructions in the cultural management.

5.0 Multipurpose Forest Tree Production System

This is a production system that has social oirentation rather than having purely economic value because large number of people, instead of a single family, are included as beneficiaries. Such examples are the establishment of community forest or farm forestry on rural wastelands, marginal public lands, large areas of ravine lands and others close to habitation including village commons and private holdings. Such projects are usually undertaken by the government with participation of the people in a community.

The intention is to plant tree species that will produce fuel, fodder, fruits and other minor forest produce and plenty of grasses and legumes in the interspaces which can either be cut or grazed by animals in controlled condition. In other cases, farmers produce on their farmlands the fuelwood, timber for construction work and packaging cases, leaves for green manure, fodder, willow sticks and twigs for cottage industries, and sometimes mulberry for silk-worm rearing, small timber for rural housing and agricultural implements, thorns for fencing etc. These supplies are obtained mainly from multipurpose trees, such as poplars and willows planted in and around their fields and farms. The trees also act as windbreaks and shelter-belts and help increase the farm productivity.

It is impossible to find a single tree species that may be close to a truly multipurpose but some of the leguminous trees like *Leucaena leucocephala*, and some species of *Acacia, Albizia, Parkia* etc. are most ideal and desirable because aside from the goods derived from them, they also enrich the soil with nutrients as they are capable of fixing nitrogen from the atmosphere.

One kind of multipurpose tree is *Parkia speciosa*, which is widely planted in Indonesia, Malaysia, and can likewise be grown in other tropical countries. Its wood is used as saw-logs as well as raw material in the manufacture of paper, chip-board, rayon, and light utility items. Its fruit is of important economic value. According to a rough estimate, the market of *Parkia speciosa* fruit in Peninsular Malaysia alone can be valued to be about M 15 million. It is capable of fixing atmospheric nitrogen, and thus useful in maintaining the productivity and stability of the soil. These are used as shade trees in cocoa cultivation.

There are many other forest tree species that have many uses yet to be identified. It would be necessary for a country to make a listing of these species, including biophysical requirements for growth and development. These multipurpose tree species (MPTS) can also be used for planting along roadsides, canals, highways, homestead, home-gardens etc. for shade, shelter-belt, erosion control and other uses.

6.0 Apiculture With Trees

This production scheme is a sub-system of multiple forest product forestry in which the trees do not produce only wood, fruits and fodder but also serve as sources of nectar for bees to convert into honey. Apiculture is honey production by bees.

A large proportion of the honey produced in tropical areas comes from trees. Certain species of Eucalyptus, such as *E. melliodora, E. sideroxylon, E. citriodora*, and *E. robusta* are the greatest producers of honey in Australia. The introduction of *Prosopis juliflora* in Hawaii made this area the world's largest producers of honey in the early 1930's. The Miombo woodlands, in eastern Africa in particular, are well-known for honey production from the species of *Acacia brachystegia* and *A. julbarnardia*. In Sunderbans mangrove forest predominated by *Heritiera minor, Excoecaria agallocha, Bruguiera gymnorhiza, Sonneratia apetala, Avicennia officinalis* etc., there is ample scope of honey production. In the Sunderbans, Khalshi (*Aegiceras majus*) and Goran (*Ceriops candelleana*) flowers are famous for sweet fragranted honey. The average yield of honey per year is 200,000 kg, and that of bee wax varies from 40,000 to 45,000 kg.

Bee-keeping in the dry zones of the tropical region has been practiced traditionally for thousands of years. Recently, in their reforestation projects, trees that can provide food, fodder, fuelwood and control desertification are being used. For instance, in Kenya bee-keeping has increased the income of many people by two to three times since it was promoted in that country. The tree species recommended for planting in these areas to serve multiple purposes are Prosopis of the Algaroba group, particularly

Prosopis juliflora, Acacia mellifera, A. tortilis, A. senegal, *A. xanthoploea* and *A. drepanolobium* for wet areas.

In Sweden, bee-keeping is very common. Some of the Avokayas who live between Mundri and Maridi, own as many as 30 or 40 hives each, and sell oildrums full of honey to people who brew alcoholic drinks such as "honey beer" from it. Making a hive is a fairly long and skill-requiring process. First, a tree has to be ring-barked in two places with an additional vertical incision on the bark to connect the two rings. After a few months, when the bark between the incision has losened, it can be pulled off the trunk in one piece. This slit bark tube forms the interior of the hive where the bees build combs. Bark suitable for this purpose comes from *Tamarindus indica, Prosopia africana, Pseudocedrela kotschyi, Terminalia species* (lokpo), *Burkea* and *Lannea* species or *L. barreri.* When the bark is dry, it is bound with thin branches of *Lannea fruiticosa*, then covered with a layer of woven grass, the inside is formigated with sweet scented smoke from the resionous wood of *Pterocarpus* species (orgestec) which attract bees. The finished hive is taken into the woods, hung up usually near the top of a tall tree, on a level at which bees are likely fly in search of the flowers. Many of the flowers they favor are tree blossoms, and moreover, the higher the hive, the safer it is from fire. Some species of trees where hive are hung are : *Tamarindus indica, Afzelia africana, Diospyroa mespiliformis, Daniella oliveri, Vitex madiensia, Lannea fruticosa,* and *Cassia* sp.(Soli) and *Stermlia* species. The hives are raised by ropes from the ground to the upper branches of these trees and honey is collected in containers.

7.0 Sericulture

Sericulture is related to agroforestry in the sense that silk-worm thrives on leaves of a tree species called mulberry. The silk-worm, in turn, produces silk which is utilized in the fabric and related industries. Sericulture is a project with social orientation, where additional income can be generated by family members staying at home. In Indonesia, some 250,000 laborers and 13 000 officials were directly employed by a company called Jerum Perhutani. Some families were involved in the silk-worm tending done in their houses, which gave them additional income.

In Bangladesh, the industry is being developed under a government agency. This budding industry is most appropriate in the Chittagong Hill Tracts where mulberry trees are raised for feeding silk-worm. These tress can be planted in the hillsides to prevent or control soil erosion. Raw material for the construction of rearing houses for the silk-worms can also be obtained from the Hill Tracts. These include small timber, bamboo, and sungrass. Women and children can easily tend the mulberry trees, gather their leaves and feed these to the silk-worm. The sericulture project in Chandraghona (Bangladesh) is progressing well. Site improvement to be done for planting of mulberry tree in the bench terraces, would facilitate planting of several other crops. The species between the trees in the bench terraces, at the early period of copping can be utilized for planting short-rotation agronomic crops.

8.0 Industrial Agroforestry

This consists of large-scale agroforestry efforts, usually by the private sector. It is aimed at miximizing outputs (profits) on an industrial scale by the production of wood in combination with crops or livestock on a given piece of land. The wood-producing companies may be able to repay the reforestation costs within 2-3 years by producing corn, sorghum or other crops among the rarely-planted tree seedlings.

There are several variations which can be applied. Examples are:

(1) If there are underemployed farmers in the locality, or if there is a land shortage, a cooperative venture would serve to meet the needs of rural people in addition to producing forest products on a large scale. Such a venture would use local labor through a variety of incentives instead of using mechanized, labor-saving techniques. If people raise livestock, fodder production may become a part of the operation;

(2) If land ownership pattterns are typified by small, unproductive farms and the private companies be interested in wood, it may be feasible for the company and the small land owners to work together to develop forestry for wood, food and fuel;

(3) If the company has a big concession allowed by the government, the company may allocate or parcellize some portions of the land into a reasonable and convenient socialized sizes for the farmers to develop.

Some large industrial concerns have been modifying their approach to use industrial agroforestry as a technique to work in partnership with rural populace. Other companies have employed industrial agroforestry techniques on their own, presumably in some degree of harmony with local populace but without their direct participation. In a wide variety of socio-economic situations, industrial agroforestry presents an opportunity for a company to make a solid contribution to the needs of local people, and a profit from industrial production at the same time.

AGROFORESTRY CROP MANAGEMENT : RESEARCH TECHNIQUE

M.A. WAHHAB[1]
M.M. BHUIYAN[2]

Agroforestry is an age-old practice followed by farmers of Bangladesh. Tree resources, whether grown on homestead, crop land or forest land, are being depleted rapidly in Bangladesh. Due to such deforestation, the ecological balance and the country's economy are at stake. Unless serious attention is given, the country will face a serious crisis. Trees grown in the homesteads are very essential from economic and ecological point of view.

Homesteads provide about 85% of the wood consumed in Bangladesh. Homestead plantation is not a new concept. In our country, more than 80% of fuelwood-supplies come from non-forest land (mostly agricultural land, marginal wasteland and home-gardens). Although the practice of planting trees on homesteads and cropland is traditional, scientific management and improvement of these systems have yet to be fully explored. A country should have at least 25% of the total area under forest for maintaining ecological balance but Bangladesh has only 6.5%. Agroforestry is an important tool to solve the acute problem of food, wood, fuel, fodder, soil fertility and ecology. Well-planned and well-managed agroforestry can play a great role in this context.

Farmers have been growing cereals, root crops, fibers, vegetables and fruits, and have been rearing animals in association with the trees and other woody perennials with the objective of meeting their daily needs of animal fodder, fuelwood, timber, fruits and other products.

Most community forestry programs include introduction of trees on farm land, either on farm-boundaries,farm-woodlots, shelter-belts or windbreaks or planting on Government-owned land (such as strip plantation along roads, railways, canals etc.).

Growing crops along with woody perennials on the same unit of land has several advantages. These are:

1. Gains in agricultural productivity are achieved through increase of soil organic matter and reduction of run- off and erosion.

2. Woody perennials, for their deep roots, are very useful for nutrient recycling from deeper soil strata.

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3. Woody vegetation has a positive effect in improvement of micro-environment through reduction of soil temperature and improvement in soil moisture through shading and mulching processes.

4. Tree growing on farm land insure easy access to fuelwood, fodder and other tree products for farmers, and thus reduces pressure on the forest land.

Tree densities vary according to the type grown in addition to light requirement and shade-tolerance. Home-garden experience shows that a mixture of trees of different species has minimum pest and disease problems.

The homestead agriculture with mixture of crops requires high labor inputs in contrast to monocultures. It is known that the labor requirement of one hectare of home-garden with intensive cropping, including livestock, is about 1000 man-days per year compared to 400 man-days for rice monocropping.

Homesteads and agroforest offer several employment opportunities like cottage industries etc. with added benefit of the use of family labor. The economic benefits of these agroforests are well-realized. For example, in Indonesia the estimated income is about 1.2m Rp. per ha/annum compared to about 0.8m Rp. from rice production alone.

A Paulownia tree (in China) over a 10-year period yields 300-400 kg of biomass including leaves (30 kg dry leaves per year), which provides a very useful fertilizer for soil improvement.

On coastal sandy soils, acacia, coconut, oil palm, cashew, coffee etc. may be planted in a mixture. Intervention on homestead, marginal land as well as crop land will require a very careful planning. Understanding of the existing system is the first step of such process. Except for isolated work confined to limited areas, little systematic work has been done in Bangladesh to understand the farmers own system of agroforestry practices, fuel and fodder use etc.

As many as 20 organizations including BARI, BRRI, BJRI, BINA, FRI, SRTI, BFRI, BLRI, SRDI, BAU, DU, RU, CU, BARD, RDA, BIDS, BUET, MCC etc. are conducting agro-based research on varietal development, cultural management, soil nutrition, pest and disease management, postharvest technologies, inter as well as mixed cropping, and they are recommending technologies.

Farmers normally follow a sequential arrangement of production system under their own resource availability. Any technology recommendations ought to be tested and verified in farmers' system in order to find out the suitability of growing different crops and tree species or vice versa.

The following steps may be effective in doing research on agroforestry:

A. Setting objectives:

1. Raise average level of well-being in growth and efficiency

* Increase total average level of net benefit to producers and consumer
* Improve well-being of specified income group (Low-income)
* Provide employment
* Improve farm tenure situations

2. Improve Security :

* Increase year-to-year income
* Enhance self-sufficiency
* Increase environmental sustainability

B. Identification of priority problems - Major criteria for research priority:

1. Economic importance of the problem
2. Technology availabilities to solve the problems
3. Cost and time needed to carry out research
4. Availability of resources
5. Scope of implementing new technology
6. Probable distribution of benefits within the society

C. Consideration to stress situation:

1) Biotic	2) Abiotic
Discuses	Soil moisture-drought
Insects	Soil salinity-salt deposition
Pests	Water logging-flood

D. Approaches to be followed:

1) Top-down approach - Traditional method

2) Bottom-up approach - Involbing farmers/users and concerned Government agencies. In grassroot level, workers through Rapid Rural Appraisal, case study, Secondary information and experiences.

E. Types of research to be conducted:

1. Basic Research - Generation of knowledge

2. Applied Research - Generation of a technology

3. Adaptive Research - Varitiation of technology for sustainability

4. Innovative Research

RESEARCH TECHNIQUES IN PLANT TO PLANT INTERACTION AND PLANT-ANIMAL RELATIONSHIP IN AGROFORESTRY

NEPTALE Q. ZABALA[1]

1.0 Introduction

Agroforestry land use systems are known to exist since man started to grow plants for food, fire and shelter. Most of the practices are proven efficient in terms of productivity and suitability. However, agroforestry as a science is still new, the problems are yet to be defined, and the details of how plant components interact between them, how plants interact with animals and the environment need further investigation.

Vast experiences and researches have accumulated in agriculture/horticulture that we know how plants of many kinds grow, how they interact in different environmental circumstances, and how to manage them. In agroforestry, however, the intercropping situation, i.e., the plant association is more complex in a wide range of environmental conditions. It is, therefore, necessary through research that we should understand how, and to what extent, the major plant growth and development process will be modified by a change in species, climate, soil and management, how animal behavior would affect plant growth and production in plant-animal relationship. In short, agroforestry research should uncover the relationships between the performance of trees and agronomic or annual crops in mixtures, particularly their productivity, involving a multiplicity of outputs; and sustainability, which implies the conservation, or even improvement, of the environmental aspects of the systems. In this respect, the plant can be viewed as an integrator of the effects of climate, soils, biotic and management factors.

2.0 Special Considerations in Plant to Plant Association

The components of an agroforestry farm are agricultural/horticultural crops and woody perennials (trees, palms and bamboos). When planted in mixture, they interact in several ways in the form of competition for nutrients, light and moisture; symbiosis in respect of soil nutrients and actions of micro- organisms; or allelopathy by inhibiting the growth of another plant due to excretion of toxic substances. Special consideration should be given to the choice of species, both trees and agricultural/horticultural crops in any given agroforestry design.

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2.1 Important characteristics of woody perennials are as follows:

- long life with long economic cycles thereby influencing investment patterns and restricting cropping flexibility;
- some are shade tolerant at early stages of growth, and become intolerant (dominant) at later stages;
- relatively large permanent organs (branches, trunks and roots), thereby enriching the soil surface through littering;
- capable of modifying the micro-climate which can bring about favourable effects on the soil and associated plants;
- strong competitor in attributes, such as capacity to shade understoried plants, and tendency to dominate the water economy at the micro-site.

Given the above attributes, one should choose for the cropping mixture the tree species that possess the following characteristics:

- rapid growth and high production of wood: (Farmers in Betagi have chosen *Gmelina arborea* because its wood resembles that of teak, which is traditionally considered high premium but can be harvested at relatively shorter period than teak);
- good coppicing ability (regrowth following topping);
- effective nutrient cycling abilities;
- multiple uses: food, feed (fodder), firewood, construction material, and other wood products;
- minimal competition with shallowly-rooted annual crops;
- small leaves readily detached (deciduous) and quickly decomposed for conversion into fertilizer. Small leaves allow the penetration of more light into the ground layer of agricultural/horticultural crops;
- good stress tolerance against drought, low soil fertility, extremes of pH and others;
- freedom from pests and diseases;

- ease of control or eventual eliminations (when monoculture of agricultural/horticultural crops becomes more economical and sustainable);

- wood is highly marketable.

Considering this list of "desiderata," it is not surprising there has been so much popular interest in leguminous tree species or to the so-called multipurpose tree species (MPTS).

2.2. The agricultural/horticultural components of an agroforestry system are short-lived (mostly agronomic crops) and relatively long-lived (horticultural crops such as coffee, tea, cocoa, papaya, lemon and other citrus, guava etc.). These crops demand high nutrient and require intensive cultural care and maintenance.

The choice of agronomic and horticultural species will be largely restricted to species which satisfy existing consumer and market preferences in a particular locality. (In the Betagi forest community project, farmers prefer lemon and guava as cash crops because these give them high financial return). Introducing completely new food or cash crops is generally a lengthy business against the risks of the species unadapted to the site and unacceptable by the consumers. Aside from its consumers' preference and marketability, the agronomic and/or horticultural crops should be shade-tolerant. These are highly productive; stress-tolerant against low soil fertility, drought, and reach extremes of pH; are free from pests and diseases; and requires less cultural care.

3.0 Determinant Factors in the Productivity and Sustainability of Agroforestry Farm

The relationship between plants i.e the way they affect productivity and sustainability of an agroforestry farm will depend on several factors, notably on the kind of crop components, number of components, spacing, arrangement of components (either in time or space) and cultural management.

In the preceding section, special considerations on the choice of species were discussed. Once the kinds of species have been decided upon, the questions of how many will be included for planting, how they should be spaced (planting distance), how they will be arranged in time and space, what cultural methods are involoved, and how these are applied need attention.

3.1 Number of components: Farmers tend to grow more than one tree crops and agronomic/horticultural crops in a unit of land because they believe that (a) diversified cropping is better than monoculture. This implies that multple commodities are produced at varying periods; (b) if one crop fails there is an

alternative; (c) more crops means more income; (d) pest and disease infestation is less. These assumptions becomes a reality only when and where the tree crops and associated agronomic/horticultural crops are compatible with one another. The basic research question to answer is how many kinds of species (of trees and agronomic/horticultural crops) should be included to make the agroforestry farm productive and sustainable.

3.2 Spacing: Agroforestry involves mixture of plant species. Woody perennials constitute the upper layer and the agronomic/horticultural crops formed the ground layer. The productivity of the agronomic/horticultural crops depends on the amount of nutrients, light and moisture made available for their growth. Closely spaced trees are likely to form a solid canopy depriving the lower vegetations of light. Intense competition for soil nutrient and moisture is also involved due to root activity.

The spacing of trees in traditional plantation crops such as coffee, tea and cocoa is well-established. For lemon, pineapple, papaya, and other horticultural/agronomic crops, spacing of the upper layer vegetation is yet to be known.

In our visit to the Betagi forest community project, we observed in the agroforestry farms and learnt from one of the farmers that too many trees of *Gmelina arborea* planted in mixture with lemon has drastically reduced fruit production of lemon. He was advised to cut some of the trees, those averaging 40 cm dbh and to replant the same or other species to reduce shading effect. He was reluctant to accept the idea. He prefers keeping the *Gmelina* trees until it reaches an average diameter of 60 cm to give him good financial return. From the economic point of view of the farmer, the reduction in fruit yield of lemon could be well compensated by the higher selling price of good-sized timber.

3.3 Arrangement of the components: In agroforestry practices, components are arranged both in space and in time. All agricultural crops that are traditionally grown or preferred by the farmers are not planted throughout the whole year or a period of years. There are crops harvested in less than one year, planted at different times of the year (relay cropping) and those that are harvested at longer periods such as the horticultural crops. The management schemes of these crops also vary with sites. Hence, measurement of the productivity of these different crops should be given utmost attention.

The measurement of growth/product.. parameters in crops arranged in space is likewise complex. Competition among crops is more intense in random mixture and alternate rows than in alley or strip with hedgerow, border trees and zonal cropping. In the latter arrangeements, competition between components for light, moisture and nutrients is more strong along the edges of the plots.

The basic research questions to answer are : (1) in temporal arrangement, when would be the most optimal time to plant trees and agronomic/horticultural crops and for how long these crops should be maintained to sustain productivity; (2) in spatial arrangement, what would be the optimal width of alley, area of block, number, of hedgerow to provide sustained production.

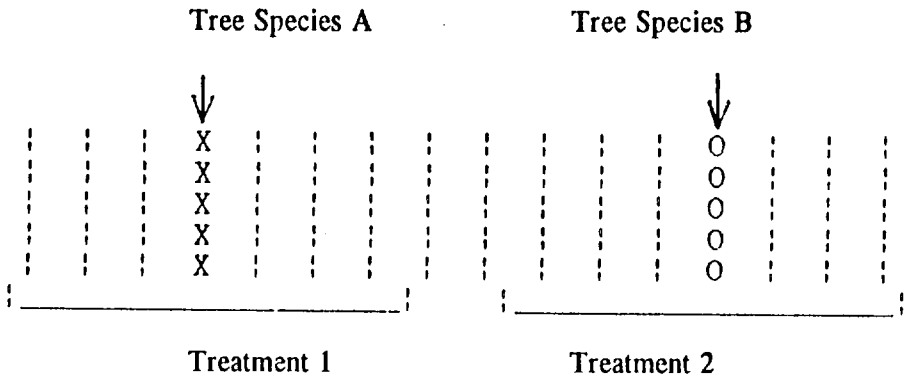
4.0 Designing the Experiment

This refers to the ways treatments are arranged or allocated in plots or blocks. The choice of experiment design is governed by the objectives, hypothesis, number of treatments of the experiment and the environmental condition or the experiment site. Where the number of treatment is quite few and the environmental condition in the experiment site is more or less uniform, the completely randomized design is used. Most agroforestry experiments are laid out using randomized complete block design when treatments are few and experimental site is heterogeneous, which often is the case. However, where the number of treatments are many, such as in multipurpose tree evaluation studies that might include as many as 30 to 100 species or provenances, RCBD is not the best approach. In a factorial experiment with three or more factors, the number of distinct combinations will be large. In such cases, it is often difficult to locate a site with sufficient uniformity to accommodate a complete replication of all the treatments to be tested. In Bangladesh condition, it would be difficult to find a large contiguous area to allow more replications. In this case, the researcher will have to use an **incomplete block design**, where the number of plots in each block is less than the total number of treatments. Such designs have been used successfully for many years in agricultural research, and it is strongly recommended for agroforestry experiments. (For further readings, see Cochran, W.G. and G.M. Cox. 1957. Experiment designs, New York, Wiley, 611 p). Analysis of data can be done by the use of desk computers.

4.1 Plot size and arrangement: Plot size and the way it will be laid-out depend on the cropping patterns or treatments:

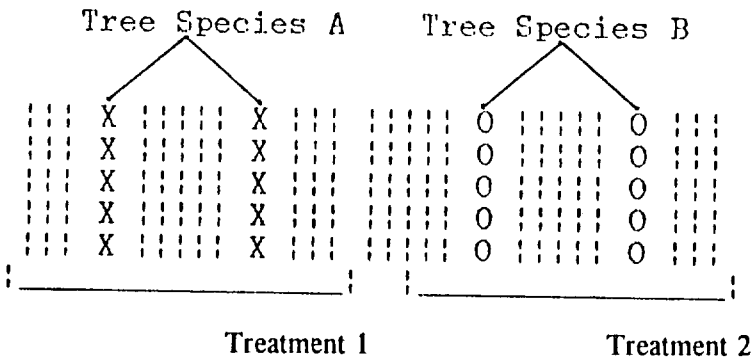
(a) To evaluate agroforestry practices for mixed tree-crops systems, a single line of trees or rectangular group of trees, suitably replicated, would be adequate. In this case, each treatment combination (tree species + agronomic/horticultural crop) will consist of a line of tree species A + rows/lines of agronomic/horticultural crop as treatment 1; a line of tree species B + rows/lines at agronomic/horticultural crops as treatment 2, etc. The single line plots of trees also simulate hedgerows, boundary plantings or living fences and allow measurement for within-row competition. For such measurement, 1 or 2-meter section at each end of a hedgerow or one or two trees at each end of a boundary/upperstory planting should be discared. The plots on either side of a block need a ground area of 2 to 3 meters or one hedgerow. The alley crops between single hedgerow plots are harvested and recorded row by row to obtain

some ideas of the effects of hedges on crops. Illustration of a single hedgerow plots in an intercropping experiment follows:



(b) In alley cropping or hedgerow-inter-cropping experiments, double or multiple hedgerow plots should be required to allow measurement of the effects of hedgerow on an interplanted crop. The width of the alley can be varied. If the hedges of adjacent plots are not interacting with each other, all the hedge material in the next plot, after discarding the ends, can be harvested to measure yield from the plot, that is, only the crop in the inner alley, between two similar hedges, is measured.

Illustration of a double hedges alley cropping treatments:



(c) In an experiment on rotational systems, treatments with different cropping sequences are randomly distributed within a block. Smaller plots of annual crops with sufficient border guards can be used in a block.

On sloping sites, trees and crops, in the plots have to be established on the contour. However, in lands with multiple slopes, it is difficult to plant all rows strictly on the contour. In this case, each treatment combination (tree species + agronomic crops) will consist of a line of tree species A + rows/lines of agronomic/horticultural crop; a line of trees species B + rows/lines of agronomic/horticultural crop etc.

4.2 Control treatments: Control plot is necessary to provide direct comparison of a standard or normal practice. The control plots are maintained to see whether the treatments under investigation have shown any positive or negative effects compared with some standards. For example, locally recommended level of fertilization for a given crop against a new level of fertilization. For direct comparison, it may be located near the new practice under investigation.

In agroforestry research, one or more controls are needed, either to compare different measurements within the experiment or to evaluate the productivity of each component as a sole crop.

In introducing new agroforestry interventions in a given locality the indigenous agroforestry practices or technologies could serve as control. To evaluate perennial species for hedgerow intercropping or boundary/upperstory tree planting, a single control of the crop component planted in pure stand is sufficient. In tree-crop interface studies or hedge row-inter - cropping studies in which fodder is removed by pruning, two control plots may be necessary. In improved-fallow experiments, usually two controls are needed as continuous annual cropping both with and without supplementary fertilizers.

These are only a few of many kinds of control that you may design for your agroforestry studies.

5.0 Measurements of Parameters

Agroforestry researches are undertaken to uncover the relationships between the performance of tree/non-tree mixture, particularly their productivity and sustainability in response to climatic and edaphic changes, management and the characteristics of the plant species or animals.

Productivity and sustainability are very closely related. Sustainability refers to maintaining certain productivity level through time as affected by soil fertility, crop management, climatic and edaphic changes, pest and diseases, etc. Productivity on the

other hand refers to the yield or biomass produced through time by the crop components. Values are measured at zero productivity; the respective value of the total agricultural and tree products over the same time; estimated changes of values with time for continuous agricultural cropping; value for 100 percent tree cover; and total production of all the different proportions of the agricultural and tree crops.

Measures of production parameters in plants include quantity of produce, quality of produce, plant performance at critical growth stages and plant reactions to important pests. The exact natures of data to be collected vary according to the crop and experiment.

Quantity of produce refers to the biological yield, such as fruits, biomass, wood products, tubers, pods, grains etc. Quality of produce refers to specific values e.g. protein or sugar contents or specific gravity (in case of wood) etc. Growth parameters are measurable indicators of plant performance at critical growth stages e.g. seedling stage, flowering stage or maturity monitored at fixed intervals. Important parameters to be measured are : plant height and diameter, number of tillers, crown/canopy, number of days to flowering, days to maturity, and leaf area index (LAI). Plant reaction to important pests can be measured indirectly by the degree of resistance or susceptibilty of the plants to diseases/pests.

5.1 Other Measurable Parameters

(a) Soil Fertility : Sustainability of production to a large degree depends on maintaining soil fertility at the optimum level in the plantation. It is important that we should have an estimate of the effects of tree cover and agricultural crops on the overall soil environment status and on productivity through time. Current status of soil fertility and the average productivity under any particular agricultural cropping will be known, and some estimate can probably be made of the trend in soil fertility/soil conservation status under existing management patterns.

Common unit to measure both soil productivity and soil conservation status can be the net present value of a unit area of a test crop which is produced or could be expected to be produced at the site.

Soil fertility indicators that could be measured are soil organic matter deposition (declining or increasing) and soil erosion. Chemical and physical analyses of the soil are done at interval periods from the time of crop establishment to harvesting.

The soil environment status is determined by measuring the changes in the conditions of the soil (its fertility and state of conservation) for agricultural cropping, tree cropping, and all ratios of the two:

i. Soil fertility level at zero productivity;

ii. productivity at the current level of soil fertility

iii. projected soil fertility changes are estimated for continuous cropping (show as declining or increasing);

iv. land under 100 percent cover of trees of the chosen species (show as declining or increasing);

v. soil changes for all ratios of the agricultural and tree crops over time.

(b) Extent of Root Systems : Agroforestry involves species mixtures of different kinds of plants, woody perennials and herbaceous annuals. These plants compete for light, moisture and nutrients. The root system has significant role in the absorption of moisture and nutrients. To make the associations of these plants more successful, we have to choose or select species with complementary root system behaviour patterns.

The aspect of research is to find species which could avoid root competition. That is, plants in the agroforestry farm must exploit different region either in space or in time. Separations in time can be done easily by relay cropping but more difficult in integral space.

The distributions of a root systems through space and time is influenced by both genetic character of the crop and by localized condition.

To determine the extent of root distribution (which is an indicator of root competitiveness), the root systems can be excavated from time to time and the extent of their proliferation throughout the soil be recorded.

(c) Amount of Light Intercepted : In order to estimate the potential productivity of multiple cropping systems involving trees, shrubs and ground-cover crops, it is essential to be able to estimate the photosynthetically active radiation (PAR) intercepted by each of the component crops at any given time and to integrate this over the period they occupy the space.

An estimate of the light intercepted by plants can be derived by determining the leaf area index (LAI), K (light extinction coefficient) and F_{max} (maximum fraction

of the available energy which it could intercept, given the tree diamensions and spacings). Definitions of LAI, K and F_{max} are as follows:

LAI : ratio of leaf area per unit of total ground area. Leaf area can be obtained by directly measuring the leaf by a planimeter. The ground area is measured by projecting the crown diameter.

K : can be calculated by using the Monsi and Sakai (1953) equation following measurement of radiant energy by cosine law sensors with appropriate wavelength response held horizontally above and below a sector of canopy of measured LAI.

F_{max} : can be calculated, as long as the shapes of the discontinuous canopy elements are simple, over any desired period of time by using simple computer or desk calculator routine based on known distributions of sun and sky irradiance (Cain 1972; Jackson and Palmer 1972). It can also be estimated by using a physical model of the tree canopy on a panel of silicon cells or other light sensors (Jackson 1983).

6.0 Plants-Animal Relationship (Agro-Silvo-Pastoral System)

In general, there are no grazing lands or pasture areas in Bangladesh. Domestic animals (cattle, goat and water buffalo) graze on newly harvested ricefields, roadside, sides of railway tracks, vacant lots and in forest plantations. The big areas to be developed into forest plantation in Bangladesh offers opportunity for combining livestock production with wood production. Such agroforestry practice is attractive because it provides early returns (from the livestock) while the trees grow.

Plant - animal relationship in this agroforestry systems is both beneficial and destructive (especially at the early stage of development). Trees provide fodder and shade to the animals. On the other had, animals contribute to the nourishment of the trees through their dung and urine which add to the fertility of the soil. Controlled grazing could minimize growth of weeds, thereby reducing the frequency and cost of weeding operation. Likewise, animals cause damage to the trees by browsing, trampling and compacting the soil.

To develop this agro-silvo-pastoral system in Bangladesh we need to conduct research to answer some relevant questions, notably:

a) What kinds of animal would be allowed to graze on different types of tree plantation consisting of one or more species ?

b) When will be the appropriate time or stages of growth of the plantation to allow animals to graze ?

c) How many animals (carrying capacity or animal stocking) should be allowed to graze at any given period ?

d) What spacing of trees to use to allow luxuriant growth of forage without much reduction in the expected total wood production in the plantation ?

e) What high-yielding forage species (grasses and legumes) can be grown in association with forest trees ?

The parameters to be measured in such experiments would vary depending on its objectives but generally the following are considered :

- Wood production : Variables to be measured through time are survival of seedlings, height and diameter of trees and quality of wood produced.

- Pasture production : To be measured at periodic intervals the biomass produced by grasses and/or legumes.

- Livestock production : To be measured the gain (or loss) in weight of animals, at periodically.

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MONITORING SOIL LOSS AND NUTRIENT IMPROVEMENT AND SOIL FERTILIZATION RESEARCH TECHNIQUE

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Introduction

The modern agroforestry concept is related to sustainable land use system which intigrates both productivity and conservation. Agroforestry practice is important in respect to ecological aspects that involves bio-physical interactions of the system.

Compared to other land use system, emphasis has been given to soil conservation and maintenance of soil fertility under agroforestry production. Techniques of soil research in agroforestry practices are associated with much complexity. Various interacting processes of different components of tree, crop and livestock with soil-climatic factors of the ecozone from the main objectives of soil study are to be considered in agroforestry research. Monitoring soil loss aiming at establishing an effective erosion control measure, improvement of soil fertility for continuous support to growing crops are the important and intigrated part of the research in agroforestry.

Research techniques for in-depth study of different soil characteristics is still not developed in favour of a sound agroforestry practice. Therefore, stress has been given on scientific synthesis of existing research techniques used in other applied biological sciences. ICRAF and some other organizations are presently engaged in development of the key problems of research methodology in soil study. The approach of system analysis has been recommended as appropriate means of soil research in agroforestry.

Soils of Bangladesh and Agroforestry Practices

Bangladesh comprises three major soil physiographic units. The floodplain soils alone cover 80% of the total land. Rest of the 20% lies under hill (12%) and terrace soils (80%). So far 20 general soil types and 500 soil series have been identified.

Most soils have been formed and developed in seasonally flooded and non-flooded area with moist and dry conditions under geological sediments of tertiary and quaternary age (Morgan and Mcintere 1959; Shaheed 1984).

A large variation in soil properties is available within the soil types. Most of the soils are poor in organis matter content. Hill soils are of loamy texture and shallow depth. Terrace soils are deep, red brown and have poor fertility. Porch and Islam (1984)

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indicated that research priorities should include N, P, Mo, Zn, S, and B. The generalized physico-chemical properties of the hill soils have been shown in table 1.

Table 1. Some physico-chemical propertices of the Hill Soils (Richard and Hassan 1988)

Physiographic unit	Texture (sub-soil)	pH 1:1 (sub-soil)	Structure (sub-soil)	Profile (depth)	Total N % (Top-soil)	CEC clay meg. % (Top-soil)
Low hills	Loamy	5.0-5.5	Strong blocky	Deep	0.08-0.25	16-20
Piedmont terrace fan	Loamy	4.5-5.5	Strong blocky	Deep	0.07-0.25	16-20
High hills	Loamy	5.5-6.0	Strong blocky	Shallow	0.07-0.25	20-24

Traditionally, the soils of Bangladesh have been using by the farmers for cultivation of cereals, fibres, pulses, vegetables etc. Growing forest and fruit trees, shrubs, rearing of animals in association with different agricultural crops have been practiced in the homesteads, crop land and hill forest areas for centuries. Several forms of agroforestry practices may be observed in different parts of Bangladesh which have been focussed in table 2.

Traditional agroforestry practices are poor in technical point of view. Low level of management in cultural practice is the characteristic feature of these AF systems. Due to this, the productivity of traditional system is unsatisfactory. Increasing rate of soil erosion and subsequent land degradation are accmpanied by the traditional systems. As a result, the environment has been threatened to a great extent.

Research Technique for Monitoring Soil Loss

Soil loss is generally monitored to find out the capability of the agroforestry system in controlling soil erosion. Soil loss estimation is also done for planning suitable agroforestry system in particular climatic condition and technology development purpose within the system.

Table 2. Forms of agroforestry practices in Bangladesh

Agroforestry system/practice	Characteristic of the component	Location of the practice
Agro-silviculture	Agri-crops+commercial MPTS in crop land	Scattered all over the country
Silvi-agriculture	Fruit/commercial trees+ agri-crops	Rajshahi,Dinajpur Kushtia and others
	Commercial trees + horticulture/agri-crops (shifting cultivation,taungya, Garo System at Madhupur)	Chittagong, CHT, Sylhet,Mymensingh and others
	Plantation crops + agri-crops	CHT, Sylhet and others
Silvo-pastoral	Fruit trees + cattle grazing	Rajshahi,Dinajpur, Kushtia and others
	Commercial/MPTS + grazing in the crop land	Sporadic occurrence all over the country
	Commercial trees/ trees+ grazing	Chittagong, CHT, Sylhet and others
Home gardens	Commercial/Fruit/MPTS + horticulture and agri-crops	All over the country

Soil conservation research strategy in agroforestry should include studies on soil fertility maintenance. In this respect, studies on loss of organic matter, plant nutrients and crop yield are important to correlate with soil loss.

Young (1989) indicated that the plot approach to erosion measurement is complimented by first order catchment studies, recording run-off and sediment content

at an outlet flume. For obtaining representative results from a mixed tree-crop system, the erosion measuring plots should be larger, as for example, 90 m x 15 m and 70 m x 10 m, are presently used in Dehra Dun of India and Ibadan of Nigeria respectively.

Monitoring soil loss is a complex subject. Most research works on estimation of soil erosion rates are based on predictive models. The standardized plots are generally used for measurement of soil loss, and then applied to field situation. For agroforestry research the equations evolved from the models may be applied in the field. Due to complexity of the measurement characteristics, we will not go for detailed discussion on these equations. Only for theoretical interest one of the equations has been cited here. The Universal Soil Loss Equation (USLE) is important in predicting the rate of soil erosion. According to the equation:

$$A = R \times K \times L \times S \times C \times P$$

where
A = total soil loss expressed in t/h/y
R = rainfall factors
K = soil erodibility factor
L = slope length factor
S = slope, steepness factor
C = cover and management factor and
P = support practice factor (Young 1989)

There are several other means of estimating soil erosion rate. Only broad approximation on soil loss can be made through these methods, and may also be tested in agroforestry research.

According to Roitzsch (1968), the long pegs are driven in the ground 60 cm or deeper. The length of the protruding end is initially measured and subsequently remeasured periodically. The increasing length of protruding end gives a measure of sheet erosion. The value of the peg measurements multiplied by 10 gives directly the value in M^3/ha.

For estimating soil loss under different ground cover, tree root exposure and collection of removed soil by surface run-off may also be used.

For agroforestry research and design, consideration, of effectiveness of the erosion barriers formed by trees, shrub, hedgerows and magnitude of the processes (run-off, deposition) may be useful in terms of effective soil erosion control. Since soil cover can have large effect in controlling erosion, research in agroforestry should give particular attention to the cover effects obtainable by using prunning from tree component as mulch.

Some examples of erosion rates under tropical forest, tree crops and some agroforestry systems are given below (Young 1989):

Low, 2 t/ha/y	Natural rain forest multistoried tree gardens tree plantation crops with cover crops/ mulch
Moderate, or high 2-10 t/ha/y High 10 t/ha/y	Cropping period is shifting cultivation/ taungya tree plantation crops, cleanly weeded forest plantation, litter removed or burnt

Improvement of Nutrients and Soil Fertilization Research Technique

In agriculture and to a lesser extent in forestry sector, fertilization is the main source of nutrient status improvement. In case of agroforestry, the interacting processes that occur within the components play the central role in soil fertility status.

Improvement in soil nutrient in agroforestry production system is largely influenced by the tree component through its high biomass production, nitrogen fixing system, mycorrhizal association etc. Besides these, trees in the agroforestry system positively affect soil physical conditions, chemical and biological processes. By reducing soil erosion, trees help in soil fertility improvement in agroforestry.

Improvement of soil nutrients in agroforestry depends upon successful designing and soil management practice. In different agroforestry system (shifting cultivation, Taungya system, woody perennial, plantation agriculture, plantation forestry, multiple cropping etc.) improvement of soil nutrients and maintenance of soil fertility is not identical.

In shifting cultivation the important relevance to the agroforestry approach is the restoration of soil fertility during the fallow period (Moore 1968). Leaf and root biomass productions in different agroforestry system vary widely. Root biomass in agroforestry system was found significantly higher compared to agricultural and forestry system.

Different nitrogen fixing trees in agroforestry may be potentially used for soil nitrogen improvement. The nitrogen fixing capabilities of some trees and creeper legumes are illustrated in table 3.

Species	N-fixation kg n/ha/y
Leucaena leucosephala	100-500
Gliricidia sepium	13
Casuarina equisatfolia	60-100
Pueraria phaseoloides	650
Calopogonium muconoides	170
Phaseolus stylosanthes	20-290

Nair (1984) stated that in agroforestry practice when short duration agricultural crops are cultivated in sole stand or in combination with perents, the fertility status of the soil changes. In that situation, fertilization becomes necessary to compansate the loss through harvest. In these areas crop response to fertiliser is uneconomic. Soil enriching trees may be fully utilized for improving nutrient status of the soil.

Agroforestry practices potentially respond to erosion control, stabilization of soil, maintenance of soil fertility, and thus a sustainable land use system may be achieved. Research approach in agroforestry for improvement of soil fertility may be divided into two parts (Young 1989):

1. Specialized soil study

2. Observation on soil in general agroforestry research

Soil fertility is the primary objective of specialized research. Direct means of measurement in soil sampling and analysis may be applied in this case. The following subjects may be included in specialized soil research:

1. Soil organic matter : formation, decomposition, nutrient cycling etc.

2. Nutrient cycling : Nutrient uptake, recycling by trees

3. Biomass production : quantity and quality of biomass, decomposition

4. Nitrogen fixation : amount of added nitrogen, nodulation behaviour

5. Effects of trees on physical properties	:	improve particular cohesion and hence prevent erosion
6. Soil erosion	:	Process under tree-crop mixture, barrier and cover functions

Soil observation in general agroforestry research should from a component in agroforestry field trial. It is necessary for evaluation of the trend of changes in soil fertility and crop production. The following observations in relation to soil fertility may be useful:

1. Take soil samples and analyze before setting the trial. After 3 years, repeat collection of soil samples component-wise and thus continuation of soil sample collection and analysis will be done up to the end of the trial.

2. Collect plant samples from each and every component in respect to biomass production and nutrient uptake.

3. Analyze the behaviour of root production and expansion through cutting a trench across selected tree-crop interface.

4. Measure erosion loss and analyze eroded sediment, organic matter and nutrient content.

5. Interpret data and correlate with agroforestry potential for maintenance of soil fertility.

The above discussions strongly indicate that fertility maintenance in agroforestry system is largely influenced by the interdependent components. In case of decline in soil fertility within the system, fertilization of different crops may be recommended. Soil and plant diagnostic methods for soil fertilization may be followed in agroforestry research.

For different components (tree, crops), fertilizer research may be carried out combinedly or separately. Fertilizer research on different species may be conducted on deficient element as a priority basis. Finding out the crop response on different nutrient elements is equally important for agroforestry research. Fertilization techniques in agroforestry include determination of fertilizer doses, forms of fertilizers, time and method of application etc.

Other than annual crops the peculiarity of trees in fertilizer research i.e. its deep-rooted characteristics, behaviour of nutrient uptake, age etc. should get due consideration. Different organic fertilizers (decomposed biomass, manure) in combination with inorganic fertilizers may be the useful part of research activities in agroforestry.

Conclusion

In Bangladesh conditions, much importance is attached to agroforestry production. Generation of suitable technology is a pre-requisite for a sustainable agroforestry system. Conservation of soil and maintenance of soil fertility are the important parts of agroforestry system. The sustainability of the agroforestry production system largely depends upon the technology developed by appropriate research techniques of soil loss monitoring and improvement of nutrients.

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ENTOMOLOGICAL ASPECTS OF TREE SPECIES IN AGROFORESTRY PRACTICES IN BANGLADESH

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Introduction

Tree plantation today is receiving unprecedented attention on global basis largely because of the increased awareness of the rapid and alarming rates of deforestation in the tropics, where more than half of the world's biological species are located (Myers 1985). It is the means to reduce pressure on the shrinking supply from natural forests, to meet the ever-increasing demand for fuel and industrial wood, for rehabilitation of the waste and unproductive lands, to stop further ecological degradation and to provide economic resource to enhance rural development (FAO 1985).

The area under plantation forestry is increasing rapidly with the trend toward monoculture of fast-growing species as opposed to mixed natural forests. This man-made environment is frequently predisposed with pest and disease outbreaks. The longer rotation of forest trees, unlike agricultural crops, provides a sustained resource base for associated insect species over the extended period of time. Hence, stands of forest trees provide more stable habitat, and insect populations tend to be more persistent and enriched. However, the mixed cropping or agroforestry is advantageous over monoculture in respect of pest and disease incidence, presumably because they cannot build up to such a devastating level as in stands of uniformly susceptible plants. This paper deals with the insects associated with tree species in agroforestry practices in Bangladesh.

Major Insect Pests of Trees of Bangladesh

It is generally said that forestry is 90% protection activity. The statement may seem to be over-stated but neverthe less, it emphasizes the importance of protecting forests from the ravages of various biodeteriorating agents of which insects play a significant role in limiting the forest productivity. A brief account of some of the major insect pests and their control is given below:

1. Cutworms

Cutworms are the larvae of *Agrotis ypsilon* (Noctuidae: Lepidoptera). They fee n large number of plants of both forestry (*Pinus caribaea, P. oocarpa* etc.) and agricultural crops (sole crops, maize, cotton, tobacco etc.). They hide in burrows 3-8 cm deep in the soil during the day and come out to the surface at night. The stems of young seedlings are

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cut down at ground level but occasionally, buds or new leaves are also cut. Some of the cut pieces are taken into their burrows in the soil and eaten there. The attack is severe during the winter months and less in summer.

Control: The larvae hidden under the soil near the cut seedlings can be collected and killed manual'y. The collecting operation can be facilitated by flooding the area if possible, to force the larva come out, poison bait (Dieldrin, rice or wheat bran and molasses in the ratio of 1:100:10 and as much water as required to make paste) may be used to control the pest. Nursery bed should be kept free of weeds that may serve as alternative food and shelter for the pest. Dieldrin 20 EC @ 35 ml/10 l of water as soil drench can give good control the pest.

2. Cockchafers

Cockchafers or white grubs (Scarabaeidae: Coleoptera) are well- known pests of agricultural crops such as groundnut but these have become serious pests of tree seedlings such as teak, rubber, babul, pines, jarul, acacia etc. The important white grubs are: *Leucopholis* spp., *Holotrichia* spp. and *Animala* spp. The larvae feed on the small roots and debark the tap root, sometimes cutting the tap root at 5-10 cm below the soil surface. The infested seedling wilts and ultimately dries up. The adult beetle feeds on the foliage of many trees.

Control : The grub can be dug out from around the soil of the infested seedlings and be killed by hand. If feasible, nursery bed may be flood-irrigated to compel the grub come out from the soil. If bed is prepared before or during swarming period, (early monsoon),the soil surface should be made compact or covered with polythene sheet or sand, ash, etc. to prevent oviposition. Weeding or other operations in the seed bed during this period should be avoided as disturbances in the surface soil invite oviposition (Roonwal 1952). Dieldrin 20 EC @ 40 ml/10 l of water may be applied as soil drench to control the pest chemically.

3. Termites and ants

Termites attack young seedlings, saplings, transplants or cuttings in nurseries and plantations. Their damage is more severe during the dry seasons as the high moisture requirements force them obtain moisture and food from the roots. The termite attack occurs below the ground level in the upper 20 cm of the soil layer. The bark of the tap root is completely eaten up in a ringed shape. After planting of the sapling in the field, the termite damage extends further to collar region. The affected seedlings/young plants show signs of wilting resulting in death. Similar damage occurs in case of stem cuttings where the underground woody portion gets decayed. Sometimes ants create havoc causing failure to nursery by catching up the seeds or embryos. Termites attack eucalypts, pines, teak, sal, etc. Most of the termites are of the genera *Odontotermes* and *Microcerotermes*. Plants generally become prone to termite attack when they are not in a vigorous state of growth or when they suffer from debility due to some mechanical injury, physiological

disturbance, adverse internal growth factor or cumulative effect of environmental stress like drought, unfavourable soil conditions etc.

Control: In preparing nursery beds woody debris, logs, stumps etc. should be cleared up. Care should be taken to avoid root damage by breaking, bending or crushing of transplant as desiccation of roots near cut or broken places make the seedling more susceptible to the attack of termite. Chemical treatment of the soil prior to sowing or transplanting or as remedial measure with a persistent organo-chlorine insecticide, such as Dieldrin 20 EC @ 40 ml/10 l of water applied as soil drench will adequately control ants and termites.

4. Teak defoliators

Teak (*Tectona grandis*) is attacked by two major defoliators *Hyblaea puera* Cramer (Noctuidae: Lepidoptera), commonly known as teak defoliator and *Eutectona machaeralis* (Pyralidae: Lepidoptera), commonly known as teak skeletonier. The mature larvae of the former consume the entire leaf leaving only the major veins. On the other hand the larvae of teak skeletonier consume only the green layer of leaf leaving all the veins intact, thereby skeletoniing the leaf which later turn brown and dries up. Teak defoliator attacks only the young leaf, thus peak infestation is found during April-July, when profuse flushing of new leaf occurs. Teak skeletonier, on the other hand, consume mature and tough leaf and thus major infestation occurs during August-October when teak leaves are old.

Control: Both the species have a rich natural enemy complex. In India natural enemies of *H. puera* consists of 48 species of insects, 4 species of birds and a bacterium and those of *E. machaeralis* include 105 insects, 38 spiders, 2 fungi and a bacterium (Sudheendrakumar 1986). Thus, a scheme for biological control using silvicultural measures to augment the efficacy of natural enemies was formulated (Beeson 1941; Roonwal 1952). These include:

(1) Subdivision of the planting area into: pure teak plantation in blocks of 8-16 ha each, having a strip of existing forests in between them as natural enemy resource and improvement of these resource by promoting desirable plant species (eg. *Cassia, Trewia, Xylia, Sterculia* etc.) which support natural enemies and eliminating undesirable ones (eg. Callicarpa, Vitex, Premna etc.) which serve as alternative food plant of teak defoliators themselves.

(2) Maintenance of varied flora of desirable species under teak canopy to provide shelter and nesting facilities for beneficial animals like birds etc., and an obstacle to flight of moths.

(3) Introduction with selected species of natural enemies (Cedria, Apanteles, Sturmia, Eucanthecona, Sycanus etc.) in localities where deficiency in natural enemy complex exists.

(4) In Thailand *H. puera* was effectively controlled by spraying with BHC 12 WP @ 2.5 kG/500 1 of water/acre with high power sprayer during 1966-68, but due to its harmful effect on natural enemies of the pest its use has been abandoned since 1969 (Chaiglom 1990). However, non-persistent insecticide such as organophosphate, carbamate or pyrethroid may be used but their use should be limited to small scale areas like nurseries and seed orchards.

(5) Bacterial toxin of *Sacllus tharingiensis* Berliner proved effective in controlling *H. puera* and teak beehole borer. Teak plantations and seed orchards in the sensitive areas have been annually treated with the biocide @ 0.5 kg/400 liter of water/acre. Low volume aerosol generators, Pulsfog Model K-3 (Bio) and K-10 (Bio) have proved very suitable as they are handy for operation in forest plantations (Chaiglom 1990).

(6) Selection and breeding of resistant varieties is another important approach for pest management, though it is a slow process.

5. Gamar defoliator

The gamar defoliator, Craspedonta leayana Latrille (Chrysomelidae: Coleoptera) is the most important pest among gamar (*Gmelina arborea*). The adult beetle feeds on the leaf, cutting large circular boles and also eats young buds and sheets. The young larvae feed mainly on the under-surface of the leaf but eventually completely skeletonize them leaving only the mid-ribs and main veins intact. Defoliation starts with the onset of monsoon and continues till October. Heavy defoliation causes drying up of leading shoots or even death of the tree when repeated attack occurs.

Control: The adults of second generation are highly attracted to white surface like large sheet of white cloth or metal which could be used as a trap. Adults hibernate in bark crevices, grass clumps, dry leaves or other sheltered places. Considerable protection is, thus, maintained by providing suitable artificial shelter traps for hibernating beetles and their destruction by chemical means. *Brachymeria* (Chelcidae: Hymenoptera) is a potential larval parasite to control it biologically. Malathion 57 EC @ 20 ml/10 liter of water may be used as foliar spray by power or pedal sprayer to control the pest.

6. Mahogany shoot borer

Mahogany shoot borer, *Hysipyla robusta* Moore (Pyralidae: Lepidoptera) is an important pest of Meliaceae, especially mahogany (*Swietenia macrophylla, S. mahogany*), toon (*Cedrela toona*) and *Chickrassia tabularis*). The larva bores into soft shoots of young (up to 6 years), vigorous trees growing in full sun. They excavate a central tunnel in the pith. A gummy mass of frizz bound with silk marks the entrance hole. The infested shoot dries up and eventually breaks off or shrivels. Heavy infestation results in forking, carped stems and often in permanent stunting. Larva is destructive as fruit borer and also attacks inflorescence, feeding under the protection of loose network of silk.

Control: The population density of the pest is directly proportional to the rate of production of leading and lateral shoots. Thus the attack is greater in pure, wide-spaced and open plantations than in those where overhead or lateral shade is provided by nurse trees, undergrowth or cover plant. Thus silviculturally, the attack can be reduced by providing adequate overhead or side shades, close plantings in mixture with faster growing species, even though growth rate is lowered for initial 5 or 6 years of planting. Cutting of attacked shoots while it contains the borer is a means of destroying the pest. The application of Furadan 3 G @ 6 g/plant to the soil around the base of the tree can ensure good control of the pest.

7. Sal heartwood borer

Hoplocerambyx spinicornis Newn (Cerambycidae: Coleoptera) is the most destructive pest of Sal (*Shorea robusta*). The adult beetle begins to appear as soon as the monsoon rain starts. The beetle ordinarily lays eggs in felled, dying or badly injured trees but healthy trees are also attacked. The young larva first bores into the bark, later in the sapwood and finally penetrates deeply into the heartwood. A great deal of frass is thrown out of the holes and accumulates at the base of the tree. The adults feed on the bark but freshly oozing sap is highly attractive to them. A beetle gorged on sap appears intoxicated and is often unable to stand or fly.

Control: Felling trees in proper season when the beetles are not in flight is a common practice to avoid pest outbreak. Improving forest hygiene by prompt removal of lop, top, slash etc. and quick disposal of attacked trees are also recommended. The pest is efficiently controlled by 'trap tree' operation. The trees that are silviculturally unsound are felled, cut into billets and distributed as small heaps in the affected areas at the advent of the monsoon coinciding with the emergence of the beetle. All beetles attracted to sap at cut ends are captured and killed in intoxicated condition.

8. Babla scale insect

Babla (*Acacia nilotica*) is grown in the north-western part of the country along the margins of agricultural land and also widely planted along the roads, railways and embankments. During the last few years a widespread mortality of babla caused by a scale insect, *Psoraleococcus* sp. (Coccidae: Hemiptera) has been observed. The insect sucks sap from the tender shoots. In heavy infestation the twigs are completely encrusted with the scale. Due to the withdrawal of sap, dig-back of the shoot starts and ultimately the whole tree dies. The attack is more severe during November-April. Some scoty mould fungus grows which gives the tree a black appearance. After death the tree looks burnt up.

Control: If the infestation is limited to a few mature trees it is controlled by pruning and burning of the infested branches of the tree irrespective of the degree of infestation. If the infestation spreads to many trees or it is limited within the young trees, pruning is not recommended. In this case Dimecron 100 EC @ 12 ml/10, liter of water should be

sprayed on the foliage with appropriate spraying machines. Trees that are already dead should be cut down and burnt to destroy the insect.

9. Ipil Ipil psyllid

Ipil-ipil (*Leucaena leucocephala*) is an important multipurpose nitrogen fixing tree species widely grown in a variety of plantations and agroforestry systems for fodder, fuel, timber, green manure and other uses. The leucaena psyllid, *Heteropsylla cubana* Crawford (Psyllidae: Homiptera), commonly known as jumping plant lice, is a serious pest of ipil-ipil grown in the tropics and subtropics since 1982. This insect is native to Caribbean, Mexico and Central and South America where they are not a serious pest. Moving as uninvited passengers on air craft or in high altitude winds they arrived in Hawaii in 1984. By 1985 they were found in Australia, the Pacific Islands and South East Asia (Thailand, Malaysia, Indonesia, Philippines). In 1987 they arrived in Sri Lanka, and came to Burma, China and India in 1988 (Anon.,1988). The invasion of the *psyllid* in Bangladesh was first detected at Bagachattar, Chittagong in February 1989, later, in the northern districts of Bangladesh. The damage is greater when foliage development is rapid. They suck sap from the young foliage. For this reason leaflets turn yellow, curl and wilt. The deposition of honey dew encourages the growth of the sooty moulds. Complete defoliation of terminal shoots occur under heavy infestation. Trees usually survive unless they are subject to other severe stress.

Control: Once the pest has entered this country, it is a matter of time that the pest will spread throughout the country. The pest also attacks rain tree *Samanea saman*. Strict surveillance should be maintained in the plantation at least for 2-3 years. As soon as the pest is detected anywhere, the immediate action is to destroy it by chemical sprays. At Bagachattar, Chittagong, the pest was controlled by spraying Malathion 57 EC @ 15 ml/10 liter of water. However, once it has established itself in a large area, this measure may not succeed. Two coccinellid beetle predators, *Curinus coeruleus* Mulsant and *Olla* abdominalis (Say) have been introduced in many countries with partial or full control (Anon 1988), but their introduction in our country should be investigated thoroughly as it is likely that the predators may also attack lac insect, *Laccifer lacca* thus adversely affecting the cultivation of lac in this country. The host -specific parasitic wasp, *Psyllaephagus* sp., *rotundiformis* and entomogenous fungi can help control psyllid pest. Planting of resistant trees should form the basis of psyllid management. Among 13 species of *Leucaena*, 5 are resistant germplasm (*L. pallida, L. collinsi, L. esculenta, L. retusa* and *L. diversifolia*). Some *L. leucocephala* varieties, eg. K636, K584, 'giants' from Mexico show some resistance. L. pallida showed the highest resistance followed by the hybrids KXI (pallida x diversifolia), KX2 (*pallida* x *leucocephala*) and *L. diversifolia* (K784 & K785), *L. diversifolia* (K156) and hybrid KX3 (*diversifolia* x *leucocephala*) showed resistant a some sites and susceptibility in others. Trials of psyllid resistance are being conducted at BFRI. As it is an international pest, a regional or international cooperation is needed to overcome the pest problem. Bangladesh should participate in regional research program for *leucaena* psyllid control as developed by Napompeth et. al.(1987). Alternatives to ipil-ipil tree such as *Gliricidia, Sesbania* etc. may be tried.

Since all species have insect pest, over use of any particular genotype should be avoided. In-country predators and parasites of the pest are being searched.

10. Mango fruit weevil and psyllid

Mango fruit weevil, *Sternochetus frigidus* F. (Curculionidae: Coleoptera) is the most important insect pest of mangoes in the eastern part of our country. The female lays eggs on fruit when they are in pea stage. The larva, after hatching, bores into the fruit and feed the inside. As fruit grows the entrance hole is closed obscuring the presence of larva inside. Pupation takes place inside the fruit and adult comes out making holes on the fruit. In the western part, especially in Rajshahi, a serious insect pest called mango psyllid, *Apsylla cistellata* Buck. (Psyllidae: Hemiptera) attacks tender shoot of mango. Due to the attack of this insect, leaf or inflorescence do not grow on the shoots, instead several conical, scaly galls are formed on shoot tip and thus no fruit setting occurs.

Control: For the control of mango fruit weevil, Diazinon 60 EC @ 30 ml/10 liter of water should be sprayed on the foliage and fruit, when the latter are in pea stage. Mango psyllid can be controlled by spraying Dimecron 100 EC @ 15 ml/10 liter of water. Two such sprays at an interval of 15 days will be required from mid-August. Twigs with galls can be removed from the tree manually to kill the insect inside.

11. Amra defoliator

Amra (*Spondias pinnata*) is severely defoliated by a beetle, called *Bodontia* 14-punctata (Chrysomelidae: Coleoptera) during August-September. The eggs are laid on the foliage. Both larva and adult feed on the leaves. The leaves are completely stripped down leaving only the mid-ribs. Pupation takes place in the ground.

Control: To control the pest, Ripcord 100 EC @ 12 ml/10 liter of water should be sprayed on the foliage.

12. Bamboo borer

Bamboo borer or ghoon, *Dinoderus* spp. (Bostrychidae: Coleoptera) is a serious pest of felled bamboo. It feeds on starchy material and enters inside only through the exposed surface. The adults bore horizontally and vertically and wood dust is rejected outside. Larva on the other hand, tunnels axially with the fibre and dust is tightly packed in the tunnel.

Control: Bamboo should be felled at the time when its starch content is the lowest. It should be felled with leaves and branches intact and be kept for a few days. If facilities are available, it should be immersed in water just after felling to leach out starchy material. If no water treatment is done, cut surfaces should be dressed with coal tar. Bamboo can also be treated with suitable preservative like CCB to prevent insect attack.

Heat sterilization by submersion in or fumigation with insecticide can kill the borer inside.

13. Cane top shoot borer

The larva of *Ommatolapus hanorrhoidalis*, commonly known as cane top shoot borer, bores into the growing shoot of cane, *Calamus guruba*. The larva makes tunnel inside the shoot to feed on the soft internal tissue. Due to its attack the inner whorl of the shoot becomes yellow, later dries up and comes out easily when pulled..

Control: The pest can be controlled effectively by spraying with Dimecron 100 EC @ 12 ml/10 liter of water. The pest can also be controlled by hand collection and destruction if the attack is not so severe.

14. Albizia defoliator

Albizia spp. is frequently attacked by two major defoliators, *Eurema blanda* and *E. hecabe*. The young caterpillars nibble on leaflets and as they grow older, they start eating entire leaflets leaving behind only the mid-ribs. In severe attack, plants are completely defoliated. Young plants are mostly preferred. Sometimes old trees are also prone.

Control: Hand collection of eggs and caterpillars should go along with insecticidal spray. Malathion 57 EC @ 20 ml/10 liter of water can be applied with knapsack sprayer in the nursery and pedal sprayer in young trees.

15. Red palm weevil

The red palm weevil, *Rhynchophorus ferrugineus* (Curculionidae: Coleoptera is a serious pest of coconut (*Cocos nucifera*) betel nut (*Areca catechu*), date palm (*Phoenix sylvestris*) etc. It lays eggs in wounds, cracks and soft areas in the stem and base of leaf-stalks of the tree. Sometimes a hole is bored with the snout and egg is inserted in the hole with the ovipositor. The larva bores into the interior which may be riddled by the larva. The tree is often killed.

Control: Metal wire may be inserted into the hole to kill the larva inside. Kerosene or insecticide, preferably a fumigant, can be poured into the hole to kill the pest. After killing, the holes should be plugged with clay, sand or coal tar to avoid rotting. Dead palms, trash, palm logs should be destroyed as they may serve as breeding place of the pest.

Influence of Combining Tree and Crop on Insect Pest Incidence

Agroforestry, as a science, is a new discipline. We have as yet very little information on the incidence of insect pest in a tree-crop association. However, in the light of isolated knowledge it can be said that cross-infestation may occur in some circumstances. For

example, the cutworm attacks many forest trees as well as many vegetables particularly Solanaceae and Cruciferae. Similarly, white grub is a pest of seedlings of teak, rubber and also groundnut. Again bruchid beetles are the serious pests of many legume seeds including pulses, such as blackgram, chick pea, pigeon pea, bean etc. as well as trees such as *Acacia, Albizia, Leucaena* etc. Many tree legumes are prolific producers of seeds which are not harvested by man and so fall to the ground as a potential source of infestation for pulse crops. Thus the danger of intercropping tree legumes with grain legumes should be assessed precisely.

When pests and diseases become established in mixed crops, control may be more difficult than in monoculture. This is because of many factors such as different sensitivities of plant species to chemical sprays, the difficulty of getting spray machinery for mixed crops and achieving adequate penetration of the canopy by the spray.

Positive Role of Insects That Can be Integrated in Agroforestry System

Though insects are generally viewed as destructive agents of plant, many of them are beneficial to human: As agroforestry advocates maximum utilization of land, the beneficial role of some insects could be intergrated into agroforestry system as a form of land use by which the farmer can generate additional income.

1. Apiculture

Apiculture is bee-keeping for honey and wax. Honey-bee requires carbohydrate and protein which are obtained from nectar and pollen of flowers respectively. Plants secrete small quantity of nectar. Honey - bees collect nectar and convert it to honey. Without the aid of bee it is impossible to collect them. It is estimated that about 90% of the potential honey crop go on wastage every year due to lack of sufficient bees and bee-keepers (Alam et al. 1961). Honey -bee cannot solely depend on agricultural crops because they produce flower only for a short period (e.g. mustard, lemon, sesame, sunflower etc.). A large portion of honey come from trees like *Eucalyptus, Acacia, Albizia* etc. Thus suitable trees which are in flower for longer period or during different months should be planted so that nectar and pollen are continually available all the year round. A list of such plants are provided by Rajan (1988). Many eucalypts including *Eucalyptus camaldulensis* flower profusely and can yield much honey (Loock 1974). Moreover, perhaps the most important role of bee as a pollinating agent is often overlooked. It is said that a bee can pollinate 12,000 flowers a day and the yield of crops like mustard can be increased by 20% (Alam et. al. 1964). Apiculture itself does not require land, extra labour, feed (unlike livestock) and virtually no capital. Thus, besides getting honey and wax apiculture will provide increased yield to agricultural crops through pollination.

2. Sericulture

It is the culture of silk worm for silk. The domesticated silk worm, *Bombax mori* (Bombycidae: Lepidoptera) feeds on leaves of mulberry (*Morus alba*) which can be raised

on marginal lands, around agricultural fields, along canal banks, road and hillside. It can be a profitable rural industry where additional income and employment opportunity can be generated. Silk worm eggs can be obtained from Bangladesh Sericulture Board. Rearing trays can be produced with locally available raw materials such as bamboo, sungrass etc. Women and children can easily tend the mulberry trees, gather their leaves and feed them to the silk worm and can produce raw silk. A family can sustain on rearing silk worm on 1000 trees (Tiwari 1984). Besides, culture of wild and semi-domesticated silkworms such as ari (*Phylosamia cynthia, P. ricini*; Host plants: *Ricinus communis, Cinnamomum* sp., Papaya, sissoo etc.) Muga (*Antheraea assama*; Host plant: *Michelia* sp.) and Tasar (*A. mylitta, A. paphi*; Host plants: arjun, sal, boroi, fig, semul, etc.) is an ancient cottage industry, especially for tribal forest dwellers including tribes of greater Sylhet districts. Marginal and waste lands, degraded forest areas, etc. can be planted with suitable host trees, such as arjun (*Terminalia arjuna*), shal (*Shorea robusta*), boroi (*Zizyphus mauritiana*), castor (*Ricinus communis*), etc. There is great scope for expansion of wild silk culture in the rural areas particularly in the tribal belts so as to improve the condition of the rural people.

3. Lac culture

Lac is a resinous substance secreted by the lac insect, *Luccifer lacca* (Coccidae: Hemiptera). Lac insect can be reared on boroi, palash (*Butea monosperma*), kusum (*Schleichera oleosa*), babul (*Acacia nilotica*) and khair (*A. catechu*). The latter two species can also produce tan, dyes, gums and resin. Lac finds a wide variety of uses in industries like plastics, electricals, leather and wood finishing, printing, polish, varnish, ink, phonographic records, sealing material etc. Lac culture, particularly in Bengal and Bihar, is an age-old industry dating back to 1590 AD. Today India is the largest producer of lac in the world. In Bangladesh lac is cultivated in Chapai Nowabgon. Under agroforestry program, there is a great potential of extending lac culture in other parts of the country. This small-scale forest-based cottage industry will help the rural people generate additional income and employment potential from the time of plantation up to harvesting of lac and production of shellac.

Conclusion

In the past, over -emphasis has been given to produce agricultural crops, particularly food crops and it is the role of trees that has been overlooked. However, improvement of rural areas can be brought out by carrying out massive tree planting program coupled with establishment of forest -based cottage industries (bamboo, cane, sericulture, apiculture, lac culture, etc.) in addition to traditional agriculture. The Government and the NGOs should take initiative, provide loans and technical know-how and supply suitable hand-run machines, whenever necessary. This integrated approach will provide the rural people with not only food but also fuel, timber, fodder, shade, shelter and employment helping them become self-reliant. Moreover they will no longer destroy forest cover, and migrate to urban areas for job.

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HOW TO PREPARE RESEARCH PROPOSAL

NEPTALE Q. ZABALA[1]

1.0 Introduction

Before a researcher can start a formal investigation on any problem he/she should first write a research proposal outlining in detail the activities he/she should conduct within a specific time frame operating within a certain budget allocation. The proposal may be submitted to financing agency or to the mother unit under its regular research programs.

2.0 Identifying a Research Project

The types of problems that need to be addressed by the research can be identified in consonance with (a) the national research policy and administration of the government; (b) research priorities set by research organizations in line with national priorities; (c) specific request by industries or organizations to give solutions to specific problems; (d) researches to enhance instruction and extension activities of academic institutions; (e) others.

3.0 Research Classification

Research is done to seek explanations to known events/ observations, to prove or disprove a hypothesis about certain objects or phenomena, to reach out information/ things, and to provide practical solutions to existing problems.

On the basis of these purposes of research, there are three major kinds of research, namely:

Basic research : experimental or theoretical work undertaken to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular or specific application or use in view. It is also called an exploratory work.

Applied research : an original investigation undertaken orde. to acquire new knowledge. It is directed primarily towards a specific aim or objective. It seeks practical solutions to well defined problems.

Development research : a systematic work, drawing on existing knowledge gained from research and/or practical experience that is directed to producing new material, products

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or devices, to installing new process, systems and services and to improving substantially those already produced or installed.

For administrative purposes, researches are of three types:

Study : the basic unit in the investigation of a specific problem identified under a project/discipline

Project : a set of related or a component of a predetermined objective(s) within a specific frame

Program: involves a group of related or complementing research projects on a multidisciplinary approach to meet established goals within a specific time frame.

4.0 Writing the Research Proposal

The research proposal should have the following headings:

4.1 Title of Research : The title should be short but vivid and clear describing what problems to be solved.

4.2 Introduction : Statement of the importance/significance of the research work. Statement should be made that will justify resource expenditure in the research, both financial and human, a general statement concerning the historical basis for this research; a statement of its feasibility, the expected output and input, impact the information generated by the research will have on (a) science, (b) the user, and (c) the country.

The justification for conducting the research should be reasonable to convince the financial donor that such an undertaking is worth financing.

4.3 Objectives : These should be specific with respect to the problem(s) that will be studied.

4.4 Hypothesis : The purpose of an experiment is to test a hypothesis based on existing differences between materials or treatments. This so-called "null hypothesis" has to be established, which assumes that any possible differences can only be attributed to contingency. It is a preliminary postulation of the problem. It helps in identifying the parameters of the experiment.

4.5 Literature Review : Gather literature that is specific to the topic of the research proposal. It should be comprehensive enough that the reader or financial donor can be convinced that the research proposal is built upon a sound information base, and is going to contribute something new.

Relevant local information from formal literature, personal communications, or verbally stated should be included.

All citations should be referred to in the bibliography or literature cited.

Search for literature has the following features:

- in enriches the knowledge of the researcher on the subject area;
- it avoids duplication of studies already done on the same problem;
- it helps the researcher identify methodologies to be applied in the conduct of his research;
- it identifies your problem as unique, in comparison with other researches already done in the same research area;
- helps the researcher to decide at what stage he has to start his research, based on literature relating to the same subject area;
- it accumulates information or data in discussing results of the experiment.

4.6 Materials and methods : This section should contain details of the experiment(s), what materials, equipment, apparatusetc.are needed, how the experiment will be conducted and analyses to be done, and where it will be conducted. Details should be given such that the reader or financial donor can evaluate whether the methods are feasible, most practical and will achieve the objectives of the proposal.

Among others, this section should include discussion or presentation of the following:

a. Factors in study (variables): These should be clearly listed,indicating what is to be measured and evaluated.

b. Treatments to be used and their layout: These should be listed in detailed form. Standard international units should be used.

c. Design of experiment : A clear statement of the type of experiment design should be made. The number of replications should be stated and briefly describe how the blocks will be laid out (for field experiment). Agroforestry researchers are generally conducted in the field. It is advisable to define the characteristics of the experimental units with respect to the number, area (total and net) form of the plot or unit limits of the plot or unit (border on guard alley), spacing of seeding or planting etc.

d. Statistical analysis: Scheme of analysis of data should be described. Computer package is used in respect to a particular experiment design. Important statistical parameters that needs to be determined in order to enable sound inferences are means or averages, correlations, regressions, significance test, and coefficient of variation. These data are properly presented in tabular form.

e. Evaluation methods and observations to be made : This should include data that will be taken and method of taking it. The method of measuring the data, when and how should be described in detail. Prepare forms to record your data. As much as possible the recording form should conform the particular design and its method of analysis to facilitate inputting in the computer.

Environmental data should be indicated at all times.

f. Specific management of the experiment : Mention specific features about management of the experiment. For example, what type of fertilizers, at what dosage and time, these will be applied to the plants.

Cultural practices that will be applied and stages of plant development when these will be applied should be properly described. Examples of these practices are land preparation, sowing or planting, weed control, insect and disease control, pruning, thinning, applicationof fertilizers, irrigation practices etc.

4.7 Literature Cited : An alphabetical, numerical list with complete source or relevant information. A constant system such as used by the American Society of Foresters or other international journal should be adapted.

4.8 Workplan Schedule : This is a brief description in chronological order of each activity to be undertaken. The planned start date, planned completion date should be indicated in year, month and day. The duration should be indicated in months. Usually, a Gantt chart is used to indicate the relative timeframe and schedule of the major activities of the proposal.

4.9 Budgetary Estimate : In most cases, this is the most important section of the proposal. The budgetary estimate must be practically reasonable reflecting the realistic financial requirements for conducting the research. The details of the budget estimate depends on the requirements of the donor institutions.

The details for the first year of implementation and its annual budget in the succeeding years are enumerated in a tabular form. Among others, the financial requirements should include personal services, maintenance and operation costs (such as material,instruments, travel, communication, computer cost, sundry etc.), equipment or capital outlay and contingency.

4.10 Curriculum Vitae : This portion provides relevant information regarding the proponent's research capability. This is attached, in a separate sheet, to the research proposal. The information should include, among others, the present position of the proponent, work and research experiences, number of technical and scientific papers published, and the time available to devote full time work to be research.

APPENDIX A

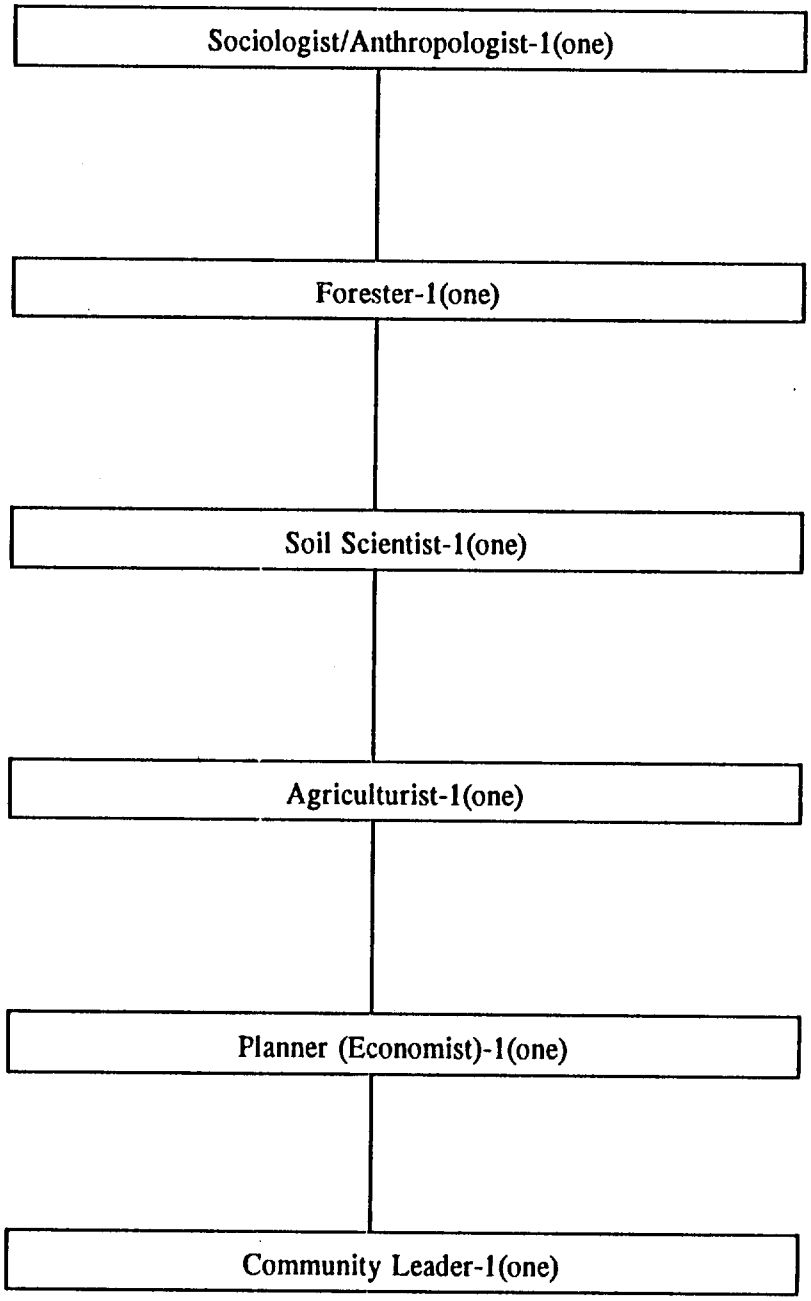
BARI/OFRD Agroforestry Research Program
List of Experiments Planned for 1988-90

	Experiment Title	Location
Initiated during 1988-89:		
1.	Studies on the tree-crop interaction in a silvi-agricultural module	Nawabganj MLT site, Dinajpur
2.	Study on the effect of fertilizer management practices on jackfruit bearing trees at FSR site, Narikeli, Jamalpur	FSR site,Narikeli, Jamalpur
3.	Impact of deep and shallow-tubewell irrigation on landuse systems at FSR site, Kalikapur, Ishurdi	FSR site, Kalikapur, Ishurdi
4.	Monitoring of growing date plam and its utilization in farming systems	FSR site, Barind, Bogra
Initiated during 1989-90:		
5.	Testing homestead agroforestry module for fuel and fodder in Barind area	FSR site, Barind, Rajshahi
6.	Effect of cutting height of ipil-ipil (Planted on the boundary of crop fields) on the biomass and crop performance	FSR site,Jessore
7.	Study on the improvement of existing homestead vegetation by introducing improved annual and perennial fruit trees	FSR site, Narikeli, Jamalpur
8.	Introduction of different quick growing multipurpose tree species in the homestead	FSR site, Palima, Tangail
9.	Introduction of improved chula	FSR site, Palima, Tangail
10.	Performance of different crops under *Dalbergia sissoo* and *Artocarpus heterophylus* plantation of different age	Damurhuda Upazila Chuadanga

11.	Monitoring species compatibility under existing agroforestry systems	FSR site, Kalikapur Ishurdi
12.	Survey on the present status of neem trees in Barind area of greater Rajshahi (2nd priority)	Godagari, Nachole, Niamatpur
13.	Studies on the growth and yield of dhaincha and country bean grown together in the homestead of different farm categories	FSR site, Bogra
14.	Growing summer vegetables of creeper type by utilizing forest species around the homestead	Kalikapur FSR Site Ishurdi
15.	Performance of dhaincha in homestead under different farm categories	FSR site,Bagherpara Jessore
16.	To study on the performance of ipil-ipil as a source of fuel and fodder in the homestead area	FSR site, Jessore
17.	Effect of fertilizer application in date palm plant (*Phoenix sylvestris*) on quantity and quality of juice	FSR site, Bagherpara Jessore
18.	Study on the performance of different plant species for fodder and fuel in the homestead area of Tista Floodplain	FSR site, Rangpur
19.	Feasibility study of different agro-forestry modules i homestead of flat Barind area and its interaction with the existing farming systems	FSR site, Bogra
20.	Feasibility study of growing seasonal vegetables and species in a semi-permanent forest of selected timber species	FSR site, Jamalpur
21.	Crop performance under various spatial arrangements of trees in the high Ganges River Floodplain	ATS, Pabna
22.	Performance of different multipurpose tree species on the crop field boundaries in Barind area	FSR site, Barind Rajshahi

APPENDIX B

Formation of RRA Team (Multi-disciplinary)



APPENDIX C

Study Tools in RRA

Environmental (Literature review, field survey)

- Biological: Flora and fauna
- Edaphic: Topography, soil characteristics etc.
- Climatic: Rainfall, temperature,humidity, etc.
- Existing crops: Versatility, adaptability, stability, growth etc.

Technological (Survey/observation,interview (individual/ group)

- Cropping pattern/land use system: Crop combination, spacing, alley cropping etc.
- Plantation management: Fencing, fertilization, grazing control, firing etc.
- Nursery Techniques: Seedling/stump, bare-rooted/polybag etc.
- Use of high yielding variety (HYV)
- Harvesting and processing techniques.

Society and culture (Observation, key informant, census etc.)

- Social hierarchy (stratification): Religions,values and norms, customs, life cycles, village politics etc.
- Demography: Population size, age, gender, labor force, landless, share croppers, housing, local elites, money lenders
- Health and sanitary (drinking water etc.)

Rural Economy (Group/individual interviews, government census etc.)

- Investment pattern
- Income generation
- Employment opportunities
- Credits/loans
- Marketing distribution
- Small-scale/cottage industries
- Expenditure: Food, entertainment, cloths, medicines etc.

Organizational/Institutional (Key informant, interview etc.)

- People's participation
- Legal and administrative support
- Coordination with other agencies
- Cooperatives
- Rural leadership

Division of labor/workload (interview)

- Gender roles
- Age class
- Types of work

Line of communication (Map, transact, census etc.)

- Accessible/inaccessible
- Roads (Paved, unpaved, footpaths)
- Water course (Launch, boat services)

Distance of markets

Mode of transportation

Research/innovation and publicity

- Suitability of different crops
- Fertilizer/insecticide application
- Market feasibility study
- Processing of products
- Publicity of innovation to motivate adoption

APPENDIX D

Data analysis/Processing

- Mapping, transacts, graphs, flow charts, bar diagrams etc.
- Constraints/problems, hindrance, land tenure issues etc.
- Opportunities: Income generation, employments etc.
- Innovatives: indigenous technologies, processing of products etc.
- Analysis of four interconnected system properties:
    a) Productivity
    b) Sustainability
    c) Stability
    d) Equitability

APPENDIX E

List of Participants

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BARC-Winrock
Agroforestry & Participatory Forestry Research and Training Support Program

The objectives of the program are to strengthen coordination and support collaborative research, training, dissemination of research results and networking in the field of agroforestry and participatory forestry in Bangladesh. Bangladesh Agricultural Research Council (BARC), the national coordinating agency for agricultural research in Bangladesh, is the host agency with whom Winrock International operates in partnership to implement the program. The program is supported by generous grants from the Ford Foundation and PACT Bangladesh.

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