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AGROFORESTRY TRAINING COURSE MODULE
FOR BANGLADESH

Proceedings of the Workshop Held at the
Bangladesh Agricultural Research Council, Dhaka
(February 27-4 March 1993)

Editor

Tej. B. S. Mahat

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FOREWORD

Successful implementation of a program depends largely on the skill of the manpower involved. Agroforestry, as a science, is new. Research and development efforts have been initiated only recently in Bangladesh. Organizations involved in research, development and extension of agroforestry expressed their interests in manpower development through long and short-training. In order to meet the needs of short-term training, National Agroforestry Working Group developed a training module on agroforestry for Bangladesh, which was tested in a training workshop. The training workshop was held on 27 February - 04 March 1993, and the participants were professionals of research, development and extension agencies including non-government organizations involved in agroforestry. The resource persons were expatriate as well as local. The participants accepted this training module to be suitable for Bangladesh. I thank the participants, resource persons and the organizers of the training workshop.

BARC-Winrock International Agroforestry and Participatory Forestry Support Program deserves special thanks for publishing the proceedings of the workshop, which will be useful for organizations involved in agroforestry research, development and extension.

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PREFACE

Though agroforestry is an age-old practice in Bangladesh, it has emerged only recently as a subject in the R&D activities in this country. Several organizations are involved in agroforestry research, development and extension activities of agroforestry. However, only a few professionals are trained in agroforestry. While developing the Five-Year Agroforestry Plan 1990-95, all organizations emphasized on the need for manpower development through training. An attempt was, therefore, made to design a training course on agroforestry that would cater to the needs of researchers, development and extension workers in Bangladesh. BARC-Winrock International Agroforestry and Participatory Forestry Support Program provided all supports to the National Agroforestry Working Group (NAWG) in designing the training course, testing it through a training workshop and finally publishing the proceedings of the workshop.

The training course is designed in such a way that a professional gets a clear concept of agroforestry and its need to alleviate rural poverty and environmental amelioration through afforestation. The course provided information on the present practice of agroforestry in Bangladesh and other countries of the world. These include : agroforestry potentials in different categories of land, and its probable linkages with the environment. A modest attempt was made to introduce the participants with potential multipurpose trees and shrubs (MPTS) including non-wood plants. Participants were enlightened with the method of Rapid Rural Appraisals, Diagnosis and Design (D&D) and Participatory Rural Appraisal method for designing appropriate agroforestry program to meet the needs of the people. The course included agroforestry research technique, development and extension methodologies giving due emphasis on gender issues. Marketing and economics of agroforestry were also included in the course.

Twenty-five professionals from research and educational institutions, development and extension agencies including NGO's participated in the training workshop. Resource persons were either local experts or expatriate consultants. The course duration was six days, with five days for lectures and one day for field exercise. Pre- and post-evaluation of the courses revealed that the participants gained significant knowledge on agroforestry from the training workshop. Proceedings of the training workshop have been incorporated in the present volume. This publication, we hope, will benefit policy planners, researchers, development and extension workers including students from the educational institutions.

Editor

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AGROFORESTRY CONCEPTS

JOHN B. RAINTREE[1]

The Roots of Agroforestry

The scientific rediscovery of agroforestry dates back to the mid-1970's but the roots of the agroforestry tradition go much deeper. In order to appreciate what modern agroforestry is and where it is going it might be useful to know something of its history.

The main taproot of agroforestry lies embedded in the traditional agroforestry practices of farmers all over the world. In some areas traditional agroforestry practices have declined but in others they are still going strong. Systematic study and improvement of viable traditional practices is still the best route of entry for those seeking to make a modest contribution to rural development in the short term. Scientific agroforestry holds promise of major improvements in the medium to long term.

Forerunners of modern agroforestry within the scientific land use specializations are several. From classical forestry we have the whole line of development which grew out of the taungya method of reforestation, first developed in Burma toward the close of the 19th century, and later disseminated to other parts of what was then the British Empire. The wider implications and potentials of the taungya approach were first recognized by Kenneth King (1968) and others at the University of Ibadan in Nigeria. King coined the name "Agrisilviculture" to refer to what later came to be called agroforestry.

It was out of these developments that the impetus for the establishment of the International Center for Research in Agroforestry (ICRAF) came. In 1976 the International Development Research Center (IDRC) of Canada commissioned John Bene, a philanthropist and prominent figure in the Canadian forest industry, to lead a study to identify the critical priorities for tropical forestry research to the end of the century. The Bene Commission concluded that the top priority for tropical forestry lay in what King and others had been calling "agrisilviculture." Bene and his team expanded on King's vision and used the term "agroforestry" to refer to the new field of interdisciplinary endeavor. Reportedly, the term itself was coined in the Philippines but it was the Bene Commission that proposed the first widely accepted definition:

> Agroforestry is a sustainable management system for land that increases overall production, combines agricultural crops, tree crops and forest plants and/or animals simultaneously or sequentially, and applies management practices that are compatible with the cultural patterns of the local population (Bene et al. 1977)

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[1]Artocarpus Network Coordinator, Winrock-F/FRED, Bangkok, Thailand

From the agricultural side, another major root of contemporary agroforestry is found in tree crop horticulture. Here we have the vision of a permanent tree crop-based agriculture put forth many years ago by J. Russell Smith in his book Tree Crops: A Permanent Agriculture (1953), and later elaborated by J. Sholto Douglas and A. de J. Hart (1973) in Forest Farming. Smith envisioned:

> ... a million hills green with crop-yielding trees and a million neat farm homes snuggled in the hills. ... The hills of my vision have farming that fits them and replaces the poor pasture, the gullies, and the abandoned lands that characterize today such a large and increasing part of these hills (Smith 1978).

The branch of the agroforestry tradition in the direct line of descent from J. Russelll Smith is represented today by the International Tree Crops Institute, publishers of the International Tree Crops Journal. A kindred development, originating in Australia, is the

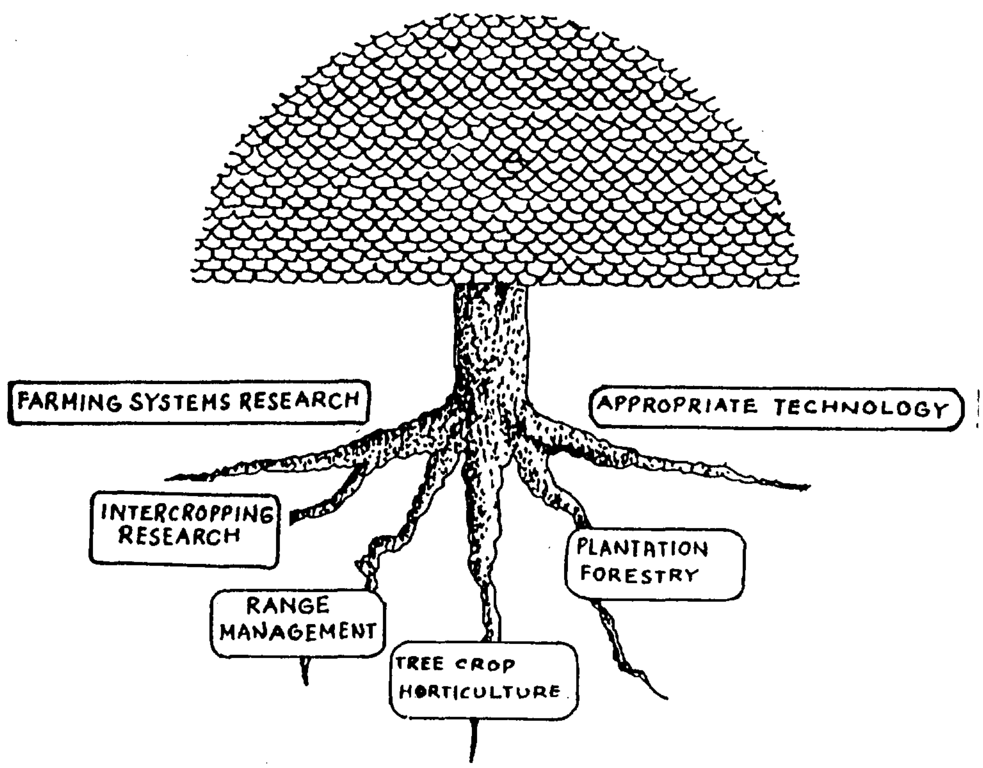

Figure 1. The roots of agroforestry within the land use sciences

approach to intercropping of trees with other crops known as permaculture (Mollison and Holmgren 1978), where the art of agroforestry design reaches perhaps its highest development and is integrated with architecture and landscape planning.

Less known possibly is agroforestry's connection with the Appropriate Technology movement, although agroforestry is, for some of the earliest agroforesters, a specialization within the broad field of Appropriate Technology. E. F. Schumacher, the father of the A. T. movement, was introduced to agroforestry by J. Russell Smith's book, which was given to him by a close associate of Mahatma Gandhi. In trees Schumacher saw the epitome of the concept of an appropriate technology. Writing during the energy crises of the early seventies, Schumacher observed:

> Since fossil fuels, the mainstay of the ' modern system', have ceased to be cheap and may soon cease to be plentiful, many people are becoming interested in solar energy. They are looking for all sorts of wonderful man-made contrivances to collect solar energy. I am not sure they always appreciate the fact that a most marvelous, three-dimensional, incredibly efficient contrivance already exists, more wonderful than anything man can make -- the TREE. Agriculture collects solar energy two-dimensionally but silviculture collects it three-dimensionally. This, surely, is the 'wave of the future' (Schumacher in Douglas and Hart 1973).

Douglas and Hart went on to develop this idea as one of the main themes of Forest Farming:

> The 'tool' with the greatest potential for feeding men and animals, for regenerating the soil, for restoring water systems, for controlling floods and droughts, for creating more benevolent micro-climates and more comfortable and stimulating living conditions for humanity, is the tree (Douglas and Hart 1973).

What distinguishes "forest farming" from conventional plantation forestry is its interest in trees as producers of food, cereal substitutes and a wide range of other foods, feeds and products besides timber. This is the "multipurpose tree" concept that has become so central to contemporary agroforestry. What distinguishes this form of agroforestry from conventional tree crop horticulture is its vision of low-input, extensively-managed, multispecies plantations in place of the traditional horticultural preoccupation with high-input, intensively-managed tree crop monocultures.

The animal component is the dominant concern of many agroforestry systems, especially in dry lands and the animal dimension of agroforestry has deep roots in the silvopastoral systems of free range forest grazing areas. A fairly long line of rigorous scientific research has led to the development of improved silvopastoral systems in some regions, notably in the southern US (Lewis et al. 1984) and New Zealand (Knowles 1991).

The great turn-about in international agricultural research which began in the mid-seventies known as Farming Systems Research (FSR) was an effort to make agricultural research more relevant and responsive to small farmer's needs. One result of the increased responsiveness engendered by FSR is the greater openness to agroforestry and other forms of intercropping. Faced with complex, multipurpose, multicomponent production systems, some kind of systems approach is inescapable in agroforestry. ICRAF's Diagnosis and Design methodology (D&D) was developed to provide a farming systems approach specifically tailored to agroforestry. The people-centered, land use systems perspective which this approach has engendered has become a hallmark of international agroforestry research undertaken in collaboration with ICRAF.

A Question of Definition

The definition of agroforestry offered by the Bène Commission was a prescriptive one. It stated not merely what agroforestry is but what it should be; namely, a cropping system that is productive, sustainable and culturally appropriate. Noting that not all combinations of trees with crops and/or livestock would necessarily meet these criteria and that they should be treated as design objectives to be aspired to, ICRAF offered what it hoped would be a more robust and neutral definition of agroforestry:

> Agroforestry is the deliberate integration, in space or time, of woody perennial with herbaceous crops and /or animals on the same land management unit. The concept of an agroforestry system implies ecological and economic interactions among the components of the system.

ICRAF advanced this definition in order to put an end to the debate over definition that characterized early conferences on agroforestry. For most purposes it has served admirably well. However, as agroforestry has gained acceptance and moved out into a wider circle of practitioners, new definitional viewpoints have emerged. The strict interpretation of this definition would place farm woodlots outside the scope of agroforestry because, unlike more intimate mixtures of trees and crops, there is not usually much ecological interaction between a woodlot and the rest of the farm.

Yet, in community forestry where agroforestry is becoming an increasingly prominent part of the tool-kit, farm woodlots are definitely considered part of a farm's general agroforestry system. Rather than getting hung up on definitional issues again, it might be better to acknowledge that there are two definitions of agroforestry currently in use -- a strict definition and a loose definition -- each with its own appropriate sphere of influence.

For some researchers, concerned with delimiting the unique focus of agroforestry as a new field of scientific inquiry, the strict interpretation of ICRAF's definition might be preferred. This would tend to focus agroforestry research on those situations in which there is a direct ecological interaction between trees and either agricultural crops or livestock. Alley cropping is the quintessential example of an agroforestry system in this narrow definition.

However, for field foresters and rural development workers, less concerned with the boundaries of scientific specialization that with the effectiveness of their interventions in rural land use systems and economies, the more pragmatic and inclusive view of agroforestry as that whole area of concern involving "trees on farms" or "farmers in forests" might be of greater utility. Numerous development agencies, NGO's, farmer groups, universities etc. use the term "agroforestry" in this larger sense to refer to a wide range of farm forestry, social forestry and natural forest management innovations that lie outside the scope of both traditional forestry and the narrow definition of agroforestry but by no means outside the experience of traditional land users in the tropics.

Agroforestry As an Approach to Improved Land Use

Whatever else it might be, agroforestry is an approach to improved land use. Not every agroforestry system will automatically be an improvement, however. In agroforestry, as in other fields, there is no substitute for good design. There are many ways to combine trees with crops and livestock. Every agroforestry system embodies at least an implicit answer to the following design questions:

Table 1. Agroforestry design specifications.

USER	For whom is the agroforestry system intended?
TECHNOLOGY	For which functions ? At what locations within the landscape ? In what arrangements ? Under what management ?
TREE	Using which species components ?

Three planting activities are too often species biased. In agroforestry, however, the choice of species is really secondary to the choice of technology. The tree should fit the technology, and the technology should fit the user.

The most important determinant of choice in selecting an agroforestry system for a particular situation is the intended user of the system. There are many different kinds of land users: farmers, foresters, herders, landless laborers etc. Each of these has different needs, capabilities, constraints and preferences. For most purposes a three-fold classification of different user groups will suffice to avoid the most serious sources of "mismatch" in agroforestry recommendations.

Table 2. Agroforestry user groups, classified according to their ability to participate in tree planting (Source : Raintree 1991)

Category	Landholding	Ability to participate
Advantaged	Large	More than adequate resources for tree planting but generally only interested in technologies that offer attractive commercial returns, or that confer other socio-economic benefits (e.g. tenure over large land holdings)
Moderately endowed	Small to medium	Adequate resources and interest for a wide range of tree planting practices for subsistence and commercial purposes; this is the main client group for the widest range of agroforestry systems
Disadvantaged	Landless & marginal farmers, minority groups, women etc.	Lack of control over land resources may restrict participation in tree planting to a very limited range of options (for cash or subsistence); special incentives and supports may be needed to enable participation; unless land or tree tenure rights can be given, the processing of tree products may be a more viable option for this group than direct tree planting

Once the user group for an agroforestry system is known, the most important question is then what functions should it perform for this user group within the prevailing land use system (Table 3).

Table 3. **Potential functions of trees and agroforestry systems in the household economy (source : Raintree 1991)**

FOOD

1. Human food from trees (fruits, nuts, leaves, cereal substitutes, mushrooms etc.

2. Livestock feed from trees

3. Fertilizer from trees for improving the nutritional status of associated crops through: a) nitrogen fixation, b) access to greater volume of soil nutrients through deep rooting trees, c) improved availability of nutrients associated with higher CEC and organic matter levels, d) mycorrhizal associations, e) feedstock for lignicolous mushrooms

4. Soil and water conservation effected by runoff and erosion controlling arrangements of trees in farming systems (indirect food production benefits)

5. Micro-climate amelioration associated with properly designed arrangements of trees e.g. shelterbelts, dispersed shade trees in crop and grazing lands (indirect benefits)

WATER

1. Improvement of soil moisture retention in rainfed cropping systems and pastures through improved soil structure and micro-climatic effects of trees

2. Regulation of stream-flow for reduction of flood hazard and more even supply of water through reduction of runoff and improvement of interception and storage in infiltration galleries through various watershed protection practices involving trees

3. Protection of irrigation works by hedgerows of trees

4. Improvement of drainage from water-logged or saline soils by phreatophytic trees

5. Increased biomass storage of water for animal consumption in forage and fodder trees

6. Purification of drinking water (e.g. *Moringa olifera*)

ENERGY

1. Firewood for direct combustion

2. Pyrolytic conversion products (charcoal, oil, gas)

3. Producer gas from wood or charcoal feedstocks

4. Ethanol from fermentation of high-carbohydrate fruits

5. Methanol from destructive distillation or catalytic synthesis processes using woody feedstocks

6. Oils, latex, other combustible saps and resins

7. Augmentation of wind power using tree arrangements to create venturi effects

SHELTER

1. Building material for shelter construction

2. Shade trees for humans, livestock and shade-loving crops

3. Windbreaks and shelterbelts for protection of settlements, crop lands, pastures and roadways

4. Fencing (living fences, fence posts, cut brush fences etc.)

RAW MATERIALS FOR COTTAGE INDUSTRY

1. Wood for craft industries

2. Fiber for weaving industries

3. Fruits, nuts etc. for drying or other food industries

4. Tannins, essential oils, medicinal ingredients etc.

CASH

1. Direct cash benefits from sale of tree products

2. Indirect cash benefits from productivity increases or input savings

SAVINGS/INVESTMENT

1. Addition of a savings/investment enterprise to farms

2. Improvement of existing savings/investment enterprises

SOCIAL PRODUCTION

1. Production of any of the above goods for socially motivated exchange (e.g. bride price or dowry, funeral and other ceremonial occasions)

2. Increased cash for social expenses (ritual expenses, development levies, political contributions etc.)

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EFFECT OF FOREST RESOURCE DEPLETION ON ENVIRONMENT AND RURAL ECONOMY

MD. FAZLUL HAQUE[1]

1. Introduction

Bangladesh is one of the least developed countries with a large and rapidly growing population and an extremely limited resource base. The per capita income is one of the lowest in the world, and about half of the population live below the poverty line. About 85% people live in the villages and are dependent on agriculture. The country is facing the problems of fast growing population, low rate of development, depletion of the natural resource base, natural calamities and environmental degradation. Less and less available resources are unable to meet the demands of multiplying development problems.

Agriculture is the mainstay of the economy. Agriculture land is being reduced to meet the rapidly growing demand for non-agricultural needs. There is an immediate need for innovative land use practices for maximizing output and income from the limited land resource. Agroforestry is considered to be a very significant tool for optimizing land use, maximizing output and integrating the production of crops, woody perennial, fodder and livestock into farming system.

In the face of its limited resource base, Bangladesh is compelled to devise appropriate strategies to meet its development needs. Adoption of sustainable land use systems and practices can be a very effective way of achieving the overall development objectives. Practice of agroforestry is one of the most effective ways for a sustainable conservation and utilization of the land.

As a land use practice, agroforestry can take care of the best land use, soil fertility and farmer's needs for food, fuel, timber and fodder. It simultaneously helps sustain rural economy and environment. It augments the food crops and the tree resources. Depletion of forest and tree resource is leading to environmental degradation and pauperization of the rural economy. Practice of agroforestry can help in a very important way to ameliorate the environment and rural economy of Bangladesh.

2. Status of Forest Resources : Past, Present and Future

Bangladesh covers an area of about 1,44,000 square kilometers. 13-14 % of this land area is considered as forest land. The tree cover, however is 7-9 % of the total land area. In the northern districts the tree cover is only 1% or less. The forests in the country are normally classified into three major categories : the mangroves (0.12 million hectares, 16 million cubic meters), the hill forests (1.4 million hectares, 28.32 million cubic meters) and the plainland forests (0.12 million hectares, 3.04 million cubic meters). In

[1]Joint Secretary (Development) in the Ministry of Environment and Forestry, Bangladesh

addition to this area of 2.2 million hectares of forest, the homestead forests cover 0.73 million hectares which supply about 70% of the timber and 90% of the fuel and bamboos used in the country.

The forests in the country have undergone serious depletion during the last few decades. In 1947, 17% of the land area had forest cover, of which 9.2% was under the Forest Department management. These forests were located in the Sundarbans, Chittagong, Cox's Bazar, Dhaka, Mymensingh, Tangail, Sylhet, Rajshahi, Rangpur and Dinajpur. There was also some 2.4 million acres of forests in the Chittagong Hill Tracts under the management of Ministry of Land/Deputy Commissioners. These forests known as unclassified state forests consisted of about 7% of the land area. The homestead forests consisted of 1% of the total forest area.

Today the forest area of the country is 13-14% of the total land area. Of this, about 2% is the village forests, 5% is the unclassified state forests and 9% is under the management of the Forest Department. The Forest Department has brought 0.25 million acres under new plantations in the coastal region. The area under unclassified state forests has been substantially reduced, and only 1.8 million hectares of these exist now with hardly any tree cover.

The estimated consumption of fuelwood per capita in Bangladesh is about 0.06 cubic meter and that of timber is about 0.018 cubic meter. The population of Bangladesh at 2% growth rate is projected to increase to 132 million by the year 2000. At that time the estimated demand for timber would be 3.28 million cubic meter and that for fuel wood be about 8.78 million cubic meter. However, the expected supply of timber would be only 1.05 million cubic meter, and that of fuel wood be about 1.87 million cubic meter.

Therefore, to meet the demand of increasing population for wood and other forest products, and also for environmental reasons, a major thrust on forestry activities is called for both in the government and private sectors.

3. Importance of Forests for Economy and Development

3.1. Role of Forest in the Economy:

Forestry sector plays an important role in the economy of Bangladesh. It contributes 4% to the GDP and 2% to the employment of the population. The trees and forest are a direct source of proteins, food, fruits, fuel, fodder, timber etc. The indirect contribution of the forestry sector in the economy is much more. 0.5-0.7 million people are dependent on different forest-related activities in the Sundarbans alone. Trees and forests supply fuel, timber, raw material for paper pulp, plywood etc. In the rural areas, various forest products including bamboos are used as basic material for construction of houses. Forest products also find important uses in industry, transport and communication sectors. It is estimated that a tree with a life span of about 50 years contributes about 2.5 million taka (US$ 65,000) of direct and indirect benefits to the economy and balance the environment.

3.2. Forest and Environment:

Trees play a vital role in the protection of the environment and the ecology. This includes the role of the tree as a supplier of oxygen, an agent for control of air pollution, a preventive against soil erosion. Some of the important roles played by trees in the protection of the environment are mentioned below:

(a) Conservation of soil: Tree roots work as soil-binders and thus prevent erosion by air, water and other natural agents. Tree leaves and branches prevent direct contact of rain drops with the soil and thus reduce erosive impacts. Depletion of forests lead to erosion of the top-soil through direct interaction between the soil and different natural agents like sun, air water etc.

(b) Increase in soil fertility: Trees increase soil fertility. Leaves of trees, fruits, dropping by birds etc. add to the humus and thus improve the quality of soil. Depletion of forests reduces the natural contents of the soil and leads to gradual degradation.

(c) Purification of air: Trees purify air by absorbing carbon dioxide and releasing oxygen. An average tree produces about 1 ton of oxygen every year. One hectare of natural forests produces about 600-650 kilogram of oxygen and absorbs about 900 kilogram of carbon dioxide.

(d) Prevention of natural disaster: Trees protect the soil and land from floods and cyclones. In the coastal areas, forests work as natural barriers against tidal bores.

(e) Increase in rainfall: Forests increase rainfall and keep the air cool. In a tropical climate, a 50-500 meter wide green belt of trees may reduce the temperature by about 3-5 degree celcius.

(f) Absorption of greenhouse gases: Forests work as carbon sinks. Thus deforestation is largely contributing to the global warming by increasing the stock of carbon dioxide and other harmful gases better known now as greenhouse gases. A serious consequence of this process of global warming would be the rise in the sea level with alarming impacts on many islands and low-lying countries such as Bangladesh.

(g) Controlling sound pollution: Trees also work as a barrier against sound pollution. In industrial areas and on busy highways, where a lot of noise occurs, tree-belts reduce the magnitude of sound pollution.

4. Causes of Deforestation in Bangladesh

Major causes of depletion of forest resources in Bangladesh have been the following:

> Population increase in the country and in the vicinity of forests

> Encroachment of forest land (estimated 1,89,000 acres)

> Release of forest land for various development purposes (estimated 1,35,000 acres)

> Leasing of forest land for agricultural purposes

> Theft by organized groups

> Unauthorized felling with the help of forestry officials

> Permits given by Deputy Commissioners in hill districts

> Jhum (Slash and burn) cultivation by the tribal people

> Over exploitation by newsprint, pulp and hard board mills; match factories and for electric (REB) poles

> Top-dying of Sundaris and stem borer attack on Gewa in the Sundarbans

> Shrimp cultivation in the coastal areas

> Over-grazing of cattle in the costal and other areas

> Firewood supply for brick kilns

> Natural calamities

> Refugees and political upheavals

5. Effect of Forest Resource Depletion on Environment

Forest resource depletion affects the environment in the following ways:

> Causes serious erosion of the soil

> Reduces soil fertility

> Creates pollution of the air

> Increases the destructive impact of natural calamities, such as floods, cyclones etc.

> Increases the droughts and decertification probabilities

> Reduces rainfall and adds to the warming of weather

> Adds to global warming by reducing carbon sinks

> Destroys biodiversity

6. Effect of Forest Resource Depletion on Economy

Depletion of forest and tree resources creates serious problems to the economy. In a rural economy like Bangladesh, the depletion of forests has adversely affected the local economy in many ways as follows:

> Created serious shortage of fuelwood

> Increased the use of agricultural residues as fuel, and thus deprived the soil of its nutrients

> Reduced the supply of timber and poles for rural housing and construction

> Caused shortage of construction material for houses in the area

> Has reduced the supply of electric poles and has led to the increase in the import of these poles from abroad

> Caused shortage of fodder, thus impeding the development of livestock in the country

> Caused shortage of raw material for manufacture of agricultural implements

> Caused shortage of other construction material for houses in the rural areas

> Has led to reduction in soil fertility and induced application of chemical fertilizers. This is creating environmental problems and reducing fish wealth.

7. Agroforestry as a Strategy for Resource Conservation

Agroforestry assumes a special significance as a strategy for resource conservation in Bangladesh. The following support this fact:

- The forest cover in the country is being depleted at the rate of about 10-15 thousand hectares per year

- The scope of allocating more government land for forestry is extremely limited

- Per capita land in the country is very small, and this is further declining with population growth

- More and more land is being diverted to non-agricultural and non-forestry activities

- Agroforestry is a very effective method of involving people, the forest land encroachers, illegal forest exploiters and other people in the protection and management of forests.

- Agroforestry has been successfully used to stop further degradation of the forest by maximizing output and income

- It has been successful in meeting the multi-dimensional needs of the rural people for food, fodder, fuel, timber, construction material, agricultural implements etc.

- The rural people have also been able to augment their cash income through practice of agroforestry in their land

- Several agroforestry models have increased the awareness of the rural people for multiple uses of land and other resources including the forests

- Agroforestry has improved the economic conditions, and hence the social status of the landless people, the destitute women, the unemployed and other under-privileged rural groups

- It has helped many among the rural poor to have a self-sustained life style

- It has introduced a sustainable use of scarce rural resources, including the land and the forests.

8. Constraints to Agroforestry its Promotion in Bangladesh

Bangladesh has limited experience in agroforestry. The Forest Department and the NGO's have been trying for about a decade from now to involve the local people, especially the poor target groups in agroforestry activities on marginal lands and forest lands. Different models of agroforestry have been experimented and are now being followed by both Forest Department and the NGO's. The main constraints to practicing agroforestry are :

> Land tenure issues

> Lack of continuity, monitoring and proper supervision

> Lack of proper silvicultural management

> Credibility gap between the government and the beneficiaries

> Lack of proper inputs

> Lack of marketing facilities

> Lack of credit facilities

> Lack of trained manpower

> Lack of research backup

> Lack of sound benefit-sharing mechanisms

> Lack of proper institutional arrangements

> Top-down approach

> Lack of recognition to role of women and other social groups

> Information gaps in agroforestry promotion

> Socio-economic issues

9. Conclusion

Depletion of forest resources has created serious environmental and economic problems in Bangladesh. The people have been adversely affected both economically and environmentally due to the degradation of forest and tree resources in the country. Agroforestry can greatly help in the regeneration of the degraded tree resources and in improving the quality of life of the people. Research backup should be strengthened to devise appropriate and rapidly replicable models of agroforestry for extension to the local people by the government agencies and NGO's.

AGROFORESTRY CLASSIFICATION

JOHN B. RAINTREE[1]

Component-based Classifications

Various schemes have been devised to classify agroforestry systems. Each of these classification schemes reveals agroforestry from a particular point of view, and each point of view reveals something unique and useful about agroforestry. It is generally agreed that there can be no all-encompassing and totally-satisfying single classification scheme for agroforestry, since it will always be useful to maintain diverse perspectives for different purposes. Whichever classification scheme is most appropriate in a given moment will depend upon the purpose of the user.

For basic descriptive terminology many agroforesters prefer a classification system based on the component combination (tree, annual crop, animal) represented by the agroforestry system. Silvicultural systems have only tree components. Agri-silvicultural systems have both agricultural crops and trees. Silvopastoral systems combine trees with animals or pastures, and agri-silvopastoral systems have all three components: trees, crops and animals/pastures (Figure 1).

Important as they may be for basic descriptive terminology, component-based classification systems address mainly the needs of researcher scientists conducting investigations on plant management for optimizing interactions between agroforestry components. Land use planners, development workers, extension agents etc. have needs for agroforestry classification systems that go beyond the fundamentals of component combination.

Classification Systems Based on Technical Specifications

One possible scheme for a more adequate approach to agroforestry classification for application-oriented users is contained within the set of technology specifications for an agroforestry intervention given in table 1 of the first article of this proceedings. The most useful of the classification systems are those based on function, location and arrangement.

A classification scheme based on function has already been given in table 3 of the first article of this proceedings. The location within the landscape in which an agroforestry function is to be performed is a very useful way of classifying or arranging agroforestry options being considered for a particular community. Whether or not a particular agroforestry intervention is appropriate for a particular user group will be determined by the landscape "niches" available for tree planting and by the opportunity

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costs of those spaces. A fairly comprehensive catalog of landscape niches or locations for tree planting is given in table 1 of the present article. Table 2 presents a classification scheme for agroforestry practices that was developed by an agroforestry extension worker using a combination of locational and functional criteria.

In designing an agroforestry system, after identifying the function and the location of the intervention, it still remains to decide in what spatial or temporal arrangement the components are to be planted. In agroforestry systems, trees (the silvicultural component), crops (the agricultural component) and animals (the pastoral component) can be associated in space and/or in time (by definition). The two main possibilities for spatial combinations are intimate mixtures or more separated zonal arrangements. In time the possibilities are successions and rotations. A classification scheme based on these principles is given in table 3.

A very useful way of classifying agroforestry systems is to use a combination of classification principles. The system shown in table 4 combines the arrangement and component-combination principles supplemented by functional and locational considerations to arrive at a pragmatic and fairly comprehensive general classification of agroforestry systems.

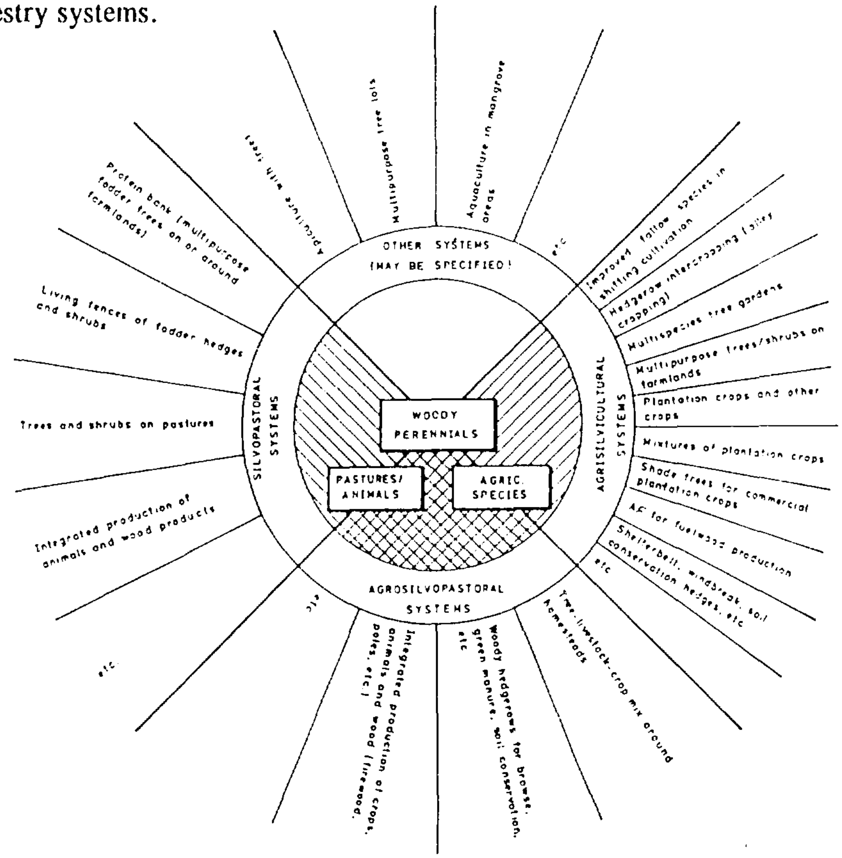

Figure 1. **Classification of agroforestry systems based on component combination; Source. P. K. Nair (1989)**

Table 1. Landscape niches for tree planting (Raintree 1991)

LANDSCAPE NICHE	COMMENTS
FOREST LANDS:	
1 Natural forests and woodlands	Private, communal, state
2 Forest plantations	" " "
3 Forest boundaries	Buffer zones on forest perimeters
FARM LANDS:	
4 Fallow cropland	Private, communal, state; irrigated/rainfed
5 Permanent arable fields	Near/far fields; currently under crops/fallow
6 Conservation structures in fields	Irrigated/rainfed annuals/perennials
7 Farm woodlots	Terraces, bunds, drainage ditches etc.
8 Orchards, groves	Monocultural or mixed/multipurpose
9 Home compounds	" " "
10 Farm boundaries	Sites of home-gardens (incipient to intensive)
	Including internal field borders, existing fencerows, hedgerows etc.
GRAZING LANDS:	
11 Range land	Rough grazing lands
12 Pasture	Planted or substantially improved grazing lands
13 Conservation structures on grazing land	Bunds, cutoff drains, micro-catchments etc.
WATERWAYS:	
14 River banks, floodplains, lake-shores	Naturally occurring waterways
15 Gullies	Naturally occurring and man-made
16 Irrigation and drainage channels	Man-made
17 Irrigation tanks	Tank foreshore
18 Wells and water-holes	Surroundings may experience heavy grazing pressure
19 Fishpond	Needing shade and/or feed
20 Seaside environments	Numerous subniches, including mangrove swamps
OTHERS:	
21 Off-farm gardens	Often in specially productive sites like floodplains
22 Public or shared spaces	General category, including market-places etc.
23 Commons	Commonly used for grazing, gathering etc.
24 Roadsides pathways	A low opportunity cost site
25 Shelterbelts	Large shelterbelts may cut across many parcels
26 Penurban environments	Numerous subniches
27 Dunes	Sites for stabilization plantings
28 Oases	Favored by high water table

Table 2. **Agroforestry systems classified by tree planting niche and function on farms (Source: Macklin 1990)**

Farm Borders

- Hedges
- Living fence posts
- Windbreaks

Trees in Crop Fields

- Hedgerow intercropping (alley cropping)
- Wide row intercropping
- Shade and nurse trees
- Support trees

Trees Around the House

- Home-gardens
- Shade/ornamentals

Temporal Systems and Woodlots

- Improved fallow
- Land rehabilitation
- Taungya
- Woodlots

Trees is Livestock Systems

- Fodder banks
- Pasture improvement

Table 3. Classification of agroforestry systems based on possible tree planting arrangements in space and time, including trees grown as monocultures and in association with other components of agroforestry systems (Source : Raintree 1991)

IN SPACE (SPATIAL):

Zonal arrangements
- Block plantings
- Forest plantations
- Farm woodlots
- Orchards
- Feeder banks

Linear plantings
- Boundary plantings
- Living fences
- Contour strips
- Hedgerow intercropping

Mixed arrangements
- Sparse dispersed trees on cropland or pastures
- Dense multistory tree gardens

IN TIME (TEMPORAL):

Successional systems
- Indigenous managed successions
- Taungya
- Experimental successions

Rotational System
- Indigenous managed fallows
- Enriched fallows
- Economically enriched fallows
- Biologically enriched fallows
- Rotational hedgerow intercropping

Rotational successions
- Complex indigenous systems
- Complex experimental designs

Table 4. General classification of agroforestry systems (Adapted from Young 1989)

MAINLY AGRI-SILVICULTURAL (trees with agricultural crops)

Rotational

1. Planted tree fallow
2. Taungya

Spatially mixed

3. Trees on crop land
4. Plantation crop combinations
- with upper-story trees
- with lower-story tree/shrub crops
- with herbaceous crops
- multistory tree gardens
5. Tree gardens
- home-gardens

Spatially zoned

6. Alley cropping
7. Boundary planting
8. Trees for soil conservation
- barrier hedges of trees
- trees on grass barrier strips
- trees on bunds etc.
- trees on terraces
9. Windbreaks and shelterbelts
10. biomass transfer

MAINLY OR PARTLY SILVOPASTORAL (trees with pastures or livestock)

Spatially mixed

11. Trees on rangeland or pastures
12. Plantation crops with pastures

Spatially zoned

13. Live fences - mainly barrier function
14. Fodder banks - multipurpose

TREE COMPONENT PREDOMINANT

15. Woodlots with multipurpose management
16. Reclamation forestry leading to production on:
- eroded land
- saline land
- moving sands
17. Taungya (see also above)

OTHER PRACTICES AND SPECIAL ASPECTS

18. Apiculture with trees
19. Aquaforestry (trees with fisheries)
20. Trees in water management
21. Irrigated agroforestry

These classification schemes help expand our awareness of the theoretical possibilities for agroforestry.

Classification Systems Based on Socio-economic and Evolutionary Criteria

Out of the range of possible agroforestry systems. only a subset will find willing acceptance in a given community. Socio-economic acceptability is often a more serious constraint than technical feasibility.

For assessing whether a given agroforestry technology is likely to be adopted by a given type of user, one needs to look at the socio-economic dimensions of agroforestry classification. The following classification schemes may help narrow down the possibilities to a set of technically and socially relevant agroforestry interventions. However, a word of caution is in order. Human behavior is exceedingly complex and defies precise prediction; only experience on the ground can teach whether a particular agroforestry intervention will be "adoptable" in a given community. Nevertheless, it is better to operate on the basis of intelligent hypotheses than none at all. As Francis Bacon once commented, "Truth proceeds more directly from error than from confusion." J. E. M. Arnold, the economist and community forester, has analyzed the reasons rural people have for planting trees. He identifies five major motivations (Arnold 1987 as described in Raintree 1991):

1. Maintain productivity of land in situations of scarce capital where the presence of trees can help substitute for purchased inputs of fertilizer and herbicide, and investments in soil and crop production

2. Make productive use of land in situations of scarce capital and labor where trees, as low-input low-management crops, constitute the most effective use of these resources;

3. Increase usable biomass outputs per unit of land area in situations where land and capital are limited, and tree/crop/livestock combinations permit fuller use of available labor than alternative uses of the land;

4. Increase income-earning opportunities from use of farm resources as size of land-holding and/or site productivity fall below the level at which the household's basic needs can be met from on-farm production;

5. Strengthen risk management through diversification of outputs, and build-up of tree stocks which can be sold in order to meet periodic or unforseen needs for capital.

By extending this analysis we arrive at a classification scheme in table 5 for agroforestry technologies based on combinations of the various possible factor scarcities (land, labor and capital).

Table 5. **Classification of agroforestry technologies in terms of the role of trees in rural economic strategies prevalent under different combinations of capital, land and labor scarcity**

CONSTRAINTS # CAP LAND LAB	USER	OBJECTIVE	ROLE OF TREES	ECONOMIC STRATEGY	TECHNOLOGY
1	All landed farmers	Capital-based production	Trees as capital assets	Cap. formation, lab. substitution	Tree crops
2 .	All landed farmers	Sustainable production	Substitute for purchased inputs	Use biological inputs	Agroforestry intercropping
3	Large farmers	Income (surplus)	Low labor production	Expand production	Cap.intensive farming, woodlots
4 .	Large farmers	Income (surplus)	Low input,low labor production	Expand extensive production	Woodlots etc.
5 . .	Small farmers	Subsistence plus income	Sustain, diversify & increase prod.	Intensification	Various AF, woodlots etc.
6 . ..	Marginal farmers	Subsistence security	Increase & diversify prod.	Intensification	Diversified home-gardens
7 . ..	Marginal farmers	Income (subsist)	Raw materials for cottage industry	Intensive cottage industry	Specialized home-gardens
8 . ..	Marginal farmers	Absentee income	Low input, low labor production	Off-farm employment	Woodlots etc.
9	Landless (house plot)	Subsistence security	Increase & diversify prod.	Hyper-intensification	Diversified home-gardens
10	Landless (house plot)	Income (subsist)	Raw materials for Cottage industry	Intensive cottage industry	Specialized home-gardens

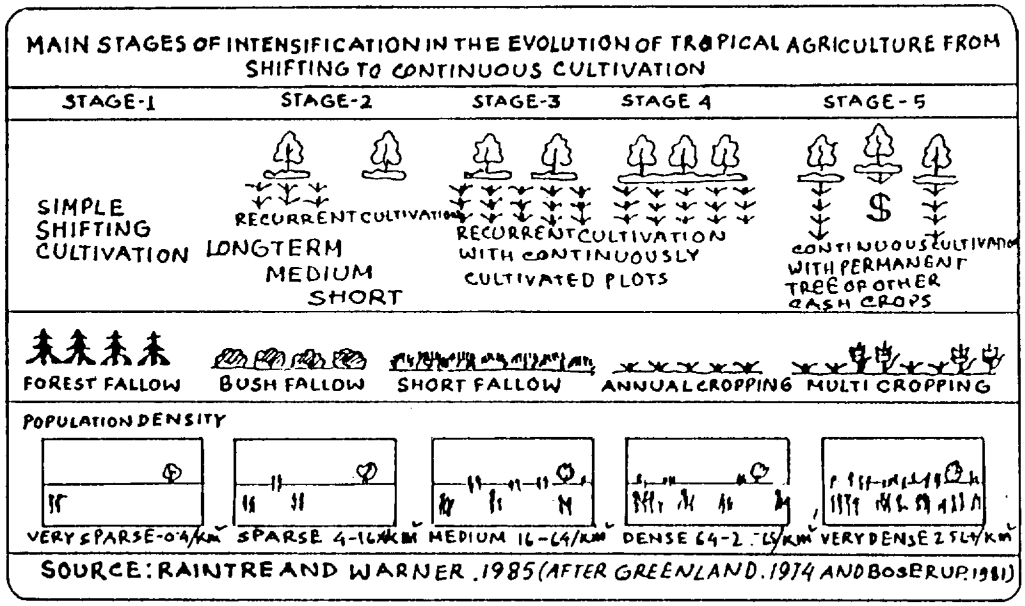

Figure 2. The evolution of tropical farming systems under population pressure; Source: Raintree (1986) based on Raintree and Warner (1986)

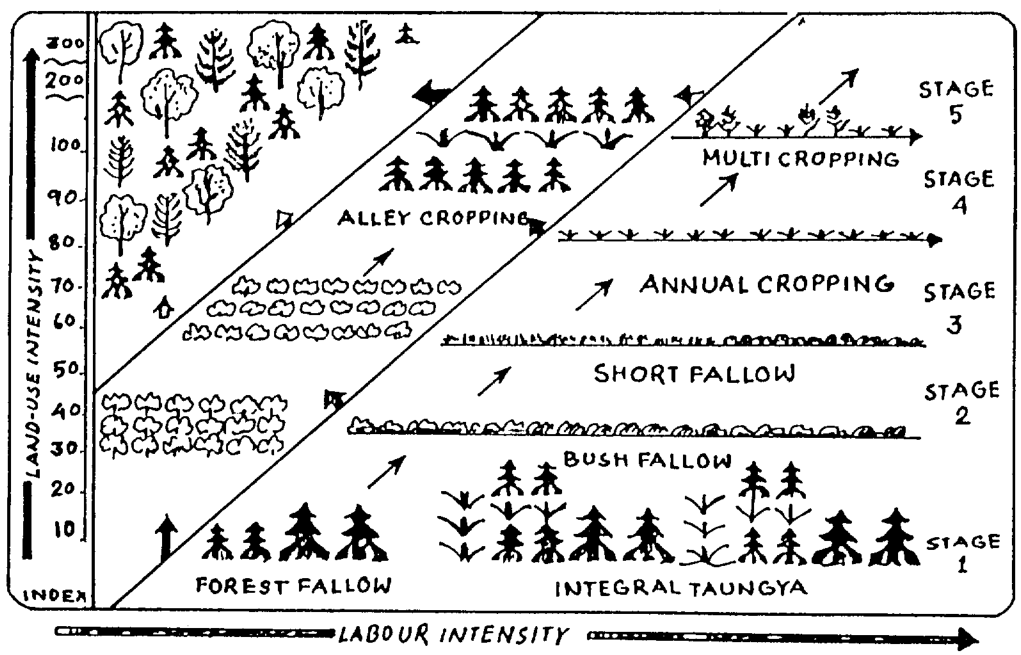

Figure 3. Pathways of agroforestry intensification in tropical farming systems; Source: Raintree (1986) based on Raintree and Warner (1986)

These dynamics operate on a macro-scale as well. As population increases there is a need to intensify land use in order to support the larger population. Land becomes scarce relative to labor, so farmers are more willing to adopt land- and labor-intensive cropping systems, resulting in the evolutionary sequence shown in figure 2. Different agroforestry pathways open up from different positions on the intensification sequence are shown in figure 3.

Table 6. Agroforestry interventions as a source of increased production and employment; (Source: Raintree 1991)

	AGROFORESTRY POTENTIALS			
		TREE CROP ALTERNATIVES		
SOURCES OF INCREASED PRODUCTION	TREE GROWING IN SUPPORT OF ARABLE CROPPING SYSTEMS	Extensive Plantation	Intensive Plantation	Interst. Plantation
1 EXPANSION OF LAND IN CULTIVATION				
Expansion of shifting cultivation into forest reserves	Integrated joint production systems for foresters and farmers (e.g. enlightened forms of taungya)			
Expansion of farming into marginal lands		Arid land tree crops Silvopastoral systems		
Expansion of farming onto steeply sloping lands	Stabilize hillside farming with trees on terraces, contour hedgerows, alley farming, strip cropping, multipurpose woodlots in upper watersheds etc.			
Cultivation of unused locations on farms and in the general landscape				Farm boundary plantings hedgerows, roadsides, waterways; trees on commons and wastelands

2 INCREASE IN THE FREQUENCY OF CROPPING				
Intensification of shif'ng cultivation	Economically enriched fallows Biologically enriched fallows Rotational alley cropping	Transition to permanent tree crops		
3 INCREASE IN YIELD PER UNIT OF LAND				
Technological Intensification of permanent arable farming	Hedgerow intercropping -Alley farming -Other forms Mixed intercropping of trees and field crops Windbreaks	Extensive tree-based economies (e.g. palm-based systems Asia, Latin America and the Pacific	Orchards Multipurpose Woodlots Fodder banks Home-gardens	Living fences for paddocks & gardens Fodder trees on grazing land Trees on improved pastures
4 DEVELOPMENT OF DECENTRALIZED PROCESSING INDUSTRIES				
Production and processing of raw material for rural industries	Various tree-based cropping systems which produce raw material for value adding processing industries located in the rural areas: small/medium-scale enterprises providing employment opportunities to landless or near-landless laborers			

These considerations provide a basis for a classification of agroforestry interventions according to their potential to contribute to increased production and employment in rural economies with different sources of production increase (Table 6).

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AGROFORESTRY PRACTICES IN BANGLADESII

A. ALIM[1]

Introduction

Agroforestry practices are not new in Bangladesh. These were embedded in the traditional forest plantation activities by way of taungya. Taungya system was first introduced in Burma. It was adopted in Bangladesh at Kaptai in the early 1870. Some eminent foresters like Sir H. G. Champion, Willium Shilch and others visited the forest plantation and recommended adoption of taungya system for plantation.

Under the Tangya system, each laborer was given 5 bighas of farmland in exchange of 19 man-days of free labor a year. The Taungya laborers were also bound by an âgreement to work in the forest on daily payment basis in addition to 10 man-days of free labor. The headman got 10 bighas of farmland. The system worked very well when the population of the taungya laborers was small, and the price of timber was low. Unfortunately, the system was never institutionalized. When the population increased, people became poorer and the prices of forest products went up, they became victims of the greedy timber merchants and land grabbers. Thus the forest started disappearing. Other than the Taungya system, agroforestry is a new innovation forestry. Its importance was appreciated when the energy crisis was felt and food and fodder crisis also appeared.

Agroforestry in Traditional Forest Plantation

In Bangladesh agroforestry has been practiced in various forest plantations. Agricultural crops including paddy, cotton, chilies, sesame, pigeon pea, mustard, maize, and different vegetables have been grown inside the plantations. In 1977-78, the area under agroforestry was 8877.5 acres and that in 1978-79 was 9098 acres. The number of families involved in agrofresatry practices in 1977-78 and 1978-79 were 2754 and 3121 respectively. With an investment of Tk. 6,85,379.00, the out-turn was Tk. 1,07,51,351.00 in 1977-78; with an investment of Tk. 9954,441.00, the out-turn was Tk. 1,54,86,094.00 in 1978-79,, as calculated on the basis of local market rates. The main vegetable crops grown were : cowpea, cucumber, brinijal, ladies finger and sweet guard. Maize and papaya can be grown in the 2nd and the 3rd year. It was found that the yield of papaya in the 3rd year at Kaptai was 45 kg per week per acre on an average. Paddy yield per acre was 45 kg at Kassalong. The plantation area has increased many fold compared to the area in 1978-79. So agroforestry offers high crop yield and employment opportunities. If medicinal plants and canes are planted, the employment potential would increase. Moreover, if programs are undertaken in consultation with the local farmers about the tree and other crops to be introduced, it will ensure their full participation in the over-all production activities.

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[1]Retired Chief Conservator of Forest, Bangladesh

Agroforestry in Encroached and Denuded Land

In Bangladesh large areas of government forest land have been encroached illegally. Moreover, large areas of the encroached forest land are lying denuded with soil erosion and other associated problems. These problems are more severe in the hill forests and in the Sal forests. It has been proved beyond doubt that the naked land can be rehabilitated with the rehabilitation of the naked man very profitably.

In Dhaka, Tangail, Mymenshing, Dinajpur and Rangpur, considerable areas of encroached and denuded land have been recovered and put under productive agroforestry and block fuelwood plantation. In Dhaka no short-term crops have been grown except paddy and groundnut. In Mymensing and Tangail bumper crops of cotton, paddy, vegetable etc, have been grown. The participant farmers feel very motivated and happy.

The land thus recovered was not under the control of the Forest Department for a long time. These lands were practically lost. These have been recovered, and vaious planned activities are now humming up. In a recent visit to a site near Dhaka, it was found that the people are quite happy and well-fed. The DFO of the area also appeared to be quite pleased with the outcome of their hard work.

In Tangail, where the missionaries have been working in association with the local Garo people, the author was informed that the participants could not sell their soyabean even at a cheap rate of Tk. 4-5 a seer for want of market. The same is the case with pineapple, which is a perishable crop. The growers hardly get Tk. 2-3 a piece whereas the same pineapple is being sold for Tk. 14-15 a piece at Dhaka market. This difference is due to the exploitation of the middlemen. The growers could overcome these problems if organized marketing infrastructure and credit facilities for their products could be ensured.

Alley cropping:

In some of the encroached and denuded lands, alley cropping mostly with 10 m x 1 m spacing in the north-south direction has been practiced in Sal forests. Because of irregular size of the plots given to the farmers, the alley sizes can not be strictly maintained. Some alternative arrengements have got to be found out to overcome thses difficulties. Another very important factor pointed out by the farmers at Bannara is that they have no cattle to plough their land where they grow paddy. The land should have been ploughed at least two monts back i.e. just after the harvest of the paddy. The land by now has become too dry and hard to use it for cultivation. However, one NGO (Proshika), which has been assisting the Forest Department, has promised to give them cattle on credit. This appears to be a good association among the three groups i.e. Forest Department, the farmers and the NGO. It is expected that in future, this cooperation will further develop.

Strip plantation:

Strip plantations are being practiced by the side of the national highways and embankments. To start with, strip plantation was practiced at Manikgonj by the side of the Dhaka-Aricha road with the help of local landless farmers. The crops raised were: napier grass, papaya, lemon, date palm, jackfruit, koroi, ipil-ipil, mahogany, shissoo etc. Data collected by the author showed that the farmers received an out-turn of Tk. 2000.00 per every 1-4 mile(s). The jackfruit trees have been giving fruits regularly for the last 8 years. The plantation was established in 1981. Some of the date palm trees have also come in tapping stage. Lot of damage to the plantation was caused by the local staff of the Department of Roads and Highways. The yield of pigeon pea per mile came to be 20 mds of pulses, and about 200 mds of fuelwood. The napier grass yield came to be about 1 md per every 20 ft x 101ft in 4 weeks' time, and these are sold for Tk.10 per md. The crop now raised in the strip plantation is : babul, koroi, shisso, eucalyptus, mahogany etc. Selection of crops depends on the socio-economic need and environmental factors in the locality.

Pigeon pea should be planted along the upper edges, and daincha should be planted along the lower edges. Ipil-Ipil should also find a prominent place in the plantation. Plantation of other species should depend on the local demand. The plantation already established should be harvested. Otherwise, they will be stolen. In fact, lot of trees have already been stolen. The strip plantation should invariably be raisised through partcipants, and a minimum period of one rotation usufractory right should be given to the participants.

Homestead Garden

The income from homestead garden has not yet been correctly calculated. The overall objectives of the homestead model are to: provide food to the family, meet petty cash requirments, provide construction material, meet demand of agricultural implements, provide protection against cyclones, provide fuelwood etc. In order to meet these general demands, the model would include : Multistrata Home-garden, Kitchen Garden and Block Plantation.

In the homestead model, bamboo should be planted in the north-western corner of the house to afford protection against nor'wester. Kitchen garden should be raised in the south-western side. Jackfruit along with trees for agricultural implements should be grown on the western side, mango on the eastern side, betel nut and coconut on the northern side. Seedling nurseries can be raised under betel nut. Cane can also be grown along with betel nut. The other plants like pineapple, lemon, papaya, guava, date plam, neem, karoi etc. can be grown in mixture. Banana can be grown on the north-eastern side with pineapple and some other vagetable in mixture.

Canal Banks

Lot of canals are being dug on self-help basis, and lot of otherwise productive land is going away,from production. The soil of the canal bank can be very productively used to make up the loss so sustained. A canal without a stabilized bank can do more harm than good. Six families per mile of canal bank can be rehabilitated through use of the canal bank soil, sale of water, rearing fishes and keeping the canal silt-free. This project was encouraged by thethen President Ziaur Rahman. Through his advice, 50 low lift pumps were procured with UNICEF assistance. These pumps were supposed to be used for irrigation in nurseries, and also for irrigation in the agricultural land by the landless farmers who were to be inducted on the canal bank.

Banks of Ponds

There are over 200000 ponds in the country. The banks of most of the ponks are lying unused or under-used, whereas through their proper use, provision of a lot of new commodities and services could be generated with care so that flow of air is not obstucted. The air-flow create ripples in the ponds, and the fishes swim and survive. The coconut palm can be planted 18-20 ft apart on the inner side of the pond banks. The outer edge can be planted with Ipil-Ipil and betal nut. Ipil-ipil leaves will provide good feed for fish and cattle. In addition, ipil-ipil wood will give good fuelwood.

USF Plantations

USF is now considered to be a very sensitive area, and the most important task is to cover the watershed area of Kaptai lake which is getting up at a much faster rate than it could be visualized. In any case, it has got to be done on participatory basis. The area that is heavily eroded has got to be covered with some leaguminous creepers, and the other crops are to be decided in consultation with local people, keeping the cultural pattern of the area in mind.

Benefits Likely to Be Obtained

The cropping patterns as suggested above are likely to yield the following benefits:

- Improve the production potential of the soils through appropriate crop mixture
- Improve the socio-economic conditions of the small/landless farmers
- Improve the social cohesion of the poor farmers
- Improve environmental conditions

> Protect soils from watershed areas and improve navigability of water-ways

> Ensure equitable distribution of opportunities and hence equitable distribution of income

> Help cottage industries and hence create employment opportunities in the rural area

> Make productive use of the otherwise fallow, under-used and improperly-used land resource

> Create employment opportunities for women.

AGROFORESTRY IN HOMESTEADS AND CROPLANDS: EXISTING PRACTICES AND POTENTIALS

MRINAL K. CHOWDHURY[1]

Introduction

Agroforestry has been a part of the traditional farming systems of Bangladesh. Planting trees in homesteads and retaining naturally occurring trees in crop fields are a common phenomenon. However, trees are more common in the homesteads than in the crop fields. Homestead trees are estimated to produce about 65 to 70% of sawlogs and about 90% of fuelwood and bamboos consumed in Bangladesh (Byron 1984).

Species Grown

There are variations in species of trees grown in different parts of the country (Chowdhury and Satter 1992; Abedin et al. 1990; Mia et al. 1990; Momin et al. 1990). Chowdhury and Satter (1992) determined the relative prevalence of tree species in the High Ganges Floodplain (Table 1). The most prevalent species in homestead was betel nut followed by coconut, jackfruit, date palm, banana, mango, mahogani, bamboo and guava. The most common species in the crop fields were date palm, sissoo, babla, jackfruit, mango, coconut, and betel nut. There is more diversity of species in the homesteads than in the crop fields. This is obvious because the primary product expected from the fields is crop and the number of species that can be grown without sacrificing much of the crop yield should not be too many.

We found that the number of plants per unit area of homestead gradually decreased from marginal farms (8 plants/10 m^2) to large farms (3 plants/10 m^2) although, on average, the total number of plants per farm was double in the large farms (108 plants/farm) compared to the marginal farms with 55 plants/farm (Table 2). This was because the size of homestead was much smaller in the marginal farms (0.097 ha) than in the large farms (0.349 ha). No such trend, however, was found in the number of trees in crop fields. Medium farms had the highest number and the highest density of plants in the crop fields. The large farms and the small farms had similar number of plants per farm although the density of plants per hectare was smaller in large farms than the small farms.

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Table 1. Relative prevalance of tree species found in the homesteads and crop fields

Homestead		Crop field	
Scientific name	Relative prevalence	Scientific name	Relative prevalence
Areca catechu	46.15	Phoenix sylvestris	37.00
Cocos nucifera	10.92	Dalbergia sissoo	8.00
Artocarpus heterophyllus	8.00	Acacia nilotica	5.00
Phoenix sylvestris	5.89	Artocarpus heterophyllus	3.00
Mangifera indica	4.74	Mangifera indica	2.00
Swietenia mahogani	3.30	Cocos nucifera	2.00
Bambusa spp.	1.74	Areca catechu	2.00
Psidium guajava	1.44	Bombax malabaricum	0.70
Polyalthia longifolia	0.84	Borassus flabellifer	0.34
Dalbergia sissoo	0.72	Swietenia mahogani	0.28
Spondias mangifera	0.64	Albizia procera	[illegible]
Bambax malabaricum	0.64	Azadirachta indica	0.16
Citurs limon	0.63	Tectona grandis	0.12
Moringa oleifera	0.60	Eugenia jambolana	0.12
Borassus flabellifer	0.60	Tamarindus indica	0.04
Zizyphus jujuba	0.56	Samanea saman	0.04
Eugenia javanica	0.50	Zizyphus jujuba	0.04
Citrus grandis	0.48	Ficus bengalensis	0.04
Eugenia jambolana	0.42	Citrus limon	0.04
Aegle mermelos	0.40	Albizia lebbeck	0.02
Acacia nilotica	0.39		
Lilchi chinensis	0.38		
Cinnamomum tamala	0.36		
Annona spp.	0.33		
Albizia procera	0.22		
Carica papaya	0.20		
Samanea saman	0.18		
Ahcras sapota	0.15		
Ficus glomerata	0.08		
Azadirachta indica	0.06		
Punica granatum	0.04		
Delonix regia	0.02		
Tamarindus indica	0.02		

Relative prevalance = Number of trees/farm X % farm with species

Table 2. Average size of farm and homestead, and tree densities in different farm categories

Farm category	Farm size (ha)	Homestead area (ha)	Tree density	
			Homestead (no./10 m^2)	Crop field (no./ha)
Marginal	0.40	0.097	7.9 (55)	205 (361)
Small	0.81	0.119	6.6 (60)	141 (547)
Medium	1.47	0.220	5.7 (84)	261 (1401)
Large	3.42	0.349	3.1 (108)	74 (549)
Mean	1.53	0.196	5.8 (77)	170 (715)

Figures in parentheses indicate average number of plants owned per farm

Species Mixture

Chowdhury and Satter (1992) noted that mixture of several tree species was more frequent than only a single species in the crop fields. Date palm, palmyra palm, coconut, sissoo, jackfruit, koroi and babla were found growing as 'sole species' in the crop fields. While date palm was common in all the three locations, sissoo, jackfruit and koroi were found in Damurhuda (Chuadanga) and jackfruit and babla at Bagherpara (Jessore).

The density of sole species ranged from 7 plants/ha of babla at Bagherpara to 865 plants/ha of sissoo at Damurhuda. Farmers were found to keep mixtures of as many as five species in one piece of land. In case of multiple species grown on the same land, the total density of trees was found very high for date palm + sissoo both at Damurhuda (1347 plants/ha) and at Keshabpur (1147 plants/ha). Date palm, which was most prevalent as a sole species, was also found to prevail in the mixtures of species. Out of 30 types of species mixture 20 were found to contain date palm.

Spatial and temporal mixtures of species were also observed. Sometimes several species were grown in the plot boundary and inside the crop fields. Trees were also planted at different intervals of time. Mixtures of young and old trees, and trees and seedling nurseries were also found mixed in individual pieces of land.

The species mixture and the dominance of tree species change over time (Abedin and Quddus 1990). In about 10 years betel nut replaced mango as dominant species in the homesteads at some locations of the country. On the other hand, date palm continued to maintain its dominance in the crop fields in the north-west and south-western regions. Abedin and Quddus (1990) noted that the distribution of species was determined mainly by ecological factors while class (farm category) specificity of trees was reflected in the diversity and abundance of trees within a homestead.

There were more plants within the age group of 5-10 years than in any other groups (Chowdhury and Satter 1992). The least number of trees were found in the less than 5 years of age category. This is an indication that although it is being advocated by agroforesters, environmental activists and the government to plant more trees to protect the environment, actually fewer plants have been planted in the crop fields in the recent years. In the homesteads also more trees were in the fruiting (mature) stage than in the sapling or vegetative stage.

Tree-Crop Association

Vegetables and spices are often grown under the trees or using trees as trellis. The most common vegetables and spices grown in association with trees are aroids, stem amaranthus, Indian spinach, radish, brinjal, sweet gourd, bitter gourd, chili and turmeric. Trees are also used as trellis to grow ribbed gourd, bitter gourd, sponge gourd, ash gourd, yam and country bean.

In the High Ganges River Floodplain the major crops grown with trees in highland crop fields in kharif season are direct-seeded upland rice, jute and aroids (particularly mukhikachu) and in the rabi season lentil, mustard, chickpea and wheat (Chowdhury and Satter 1992). Mustard is frequently mixed with lentil or chickpea. Turmeric is common as a year-round crop, particularly in the fields where tree density is relatively high. The number of minor crops was higher than the number of major crops but the minor crops were grown by only few farmers. Banana, sugarcane, pineapple, and pigeon pea were found to be the minor year-round crops in highland. Occasionally, seedling nurseries were found in the fields planted with trees.

In medium highland transplanted aman rice is the only crop in the kharif season and boro rice, wheat, chickpea and linseed are the major crops in the rabi season. The minor crops are direct-seeded aus rice or jute in kharif and wheat, grasspea and sweet gourd in the rabi season.

Information on the management of trees is rarely available. Farmers sometimes apply organic manures to fruit trees planted in the homesteads (Hossain et al. 1988). Occasionally, some farmers also apply a little chemical fertilizers and water in the dry season to fruit trees like mango and litchi. In the crop fields farmers do not apply any manure or fertilizer specifically for the trees. Fallen leaves, crop residues and weeds removed from the crops are sometimes dumped at the base of the trees which eventually serve as manures.

Why Do Farmers Grow Trees ?

Why do farmers grow trees ? The reasons cover a wide range of uses and services derived from the trees which contribute toward meeting various needs of the families (Chowdhury and Sattar 1992; Aktar et al. 1989). Farmers grow trees in homesteads for shade, beautification, protection against storm and vegetable products. On the other hand, they grow trees in the crop fields because crops can not be grown profitably due to poor fertility of soil, to get specific products like fruits, fodder, or juice of date palm, to earn cash to buy more land, to harvest additional products other than the crops, or simply they keep the trees which grew naturally (Table 3). Other reasons for growing trees were to generate cash for various purposes, to get fuelwood, timber and construction material, control soil erosion, and as insurance against risks of crop failure. Use of trees as living fence and for demarcation of plot boundary is also common. Some farmers are even aware of the contribution of the trees in keeping environmental balance.

Use of Trees and Tree Products

Various uses of trees and tree products by the farmers are shown in table 4. The relative importance of different species as multipurpose trees was calculated by multiplying the total score for different uses of a species by the percentage of farmers having the species. The major species based on their uses were, in order of importance, jackfruit, date palm, coconut, mango, bamboo, betel nut, babla, palmyra palm, sissoo and guava. Among them, jackfruit, date palm, mango and babla were used for more purposes than of the other species. All the species listed in table 4 were, however, used as fuel aside from other uses mentioned by the farmers.

The relationship between farmers' stated purposes of growing trees, their reasons for felling them and the use of sale proceed derived from trees was studied by Chowdhury and Satter (1992)). It was found that only 14% of the farmers intended to generate cash from the trees but actually 46% felled trees for this purpose (Table 5). Other activities like buying land, agricultural inputs and bullock, repaying loan, meeting day to day household expenditure and marriage costs accounted for about 24% farmers' cash expenses. Farmers often make a distinction between 'cash' and 'activities requiring cash'. The cash required for marriage of family members, buying land, agricultural inputs and bullocks, repaying loan and meeting day to day household expenditure were all considered by farmers as separate uses.

While only 15% of the farmers planted trees for fuel, actually 34% felled trees for this purpose, and although only 3% thought that they would use trees as construction material, much higher proportion of them (16%) did so. It is also interesting to note that about 8% of the farmers considered trees as insurance for meeting emergency needs but in practice 19% used the sale proceed to buy agricultural inputs, 2% to buy bullock, 15% to repay loan and 46% used it to meet day to day household expenditures all of which were perhaps done on emergency basis. Aktar et al. (1989) mentioned that farmers considered trees as a source of stable income and a means of risk management. Trees are also seen as savings and insurance (Evans 1988). Farmers considered trees as alternative source of food and cash in times of crop failure due to natural hazards like drought, flood etc. Poor farmers who do not have much land, plant trees to create asset and alternative credit source for future generation.

Table 3. Purpose of growing trees by different categories of farmers (%)

Purpose/reason	Crop field				Homestead				
	Marginal	Small	Medium	Large	Marginal	Small	Medium	Large	Total
Fruit	4	2	4	11	25	20	27	16	109
Generate cash	11	9	14	9	14	14	20	7	98
Insurance	4	7	11	7	9	12	12	4	66
Fuel	5	7	7	9	12	4	9	5	58
Sade	0	0	0	0	16	12	23	7	58
Specific products	11	11	18	4	0	0	0	0	44
Protection against storm	0	0	0	0	7	5	11	4	27
Beautification	0	0	0	0	7	7	5	7	26
Environmental balance	0	0	0	7	4	0	4	10	25
Poor fertility of soil	4	11	5	4	0	0	0	0	24
Trees grow well in crop field	0	0	2	0	0	0	0	0	24
Construction material	0	0	0	4	2	0	2	4	12
Additional products	0	2	9	0	0	0	0	0	11
Vegetables	0	0	0	0	5	0	4	0	9
Fodder	0	0	2	0	0	0	0	0	8
Asset for children	0	0	0	0	0	2	2	0	4
Buy land	0	0	2	0	0	0	0	0	2
Timber	0	0	2	2	9	2	4	5	2
Control soil erosion	0	0	2	0	2	0	2	2	2
Demarcation of plot boundary	0	0	0	2	0	0	0	0	2
Cash for marriage	0	0	0	2	0	0	0	0	2
Trees grow voluntarily	2	0	0	0	0	0	0	0	2

Table 4. Use and relative importance of different tree species

Species	% farms having the use of trees for: Fruit	Fuel wood	Leaves as fuel	Leaves as fodder	Timber	Fencing	Household construction	Agril. implement	Medicinal	Others *	Total score	% farm with species	Relative * importance
Jackfruit	92	50	42	76	80	0	80	6	2	92	520	89	463
Date palm	53	60	69	9	0	24	60	0	4	90	369	98	362
Coconut	92	42	77	0	0	11	75	2	2	52	353	95	335
Mango	89	82	53	18	69	2	64	7	0	0	384	80	307
Bamboo	0	84	51	49	0	76	76	65	0	11	412	66	272
Betel nut	0	8	43	0	0	24	16	68	3	89	251	66	166
Babla	0	59	3	3	15	41	35	41	6	15	218	61	133
Palmyra palm	74	37	58	0	0	5	53	5	5	16	253	34	86
Sissoo	0	45	10	0	50	15	25	0	5	0	150	36	54
Guava	52	30	0	0	4	0	11	4	7	0	108	48	52
Mahogani	0	10	10	0	62	5	43	0	0	0	130	37	48
Jujube	65	24	6	12	6	41	0	0	0	0	154	30	46
Black berry	75	58	8	0	33	0	42	0	0	0	216	21	45
Litchi	78	44	11	0	67	55	0	0	0	0	255	16	41
Wood apple	89	33	0	0	33	0	0	0	56	0	211	16	34
Koroi	0	33	0	0	67	11	44	0	0	0	155	16	25
Jiga	0	100	0	0	0	25	50	0	0	0	175	14	25
Lemon	90	20	0	0	0	0	10	0	0	0	120	18	22
Drumstick	0	9	0	9	0	0	0	0	0	75	91	20	18
Raintree	0	50	0	25	75	0	25	0	0	0	175	7	12
Neem	0	40	0	0	80	20	40	0	80	0	120	9	11
Silk cotton	0	22	0	0	0	33	11	0	0	67	66	16	11

Other uses include: Juice of date palm and palmyra palm; Oil and broom made from coconut; Cart wheel from babla wood; Basket and handicrafts from bamboo; Cotton from silk cotton; Condiments (chewing) from fruits of betel nut; Fruits of jackfruit and babla for fodder

* Relative importance = Total score x % farm with species

Tree-Crop Interactions

Tree-crop interactions as perceived by the farmers have been described by Chowdhury and Satter (1992). Almost all the farmers (98%) thought that crop yields are reduced when trees are grown in the fields. However, up to certain age of the trees the reduction in crop yield is not probably significant. Farmers stated that mango did not reduce yield of crops up to about seven years, and jackfruit, babla, sissoo and mahogani up to about five years (Table 6). The case was reverse with date palm and palmyra palm. At the early stages of growth, palms develop thick covering canopies which do not allow much sunlight for the crops to grow well under their shade. These species caused yield reductions up to about 4.6 and 10.5 years, respectively. Later on, the plants grow erect and tall, and therefore, do not affect the growth of the crops underneath. However, the number of observations were a few except for babla and date palm and the information was generalized regardless of the crop species, varieties and growing season of the crops.

Table 5. Relationship between some of the purposes of growing and felling trees, and the use of sale proceed from the trees by the farmers

Item	Mean response (%)		
	Purpose of growing	Purpose of felling	Use of sale proceed
Generate cash	14	46	8
Buying or leasing-in land	1	6	4
Cash for marriage	1	6	7
Buy agricultural inputs	0	2	19
Buy bullock	0	2	2
Repay loan	0	1	15
Meet daily expenditure	0	7	42
Fuel	15	34	0
Timber	4	2	0
Construction material	3	16	7
Furniture	0	14	4
Other purposes *	86	21	6

*Summarized from tables 1, 14 and 15

It seems that the yield of mustard, chickpea, rice, jute and lentil are more severely affected when grown under the trees (Table 7). Their yields were reduced by 23-29% of that obtained in the fields without any trees. Rice grows vegetatively and develop more unfilled grains under the shade. Jute grows tall but the bark becomes very thin thus reducing the yield and quality of fibers. Other crops like wheat, aroids, turmeric and potato can be grown with relatively good yields.

Looking at the standard deviations given in table 6 and 7 it can be concluded that farmers fairly agreed about the age of trees up to which they do not significantly reduce crop yields but their observations on the yield reduction of crops varied widely as reflected by the large values of standard deviations. The effects of trees on the crops depend on many factors. The density, age and planting configuration of the tree species, management practices applied to the trees and the crops, growing season affect the tree-crop interface.

Majority of the farmers (58%) did not take any preventive or corrective measure to reduce the harmful effects of trees on the crops. However, about 20% of them practiced lopping and another 20% dug trenches near or around the base of the trees to avoid obstruction in ploughing by the roots. About 2% farmers tied up the leaves of young palm trees to facilitate ploughing and laddering and to reduce the size of the shady area due to the canopy.

Table 6. Age of trees up to which crops can be grown without significant yield reduction

Species	No.of observations	Age of tree (Years)	Standard deviation
Palmyra palm*	4	10.5	3.4
Mango	3	6.7	3.8
Mahogani	3	5.7	0.6
Jackfruit	10	5.3	2.2
Babla	25	5.2	2.8
Sissoo	3	4.7	2.1
Date palm*	43	4.6	1.3

*In case of palms crop yield is reduced up to the age mentioned in the table

Table 7. Farmers' perception of yield reduction of different field crops grown under trees

Crop	No.of observations	Yield reduction (%)	Standard deviation
Mustard	33	29	21.4
Chickpea	20	29	24.1
Lentil	48	24	20.1
Rice	52	23	18.1
Jute	47	23	18.7
Aroids	13	18	16.5
Wheat	4	18	11.9
Turmeric	10	16	9.5
Potato	5	11	11.4

Interaction With Other Farm Components

Typical farm households in Bangladesh have homestead, croplands -- small or big, ponds or backyard ditches, livestock and poultry and trees. Farmers derive different kinds of products and services from these components to meet a variety of household needs. Because household activities are directed to meet these needs. Farmers try to optimize the uses of all these farm components. This results in various types of linkages among the components.

From our previous discussions on the multiple uses of trees, we can see that farmers get fruits from many trees and juice from the palms which are consumed as food. Wood and leaves of some trees provide fuel which is in very short supply in some parts of the year and in some areas of the country. Abedin and Quddus (1990) reported that rainy months were the most critical period for fuel shortage; in some areas farmers suffered from fuel shortage during two-thirds of the year. Landless and marginal farmers suffered more than the medium and large farmers. They identified more than 13 types of fuel material used by the farmers among which branches of trees, leaves, wood and bamboo together contributed 42% of the total requirement. Use of trees and tree products as fuel saves cowdung from being burnt for cooking and thus increases the opportunity of its use as manure in the crop fields. Leaves and fruits of trees provide fodder for animals.

Leaves and branches of trees and bamboos are used for fencing in the homesteads and crop fields; some shrubs are particularly preferred for fencing plots of vegetables and spices. Agricultural implements are made from some trees; others provide timbers and construction material. Leguminous tree species fix atmospheric nitrogen and help improve soil fertility. Trees are also used in controlling soil erosion. Some plants have medicinal values; bamboo and cane are used for making handicrafts. In the homesteads trees give protection against storms and keeps the dwelling areas cool during summer.

Constraints to Growing Trees

A major constraint to planting trees is the unavailability of good quality seedlings. The major source of saplings is market where the supply comes from small private nurseries. Sixty one percent of farmers was found to buy seedlings from market, while 45% used seedlings raised by themselves. Farmers also borrowed seedlings from neighbors (18%) and relatives (2%) and occasionally purchased from government nurseries (4%). Quite a number of farmers (27%) used seedlings from more than one sources.

The major problem in tree establishment was the damage caused by animals (Table 8). Animals which are very essential for draught purpose and postharvest operations eat up leaves and branches of trees and trample on the seedlings and young trees. Seedlings are also damaged by children and by storm. Farmers reported more damage by animals and storms in the homesteads than by children in the crop fields. Insect pests were also reported to cause damage to trees.

Table 8. Problems faced by farmers in establishing and raising trees

Problem	% respondent	
	Homestead	Crop yield
Damaged by animals	63	32
Damaged by storms	9	2
Damaged by children	5	11
Insect pests	5	2
Lack of technical knowledge	4	-
Roofs are damaged	4	-
Obstructs sunlight and air	2	-
Difficulties in postharvest operation	2	-
Conflict with neighbours	2	-
Fruits are stolen	-	5
Difficulty in ploughing and laddering	-	13
Not sure	-	31
No problem	5	4

In the crop fields, trees caused difficulties in ploughing and laddering. Farmers lopped the trees and cut trenches around the trees to minimize these problems. When fruit trees were planted in the crop fields, farmers could not realize the potential benefits because in many cases fruits were stolen.

Four percent of the farmers said they had no problems in raising trees in crop field, and 5% had no problem in the homesteads. About 31% was not sure whether they faced any problem in establishing trees.

Potentials for Improvement

Most of the homesteads in Bangladesh are crowded with trees which have low potentials for multipurpose use. The trees are also not managed properly. There has been little research on the potentials for improvement of agroforestry practices in homesteads and crop lands. Bangladesh Forest Research Institute, Forest Department, Bangladesh Agricultural Research Institute and Bangladesh Livestock Research Institute are conducting agroforestry research and development activities to a very limited extent. Some non-governmental organizations (NGO's) are also involved in agroforestry development. Swiss Development Corporation (1992) tested the suitability of local and exotic tree species in the north-western part of the country and has identified some promising specis for crop fields as well as homesteads. A lot more research is required on species selection for various agro-ecological and socio-ecnomic conditions, and on the management of trees for different purposes like fodder, fruit, timber, fuel etc. Suitable management practices for trees and crops also need to be developed for growing trees without severely reducing crop yield.

Table 9. Percent farmers planning to grow trees in future

Farm category	% respondent	
	Homestead	Crop field
Marginal	93	53
Small	92	69
Medium	100	43
Large	100	58
Mean	96	56

Table 10. Farmers' choice of tree species for future planting

Species	% respondent		Total score
	Homestead	Crop field	
Mango	61	0	61
Jackfruit	34	14	48
Coconut	30	5	35
Mahogani	20	12	32
Litchi	30	0	30
Date palm	2	20	22
Betel nut	18	4	22
Sapota	21	0	21
Sissoo	7	9	16
Jamrul	14	0	14
Teak	5	2	7
Black berry	7	0	7
Guava	7	0	7
Bay leaf	5	0	5
Jujube	4	0	4
Babla	0	4	4
Banana	2	0	2
Lemon	2	0	2
Palmyra palm	0	2	2

Future Planting and Extension Support

Almost all the farmers (92-100%) opined that they will plant trees in the homesteads, and 43-69% planned to plant trees in the crop fields (Table 9). Farmers' first choice of species for future planting was mango trees for homestead and date palm for crop fields (Table 10).

Majority of the farmers (89%) did not get any formal advice about planting and managing the trees. About 75% of the respondents would like to have training on the management of trees, 20% on pest management and 11% on the selection of tree species (Table 11).

Table 11. Farmers' response for training needs on different aspects of growing trees

Area of training	% respondent
Management	75
Site selection	23
Pest control	20
Species selection	11
Seedling raising	7
Grafting technique	4
Time of planting	2
Not specific	18
No need of training	5

Conclusion

Agroforestry practices in Bangladesh are still at traditional level in terms of management practices and use of trees. Farmers depend to a large extent on the naturally growing trees in the crop fields. Systematic plantation is becoming popular slowly only in the recent years. Farmers do not seem to make vigorous efforts to maximize the returns from the tree-crop interface. Although trees are used for various useful purposes, the only systematic use seems to be the extraction of juice from the date palm trees.

Proven technologies are not yet available for improvement of the traditional agroforestry systems; extension support is almost non-existent. Agroforestry research on carefully thought out agenda is the urgent need of the time. This research must be based on farmers' own knowledge of the trees and the farming systems.

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AGROFORESTRY POTENTIALS IN DEGRADED FOREST LAND AND MARGINAL LANDS

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Forest Degradation Perspectives

Historical perspectives and major causes of forest degradation in Bangladesh are described below:

1. Situated in one of the world's most fertile alluvial soil zone, the Gangetic delta, Bangladesh drew a crowding population in ancient time primarily because of easy, cheap and otherwise alluring living conditions. Life was easy with abundant agricultural production even with a primitive technology, and fishing with minimum efforts. Over the centuries, the population grew. The present population density of 800 persons per square kilometer is now increasing at the rate of 2.2 percent per annum.

2. Although population increased in geometric progression, the farming and industrial technology lag far behind. As a consequence, people in their desperate bid to earn a living, resorted to spatial expansion of primitive, low output agriculture by clearing forests and protected areas. However, up to 18th century, forest clearance for human settlement and agriculture was more or less on individual scale and was confined to easily accessible areas like flat lands by river and stream sides. Forest clearance was taken up as a governmental program during the British colonial rule in the 19th and early 20th century. Posts of Colonization Officers were created, who were assigned with the task of settling people by clearing forests for increased land revenue earnings for the crown as well as to meet immediate food shortages of the citizens.

3. Notwithstanding such clearings, the forest cover and village tree groves were enough in those days to cater to the country's need of wood and wood products. However, since the middle of the 20th Century, the forestry sector of Bangladesh has been rapidly declining due to a number of formidable factors as indicated below :

    i. With the partition of India in 1947 into two independent countries India and Pakistan, the traditional supply source of quality wood from the Himalayan foot hill forests was cut off. accessible quality forests went to the Indian territory. Increased exploitation of the indigenous forest started in Bangladesh since then.

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ii. The traditional industrial base of British India also fell in the Indian share after the partition in 1947. The resultant mushroom growth of wood-based industries, often without feasibility survey, took a great toll of timber from the forest and village groves through irregular fellings.

iii. Urbanization, housing, industrial construction, domestic fuelwood needs of expanding population and ever-increasing demand for expanding land for food production put heavy pressures on forest land and prompted clearance of forests.

iv. After the independence of Bangladesh in 1971 the demand for wood of the new nation increased for the post-war reconstruction program. This also resulted in serious depletion of resources from the government forests and rural homestead areas. Loss of plenty of forest land also took place through encroachment.

The cumulative effect of all these factors is manifested in the dwindling of forest and tree cover of the country from over 20 percent in 1947 to an estimated 9-10 percent at present. Foresters are fighting a losing battle to hold on to the last crumb of forest and protected areas from further denudation.

Extent and Condition of Degraded Forest Land and Marginal Lands

1. Present practices on degraded forest land and marginal land are briefly described in this section:

(a) The forest land all over the country suffered from varying degrees of degradation. In certain areas (except the Sundarbans), total denudation of forest cover took place due to encroachment for dwellings and agriculture. The entire area of unclassed state forests (USF) of greater Chittagong Hill Tracts and Sylhet districts (about one million hectare) is now practically denuded of forest cover, and has either assumed the character of Savannah with the invasion of *Imperata cylindrica* or is totally barren with severe soil erosion and landslides. This was once a high-density rich tropical rain forest and natural sanctuary of wildlife.

(b) The plain forests of central zone and northern districts in general, and the hill forests n the neighboring dense human habitation in greater Chittagong and Sylhet districts suffered from encroachment and degradation of varying degrees. The extent of such degraded forest areas runs to some 80000 hectares. These areas have severe limitations for land use other than forestry or agroforestry. However, Government attempts in the past to reforest the denuded areas and rehabilitate the degraded forest lands through traditional forest plantations failed to achieve desired success because of non-cooperation and hostilities of the local people. This is true that people living in the neighborhood of forests do not ordinarily have the prerogative for forest protection. Thus a symbiotic relationship of coexistence with the forests could not grow. Conscientious people do perceive the ill effects of forest denudation but they tend to ignore their responsibilities toward state-owned forests. Therefore, an effective mechanism of Government-people linkages for cooperation and concern in forest management and conservation is called for.

2. The country has some 4,500 km of roads and highways, 16,000 km of District Council roads, 105,000 km of Thana and Union Parishad roads, 2,900 km of railroads, 5,600 km of river and coastal embankments, and 2 million big and small tanks with prominent high banks. The marginal lands available along these structures amount to about 80,000 ha. These marginal lands have limitations for other uses but could be appropriately used for tree plantation and agroforestry or silvo-pastoral practices.

3. The 10 million homesteads in the country occupies about 0.27 million ha of marginal land. The homesteads bear testimony to deep-rooted agroforestry traditions. However, the tree wealth of these homesteads has been severely depleted in the past 3 to 4 decades. Tremendous scope exits for both qualitative and quantitative enrichment of these homestead forests. Because of private land ownership and intensive care and management, homestead forestry could potentially be the most productive sector.At present, homesteads are supplying up to 60 percent timber, 80 percent of fuelwood and 90 percent of bamboo needed in the country.

4. There exists another 50,000 ha of private degraded hilly and undulating area with a potential for private forestry in the greater Chittagong, Comilla, Sylhet, Mymensingh, Dhaka, Rangpur, Dinajpur and Rajshahi districts. This land belongs to the to big landholders or absentee landlords. Some of this land, even though categorized as forest land, escaped the wholesale acquisition provided by the East Bengal State Acquisition and Tenancy Act 1950. The owners, however, did not bring this land under productive tree cover, be it forestry or horticulture. These lands could be brought under highly productive agroforestry land use system, which would also warrant control of soil erosion and further degradation.

5. There are 156 tea gardens in the country. These tea gardens encompass an area of 0.114 million ha of hilly and undulating land of which only about 50,000 ha is under tea bushes. The rest 64,000 ha of tea garden is in highly degraded condition with problems of soil erosion, landslide and decreasing fertility. Agroforestry program on these degraded lands could rehabilitate the land with productive vegetative cover and generate additional income for the owners bringing about marked socio-economic impacts in favor of the tea garden workers.

The extent of forest and marginal land with potentials for agroforestry development in Bangladesh is summarized below:

Type of land	Area (million ha)
Degraded forest land	1.00
Marginal striplands (roadside and embankments)	0.08
Homestead	0.27
Degraded tea garden	0.11
Private hill and undulating wasteland	0.05
Total	1.51

Compared to the overall meager forest area of Bangladesh, the potential agroforestry land, by any measure, is substantial and amounts to almost 10.4 percent of the country's land surface. If the production potential of this land could be developed, it could dramatically change the production scenarios of both forestry and agricultural products.

Agroforestry Potential in Degraded Forest Land and Marginal Lands

1. Agroforestry is not a new land use concept, even though it received attention, publicity and prominence in recent years. Homestead and farm boundary plantings of fruit- and other utility trees, practiced for centuries in Bangladesh and other countries of the world, are evidences of agroforestry land management. However, agroforestry as a scientific and planned land use concept has emerged very recently. While developed countries pursued agroforestry on the principles of comparative economics in land management, the developing countries adopted this primarily as a means of problem-solving under pressing socio-economic adversities. Developing countries, particularly those with high population burden resort to agroforestry as the only viable option for reforestation of the fast-degrading forest lands.

2. Under tropical soil and climatic conditions, some form of agroforestry including silvi-pasture and silvo-fisheries is technically feasible, socially desirable and economically viable. In agroforestry land management practices, labor input is exceedingly high, 3-5 times higher than in the traditional block forestry because of more intensive care and attention needed and given for agricultural crops. As illustrated in the previous section, the available potential land for agroforestry in the country is about 1.51 million hectares. If a 7-year rotation is prescribed for harvesting tree crops grown under the agroforestry production system, one-seventh of this area or 0.22 million ha could be brought under agroforestry plantation per year. Moreover, tree seedling nurseries, planting and maintenance operations, agricultural crop production practices, marketing etc, could generate

about 90 million man-days of employment opportunities. Implementation of these programs will need a capital investment of about 2750 million taka in the rural sector; 80 percent of which would be labor wages. Agroforestry could thus add a new dimension to activity in the rural area. Along with agricultural practices, livestock rearing and fishery activities could help in solving the problem of rural unemployment and poverty.

3. In resource building, the agroforestry production area of 0.22 million ha is capable of yielding 15.4 million cubic meter wood at harvest in a 7-year rotation period, even with a moderate production of 10 cubic meter wood per ha per year. Its value would be Tk. 3200 million even as fuelwood in standing sale. This means a gross 16 percent interest gained on the investment. Besides production of wood, agricultural crops, such as paddy, wheat, cotton, sesame, groundnut, pulses, vegetables and fish worth over Tk. 200 million would be produced annually in the first 3-4 years before shading effect of trees starts. This would greatly contribute to the food production of the country from the non-traditional agricultural sector and help bring prosperity to the rural poor in particular.

4. The enormous potential for agroforestry indicated above is capable of changing the country's landscape altogether. The changes envisaged would not be confined to enhanced scenic beauty or abstract feelings. The block and strip plantations so created will constitute a multi-directional shelterbelts criss-crossing the length and breadth of the country. Such shelterbelts greatly reduce evapotranspiration and increase agricultural production by reducing the wind speed in dry seasons, and protect life and property of the citizens by diverting the devastating effects of Nor'westers, cyclonic storms and tidal surges.

5. The production and supply of wood in general and fuelwood in particular will greatly increase through implementation of agroforestry program in the country. As a consequence, use of agricultural residues and animal dung as domestic energy sources would prove unnecessary The biomass so saved would be used. as organic manure for the farm land. This would help boost up farm productivity and production toward achieving self-sufficiency in food. Afforestation in the denuded hills and reforestation of the barren catchments of rivers, streams and lakes will augment dry season water outputs, facilitate cheaper irrigation and increased crop production, and will reduce rainy season floods due to increased percolation of rain water in the forested floor.

Silvi-Pasture Potential

1. Organized dairy farming and ranches for rasing beef cattle are almost non-existent in the country. Scarcity of fodder supply is the primary cause for this. A sustained supply of feed and fodder is essential for warranting systematic development of livestock industry. This is again a legacy of the generally low-output farming which prompted farmers to concentrate on cereal production on every available piece of land. Livestock rearing today is totally a marginal activity with the cattle solely dependent on agricultural wastes or cropland weeds. Literally, not a decimal of land in the country is devoted exclusively to fodder cultivation. For balanced growth and healthy sustenance of human beings, milk and meat products are indispensable. It is in the overall national interest that endeavors be made to foster milch and meat animal husbandry at the domestic and farming industry level.

2. In the developed countries, major activity in agricultural sector is concerned with livestock rearing and fodder cultivation. In these countries, cereal output per unit area of land is high, and cultivation of only a fraction of the total farming land provides enough to meet the cereal requirements. The balance farm land is available for fodder production. Because of low-output farming technology in Bangladesh, poor input use and consequent low productivity, people can hardly think of putting their cropland under fodder cultivation. In such a situation, silvi-pasture on degraded forest land and marginal lands could be an alternative to help livestock development in the country. A combination of herbs, shrubs and fodder trees could be a sustainable source of feed for organized dairy farming and ranching. In Nepal, tree fodder is the principal source of animal feed. In Australia, New Zealand and whole of Africa, tree fodder is a major supplemental feed. Indonesia is well-adapted to cattle rearing under silvi-pasture and stall feeding conditions. Thus a great potential exists for the development of the livestock sector in Bangladesh through cultivation of fodder and forage in forests and marginal lands. Albizia, erythrina, ficus, artocarpus, figs, ipil-ipil, gliricidia, bamboo and a host of other species help the farmers to tide over adverse fodder situation during floods and droughts. Organized cultivation of these and other fodder species would greatly help development of livestock sector.

   Experiments in New Zealand have firmly established that silvi-pasture on appropriate sites is more profitable than block forestry economically. In our situation also, the plain land degraded Sal forest and marginal strip lands could be managed more profitably and economically if put under silvi-pasture management with stall feeding arrangement for the livestock.

Silvo-Fishery Potential

1. Shrimp culture is a foreign exchange earning sector for Bangladesh. Higher production of shrimp means more foreign exchange and greater economic good to the country. The Government and the people are equally eager to expand shrimp culture in the country. However, it must be realized that very place is not good a fish habitat. Every living being has a specific habitat of its own. This is why Chakaria-Sundarbans and Khulna Sundarbans are good sites for shrimp culture, and open surroundings of Potenga or Cox's Bazar beaches are not. These realities must be explored and evaluated before trying to expand shrimp culture all over the country.

2. The fresh as well as decaying leaves, twigs, flowers and fruits of mangroves offer essential fish meal. This is why fish is attracted to the mangrove surroundings. The forested environment also attract large variety of insects. These insects, their eggs and offsprings are attractive fish meal. The droppings of wild animals also supply essential fish food. Moreover, the shelter of the jungle is liked by fish as safe refuge to gather around. However, some 9000 ha of age-old mangrove forests of Chakaria-Sundarbans have been damaged for fish culture. Even the new plantation created under coastal afforestation scheme in the past 2-3 decades by spending millions of taka borrowed from World Bank were also damaged by clearing and diking for shrimp cultivation. These activities were undertaken through Government decisions because of lack of coordination and understanding.

3. There is no need to destroy forest for shrimp cultivation. Rather mangrove habitat is indispensable for long-term shrimp culture. Thailand, Indonesia, Indochina and Malaysia practice both intensive and extensive shrimp culture but nowhere by destroying mangrove forests. Such cultivation is done in the existing or by creating new mangroves under specified plan and designed ponds/canals alternating with forest blocks. And those are the ideal methods of estuarine shrimp cultivation. Irreparable damage has already been done to the mangrove and coastal afforestation efforts. Any further damage must be stopped.

4. Participatory silvo-fishery by associating the local community is the answer to sustainable fish cultivation program in the mangrove ecosystem. Education and training of the local community should constitute an essential component of the program to understand that mangrove and fish are intimately connected, that the mangrove ecosystem is indispensable for their economy and subsistence, and that their very existence against cyclone and tidal bores is dependent upon the presence of a tree-belt along the coast. Once the local community understands the importance of coastal mangrove forests for their economy and existence, their interest and participation would be ensured to resist any outside adventurism to disturb and destroy the natural habitat permanently.

5. Similar potentials for agroforestry, silvi-pasture and silvo-fishery exist in the inland river accretions (chars), 'Haors' and 'Baors'. A belt of trees along the fringes of 'Haors' and 'Baors' will protect the hinterland from wave action and scouring, and thus consolidate the banks. The trees will attract the indigenous and migratory birds for shelter and nesting. A symbiotic relationship of bird and fish will also foster fisheries and tourism development in the country. Trees could supply essential fodder and fuelwood to the surrounding community.

Here also, the strategy will have to be participatory. Without the willing participation of the neighboring people, resource building and its sustainability will not be feasible.

AGROFORESTRY-ENVIRONMENT LINKAGES

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Introduction

Owing to historical reasons viz. feudalism and colonial rule and the population explosion combined with improper/inadequate management, the forest resources of Bangladesh has considerably been dwindling and is below acceptable level. At the same time forests are gaining importance for environmental amelioration, improving the biological productivity of land and for in conserving biodiversity.

Agroforestry refers to land use system in which trees or shrubs are grown in association with agricultural crops, pastures or livestock and in which there are both ecological and economic interaction between trees and other components. It covers combination of trees with plants or animals, and there must be interaction between the trees and non-tree components of the systems. Ecological interaction is the most important feature that distinguishes it from social forestry although, there are large overlapping of the two (Young 1989).

If we consider the main components of agroforestry system viz. trees and shrubs, crops, pastures and livestock together with the environmental features of climate, soil and land forms, it is very clear that there is a strong linkage of agroforestry and with environment.

Bangladesh is one of the few countries in the world with high density of population having 800 people/km^2. There is less than 6% land under actual forest with almost no scope for expanc i ıg the area under forest cover, except by planting in depleted and mangrove/coastal area, denuded area of hill tracts or introducing agroforestry in the encroached forest land as well as privately-owned marginal agricultural land.

Major constraints to environmental amelioration

Trees/plants play a very important role in the welfare of human beings and improved quality of life. This is not only because of their diverse economic contribution but also owing to their abstruse beneficial influence/effects on the environment. The major constraints in agroforestry to environmental amelioration are described below:

1. Control of Air Pollution

Trees in their process of photosynthesis use atmospheric carbon dioxide, water and solar energy, and release oxygen thus reducing the amount of carbon dioxide in atmosphere.

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This oxygen is used by man and animals for their respiration through a good exchange of carbon dioxide and oxygen, between plants and animals resulting in replenishment of the environment. This phenomenon maintains balance between these two gases in the air.

A leaf acts as a filter and attracts fine particles or dirt and various chemical elements to keep atmosphere clean. One healthy man releases about 1 kg of co_2 in the air and a medium-sized leaf releases about one kg of oxygen per day. On the other hand, one hectare of natural forest releases 600-650 kg of oxygen and absorb about 900 kg of co_2 per day.

Dirt and dust travel thousands of miles with air e.g. sandy air from Sahara desert crosses Arabian sea and reaches Indian Sub-continent.

Atmospheric air contains oxygen, nitrogen, carbon dioxide, water vapor, some percentage of different gases and floating fine chemical elements. Floating particles may be helpful for rainfall up to certain limit but if these exceed the limit, these may cause diseases like asthma, bronchitis etc.

Again, air also carries pollens of flower, fungal spores, and other floating particles from one place to another. Trees/plants hinder the movement of those fine particles and attach them on the leaves, some form colloid with the trunk and branches of the trees and fall down, and the rest travel to other directions after collision. It has been observed that green trees with long leaves e.g. *XKD grandis* (Teak), *Shorea robusta* (Sal), *Polialthia longifolia* (Debdaru), *Terminal'a arjuna* (Arjun), *Mangifera indica* (Mango) etc. (Table 1) catch more floating particles. It means more trees in an area will ensure more purified and filtered air in the atmosphere 'Ashrafuddin 1989).

Table 1. Leaf dirt indices of some tree species

Name of trees (in descending order)	*Leaf Dirt Index		
	Leaves of upper layer	Leaves of under layer	Total index
1. Teak	4.10	1.25	5.35
2. Debdaru	3.92	0.64	4.56
3. Sal	3.40	1.01	4.50
4. Arjun	3.25	1.24	4.49
5. Asothwa	2.56	1.59	4.15
6. Pakurh	2.64	1.54	4.09
7. Mango	2.50	1.55	4.05
8. Jarul	2.80	1.22	4.04
9. Bot	2.71	0.88	3.59
10. Krisnachura	2.70	1.20	3.90
11. Kadam	2.42	1.15	3.57
12. Tulip	2.82	0.71	3.53

1. **Table 1. Continued**

Name of trees (in descending order)	*Leaf Dirt Index		
	Leaves of upper layer	Leaves of under layer	Total index
13. Ausok	2.56	1.22	3.78
14. Palash	2.20	0.85	3.05
15. Neem	2.20	0.72	2.92
16. Shedur	1.82	0.42	2.24
17. Tentul	1.56	0.52	2.08
18. Gulmahar	1.12	0.32	1.44

*Leaf Dirt Index = Weight of dirt in gram per sq. m area
Source: Ashrafuddin, 1989

Control of Temperature/Reduction of Greenhouse Effect

Trees absorb Co_2 and help keep temperature within tolerable limit. It may be mentioned that if atmospheric Co_2 level increases to 0.069%, it would cause a greenhouse effect resulting in excess heat accumulation on the earth surface. Trees can reduce this greenhouse effect to a great extent by absorbing Co_2.

3. Control of Soil Erosion

Erosion is one of the important causes of serious deterioration of soil conditions. When soil is eroded, plant nutrients associated with this soil are removed to places where these are not required, for instance, in the water ways, lakes and reservoirs. When sediments eroded in a catchment reach the streams, the sediments themselves, nutrients contained in them and absorbed chemicals can act as pollutants and affect the environment. At the same time, when the top-soil is eroded, the productivity of soil can be reduced to a great extent.

In agroforestry practices, trees/plants play vital role in controlling soil erosion mainly through interception, infiltration etc.

3.1 Interception:

Trees act as a sponge to intercept much of the precipitation, part of which is absorbed and substantial part of which flows down the stems and drips from the foliage. The interceptions of precipitation by tree cover hold particular relevance to flood control and vary with the crop densities and tree species.

It may be mentioned that 20% of rainfall is checked by tree cover, whereas ground shrubbery checks about 10%. In addition, the forest floor also intercepts rainfall to the extent of at least 5%. In this way, grossly 35% of rain drops is checked. Tree cover prevents rapid run-off of water and thereby checks soil erosion.

3.2 Infiltration:

The decomposed tree cover in the form of humus improves physical and chemical properties of soil. It improves soil texture, build its water-holding capacity and significantly neutralizes the impact of rainfall, surface run-off and erosion.

4. Maintain of soil fertility/organic matter level

4.1 Organic matter:

Soil organic matter plays the key role in maintaining fertility of soil. Its main effects are to improve soil physical properties and to provide and reserve nutrients released by mineralization. During decomposition of herbaceous and woody residues, there is a loss of carbon and release of nutrients. The remaining material become converted to soil organic matter or humans.

4.2 Nitrogen fixation:

Leguminous trees/plants in agroforestry practices are a good source of nitrogen;, play a significant role in soil improvement. Nitrogen fixing trees and shrubs growing within agroforestry system are capable of fixing about 50-100 kg N/ha/year. The nitrogen returned in litter and prunings may be 100-300 kg N/ha/year. (Nair 1984; and Dommergues 1987). Another major role of tree is to improve the efficiency of nutrient cycling. Mechanisms involve uptake from lower soil horizons, reduction of leaching loss by tree root system, balanced nutrient supply and improvement in the ratio between available and fixed minerals.

4.3 Root biomass:

Root biomass of trees is typically 20-30% of total plant biomass (Young 1989). Roots form an appreciable store of nutrient and since they almost invariably return to soil, constitute a substantial element in nutrient recycling.

5. Biological reclamation of saline and alkali soils

Various authors reported biological amelioration for reclamation of saline and alkaline soils by planting tree species resistant to salinity and waterlogging (Sheikh 1974; Sandhu 1978; Yadav 1980; Annon 1982; Ahmed 1983).

Tree grown in salt-affected soil is reported to exert ameliorative effects by improving physical, chemical and biological properties of soil. Deposition of salts in the upper layer of soil is maintained due to greater loss of moisture through transpiration rather than through evaporation from the soil surface. Further, their shade reduces soil evaporation thus reducing the upward movement of ground water. In higher water table area, salts accumulated on the surface are prevented due to lowering down of water table as a result of accelerated moisture losses by trees. The trees through their deep and sturdy root systems open up the soil and improve water permeability, thereby facilitating leaching of salts (Yadav 1980). The incorporation of organic matter in the form of foliage etc. from the trees brings about favorable changes in the physico-chemical properties of soil.

6. Shelterbelt and Windbreak

Trees act as shelterbelt and windbreaks. The shelterbelt greatly reduces the wind velocity and leads to increased crop yield. In addition, trees act as screens and check infiltration of wind-borne sand into the fertile soil and protect life and property to a great extent during cyclone, tidal surge etc.

7. Poverty Alleviation

The total population of Bangladesh is about 110 million confined within 144000 km^2. making its population density the highest in the world. Over 50% of the population is below 15 years, and hence in the next 10 years, there will be an abrupt risk in demand for employment. 64% of the total GDP earned from agricultural sector appears to be limited, and other sectors are not creating sufficient new jobs. The population continues to grow at a rapid rate of 2.4% and poverty may now cause and certainly will cause in future an over-exploitation of natural resources resulting in environmental degradation. Moreover, the poor cannot afford to protect environment; their living conditions generate such wastes that are neither treated not disposed off. The activities/cultural practices in agroforestry and material resources provide employment opportunities for the rural poor to a considerable extent, and thereby help in the alleviation of poverty.

Conclusion

The agroforestry is directly linked with the environment. The importance of agroforestry for the rural environment is becoming more and more evident. Appropriate agroforestry systems not only provide diverse economic contribution for socio-economic development but also play great role in controlling air pollution, soil erosion, maintenance and promotion of efficient nutrient cycling, including the reclamation/biological amelioration of salt-affected soil.

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AGROFORESTRY - FARMING SYSTEMS LINKAGES

R.N. MALLICK[1]

The Concept

Agroforestry is a holistic land use approach in which woody parennials are combined on the same land management unit with herbaceous crops and/or animals, either in the same form of spatial arrangement or temporal sequence. When woody parennials interact positively with food crop farming and/or livestock production and improve the overall performance of the farm enterprise, it may be called an effective agroforestry.

Farm means a piece of land cultivated by its owner or a tenant, a homestead used for housing of the farmer, his family members, farm animals and implements used for farming. A system has components or elements that are interrelated and interact among themselves. Two systems may share a common component or environment and one system may be a subsystem of another. Commodity research has a history of 200-300 years, whereas systems research is an innovation of the past 30 years or so. The farmer views his farm as a system, and he has knowledge of the interactions among its components. Objective of systems research is to increase the efficiency of the systems as a whole.

For example, an eucalyptus specialist will always look how he can increase the efficiency of a resource used for eucalyptus, whereas systems researcher will see the efficiency of agroforestry systems as a whole. So systems approach in more realistic in orientation than the more conventional reductionist approach which involves studying one or two factors at a time.

A systems approach to any activity starts with the concept that everything is connected and a change introduced in one component will induce a change in other parts of the system.

What farmers do under a given set of farming conditions determines the nature of a farming system. Farmers manage a complex system of land, labor and capital resources. Farm families allocate time, space and flows of products, income, by-products, cropping sequences and labor based on decisions derived from personal judgements, values and desires.

A farming system is a unique and reasonably stable arrangement of farming enterprises that a household manages according to well-defined practices in response to the physical, biological and socio-economic environments and in accordance with the household goals, preferences and resources. The farming system is a part of the larger

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systems and can be divided into subsystems e.g. cropping, livestock, fisheries, agroforestry and household or homesteads. Crops, livestock, fish, homestead vegetables, and forest outputs represent products of farming activities. Fundamental premise of farming system is that only farmers can perceive what is needed to improve their farming system.

Technical feasibility, economical viability and social acceptability are part and parcel of farming systems. All these, at any stage, are studied in a farming systems approach, whereas in other studies, only one or two of them are given focus.

The goal of the farming systems research is to generate appropriate technology in the farmers' field. Appropriate technology is a generic term for a wide range of technologies characterized by one or several of the following features:

i. Low investment cost per work
ii. Low capital investment cost for unit of output
iii. Organizational simplicity
iv. High adaptability to a particular social or cultural environment
v. Sparing use of natural resources
vi. Low cost of final product
vii. High potential for employment

National Farming Systems Research Program was initiated by NARS in 1985 with farming systems approach including livestock, fisheries and agroforestry in addition to crops. Promotion of farming systems approach advanced through bottom-up research planning by developing proposals at field level with farmers and extension workers and institutionalizing the practices of regular review. This has strengthened research extension linkages but the linkage with the private sector institutions needs to be strengthened for rapid dissemination of innovations.

The goals of the FSRD is total development of farmers to increase income for improved standard of living and social status with on-farm and off-farm interventions involving livestock, fisheries, crops agroforestry and homestead production components. This development should be sustainable and focused on resource-poor farmers.

The Objectives of FSRD

i. Develop technologies to improve and sustain farm productivity;
ii. Improve resource utilization efficiencies with farm-labor, lands, capital;
iii. Improve diets and nutrition of farmers;
iv. Increase income-generation opportunities of farmers;
v. Strengthen linkages with farmers, extension, NGO's and agribusiness entrepreneurs;
vi. Foster FSRD approach as part of development including commodity research

The goal of agricultural research in Bangladesh is to provide technologies to sustain increased farm productivity. To attain this goal farming systems approach is the thrust. Farming system approach involves farmers, extension agents and researchers to identify problems and to determine research priorities. FSR cuts across traditional commodity and disciplinary boundaries. Collaboration among biological scientists and social scientists is needed to understand the condition under which small farmers operates and diagnose constraints. FSR also aims at developing improved technologies suited to those conditions. The majority of people are dependent upon their own farm production for their livelihood. So a single farm produces several crops in order to be as self-sufficient as possible.

Program area of farming systems

1. Crops - homestead - livestock
2. Crops - homestead - livestock
3. Crops - homestead - livestock - fisheries
4. Crops - homestead - livestock - agroforestry

Agroforestry can be a part of any system

There are 30 agro-ecological regions and 88 sub-regions, which has a unique combination of physiographic, soil, hydrological and agro-climatic characteristics. Land forms, soils, inundation regime, and climatic parameters have been used for land use. Crops contribute 36.8% to the GDP, while livestock contribute 6.5%, fisheries 3-6% and forestry 3.1%.

Model is a means of describing and summarizing a system with its known properties. It helps in understanding what study is going on, and where lies the gaps in knowledge. Structural model focuses on the levels of interactions and integration among the various crops, livestock, agroforestry, fisheries and off-farm enterprises of a farm family.

Understanding the linkages between farming systems and agroforestry is extremely important for the success of a farming systems approach involving agroforestry as a component. Agroforesters hold baseline data and information about improved technologies crucial to the system analysis and designing process. Equally, data gathered through farming systems can be usefully employed to help determine agroforestry priorities.

To bring appreciable changes in farm produce level the following are needed:

1. Technologies that suit farmers production environment;

2. A strong extension system to feed the farmers with recent technical information and strengthening the research with feed back from them;

3. Appropriate policy support to keep farming profitable.

Intercropping

Intercropping is the growing of two or more crops simultaneously on the same field such that the period of overlap is long enough to include the vegetative stage. The crops are not necessarily sown at exactly the same time and their harvesting times may be quite different. Two types of intercropping are described below:

Mixed Intercropping (also called mixed cropping): Refers to any cropping arrangement, where there is irregular broadcasting or mixing of crops within the rows.

Row intercropping: Refers to an intercropping system where at least one crop is planted in rows.

In an intercropping system, component crops are used to refer to individual crops making up the intercropping, while sole crop refers to a component crop being grown alone, generally at optimum population and spacing. Intercropping yield rate refers to the yield of a component crop when grown in intercropping and expressed over the total intercropped area.

A farming system includes all the activities performed on a farm to fulfill the needs and objectives of the family. Farming system is participatory, holistic, interdisciplinary and involves farmers and encourages linkages.

Cropping pattern

The major factor governing cropping system in Bangladesh is the water regime, particularly the depth and duration of flooding. By national water plan, the country is divided in four agro-ecological zones.

Land Type	Flood Depth	Percentage of Cultivated area
Highland	- flood-free	35
Medium highland	- 0.0 - 90 cm	35
Medium lowland	- 91 cm - 180 cm	20
Lowland	- 180 cm	10

In the absence of irrigation, yields of most crops are low due to unreliable rainfall which makes it risky for the farms to invest in inputs.

Livestock component

Cows, bullocks and water-buffalo are next to crops in importance. Livestock contribute 6.5% to the gross domestic product, whereas crops contribute 36.8%. Effect of alternative cropping systems technologies on agroforestry needs to be estimated. Following change in cropping systems influences type and number of species grown on particular lands:

a. Quantity of feed and fodder both from home production and by purchase with price for each type and source of feed.

b. Labor used for growing, watering and working on plant species.

c. Straw treatment with urea in baskets, plastic bags and or stocks to test both value for storage and value as measured by performance of animals consuming the feed.

d. Relay legume or maize crop to minimize tillage for food grain and for storage to be directly or after storage.

e. Use cows for draft with seasonal breeding to avoid season of heavy work during late pregnancy and lactation.

Fishery subsystem

Ponds and haors contribute 3% to the water resources for inland fish production. Grass carp eats leaf. This has created new area for agroforestry, especially where polyculture of fish is practiced. Agroforesters need to find out the right species and grow them in abundance to support fish culture.

Homestead Production Systems

The homestead of a farmer in Bangladesh is a multipurpose production and utilization center. Approximately 70% of wood and 90% of fuelwood and bamboo come from rural homesteads. Cattle, poultry, goats, a few plants of different cucurbits, other vegetables and trees for multiple use are raised in different combinations on and around the homestead. These production activities are almost exclusively looked after by the women folk but have tremendous impact on family income and expenditure. These aspects should be carefully studied to see interaction with other components of FSR. Alternatives should be tested putting emphasis on family nutrition, small cash earning throughout the year, family fuel needs and employment of the women labor force at the family level.

Agroforestry component

Forestry occupies about 8% of the land area, and forest products make up about 5% of the total value of all agricultural products. Most forestry improvement projects in Bangladesh are concerned with production on forest reserves. However, approximately 70% of the timber and building material and 90% of the fuelwood and bamboo come from the rural homestead. Some tree species, such as mango and jackfruit are multipurpose, producing fruit and timber.The twigs and dried leaves of all trees are used as fuel for cooking. The young shoots and bark of the drumstick tree are often eaten as a vegetable, while the leaves of jackfruit trees are fed to goats and sheep. Fruit, timber and seedlings are also sources of cash income for the farm family. Just as with the livestock sub-system, the long life span of trees and their multiple uses complicate FSR model in agroforestry. Initial studies usually focus on the introduction of new fast-growing species. More recently, attention has been given to improving the productivity of trees through fertilization of micronutrient and the use of plant growth hormones, particularly in the case of mango trees, to prevent flower dropping and fruit splitting. Attention has also been given to pest control and pruning management.

As the process of land fragmentation continues, the general trend is toward an increase in the number of homesteads each year. This means that nursery facilities and nursery management techniques are also potential areas of FSR intervention. Survey information suggest that there is a difference in species composition and forestry management on landless and landed farms with larger land holdings. Shade trees are detrimental to vegetable production on the homesteads with limited land areas. This suggests the need for class specificity in approaches to agroforestry.

Village Tree Cultivation

The following studies are proposed for promoting village-tree cultivation:

i. Bench-mark survey on homestead production by homestead size and income groups.

ii. Sociological research to determine farmer and local community perception of the usefulness of trees, their views on such critical matters regarding choice of species and their willingness to cooperate with Government in management and protection of forest.

iii. Identification of high-yielding and fast-growing fuelwood species and other multipurpose crop for on farm-trials.

iv. Identification of light-demanding and shade-tolerant agricultural, horticultural, forage and medicinal plants for intercropping with tree species in planting both on government forest land and on marginal and wasteland.

v. Research on the development of multi-storied forest with multiple use species for timber fuel, fodder, food and medicine.

vi. Development of techniques for maximizing sustainable production of tree fodder and fuelwood using such techniques as branch wood, lopping, pollarding, coppicing and hedgerow management.

vii. Studies on agricultural, horticultural and forest trees crop mixtures.

Some of the on-going research information from the FSR sites are as follows:

a. Acacia plants are grown in highland of Sara and Gopalpur Soil Series in the upland condition. Information is not available about the effect of this tree plant on soil and crop growth.

b. Medium lowland remains fallow after rice harvest under rainfed conditions.

c. Homesteads have some slow growing fuel-cum-fodder plants which are not so productive.

d. Fuel is a serious problem in rural farm families and more acute with marginal, small and landless farmers of the project area.

Classification of Farming System Interactions

	Type of interaction		Example
1.	Biological Interactions between crops		
	a) Biological interactions in space	i.	Intercropping
	b) Biological interactions overtime	i.	Conflicts in planting a crop in relation to harvest or previous crop
		ii.	Carry-over of soil structure and crop residues from preceding crop
		iii.	Carry-over fertility from previous crops
		iv.	Carry-over and build-up of weed seeds and other pest populations from previous crops
2.	Biological interactions between crops and livestock	i.	Use of crops and crop residues for fodder
		ii.	Use of farm yard manure as crop nutrient source
		iii.	Use of animals for
3.	Resource competition and complementarily	i.	Conflicts in labor use between enterprises
		ii.	Cash flows from sale of one product for purchase or input for another enterprise
		iii.	Competition for irrigation water between enterprises
4.	Meeting multiple objectives of farm households	i.	Choice of multiple crops and production practices to manage risk
		ii.	Planting and storage of food crops to balance seasonal food needs

LAND USE PLANNING IN AGROFORESTRY

K. B.MALLA[1]

Introduction

The objective of land use planning is to ensure optimum utilization of each area of land to the best possible advantages of the people living in the land. Thus the concept of optimum utilization of land embraces two factors i.e. Land and the people.

Land and the people are multifaceted in nature. Therefore, land use planning demands a thorough evaluation of land. It is important to know the inherent limitations in the land evaluation process. It is difficult to undertake land use planning work for such purposes as agroforestry in the degraded forest land. Such forest land must be developed in such a way that it will continue to produce food, fodder, fuelwood and small timber for meeting the local needs. Therefore, land assessment must be carried out in a systematic manner based on sound scientific and socio-economic facts.

Land Capability Concept

Assessment of land capability is an important factor in land use planning. The capability of land should be assessed based on the following factors:

a) The specific objectives of the use of land

b) Possible land use system and development technique such as agroforestry in the degraded forest land

c) Develop the interpretation criteria relevant to the land evaluation

d) Collect all the relevant resource data including soils, climate, economy and the population

Objectives

The objectives must be clear from the beginning of land use planning. The team organized to undertake the planning work must be of 71]] nature. This will ensure interaction among personnel of various disciplines to increase efficiency in land use planning exercise and to avoid misunderstanding at the implementation stage.

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Land Use System and Techniques

Based upon the identified objectives, a set of suitable strategies needs to be developed for achieving success. For land development, it is necessary to decide which type of land use system is suitable for a particular piece of land to achieve the objectives. It is also required to consider the economic conditions and level of know-how among the local people involved in using the land under consideration.

Production techniques will also depend on the economic level of the people involved. They are also much influenced by the political power structure in the area as local people form the electorate.

Interpretation Criteria

The criteria used for land use planning are largely dependent on the specific purpose of land development.

It is important to determine a definite land use system and production technique to be adopted to a particular kind of land. The soil properties and the land characteristics need to be identified for a particular land use pattern. In the same way, limitations of the soil or land need to be defined for particular species that are going to be used.

For example, in assessing the suitability of a particular piece of land for a specific use, it is important to consider such factors as soil aeration, wind speed, soil depth, soil moisture, soil fertility, soil pH and climate.

Various alternative approaches are needed for the final land evaluation. Based on such alternatives, it is required to reach a decision as to what criteria would be adopted for example, low-yielding varieties for high profit or high-yielding varieties with low quality. This is also a basis for land evaluation in land use planning.

Collection of relevant data is required for analysis and developing classification criteria and class limits. Resource maps play an important role in the identification of a particular kind of land for the purpose of specific land use. In this regard the piece of land should be identified whether that particular lands is located on a ridge, slopes, crest, valley or cliff. They are known as land components.

Soil profile data are collected either by using soil auger or by digging a pit of 2' x 2' x 3' in size.

Criteria and class limits developed for particular species should also be adopted for the production system to be used. For example, land which is steep, sloping and stony is regarded as non-arable for mechanized farming but the same land when farmed either manually, with the help of animals or small machines can be classified as arable. Therefore, quite different criteria are evolved that are dependent on the type of land and their production systems. Land use planning criteria for soil conservation are important factors to consider. Erosion/slope is dependent on the nature of the soil type, intensity of rainfall. The grey soils developed in mud-stones are highly erodible but the red soils developed from dolomite are fairly stable, even when cultivated.

Resource Data

Resource data, such as soil maps are needed in a fairly large scale. Optimum use can be accrued from such maps. To ensure maximum benefit from such soil maps or other

resource maps, it is essential to establish a dialogue between soil scientists and other experts, such as foresters, crop scientists, agriculture economists and engineers.

These resource data are used to assess land characteristics relevant to land use planning. The methodology described here is fairly detailed for a small area of the land.

Evaluation/Assessment Procedure

This procedure describes two types of techniques involved in assessing soil or land characteristics for a particular use: (A) through ranking (B) map overlaying.

(A) Through ranking technique: This technique involves data collection on:

- Soil depth
- Soil texture
- Soil moisture regime
- Soil pH
- Soil fertility
- Site classification type
- Site capability index
- Site suitability for particular species

Rating is done by assigning numerical valyes to some of them and which are considered to be important for this purpose. The is a need for identifying the land component for knowing whether the land is located on ridge, crest, cliff, slope or flat valley. Soil profiles are describe on the basis of their root permeability depth, fertility, acidity, texture and presence of coarse material.

Soil depth is ranked on the basis of root-permeable soil depth classified as follows:

Observation	Rating
- less than 30 cm	20
- between 30-60 cm	50
- between 60-90	90
- mote than 90 cm	100

Presence of coarse material is also considered for rating the soil profile with the following considerations:

Observation	Rating
less than 30 cm (SD) with stone	10
between 30-60 cm (SD) with stone	40
between 60-90 cm (SD) with stone	80
- more than 90 cm (SD) with stone	90

SD-Soil Depth

The rating of soil texture is as under:

Observation	Rating
- Sandy soil	15
- Loamy soil	33
- Clay soil	25

In case of the compact soils, the rating is given in the following manner:

Observation	Rating
- Sandy	5
- Loamy	23
- Clay	15

The soil moisture regime is rated on the basis of presence of wetness or water which is as follows:

Observation	Rating
- Saturated for 9 months	10
- Covered with water for 6 months	30
- Wet within the soil	60
- Well drained but moist 9 months	100
- Well drained but moist 6 months	70
- Very dry for 9 months	30

Soil acidity is determined by using the pH kit and rating is done in the following way:

		Alkaline	Neutral	Acid
-	Top soil	2	4	1
-	Middle soil	2	4	1
-	Bottom soil	2	4	1

Soil fertility is rated according to the presence of organic matter in the soil profile as follows:

-	Very dark-colored top soil	100
-	Fairly dark-colored soil	80
-	Light-colored soil	60
-	Eroded soil	20

Site Classification

The site classification is done by dividing the soil depth, texture, soil moisture and soil fertility rating by 100, and multiply them and then again multiplying them to get the round figures such as:

Middle slopes

Soil depth	100
Texture	99
Well drained soil moisture	70
Soil fertility is high	100

Rating is 1.0 x 0.99 x 0.70 x 1.0 = 0.69 = 69
It is considered to be a good soil

Site Capability Index

The following site capability index has been suggested as a guide line for choosing suitable species for developing a suitable land use plan for agroforestry in a given degraded forest land:

1. Excellent CR 50 - 99
2. Moderate CR 20 - 49
3. Poor CR 6 - 19
4. Very poor CR 1 - 5

The above techniques are dependent on the field observations. These are applicable to small areas, and not suitable for large areas.

Map Overlaying Technique

The technique takes advantage of the existing resource maps prepared by different agencies for identifying suitable areas for specific uses. These data are scattered and need some efforts to collect them. If there is any gap or lacking in such resource information, it is better to prepare maps by using aerial photographs combined with observations from field visits.

The map overlaying technique is used for prioritizing areas for specific land use. Land use patterns are classified into three categories as : high, medium and low. In the same manner, soil and climatic maps are also classified into these three categories.

This technique also embraces the same techniques that are generally adopted by computerized geographical information system (GIS) for analyzing spatial data for land use planning but this technique is simple, economical and comprehensive and does not require complicated equipment that are needed for GIS analysis.

Ground survey using the conventional technique for land use planning for larger areas is expensive and time consuming. The GIS technique which uses sophisticated computer device is not suitable and practicable for doing land use planning work by field staff. Hence a map overlaying technique was introduced by the author in Nepal to identify the specific area for land use development based on certain criteria useful for the specific land use.

A Case Study

A watershed area has been considered as a planning unit for watershed planning. A watershed has its own geographic unit i.e. defined by the physical boundaries with its own drainage system, road/track, climatic and socio-economic conditions.

This study, presented as an example here, was carried out in a watershed of Dhankuita district for investigating into the interactions among the existing land use, soil types, and slope of the land of a small watershed.

Methodology

Maps of present land use, land system map, and slope map prepared using 1 :50,000 scale maps were used.

Land use map

This map was prepared by using aerial photographs followed by ground checking to depict the present land use patterns, such as forest, agriculture, grazing and others.

Cultivation classification: Terai (flat land), hill slopes and valley are the major cultivation area. Terai (flat Land) is classified into four categories based on soil moisture and dryness by months. Valley cultivation is categorized into two groups, namely sloping terraces and level terraces.

Cultivation intensities were also considered important for the classification as follows:

1. 25 to 50 percent of the area under cultivation
2. 50 to 75 percent of the area under cultivation
3. More than 75 percent of the area under cultivation

Forest classification: Four forest cover types were grouped on the basis of species prevalence, such as conifer, hardwood, mixed, and shrubs. Except shrubs, these were further classified by crown densities and species-wise as follows:

1. denotes forest with less than 10 percent crown density
2. denotes forest with 10-40 percent crown density
3. denotes forest with 40-70 percent crown density
4. denotes forest with more than 70 percent crown density

Grazing land classification: Lands used for grazing are classified as grazing land.

Other classification: The areas with snow, ice, rock, sand, gravel, urban etc. are classified as others.

Land system map

This map provides information on land forms, soil, slope, dominant soil texture, soil moisture, soil depth and soil acidity. Land units are classified on the basis of the above mentioned soil characteristics.

Land Use Development Prioritization

Factors limiting the development of specific land use are identified first so as to avoid unnecessary expenses that may go as input for land use development purpose. In watershed development, control of soil erosion is considered the main factor that needs to be identified for its proper treatment before resource development is carried out.

Identification of Critical Area in the Watershed

Maps are collected in order to pursue the map analysis of land use and land system map for the identification of critical areas that need to be handled on a priority basis.

Selection of the area depends on the level of activities that should be taken up so as to improve its condition.

Translate the values of both land use and land system on high, medium and low on the basis of slope, crown density, soil texture, soil moisture, flooding frequency, soil depth and altitude etc. These are very much dependent on classifier's observation, research and experience.

A matrix analysis is done to ascertain which area is going to be in what class. The following figure illustrates this:

Land System

Land Use	High	Medium	Low
High	M x H	H x M	H x L
Medium	M x H	M x M	M x L
Low	L x H	L x M	L x L

High	M x H, H x M,
Medium	M x M, H x L, L x H, M x L, M x H
Low	L x l, L x M x L

Watershed Condition Classification

The following land characteristics are considered important for the classification of watershed into various categories as follows:

<u>Potential low erosion</u>
slope 0-5 degree

Substantial area under vegetation, terraced cultivation and grass land;
sandy clay loam soil with more than 20 inches of soil depth;
Well drained soil.

Potential medium erosion
Slope between 5-30 degree

Large area under cultivation with medium vegetation coverage;
sandy clay soil with 10-20 inches soil depth;

Potential high erosion
slope more than 30 degree

Shallow soil; shifting cultivation and low vegetation coverage;
overgrazed pasture; less organic matter presence in the top soil.

Conclusion

The first technique described above is the most appropriate at the field level provided the land area is small. It is a simple technique but provides little information to the decision makers who would like to see them on the map and relate these with the ground realities.

The second method appears to meet objectives of utilizing the existing maps by providing a relatively simple, comprehensive, rapid and low-cost information. The usefulness of this method depends on the equality and reliability of resource maps and the good judgement of the classifier in providing the classification values, such as high, medium and low so as to identify the potential area for its development.

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AGROFORESTRY DIAGNOSIS AND DESIGN

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Given all the different ways in which trees can be grown together with crops and/or animals in agroforestry systems, it is important to decide which agroforestry practices are best for a given user group or land use situation or which technologies exert a priority on scarce research resources. The challenge of identifying research and extension priorities in a field is as complex, as enthusiastically embraced, and as initially under-funded as agroforestry was a central preoccupation of ICRAF's early program of work, resulting in the Diagnosis and Design methodology (D&D).

What is D&D

In the first instance, D&D is a family of procedures for the diagnosis of land management problems and potentials and the design of appropriate agroforestry interventions. Ultimately, D&D refers also to the body of heuristic knowledge and practice which is called upon in making the sequence of decisions taken in the course of a D&D application.

To grasp the full meaning of D&D, it is important to understand why we speak of it as a family of procedures, rather than just a single procedure. When work on the D&D methodology first started at ICRAF, there was a tendency to think of this work as leading, through repeated trial and user feedback, toward a single, optimized set of procedures. However, we soon discovered that different users had different needs and resources, and they preferred to use differently adapted forms of the same underlying logic. As a consequence of this openness to user modification and feedback, D&D has retained its essential flexibility and has evolved, like medical diagnosis and treatment, into a varied body of literature and practice (Raintree 1978a for a review of the state of the art).

The operational context in which D&D was first developed and applied was the need for a coherent, interdisciplinary, rapid appraisal methodology for use by multidisciplinary teams in formulating research plans for national agroforestry programs. This is still the most prevalent use of the D&D methodology within ICRAF's research network but the basic framework is now used for other purposes outside this network by other researchers, as well as by extensionists and rural development workers. There has been a certain tendency for each set of D&D users to think of their particular variant of the D&D approach as the D&D methodology but it is clear in a more neutral perspective that the D&D approach is broader and more powerful than any one of its user-specific variants. And this is as it should be because the D&D approach is based on a universally applicable problem-solving logic which is grounded in common sense.

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Table 1. The basic logic of agroforestry diagnosis and design

Basic Questions	Key factors to Consider
Prediagnostic stage	
WHICH LAND USE SYSTEM?	Distinctive combinations of resources, technology and land user objectives
HOW DOES THE SYSTEM WORK?	Production objectives and strategies, subsystems and components
Diagnostic stage	
HOW WELL DOES THE SYSTEM WORK?	Problems in meeting objectives, causal factors, constraints and intervention points
Design and evaluation stage	
HOW TO IMPROVE THE SYSTEM	Specifications for problem-solving or performance-enhancing interventions
Planning stage	
WHAT TO DO TO DEVELOP AND DISSEMINATE THE IMPROVED TECHNOLOGY	R&D needs, extension needs
Implementation stage	
HOW TO ADJUST THE PLAN OF ACTION TO NEW INFORMATION?	Feedback from research and extension trials, independent farmer innovations etc.

The Logic of Agroforestry Diagnosis and Design

In the medical profession, where the diagnostic approach has reached its highest development, there is a saying that diagnosis should precede treatment." It is a common experience in all professions that a clear definition of a problem is often all that is needed in order to suggest the outlines of a solution. This logic is so fundamental to problem-solving capabilities of humans as to appear, like the human capability for language, to be almost a species characteristic. As such it is expressed in many forms. When applied systematically to the diagnosis of land use problems and design of agroforestry solutions, it takes the form of the logical framework shown in table 1.

This logical framework is equally applicable to research and extension activities. If the envisaged agroforestry technologies already exist, the design can be applied directly as a guide for agroforestry interventions by extension agents and rural development workers. If the envisaged technologies have not yet been developed or are not yet sufficiently well-understood to warrant confidence in extending them to farmers, the design then serves as a basis for identifying the research gaps that need to be filled in order to develop the required technologies. What is methodologically most significant is the way in which D&D can be used to amplify the practical impact of research by relating the research objectives to specific development objectives.

Most D&D applications have been carried out within the time constraints of a "rapid appraisal exercise (Chambers and Carruthers 1981). Specific techniques have been developed to sharpen the accuracy of such time-limited applications but there is nothing within the logic of D&D to discourage longer, more thorough-going applications if time and human resources permit. Successful D&D requires intelligent and flexible use and adaptation of various diagnostic and design procedures.

Definition of "the System" for D&D Purposes

The focus of D&D is the land use system. Since different systems have different problems and require different solutions, D&D results tend to be system-specific but not site-specific. Ideally, for the best results, each distinct land use system should have its own diagnosis and design exercise. In normal practice, however, shortcuts might be taken. For the purposes of a D&D exercise, a land use system is defined as a distinctive combination of several interrelated factors: the land resources exploited by a particular technology to meet the production objectives of a particular type of land user.

This definition contrasts with other commonly used definitions of land use system in the emphasis it gives to the land user as part of the system. In a strict application of formal systems theory it is incorrect to leave the land user out of the definition of the system because a system so defined would be lacking a central control element. Any theoretically respectable formulation must recognize that land use systems are definitely organized by human purpose. In purely practical terms, if the human element is left out of one's mental picture of "the system," it becomes all too easy to overlook the specific objectives around which the system is organized. Often the key to the accurate delineation of land use systems for diagnostic and design purposes is the recognition of distinctive user groups (Rocheleau 1987a).

Table 2. Potential role of trees and shrubs in satisfying basic human needs

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FOOD

1. Human food from trees (fruits, nuts, leaves, cereal substitutes, mushrooms etc.).

2. Livestock feed from trees (moving down the trophic chain)

3. Fertilizer from trees for improving the nutritional status of associated food and feed crops through a) nitrogen fixation, b)access to greater volume of soil nutrients through deep rooting trees, c) improved availability of nutrients associated with higher CEC and organic matter levels, d) mycorrhizal associations

4. Soil and water conservation effected by runoff and erosion controlling arrangements of trees in farming systems (indirect benefits through enhanced sustainability of cropping systems).

5. Micro-climate amelioration associated with properly designed arrangements of trees (e.g. shelterbelts, dispersed shade trees) in crop and grazing lands (indirect production benefits).

WATER

1. Improvement of soil moisture retention in rainfed cropping systems ad pastures through improved soil structure and micro-climatic effects of trees)

2. Regulation of stream-flow for reduction of flood hazard and more even supply of water through reduction of runoff and improvement of interception and storage in infiltration galleries through various watershed protection practices involving trees

3. Protection of irrigation works by hedgerows of trees

4. Improvement of drainage from waterlogged or saline soils by phreatophytic trees

5. Increased biomass storage of water for animal consumption in forage and fodder trees

6. Purification of drinking water

ENERGY

1. Firewood for direct combustion

2. Pyrolytic conservation products (charcoal, oil, gas)
3. Producer gas from wood or charcoal feed stocks

4. Ethanol from fermentation of high carbohydrate fruits

5. Methanol from destructive distillation or catalytic synthesis processes using woody feed stocks

6. Oils, latex, other combustible saps and resins

7. Augmentation of wind power using tree arrangements to create venturi effects

SHELTER

1. Building material for shelter construction

2. Shade trees for humans, livestock and shade-loving crops

3. Windbreaks and shelterbelts for protection of settlements, croplands, pastures and roadways

4. Fencing (living fences, fence posts, cut brush fences etc)

RAW MATERIALS(for local industries)

1. Wood for a variety of craft purposes

2. Fiber for weaving industries

3. Fruits, nuts etc. for drying other food processing industries

4. Tannin, essential oils, medicinal ingredients etc

CASH

1. Direct cash benefits from sale of tree products

2. Indirect cash benefits from productivity increases (or input savings)

SAVINGS/INVESTMENT (as insurance against contingencies/for future goals)

1. Addition of a savings/investment enterprise to farms lacking one

2. Improvement of existing savings/investment enterprises (e..g. fodder for cattle as savings on the hoof)

SOCIAL PRODUCTION

1. Production of any of the above goods for socially motivated exchange (e.g. bride price or dowry, funeral and other ceremonial occasions, political expenses etc)

2. Increased cash for social expenses (ritual expenses, development levels, political contributions etc.

The Basic Needs Approach

Although here is nothing in the core logic that makes it obligatory, one of the most commonly employed D&D techniques is the use of a "base needs approach" as the starting point for assessing the performance of production subsystems in meeting the objectives of the land user. A "production subsystem" is defined for D&D purposes as all resources, activities and decisions involved in the production of a desired output.

This output-oriented approach to the definition of subsystems cuts across the divisions created by disciplinary or structurally oriented approaches (e.g."crop subsystem", "livestock subsystem" etc) and it has the advantage of being consistent with many useful types of input output analysis.

Using the basic needs approach, rapid entry into the diagnostically relevant features of the system is effected through the use of a locally adaptable but universally applicable checklist of "basic needs": - food, fuel, water, shelter, raw materials for local industry, cash, savings/investment, and social production. The utility of this approach in identifying potential contributions of agroforestry to the performance of basic needs subsystems is indicated in table 2.

The assumption behind this approach is that, whatever else they might do, and use systems are organized so as to satisfy these basic needs. In commercially oriented systems, the strategy of the land user is to produce enough cash to purchase what is needed. The vulnerability of this strategy is that when scarcities of basic commodities prevail cash cannot always be readily converted into the needed commodities at a reasonable price. In subsistence oriented systems, basic needs are satisfied more directly from the resources at the disposal of the land user. In any case a separate assessment should be made of the performance of the land use system in meeting each of these basic needs.

As done in D&D applications, those subsystems with performance problems then become the focus of an in-depth trouble-shooting exercise to uncover the relevant causal factors, problem-generating syndromes and key constraints. The analysis of key constraints then suggest the leverage points at which specific functional interventions are likely to have the greatest impact on system performance. In the "specifications" for appropriate technologies.

The Iterative Nature of D&D

It stands to reason that any rapid appraisal methodology used to initiate research or development activities must be followed up by continued monitoring and evaluation of the situation as it develops over the course of the project. In the D&D framework, this internal monitoring and evaluation process takes the form of a reiteration of the basic diagnostic and design process to refine the original diagnosis based on more in-depth information resulting from continuous exposure to the site and to improve the technology design in the light of new information from on-farm trials with farmers, more complex and rigidly controlled on- station experiments and eventual extension trials in a wider range of potential sites (Figure 1).

The iterative D&D process provides a basis for close feedback and complementarity between the different components of an R&D project. By adjusting the plan of action to new information, the D&D learning process becomes continuous and self-corrective, ideally, it shouldn't stop until the design is well-optimized and/or further refinements are judged not worth the additional effort. Until that point is reached, the D&D logic can be used to identify fresh opportunities for progressive refinement and adaptation of the experimental technologies to the needs of the client system. The farmer's themselves are often the best source of relevant design improvements and,in any case, the ultimate fine tuning of the technology is best left to the intended beneficiaries. (Scherr 1988a and 1988b or a systematic follow-up on farmers' adoption and modification of agroforestry technologies based on an initial D&D analysis).

Variable Scale D&D Methods

There are numerous ways of applying the basic D&D logic. Which of several variations is used depends upon the purposes and resources of the user, the geographic scale and time frame of the application, and what is already known about the area. The most important procedural variations are those that have been developed for different scales of application.

For research purposes we isolate and simplify the phenomena we are studying but in reality we are always confronted with a hierarchy of systems: the plant, the plot, the farm, the local community or ecosystem, the regional economy, the national political system, the world economic order, the biosphere etc. The hierarchy of naturel complexity can be extended further in both directions, of course, but for D&D purposes it has proved useful to develop methods for three scales of application (Table 3).

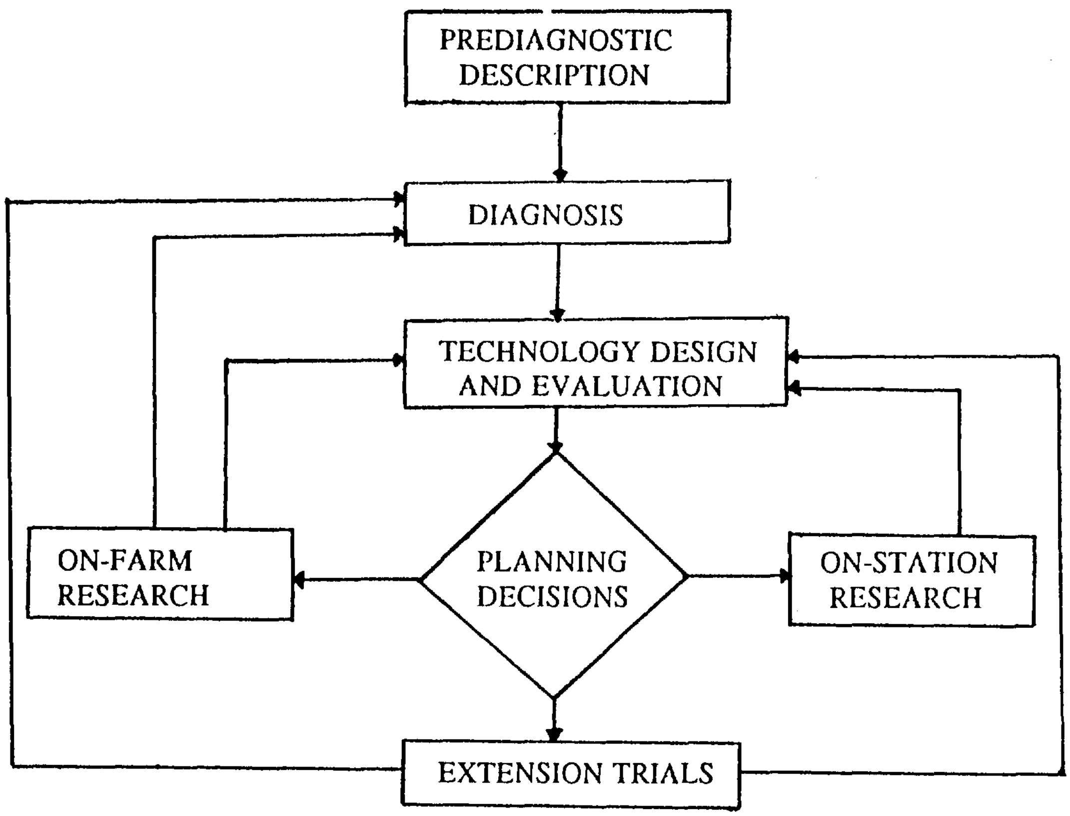

Figure 1. **Feedback between components of a research and development project using iterative D&D for monitoring and evaluation of progress toward project goals**

Micro-scale D&D : Household Level Focus

This was the first of the three sets of D&D methods to be developed (Raintree 1981, Raintree and Torres 1982). The decision to focus the initial D&D work on the elementary land management unit-in most cases the "household"--was based on the premise that this is where most of the land management decisions relevant to agroforestry are made and that it is primarily these decisions that must be affected if agroforestry is to have a significant impact on the landscape.

The basic needs approach works best at this scale of application. It provides a quick means of identifying the relevant production subsystems within the household economy and sets the stage for the problem assessment and troubleshooting analyses which follow. Problems are identified in terms of poor performance in meeting the objectives of the land user (usually "supply problems" in the form of seasonal or chronic shortages of desired goods, exorbitant labor demands for firewood or fodder collection, insufficient cash income etc). The D&D team then probes the causes of the identified problems with the farmer, using a troubleshooting logic (what is causing this problem ? why is this so? why is that so?-- and so on until the team feels it has got to the bottom of the problem). Each of the identified causal links in the etiology of the problem is a potential leverage point for a functionally appropriate agroforestry intervention (Fig. 2).

Table 3. Variable scale D&D methods

Scale	Focal system or unit
Micro	Household management unit (e.g. the family farm, household herd, or other elementary land management unit)
Meso	Local community or ecosystem (e.g. a neighborhood, village or small watershed)
Macro	Region, country, ecological zone

This approach has the advantage of clearly linking the diagnosis of technical subsystems to the objectives of the producer and of streamlining the enquiry to focus on those subsystems with problems and/or potentials for improvement, thus avoiding a lot of irrelevant information gathering. In practice, of course, the farmers' perceptions of

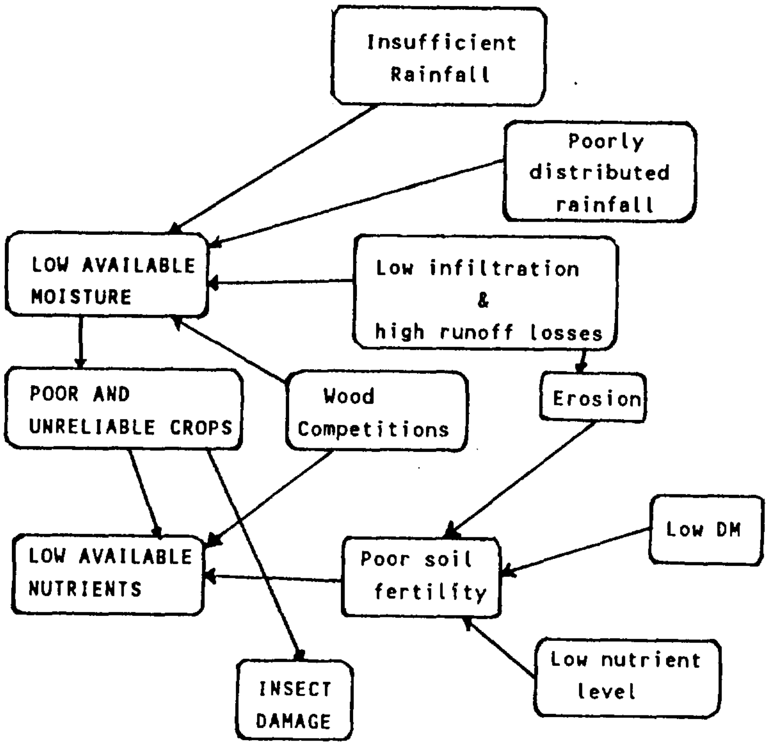

Fig.2. Causal diagram showing the etiology of a low yield syndrome in a farming system in Kenya (Source:Raintree 1982)

problems, causal factors and potential improvements are supplemented by direct field observations of the D&D survey team. Gr at emphasis is placed on open discussion with household members and neighbors to resolve contradictions and arrive at a common understanding of the situation. This then provides the basis for a lively discussion of agroforestry potentials and research needs with the farm household. Table 4 summarizes the results of a typical household level D&D analysis.

Limitations of the Household Focus

As important as the individual farm or household decision-making unit may be as a focal point for agroforestry diagnosis and design, it must also be acknowledged that the D&D procedures used at this scale may not provide complete coverage of all the diagnostically relevant factors. One very significant limitation is that the focus on smallholder farms and other landed production units contributes little to an understanding of the needs of landless rural residents who may not even possess a farm.

A second limitation is that not all of the land use problems experienced by people originate within a single farm, nor can they always be solved by action at the individual household level (e.g. the effects of runoff from farms in the upper watershed on erosion problems on farms down slope, over-grazing of the commons, land for the landless etc). Such problems may require a larger-than-farm approach both to the diagnosis of problem causes and to the design of appropriately scaled solutions. An exclusive focus on household level interventions may also forego important opportunities for "socializing" agroforestry development by taking advantage of group learning processes and other dynamics associated with larger scales of social organization.

Another important consideration is that "the household" is not always a homogenous interest group. In Africa and elsewhere, men and women within the same household may have very different production rights and responsibilities, different degrees of access to or control over credit, capital inputs, labor and decision making-and, therefore, very different responses to agroforestry opportunities. This may necessitate a special effort within a variable scale D&D approach to distinguish different types of households (e.g. women-headed households, households with a high dependency ratio, etc.) and different types of producers within a household -- each of which may require specially-designed agroforestry alternatives. Adequate attention must also be given to extra-household constraints and opportunities, e.g.land and tree tenure regulations (Raintree 1987), the use of off-farm resources and the role of community-based groups as an alternative focus for agroforestry activities (Rocheleau 1084).

For planning purposes the most obvious limitation of the household level approach is that the scale is simply not big enough for large-scale agroforestry undertakings, like national or regional agroforestry R&D programs. Something more is needed than just an aggregation of individual site results; sites must be placed within a regional environmental, economic policy and program planning context (Figure 3).

Macro-scale D&D: Region/Country/Ecozone Level

The impetus to develop methods to facilitate large-scale applications of D&D principles has sprung mainly from the development of the AFRENA program of continent-wide collaborative research networks in Africa.

For purposes of implementing large-scale research planning and training activities (Torres 1985 1986) in the AFRENA network, the D&D approach shown in figure 3 has been adapted along the lines shown in table 4.

Table 4. Stages in the AFRENA research planning process incorporating macro and micro level D&D activities (Source: Scherr 1989)

Institutional arrangements

1. Set up a multi-institutional National Agroforestry Committee which appoints a National Agroforestry Task Force to carry out planning activities

Zonal description

2. Delineate land area within target ecological zone

3. Describe general biophysical and socio-economic characteristics of target ecological zone

4. Review policy factors affecting agroforestry priorities and programs in the target zone

5. Identify and evaluate research institutions which could participate in agroforestry research, and development institutions that could collaborate in on-farm research

Land use system description

6. Identify major land use systems with the target zone

7. Characterize land use systems and identify key system constraints (complete "Work sheets for Land Use System Evaluation" and prepare "Land Use System Summaries")

Evaluation of agroforestry potentials

8. Identify candidate agroforestry technologies for each system by "matching technologies with system characteristics described in Work sheets

9. Carry out "macro D&D mission with experienced ICRAF agroforesters to propose specific technologies and research approaches (resulting in a country "Blueprint for Agroforestry Research")

Prioritization of systems and technologies for research

10. Identify priority land use systems and priority agroforestry interventions for national agroforestry research (priorities set by National Agroforestry Committee)

11. Organize zonal planning workshop to identify priority land use systems and agroforestry interventions for zonal research and possible research complementarity

Design of specific research projects

12. Prepare for "micro D&D" mission: choose research sites, collect background data for the sites and identify mission information needed for research design

13. Carry out "micro D&D" mission in representative sites of the priority land use system to verify "macro D&D" hypotheses and finalize specifications for proposed interventions ("Micro D&D Report")

14. Organize research design workshops to develop research guidelines, experimental sequence, tentative research designs, and division of labor among research institutions ("Proposal for Agroforestry Research")

5. Complete, de led research planning, including research designs, assessments, administrative planning, selection of MPTS ("Agroforestry Research Protocols")

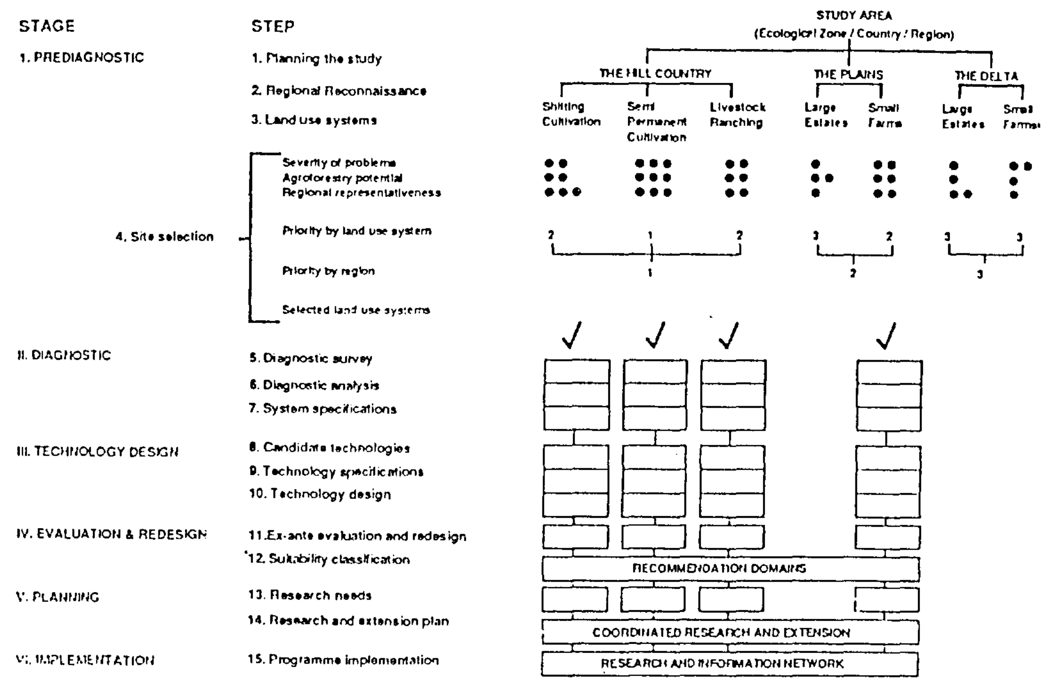

Figure 3. Framework for large-scale D&D applications (Source: Raintree 1987a, adapted from Young 1985)

The process shown in table 4 consists basically of a combination of "macro" and "micro" D&D procedures. The "macro D&D exercise, results in a comprehensive broad brush treatment of the main agroforestry-related problems and potentials in a national or ecozonal perspective. This has proven to be the right level of resolution for initial identification of national research priorities (which land use systems and which agroforestry technologies to focus on), but the formulation of more detailed research plans and prototype technology designs requires a "micro D&D" exercise in the target land use system.

Within the multi-country networks for each AFRENA ecozone, each participating country is following more or less the same procedures, and personnel have been made available to carry out the various steps and to backstop the entire effort from ICRAF headquarters. This has made it possible to give more specificity on the methodological procedures. Detailed guidelines for implementation of critical steps in the AFRENA research planning process have been produced (Scherr 1987, Scherr in press) and others are planned.

Using macro D&D's to delineate broad land use patterns and agroforestry potentials, supplemented by micro D&D's to provide site-specific "ground truth" information and give more detail to the proposed agroforestry design concepts, this combination of macro and micro D&D methods is an effective approach for the identification of priorities for large-scale technology generating research programs. It achieves the right level of resolution for most research planning purposes. By itself however, the combination of macro and micro D&D fails to address one of the most important scales of resolution for community development purposes.

Meso-scale D&D : Community/Watershed Level

Methods for this scale of diagnosis and design have been developed and applied at sites in Kenya (Rocheleau 1983a, 1983b, 1984, 1985, Rocheleau and Vonk 1983, Rocheleau and Hoek 1984, Duchhart 1988) and India (ICRAF and ICAR 1986. Rocheleau 1987a). The most distinctive elements of these methods are:

- Working with larger-than-farm scale units of landscape and ecosystem analysis and design;
- Identification of agroforestry opportunities through analysis of spatial and functional complementarities within the larger system;
- Community group process approaches to the organization of agroforestry activities.

Landscape and Ecosystem Level Method

The clearest example of the first type of analysis is given in the case study materials from ICRAF's Kathama research site in Kenya. Following an initial phase of household level D&D, a full- scale landscape planning exercise was conducted and an agroforestry plan

(Fig. 4a) for erosion control within the watershed was developed (Hoek 1983) along with detailed designs for rehabilitation and productive use of degraded lands between farms and other common access areas (Rocheleau and Hoek 1984, Rocheleau 1983). In a sample catchment area, areal photos were analyzed to identify linear features of the landscape where hedgerows of multipurpose trees might be planted (Fig. 4b). The study concluded that if all of the available linear tree planting riches (roadside/paths, farm boundaries and water courses) were planted with the appropriate trees, some 50 percent of the fuelwood and 40 percent of the fodder requirements of households living in the catchment area could be met from these plantings alone, at little or no opportunity cost to existing agricultural land use and with significant benefits to soil and water conservation in the catchment area (Rocheleau and Hoek 1984).

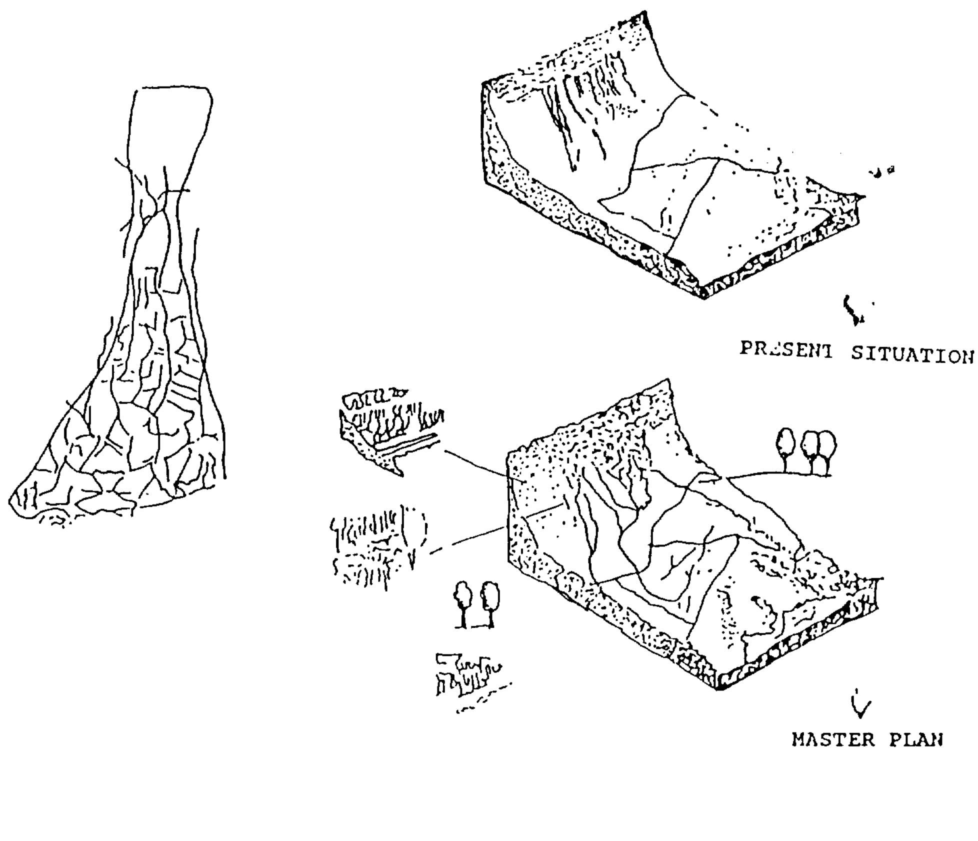

Figure 4. Proposed agroforestry interventions in the Kathama watershed, Kenya (Source : Rocheleau and Hoek 1984)

Another type of meso-scale D&D analysis examines differences between land use systems in different landscape zones within an area, to determine whether opportunities exist for complementary production. An example of this would be the production of fuelwood or fodder by low-resource farmers in the upper watershed for sale to fuel-scarce commercial farmers in the valley bottoms (Rocheleau 1983a). A variation on this type of "analysis is used to ascertain which landscape riches on farms and within the general environment are used by different land users (men, women, farmers, herders, landless etc.), for what purposes (cash cropping, subsistence cropping, grazing, gathering of natural products etc.), and under what terms of access and degree of tenure security (Rocheleau 1987a, Rocheleau 1987b). This kind of analysis of user needs in relation to landscape opportunities requires a high degree of social sensitivity as well as a good eye for landscape processes but it may hold greater promise for achieving equity goals in complex and socially stratified landscapes than simpler forms of diagnosis and design.

Small-group Process

At the other end of the spectrum of meso-scale methods are the various "group-process" approaches that seek to maximize direct local participation in agroforestry activities in the hope that the people themselves will sort out the most effective and equitable development of agroforestry potentials in the landscape. More formal, research-oriented approaches to D&D have demonstrated an unfortunate but understandable tendency to simplify the landscape and focus on a reduced set of "priority" interventions, encouragement of a more participatory and opportunistic "do-it-yourself" approach of this type may afford the best way of tailoring agroforestry designs to the complexities of local land use systems.

In some cases a group activity approach is necessitated by resource constraints at the farm level. For example, at the Kathama site in Kenya, lack of water for tree seedlings during the dry season was a severe constraint on household level agroforestry nurseries. This impediment was overcome by the formation of small-scale nurseries operated by neighborhood self-help groups and located near a year-round well or spring owned by one of the group members (Raintree and Rocheleau 1987, Rocheleau 1984).

Use of group level process may also offer certain methodological advantages. For example, in D&D activities in CARE's Agroforestry Extension Project in Siaya District in Western Kenya, group interviews have been used as a basis for project planning and have been found to be a better way of getting at certain kinds of diagnostic information than individual household interviews. By exposing conflicting interests (e.g. men's vs. women's trees) and creating a forum in which different user perspectives can be aired, group interviews can be an effective way of stimulating lively discussion of land use conflicts and agroforestry alternatives within the farmers's own peer group (Rocheleau 1984).

It is a well-known principle of extension communication that discussion of new ideas within one's own peer group is an important component of the adoption decision process. One tactic based on this principle that was successfully employed in the Siaya project was to ask the group members to prepare themselves for the next meeting with the project facilitator by discussing among themselves how, where and which trees they might best plant on their farms (Rocheleau 1984). The quality of the diagnostic information about the people's own assessment of agroforestry- related needs and potentials was found to be in some ways superior to what could be obtained from dialogues between farmers and researchers alone.

If you want to know what people really think about a new technology, what they say about it is almost always less informative than what they do. One way in which the group nursery approach used in the Kathama and Siaya projects contributed to the improvement of diagnostic information was through the monitoring of which types of trees (fruit, fodder, fuelwood, green manure, etc.) individuals actually preferred to produce and take home with them from the nurseries (Rocheleau, personal communication). This kind of behavioral information can give a better reading of felt needs than any amount of diagnostic discussion. In responding to this kind of user feedback by adjusting the type of seed provided to the nurseries, projects using this approach demonstrate one example of what is meant by iterative diagnosis and design. The CARE approach (Buck 1989) also illustrates a more participatory style of D&D which is appropriate to community-based research and agroforestry extension projects.

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GIS APPLICATION TO AGROFORESTRY

K.B.MALLA[1]

Introduction

Farmers in the developing countries are struggling to grow more food, fodder, fuel and timber for housing for themselves and for their livestock every year. Forests are being exploited to meet these needs and large chunks of forest are turning into degraded land every year. Successful management of these and other degraded lands require consideration of the need of local people and ecological conditions affecting production. In order to use the land properly, there is a need to understand the inherent characteristics of land and climatic conditions acting upon them. Therefore, collection of data on biophysical and climatic parameters is necessary for the land where agroforestry programs are to be launched. These data help prepare various thematic maps. Thematic maps are needed for the data base. Conventional techniques of information collection are expensive and time consuming.

Remote sensing techniques combined with aerial photographs and ground checking play an important role to reduce the time and cost in preparing thematic maps. These maps are the primary data sources which are further analyzed to bring out a meaningful result. Geographical Information System (GIS) is the technique through which maps are analyzed.

Geographical Information System (GIS)

Geographical Information System (GIS) technique is defined as "a computer system capable of holding and using data describing places on land surface". More specifically, "it is a system of hardware, software and procedure designed to support to capture, management, manipulation, analysis, modelling and display of spatially referenced data for solving complex planing and management problems."

In order to fulfill the objectives of developing a suitable land use plan for controlling degradation, a comprehensive geographic information system would be needed. Sources of data can be the large scale aerial photographs, various thematic maps and attribute information.

To produce thematic maps of a degraded land for developing agroforestry-land - use plan, a thorough understanding of the concept of both proper land management practices and the map generation process is required. The system used in Nepal for implementing GIS technique is as follows:

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> Determine the basic resource information required for the production of various thematic maps and statistics

> Determine the elements of classification

> Develop a set of criteria for various thematic mapping objectives

> Implementation of the criteria that use the basic resource information to generate thematic maps denoting the potential capability of land where agroforestry program is to be launched.

The classification should meet a set of criteria in the development of which various thematic maps are taken into consideration. These thematic maps include:

Soil map		Application
Land use map		*Limitation
Geology map		*productivity
Slope map		*suitability
Rainfall map	Classification Scheme (use of ERDAS)	*Land use
Temperature map		*Capability
Altitude map		estimation
District/village map		
Population map		

Construction of data structure with the basic resource information is the most suitable approach for GIS analysis. The maps and statistics are the result of a combination of various factors that are determined by the structure of the basic data and a classification scheme previously determined. The GIS involves the following steps:

- Identify factors that should be included in the exercise

- Prepare an inventory for each factor showing how it varies over the study area.

- Create composite maps by overlaying two or more thematic maps

- Analyze the composite maps to make inferences relevant to the subject such as the development of agroforestry in the degraded forest or marginal land

All the pertinent primary data should be digitized. These digitized data are analyzed to produce composite maps. These maps are the source of identifying and developing suitable land use plan. All GIS operations were performed by using ERDAS (Earth Resource Data Analysis System) a raster-based GIS and image processing software. Within the ERDAS-GIS, each pixel contains a numerical value between 0 and 255 but instead of the numerical value the conceptual value is used for preparing various thematic maps. Conceptual values are, in fact, symbolic language, such as low, moderate or high for various factors, such as soil, slope and climate etc. The GIS uses conceptual values to relate the actual GIS overlay pixel numbers generated from the rule and fact basis. ERDAS is also used for displaying the final map and preparing GIS processing.

To create various thematic maps for land use development such as agroforestry in the degraded forest land from multiple overlay, the users must specify information relating the pixel values in the conceptual values. The specific rule of application is used for performing the matrix operation. The conceptual values are instantly recorded in the ERDAS-GIS file. A legend is placed in a trailer file to facilitate interpretation of pixel values generated by GIS.

System Design and Implementation

System design starts with the determination of the requirement that will fulfill the objectives of the system. The first step prior to system development is to select the hardware and software available to facilitate implementing the system. The system environment is selected as follows:

Hardware

- Microcomputer IBM/PCAT
- Digitizer-Calcom 9100
- Tape Drive
- Tektronix color printer
- RGB color monitor
- Number 9 Graphic card for image processing
- Voltage stabilizer

Software

- DOS
- PC/ERDAS (Earth Resource Data Analysis System)

The selection of the system environment should be of low cost, easy learning and managing and simple maintenance. It should also provide sufficient system environment to support the data processing for small area.

Generally, the basic structure of a Geographic Information System is composed of four parts as follows:

- Data input
- Spatial analysis
- Data management
- Output information products

The main objectives of the system is to collect and manage information on natural resources. Therefore, an emphasis is placed on data base design and spatial data processing. The structural pattern of the system is described below:

Data input and data processing: The information sources of the whole system could consist of SPOT-image, strip aerial photographs taken on small format, various thematic maps and ground survey works.

The accuracy of digital data is directly affected by the quality of map manuscripts from digitized map. Therefore, attention must be paid as far as possible in getting the most reliable and updated maps.

Spatial analysis subsystem: A spatial data processing subsystem can be designed by taking advantage of GIS software. ERDAS software can be employed to do the overlaying, indexing, buffer generation, matrix and area calculation. The main data sources for this subsystem are various thematic maps as mentioned above.

Data base: A data base is a collection of all information related to specific application. The main purpose is to develop suitable land use plan in order to combat the degradation force depleting the land resource base. The first task is to make assessment of land use structure and an optimal use model is proposed. It is, therefore, necessary to compile and land resources data base which takes the block of land as a basic unit to collect and store information of basic attributes and situation of land use. Based on this, assessment of various resources can be carried out effectively.

Information products output: To fulfill the objectives of the system defined in the functional requirement study, various forms of information were obtained, such as thematic maps, advisory suggestions for development planning and information retrieved. The attributes retrieved from data base can be located on the various thematic maps if necessary.

Application: The Geographic Information System (GIS) in itself is only a tool; the key point is how to use it to support the resources development such as the development of degraded forest land by using agroforestry approach. Success of GIS is evaluated by its practical application.

Table I below shows how ERDAS command system is to be used for application activities. This describes the operations needed to create composite maps by combining various thematic maps mentioned before.

Table 1. ERDAS Commands

Command	Definition
Index	Create a new map by adding values of two or more existing maps on a cell by cell basis
Matrix	Analyzes two GIS files and prepares a new GIS file which contains class value that are coded to indicate how the class value from the original files coincide or overlay

The land suitability map, for example, has high value where the land is highly suitable for specific land use. Suitability is derived from the soil, rainfall, temperature and growing period by ranking and recording. The following values are used to represent suitability for specific crop, such as rice and wheat:

Soil	- No limiting factor	= High
	- Moderate limiting factor	= Moderate
	- Severe limiting factor	= Low
Rainfall	- No limiting factor	= High
	- Moderate limiting factor	= Moderate
	- Severe limiting factor	= Low
Temperature	- No limiting factor	= High
	- Moderate limiting factor	= Moderate
	- Severe limiting factor	= High

The following table shows the statistics of specific crop suitability:

Table 2. Suitability for rice

Class Name	Percentage	Hectares
High	19.3	22117
Moderate	6.9	7990
Low	73.6	84244

In the same manner Land productivity Index map can be produced to indicate how much good land is available to support increasing food production. They also provide information needed for avoiding unnecessary inputs where land productivity is inherently poor. The following table gives the area under different land productivity classes:

Table 3. Land productivity classes

Class	Hectares
Fair	30406
Poor	78565
Very poor	5381

Conclusion

Geographical Information System (GIS) is an effective tool for the development of agroforestry in the degraded forest land. The system can provide scientific basis for making integrated development plan such as agroforestry in the degraded forest land for the advantage of local people. The production of various thematic maps and reports with statistics and tables from GIS makes the work cost-effective and easier. However, there is a danger of raising the expectation s of the potential GIS users too high. Therefore, it is important to consider the limitations associated with GIS. GIS cannot work without data. Input of these data requires a lot of trained man-power, resources and time which depend on the complexity of the GIS system used. GIS cannot improve the quality of input data. The accuracy and reliability of output data depends on the quality of input data.

If there is a lack of firm financial commitment to continue it, the GIS system will not function properly. The result will be the loss of money and wastage of time. Similarly, trained man-power would be required to work with the GIS; otherwise, money and time both will go in vain.

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AGROFORESTRY FOR WATERSHED MANAGEMENT AND SOIL CONSERVATION

K.B. MALLA[1]

Introduction

Rural development basically depends on the production of food, fodder, fuelwood, fisheries etc. which are the basic needs of the local people for survival. Land and water are the life-supporting natural resources for production of these goods. In order to keep these natural resources productive for their sustainable use, it is essential to manage them scientifically. A Watershed will be an ideal planning unit for undertaking such activities.

Watershed development is generally carried out in rainfed areas where water availability is dependent on the intensity and distribution of rainfall. Therefore, the mixed type of farming system is practiced in such areas which include agriculture, forestry, rearing livestock fisheries etc.

It is estimated that 7.7 million hectares of land constituting about 40 percent of the total area of Bangladesh is under rainfed farming systems. Livelihood of 41 percent of the total population of Bangladesh depends on such farming. Therefore, sustainable development by taking watershed as planning and development unit should be the primary objective for benefit of the people.

Watershed Development : Salient Features and Constraints

Sloppy terrains and erodible soils : Disturbances in sloppy and undulating terrains will induce the erosion process in faster rates. Production capacity of the soil is also influenced by the erosion process.

High rainfall intensity and long dry season : Rainfall pattern is characterized by 3-4 months of wet season followed by 8-9 months of dry season. Concentrated rainfall during the monsoon leads to heavy erosion and runoff.

Low productivity : The low and declining productivity in these areas is primarily due to accelerated erosion causing excessive nutrient loss from the soil. Without replenishment of these nutrients, these lands are not capable of increasing productivity. As a result, more marginal land goes under cultivation.

Deforestation : Forest land is under high pressure from the people who encroach such land for food production. Therefore, forest cover is declining in alarming rate. The consequences are ecological and socio-economic imbalance.

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Population pressure and poverty : The growth rate of population is very high in Bangladesh. Population pressure is high in the watershed areas also. This has forced over-exploitation of the natural resources, especially of land and water, and has resulted in erosion, degradation and low productivity of soils.

Poverty deprives the people of adopting new technologies for improving their land condition and obtaining higher production of food, fodder and fuelwood. The result is the alarming migration younger generation from the rural areas to the cities, thus creating labor crisis in the rural farming.

Sedimentation : Sedimentation in the natural drainage system puts physical development at risk due to high maintenance cost and life expectancy.

Floods : Floods are inherent in Bangladesh ecosystem. The severity of floods is related to degradation of vegetation in the watershed areas. Therefore, integrated management of these watersheds has a vital role to play in mitigating the impact of floods.

In view of the above ecological and socio-economic realities, the rural development strategies must encompass integrated watershed development program by combining conservation measures and production systems.

Watershed Management As a Tool to Rural Development

The basic strategy of watershed management for rural development is approached through various types of programs undertaken to ensure sustainable and increased productivity. However, differences of opinion on this matter do exist among various agencies that are influenced by their organizational philosophy.

Soil conservation measures are basically structure-oriented. This objective alone is not sufficient to keep the balance of ecology and development. Therefore, it requires multiple activities through integrating conservation measures with production systems.

Using the land according to its capability is not possible for small landholders, especially where the population is high and the availability of arable land is limited. It requires development of technologies that support propagation of various crops, grasses, trees etc. capable of meeting the conservation needs and the production system of small landholders.

Issues related to programs : Programs with many activities are found difficult to plan and implement. Formulation of the ideal range of activities for watershed development needs consideration because each watershed would need a peculiar package of activities in accordance with ecological potentials and socio-economic needs.

Conservation measures : Land and water conservation measures must be planned in such a manner that these meet the needs of the proposed land use. This includes the treatment of arable lands, non-arable lands and drainage systems in an integrated way.

Production systems : A biomass-based production system should be developed on land that would include annual crops, agroforestry, pastures and grass lands.

The rearing of animals should be integrated with the primary production system on a symbiotic manner so as to avoid further depletion of the resource base. Once the primary and secondary production systems are integrated to achieve balanced biophysical watershed, the agro-industrial watershed base will evolve. This will help accommodate and provide employment to the rural people.

As agroforestry activities are concerned with the primary production systems, biomass production becomes the prime objective of agroforestry to achieve. Activities like pasture, annual crop, fodder and homestead development should be given high priority to generate tangible benefits within a given period of time for the local people of the area undertaking agroforestry activities. For this purpose the project area needs to be identified, which requires a detailed survey of the area for judicious planning and successful implementation of the watershed development plan.

Watershed management has been synonymous with soil conservation. Soil conservation concept and measures were developed to control the sedimentation and floods. Therefore, activities are oriented more toward structure-based technology and hence are expensive. Developing countries cannot afford the expenses. They find it difficult to justify undertaking the soil conservation activities alone for solving the erosion problems.

The value of permanent vegetation to control soil erosion is now widely realized. Therefore, vegetative conservation measures should be integrated as far as possible into the land use plans to serve as conservation hedges. In this regard, agroforestry comes in the forefront to play a role in watershed management. The vegetative measures can be used in stabilizing the stream banks, and controlling the gullies with a little emphasis on engineering structures.

Agroforestry As a Watershed Management and Soil Conservation Technique

This technique has attracted a lot of interest in the developing countries because of the following reasons:

> In this technique, greater reliance is placed on the vegetative measures rather than in structural engineering works. Therefore, it is a low-cost but effective soil conservation device.

- This technique is simple to understand by the villagers who can adopt and replicate if some training is provided.

- It combines both production system and conservation measures, and hence tangible benefits can be obtained by the villagers within a short time. Propagation of grasses, legumes, and shrubs would ensure the faster production of food, fodder, fuelwood and fruits. This requires location-specific survey and research for providing benefits to the local people, especially from the degraded forest land. These forest lands are not capable of producing adequate biomass and reducing the erosion process. As a result, productivity continues to decline.

- The need for people's participation in planning and implementation of soil conservation and watershed development plan cannot be over-looked. Therefore, the role of the local people who are also the beneficiaries and of the NGO's must be considered on the following line of thoughts:

  > Appropriate from of people's organizations, local institutions, cooperatives, formal and informal associations should exist and be promoted for their active participation.

  > Find ways and means of building their technical and managerial capabilities.

  > Allocate funds for sensitizing and involving them in agroforestry activities more actively.

  > Requirement of fuelwood and timber is very high in Bangladesh. It is estimated that by the end of the century, the shortage of fuelwood would be about 185 million cubic feet and the deficit of timber be 60 million cubic feet. Agroforestry program can play a vital role in replenishing the unproductive degraded forest land, homesteads and marginal lands by suitable vegetation.

Resource Inventory

In the absence of adequate inventory of resource base, it becomes difficult to improve the quality of planning, implementation and monitoring of the watershed production system. Therefore, modern techniques, such as aerial photographs, satellite remote sensing, with ground checking and GIS-map analysis technique should be employed to survey the resource base. Adequate attention should also be given so that the attempt does not end in mapping and cartography only. This deserves serious consideration.

Conclusion

In order to make agroforestry meaningful for sustainable watershed management and soil conservation, activities related the economic development and restoration of environment on the degraded forest land and marginal lands should be combined to bring the benefits to the local people. This will help reduce the poverty and prevent deterioration of the ecosystem.

There exists considerable potential for value addition and employment generation through biomass-based agro-industries. Such industries include extraction of oil from oilseeds, pulses from grain legumes, sugar mills, saw mills and timber products, a whole range of processed and preserved foods from horticulture and vegetable products. Biomass production and processing activities will stimulate the building of the rural infrastructure which is vital for integrated rural development. Thus sustained biomass production holds the key for solving the rural poverty. Therefore, deterioration of ecosystem cannot be allowed to continue further hampering the whole production system.

Restoration of the ecological base is essential for mitigating soil erosion, sedimentation, floods, and thereby for increasing the productivity. Sustained production of biomass needs emphasis for safeguarding the agro-based economic development interest, especially for rural areas.

Rural development depends on the integration of restoration of the ecosystem and climatically suited production system. Therefore, the role of agroforestry in watershed management is vital in the production of biomass stimulating the people to harness the economic benefits and in generating employment opportunities. Thus watershed management is an ideal approach for integrated rural development and conservation of production and processing systems.

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AGROFORESTRY AND SOIL CONSERVATION

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1. Introduction

Soil conservation is interpreted here in its broader sense to include both control of soil erosion and maintenance of soil fertility.

The main objective of soil conservation is maintenance of soil fertility. To achieve this objective, control of erosion and maintenance of the physical, chemical and biological conditions including nutrient status of soil are equally important.

In Bangladesh active soil erosion and land degradation are taking place in the hilly areas at an alarming rate. The extent affected area is not known and it would be required to quantify the problem of soil erosion and degradation. There exists several hilly areas in the country, which account for about 12% of the total area of Bangladesh covering about 4.3 million acres of land in the greater (former) districts of Chittagong Hill Tracts, Chittagong, Sylhet and some other locations. Soil degradation and erosion are of different forms in different parts of the country. At present, the hilly areas in general, despite low population, are not properly utilized though often put under cereals, vegetables, fruits and forests. Shifting type cultivation has ruined the soil health considerably. With a gradually expanding population in recent years, an increasing number of farmers has been moving into the hilly areas. These farmers, with no previous experience of upland cultivation, are using practices which are causing serious erosion and landslides in the steeper hills, resulting in land degradation in the lower catchment areas. In Sylhet district, massive soil erosion is being caused due to growing of pineapple. In Chittagong Hill Tracts, soil erosion is mainly caused by "jhum" cultivation.

There is neither a plan to tackle the problems of erosion on a national basis nor any department within the Government having manpower with required expertise to do it. These issues call for immediate attention of the scientists, extension agencies and policy makers.

2. What is Agroforestry

Agroforestry refers to all land use systems and practices in which trees or shrubs are grown in association with crops (agricultural crops or pastures), in a spatial arrangement or in rotation and in which there are both ecological and economic interactions between the trees and other components of the system.

An agroforestry practice is a distinctive arrangement of components (e.g. trees, crops, pastures, livestock) in space and time. There are thousands of agroforestry

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systems -- traditional and modern -- but only some 20 distinct practices are important for practical purpose. Thus agroforestry offers a wide range of choice, giving opportunities to design systems suited to a variety of physical environments and socio-economic conditions.

The various agroforestry practices are applicable to a wide range of environmental conditions. One of the greatest potentials is to help solve land use problems in areas with sloping lands i.e. hilly areas.

2.1 Agroforestry for control of soil erosion

(i) *Trends in soil conservation research and policy* : Earlier approach to soil conservation was centered around assessment of rates of soil loss. At present more attention is being given to the effects of erosion on soil properties, fertility and crop yields. In conservation strategy, there is a greater emphasis on maintaining soil cover compared to prevention of runoff. In the extension efforts, it is recognized that conservation is likely to succeed only where it is implanted through the farmers willingness.

Significant aspects of the recent trends in agroforestry are:

- Potential of agroforestry for erosion control should be considered jointly with that for maintenance of soil fertility.

- Particular attention should be given to the capacity of tree litter to maintain soil cover.

- It is important to develop agroforestry system with the potential for sustainable use of the sloping lands.

- Through its capacity to combine production systems with conservation strategies, agroforestry offers a means of securing cooperation of the farmers (Anthony Young 1989).

Soil erosion is the cause of substantial lowering of crop yields and loss of production. The effect on yield is in general greater on tropical soils than on temperate soils, and the greatest on highly weathered tropical soils. The major causes of such yield reduction are loss of organic matter and nutrients, and in dry areas, loss due to runoff and lowering of available water capacity. Hence, agroforestry practices which combine maintenance of fertility with control of soil loss are of particular interest.

(ii) *The barrier and cover approaches to erosion control* : Erosion can be controlled through checking down-the-slope flow of water and entrained soil by means of barriers to runoff (the barrier approach) and through maintenance of ground surface cover of living plants and litter (the cover approach). The cover approach helps control the impact of rain drops and provide dispersed micro-barriers to runoff. On the basis of limited available evidence, the effects of agroforestry on the causal factors of erosion appear to be as follows:

- o Rainfall erosivity is often reduced only slightly (about 10%); may sometimes increase by the presence of tree canopy.

- o The resistance of the soil to erosion, which commonly decreases continuous arability, can be sustained through the capacity of agroforestry to maintain soil organic matter.

- o Reduction in runoff and effective slope length can be achieved firstly by means of barrier hedges and secondly by combining trees with earth structures.

- o There is a considerable potential to increase soil cover by means of plant litter.

The rates of soil erosion under agroforestry and other tree-based systems have been reviewed by Weirsum (1986) and more recently by Young (1989). Agroforestry systems are assumed to be superior to other cropping systems in respect of erosion control because trees and other vegetative covers protect the soil against erosion by ways they affect erosion agent (rainfall) and the medium being eroded (soil).

2.2 Role of trees and other vegetation layers

Trees not only influence rainfall and soil independently, they also affect the level where these factors interact-- the soil surface. These three processes by which trees influence erosion may be summarized as follows (Wiersum, 1985; Young 1986(:

Trees exert a positive influence on soil detachability and infiltration capacity because sustained litter input to the soil causes higher humus content. In addition, favorable microclimate conditions under tree canopies positively influence various soil organisms that affect such soil processes as decomposition, humification and pore formation.

The litter and surface vegetation protect the soil directly against the erosion force of rain drops and surface runoff. By filtering splashed soil particles surface vegetation and litter also prevent clogging of soil pores, which decreases the infiltration rate and increases surface runoff.

Recorded erosion rates under agroforestry and other tree based systems are shown in table 1. Taking low rates of erosion as less than 2 t/ha/year, moderate rates as 2-10 t/ha/year and high rates as 10 t/ha/yr, these systems can be grouped as follows:

Low	Natural rain forest; forest fallow in shifting cultivation; multistoried tree gardens; most forest plantations (undisturbed); tree plantation crops with cover crop and/or mulch.
Moderate or high	Cropping period in shifting cultivation, forest plantation, litter reserved or burned, taungya), cultivated tree crops,clean weeded.

The data show that in the systems which have high erosion potential; the range of values is large. This indicates that management practices, rather than particular types of land use, are more important in minimizing erosion potential.

Table 1. Rates of soil erosion in tropical ecosystems

Land use systems	Erosion (t/ha/year)		
	Minimum	Medium	Maximum
Multistoried tree gardens	0.01	0.06	0.14
Natural rain forest	0.03	0.30	6.16
Shifting cultivation, fallow period	0.05	0.15	7.40
Forest plantation, undisturbed	0.02	0.58	6.20
Tree crops with cover crops or mulch	0.10	0.75	5.60
Shifting cultivation, cropping period	0.40	2.78	70.05
Taungya, cultivation period	0.63	5.23	17.37
Tree crops, clean weeded	1.20	47.60	182.90
Forest plantations, litter removed or burned	5.92	53.40	104.80

Source : Wiersum (1986)

It is clear that maintaining a surface cover of plant litter, which is possible in most agroforestry systems, is the most effective way of reducing erosion. There are several types of agroforestry practices which, with good management, have the potential to reduce erosion to acceptable levels. These include multistoried tree gardens, planted tree fallow, alley cropping, plantation crop combinations, multipurpose woodlots and reclamation forestry. In all these cases, however, what matters is not simply the presence of trees but the way in which the system is designing a device for erosion control. The major aims should be ensuring a good surface cover of plant by appropriate row alignment. Maintenance of soil ability to resist erosion is also important. Erosion control based on tree canopy is not likely to be effective, except possibly where the canopy is low and dense.

2.3 Practices for erosion control

The role of trees and shrubs in erosion control may be direct or supplementary. In direct use, the trees and shrubs are themselves the means of checking runoff and soil loss. In supplementary use, control is achieved primarily by other means (grass strips, ditch and bank structures, terraces); the trees serve to stabilize the structures and to make productive use of the land which they occupy.

The functions of the tree component in erosion control may include any of the following:

(i) to reduce water erosion by a surface litter cover.

(ii) to act as barrier to runoff by closely planted hedges coupled with the litter that accumulates against them.

(iii) to prevent decline in soil erosion resistance through maintenance of organic matter.

(iv) to strengthen and stabilize earth conservation structures where present.

(v) to reduce wind erosion by windbreaks and shelterbelts

(vi) to serve as helper to link erosion control practices with production systems.

A summary of agroforestry practices with potential for the control of soil erosion is given below (Anthony Young 1989):

(a) Rotational Practices

Improved tree fallow can check erosion during the fallow period but erosion control as a whole will depend mainly on practices during the cropping period. For taungya, a limited evidence suggests that there may be some increase in erosion during the cropping period compared to pure tree plantations.

(b) Spatial mixed practices

Plantation crop combinations and multistoried tree gardens, including home-gardens can control erosion through the provision of a dense, regularly renewed ground surface cover. In the case of multistoried gardens, such control is intrinsic to the nature of practice. For plantation crop combinations, control depends on management, specifically of a ground cover for littering.

(c) Spatial - Zoned practice

For hedgegrow intercropping (alley cropping, barrier hedgegrows) there is substantial inferential and limited experimental evidence of potential erosion control through provision of a litter cover on the cropped alleys and a barrier function through the hedgegrows. Effective erosion control will not be effective and will vary with detailed design and management practices.

(d) Silvo-pastoral practice

Erosion control on gazing land depends primarily on the basic established practices of pasture management, notably the number and frequency of livestock gazing. Silvo-pastoral methods alone is not likely to succeed but it can contribute when carried out in association with other measures for pasture management.

(e) Reclamation forestry and Watershed Management

There a.. opportunities for integrating agroforestry with the known benefits of reclamation forestry. A period of reclamation is followed by controlled productive use, retaining part of the tree cover, for continued conservation. Agroforestry can form a component, together with other major kinds of land uses in integrated watershed management.

3. Measures of Soil Conservation

Owing to the difficulty in measuring erosion rates, much of erosion control work is based on the use of predictive models. These are equations which have been calibrated by means of measurements of standardized plots, and which are then applied to field situation. These are relevant to agroforestry because of the rates of erosion, which indicate factors of significance for the planning of erosion control through agroforestry.

Three models are widely used to predict rates of soil erosion. These are:

(1) The Universal Soil Loss Equation (USLE)

(2) The Soil Loss Estimation Model for Southern Africa (SLEMSA)

(3) The Erosion-based parts of FAO Method for soil degradation assessment (FAO Model).

Besides these, there are also computerized models which combine prediction of soil erosion rates with impact. These include CRFAMS (Chemicals, Runoff and Erosion from Agricultural Management System) and EPIC (Erosion-productivity Impact Calculator) (Krisel 1980; Williams 1985; Flach 1986; Foster 1988).

The USLE predicts soil loss, 'A' as t/ha/year by the effects of six factors multiplied thus:

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

where 'R' is the rainfall factor; usually a rough approximation can be obtained by taking half of the value of mean annual rainfall in millimeters, somewhat lost). Thus a site with 2000 mm rainfall has an R factor in the region of 800-1000.

The K value for a given soil is found out by experiment such that it gives the soil loss where multiplied by R. Typical values are 0.1 for more resistant tropical soils (e.g. ferralsols with stable micro-aggregation), 0.3 for soils of intermediate nature (e.g. ferric lixisols) and 0.5 or more for highly erodible soils.

L is the slope length factor, which gives the ratio of soil loss from the length of the field for which erosion is to be predicted; the relation is approximately linear but a doubling of slope increases erosion by less than 50%.

S is the slope steepness factor, which is the ratio of soil loss from a field under consideration. In practice, LS are combined as single topographic factor. Most of the experiment data for USLE are from gently to moderately sloping plots, the quoted values for steep slopes being partly extrapolations.

C is the cover and management factor or cover factor giving the ratio of soil loss from a specified crop cover and management to that from bare fallow. In practice, C varies over almost the full range of these extremes. For example, an overgrazed pasture or an annual crop with low soil cover such as a low-yielding maize or tobacco, may have a C factor as high as 0.8 meaning that erosion is not much less than on bare soil. On the other hand, a dense cover crop or perennial crop (e.g. well-maintained tea) can have a C value of the order of 0.01, and natural rain forest as low as 0.001, meaning that erosion is one hundredth or one thousandth as fast, respectively, as on bare soil under the same climate, soil and slope.

P is the support practice factor. It is defined as the ratio of soil loss with a given conservation practice to that under crops in rows running up and down the slope. Well-maintained terraces can produce P values in the range of 0.1 to 0.05.

4. Agroforestry for Maintenance of Soil Fertility

Soil fertility is the capacity of soil to support the growth of plants on a sustained basis under given conditions of climate and other relevant properties. It is part of the wider concept of land productivity.

4.1 Effects of trees on soil

The association between trees and soil fertility is indicated by the high status of soils under natural forest, their relatively closed nutrient cycles, the soil restoring power of forest fallow in shifting cultivation and the success of reclamation forestry.

Trees maintain or improve soils by the processes as described below:

(i) addition of organic matter and nutrients to the soils

(ii) reduction in losses from the soil, leading to more closed cycling of organic matter and nutrients

(iii) improvement of soil physical conditions

(iv) improvement of soil chemical conditions

(v) affecting soil biological processes and conditions.

Some of the processes are proven and others are hypotheses that need testing emperically.

4.2 Soil organic matter

Soil organic matter plays a key role primarily in maintaining fertility under low inputs conditions. Organic matter improve soil physical properties and provide a reserve of nutrients progressively through the process of mineralization.

Herbaceous plant residues applied to the soil initially decompose rapidly, with a half life in tropical soils of less than six months. Woody residues decompose more slowly. During decomposition, there is a loss of carbon and release of nutrients. The remaining material becomes soil organic matter or humus.

The following are the approximate rates of production of above-ground biomass which, if returned to the soil, can be expected to maintain organic matter at levels acceptable for soil fertility:

Humid tropics	- 8000 kg DM/ha/year
Sub-humid tropics	- 4000 kg DM/ha/year
Semi-arid zones	- 2000 kg DM/ha/year

In agroforestry systems, the requirements to maintain soil organic matter can certainly be met if all tree biomass and crop residues are added to the soil. The rate of litter decay is influenced by its quality or relative content of sugars, nutrient elements, lignin and other polyphenols. Rates of decay determine the timing of nutrient release. It is desirable to synchronize nutrient release with plant uptake requirements. Agroforestry systems offer opportunities to manipulate this release through selection of tree species and tine of pruning.

4.3 Nutrient cycling

Nitrogen-fixing trees and shrubs, growing within practical agroforestry systems are capable of fixing about 50-100 kg N/ha/year. The nitrogen returned in litter and prunnings may be 100-300 kg N/ha/year, partly derived by recycling of fertilizer nitrogen.

The second major role of trees is to improve the efficiency of nutrient cycling. Mechanisms through which this occurs are : uptake from lower soil horizons, reduction in leaching loss by tree root system, balanced nutrient supply and improvement in the ratio of available and fixed minerals. For a tree leaf biomass production of 4000 kg DM/ha/year, the potential nutrient return in litter as kg/ha/year is in the range of 80-120 for nitrogen, 8-12 for phosphorus, 40-120 for potassium and 20-60 for calcium. These amounts are substantial in relation to the nutrient requirements of crops (Anthony Young 1989).

4.4 Maintenance of soil properties and others

There is substantial evidence that trees in agrofo:estry systems can help maintain soil physical properties, a major element in soil fertility. The base content of tree litter can help check acidification. It is unlikely to be of sufficient 'magnitude appreciably to moderate the acidity of strongly acid soils, other than in the systems which make use of tree biomass accumulated over many years. Afforestation has been successfully employed as a means of reclaiming saline and alkaline soils.

4.5 The role of roots

There has been increasing recognition to the importance of root system as a component of primary production. Root biomass of trees is typically 20-30% of total plant biomass (or 25-43% of above-ground biomass). However, net primary production of roots is substantially more than standing biomass, owing to the turn-over of fine roots. Roots form an appreciable store of nutrients, and since then, they are almost invariably returned to the soil, constituting a substantial element in nutrient cycling. Tree root system, together with its associated mycorrhiza, improves the efficiency of nutrient cycling, which is defined as the ratio of nutrient uptake by plant and losses by leaching and erosion. They also contribute to soil physical properties.

5. Trees and Shrubs for Soil Amelioration

The properties that constitute a good soil are not well established. However the following properties are believed to contribute to formation of a good soil:

- o high nitrogen fixation
- o high biomass production
- o a dense network of fine roots or associated mycorrhizae
- o some deep roots
- o high, balanced nutrient content in the foliage
- o appreciable nutrient content in the roots
- o either rapid litter decay, where nutrient release is desired or a moderate rate of litter decay for protection against erosion
- o absence of toxic substance in foliage and root exudates
- o for reclamation or restoration, a capacity to grow on poor soils.

So far 55 tree and shrub species belonging to 32 genera have been identified to have potential for maintaining or improving soil fertility, (Anthony Young 1989). Of these, the species worth mentioning are : *Acacia albida, Acacia tortilis, Calliandra calothyrsus, Casurina equisitifolia, Erythrina paeppigiana, Gliricidia sepium, Inga jinicuil, Leucaena leucephala, Prosopis cineraria,* and *Sesbania sesban.*

5.1 Inorganic versus organic fertilizers

Application of inorganic or chemical fertilizers on depleted lands is one of the quickest means of restoring or maintaining soil productivity. It is difficult to use this approach in the case of marginal uplands. First, there is a need to replace not only the nutrients but also the soil lost through erosion. Inorganic fertilizers can add nutrients but cannot contribute to soil formation, unlike fallow vegetation, for example, which can accumulate organic matter from litter by as much as 5 to 17 tons per hectare per year (Anthony Young 1989). Second, the high cost of chemical fertilizers, relative to the farmers' meager income, is prohibitive.

Since most upland farmers have little or no cash income, this type of input is out of reach for most of them. For this reason the greatest hope for regaining or maintaining the production capacity rests upon low-cost biological approaches, such as the use of forest fallow or introduction of N-fixing trees. Agroforestry, as a production system, can combine nutrient and soil-conserving trees and soil-forming as well as soil-improving perennials with food crops, and therefore, possesses the potential for achieving the desired sustainability in managed areas of the humid tropics.

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MULTIPURPOSE TREES AND SHRUBS (MPTS) IN AGROFORESTRY

M. K. ALAM[1]

Introduction

Trees are important component of agroforestry systems and technologies both from ecological and economic points of view. As dominant overstored plants, trees play a key role in both productivity and sustainability of agroforestry systems.

The present and future demands for tree products, especially for timber, fuelwood, fodder and food at the family level are considered dominant criteria for selecting trees in agroforestry activities.

The multiplicity of demands and priorities is best met by multipurpose tree species. In agroforestry, a prominent role has been assinged to multipurpose trees and shrubs (MPTS). Their role is indeed so prominent that MPTS and agroforestry may sometimes be used, mistakenly, as two terms for the same subject (von Carlowitz 1989).

Agroforestry, by definition, is a multidisciplinary and multicomponent approach. Contrary to other components, like crops and animals, which are fewer in number of species and usually well researched, the number of potentially useful multipurpose tree species is vast, and most of them are little-known. Therefore, much emphasis is given in MPTS in agroforestry.

Definition of MPTS

Many authors have given many definitions of MPTS. Burley and von Carlowitz (1984) reviewed many definitions and gave a synthesized definition as "multipurpose trees and shrubs are those which are debiberately grown or kept and managed for preferably more than one intended use, usually economically and/or ecologically motivated major products and/or services in any multipurpose land use systems, especially agroforestry systems."

Forestry/ Fuelwood Research Development Project (1992) defined precisely "multipurpose tree species" to mean "tree species that are grown to provide more than one significant crops or functions on the farm. On small farms, this can often mean, for instance, that the farmer uses both wood and leaves from the same tree". Tree species can be multipurpose in two ways: firstly, a single tree can yield more than one crops, for example, farmers in our country grow kanthal (*Artocarpus heterophyllus*) that provides food, fodder and timber. Secondly, trees of the same species, when managed

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differently,can yield different crops, for example, in the Philippines, ipil-ipil (Leucaena leucocephala) is managed such that some trees will yield principally wood and others principally fodder or leaf meal.

Why Grow MPTS

Reducing risk of total crop failure : Growing multipurpose trees can reduce the risk of total crop failure. For example, if farmers usually grow ipil-ipil for animal fodder but the leaves of trees are eaten by pests; they still have wood that can be used for fuel or sold for fuel, pulp or light construction material. Having a variety of plants on a farm, as in agroforestry systems can also reduce the risk of total crop failure. Intercropping several types of plants provides a type of "insurance": if the yield of one crop is reduced by pest damage, the farmer can make up for it by the harvest of another crop. Also, growing a variety of species makes the farm less vulnerable to any one pest.

Income generation and distribution : Agroforestry practices can increase farmers' annual income. Some increases in revenue come from harvesting different tree crops in different seasons. For example we get fruit, fodder from kanthal in different seasons, and ultimately we get timber.

Production and Services of MPTS

Dozens of different products, services and benefits obtainable from woody perennials have been identified and listed by various scientists and practioners. In the early days of agroforestry when trees and shrubs were discovered, or rather rediscovered, as useful components of land use systems, it was believed that the longer the list of uses, the more convincing would be the value and usefulness of trees and shrubs. In principle, this opinion still holds true but it requires some interpretation, qualification and systematization. Benefits obtainable from trees and shrubs can be divided into service and production uses. From a systems point of view and its economic performance, a further distinction can be made between those services that directly promote agricultural production, for example, N-fixation of leguminous tree species and mulch, and others that indirectly influence production, for example, soil conservation, windbreaks, live fences and shade. Service uses may help decrease inputs.

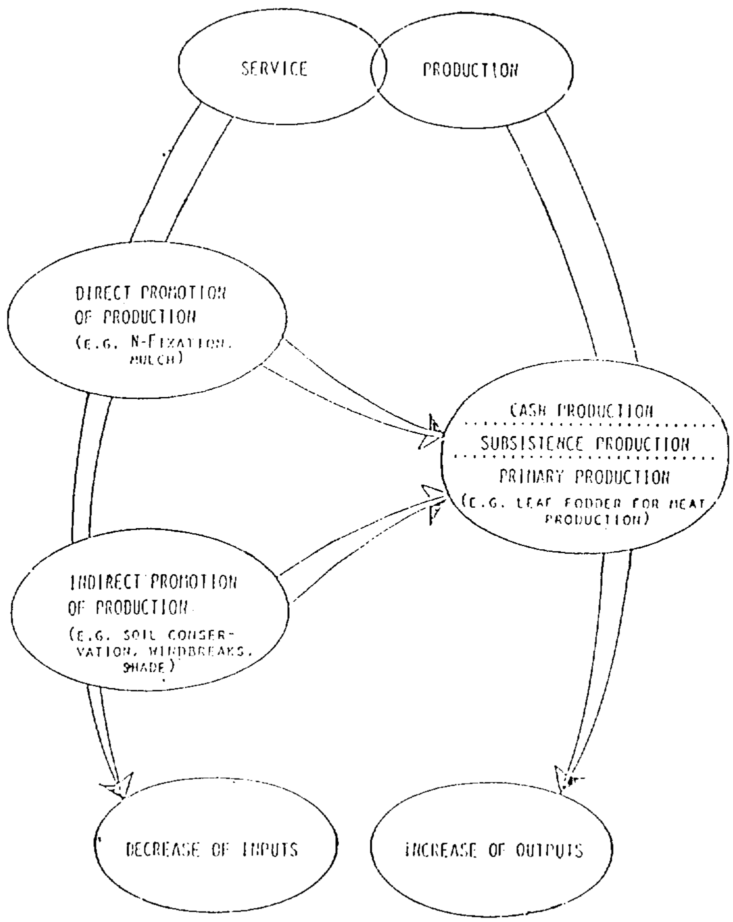

Fig. 1. Production and services of MPTS

Production uses can be subdivided into food, fodder, wood and general utilities (e.g. medicines, fibers, cosmetics, thatches etc.). While service uses decrease inputs, production uses of trees and shrubs increase outputs of a farming system (Fig.1).

Benefits from trees and shrubs that are not mentioned so far may be grouped as amenities. Ornamentation of the environments, provision of shade for humans and house roofs and use of trees as traditional meeting places are examples of this type of uses of trees.

Considerations for Choice of MPTS

The process which leads to the final decision of what species to choose is divided into the following basic stages (von Carlowitz 1989):

Diagnostic Stage:

- Inventory, assessment and analysis of prevailing land use situations, characteristics and components;

- Identification and prioritization of land use problems;

- Determination of the point of intervention.

Design Stage:

- Decision on the type of agroforestry technology to effect the intervention;

- Indentification of MPTS associated with the technology and its intended rôle and function.

Technical Stage:

MPT specification related to the expected functions and outputs of the technology they are associated with.

Bearing in mind that the objective of this paper is to highlight MPTS, only the diagnosis, design and technical stages have been mentioned briefly. That is not to say that these are of minor importance. To the contrary, without information generated in its cause, the subsequent stages would not be possible or at least remain incomplete.

Once the priority land use problems have been identified, agroforestry technologies that have the capability to overcome successfully or ease the cause and effects of these problems, are chosen. The problem-solving effectiveness and efficiency of a chosen technology depends on:

- choosing the right place for the technology in the default land use system;

- the appropriate arrangement of the components, mainly MPTS, within the technology;

- the adequate management of the technology and its components; and

- on the capability of the MPTS to provide the outputs and services expected as part of the function of the technology, and to respond to the management that is characteristic of the technology.

The actual selection of species for technologies chosen for their capability of solving or easing identified land use constraints, has to be based on the following criteria (Fig.2):

- Biophysical conditions (climate and soils) at the site of the intended tree that has to be matched with species-specific environmental requirements and tolerances.

- technology-specific tree characteristics (ideotype); and

- positive response of candidate species to management and tree manipulation required as part of the technology concept and function.

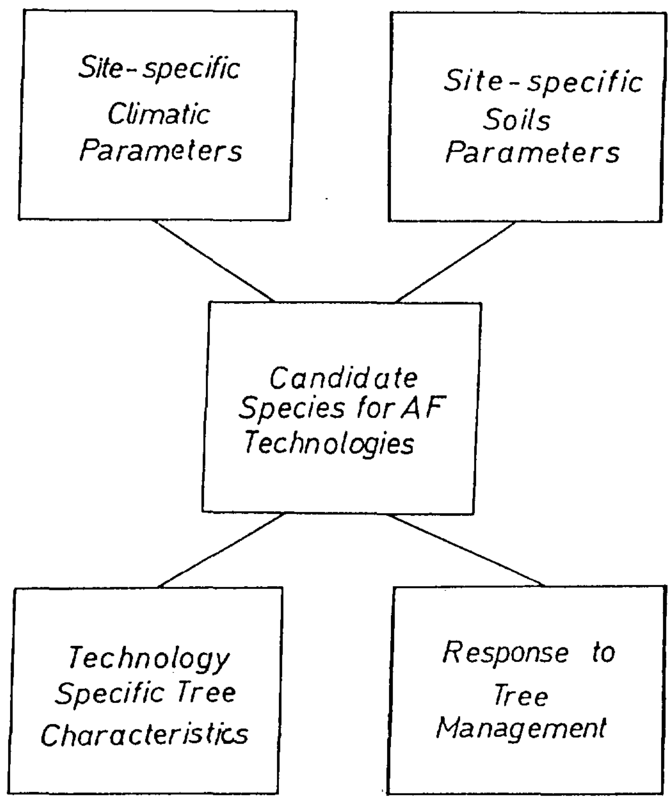

Fig.2. Criteria for selection of MPTS

As far as candidate species for certain technologies are concerned, their selection is a process of matching of site with tree characteristics.

Ideotypes and tree management are briefly discussed in the following sections.

Ideotype

For a particular agroforestry technology, different characteristic features of tree species should be considered for a compatiable and permanent combination. Desired intervention, functions of the system, site-configuration, farmers' choice determine the "ideotype" of a tree which should be considered in selecting MPTS.

"Ideotype" means a form denoting an idea; an "ideotype" tree is a plant model designed to yield products of greater quality and quantity than a conventional cultivar or wild plant (Dickmann 1985 cited in Raintree and Taylor 1992). Ideotype includes stem form, crown shape, root system, deciduousness and response to management.

Tree management

To meet the multiplicity of demands, such as for fuel, fooder, poles etc. from a very limited species and individuals in a small unit of land, MPTS with multiple management attributes need to be considered. Cannell (1983) stated that "multipurpose" might mean "multimanagement." Trees in agroforestry system are almost bound to demand or benefit from individual management. Because their persistence, size and dominance, various products may be harvested from them over many years. Cannell (1983) gives sound idea about the management of individual trees for different purposes and also tree management in crop mixtures. Various pruning practices, such as bending, coppicing, lopping, pollarding, bushing, basal branch pruning and selective branch pruning may be useful. These can be practiced to supply the sustained yield of fuel and fodder with limited effort and minimum investment.

Pruning of any sort can alter tree shape, total dry matter production per tree and dry matter distribution within the tree. High pollarding will produce trees with a greater potential for wood production. Pruning of basal branches improves timber quality and provides fuel much periodically.

Once the diagnostic stage has exposed the problems and the design phase identified both the type of intervention in terms of technologies, site-matching MPTS with desired ideotype need to be selected. Forestry/Fuelwood Research Development Project (1992) has developed a package of MPTS for small farms in Asia. Alam and Mohiuddin (1992) published a list of 53 potential MPTS from Bangladesh along with ecological notes, propagation methods, management practices and wood properties.

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TREE LEAVES AS GREEN FODDER FOR LIVESTOCK IN BANGLADESH

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T. N. Nahar[2]

Introduction

The population density in Bangladesh is 624.62 per sq. km, and that of ruminants including sheep and goats is 252.09 per sq. km (BBS 1980). Because of high demand for human food, forage crops receive less attention, and almost all land areas are utilized for agricultural crops, particularly cereals. In most areas of the country, cereal straw and their by-products, which are very poor in protein, constitute the principal feed for livestock. Trees, therefore, deserve due attention for production of green nutritious fodder for livestock under silvicultural practices under Bangladesh conditions, especially in areas where conventional agriculture may not be possible or desirable.

This paper will report the results of studies conducted on the performance of 7 tree leaves based on composition, nutritive value, feed efficiency and weight gain of small ruminants (goat) under confinement.

Methodology

The study was conducted at the Animal Research Station, Pachutia (ARSP) of Animal Production Research Division of Bangladesh Livestock Research Institute, Savar, Dhaka. Samples of seven tree leaves and feces of animals were analyzed by AOAC (1975) method for dry matter in the leaves and components in the animal feces. NDF and ADF were determined following Goering and van-soet 1970. Digestible energy (DE) and metabolizable energy (ME) were calculated according to FAO (1981). Total daily feed intake and feces were recorded.

Fattening experiment was continued for five months. A concentrate was prepared by mixing wheat bran, mustard oil-cake and sesame oil-cake in the ratio of 50:25:25. Vitamin-mineral premix was added to the mixture at the rate of 0.1%. The concentrate was fed at the rate of 2% of the body weight of goats under study. 28 castrated goats were used as small ruminants taking 4 animals for each kind of tree leave.

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Performance of Tree Leaves

Chemical composition:

Dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF), nitrogen-free extract (NFE), ether extract (EE), ash, neutral detergent fiber (NDF) and acid detergent fiber (ADF) of tree leaves are presented in table 1. DM and OM of each leaf were found to vary. The highest amount of DM was available in mango, whereas the highest OM was found in sal leaves.

The highest CP was found in ipil-ipil, followed by mander and kishnachura. CF, NFE (carbohydrate) and EE (crude fat) were found to vary across leaves. Mander contained the highest amount of CF, whereas the highest amount of NFE was found in guava, and the highest EE was available in kishnachura. Ash content is the indicator of the presence of minerals. The mander leaves contained 17.29% of ash according to the analysis.

Natural detergent fiber (NDF) and acid detergent fiber (ADF) are the groups of complex carbohydrates containing hemi-cellulose, cellulose and lignin. Lignin is undigestible. Mander leaves contained the highest amount of DNF, whereas guava leaves were found to contain the highest of ADF.

Dry Matter Intake and Palatability

Dry matter intake (DMI) of jackfruit leaves was found to be the highest in this study followed by ipil-ipil (Table 2). The highest DMI of jackfruit leaves may be due to higher palatability, whereas lower intake in other leaves may be due to some unpalatable alkaloids present in the leaves.

Digestible Nutrients and Availability of Energy

Digestible crude protein/digestible crude fiber (DCF), digestible nitrogen-free extract (DNFE), digestible ether extract (DEE), total digestible nutrients (TDN), digestible energy (DF) and metabolized energy (ME) of the leaves under study are presented in table 3.

A balanced ration supplying 5-6 percent DCP is considered quite satisfactory for the small ruminants (Pathak and Kamara 1989). The mander, ipil-ipil and krishnachura leaves were found have the highest DCF for their leguminous character. However, the highest DCF was found in mander, sal, mango, ipil-ipil and krishnachura leaves, whereas the highest DANEF was observed in jackfruit, krishnachura, sal and ipil-ipil leaves.

The TDN value is the most important measure for the nutrition of animals. TDN value was found to be the highest in ipil-ipil and mander leaves compared to other 5 types of tree leaves. The lowest TDN was found in guava leaves.

Table 1. Mean ± SE of different tree leaves composition

Name of tree	AS basis (%)								
	DM	OM	CP	CF	NFE	EE	Ash	NDF	ADF
Mander (Erythrina variegata)	19.57^{g} ±0.85	82.71^{f} ±0.92	20.46^{b} ±0.20	36.06^{a} ±0.14	23.66^{f} ±0.66	2.53d^{e} ±0.22	17.29^{a} ±0.69	51.90^{a} ±0.60	30.9b^{c} ±1.53
Sal tree (Shorea robusta)	39.39^{d} ±0.28	95.47^{a} ±0.28	8.11^{g} ±1.07	30.64^{ab} ±0.25	53.69^{bcd} ±0.75	2.53^{e} ±0.11	4.53^{f} ±0.28	49.9^{ab} ±0.82	37.9^{ab} ±0.74
Krishnachura (Dolonix regia)	43.88^{b} ±0.13	94.15^{ab} ±0.05	14.4^{bc} ±0.16	15.96^{e} ±0.25	57.46^{ab} ±0.60	6.25^{a} ±0.15	5.85^{ef} ±0.12	22.9^{f} ±1.18	21.30^{e} ±1.20
Jack fruit (Artocarpus heterophyllus)	31.20^{e} ±0.21	88.0d^{ef} ±0.35	11.22^{e} ±0.21	20.48^{cd} ±0.19	53.40^{cd} ±0.84	2.90d^{ef} ±0.22	12.0^{b} ±0.60	28.4^{ef} ±0.63	23.8^{cde} ±1.08
Ipil-Ipil (Leucaena leucocephala)	24.48^{f} ±0.41	92.46^{cd} ±0.10	30.62^{a} ±0.33	18.28^{d} ±0.13	38.77^{ef} ±0.46	4.79^{b} ±0.15	7.53^{cd} ±0.08	31.9^{de} ±0.5	26.2^{c} ±0.51
Mango (Mangifera indica)	47.02^{a} ±1.22	91.52^{de} ±0.20	8.84^{fg} ±0.33	27.46^{b} ±0.30	53.04^{d} ±0.77	1.96^{f} ±0.12	8.48^{c} ±0.16	45.02^{bc} ±0.35	32.8^{b} ±0.51
Guava (Psidium guajava)	40.37^{cd} ±1.37	93.21^{bc} ±0.09	11.57^{de} ±0.19	16.8^{de} ±0.13	61.66^{a} ±0.04	3.18^{bc} ±0.09	6.79^{de} ±0.11	38.6^{c} ±0.50	38.70^{a} ±0.58

P value <0.01

Table 2: Mean ± SE of bodysize, DM intake of goats feeding on different tree leaves

Parameter	Mander	Sal tree	Krishnachura	Jack fruit	Ipil-Ipil	Mango	Guava
Average body weight (kg)	16.30^{a} ±0.20	15.80^{a} ±0.18	16.10^{a} ±0.14	16.20^{a} ±0.36	16.20^{a} ±0.26	16.30^{a} ±0.37	16.10^{a} ±0.29
Average metabolic body size (W0.75) kg	8.13^{a} ±0.08	7.90^{a} ±0.07	8.05^{a} ±0.05	8.06^{a} ±0.14	8.07^{a} ±0.10	8.11^{a} ±0.14	8.04^{a} ±0.11
Daily total DM intake (g/goat/day)	283.20^{c} ±3.25	258.51^{d} ±5,51	240.79^{de} ±3.73	424.52^{a} ±6.14	303.33^{b} ±1.80	234.51^{e} ±11.21	170.58^{d} ±5.79
Daily DM intake as percentage of body wt.	1.75^{bc} ±0.01	1.67^{c} ±0.02	1.50^{d} ±0.02	2.63^{a} ±0.07	1.87^{b} ±0.02	1.45^{d} ±0.06	1.06^{e} ±0.05
Daily DE (W0.75) kg	34.87^{c} ±0.09	33.34^{c} ±0.24	29.93^{d} ±0.48	52.74^{a} ±1.15	37.58^{b} ±0.39	28.93^{d} ±1.10	21.23^{a} ±0.95

p value <0.01

Table 3. Mean ± SE of digestible nutrients in tree leaves

Name of tree	CP	CF	NFF	EE	TDN	Total DE (Mcal/Kg)	Total ME (Mcal/Kg)
Mander (Erythrina variegata)	18.92^{b} ±0.12	34.24^{a} ±0.15	17.68^{c} ±0.47	1.76^{c} ±0.06	74.81^{a} ±0.88	3.50^{a} ±0.04	2.80^{a} ±0.03
Sal tree (Shorea robusta)	4.21^{d} ±0.25	25.25^{b} ±0.22	37.00^{b} ±0.84	1.01^{d} ±0.08	69.73^{b} ±1.32	2.98^{b} ±0..06	2.55^{b} ±0.05
Krishnachura Dolonix regia)	7.58^{c} ±0.18	10.89^{e} ±0.13	40.03^{a} ±0.44	4.13^{a} ±0.06	67.78^{b} ±0.86	2.90^{b} ±0.02	2.51^{b} ±0.02
Jack fruit (Artocarpus heterophyllus)	6.92^{c} ±0.29	10.33^{e} ±0.67	40.02^{a} ±0.89	0.69^{e} ±0.15	58.81^{c} ±2.17	2.54^{c} ±0.10	2.20^{c} ±0.08
Ipil-Ipil (Leucaena leucocephala)	26.25^{a} ±0.20	13.88^{d} ±0.20	28.07^{d} ±0.50	3.58^{b} ±0.06	76.27^{a} ±1.02	3.60^{a} ±0.04	2.93^{a} ±0.04
Mango (Mangifera indica)	2.90^{e} ±0.28	18.91^{c} ±0.39	31.95^{c} ±0.97	1.03^{d} ±0.05	56.07^{c} ±1.74	2.38^{c} ±0.08	2.04^{c} ±0.06
Guava (Psidium guajava)	3.78^{d} ±0.46	8.33^{f} ±0.51	35.53^{b} ±1.56	1.06^{d} ±0.13	50.02^{d} ±2.80	2.12^{d} ±0.12	1.84^{d} ±0.10

p value <0.01

DE and ME were the highest in ipil-ipil and mander leaves and significantly lower in guava leaves. For maintenance and low activity, a doe weighing 20 kg needs in her early poregnancy 1.47 Mcal DF (NRC 1981), whereas a goat starter may have 2.5 to 2.9 Mcal ME for kids (Pathak and Kamara 1989).

Feed Efficiency and Weight Gain

The feed efficiency is the ratio of output per unit input (Spedding 1975). With reference to small ruminant, the products are meat, milk, fiber and leather. Considering all the leaves, there was a better response for ipil-ipil leaves per unit input, followed by jackfruit leaves (Table 4). Goats fed with guava leaves were found to lose weight. All animals gained in weight with the all the leaves fed, except guava.

Table 4: Feed efficiency and live weight change of experimental goats

Tree leaves	Feed efficiency (feed/gain)	Weight gain Per day(g)
Mander (Erythrina variegata)	10.22[f]	33.30[c] ±0.38
Sal (Shorea robusta)	12.26d[c]	26.90[d] ±0.34
Krishnachura (Dolonix regia)	17.10[c]	12.10[e] ±0.95
Jack fruit (Artocarpus heterophyllus)	12.29[d]	43.90[b] ±0.66
Ipil-Ipil (Leucaena leucocephala)	8.71[g]	52.80[a] ±1.49
Mango (Mangifera indica)	38.25[b]	6.40[f] ±0.38
Guava (Psidium guajava)	54.20[a]	-3.90[g] ±0.39

p value <0.01.

It can be concluded that ipil-ipil is better than any other leaves; jackfruit leaves can be considered second in order of merit; mander is in the third position and sal leaves can be considered a good livestock feed in the forest area. With proper management and care tree leaves, except those of guava can be used as feed resource for small ruminants.

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NON-WOOD PLANTS IN AGROFORESTRY

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1. Introduction

In agroforestry, sustainable utilization of environmental resources may be as important as absolute yield (Vose 1981). Optimum utilization of light, nutrients and water in any agroforestry system should be considered as prime objective since these are the important environmental determinants of plant growth and development. The selection of appropriate agroforestry components for a particular area is reasonably logical to achieve the goal of agroforestry. Generally agricultural annuals and woody perennial (trees, in particular of different values) are important components of agroforestry with or without association of animals.

In Bangladesh the selection of agroforestry components for a particular area has been carried out mostly on the basis of socio-economic conditions. In this circumstance inappropriate components in relation to environmental variables may induce complete or partial failure of the system. Thus the selection of agroforestry components should be in relation to their response to environmental variables of a particular area in association with socio-economic aspects. Since in agroforestry both annuals and woody perennial are grown under similar land management system the knowledge of response of component species to environmental resources significantly provides a basis for the selection of complementary components. On the other hand, component species may compete for resources resulting in detrimental effect on the growth and development of both components.

Non-wood plants refer to a group of plants other than those that yield timber and fuelwood. The role of non-wood plants in agroforestry plantation yet to be investigated. However, a number of non-wood plants have been cultivated particularly in homestead areas in association with other agroforestry components according to the rural needs. Besides, a number of naturally grown non-wood plants have also been observed in the forest areas. Generally, bamboo, cane, pati-pata and plants of medicinal value are considered important non-wood plants in Bangladesh because of their significant economic values. Although these plants have significant contribution in the alleviation of rural poverty in the various way the suitability of these plants as agroforestry component yet to be identified. Pattern of their growth, morphology and physiology in relation to environmental variables under various combination with other components of agroforestry needs to be investigated. However, propagation and cultivation of some non-wood plants have been carried out under the research program of Bangladesh Forest Research Institute. Knowledge of propagation, cultivation and management of non-wood plants enable to provide the basis of role of non-wood plants in agroforestry.

2. List of Important Non-Wood Plants

2.1. BAMBOO

There are two groups of bamboo viz. Hill-grown and village-grown. Most of the hill-grown bamboos are naturally regenerated. Village-grown bamboos are mostly cultivated.

2.1.1. Hill-grown bamboo: *Melocanna baccifera (Muli)*
Bambusa tulda (Mitinga)
Dendrocalamus longispathus (Ora)
Oxytenanthera nigrociliata (Kali)
Neohouzeaua dullooa (Dalloo)
Melocalamus compactiflorus (Lata)
Dendrocalamus hamiltonii (Pecha)

2.1.2. Village-grown bamboo: *Bambusa balcooa (Barak, Buru, Thali barua, Shil buru)*
B. vulgaris (Bariala, Baijja, Jai)
B. longispiculata (Mirthinga, Mahal)
B. polymorpha (Farua, Barma bansh)
B. arundinacea (Ketua, Kata)
Dendrocalamus giganteus (Bhudum)
D. strictus (Lati bansh)

2.2. CANE

There are a number of cane species available both in the village groves and hilly areas. With a few exceptions, most of the available clumps distributed in different parts of the country are naturally regenerated.

Calamus guruba (Jali, Jai bet)
C. tenuis (Shundi, Bandari bet)
C. letifolius (Budum, Korak bet)
C. viminalis (Bara, Karkaira, Kerak bet)
C. longisetus (Udam bet)
Daemonorops jenkinsianus (Golla bet)

2.3. PATI-PATA

Pati-pata generally grown in the marshy places, particularly in the village groves. Most of the clumps are cultivated. Botanical name of the available species in our country is Schumannianthus dichotoma.

2.4. MEDICINAL PLANTS

Large number of medicinal plants available in our country grown both in the village groves and hilly areas. These are belongs to trees, shrubs and herbs. A significant number of trees and shrubs are generally cultivated mostly in the village areas. Most of the medicinal herbs are wild both in the hilly areas and village groves.

2.4.1. Tree

Terminalia arjuna (Arjun), *T. bellirica* (Bahera) *T. chebula* (Harithaki) *Acacia catechu* (Khair), *Aegle marmelos* (Bel), *Adenanthera pavonina* (Rakta kambal), *Moringa oleifera* (Shajina)

2.4.2. Shrubs

Calotropis gigantea (Akanda), *Abroma augusta* (Ulatkambal), *Datura metel* (Kalodutura), *Ocimum sanctum* (Tulshi), *Adhatoda vasica* (Bashak), *Lawsonia alba* (Mendi) *Rauwolfia serpentina* (Sharpaganda), *Solanum xanthocarpum* (Kantikari).

2.4.3. Herbs

Mimosa pudica (Lajjabati), *Acorus calamus* (Bach), *Piper betel* (Pan) *Centella asiatica* (Tankuni), *Andrographis paniculata* (Kalomeg).

3. Propagation and Cultivation

3.1. BAMBOO

3.1.1. Propagation: Propagated both sexually and vegetatively.

3.1.1.1. Sexual propagation: Through seeds.

Flowering period: October-December; once in life of each clump at the age of 25-40 years.

Maturity of seeds and their viability: Seeds become matured within 3-4 months of flowering. Seeds generally lose their viability within one-two months after collection.

Seed germination and raising of seedlings: Seeds generally germinate within one week after sowing. Seeds can be sown in any container or polyethylene bag containing a compost of soil and cowdung in a proportion of 3:1 at the depth ca 5 mm. Sprouted seedlings of 2-6 months old should be kept under shade and then transferred to sunny place. Each seedling of 9-12 months old could be proliferated into 2-3 seedlings with sufficient root system and consequently large number of seedlings can be raised.

Wildings: Large number of seedlings under the flowering clumps also occurred both in the forest and village groves, named as wildings. These also could be transferred in the polyethylene bag containing compost to raise established wildings.

3.1.1.2. Vegetative propagation: Through rhizome, offset, culm cutting, pre-rooted branch cutting etc.

Rhizome: It is the underground portion of culm with profuse root system. Long period is required long period for the production of new cul ns.

Offset: (Rhizome with 3-4 nodes). More suitable for propagation than is rhizome since it produces new culms within a very short period. 1-2 years old healthy cums are ideal for the collection of offset. The period just before the rainy season is suitable for offset collection. However, offset could also be placed on temporary sand bed for ca two months with regular watering to develop sufficient root system in order to avoid the following possible drought in the field after plantation:

Culm cutting: (Portion of culm with one or two nodes). 1-2 years old healthy cums are suitable for the collection of culm cutting. Cutting needs to be sown on sand bed to develop sufficient root system before planting in the field.

Pre-rooted branch cutting: (Branch with aerial roots at the nodes of culm). These need to be sown on propagation bed after collection, and then watered regularly to develop sufficient root system before planting in the field.

3.1.2. Cultivation: Bamboo can be cultivated both in the hilly areas and village groves. Beginning of the rainy season is the suitable period for the plantation of propagules in the field. Propagules are planted in the pits (one propagule in each pit) of various sizes depending on the type and size of propagule with a distance of five meters in between. Before planting of propagules pits could left for about two weeks with a mixture of cowdung in association with urea or ammonium sulphate and soil in a proportion of 1:2. Seedlings and pre-rooted branch cuttings are generally planted at the age of about two and six months respectively. After the plantation of rhizome, offset and culm-cutting in the field the viability of them should be considered. In some cases occasional watering (twice a week) may be required initially for their establishment.

3.1.3. Cultural practices: New culms may produce within one year of plantation. Generally, initial (first two years) new culms are small in height and diameter. Removal of these culms is better for the production and development of new healthy culms. Weeding is necessary. Dead and infected culms need to be removed from clumps to avoid any contamination of diseases. Firing at the soil surface of clumps during the dry season, winter in particular, may check the spread of any diseases. Occasional watering and mulching may improve the productivity of bamboo. Application of NPK fertilizer before the rainy season of each year may also enhance the growth.

3.1.4. Harvesting: Generally, harvesting time is recommended to be the dry period. However, may also harvest through out the year except the period of new culms production. Tree to four years old cums are generally harvested when culms become yellowish with blackish aerial roots. Culms from the center of clump are appropriate to harvest since these are older than the culms of the periphery. Culms should be oblique cut leaving one node above the soil surface. Harvesting of bamboo could be done from the same clump after every two years.

3.2. CANE

3.2.1. Propagation: Propagated both sexually and vegetatively.

3.2.1.1. Sexual propagation: Through seeds.

Flowering and fruiting: Once a year in most of the species, except Calamus viminalis (Bara bet) in which twice a year.

Seed collection period: Varies from species to species.

Calamus guruba and *C. tenuis*: April-May; Ripe fruits are light yellow or like dry straw. Fruits of *C. tenuis* is smaller than those of *Calamus guruba.*

C. letifolius : June-July; Ripe fruits are deep green

C. viminalis: March-April and September-October; Ripen fruits are light green.

C. longisetus: July-August; Ripen fruits are brown but look like chocolate color because of chocolate color scale apex.

Daemonorops jenkinsianus: June-July; Ripen fruits are yellow or brown.

Seed storage : Exposed seeds as well as seeds with cover could be stored separately. Generally, seeds may lose their viability within a vary short period when stored in open container. However, dry seeds could be stored for longer period (3-5 months) after being treated with fungicide (captain).

Seed germination and raising of seedlings: Seeds can be sown in well-prepared seed bed as well as in earthen pot, polyethylene bag, wooden box etc. containing a compost of loamy soil and cowdung (3:1). However, seed germination may enhanced by sowing in wet saw-dust as well as in a mixture of saw-dust and sand (1:1). Ash and acid treatment on cane seeds may also accelerate germination.

Seed germination starts within 3-13 weeks of seed sowing and could continue up to 8-29 weeks, which are species-specific. Seedlings of four weeks can be transferred in polyethylene bag containing a compost of soil and cowdung (3:1) and then left in the nursery for about one year for hardening of seedlings.

Wildings: Naturally grown seedlings available under the clumps could be transferred in polyethylene bag containing a compost of soil and cowdung (3:1) to raise established wildings.

3.2.1.2. Vegetative propagation: (Through rhizome, an underground portion of culms with juvenile shoot). Rhizome can be sown directly in the field or in polyethylene bag containing a compost of soil and cowdung (3:1) for establishment before planting in the field.

3.2.2. Cultivation: Cultivated both in the forest and village groves. Seedlings or rhizomes are planted in well prepared pits containing fine soil and cowdung including fertilizers. Rainy season is the suitable period for cane plantation. Cultivation of cane in association with other fast-growing trees (e.g. Mander, Simul, Koroi etc.) is better since most of the cane species are climber and need supporting trees for successful growth. Large-scale cultivation through rhizome is relatively expensive because of requirement of maximum labor and time.

3.2.3. Cultural practices and harvesting: Weeding is necessary twice a year. Growth and development may enhance using fertilizer (e.g. NPK). Generally, cane can be harvested within the period of 5-7 years of plantation.

3.3. Pati-pata

3.3.1. Propagation: Sexually and vegetatively.

3.3.1.1. Sexual propagation: Through seeds.

Flowering period: March - May.

Seed collection and storage of seeds: Matured fruits may collect within 2-3 months of flowering. Fruits are with 2-3 lobes and 2-3 seeds. June-July is the seed collection period from the ripen fruits. Exposed seeds as well as fruits could be stored for longer period after being treated with seed dressing fungicide (e.g. Captain).

Seed germination and raising of seedlings: seeds can be sown in well prepared seed bed as well as in earthen pots, wooden boxes and polyethylene bags containing loamy soil and cowdung in a proportion of 3:1. Only saw-dust or a mixture of saw-dust and cowdung (1:1) could also be used as medium. Seeds are germinated within 20-25 days of sowing and continue up to 35-45 days. Seedlings of two weeks age are transferred in polyethylene bag containing a compost of soil and cowdung (3:1) and then kept in the nursery with regular watering for one year to raise established seedlings.

3.3.1.2. Vegetative propagation: Through rhizome and branch cutting.

Rhizome: (Underground portion of culms with enormous root system). Generally collected during June-July, the period of plantation from the old clumps.

Branch cutting: Since pati-pata generally grows in marshy land near pond etc., some roots may develop from the nodes of branches with or without attachment to the water.

These pre-rooted branch cuttings can also be used as propagating material.

3.3.2. Cultivation: Marshy land around the house, particularly in village areas is suitable for cultivation. Areas adjacent to water of ponds, rivers, ditches etc. are suitable for pati-pata cultivation. Propagules may be sown directly in the well-prepared field with a spacing of about 0.75 m x 1 m.

3.3.3. Cultural practices: After plantation, weeding is necessary twice a year. Mulching with soil may improve the growth. Growth may also be enhanced with the application of cowdung in association with a mixture of urea and phosphate fertilizer.

3.3.4. Harvesting: Mature culms could be harvested within two to three years of plantation. Cultivation through rhizome may provide earlier mature culms than through seedlings and branch cuttings. The period before the rainy season is the suitable harvesting period.

3.4. Medicinal plants

There is no large-scale cultivation of medicinal plants in Bangladesh. However, Bangladesh Forest Research Institute has been trying to develop propagation technique of some important medicinal plants.

Arjun: Propagated through seeds. January-February is the period of fruit maturity. Seeds germinated both in seed bed and polyethylene bag containing a compost of soil and cowdung (3:1). Seed germination takes place within 20-25 days of sowing in a percentage of 50-60. Seedlings of 4-5 months' age are suitable for plantation. Land with loamy soil may be suitable for cultivation.

Khair: Propagated through seeds. December-February is the period of fruit maturity . Seeds are sown in seed bed with a compost of soil and cowdung (3:1). Seeds need to be sown within one month of seed collection. Seed germination takes place within 7-15 days of sowing with viability of 30-35%. Seedlings of 15-20 days' age are transferred in the polyethylene bag containing a compost of soil and cowdung (3:1) to raise seedlings, and then planted in the field at the age of 3-4 months. Land with relatively dry soil may be suitable for cultivation.

Bahera: Propagated through seeds. February-March is the period of fruit maturity. seeds germinated both in seed bed and polyethylene bags containing a compost of soil and cowdung (3:1). Seed germination takes place within 20-25 days of sowing after soaking in water for 48 hours with percent germination of 75-90. Germination percentage is better in polyethylene bag. Seedlings of one month old are transferred in polyethylene bag containing a compost of soil and cowdung (3:1) to raise established seedlings and then planted in the field at the age of 3-4 months. Sloppy land with relatively dry soil may be suitable for cultivation.

Bel: Propagated through seeds. June-July is the period of fruit maturity . Seeds germinated in seed bed with a compost of soil and cowdung (3:1). Seed germination takes place within 20-25 days of sowing after soaking in water for 24 hours with percent germination of 50-60. Seedlings of one month age are transferred in polyethylene bag containing a compost of soil and cowdung (3:1) to raise seedlings, and then planted in the field at the age of 3-4 months. Land with relatively moist soil may be suitable for cultivation.

Raktakambal: Propagated through seeds. December-February is the period of fruit maturity. Seeds germinated in seed bed with a compost of soil and cowdung (3:1) as well as saw-dust without compost. Seed germination takes place within 20-30 days of sowing with percent germination of 25-60. Seeds treated with conc. sulfuric acid germinate better (60%). Seedlings of 25-30 days age are transferred in polyethylene bags containing a compost of soil and cowdung (3:1) to raise seedlings, and then planted in the field at the age of 3-4 months. Soil with sufficient water holding capacity may be suitable for cultivation.

Haritaki: Propagated through seeds. January-March is the period of fruit maturity. Seeds are sown in seed bed with a compost of loamy soil and cowdung (3:1). Seed germination takes place within 25-30 days of sowing after soaking in water for 48 hours with a percent germination of 50-70. Seeds treated with 10% conc. sulfuric acid germinate better. Seedlings of 30-45 days age are transferred to polyethylene bag containing a compost of soil and cowdung (3:1) to raise seedlings, and then planted in the field at the age of 4-5 months. Hill slope with moist soil may be suitable for cultivation.

Akanda: Generally propagated through cuttings. Seeds may also be used as propagules. With regular watering, 60-70% of cuttings are rooted in cutting bed with a compost of soil and cowdung (3:1). Rooted cuttings are transferred in polyethylene bags containing a compost of soil and cowdung (3:1) to raise cuttings, and then planted in the field at the age of 3-4 months. Land with moist soil may be suitable for cultivation.

Ulatkambal: Propagated through seeds. June-July is the period of fruit maturity. Cuttings from both shoot and root are also used as propagules. Seed germinated in seed bed with a compost of soil, saw dust and cowdung (2:1:1). Seed germination takes place within 3-4 weeks of sowing with a viability of 60-65%. Seedlings of one week old are transferred in polyethylene bag containing a compost of soil and cowdung (3:1) to raise seedlings, and then planted in the field at the age of 25-30 days. Seedlings from seed bed may also be directly planted in the field. Land with sandy loam soil may be suitable for cultivation.

Kantikari: Propagated through cuttings. Seeds may also be used as propagules. Rooted cuttings may raise in seed bed or directly in polyethylene bags containing a compost of soil and cowdung (3:1) and then planted in the field at the age of 3-4 weeks. Land with loamy soil may be suitable for cultivation.

Kalodutura: Propagated through seeds. December-February is the period of fruit maturity. Seeds germinated both in seed bed and polyethylene bags containing a compost of soil and cowdung (3:1). Seed germination takes place within 10-15 days of sowing. Seedlings of 20- 30 days' age are transferred to polyethylene bags containing a compost of soil and cowdung (3:1) to raise seedlings, and then planted in the field at the age of 2-3 months. Moist plain land may be suitable for cultivation.

Bashak: Generally propagated through cuttings. Rooted cuttings may be raised both in cutting bed and polyethylene bags containing a compost of soil and cowdung (3:1).. Cuttings are rooted within 20-30 days of sowing with percent germination of 80-85. Rooted cuttings are directly planted in the field at the age of 4-5 weeks. Land with relatively moist soil may be suitable for cultivation.

Sharpaganda: Propagated through seeds. July-September is the period of fruit maturity. Seeds germinated in seed bed with a compost of soil and cowdung (3:1, respectively). Germination takes place within 30-35 days of sowing in a percentage of 50-60. Seedlings of 45-50 days old are transferred to polyethylene bag containing a compost of soil and cowdung (3:1, respectively) to raise established seedlings and then planted in the field at the age of 3-4 months. Land with relatively moist soil may be suitable for cultivation.

4. Environmental and socio-economic aspect of non-wood plants as agroforestry component

Because of increasing reduction of tree cover (in addition to the use of fossil fuels), carbon dioxide concentration is increasing in the atmosphere leading to a predicted increase in global temperature. Eventually, agricultural production may be adversely affected directly. So, growing non-wood plants in association with other trees and agricultural crops in agroforestry may contribute in the improvement of environmental condition since of maximum crop covering per unit area of land. Such system may also solve a number of problems, notably soil erosion for which about 10-36% of rainfed cropland has been lost, leading to a predicted 29% reduction of crop production by the year 2000 (Higgins et al. 1983). Control of soil erosion may also eventually reduce siltation in the river resulting in the control of flood, an acute problem of Bangladesh.

Most of the non-wood plants viz. bamboo, cane, pati-pata etc. are provided house building material in the rural areas. Besides, these are also valuable raw material for rural cottage industries in which large number of people including women are engaged. Many families in the rural areas are totally dependent on such industry. So, non-wood plants in agroforestry have large impact in the alleviation of rural poverty. Moreover, some improved quality of furniture and decorative material, which have considerable economic value both in home and abroad, are made from such non-wood plants. Medicinal plants are important raw material of Ayurbed industries, which in Bangladesh are completely dependent on imported raw material. Besides, most people in the rural areas use medicinal plants for the treatment of various diseases. Thus large-scale plantation of various medicinal plants as agroforestry component could solve such problems.

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ORGANIZATIONS AND ACTIVITIES OF AGROFORESTRY RESEARCH AND DEVELOPMENT AND EXTENSION IN BANGLADESH

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Introduction

A paper entitled "Agroforestry in Bangladesh : Synthesis of Research and Development Efforts" by Lai (1990) described the current status of agroforestry work by 10 organizations or programs. Five organizations viz. Bangladesh Agricultural Research Council (BARC), Bangladesh Agricultural Research Institute (BARI), Bangladesh Forest Research Institute (BFRI), Bangladesh Livestock Research Institute (BLRI) and Bangladesh Agricultural University (BAU) are involved in agroforestry research within the national FSRD network.

The Forest Department is experimenting with agroforestry models involving landless families on a crop-sharing basis on denuded Sal forest lands. BRAC and Proshika, among the NGO"s have been carrying out a number homestead and roadside tree plantation projects. Through local NGO's in the North Bengal, SDC is supporting agroforestry action research in the farmers' fields. Successful khas land agroforestry project is being implemented by formerly landless settlers in Betagi, Chittagong.

With a view to assessing the agroforestry research and development programs for completed, on-going and proposed projects a survey questionnaire was formulated and supplied to different Government and non-government organizations. Survey responses provided updated information on these projects.

1. Activities of the Forest Department

Lack of quality planting material and farmers' knowledge of improved management techniques are the major limitations for improving homestead productivity (Abedin and Quddus 1988). In this regard the Government and some NGOs are involved in producing seedlings and motivating and training farmers to raise seedlings at the local level. During 1981-87 the Forest Department established 40 nurseries and training centers in seven greater districts of north-west region of Bangladesh under the Community Forestry Project to enrich homestead woodlots in 4650 villages. In the second phase of the project (Thana Banayan Prokalpa), the program has been extended throughout the country by setting a seedling nursery in each of the 460 thanas. Though the Community

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Forestry Project was initiated in 1981, establishment of demonstration farms in the encroached forest areas was started in 1985. Under this program 0.98 - 2.96 acres were allocated to landless families on an annual renewable lease basis on condition that the farmers would follow the agroforestry modules prescribed by the Forest Department. They would enjoy 100 percent of the agricultural crops and intermediate tree products as well as 50% of the final tree harvest. Suitable modules are yet to be developed. The community forest project had also a linear plantation program for 4800 km alongside roads, railways, canals in seven greater districts of north west region of the country. *Acacia nilotica, Dalbargia sissoo* and *Acacia mangium* were the tree species planted. As a strategy to protect the plantations, local farmers were involved, and fences of *Cajanus cajan* were planted along the trees, the benefit of which was totally intended for the participating farmers.

2. Agroforestry Research in Bangladesh

Different forms of agroforestry are being traditionally practiced by farmers in Bangladesh, especially home gardens, boundary planting and mixed intercropping (the later two in rainfed croplands). There has been a concern among the scientists and extension agents for tree growing by farmers for some time.

Both Government and non-government agencies are undertaking various agroforestry research and development activities. The Government and non-government organizations involved in the agroforestry research and development activities are as follows:

2.1 BARC

BARC is an apex body mandated for coordinating all agricultural research in the country. It has formed the "National Agroforestry Working Group (NAWG)" in 1989, which includes representatives from the major Government and non-government organizations active in agroforestry. This followed the recommendation of a national workshop on "Homestead Plantations and Agroforestry" organized in 1988 held at BARI, Joydebpur, Gazipur (Abedin et al 1990). The roles of NAWG are research co-ordination, collaborative field research and training support. BARC is assisted by "Agroforestry and Participatory forestry Support program" funded by Winrock International.

The National Coordinated Farming Systems Research Program is also coordinated by BARC and has agroforestry activities in several of its 19 sites across the country.

BARC is also organizing a week long training course on agroforestry for 20 professionals from different Government and Non-government organizations through Agroforestry and Participatory Support Program.

2.2 BARI

BARI, mainly through its On-farm Research Division (OFRD) and FSR sites has completed surveys and studies on different homestead and crop field agroforestry systems, such as household fuel situation, woman's role in homestead production, bamboo supply, demand, cultivation, and economic and tenurial aspects of agroforestry.

BARI's on-going activities in relation to agroforestry include: testing of fast-growing fruit trees and MPTS on homesteads in different FSRD sites; border planting of MPTS on the Barind Tract; cropping patterns in agroforestry modules on forest land; fertilizer management for date palms; and tree crop interactions in existing agroforestry systems. Proposed research projects include: Silvo-pastoral modules in existing jackfruit and shishu orchards in the High Ganges River Floodplain; optimum spacing of babla, shishu and jackfruit on crop lands; and resource utilization in Modhupur Tract agroforestry systems.

2.3 BFRI

It has four on-going agroforestry research projects which include: (i) Socio-economic study on Betagi and Pomora Community Project (ii) Agroforestry research on forest and marginal lands (iii) FSR trials at BFRI Headquarters, Chittagong and Bandarban hills and (iv) under planting of cane and medicinal plants in forest plantations.

Proposed projects include : continuation of the above work as well as surveys of traditional agroforestry systems and indigenous multipurpose trees and shrubs, socio-economic analysis of agroforestry and farming systems; testing of tree management practices for sustained fodder and fuelwood production, development of suitable nursery propagation techniques and training and extension of bamboo and agroforestry technologies.

2.4 BLRI

Bangladesh Livestock Research Institute (BLRI) is conducting experiments on several species of fodder trees e.g. *Samanea saman, Leucaena* spp, *Flemingia congesta, Tephroz candida, Derris indica* and *Acacia* spp.

2.5 BAU

Agroforestry component research is carried out under BAU's Farming Systems Research and Development program (FSRD). Completed projects include: tree surveys and monitoring on FSRD sites; biomass fuel use monitoring; Leucaena fodder and biomass planting and Sesbania as a relay crop in aus rice systems.

Current work emphasizes the above and also: multilocation testing of *Sesbania rostrata*; pigeon pea hedge-grows around banana orchards; and further MPTS testing. Proposed projects include series of experiments utilizing Sesbania in different cropping systems as well as spatial and temporal arrangements. Other future research interests include; planting of trees on homesteads in haors (low-lying, flood-prone areas) and seed collection from haor areas to select flood-resistant tree varieties.

2.6 IFCU

The Institute of Forestry at Chittagong University has no agroforestry project activity. However, agroforestry courses have been introduced in the syllabus and some students are conducting review work on agroforestry-related topics.

3. Non-government organizations

3.1 ADAB

ADAB has completed a project in which it channelled funds from EZE (a German church-based organization) to 18 NGO's in northern part of Bangladesh and organized training on nursery development.

During 1990-93 plan, ADAB proposes to organize an agroforestry/social forestry training course for 25 NGO participants each year in collaboration with relevant Government agencies and resource NGO's. A nursery development training course will be offered to 10 NGO-participants each year. ADAB will also collaborate with World Food Program and other donors to provide necessary development inputs.

3.2 BRAC

The on-going agroforestry development programs of BRAC are: nursery development, roadside plantation with agricultural crops, homestead agroforestry, sericulture and ericulture, Leaucaena plantings for fodder production and agroforestry demonstration trials. Proposed programs will include expansion of all the above programs. The sericulture program will be extended to produce 20 metric tons of silk annually.

3.3 Proshika

In respect of social forestry and agroforestry program, Proshika has so far established over 200 km of roadside agroforestry, collected over 1200 kg of babla, pigeon pea, Sesbania and Leucaena for direct seeding and seedling production, developed about 225 nurseries (over 50 financed with group members' own savings and half of nurseries run by female members) that produce about 2 million seedlings annually, protected over 1400 acres of degraded sal forest areas and (v) planted about 300,000 trees annually on homesteads.
Proshika proposes to expand these activities and also enter into a collaborative program

with the Forest Department for agroforestry development on denuded Sal forest sites, where Proshika staff have identified about 200 acres of potentially suitable sites.

3.4 CARE-International

In the LIFT (Local Initiatives for Farmers' Training) program of CARE, an agroforestry component has been recently introduced to complement the bio-intensive gardening (BIG) technology by emphasizing nitrogen-fixing trees (for green manure), line fencing and improved management of homestead trees. The on-going pilot demonstrations are located at LIFT sites in Kishoreganj thana of Nilphamari district and Kasba thana of Brahmanbaria district. Training is provided to CARE and DAE staff and to participating farmers. Once the agroforestry component is well developed, it will be fully integrated into the LIFT program. Proposed expansion areas include greater Noakhali and Patuakhali districts.

4. Donor Agencies

4.1 SDC

The Swiss Development Corporation (SDC) in Bangladesh is supporting action research programs on homestead agroforestry through different local NGO's. The objectives of these programs are to increase the income of marginal and small farmers by introducing fast-growing fruit trees and vegetables in the under utilized areas of the homesteads as understoried crops of long rotation fruit and timber trees by utilizing women and other under utilized family labor. SDC is also involved in developing agroforestry technologies for private agricultural lands. SDC's crop land action research program has been operating since 1987 in five districts in the north-west region through small, local NGO's. The program aims at increasing the supply of rural energy and fodder through planting trees in crop lands.

4.2 Ford Foundation

As a donor organization, Ford Foundation currently supports the Proshika Social Forestry and Agroforestry Program. Future project support includes the Forest Department's pilot agroforestry project in the Dhaka, Tangail and Mymensingh sal forest zone, where 300 acres of experimental agroforestry systems will be established with the participation of organized groups. Ford Foundation also wishes to support the development of agroforestry research and training.

5. Extension

National workshop on "Agroforestry and Homesteads" held at BARI in 1988 recommended and provided guidelines in respect of agroforestry extension activities as to who should be responsible for different categories of programs.

(a) All agroforestry development programs other than on homesteads and farmlands, should be implemented by the Forest Department, with the active cooperation of DAE.

(b) Homestead and on-farm agroforestry extension programs should be implemented by DAE, with technical assistance from the Forest Department.

(c) The involvement of women's groups and NGO's in field programs should be encouraged.

(d) High quality seeds and seedlings should be available to farmers. Establishment of private, small-scale nurseries in rural areas should be encouraged.

To make agroforestry extension successful, there are important roles need to be played by the Forest Department, DAE, NGO's, Women's groups, Government and private nurseries. The NAWG should continue to be operative for stimulating closer collaboration between research and extension organizations and for reducing the existing gaps between these organizations. A participatory action research approach will be more effective in this regard because extension staff and farmers\ will be integrated into the research process.

6. Training

Insufficient training opportunities on agroforestry is one of the major constraints and weaknesses in this sector. No formal agroforestry training is offered anywhere in the country.

IFCU reports that some agroforestry courses have been introduced in their syllabus and some students conduct review work on agroforestry-related topics. It is a felt need that agroforestry principles and practices be integrated into the curricula of BAU and IFCU. To meet long-term educational needs, a bonafide agroforestry course should be developed and offered at BAU and IFCU. At present agroforestry training both for long-term and short-term duration abroad is an immediate and high priority. This will strengthen technical and leadership abilities

6.1 Short-term training

A limited number of Bangladeshi scientists and extension staff have received short-term, agroforestry-related training abroad. Besides, a number of organizations have provided short-term training in Bangladesh which include the following:

BARI:

- Organized training workshop on homestead plantation and agroforestry in Bangladesh for over 60 participants from 18 national and international organizations.

  - In conjunction with ICRAF and BARC, BARI conducted a three-week training course during October 1990 on agroforestry development for 30 participants from NARS, NAWG and NGO's.

BFRI

- Conducted training course on (i) bamboo, cane and pati-pata propagation, cultivation management and preservation and (ii) seed, seedling and nursery management for a total of 330 participants from various extension organizations.

Forest Department

Through the Community Forestry Project, the Forest Department of Bangladesh Government provided social forestry training to more than 1500 professional and extension staff from Forest Department, DAE and NGO's and more than 20,000 farmers and village leaders; Thana Banayan and nursery Prokalpa has targeted of 1600 person- months of training for staff and 6400 person-months for participating farmers and groups (GOB 1987).

ADAB

- Organized training on nursery development for 18 participants from local NGO's in northern Bangladesh.

- Provided training on nursery development to 14 participants from women's organizations all over the country.

Proshika

- Conducted 36 social forestry training modules one weak each, for 1080 participants from Proshika and other NGO's.

- Conducted 108 informal four day social forestry sessions for more than 4500 participants comprising NGO staff and group members.

- Conducted 38-week long homestead agroforestry and nursery development modules for 1140 participants.

- Provided a four-month social forestry and agroforestry training at Koitta Training Center for 16 technical workers.

CARE International

- Prepared homestead agroforestry training modules that will be used by field-based forest officers, initially in two sites to train all project staff and participants (about 15 and 1500 participants in each site.

7. Policy support

Relevant ministries who should provide policy support for agroforestry research and development activities include:

- o Ministry of Environment and Forests
- o Ministry of Agriculture
- o Ministry of Land

With policy support provided by the ministries several concerned government, semi-government organizations as well as NGO's should take the lead to stimulate action on various aspects of agroforestry development in the country.

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AGROFORESTRY RESEARCH NEEDS IN BANGLADESH

M. K. ALAM[1]

Introduction

Agroforestry has been practiced for centuries in Bangladesh as a land use system to jointly produce trees, crops and livestock on the same land unit, either simultaneously or sequentially. In all agro-ecological zones, trees, crops, livestock and fishes are integrated into the homestead production system. In some areas, particularly on rainfed agricultural highland, trees are intentionally planted or retained by farmers, either along the 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 lands, such as strips along roads, railways and ponds.

The farming systems concept views the entire farm and the household as integral production and consumption units. In Bangladesh the major farming system components are crops, livestock, trees, fish ponds and homesteads. Usually no land is allocated on a farm for purely tree-growing in Bangladesh. Instead, trees are mixed with other components to form agroforestry subsystems.

Agroforestry is an age-old practice in Bangladesh. It is new in that it has recently been included as part of R&D activities. Agroforestry can be employed as a strategy to alleviate both rural poverty and forest depletion. The importance of agroforestry is recognized in Bangladesh Fourth Five-Year Plan (FFYP). Both action-oriented agroforestry activities and research programs have been initiated simultaneously in Bangladesh. As a science, agroforestry is new in the country. So, there is a gap between the research and action programs. In the present paper, agroforestry research needs in Bangladesh are discussed in brief.

Agroforestry Projects and Activities

Five organizations : Bangladesh Agricultural Research Council, Bangladesh Agricultural Research Institute, Bangladesh Forest Research Institute, Bangladesh Livestock Research Institute and Bangladesh Agricultural University are involved in agroforestry research. Forest Department is establishing agroforestry modules. NGO's are involved in agroforestry programs in roadsides, homesteads and many action research programs in farmers' fields.

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Agroforestry Research and Development

To improve existing agroforestry systems and test alternative interventions, appropriate research and development is urgently needed. Based on the potential availability of land and the scope for improving productivity and benefits through agroforestry, priority areas for research and development were identified at a national agroforestry workshop at Bangladesh Agricultural Research Institute in 1988 (Abedin 1990; Lai and Ali 1990):

Highest priority areas	**Lower priority areas**
- rural homesteads	- khas land
- degraded/encroached forest land	- marginal land
- agricultural highland	- community land

At the same workshop, participants also articulated agroforestry research objectives for the short-term targets as : to obtain immediate and increased returns for resource-poor farmers by improving the management of existing agroforestry systems. And the long-term objectivees to be : improvement of the living standards of the rural people by maximizing agricultural and forest production on scarce land resources, and by contributing to ecological stabilization.

Agroforestry Research Priorities

In agroforestry, as well as in other fields, priority setting is important because there are insufficient resources to allocate to all identified research, extension and training needs. The National Agroforestry Working Group (NAWG), convened by Bangladesh Agricultural Research Council (BARC) summarized agroforestry priorities in research, extension and training from a survey of organizations involved in agroforestry activities (BARC 1991). Summary of agroforestry research priorities expressed by responding institutions are given below:

- improve traditional agroforestry technologies;

- enhance homestead agroforestry productivity;
- develop sustainable agroforestry systems on farm and forest lands;

- adopt action research and RRA techniques, integrate agroforestry into Farming System Research and Development;

- monitor and evaluate socio-economic and ecological impacts.

Research Themes

Research focus should be on improving traditional agroforestry systems, homestead agroforestry and agroforestry practices on farm and forest land. Instead of ad-hoc and short-term programs, long-term regional research program should be formulated in agroforestry sector. Specific agroforestry research themes for general land categories are identified by NAWG in "Bangladesh Agroforestry Plan (1990-95): An Agenda for Policy, Research and Action (BARC 1991), in a diagnosis and design survey in an encroached forest area in Dhaka (Torquebiau and Abedin 1991), diagnosis and design survey in Barind Tract, Rajshahi (Torquebiau 1991; Lai 1990; Ahmed 1991; Abedin, Lai and Ali 1990). These and other findings are summarized below:

Homestead agroforestry research needs

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

- identifying fast-growing fruit trees, MPTS, nitrogen-fixing trees, live fence species, fodder species, shade-tolerant or shade-loving crops and agroforestry cropping patterns suitable for homesteads in different agro-ecological zones

- determining proper tree management (pruning, lopping, pollarding, coppicing), homestead cultivation practices, and spatial arrangements to maximize production and income, especially on small homesteads

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

- conducting socio-economic research on homestead system, with particular focus on gender roles and problem

- Studies on promotion of market opportunities for horticultural, timber and agricultural products

- Studies on wood properties and utilizations of both existing and introduced trees and shrubs of the homesteads

- Pest and disease surveys for homestead trees and crops

Cropland agroforestry research needs

- Surveying and diagnosing existing cropland agroforestry systems, especially those in the lower rainfall zones, to better understand problems and design potential remedies

- developing silvo-pastural modules for existing jackfruit, sishu and mango orchards in the High Ganges River Floodplain

- determining optimal spatial arrangements of babla, sishu and jackfruit in different cropland 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 effects on crops, and to accelerate sustained and low-cost production of fodder and fuelwood

- determination of ideotypes of MPTS, NFTS and other trees involved in different interventions

- Screening of site-specific green manuring trees

- monitoring of changes in soil organic matter and other chemical and physical properties of soil

- fertilizer management for trees and crops

Forest land agroforestry research needs

- Surveying different existing agroforestry systems including ethno-botany practiced by different tribes and local people in different forest areas and designing improvement

- testing different cropping patterns in agroforestry modules established in Dinajpur and Sal forest zones

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

- developing of modules for denuded hills

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

- determining modules, 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 including fodder, mulch species, for their compatibility and value in agroforestry modules
- technology screening to assess the productivity (both in terms of production and services) of the promising agrofrestry technologies under different species and planting arrangements

- monitoring of soil changes; fertilizer management of both trees and crops

- screening of mulching trees and development of harvest schedules for the multistrata mulch bank

- recording and monitoring of tree growth at different modules and management practices.

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AGROFORESTRY EXTENSION

A. Z. M. SHAMSUL HUDA

Introduction

In agroforestry there are various production technologies, such as agro-silviculture, silvi-pasture, agro-silvipasture, home gardens, silvo-fisheries etc. which should be transferred and brought to the people for the improvement of their socio-conomic status.

Agroforestry is a new concept at the professional levels but it is an age-old practice in different forms among the rural people in different places. In the Chittagong Hill Tracts region, for example, the tribal people have been practicing shifting cultivation and the Forest Department used tanyngya system for reforestation. The taungya system of plantation is developed as an agroforestry practice but it has not been able to reach those people who are practicing shifting cultivation. As a result, about 1.8 million acres of unclassed state forest (USF) land has become completely denuded. If the taungya system of agroforestry practice could be extended to the tribal people, their socio-economic conditions would have been much improved. The production of both crops and trees could also increase. Thus agroforestry extension can play a vital role to develop an alternative land use practice for the improvement of social and economic conditions of the people.

Agroforestry extension is a people-oriented activity combining forestry and agriculture for food and wood. Agroforestry extension is a process in which the efforrts of Government or other organizations and the people are combined. It can be described as an informal process of learning and teaching method based on the need or problems of the people in a particular locality or site.

Agroforestry extension is an out-of-classroom effort to inform and educate the masses on the value and importance of trees and multiple cropping and motivate them to take active part in various farming systems or activities.

In agroforestry the extension laboratory is the farm where practitioners can demonstrate to the farmers the proper spacing and patterns of the different crop combinations. In fact, agroforestry extension is a multidisciplinary work. It is not the monopoly of the foresters. agriculturists, agronomists, sociologists, or others. All extension personnel, however, must have common knowledge and understanding of the values and importance of forest resources, land uses and various agroforestry pracrices.

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Components of Agroforestry Extension Program

Generally, an agroforestry extension program may consist of the following four major activity areas:

(1) Non-formal Agroforestry Education

(2) Public Information

(3) Technology Packaging and Transfer

(4) Technical Assistance and Service

1. Non-formal Agroforestry Education

The main objective of this component is to improve knowledge, skills and attitudes of the target groups on certain aspects of agroforestry system. This is done through demonstration, short training courses, seminars and educational tours etc.

2. Public Information

This involves the dissemination of agroforestry information to the general public or specific groups through various available media, such as newspapers, radio, television etc. The aim is to make people aware of the current and future status and programs on agroforestry.

3. Technology Packaging and Transfer

This component seeks to make available the agroforestry technologies and practices, such as agro-silviculture, silvo-pasture, home-gardens and various farming systems to the rural people.

4. Technical Assistance and Service

This involves provision of technical advice, material assistance and service to participants of agroforestry programs.

Role of Agroforestry Extension

The role of agroforestry extension is primarily to deliver the agroforestry techologies, such as the agro-silviculture and silvo-pasture models of cropping patterns, farming systems, home-gardens etc. that could improve the socio-economic conditions of local people.

Methods of Extension

Method of agroforestry extension can be classified into three categories, namely individual method, group method and mass method:

1. Individual Method

Individual face-to-face contact has been found to be an effective way of changing attitude of the rural people. This may be done in various ways, namely:

1. Farm/Home visit
2. Personal letters
3. Enquiries
4. Informal contacts

These are, however, expensive, time-consuming and progress is very limited.

2. Group Method

This method is generally designed to reach specific people, such as farmers, villagers, professionals, and may include:

1. General meeting
2. Demonstration
3. Field trip and tour
4. Group discussion
5. Training
6. Seminar
7. Workshop etc.

3. Mass Method

This method is adopted mainly to reach general people through various media of communication, namely newspapers, radio, television and audiovisual media etc. This method can reach a large number of people very quickly. However, such media-based method may not be easily available to the rural people.

The most common mass extension methods are: Circulars, newspapers, posters, pamphlets and leaflets, folders, fact sheets, exhibits/displays, radio, television, filmshow, slide show etc.

Of all extension methods mentioned above, demonstrations and field visits are the most effective and important for agroforestry extension. As agroforestry is a new concept and the models are not known to the people, it is difficult to make people understand without demonstrations and field visits.

An enterpreneur farmer may have a very beautiful home-garden or multiple production system. This could be replicated to other places if it could be demonstrated through field visits. Seeing is believing. So, the participatory concept of agroforestry must be demonstrated to the farmers.

There are many agroforestry systems in Bangladesh which have been documented. For example, in Sylhet district, the Khasia Punji pan cultivation is a very good agroforestry system in the hilly areas of Sylhet. This has not been developed as agroforestry technology. In coastal areas, silvo-fishery is being practiced but that has not been developed as an agroforestry system. Research scientists should study these practices and new technologies should be developed.

Approaches to Agroforestry Program Planning

There are various approaches for agroforestry extension and development planning, namely: 'Blue-print' approach, 'Bottom-up' approach, 'D&D' approach, 'Participatory' approach etc.

1. 'Blue-print' approach

It is a pre-determined approach which is normally prepared by the government. It is based on what it can do or wants to do. The plan is handed over to the people by the government i.e. it involves a 'top-down' plan.

2. 'Bottom-up' approach

This is the opposite of the first approach. It is also known as "self-determined" approach. It is based on "feld needs" which may contradict to the "national needs."

3. 'Diagnosis & Design' (D&D) approach

It is the most appropriate approach in agroforestry. Here various experts go to the field, talk to the people, exchange ideas, determine the needs and find out the problems. Then a probable solution is suggested and accordingly plan is prepared.

4. 'Participatory' approach

It is also known as "joint planning" approach. Presently this is also a very common approach in various participatory forestry programs. Here the villagers are actively involved in the planning stage.

Extension activity should be done in all the stages i.e. planning, implementation, monitoring and evaluation of any agroforestry projects.

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EDUCATION AND TRAINING IN AGROFORESTRY

A. ALIM[1]

Definition

Education may be defined as production of changes in human behavior. Accordingly, the aim of agroforestry education is to influence people to work those desirable changes in the behavior that contributes to better land use, home-making and socio-economic advancement. It brings awareness, imparts knowledge, develops knowledge and skills and assists in forestry practices and services in biological, physical and socio-economic terms. It also teaches how to establish a gainful connection between land, man and the nature for survival of human civilization, which in turn, depends on the earth's biological production system, food crops, forests, fisheries and fodder.

Because of unwise use of forest land, population pressure and consequent clearance of forest areas for agriculture and dwelling houses, the results have been disastrous in ecological and economical terms.

FAO, UNDP, UNESCO and many other international organizations and governments have come to realize the overall importance of forest as a component of rural development. The land use professionals have also come to realize that neither the old forest can be protected nor new forests can be created without direct participation of the people who live in and around the forest and derive benefits for their survival. In this context, it is now felt that all land use professionals should undertake integrated programs on agroforestry to make people aware, to change their attitude toward scientific land use and to ensure a sustained supply of new goods and services through research, education, training and extension services. Creation of new goods and employment opportunities in the rural area shall also go to stop migration of population from village to towns.

In Bangladesh formal education in agroforestry is being given at professional level only at the universities. There is, of course, forestry education at the forestry schools at Rajshahi and Sylhet. However, the level of education is very primitive in nature. At foresters' level, the officers are educated only on standard nursery practices and plantation of timber tree and their aftercare to some extent. The professionals are given education on the organization of the other allied departments and on agroforestry crops, their uses and marketing. They are also offered courses on scientific use of land, prevention of soil erosion etc.

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Training

Training of the agroforestry participants and extension workers of all the land use agencies is considered to be very important. The Thana Banayan Project has started this training program. The Extension workers, in addition to having a thorough knowledge about their subject, should also acquaint themselves with the needs and aspirations of the people and the government and non-government organizations (NGO's) engaged in rural development activities. It is necessary to remember that agroforestry and rural woodlots program is only a part of the total rural development program. Government, NGO's and mass media can play important roles in this respect. Training of the participant farmers is another very important aspect of the total program. In Bangladesh a 7-day training for 3000 landless farmers was completed in 1980. Out of these, 130 were selected for another 4 days' follow-up training. Out of those 130, thirty farmers were elected as leaders .Training was given on land use, plantation technique, forage, horticulture species and on nursery raising. These 30 leaders were also trained on organizational aspects. Training program of the participating farmers and officers have also been taken up by some of the NGO's.

Necessity of Extension

Extension program is a statement of situation, objectives, problems and their solutions. An understanding of what is to be done and why it has to be done, is necessary to make the program successful. It represents the thinking and decision making of all who have a part in its development. Extension program encompasses the following:

1. It ensures careful consideration of what is to be done and why.

2. It furnishes a guide based on which all new proposals are judged.

3. It establishes objectives against which progress can be measured and evaluated.

4. It gives continuity during the changes of staff and officers.

5. It helps in the development of new leadership from amongst the participants at village level.

Principles of Program Building

The following elements are to be considered in building a sound extension program:

> Analytical facts should be brought about under a particular situation through mutual discussion.

> selected problems should be based on facts and on mutual discussions and agreement.

> determined objectives and possible solutions should satisfy all and should meet the ultimate goals of the program.

> definite plan of work should be worked out and put on record.

> the process should be sustainable.

> the teaching and training program should satisfy all.

> the coordinating body should be able to satisfy every body's needs and aspirations.

What is Agroforestry Extension

Agroforestry extension is a non-formal two-way education outside the classroom, schools, colleges and research laboratories. It brings scientific and socio-economic information to the trainees and takes the participants' problems to the research institutions, technical departments and experts for solutions. It helps the target groups to become self-reliant through motivation. It teaches them to become responsible citizens without imposing practices for their unwilling acceptance. It also convinces, but does not command the participating target groups to follow an appropriate technology for their socio-economic survival.

Extension Teaching

> Help people to realize their problems by giving examples. It increases the participants' understanding for changing their attitude.

> Give them appropriate ideas about things without telling them what they want and what for.

> extension also means making enquiries in subtle ways about the problems of the participants and getting suggestions from them to solve these problems.

> extension also changes the attitude of the people without being directed.

> extension is working with men, women, young people, boys and girls and helping them to find out answers to their needs and aspirations by themselves.

Understanding Changing Behavior

The extension staff must have clear understanding of the following points while he/she carries out the extension program for changing the behavioral pattern of the target groups:

a. the specific change in knowledge, understanding, skills, and attitude are desirable.

b. how people can be influenced to change.

c. how to teach people to take to a new way of life style.

b. how to draw others' attention to any topic new to them.

An effective extension program brings in the following points to their clients:

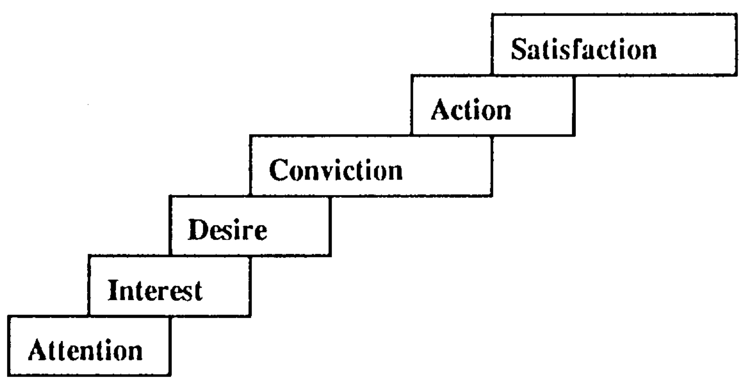
a. Incites imagination to make them aware.

b. motivates action to arouse a new desire to take to decent life style

c. broadens the horizon of understanding on how and why certain things could be improved.

Steps in Teaching

To have maximum benefit of extension program, the staff should exercise the following steps:



Some Appropriate Extension Methods

1. Instruction manual
2. Circular letter
3. Working plan
4. Survey and evaluation report
5. Appropriate technology for the target group
6. Highlighting the achievement of the target groups to attract others.

Variety of Extension Methods

Some extension methods over others have been found to be more effective in different situations and at different stages in the adoption process. Appropriate methods which agroforestry extension staff can use fall into three main categories. They are:

a. Individual method
b. Group method
c. Mass method

Mass media can play the most important role to motivate the beneficiaries, policy makers and the economic planners.

Agroforestry production system under social forestry management has very important role to play in preventing further negligence toward the rural poor. In Bangladesh the importance of social forestry and canal digging were recognized by the Late President Ziaur Rahman but later on these were neglected. Rural people have sacrificed their homestead woodlots to obtain fuel and more land for food. In this process, great environmental hazards have been brought about. In the rural communities, there are large areas of unused, under-used, marginal lands which can be very fruitfully utilized by the rural poor, and this can be a big source of new goods and employment opportunities. In addition, large areas of encroached and denuded lands are lying unused, which are creating the havoc of soil erosion and environmental hazards. These areas can be rehabilitated with rehabilitation of the rural poor. This can also stop alarming migration of the rural poor from villages to the cities.

Research

Very little research on agroforestry and social forestry and silvipasture has so far been done. It is necessary to establish models under different agro-ecological zones. The work involves not only the biological aspects but also a through understanding of the socio-economic and socio-cultural variables.

Available knowledge on the number of multipurpose tree species is limited. Mixture of forage crops with horticultural and forestry crops has got to be made updated.

Mixture of shade-tolerant medicinal plants and cane shall benefit a given site and will be a sustainable source of employment.

Another very important factor is our limitations in the knowledge of tree improvement and development of silivicultural treatment under different site conditions. FAO, Commonwealth Secretarial etc. dealing with forestry program may very conveniently coordinate and fill the knowledge gap through information exchange among the member countries.

The local schools for the children of the agroforestry participants can serve as an "Agroforestry Community House", by way of making it the meeting and training center and office of the local agroforestry staff. The community house will ultimately be the focal point of all activities.

All programs on forestry development should be based on the philosophy : "Forestry for the people, with the people and by the people."

WOMEN IN AGROFORESTRY

YASMIN AHMED[1]

Bangladesh, with its fragile ecosystem and a large number of population, has reached the safe limits of agricultural production. Bangladesh economy depends on agriculture, which acts as the major source of economic growth, export earnings and poverty alleviation. Nevertheless its contribution to the country's GDP has decreased continually. In 1990-91, it accounted for 38.9% against 43.3% in 1984-85. Land degradation is one of the major issues of environmental degradation. Over the years, it has been accelerated by over-exploitation due to increasing size of population. Shifting cultivation, over-grazing, unplanned land use, deforestation, over- exploitation of biomass from fields and monocropping accelerated soil erosion in some parts of the country.

Agroforestry has been practiced by the farmers for centuries in Bangladesh. It is a land use system which combines trees, crops, livestock on the same land. "It is a sustainable management system that increases overall production, combines agricultural crops, tree crops, forest plants and animals simultaneously or separately that are compatible with the cultural patterns of the local population". Agroforestry has certain advantages as follows:

a) It increases agricultural productivity through increasing soil organic matter and preventing soil erosion.

b) Woody perennial, for their deep roots, are useful for nutrient recycling.

c) Tress reduce soil temperature and improves soil fertility through shading and mulching. Agroforestry provides sustainable land use system which was given priority in Tropical Forestry Action Plan by FAO.

Although a new subject for the professionals, agroforestry is nothing new in this country. Farmers in our country are practicing it for ages. The 'Garo' tribe has developed jhum or shifting cultivation into a market-oriented production system based on pineapple production. The pineapple production is associated with ginger, arum, sal, jackfruit and other trees.

With limited land and increasing population, participatory agroforestry should get priority. Through proper agroforestry practices, poor farmers can get the immediate return from agricultural crops and long-term benefits from trees. There is a growing consensus that to alleviate poverty, to check deforestation, to prevent soil erosion as well as to increase soil productivity, agroforestry programs be given more serious considerations.

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Homestead forestry provides 80% of timber, most of fuelwood and bamboo used in Bangladesh. According to a report of Forestry Master Plan, village forests or woods contribute two-thirds of the current national wood supply, whereas reserve forests provide only 35% of the total regulated wood products and 20% of the bamboos used in Bangladesh. Homestead and village woodlots with only one-seventh the area of reserve forests produce the remainder. In this village agroforestry, women play the predominant role. About 86% of women living in rural areas are involved in agricultural production. Women are involved in all stages of agroforestry vis-a-vis agricultural practices from preharvest to postharvest period. They rear the cattle, process food for home consumption and for the market, collect fuel, water and participate actively in crop production. Growing Landlessness has forced them to work outside home. Though they are pioneer in the agricultural activities and great contributors to the agricultural production, their role is not even acknowledged and always under-estimated at the family level even in the national statistical records. A recent study shows that in addition to household works, agricultural production is the primary occupation of 43% of women and the secondary occupation of another 15% making total involvement 58% (Mahmud and Saffilos 1989).

Women's participation remains limited by social norms and religious practices where women have to work within the homestead. Women labor is usually unpaid, or they are self-employed. Their working hours vary from 10 to 14 hours which is higher than men who usually work for 8 hours. Women's work is seasonal. The higher social status is associated with non-working wife. Though some women do not work in the field, they are engaged in the activities of preharvest and postharvest period. It is revealed that one-third of the women in small and medium households is actively involved in crop production. In landless families, more than half of the women work as agricultural laborer, and one-fifth of women in small farms are engaged in agricultural production.

However, in homestead plantation, 90% of women are involved with 70% in livestock or poultry-related works. As women are more interested in immediate returns, participation of women in the production process and storage of vegetable seeds are greater than men. 70% of women are involved in vegetable seed production. In raising vegetable seedlings, 36.4% of women are involved compared to 17.6% men. Extent of participation vary according to the size of the farm. Wives of landless and marginal farmers are more involved in homestead plantation. According to the findings of BARD, women's participation is more than that of men with respect to vegetable seed storage. The participation of the female in vegetable seed drying (47.4%) storage (58.8%) was more than the male (28.8% and 5.6% respectively), regardless of farm category. Medium and small farmers put more emphasis on vegetable production. In homestead gardening, women play a significant role. The smaller the size of the farm household, the more is the involvement of women. For most of the vegetables grown in the homesteads, one-third is sold to supplement family income. Small and landless farmers sell more homestead products than medium and large farmers.

Women do not participate actively in marketing of their produce. Very few women have access to the marketing of the products they produce. The social restriction imposed on women mobility limits their authority to participate in the marketing stage of any production system. Women depend on husbands or male members and occasionally middlemen to sell their homestead vegetables and crops.

In spite of the fact that women participate actively in the various stages of agricultural production i.e. seed storage, homestead gardening, preharvest and postharvest activities, they are not given fair or equal share of the land.

With low social status, lack of technical knowledge and training facilities, poor participation in the marketing of the agricultural produce and poor access to agricultural means of production limit the participation of women in this field.

In addition to Government's afforestation program, NGO's in Bangladesh have undertaken innovative social forestry and agroforestry programs. NGO's working with the grassroot people have embarked upon participatory development where local people are involved in every stage of the programs from the decision making to implementation. Some NGO's like BRAC, Proshika, RDRS, CARE, POUSH, Caritas, Saptagram Nari Swanirvar Parishad have shown spectacular performances through involvement of women in agroforestry.

BRAC's Experience

BRAC's social forestry program focuses on the women folks, the most disadvantaged member of the society. As 60% of the rural population is landless , BRAC made a conscientious effort to generate income for the landless poor, especially women. BRAC's agroforestry program is taken up to maximize utilization of land to generate income for the rural poor. Their agroforestry model is carried out by the members who own a lease of 50 decimal land. The members plant short-term, mid-term and long-term species of trees following intercropping pattern. Long-term species are : jackfruit, coconut, sishu, carambola, koroi, lemon, guava, ipil-ipil. The short-term vegetables are : cowpea, eggplant, cucumber, white gourd, pumpkin, lau (*Lagenaria vulgaris*). Turmeric and ginger are planted as intercrops. The annual income from 50 decimal plot for the first year is estimated to be Tk. 5,430 (gross income is Tk. 9705 and cost is Tk. 4275). It increases to Tk.28,828 in the third year. Women groups are involved in roadside plantations. Each woman plants 500 mulberry trees over half km road. For the maintenance of these trees for one year, she gets daily wheat ration. After one year, the woman taking care of the trees, is trained as a silk-worm rearer. Five hundred trees are divided among 4 women including the caretaker. Women beneficiaries get all the earnings from leaves. So about 3720 women caretakers are involved in 2320 km road. BRAC has successfully integrated agroforestry with silk industry. In the horticulture nursery program, there is seasonal cycle of 3 months so the nursery workers are getting return at 3 months interval. Hence, it is proved that women beneficiaries can generate income through their involvement in plantation. BRAC has established 197 nurseries;

most of these are run by women. In the northern region, about 125 acres of forest land are cultivated by twenty BRAC-organized village groups (10 men's and 10 women's). The women beneficiaries are involved in poultry, cattle rearing, apiculture and other agricultural activities. So, BRAC has shown that given appropriate facilities like credit, seeds, inputs and training, women can participate actively and generate income for the families.

Proshika Experience

Proshika's target groups are landless agricultural laborers and marginal farmers. Most of them are women. Proshika works with participatory approach where group members identify their problems. By investing their savings, the group members get short-term economic return through planting of fast-growing agricultural crops and long-term benefit from trees. Agricultural crops like pigeon pea, sweet gourd, turmeric and sungrass (thatching material) are chosen. Babla, a thorny species is chosen to protect agricultural crops. Through lease from Thana Parishad and Union Parishads, the women members grow pigeon pea and other agricultural crops. Sungrass which can be harvested twice or thrice a year fetches a good income for the beneficiaries. Pigeon pea is also a profitable cash-generating crop. By selling its pods and the plant as firewood, Proshika women members generated Tk. 10,000 net profit per km of road. The plantation and management costs of the agroforestry model of Proshika vary from Tk. 1,500 to Tk. 2,000 per km which is certainly low. According to Proshika experience, women are the better manager of the roadside forestry and homestead plantation. In forest protection also, they have proven their skills. The success of agroforestry depends on the group motivation to protect and manage the roadside plantation. In the designing of agroforestry models, the beneficiaries, especially the women need to be involved. Given the technical assistance regarding spacing, tree-crop combination, credit and freedom in decision making, the women have played important roles in the agroforestry and homestead plantation in Proshika's project area.

Of total 224 nurseries, more than half are owned by women. Proshika is also entering into a collaborative agreement with Forest Department for agroforestry development in Sal forest sites.

Same experiences have been achieved by RDRS, POUSH, Caritas, CARE, Saptagram Nari Swanirvar Parishad, GUP, SCI and other NGO's where agroforestry practices have been adopted with the aim of increasing income of poor rural women. Vegetables like cabbage, gourd, pumpkin are grown between the lines of trees. POUSH has encouraged the cultivation of turmeric in Chokoria, Jhinaigati, Kaliakoir as intercrop.

The women beneficiaries are involved in raising the agricultural crops, and they get benefitted. Under 'Food for Works program,' the caretakers who are responsible for taking care of 550 seedlings get 4.67 kg wheat per head per day for 3 years. So, in this way employment opportunities are created for women. In 1991, POUSH generated over

7,50,000 person-days of employment. RDRS has planted 200,103 trees in 1991, of which 60% are planted by women. NGO's are putting emphasis on choice of local species that play important roles in preserving biodiversity.

ADAB's program aims at skill development of women. With the active support from Winrock and Ford Foundation, it is providing training to women on agroforestry, social forestry and nursery development. Some NGO's have proved that given the appropriate training and access to resources, women can play a more pivoting role in agroforestry.

Despite women's significant contribution to agricultural production and rural households, they have less access to production resources, such as land, capital, credit, technology, information, seeds, tools, fertilizers, water, fuel and training. In our society, girl-child discrimination has put them in vulnerable conditions. Women have less access to and control over economic resources which reduce the productivity of both rural sector and entire national economy. Women in our society are malnourished and burdened with a large number of children. In this situation they have to do extra household work apart from collecting water and fuel. Another striking feature is that as there are less professional women staff in Forest Department and Department of Agricultural Extension, they cannot meet the needs of rural women involved in the participatory agroforestry program.

Recommendations

The possibilities to involve women in agroforestry are limitless. To increase the agroforestry production, women should be more involved for the adoption of new technologies suitable for different agro-ecological zones. The technologies must be diffused among the rural households along with other necessary inputs.

Opportunities should be created for gaining access to natural resources and decision making in the household by women. Once the women can take the leadership in increasing homestead production and can control the resources involved in it, their active role in decision making will automatically come.

Village women are sometimes innovative; so, local technologies should be incorporated in the agroforestry systems, and research should evolve appropriate technologies suitable for meeting the needs of different agro-ecological zones of Bangladesh.

Social security to women working outside home should be ensured. Women's program in both GO and NGO level should be strengthened and coordinated. The extension services should be restructured so that female extension workers can reach rural women. More women should be provided training on livestock, poultry and agriculture to act as role models for women.

Support services like supply of seedlings, irrigation facilities, fertilizers, vaccines and medicines for cattle and pesticides should be provided to women.

Credit should be made available to women at the easiest terms to buy agricultural inputs. Women should be given preference in granting of khas land, lease or permit.

Intensive training should be provided with regard to choice of species, intercrop spaces and others related to agroforestry. Each village should have a demonstration farm for the practical training of local women. Some households should be selected for raising of seedlings, which will minimize the dependence of rural women on outside agencies.

Marketing is the most important sector to sustain agroforestry activities. Proper marketing facilities should be provided to women to sell their homestead agricultural products at local level. If they get the actual benefits from selling the agricultural products, they will be more interested in agroforestry activities.

Integrated farming system should be developed where women should be considered an important component in designing research or extension projects in agroforestry. Explicit strategies should be undertaken to address gender roles in farming to outreach services like extension and training.

It is necessary to develop information and data on agroforestry, and these should be disseminated among rural women through NGO's, women's cooperatives and female extension workers.

The inheritance law discriminates against women. All persons are equal before the law. So, women should be given fair and equal rights to the land, which is the most important productive resources in Bangladesh.

In promoting agroforestry, NGO's should extend their agroforestry program on homesteads and strip lands involving women. NGO's should develop a comprehensive plan with the Land Ministry for khas land agroforestry settlements.

Poor availability of high quality seeds often hampers the program on agroforestry. So, small nurseries involving women should be developed. Regular supply of seeds at local level should be ensured.

According to a report of CIDA Consultant Theodora Carroll Foster on 'Women's Programs and Organizations,' women's project initiated by organizations like Proshika, Saptagram Nari Swanirvar Parishad, BRAC etc. indicates that women are prepared to grow vegetables to learn new rotational cropping etc. Women are prepared to move away from the use traditional implements if given the opportunity.

It is a general observation that women in rural areas are very active and responsive. If motivated properly, they can act as productive labor force to generate income for the households. Women, especially rural women are deprived of education, health and food. Agroforestry is the most vital sector where women can participate actively to generate income. Once the rural women realize the benefits of planting trees in the homestead or croplands, they will be more encouraged to take part in agroforestry activities, and thereby they will take part in sustainable environmental development.

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MANAGEMENT AND MARKETING ASPECTS OF AGROFORESTRY

A. R. SIDDIQUI[1]

Introduction:

Most people recognize the importance of both agriculture and forest production in developing countries. Rapid population growth in many parts of the world has undoubtedly posed many social and economic problems: the need for food, fodder, energy, biomass and wood continue unabated. Though the functional allocation of land for agriculture and forestry exists it does not appear to be capable of meeting this increasing need.

Realizing the conflict between agricultural production and forestry development, there appears interest in adopting agroforestry as an alternative system of land use. The objective of agroforestry is to maximize land use and economic return from land. In the simplest sense, agroforestry refers to any sustainable land use system that combines forest trees and agricultural production including livestock on the same unit of land, either simultaneously or sequentially. This system of land use can produce diversified raw material, crops, livestock and wood products and contributes to stable employment.

Type of Agroforestry System

(1) Forestry - Agronomy

(2) Forestry - Agronomy - Animal Husbandry

(3) Forestry - Agronomy - Fishery

(4) Forestry - Agronomy - Animal Husbandry - Fishery

Management of Agroforestry System:

The success of any program depends on how the program is managed. Even the simple agroforestry system is more complex, ecologically and economically, than a monocropping system, as a result of which the management of agroforestry system bears a very complex character. There are many management constraints which need to be overcome before agroforestry system can be

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economically viable. The raising, establishment, protection and management of tree require skills and sustained effect which are new to many farmers. Different research institutes, extension agencies and non-government organizations can develop programs in order to solve these problems.

Water availability for nurseries, protection of young plants against domestic animals, increased time in managing more than one components and minimization of negative interaction between trees, crops and animals are likely to require additional resource like labor and capital, which may be beyond the means of poor farmers. Credit and aid schemes will contribute to overcome this problem.

Marketing of Agroforestry Products

Except fuelwood, fodder and food, most of the items obtained from agroforestry systems can not be consumed by the producer. These items are produced in small scales, and the producers depend on intermediate agents and processing units for their utilization. Because of unassured prices, high cost of marketing, exploitation by middlemen and lack of processing facility, these commodities are neglected by the farmers.

Present System of Agroforestry marketing in Bangladesh

A. Fruit Trading

The fruit traders in towns purchase fruits from 'beparis' who, in turn, purchase from the farmers. Petty traders and farmers themselves also sell fruits in local markets.

B. Timber Trading

Rural traders purchase trees from owner, fell and log them and sell these to urban timber traders. The urban trader saw the log into usable timber.

C. Fuelwood Trading

There are two types of fuelwood trading. One type is associated with the brick-making business, while the other one is linked with households and restaurants.

The brick kiln owners make contracts with professional fuelwood traders who go around villages and purchase whole-trees and branches of cut-trees.

In the urban areas, saw-mill owners and timber traders sell discarded portions of wood as fuelwood. Some saw-mill owners and timber traders also purchase and sell branches of trees. Besides, fuelwood shops can be seen in urban areas, that purchase fuelwood from saw-mill owners and rural people.

Artisan Enterprises:

There are different types of artisans whose businesses are based on supply of wood from the villages. They are: Karatee, Carpenters, agricultural implement makers, cart-wheel makers, boat makers, makers of bodies of buses and trucks.

Handicrafts Enterprises

Handicrafts are made from tree products. For example, women prepare mat from leaves of khejur trees.

Food Processing Enterprises

"Gur"-marking is a very profitable business in Jessore, Kushtia, Faridpur, Chuadanga, Pabna and Rajshahi. The Juice is tapped and "Gur" is prepared by "Gacchi". A "Gacchi" leases trees from the tree owners. In a tapping season, 200 to 250 kg of juice is obtained per tree from which 25 to 30 kg gur is prepared.

Industrial Raw Material

Trees grown in the villages can be used as raw material in pulp and paper mills, hardboard mills and match factories. The match industry uses 'Kadams" and 'Pituli' for splint-making and "Simul" for box making.

Marketing Strategy

The objective of an ideal marketing network for agroforestry produce should be:

1. Selling at best price
2. Creation of additional demand
3. Reduction in the marketing cost
4. Creation of additional employment

Selling at best price

Proper information about demand and supply, well-planned production program etc. help in better price recovery.

Creation of additional demand

It is possible to create additional demand by developing new products or installing new processing units.

Reduction in marketing cost

Correct information about the demand, direct link between producers and consumers can reduce marketing costs and as a result, market prices.

Generation of additional employment

Installation of processing units will generate additional employment.

ECONOMIC EVALUATION OF AGROFORESTRY

A. R. SIDDIQUI[1]

Necessity of Economic Evaluation of a project

We undertake economic analysis of agricultural projects to compare costs with benefits and to determine which among alternative projects have an acceptable return. The costs and benefits of a proposed project must be identified. Furthermore, once costs and benefits are identified, they must be priced and their economic values be determined.

Costs : Goods and services that reduce the income of farmers (financial analysis) or reduce the national income of the society (economic analysis)

Benefits : Goods and services that increase the income of farmers (financial analysis) or increase the national of the society (economic analysis)

Cost items:
(a) Physical goods
(b) Labor
(c) Land
(d) Contingency allowances
e) Taxes
f) Debt services

Sources of Benefit :
(a) increased production
(b) quality improvement
(c) change in time of sale
(d) change in location of sale
(e) change in product form
(f) cost reduction through better management practices.

Tangible and Intangible Costs and Benefits

Tangible costs and benefits : Costs and benefits that can be quantified and valued.

Intangible costs of benefits : Costs and benefits which can not be easily quantified. If quantified can not be easily valued.

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Approaches of Project Evaluation

"With" and "Without" Approach: Compares the costs and benefits that will arise with the proposed project with the situation as it would be without the project.

"Before" and "After" Approach: Compares the costs and benefits that arise before the project was implemented with the situation as it would be after the implementation of the project.

Types of Projects

X Type : Self-financing projects - Projects which create tangible benefits and benefits go to the investors.

Y Type : Projects which create tangible benefits but the benefits are not enjoyed by the investors but a second party.

Z Type : Projects which do not create any tangible benefits - service sector projects.

Time Value of Money

A bird in hand is worth two in the bush:

Compounding : Determining future value (FV) of present money (PV)

$FV = PV (1+i)^t$
Where i = interest rate
t = time

Calendar year		Amount at beginning of year		One plus interest rate		Amount at end of year (J$)
t_1	1991	817	x	1.08	=	882
t_2	1992	812	x	1.08	=	953
t_3	1993	953	x	1.08	=	1.029
t_4	1994	1,029	x	1.08	=	1,111
t_5	1995	1,111	x	1.08	=	1,200

Discounting:- Determining present value(PV) of Future money(FV)

$$PV = \frac{FV}{(1+i)^t} = FV\,(1+i)^{-t}$$

Calendar year	Amount at end of year		One plus interest rate		Amount at beginning of year
t_5 1995	1,200	/	1.08	=	1,111
t_4 1994	1,111	/	1.08	=	1,029
t_3 1993	1.029	/	1.08	=	953
t_2 1992	953	/	1.08	=	882
t_1 1991	882	/	1.08	=	817
t_0 1990	817				

Cost-Benefit Analysis

An analytical framework for evaluating a program or project through a comprehensive assessment of both the advantages (profits) and disadvantages (costs) that would occur if the program were implemented.

Assumptions of Cost-Benefit Analysis

Cost-benefit analysis makes certain assumptions about the program that is being analyzed. To the extent that these assumptions do not correspond to the assumptions held by the manager, cost benefit analysis is an inappropriate technique.

Impacts

Cost-benefit analysis assumes that all the major or important impacts (costs or benefits) of a project can be identified or described.

Quantification

Cost-benefit analysis assumes that every impact can be measured in a common unit of measure, usually money so that alternatives can be prepared.

Individual Knowledge

Cost-benefit analysis assumes that individuals know the value of program consequences in both the present and the future.

Maximization of the Differences

Cost-benefit analysis assumes that the goal of a program is to maximize the differences between benefits and costs.

Techniques of Cost-Benefit Analysis

On a theoretical level, the techniques of cost-benefit analysis are straight forward and attractive to the decision maker seeking to allocate agency resources efficiently. The steps in a cost- benefit analysis are as follows:

1. Identify the project or projects under consideration as specifically as possible.

2. List all the impacts, both negative and positive, on society both in the present and in the future.

3. Provide a monetary estimate for each identified impact, either positive (benefits) or negative (costs).

4. Calculate the net benefits for the project or for each of the alternative projects by subtracting the total costs per project from the total benefits per project.

5. Make a choice based on the decision criteria that have been established, or present the information to the designated decision maker clearly enough so that he or she can make a decision.

Measures of Profitability of a Project

a) Benefit -Cost Ratio $= \sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t} - \sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}$

b) Net present value: A number representing the current value of potential project after the stream of costs and benefits expected to occur over the project life are discounted and aggregated.

$$NPV = \sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t} - \sum_{t=1}^{t=n} \frac{C^t}{(1+i)^t}$$

c) Internal rate of return: The discount rate that would reduce the present value of a project under consideration to zero.

$$IRR = S + \frac{N}{N+M}(R-S)$$

S= lower limit of Discount

R= higher limit of Discount

N= NPV at lower rate of Discount

M =NPV at higher rate of Discount

Sensitivity analysis

A slight varying of the values of parameters or variables in a model in order to see the effect of such changes on the outcome. Particularly useful when there is uncertainty about the accuracy of the data used for the analysis.

When to accept a project?

a) Accept a project if NPV is positive
" " " DBCR is greater than 1
" " " IRR is higher than the cut-off rate of interest

b) Reject a project if NPV is negative
" " " DBCR is less than 1
" " " IRR is lower than the cut-off rate of interest

A. ESTIMATED COST AND RETURN PER ACRE MATCH WOOD PLANTATION FOR COMMERCIAL PLANTATION

(Block Plantation In the Under-utilized/Unutilized Waste Land, Dhaka Match Factory)

Estimated cost

	Taka
Seedling raising cost @ Tk. 2.00 x 600	1,200.00
Seedling transport and planting @ Tk. 2.00 x 600	1,200.00
Fencing of plantation @Tk. 2.00 x 1260 RF	2,520.00
Weeding costs @ Tk. 500.00 per acre one time x 3	1,500.00
Fertilizers and insecticides @ Tk. 100 x 600	600.00

Organizational cost/acre/yr.*
(1 PO + 1 AO + 10 Supv/100 acre)

- PO @ Tk. 7,000.00, AO @ Tk. 5,000.00,

	3,840.00
FS @ Tk. 2,000.00	
- Establishment cost and other expenses	600.00
Renting of land	3,000.00
Operational and organizational	
expenses in the first year	14,[illegible]20.00 (A)
<u>Second Year</u>	
Renting of land	3,000.00
Weeding 3 times @ Tk. 500.00 x 3	1,000.00
Insecticides @ Tk. 0.50/seedling	300.00
Organizational cost:	
- Personnel costs	3,840.00
- Establishment, fuel and	660.00
Second year operational and	
organization cost	9,300.00(B)
<u>Third Year-Tenth Year</u>	
Renting of land	300.00
Organizational cost:	
- Personnel costs	3,840.00
- Establishment, fuel etc.	660.00
Operational and organizational cost	7,500.00 Tk/Yr.x 8 years
	=60,000.00(C)

Total Costs (1st. year to 10th year) (A + B + C)		83,820.00 Tk/acre/10 years
Cost components (Cumulative)		
Land		30,000.00
Operation		8,820.00
Organization		45,000.00
Total		Tk.83,820.00 Acre/10 years
<u>Estimated Return</u>		
15 cft/tree	10 cft. match wood x 300	3,000 cft.
	5 cft. packing x 300	1,500. cft.
Value of match wood @Tk. 150.00/cft. x 3,00 cft.		450,000.00
Value of packing wood @Tk. 75.00/cft. x 1,500 cft.		112,500.00
Total value		562,500.00

Benefit-Cost Analysis

Year	Cost	Benefit	Discount Factor (10%)	Dis.Cost	Dis. Benefit
0	14,520	-	1.000	14,520	-
1	9,300	-	0.909	8,454	-
2	7,500	-	0.826	6,195	-
3	7,500	-	0.751	5,632	-
4	7,500	-	0.683	5,123	-
5	7,500	-	0.621	4,658	-
6	7,500	-	0.564	4,230	-
7	7,500	-	0.513	3,848	-
8	7,500	-	0.467	3,502	-
9	7,500	562,500	0.424	3,180	2,38,500
Total	83,200	562,500		59,442	2,38,500

BCR = 6.76 DBCR = 4.01

Discounted Cash Flow Chart

Year	Benefits	Discount Factor 15%	Cost	Value of Total Cost	Value of Benefits
0	50000	1000	50000	-	-
1	10000	0.870	8700	20000	17400
2	15000	0.756	11300	30000	22680
3	18000	0.658	11844	36000	23688
4	20000	0.572	11440	40000	22880
5	20000	0.497	9940	40000	19880
6	20000	0.432	8640	40000	17280
7	20000	0.376	7520	40000	15040
8	20000	0.327	6540	40000	13080
9	20000	0.284	5680	40000	11360
10	20000	0.247	4940	40000	9880
Total				136544	173168

NPV = 173,168 - 136.544 = 36,624

$$BCR = \frac{173,168}{136,544} = 1.27$$

Internal Rate of Return

Years	Total Cost	Discount Factor 35% of Cost	Discount Value of Benefit	Benefit	Discount Value
0	50,000	1.000	50,000	-	
1	10,000	0.741	7,410	20,000	14,820
2	15,000	0.549	8,235	30,000	16,470
3	18,000	0.406	7,308	36,000	14,616
4	20,000	0.301	6,020	40,000	12,040
5	20,000	0.223	4,460	40,000	8,920
6	20,000	0.165	3,300	40,000	6,600
7	20,000	0.122	2,440	40,000	4,880
8	20,000	0.091	1,820	40,000	3,640
9	20,000	0.067	1,340	40,000	2,680
10	20,000	0.050	1,000	40,000	2,000
Total			93,333		86,666

NPV = 86,666 - 93,333 = - 6667

Using the formula we get the following value of IRR :

$$15 + \frac{36,624}{36,624 + 6667}(35 - 15) = 15 \frac{36,624}{43,241} \times 20$$

IRR = 31.92

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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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