CLASS NOTE
OF
SFB 602: AGROFORESTRY

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Unit 1: Introduction

1. Historical Development of Agroforestry in the World and in Nepal

Agroforestry practices are traditional, very old, and very specific to the local social, economic and agroecological conditions. The farmers, graziers, and forest dwellers have an intimate knowledge of these traditional practices. **1)** History of agroforestry dates back to almost 1700 years ago in parts of China. **2)** In Europe until the middle ages, forests were clear felled and burn the slash, and cultivate food crops. **3)** This practice followed in Finland in the 18th century, and was practiced in some part of Germany until 1920s. **4)** In tropical America, multistory agroforestry system was practiced, where coconut with lower layers of papaya, banana or citrus fruits and shrub layers of coffee and maize were grown. **5)** In southern Nigeria, yam, maize, pumpkins and beans were grown under scattered trees from the beginning of human settlement. **6)** In Philippines, a complex and sophisticated systems or types of shifting cultivation were practiced. **7)** At the end of 19th century, forest plantation has been established adopting agroforestry systems, which is known as Taungya agroforestry system. **8)** This system was first started from Burma in 1850s, where teak (*Tectona grandis*) plantation areas were given to shifting cultivators to grow agriculture crops. **9)** Taungya agroforestry has been adopted widely in South Asia in 1890s. **10)** In present Bengladesh, plantation was established adopting Taungya approach in between 1887 to 1890s, where as this in West Bengal of India in 1896.

Internationally, **11)** the International Development Research Centre (IDRC), Food and Agriculture Organization (FAO) and Swedish International Development Authority (SIDA) have initiated research in agroforestry. **12)** The International Centre for Research in Agroforestry (ICRAF) has been established in 1977 for agroforestry research and extension, and its head office is in Nairobi, Kenya.

In Nepal, **13)** agroforestry is a method of farming that allows trees and shrubs to grow along with crops and/or livestock, therefore blending agriculture and forestry in the same production system. It is a traditional practice, where fodder, fire wood and timber species are grown along terrace bunds, borders and slopes. **14)** Shifting cultivation is also found commonly in Nepal until now.

15) Taungya agroforestry practice was first started in Nepal in 1972 in Tamagadhi of Bara district, where forest areas encroached by the hill migrants were planted and given to encroachers to grow agriculture. The main aim of this practice was to protect remaining forests from encroachment. **16)** After that Terai Community Forestry Development Project and Sagarnath Forestry Development Project have also practiced this system in large scale from 1983 to 1992. These projects have given plantation areas (generally 1 ha for one family) for poor farmers living around for 4-5 years on simple agreement to grow agriculture crops without any damage to trees. Farmers were responsible to replant seedlings when planted trees were damaged during growing crops in Taungya plots.

17) Traditional agroforestry farming system of Nepal includes growing of trees, agriculture crops and livestock for the purpose of subsistence livelihood, which is gradually replaced by the cash crops. **18)** Farmers have started cultivating cash crops such as cardamom under Uttis (*Alnus nepalensis*), ginger and turmeric under tree shade and home gardens, and coffee under Ipil Ipil (*Leucaena leucocephala*) and shade trees, and tea under Sissoo (*Dalbergia sissoo*) and Siris (*Albezzia spp*), vegetables, and fruits (orange, banana, papaya, mango, apple etc) for

commercial purposes. These changes in crops and cropping pattern have changed the agricultural landscape and environment resulting to agricultural evolution.

Nepal Agricultural Research Council (NARC), Department of Forest Research and Survey (DFRS), Nepal Agroforestry Foundation (NAF)/ Kathmandu Forestry College (KAFCOL), Institute of Forestry (IOF) and other I/NGOs are promoting agroforestry research and extension work in Nepal.

2. Definition and basic concepts of agroforestry

Agroforestry is a traditional practice in Nepal, where trees and agriculture crops are grown together. This practice differs in socio-economic condition of the farmers and ecological zone of the country. Based on ecological zones, Nepal can be divided into three parts: the high Himalayas in the north covering 24% of the total area; the lower hills, siwalik and mountain slopes in the centre consisted 56%; and Terai and inner Terai in the south at an elevation below 300 m from the sea level covered 20% of the total lands.

Agroforestry has three components that are forestry, agriculture and livestock/fodder and forage. The combination of these components is known as agroforestry. However, the definitions of agroforestry given by various scientists and institutions are as follows:

- ICRAF (1982) defined agroforestry system as a land use system that integrates trees with agriculture crops, and or animals simultaneously or sequentially to get higher productivity, more economic returns and better social and ecological benefits on a sustainable yield basis than are obtainable from mono-culture on the same unit of land, especially under conditions of low levels of technological inputs on marginal sites.

- A collective name for land use systems and technologies where woody perennials (trees, shrubs, palm, bamboo etc) are deliberately used in the same land management unit as agriculture crops and or animals either in same form of spatial arrangement or temporal sequence (Lundgren and Raintree, 1983).

- In simple word, agroforestry is a science that combines trees and agriculture crops (food, fruit, vegetables, fodder and forage etc) together in the same land at the same time.

- Agroforestry is form of land use that successfully satisfies the needs of the crop farmers, foresters and or stock farmers.

Principles of Agroforestry

- **Productive-** Agroforestry systems have **c**apacity to produce food crops, fruits, leaf litter, timber, fuel wood, and fodder for livestock.
- **Protective-** Agroforestry helps to minimize the degradation of the farm lands and other natural resource by working as shelterbelt.
- **Ameliorative-** Agroforestry systems with legume trees and crops help to maintain or improve the productivity of the land.
- **Livelihood improvement-** Income can be generated from the sale of forest and agriculture products.

Characteristics of agroforestry systems

- Involves two or more species of plants (plants or animals) at least on of which is woody perennials.
- Always have two or more outputs.
- Cropping cycle is always longer than one year.
- Ecologically and economically complex system than a mono-cropping.
- Significant interaction between woody and non-woody components of the system.
- Efficient use of available resources.
- Improve local environment.
- Finally, income generation from the sale of agroforestry products.

Objectives of agroforestry

- To maximize the overall production of food/fruits, woody crops and fooder and forage including livestock per unit area.
- To provide support for the conservation of soil, water and other resources including soil productivity.
- To improve local environment.
- To enhance the socio-economic condition of the farmers.
- Finally, to improve the livelihoods of the farmers.

3. Scope or benefit or importance of agroforestry

Scope of agroforestry in Nepal is wider because it has direct effect on socio-economic condition of the farmers and their surrounding environment, which is as follows:

Economic benefits

- Produce multiple products to meet growing demand of increasing human population and livestock. These products are food/vegetables/fruits, fodder and forage needed for livestock, fuel wood, timber, leaf litter needed for organic manure production and other NTFPs.
- Agroforestry practice is needed to minimize total crop failure when farm is attacked by insects, pests and diseases.
- Improve and sustain the crop productivity which increases the level of income of the farmers.
- Improve the nutritive value of animal and human diet.
- Agroforestry is the best practice for soil nutrient recycling, which also helps to reduce chemical fertilizer purchase.

Social benefit

- Improving the living standard the farmers through sustained agroforestry yield, income and employment.
- Access of health, education, and other social services of the farmers could be improved due to the regular income and employment opportunities.
- Majority of the Nepalese farmers have less than 1 ha farmland and increasing population requires more food, fuel wood, fodder and forage, and timber. To meet these demands, agroforestry is the only one option for our country.

- Agroforestry farmer groups could be formed easily involving farmers practicing agroforestry practices, and their capacity can be built up easily.
- This is a traditional practice in Nepal. Therefore, farmers can be motivated and empowered easily.

Environmental benefit

- Agroforestry practice helps to stabilize shifting cultivation which leads the protection of the remaining forests.
- Improve the farm site ecology by reducing surface run off, soil erosion and nutrient loss, gully formation, landslides, and river bank erosion.
- Improve the local micro-climate and enhance the productive capacity of the farm.
- Reduce pressure of community forests and other natural forests for fodder, fuel wood and timber.
- Agroforestry helps for the beautification of the surrounding areas.
- Agroforestry works as carbon sequesters, which helps to reduce the effects of climate change.

Highly productive agroforestry systems such as silvi-pastoral system can play an important role in carbon sequestration in soils and in the woody biomass. For example, traditional cattle management involves grass monocultures which degrade in about 5-7 years after establishment, releasing significant amounts of carbon to the atmosphere. Veldkamp (1994) estimated that the cumulative net release of CO_2 from low productivity pastures (Axonopus compressus) varied from 31.5 to 60.5 Mg C/ha in the first 20 years after forest clearing. Well managed silvopastoral systems can improve overall productivity (Bustamanate et al., 1998; Bolivar et al., 1999), while sequestering carbon (López et al., 1999; Andrade, 1999), a potential additional economic benefit for livestock farmers. Total carbon in silvopastoral systems varied between 68-204 t/ha, with most carbon stored in the soil, while annual carbon increments varied between 1.8 to 5.2 t/ha.

The amount of carbon fixed in silvi-pastoral systems is affected by the tree/shrub species, density and spatial distribution of trees, and shade tolerance of herbaceous species.

Disadvantages of agroforestry

- Increase tree and agriculture crop competition for light, nutrient and space.
- Plant nutrient deficiency due to the over absorption.
- Amount of plant nutrient needed for crop produced increased due to the tree crop competition.
- Nutrient availability in under storey crops reduced due to the tree shade.
- Habitat to wild animals
- Damage to trees and crops from wild animals.
- Allelopathy effects.
- Damage to trees and crops from cultivation and tree harvest.
- There is huge possibility for soil erosion during tree harvesting in sloppy lands.
- Habitat or alternative hosts for insects, pests and diseases.

Socio-economic disadvantages or limitation

- Require more labour inputs.
- Crop yield reduced due to the tree crop competition.
- Longer period may be required for trees to grow and mature.
- High possibilities for replacing food crops by trees.
- Complexity for practicing agroforestry systems to farmers compared with mono-cropping.
- More financial resource needed to follow agroforestry practice properly.

Strategy to over come limitation

- Select legume trees with light crown covers to reduce tree crop competition.
- Select deep rooted trees.
- Trees should be planted in wider space.
- Select appropriate under storey crops such as turmeric and ginger in heavy trees shade, cardamom under Uttis trees etc.
- Manage trees adopting following practices:
    - Singling, pruning and thinning for timber species
    - Lopping, pollarding and coppicing for fodder species.

Relation of Agroforestry with other disciplines

1. Forestry

Forestry and agroforestry have close relationship because

- Agroforestry is a branch of forestry science.
- Woody perennial trees are common in both sciences and land use system.
- Forestry has mainly monoculture of natural occurrence, where as agroforestry is a polyculture and has been integrated with trees.
- Both practice supply similar forest products like fodder, fuel wood and timber, and other NTFPs.
- Agroforestry helps to protect forest by reducing dependency on forest for the supply of the main products.
- Knowledge of forestry and silvics of different species gained from forestry science can be applied in agroforestry system development and management.
- Similarly, knowledge and skills on tree management gained from agroforestry can be applied in forestry.

2. Agriculture

Agriculture and agroforestry have close relationship because

- Both land use systems include agriculture crops.
- Tree products like fodder, leaf litter and poles are required for agriculture activities.
- Trees, livestock and agriculture crops have strong linkages and interrelationship.
- Tree products like fodder and leaf litter obtained from agroforestry are one of the main sources of organic or compost manure which is fundamental components for sustaining the farming system.
- Legume trees grown in agroforestry system help to improve soil productivity by fixing atmospheric nitrogen into the soil, which provide support to increase

agriculture production.
- Trees grown in agroforestry plots work as shelterbelt for agriculture crops.
- Knowledge and skills on agriculture crops gained from agriculture science can be applied in agroforestry system development and management.
- Similarly, knowledge and skills on agriculture crops gained from agroforestry science can be applied in agriculture system development and management.

3. Social forestry

Social forestry and agroforestry have close relationship because
- Both sciences have woody perennials trees.
- Both systems need trees for sustaining the farming systems.
- Both sciences have two fold relationships that are vertical and horizontal relationship because agroforestry is a part of social forestry with vertical relationship, and both social forestry and agroforestry involve farmers and have horizontal relationship.
- Social forestry passes research results to farmers and its feedback to the agroforestry scientists.

Unit 2: Description and Analysis of Different Agroforestry Systems

1. Farming System in Nepal

Farming systems are a complex combination of inputs managed by farming families for obtaining the outputs from a land, which is influenced by environmental, political, economic, institutional, and social factors. In other word, it is the complex combination of all of the factors that influence the farm and its productivity.

Types of farming system

The main farming system of Nepal is irrigated and dry land farming, which are discussed below:

1. Dry land farming

Dry land agriculture is common under conditions of moderate to severe moisture stress during a substantial part of the year, which requires special cultural techniques and crops and farming systems adapted for successful and stable agricultural production.

Pastoral system is also an important part of dry land agriculture. Dry land farming emphasizes water conservation in all practices throughout the year.

2. Irrigated farming

The irrigated farming system is quite complex because in many cases, irrigated cropping is combined with rainfed cropping or animal husbandry. Full and or partial water control is needed to manage irrigated farming system. Livelihoods are vulnerable to irrigation scheme breakdowns and deteriorating input/output price ratios. Major constraints include soil acidity

problems due to the application chemical fertilizers, scarcity and quality of water resources in rainfed regions and excessive water in humid zones during rainy season.

Trees in farming systems

Large number of fodder, fuel wood and timber species are incorporated on farms of Nepal. These trees are maintained in contour strips across the slope and around the field. The contribution of these trees is the production of fodder, fuel wood and timber. Trees in principle enhancing natural biological processes above and below the ground, the integrated system represents a winning combination that (1) reduces erosion; (2) increases crop yields, soil biological activity and nutrient recycling; (3) intensifies land use, improving profits; and (4) can therefore help reduce poverty and malnutrition; and (5) strengthen environmental sustainability.

Change in farming systems

Traditional farming system of Nepal includes growing of cereal crops and livestock for the purpose of subsistence livelihood, which is gradually replaced by the cash crops. Farmers have started cultivating cash crops such as cardamom, ginger, broom-grass, vegetables, and coffee, orange and dairy cow/buffaloes for commercial purposes. These changes in crops and cropping pattern have changed the agricultural landscape and environment resulting to agricultural evolution.

2. Principles of classification of agroforestry system

The main purpose of agroforestry system classification is: 1) to arrange agroforestry system in logical groups based on production. 2) agroforestry management system improvement, 3) flexibility in regrouping the information and 4) to make easy for understand and readily handled.

Principles of agroforestry system classification

The most common criteria's for the classification of agroforestry systems are the structural basis, in which components of agroforestry (forestry, agriculture and livestock) are combined. Other criteria's include its function, socio-economic scale and management level and ecological basis.

The major agroforestry systems of the High Mountain and mid-hills of Nepal are home gardens, agri-silviculture system (planting trees along terrace bunds, borders and slopes), silvi-pastoral system (kharbari), agri-silvi-pastoral system (typical hill farming, in which agriculture crops are grown on terrace flat, trees on terrace bunds and borders, and grasses on terrace slopes-kanla), and alley cropping, where as this in Terai and inner Terai are home gardens, agri-silviculture system, silvi-pastoral system, horti-silviculture system and silvi-fishery or aqua-silviculture. Taungya agroforestry system was also practiced in Terai and inner Terai of Nepal for plantation establishment. Shelter belt establishment and management practice is common in fruit orchard of Terai and inner Terai of Nepal. Apiculture, sericulture, and shifting cultivation can also be considered as minor agroforestry systems.

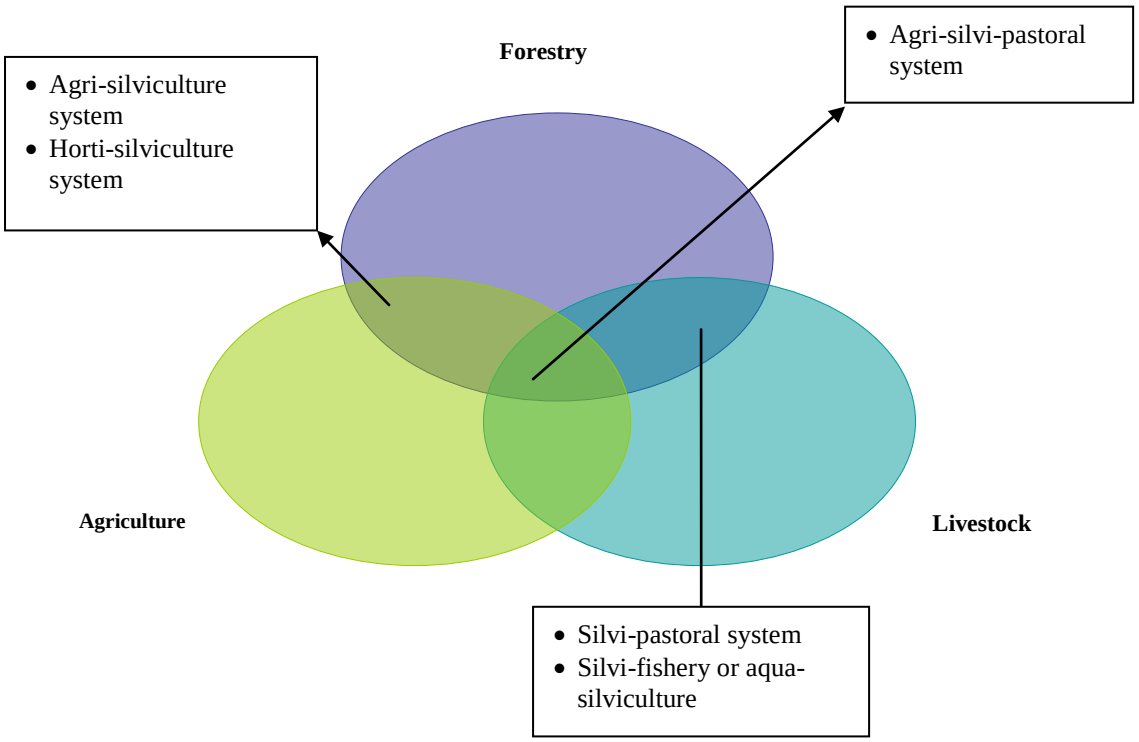
According to Nair (1987), following are the main principles or criteria's for agroforestry system classification:

1. Structural basis

It refers to the composition of components such as forestry, agriculture and livestock. This component composition can be in time (temporal or short duration and long duration) and space (dense or spatial), and other terms are used to justify the various arrangement made for system development.

- Considers the composition of components including spatial and mixture of the woody components.
- Vertical stratification of the components mix and temporal arrangement of the different components.
- The spatial arrangement of trees in agroforestry system can be categorized as mix dense (like in home garden), mix sparse (like in pasture land or Kharbari), strip of trees, and boundary plantation.

The main agroforestry systems under components composition are as follows:



1.1. Agri-silviculture system

It is defined as growing of trees and agriculture crops together in same lands at the same time. This system is common in all agro-ecological zones of Nepal, where agriculture crops are grown in terrace flat and trees are grown in terrace bunds, borders and slopes. Trees grown in different regions are Terai (Sissoo, Eucalyptus, Baikaino, Ipil IPil etc) hill (Mainly fodder trees such as Badahar, Tanki, Koiralo, Ipil-Ipil, Mulberry etc) and mountain (fodder trees such as Gogan, Dudhilo etc.

The main advantages of this system are as follows:

- Produce multiple products such as food/vegetables/fruits, fodder and forage needed for livestock, fuel wood, timber, and leaf litter needed for organic manure production.
- Improve and sustain the crop productivity which increases the level of income of the farmers.
- Improve the nutritive value of animal feed due to the supply of green fodder..
- This is also the best practice for soil nutrient recycling, which also helps to reduce chemical fertilizer purchase.
- Improve the farm site ecology by reducing surface run off, soil erosion and nutrient loss, gully formation and landslides.
- Improve the local micro-climate and enhance the productive capacity of the farm.
- Reduce pressure of community forests and other natural forests for fodder, fuel wood and timber.
- This practices helps for the beautification of the surrounding areas.

Inter cropping practices can also adopt in this system in plain areas where trees should be grown maintaining rows to rows distance (5 meters) and plant to plant distance (2-3 meters). Management operations such singling, pruning and thinning in timber species and lopping, coppicing and pollarding in fodder species should be applied to reduce shading effects of trees on agriculture crops.

1.2. Silvi-pastoral system

This system can be defined as growing of trees and grasses or forage species together in same lands at the same time. This system is common in all agro-ecological zones of Nepal, where land is marginal for crop production. In mid-hilly region, land having grasses is known as kharbari. Trees grown in Kharbari in different regions are Terai (Sissoo, Eucalyptus, Ipil Ipil etc) hill (Mainly fodder trees such as Badahar, Tanki, Koiralo, Ipil-Ipil etc and timber species like Chilaune) and mountain (fodder trees such as Gogan, Dudhilo, Khasru etc.

The main advantages of this system are as follows:

- Produce multiple products such as fodder and forage needed for livestock, fuel wood, timber, and leaf litter needed for organic manure production.
- Improve and sustain the livestock productivity which increases the level of income of the farmers.
- Improve the nutritive value of animal feed due to the regular supply of green fodder.
- This is also the best practice for soil nutrient recycling, which also helps to reduce chemical fertilizer purchase.
- Improve the farm site ecology by reducing surface run off, soil erosion and nutrient loss, gully formation and landslides.
- Improve the local micro-climate and enhance the productive capacity of the farm.
- Reduce pressure of community forests and other natural forests for fodder, fuel wood and timber.
- This practices helps for the beautification of the surrounding areas.

1.3. Agri-silvi-pastoral system

Growing of trees, agriculture crops and grasses together in same lands at the same time is known as agri-silvi-pastoral system. This is typical hill farming system of Nepal, in which agriculture crops are grown in terrace flat, trees in terrace bunds, border and slopes and grasses in terrace slopes, and some farmers have been growing improved legume and non-legume grasses such as Mott napier (*Pennisetum purpureum*), Setaria (*Seteria splendida*), Mulato (*Brachiaria brizantha x B. ruziziensis*) and Forage peanut (*Arachis pinotoi*) along terrace bunds and borders.

The main advantages of this system are as follows:

- Produce multiple products such as food/vegetables/fruits, fodder and forage/grasses needed for livestock, fuel wood, timber, and leaf litter needed for organic manure production.
- Improve and sustain the crop productivity which increases the level of income of the farmers.
- Improve the nutritive value of animal feed due to the supply of green fodder.
- This is also the best practice for soil conservation and soil nutrient recycling, which also helps to reduce chemical fertilizer purchase.
- Improve the farm site ecology by reducing surface run off, soil erosion and nutrient loss, gully formation and landslides.
- Improve the local micro-climate and enhance the productive capacity of the farm.
- Reduce pressure of community forests and other natural forests for fodder, forage/grasses, fuel wood and timber.
- This practices helps for the beautification of the surrounding areas.

1.4. Horti-silviculture system

This system is defined as growing of trees and fruit trees or ornamental trees or vegetables/flower together in same lands at the same time. This system is common in Terai and Inner Terai of Nepal, where trees such as Sissoo, Eucalyptus, Baikaino, Ipil IPil etc are grown around fruit orchard that act as shelter belt.

The main advantages of this system are as follows:

- Produce multiple products such as fruits, fodder and forage needed for livestock, fuel wood, timber, and leaf litter needed for organic manure production.
- Fruits and vegetables grown under this system increase the level of income of the farmers.
- Trees grown around fruit gardens also provide extra-income.
- This is also the best practice for soil nutrient recycling, which also helps to reduce chemical fertilizer purchase.
- Improve the farm site ecology by reducing soil erosion and nutrient loss.
- Improve the local micro-climate and enhance the productive capacity of the farm.
- This practices helps for the beautification of the surrounding areas.

1.5. Agri-horti-silviculture

This system is defined as growing of agriculture crops, trees and fruit trees or ornamental trees or vegetables/flower together in same lands at the same time. This system is common in

home gardens of mid-hills, Terai and Inner Terai of Nepal, where fodder trees such as Badahar, Tanki, Ipil Ipil etc and timber and fire wood species such as Sissoo, Eucalyptus, Baikaino, etc are grown around fruit orchard that act as shelter belt, and agriculture crops such as ginger, turmeric, yam, colocassia and vegetables are grown under fruit trees.

The main advantages of this system are as follows:

- Produce multiple products such as food, fruits, fodder and forage needed for livestock, fuel wood, timber, and leaf litter needed for organic manure production.
- Improve and sustain the livelihoods of farmers by increasing the level of income through the sale of fruit/vegetables.
- Trees grown around fruit gardens also provide extra-income.
- This is also the best practice for soil nutrient recycling, which also helps to reduce chemical fertilizer purchase.
- Improve the farm site ecology by reducing soil erosion and nutrient loss.
- Improve the local micro-climate and enhance the productive capacity of the farm.
- This practices helps for the beautification of the surrounding areas.

1.6. Silvi-fishery or aqua-silviculture

Growing of trees around fish pond is known as silvo-fishery or aqua-silviculture. In this system, trees and fruit trees are being planted along the embankment of the fish pond. This system is popular in Terai and inner-Terai of Nepal, where trees and fish included in the same system.

Tree species grown along the embankment of fish pond are Sissoo, Eucalyptus, Bakaino, Ipil-ipil etc and fruit species are Banana, Papaya and Pineapples.

Some farmers also included duck and pigs in aqua-silviculture systems. The main advantages of this system are as follows:

- Produce multiple products such as fish, fruits, fodder, fuel wood, timber, and leaf litter.
- Improve and sustain the fish and fruit productivity which increases the level of income of the farmers. Extra income can also be generated from trees, fruits ducks and pigs.
- Improve the farm site ecology by reducing soil erosion and nutrient loss.
- Improve the local micro-climate creating cool environment to fish during summer season.
- This practices helps for the beautification of the surrounding areas.
- Leaves, flowers, and fruits fallen into the fish pond can provide food to fish.

1.6. Apiculture

- This is combination of trees and bees.

1.7. Sericulture

Growing of mulberry trees for silk production is known as sericulture, in which mulberry leaves are used to feed the silk worm at larva stage for the production of silk. The cocoon of the silk worm is harvested for reeling the silk.

1.8. Agroforestry system with reference to plantation crop practice of tea, cardamom, coffee and medicinal plants in Nepal

Many farmers view shade as a challenging situation for growing plants. While some plants do not grow well in low light, numerous others thrive under these conditions. Just as moisture, temperature, and soil conditions may limit plant growth, the amount of shade present may determine which plants will grow successfully. Tea, cardamom, coffee etc are shade loving plants.

Tree shade can be divided into three categories that are light, medium and full shade, which are described below:

Light shade may be described as an area that is partially shaded. It may be shaded for only few hours each day. The sun's rays may be blocked by tree canopy for several hours at midday or early in the morning etc, but the area is sunny the rest of the day.

Light shade may also be found in areas that receive filtered or dappled sunlight for longer periods. Edges of shady areas under the canopy of solitary, lightly branched trees are typical of filtered sunlight. During the heat of summer, light shade at midday will provide a beneficial cooling effect. Flower and foliage color may be more brilliant when plants are shielded from intense midday sunlight.

Partial or **medium shade** is present when direct sun rays are blocked from an area for most of the day. Many established landscapes have large areas of partial shade, where sections of the yard are shaded by mature trees for much of the day but receive some direct sun early or late in the day. Bright, north-facing exposures may also be classified as medium shade.

Tea, coffee and cardamom are light to medium shade tolerant crops. In eastern Nepal, cardamom is planted as an under storey with Uttis (*Alnus nepalensis*) trees. Similarly, Siris (*Albezia spp*) and Sissoo (*Dalbergia sisssoo*) trees are planted for providing shade to tea, and Ipil Ipil (*Leucaena leucocephala)* is the best trees for providing shade to coffee plants. Medicinal plants such as Chiraito (*Swertia chirayita)* can also be grown successfully under light to medium tree shades.

Full shade lasts all day. Little or no direct sunlight reaches the ground at any time of the day. There may be reflected light from sunnier areas of the yard or off light-colored walls. Dense shade refers to full shade under thick tree canopies or in dense groves of trees.

Some forage (Desmodium- *Desmodium intortum* and forage peanut - *Arachis pinotoi* and horticulture crops such as ginger (*Zingiber officinale*), turmeric (*curcuma longa*), yam (*Dioscorea spp*) etc can be grown well under full to medium shade.

Plants growing in the shade must compete with shading trees for nutrients and water, and tolerate poor air circulation.

Agroforestry systems under temporal arrangement of different components

The main agroforestry systems under temporal arrangement of the different components are shifting cultivation and Taungya agroforestry practices. In these systems, agriculture crops are grown for few years (2-3 years), and then Taungya agroforestry plot developed as forest and shifting cultivation areas left as degraded lands. In some hilly districts of Nepal, such

degraded forest lands have been handed over to Leasehold Forest User Groups (LFUGs) as leasehold forests.

1.9. Shifting cultivation

This is a low input agriculture practice and fallow management which is common practice in Asia. This system also know as slash and burning agriculture, in which forest land is cleared through cutting and burning for agriculture. In this system, few big trees are left as such for shade.

After clearing the forest lands, farmers carry out tillage operation and land preparation, and then sow crop seeds.

Generally, farmers grow agriculture crops in such lands for 2-3 years. When crop production decreased due the lack of plant nutrients into the soil, farmers move to another areas and then start to continue same practice of agriculture.

Advantages of shifting cultivation

- Weed control.
- Easy methods for clearing forest lands for agriculture.
- Suitable for root crops, and crops like banana.
- Farmers get food, fruits and income.
- It also gives employment opportunity for farmers for short period.

Disadvantages of shifting cultivation

- Increase soil and soil nutrient loss.
- Soil nitrogen will be lost by burning.
- Low input in long run.
- Soil erosion occurs in sloppy areas.
- Biodiversity lost due to burning and tillage operations.
- Silt eroded from shifting cultivation areas will be accumulated in low lying areas.
- Land degradation and other environmental problems increased.

1.10. Taungya agroforestry

Taungya is Burmese words which means (Taung = hill and ya = cultivation) hill cultivation. But this system is well adopted in plain areas of Myanmar, Bangladesh, India and Nepal. In 1850s, Burma has established teak plantation using Taungya method of agroforestry, in which poor farmers (shifting cultivators) were given teak plantation areas for agriculture crop production.

This practice also adopted by India in West Bengal in 1890s, where shifting cultivators were given plantation areas for agriculture crop production until tree canopy closed. After that farmers were shifted in another area.

This practice consists of land preparation, tree planting and growing of agriculture crops for 2-3 years until the shade become too dense. In some areas, crops were grown one year before tree planting.

In Nepal, this system has been started in 1972 at Tamagadhi of Bara district, which was encroach by migrants from the hills. To protect remaining forests from encroachment, the Taungya system of agroforestry was practiced. After that Terai Community Forestry Development Project and Sagarnath Forestry Development Project have also practiced this system in large scale from 1983 to 1992. These projects have given plantation areas (generally 1 ha for one family) for poor farmers living around for 5 years on lease to grow agriculture crops with out any damage to trees.

Advantages of Taungya agroforestry

- High tree growth and survival rate due to the care and addition of organic matter into the soil by Taungya farmers..
- Problems of unemployment are reduced for short time.
- Maximum utilization of plantation areas.
- Low cost methods for plantation establishment (weeding costs and protection costs reduced).
- Fire hazard reduced.
- Food crops obtained from plantation areas.
- Weeds and tree climbers controlled.
- Some farmers have generated income from the sale of vegetables grown in plantation areas.
- People's participation in plantation establishment and management increased.
- Easy for the formation of community forest user groups.
- Good relation of forestry field staff with local farmers.

Disadvantages of Taungya agroforestry

- Danger of epidemics diseases to both trees and crops due to agriculture practices. Both trees and agriculture crops work as alternative hosts to insects, pests and diseases.
- Loss of soil nutrients due to the exposure of soils.
- Legal problems.
- Susceptibility of lands to accelerated soil erosion in sloppy areas due to the cultivation practices to grow agriculture crops.
- Damage to young trees during tillage operation.

2. Functional basis

It refers to the major function or role of the system mainly of the woody components of agroforestry system. These functions can be productive, which means production of fuel wood, fodder, timber and leaf litter etc, protective means shelterbelt, wind break and soil conservation etc and ameliorative means soil fertility improvement. The main agroforestry system, which has protective function, is as follows:

2.1. Shelterbelt and wind break

A shelter belt is defined as a belt of trees and or shrubs maintained for the purpose of shelter from hot, dry and cool wind, sun and snow drift to agriculture crops, fruits, livestock and farm houses etc. Shelter belts are also called protection belt which covers larger areas than wind breaks.

Wind break is defined as any obstacle that reduces wind velocity. These obstacles could be stone wall and or strips of living trees and shrubs to provide shelter to agriculture crops, fruits, livestock and farm houses etc from hot, dry and cool wind, sun and snow drift.

Tree shelter belt can improve crop yields at the same time provide valuable timber and other non-timber forest products.

In Nepal, shelter belts and or wind breaks are maintained in Terai and inn- Terai areas where strong hot and dry wind damage agriculture crops and fruits.

For the establishment of effective shelter belts or wind breaks, 1-2 rows of trees are planted at 1-2 meters row to row distance and 2-3 meters plant to plant distance maintaining 35-50% porosity from top to bottom.

Tree species selected for shelter belt should be easy to propagate and plantation establishment, deep rooted, nitrogen fixing, well branched with straight stem, moderate to dense wind breaking capacity, produce high demanding valuable products and have good shelter providing capacity etc.

Eucalyptus camaldulensis, Casuarinas equisellifolia, Dalbergia sissoo, Acacia auriculiformis, Melia azedarac, Leucaena leucocephala and *Bambusa* species are planted as wind break and or shelter belt. In temperate countries like New Zealand pine species also used for establishing wind breaks or shelter belt.

Function of wind break and shelter belts

- Protecting agriculture crops, fruit trees and fruits, and livestock from hot, dry and cool winds, sun and snow, and then improving their productivity.
- Providing shelter to houses and other farm construction.
- Controlling strong wind to reduce its damage.
- Improving surrounding environment and moderating micro-climate.
- Controlling wind erosion and shifting sand dunes in arid areas.
- Providing fodder, fuel wood and timber from which farmers can generate more income.
- Diversification of farm income.
- Legume trees improve soil fertility.
- Improving aesthetic value and generation of recreation areas.

3. Socio-economic basis

Agroforestry system under this category can be classified based on 1) level of inputs for management such as high inputs (agro-silviculture) and low inputs (silvi-pastoral system and shifting cultivation), 2) intensity or scale of management, and 3) commercial goals. These commercial goals for agroforestry system classification are as follows:

- Subsistence goal used by farmers (home gardens)

- Intermediate goals used by government (Taungya agroforestry system) for plantation establishment in low cost.
- Commercial or large scale production by private company.

3.1. Home gardens

Home gardens are established near home for their food, vegetables, fruit and fodder production, for aesthetic and ornamental values and for religious purposes. It is multistory types in which fodder or timber trees, fruit trees, and vegetables are grown together. This system is common in both hills and Terai belt of Nepal.

Poor farmers in home garden like to grow more food crops and vegetables, while rich farmers plant and grow more ornamental trees and fruit trees.

Tallest trees (Sissoo, Eucalyptus in Terai and Inner Terai, coconut and nut trees also included in Jhapa district and fodder trees in hills) of this system are strong light demander and middle storey trees are moderately shade tolerant fruit trees. At the ground level vegetables and other herbaceous shade tolerant crops like ginger, turmeric, chilly, pine apple, coffee, cardamom etc) are grown under tree shade.

Home garden with fodder (*Ficus spp*) and fuel wood (Bakaino etc) species is common in those areas where natural forests has been destroyed or exhausted long time ago. The main advantages of home gardens are as follows:

- Produce diversify products such as vegetables/ food/fruit, spices, fodder and timber.
- Nutritive value of farmer's diet is increased.
- Farmer can generate income from the sale of surplus vegetables.
- Labour has been highly efficient due to proximity of farmer's residence.
- Agroforestry products can be obtained throughout the year.
- Favorable environment can be created for the farmers through provision of shade, wind breaks and privacy.

Disadvantages:

- Habitat for insects, pests (snakes and rodents) and diseases.
- Primitive form of subsistence land use.

4. Ecological basis

It refers to the environmental condition and ecological suitability of systems, based on the assumption that certain types of systems can be more appropriate for certain ecological conditions; i.e., there can be separate sets of agroforestry systems for arid and semiarid lands, tropical highlands, lowland humid tropics, etc.

Agroforestry systems found in low lands and high altitude are shelterbelt and wind breaks. This system is also useful for arid or semi arid regions.

Ecologically, agroforestry needs to be practiced for the protection of crops, fruits, soil and other resources from cold and dry winds, extreme heats and snow, and water.

It also improves ecosystems, increases landscape diversity, and creates additional wildlife habitats. The best systems under this ecological consideration are shelter belts, multi-storey agroforestry system, alley cropping and mix intercropping. The main description of multi-storey agroforestry, alley cropping and mix intercropping are as follows:

4.1 Multistory agro-forestry

It means multi-tier crop cover, in which tallest species like Coconut, Eucalyptus and other tree species are grown that is followed by Banana, Papaya, Pineapple, Coffee etc. Ginger, Turmeric, Pepper, Yam, Colocasia are the ground or lower tier crops.

While designing this 3 tier system, level of organic matter and mineral content into the soils should be considered.

This system improves the productivity and conserves the environment. It also controls soil erosion, moderates surface soil temperature, suppresses weeds, recycles nutrients and preserves moisture.

4.2. Alley cropping

It is also known as hedge row intercropping, and involves managing rows of closely planted woody trees with annual crops grown in alley in between hedge rows. Woody plants are cut regularly, and leaves and twigs are used as mulching materials on the alley cropping areas for reducing evaporation from soil, control weeds and add nutrients and organic matter into the soil. Increase crop yield due to the addition of organic matter into the soil.

Legume plants (Ipil-Ipil etc) are grown on the hedge rows which fix nitrogen into the soil. Hedge rows give products like fruit, fodder, leaf litter, fuel wood and poles.

This system is generally practice in sloppy lands which helps in reducing soil erosion. The position and spacing of hedge rows and crops plants in alley cropping system depend on plant species, climate, slope, soil condition and space required for the movement of people and tillage equipment.

Hedge row distance should be maintained 4-8 meters, which should be based on slope of the land (more slope less row to row distance) and plant to plant distance from 25 cms – 2 meters. Hedge rows should be developed across the slope of the land.

Species for hedge rows

- Easy to propagate.
- Easy to plantation establishment, care and management.
- Legume tree species to improve soil fertility through nitrogen fixation and to improve feeding value of fodder because legume species contain high protein.
- Tree should have light crown cover to permit sunlight.
- It should re-sprout rapidly after pruning, coppicing, pollarding and lopping operations.
- It should have deep root system with few lateral roots near the surface so as not to compete with crop roots.
- It should have shallow lateral roots that are easily pruned by ploughing along the hedge rows without serious damage to plants.

- It should have leaf litter which could be easily decomposed to add nutrients into the soil.
- It should be multipurpose species which should give fruits/food, fuel wood, fodder/leaf litter, timber and medicines.
- It should grow well under specific limitation sites such as acidic soil, alkaline soil, drought, degraded soil, floods and heavy windy areas.
- It should suitable in local environment.
- It should resistant to insects, pests and diseases.
- It should be fast growing.
- It should have high demand with high market value.

Suitable species

- *Leucaena species (Ipil-Ipil)*
- *Gliricidia sepium*
- *Calliandra*
- *Sebania sesban*
- *Artocarpus lakoocha*
- *Morus alba*

Limitation

Alley cropping requires fairly close tree rows which reduces the amount of lands left for growing agriculture crops.

4.3. Hedge row planting

Establishment of dense vegetation in a linear design to achieve natural resource conservation and living fence development purposes is known as hedge row planting. The hedgerows shall be established using woody plants (fodder species) or perennial bunch grasses (Mott napier/NB21) producing erect stems attaining average heights of at least 3 feet persisting over winter. Plants selected must be suited and adapted to soil and site conditions, climate, and conservation purpose. Species shall be selected that do not host pests or diseases that could pose a risk to nearby crops.

Close planting is needed for establishing living fences of hedge row, and the practice shall be protected from livestock grazing and trampling to the extent necessary to ensure that it will perform the intended purpose(s). Competing vegetation shall be controlled until the hedgerow becomes established.

In places where animal grazing is a problem, hedge rows can be established using non-palatable species such as Jatropha (*Jatropha curcus*), Simali (*Vitex nergundo*) and Khirro (*Sepium insegne*).

4.4. Mix intercropping

This is field crop based agroforestry system, in which two or more crops are grown together as under storey crops. Trees species are selected based on farmers need as well as market demands.

Multipurpose tree species

Multipurpose tree species are those species which gives multiple products such as fruit, fodder, fuel wood, timber and medicines. These species are as follows:

- Chiuri (*Bassia butyracea***)**–gives fruit, fodder, fuel wood and timber, and herbal soap are produced from Chiuri ghee.
- Badahar *(Artocarpus lakoocha)*- gives fruit, fodder, fuel wood and timber
- Ipil Ipil *(Leucaena species)*- gives fruit for livestock, fodder, fuel wood and light timber and fix nitrogen
- Kimbu *(Morus alba)*- gives fruit, fodder, fuel wood and feed to silk worm.

Characteristics or criteria for the selection of multipurpose species in an agroforestry system

- Easy to propagate.
- Easy and cheap to plantation establishment, care and management.
- It should give multiple products fruits/food, fuel wood, fodder/leaf litter, timber and medicines.
- Legume tree species to improve soil fertility through nitrogen fixation and to improve feeding value of fodder because legume species contain high protein.
- Tree should have light crown cover to permit sunlight.
- It should re-sprout rapidly after pruning, coppicing, pollarding and lopping operations.
- It should have deep root system with few lateral roots near the surface so as not to compete with crop roots.
- It should have shallow lateral roots that are easily pruned by ploughing along the hedge rows without serious damage to plants.
- It should have leaf litter which could be easily decomposed to add nutrients into the soil.
- It should grow well under specific limitation sites such as acidic soil, alkaline soil, drought, degraded soil, floods and heavy windy areas.
- It should be suitable in local condition.
- It should resistant to insects, pests and diseases.
- It should be fast growing.
- It should have high demand and better value for the produce.

4. Components of Agroforestry and their interactions (tree-crop interactions)

Forestry, agriculture and livestock are the main components of agroforestry. Generally, trees grow in close proximity to crops and pastures, and therefore, interactions between trees and crops occur both above and below the ground, which will have both beneficial and harmful effects to understory crops.

Beneficial effects of tree-crop interactions

- Trees and shrubs grown in agroforestry system help to secure and renew the soil.
- Trees cover and protect the soils from extreme heat and cold, and then slow down the natural forces of soil erosion like wind, water and gravity. They can also control runoff and soil erosion, thereby reducing losses of water, soil material, organic matter and nutrients.

- Fallen leaves, wooden debris, twigs, flowers and fruit etc help to add organic matter and humus into the soil, which increases microbial activities in the soil.
- Legume trees and crops help to improve soil fertility fixing atmospheric nitrogen into the soil or roots. Subedi *et al.* (2001) give the following values for the nitrogen fixation capacity of legume fodder and forage species which is 900 kg/ha/year for *Desmodium*, 40-70 kg/ha/year for *Stylo*, 52-77 kg/ha/year for *White clover*, 60-168 kg/ha/year for centro and 63-342 kg/ha/year for *Ipil Ipil*.

- Trees help to soil **nutrient recycling**.

  a) Nutrient recycling from the soil is a common agroforestry hypothesis.
  b) Deep-rooting trees can absorb leached nitrate and other nutrients from the subsoil.
  c) This depends on trees and crop species, climate and soil conditions.
  d) Deep nutrient capture by trees increases total nutrient availability in the system.
  e) Fallen leaves, twigs, flowers and fruit, and crop residues etc help to add organic matter and humus into the soil, which also increase microbial activities in the soil.
  f) Soil microorganisms are decomposers that break down organic matter into humus and plant available nutrients and cycle nutrients back to plants, starting the cycle over again.

- There is symbiotic relationship between trees, crops and microorganisms in an agroforestry system:

  Symbiosis (from Ancient Greek syn "with" and biosis “living”) is close and often long-term interactions between different biological species. In 1877 Bennett used the word symbiosis to describe the mutualistic relationship in lichens. In 1879, the German mycologist Heinrich Anton de Bary defined it as "the living together of unlike organisms. In agroforestry system, exchange of nutrients among the plants occurs from the activity of appropriate micro-organisms.

  Rhizobium (legume species) and frankia (uttis-*Alnus nepalensis*) have potential roles for nitrogen fixation, plant growth regulation, phosphate solubilization and concerned with nutrient transformation of decaying plant materials.

  The most common and possibly the most important-mutualistic, symbiotic relationship in the plant kingdom is known as **mycorrhiza.**

  a) The word mycorrhiza is derived from the Greek words mykes, meaning "fungus," and rhiza, meaning "root."
  b) Mycorrhiza is a specialized, symbiotic association between the roots of plants and fungi that occurs in the vast majority of plants-both wild and cultivated.
  c) In a mycorrhizal relationship, the fungi assist their host plants by increasing the plants' ability to capture water and essential elements such as phosphorus, zinc, manganese, and copper from the soil, and transfer them into the plant's roots.
  d) The fungi also provide protection against attack by pathogens and nematodes.
  e) In return for these benefits, the fungal partner receives carbohydrates, amino acids, and vitamins essential for its growth directly from the host plant.
  f) It has been estimated that mycorrhizal fungi amount to 15 percent of the total weight of the world's plant roots.

- Trees and shrubs and crops residues provide feed to animals and animals add organic matter (manure) into the soil. In the maintenance of soil fertility under agroforestry, the role of roots is at least as important as that of above-ground biomass.
- Trees and shrubs and organic matter added by these help to increase water holding capacity of soil.
- Trees can check the development of soil toxicities, or reduce existing toxicities - both soil acidification and salinization can be checked, and trees can be employed in the reclamation of polluted soils.
- Trees can moderate **microclimates**. Shelter given by trees improves yields of nearby crops and livestock. Shade in summer can be beneficial for livestock, reducing heat stress. Trees in agroforestry system are capable of increasing the precipitation and relative humidity of the area. This results in decreasing requirements of irrigation water. Trees also control soil erosion by reducing the impacts of rainfall on soil because about 25-30% rainfall is intercepted by the tree crown, and 10-15% of the rainfall reaches the ground as stem flow. Thus, only about 50-60% rainfall comes to the ground directly, which will have less impact on soil erosion.
- Finally, trees and shrubs grown in agroforestry systems also improve the soil productivity, and production.

Harmful effects of tree-crop interactions

- There is competition between trees and crops for soil moisture, nutrient, light and space.
- Shading by trees reducing light intensity at the understory crop level. *In such situation etiolation* occurs in understory plants. ***Etiolation*** is a process in flowering plants grown in partial or complete absence of light. It is characterized by long, weak stems; smaller, sparser leaves.
- Trees in agroforestry can augment soil water availability to land-use systems. In dry regions, competition between trees and crops is a major problem.
- Fast growing tree species absorb more soil moisture, which will have adverse effects on dry environment.
- Root competition between trees and crops for water and nutrients occurs in the top soil. Therefore, trees having shallow root system and crops with deep roots compete more with crops and trees for nutrients and moisture respectively.
- Some trees will also have adverse chemical and biological effects such as acidification. For example soil under pine species is found acidic.
- Growing of some agriculture crops such as maize, sugar cane etc during early stage of plantation establishment will affects the growth and survival rate of young seedlings/trees.
- A badly managed tree stand may cause soil erosion due to the increase in surface run off, which will also have adverse effects on hydrological cycle.
- **Allelopathy** is a biological phenomenon by which an organism or plant produces one or more biochemicals that influence the growth, survival, and reproduction of other organisms or plants. These biochemicals are known as **allelochemicals** and can have beneficial (positive allelopathy) or detrimental (negative allelopathy) effects on the target organisms.

Allelochemicals with negative allelopathic effects are an important part of plant defense against herbivory.

Allelopathic interactions are an important factor in determining species distribution and abundance within plant communities, and are also thought to be important in the success of

many invasive plants. For example: pine litter completely suppresses germination of understory plants or grasses despite the relative openness of the canopy and ample rainfall at the location.

Chemicals like Phenols, Benzoic acid; Aldehydes, Aceptophenon, Cinnamic acid, Flavonoids, Tannings and Gentistic acid have negetive allelopathy effects to neighboring plants. For example: pine litter completely suppresses germination of understory plants or grasses despite the relative openness of the canopy and ample rainfall at the location. Allelopathy interference can result from natural products in intercrop foliage leaching. Root products, and volatiles.

- **Leaching:** inorganic and organic natural products are leached from plant tissues (Tukey, 1970)
- **Root exudation**: A variety of natural products has been found in plant root exudation. Clayton and Lamberton (1964) reported that root exudation is increased greatly by wilting condition and root damage.
- **Volatilization**: It is the release of natural products into the atmosphere. A variety of plants either secretes or excretes metabolic products into the special structures such as glands, intercellular space, and canals, onto leaf surface. In hot and dry weather, natural products with high vapor pressure released into the atmosphere, which may be directly absorbed by the plants and soils.

Aboveground and underground relationship

Trees and agriculture crops compete with each others for light, space, moisture and nutrients. This competition can be grouped into two main classes, which are **1)** aboveground and **2)** underground competition.

1) Aboveground competition

The aboveground competition between trees and agriculture crops takes place for light and space. It is usually limited in areas of physical interaction. The aboveground physical possessions of trees that compete with crops are stem, clumps and foliage. The tree crown is mainly responsible for **light competition**.

The productivity of understory crops depends on its capacity to utilize solar energy. Low light intensity is one of the important constraints for higher yield in agroforestry system. Tanaka *et al* (1964) reported lower dry matter accumulation and decreased photosynthesis under shaded condition.

In low light intensity, *etiolation* occurs in understory plants, which is characterized by long, weak stems; smaller, sparser leaves. Janardhan and Murty (1980) reported that grain yield of tall and semi dwarf rice cultivars reduced under low light due to the low grain number per panicle and small grain size.

Tree canopy also disturbs rainfall pattern. For example, about 25-30% rainfall is intercepted by the tree crown, and 10-15% of the rainfall reaches the ground as stem flow. Thus, only about 50-60% rainfall comes to the ground directly, and therefore, soil directly under trees remains dry, which also creates moisture deficiency situation to understory crops.

2) Underground competition

Underground competition between trees and crops occurs mainly for moisture, nutrients and space, which is more important in agroforestry systems than above ground competition.

This competition depends on root system of both trees and agriculture crops. Generally, agriculture crops absorb nutrients from the top layer of a 30 cm soil depth, and to some extent up to 50 cm depth. A higher concentration of fine roots of trees in the soil layer up to 50 cm suggests that trees also obtain most of the nutrient requirements from the soil layer up to 50 cm. This suggests that there is huge competition between trees and agriculture crops for water and nutrient absorption in 50 cm soil depth. In addition, some trees like eucalyptus absorb and transpire more soil water.

To avoid this kind of water and nutrient absorption completion, trees in agroforestry system should be deep rooted with few lateral roots, and agriculture crops should be with fibrous root systems concentrating roots in 30 cm soil depth. The desirable characteristics of trees and agriculture crops to avoid aboveground and underground competition are given below:

Desirable characteristics of trees

The main desirable characteristics of trees for reducing negative effects on agriculture crops are as follows:

- Tree species should have adequate shade regulation and upright stems.
- Trees should not interfere with agriculture crops with respect to soil moisture, nutrients, solar energy and agricultural operations.
- Trees should not attract birds.
- Tree species should have fast growth and high survival rate.
- Tree species should have ability to fix atmospheric nitrogen.
- Tree species should have high re-sprouting capacity after lopping, coppicing, pollarding and pruning operations.
- Tree species should have deep rooting system with very few lateral roots.
- Tree species should not have any toxic effects on soil and on associated crop plants.
- Tree species should give multiple products.
- Tree species should have high yield potential and higher profitability.
- Tree species should be suitable to local climatic condition and widely acceptable by the local farmers.

Desirable characteristics of agriculture Crops

The main desirable characteristics of agriculture crops for reducing negative effects on trees are as follows:

- Crops should be grown well under high density planting.
- Crops should be partially or completely shade tolerant.
- Crops should not compete with trees for water, nutrient, space and light.
- Crops should be of short duration with fast growing capacity.
- Crops should have nitrogen fixing capacity.
- Crops should have capacity to bear adverse condition like water stress or excessive water.
- It should be suitable for multiple cropping or mix cropping.
- Crops should return adequate organic matter into the soil through fallen leaves, roots and crop residues.

- Crops should be suitable for local climatic condition.
- Crops should be high yielding.
- Crops should be resistant to insects, pests and diseases.
- Cash crop for income generation.
- High demand and market value.
- Products other than grain can be used as animal feed.

Effects of agriculture crops on trees

Agriculture crops compete with tree seedlings for nutrient, water, light and space, particularly during the first few years. If this competition is intense, it will adversely affect the growth and survival rate of trees. Agriculture crops like maize, sugarcane etc overtop the trees species during the first 1-2 years of plantation establishment. Trees suffer as light availability is considerably reduced. Some other agriculture crops such as beans, cow-pea climbs on the saplings and deform their stem creating problem in growth.

Cultivation practice applied for growing agriculture crops also affects the growth and survival rate of trees. Intensive working of surface soil often destroys the surface root systems of trees. When roots are damaged, trees will not be able in full absorption of water and nutrients from the soil.

Effects of animals on vegetation

In several agroforestry systems, animals are an important component. Animals graze and affect the grasslands and fodder trees considerably. The effect of animals on vegetation includes direct harmful and beneficial effects, which are described below:

Harmful effects

Grazing animals directly affects on vegetation by mechanical damage and browsing of young plants and regeneration, reduction in combustible materials such as fire wood, twigs, leaf litter due to the mechanical damage by grazing animals, and indirectly affects on regeneration, and effect on soil properties (soil compaction which results on reduction in pore space that means disturbance in aeration, infiltration and permeability), which affects on tree growth. These effects are very much related to the number of grazing animals to be grazed within the carrying capacity of the land, quantity of grass and fodder, grazing season, grazing frequency etc.

Over grazing can also result on soil erosion and land degradation, which will have negative effects on vegetation.

Beneficial effects

- Grazing animals help in seed dispersal by adhering to them or by being eaten by them.
- Add organic matter into soil by breaking down and mixing of leaf litter into the soil, and by urine and dung of grazing animals.
- Reduce fire hazard by reducing the amount of burning materials.

Effects of trees on animals

- **Supply of fodder and fruits**

The leaves of several trees are good fodder for animals, which are also rich in nutritive value. The fodder yield from the tree is quite substantive and annual dry matter production may vary from about 10-40 kg per tree (Singh, 19982). Fruits are also palatable to animals.

Trees also improve the carrying capacity of agroforestry plots, and increase productivity of grazing animals.

- **Provide shade and shelter**

Trees provide shade to grazing animals during hot and dry sunny days, and shelter during cold and snow.

Biosphere Management Through Agroforestry

Nepal is overpopulating and the demand of fodder, forage, fuel wood and timber for higher standard of living is constantly on the rise. Therefore the demand for more resources is growing to levels that cannot be sustained. Since forests provide a large portion of the world's resources, many forests are cut down or burned, which is directly associated with the high demand of fodder, forage, fuel wood and timber to meet the need of farmers and other manufacturing companies. Wood is used in home building, furniture and the list seems like it's endless.

Another major direct cause for forest depletion is simply burning forests for farmland. Many poor farmers burn or cut small portions of forests so they can have room for farming and cattle. The reason forests are burned for the farmland is due to the rich minerals fertility of the soil and the need of agriculture products to provide food for growing population.

Trees are also cut down for economical purposes. Another cause for forest degradation is the forest fire. The deforestation rate in Nepal is about 2.2%, which is to meet the need of fodder, forage, fuel wood, timber and other purposes. As more roads are built to provide access to rural areas of Nepal more deforestation is evident.

Fertility of soils has been reduced due to the soil erosion, unbalance use of chemical fertilizers and less use organic manure, and over cropping. Water sources are also drying out due to the lack of vegetation in sloping lands, which increases run off of rain water and reduces infiltration rate of rain water.

Another extent of the problem with deforestation is a decrease in biodiversity. Biodiversity is important for ecosystem sustainability, agriculture, medicine, and recreation, aesthetic and commercial value. There are about 5 to 80 million species that live on this earth (lawton and may 1995).

According to the National Forest Inventory (1996) report Nepal ranks twenty-fifth in biodiversity with about 118 ecosystems, 75 vegetation types and 35 forest types. There are over 5,100 species of flowering plants, over 1,600 species of fungi and over 460 species of lichen. Out of the 5,100 species about 370 species of flowering plants are considered endemic to Nepal and about 700 species are known to possess medicinal properties. Protected Areas

alone contain 191 endemic species. Anthropogenic disturbance has led to inclusion of 61 species on the list of threatened species for Nepal.

Nepal also has an estimated 700 species with medicinal properties and about 571 species have already been confirmed as medicinal plants. Out of these species about 30 percent are trees, 25 percent shrubs, 32 percent herbs, 10 percent climbers and 3 percent other. However, documented information about the utility, collection, drying and storage of medicinal plants is available only for 97 species.

Faunal diversity in Nepal is also equally impressive with about 175 mammal species, 836 bird species, 147 reptile and amphibian species, 180 species of fish, 640 species of butterflies, and over 6 000 species of moths. Of these, 26 mammals, nine birds, and three reptiles are endangered, vulnerable, or threatened. These are the results of forest resource depletion.

Modification in vegetation cover will be occurred and weedy species (banmara etc) and other exotic species will dominate in these forest areas.

How agroforestry helps to conserve biodiversity?

Biodiversity is the variety and variability of plants, animals and microorganisms. Our planet's essential goods and services depend on the variety and variability of genes, species, populations and ecosystems. The loss of world's biological diversity is mainly from habitat destruction, over harvesting, pollution, environment change and inappropriate introduction of exotic species.

To overcome the problems of resource depletion and biodiversity loss, efforts are needed to conserve and maintain gene, species and ecosystem with a view to sustainable management and use of biological resources. In situ protection and exsitu conservation of biological and genetic resources can help in sustaining biological and genetic resources.

Agroforestry can play an important role in the conservation of biodiversity within deforested, fragmented landscapes by providing habitats and resources for plant and animal species, maintaining landscape connectivity, making the landscape less harsh for forest-dwelling species by reducing the frequency and intensity of fires, potentially decreasing edge effects on remaining forest fragments and providing buffer zones to protected areas (Schroth *et al*., In press).

Agroforestry systems cannot provide the same niches and habitats as the original forests and should never be promoted as a conservation tool at the expense of natural forest conservation. However they do offer an important complementary tool for conservation and should be considered in landscape-wide conservation efforts that both protect remaining forest fragments and promote the maintenance of on-farm tree cover in areas surrounding the protected areas.

The degree to which agroforestry systems can serve conservation efforts depends on a variety of factors, including the design and origin of the agroforestry systems, its permanency in the landscape, its location relative to remaining natural habitat and the degree of connectivity within the habitat, as well as its management and use, particularly pollarding, use of herbicides or pesticides, harvesting of timber and non-timber products and incorporation of cattle, goats, etc.

Home gardens provide a variety of niches and resources that support a high diversity of plant and animals, though usually less than that of intact forest (Perfecto *et al*., 1996; Rice and Greenberg, 2000). However, even agroforestry systems with low tree densities and low species diversity may help in maintaining biotic connectivity.

Unit 4: Soil and Water Conservation Under Agroforestry Systems

a) Problems

- Rapid increase in population resulted deforestation (Slash and burning of forests to grow crops)
- Massive exploitation of resources resulted ecological disaster, biodiversity loss and poverty
- Soil erosion (8–12 tones/ha/year) and flooding
- Soil fertility decline
- Siltation problems in down stream
- Upland farmers working on sloping lands, which is susceptible to soil erosion.
- Land degradation due to the soil erosion
- Increase surface run off and decrease infiltration rain water.
- Drying out water sources
- Modern technology not available in uplands
- Research concentrated only in low lands and fertile areas.

There is some problem in agroforestry system practice, which is the small and fragmented land holding, sloppy and degraded sites, uncertain land tenure, lack of capital and expensive labour etc

b. Potential

Agroforestry is needed for i) soil and water conservation, ii) stabilization of slash and burning practices, iii) reducing deforestation iv) soil fertility improvement, v) producing adequate food and feed for animals, vi) family nutrition improvement and income generation from the sale of surplus products, vii) protecting and conserving biodiversity and environment and viii) beautification of land.

Concept of land capability classification in AF

- **Use of biophysical data**

  a) Biological data

  Flora (types of vegetation cover, species. weeds, crop plants) and fauna (wild animals, domestic animals, insects, pests and pathogenic organisms etc)

  b) Physical data

- Soil factors- Physical properties (Texture, structure, depth, drainage, porosity, dryness etc), chemical properties(nutrient content, soil pH, organic matter, salinity, cation exchange capacity etc) and biological properties (soil microorganisms)
- Climatic factors
- Physiographic factors
- Land use systems (history, present use, human activities of surrounding areas, potential alternate use of land, land capability class and accessibility etc)

- **Use of meteorological data**

Metrological information needed for i) planning appropriate AF system, ii) sustaining AF productivity iii) improving degraded lands (soils of low fertility, soil subjected to water and wind erosion, soil subjected to drought condition and soils having salinity, acidity, alkalinity and water logging problems etc are degraded soil)

Land Capability Class

Class 1: Land suitable for tillage operation (Emphasis on crop production with few trees)
Class 2: Land suitable for moderate tillage operation with SWC practice (moderate slope land- Agrisilviculture, Silvipastoral and Horti-silviculture)
Class 3: Tillage possible after SWC practice and poor soil fertility status (Alley cropping with legume trees, SALT etc)
Class 4: Steep slope, tillage difficult, sallow soil with poor drainage (Alley cropping with forage crops)
Class 5-8: Steep slope, severe soil erosion problems, not suitable for agriculture operation (Silvi-pastoral system, protected area development)

Potential agroforestry methods for improving soil productivity or fertility

Soil fertility- It is the capacity of soil to support trees, grasses and agriculture crops, which can be improved adding organic manure, growing legume trees, shrubs and herbs etc.

Soil is one of the most important natural resources for regulated supply of multiple products from an agroforestry system. This resource has been suffered greatly from deforestation and erosion. Its productivity is declined, and becoming difficult to support human and animal population. Therefore, soil should be protected to sustain its fertility, productivity and production. Some agroforestry systems have their potentiality to improve soil fertility. These agrofrestry methods are as follows:

- Home garden
- Alley cropping with legume species
- Development of multi-storey tree garden
- Combination of plantation trees with legume species, which improves soil fertility through nitrogen fixation (Ipil-Ipil and *sesbania* add 50-500 kg nitrogen per hectare).

- Trees and grasses for soil conservation and land reclamation
- Multi-purpose trees on farm lands and range lands
- Boundary plantation of trees and improved grasses such as Mott napier, Setaria, Forage peanut etc
- Wood lot for green manuring or leaf litter, woody mulch or fodder
- Growing of green manuring crops such as Dhaicha (gives 8500-11000 kg OM/ha@45-60kg N/ha,) and Rahar 3000-4500 kg OM/ha and 20-30 kg N/ha)
- Improved fallow management

Mechanism or trend for soil productivity improvement in AF

Trend in soil productivity improvement in agroforestry can been achieved planting compatible and desirable species. This helps to reduce soil erosion and to improve physical condition of soil. It also influences hydrological cycle by reducing surface run off and by increasing infiltration of rain water. The soil productivity improvement trend in agroforestry is as follows:

1. Plantation of compatible and desirable species

   Plantation of compatible and desirable trees species **i**) add organic matter through leaf litter, twigs, fruits, and roots into the soil **ii**) nutrient recycling more efficiently **iii**) biological nitrogen fixation **iv)** enhance nutrient use and nutrient economy planting shallow and deep rooting trees and crops **v**) better sharing of nutrients between trees and crops and **vi**) enhance nutrient release pattern adding more organic matter into the soil, **vii**) enhance microbial activities adding more organic matter.

2. Improve physical condition of soil with proper inclusion of trees, grasses and legumes
3. Reduce upstream soil erosion and downstream siltation problems through planting desirable trees and grass species in upstream
4. Planting trees and grasses for micro-climate improvement and for influencing hydrological cycle by reducing surface run off and increasing infiltration of rain water
5. Planting nitrogen fixing trees and crops like coffee, tea, cardamom to get more benefits from nitrogen rich leaf litter and soil nitrogen

Effects of trees on soil

Effects of trees on soils can be grouped into two categories that are beneficial and harmful effects.

Beneficial effects:

- Trees help to secure and renew the soil.
- Trees cover and protect the soils from extreme heat and cold.
- Trees help to slow down the natural forces of soil erosion like wind, water and gravity.
- Fallen leaves, wooden debris, twigs, flowers and fruits etc helps to add organic matter and humus into the soil.
- Legume vegetation helps to improve soil fertility fixing atmospheric nitrogen into the soil or roots.
- Tree provides feed to animals and animals add organic matter (manure) into the soil.
- Trees help to reduce surface run off by increasing infiltration of rain water into the soil.
- Trees help to increase water holding capacity of soil.

- Trees also help to increase microbial activities into the soil, which converts organic matter into humus and soluble nutrients, and helps for the solubilization of unavailable nutrients such as phosphate through activities of mycorrhiza and phosphate solubilizing bacteria.
- Tree roots contain 20-25% of the total biomass which also helps to make soil more fertile.
- Finally, trees improve the productivity and production of the land.

Harmful effects

- Trees make soils deficient in basic plant nutrients by regularly absorbing nutrients.
- Soil compaction occurs when animals are allowed for grazing the vegetation regularly.
- Adverse chemical, biological and allelopathy effects such as soils under pine trees are found acidic, and barren.
- Fast growing tree absorbs more water from the soil and then soils become dry more easily.
- Nutrient loss from whole tree harvesting
- Shading effects on under storey crops
- Badly managed tree stand may cause soil erosion during tree harvesting, and affects hydrological cycle due to the increase in surface run off of rain water

Potential of Agroforestry Systems for Soil and water Conservation

Agroforestry is a method of land management. Initially, agroforestry study has given focus on the biological and socio-economic advantages as well as disadvantages of the agroforestry systems, which was followed by evaluations of productivity of both existing and modern agroforestry systems. Recently studies on the interactions between the component species with a view to improving management and profitability have been conducted.

At the end of the 1990s, increased international concern about environmental issues led to new treaties (e.g. Kyoto Protocol) and emphasis on the environmental service functions of alternative land uses.

Agroforestry provides a service to the local, national and global community, which is a new option to the financial viability of farms. The main service functions of the agroforestry systems considered are soil conservation, conservation of water quality, carbon capture (climate change) and biodiversity conservation.

Soil erosion control

Agroforestry helps to improve soil fertility due to the growth of nitrogen-fixing trees or deep-rooted trees and shrubs that increase nitrogen availability through biological fixation, recycle plant nutrients from depth and build up soil organic matter.

Greater accumulation of organic material and nutrient storage in biomass, increased root density as well as greater vertical extension of tree roots help maintain nutrient stocks by reducing leaching losses or by taking up nutrients from deep layers.

The benefits of shade trees include reduced soil erosion as natural litter fall or pruning residues cover the soil, which reduce the impact of raindrops on soil, improve soil structure,

increase soil nitrogen content and enhance nutrient retention and finally improve the growth of trees and understory crops.

Ways for soil conservation

The best agroforestry systems for soil conservation are silvi-pastoral system and alley cropping with grass cover in alley etc. Roots of trees grown in these agroforestry systems firmly hold on to the soil. As trees grow tall, they also keep rooting deeper into the soil. As the roots of the trees spread deep into the layers of soil, they contribute to the prevention of soil erosion. Soil that is under a vegetative cover or grass has hardly any chance of getting eroded as the vegetative cover or grasses acts as a wind barrier as well. Additional methods or ways for better soil and water conservation results to be obtained from the agroforestry systems are as follows:

Terraces: Terracing is one of the very good methods of soil conservation. A terrace is a leveled section of a hilly cultivated area. Owing to its unique structure, it prevents the rapid surface runoff of water. Terracing gives the landmass a stepped appearance thus slowing the easy washing down of the soil. Dry stonewalling is a method used to create terraces in which stone structures are created.

Zero tillage farming: When soil is prepared for farming by ploughing it, the process is known as tiling. Zero-tillage farming is a way of growing crops without disturbing it through tillage. The process of tilling is beneficial in mixing fertilizers in the soil, shaping it into rows and preparing a surface for sowing. But the tilling activity can lead to compaction of soil, loss of organic matter in soil and the death of the organisms in soil. No-till farming is a way to prevent the soil from being affected by these adversities.

Contour ploughing: This practice of farming across the slopes takes into account the slope gradient and the elevation of soil across the slope. It is the method of ploughing across the contour lines of a slope. This method helps in slowing the water runoff and prevents the soil from being washed away along the slope. Contour ploughing also helps in the percolation of water into the soil.

Crop rotation: Some pathogens tend to build up in soil if the same crops are cultivated consecutively. Continuous cultivation of the same crop also leads to an imbalance in the fertility demands of the soil. To prevent these adverse effects from taking place, crop rotation is practiced. It is a method of growing a series of dissimilar crops in an area sequentially. Crop rotation also helps in the improvement of soil structure and fertility.

Soil pH: The contamination of soil by addition of acidic or basic pollutants and acid rains has an adverse effect on the pH of soil. Soil pH is one of the determinants of the availability of nutrients in soil. The uptake of nutrients in plants is also governed to a certain extent, by the soil pH. The maintenance of the most suitable value of pH, is thus, essential for the conservation of soil.

Water the soil: We water plants, we water the crops, but do we water the soil? If the answer is negative, it is high time we adopt the method of watering soil as a measure of conserving soil. Watering the soil along with the plants is a way to prevent soil erosion caused by wind.

Salinity management: The salinity of soil that is caused by the excessive accumulation of salts, has a negative effect on the metabolism of the crops in soil. Salinity of soil is

detrimental to the vegetative life in the soil. The death of vegetation is bound to cause soil erosion. Hence, salinity management is one of the indirect ways to conserve soil.

Soil organisms: Organisms like earthworms and others benefiting the soil should be promoted. Earthworms, through aeration of soil, enhance the availability of macronutrients in soil. They also enhance the porosity of soil. The helpful organisms of soil promote its fertility and form an element in the conservation of soil.

Maintaining water quantity and quality

Agroforestry systems help secure water supplies both in quantity and quality because trees influence water cycling by increasing rain and cloud interception (with possible negative and positive effects), transpiration and retention of water in the soil, reducing runoff and increasing infiltration. Bharati *et al.* (2002) reported that infiltration in areas cultivated with maize or soya, or under pastures, was five times less than under riparian strips cultivated with a variety of plant and tree species.

Agroforestry practice can also reduce ground water contamination by nitrate and other substances that are harmful to the environment and human health. As a result of less runoff and leaching, micro-watersheds with agroforestry systems that cover a high percentage of the soil surface produce high quality water (Stadtmüller, 1994).

Key principles of soil and water conservation

- Soil conservation works should be initiated from the upstream considering upstream and downstream linkages.
- Loss of soil productivity is much more important than the loss of soil itself.
- Erosion is the cause of land degradation, which should be prevented before it occurs, rather than rehabilitating afterwards.
- Bottom up approach should be used for land study and for formulating holistic land use system.
- Long term program should be planned for more successful soil conservation rather than short and fixed term approaches.
- The farming household and its environment should be the focal point of every soil conservation program.
- It is important to address farmer's immediate needs through the development and introduction of production strategy that should be both production and conservation effective.
- In uplands, crop yield are reduced more by a shortage of soil moisture than soil loss, and therefore, mulching and moisture conservation tillage operation should be carried out to reduce soil erosion and to conserve soil moisture.

Soil conservation strategy/method for sloping land

- Adopt alley cropping and contour farming in erosion prone areas
- Prepare contour canal- dig canal of about 30 cm deep and wide along the contour line to drain rain water, and or drainage ditch of 0.5-1 meter wide, and 0.5 meter deep should be prepared to drain rain water.
- Rock wall should be prepared to make terrace in erosion prone fragile areas.
- Check dam (brush wood, dry stone and gabion) should be prepared to control gully erosion.

- Soil pits or soil traps of 1 meter length, 1 width and 0.5 meter deep should be prepared to accumulate eroded silt into the pits.
- Bench terrace should be prepared.
- Grasses such as mott napier, setaria, mulato, forage peanut should be planted along terrace bunds.
- Planting crops- short crops (Maize, vegetables and other legume crops) and long term crops (coffee, banana and citrus) should be grown. Care should be given to minimize soil erosion.
- Crop rotation practice including legume crops should be followed to reduce soil erosion and to improve soil fertility.

Farm management practice to reduce soil erosion

- Good crop rotation practice- include legume crops
- Practice relay planting of crops to cover lands, which helps to reduce soil erosion.
- Plant crops along the contour line or across the slope.
- Add organic matter into the soil
- Put crop residue into the soil
- Diversify farm products/ enterprises
- Maintain forest in upper slope of farm lands
- Grown improved grasses (mott napier - *Pennisetum purpureum*, setaria - *Seteria splendida*, mulato- *Brachiaria brizantha x B. ruziziensis* and forage peanut- *Arachis pinotoi*.) and medicinal herbs (citronella, lemon grass and vetiver grass etc) along terrace bunds and borders.
- Protect the land from erosion during fallow period by using mulching.
- Stall feeding of animals should be practiced to reduce soil erosion.
- Use SALT (Slope Agriculture Land technology) to grow crops on upland and sloppy lands
- Other practices includes **composting** (preparation of organic fertilizers using plants and animal waste, and add that fertilizer into the soil to improve soil fertility), **cover cropping** (beans, cowpeas etc are grown to protect soil erosion and to improve soil fertility) and **minimum tillage** (simple farm tools such as hoe and digging stick are used to prepare land and to plant food crops).

Soil productivity trend in agroforestry

Deep-rooting trees in agroforestry system can absorb leached nitrate and other nutrients from the subsoil. The deep nutrient capture by trees increases total nutrient availability in the system. In addition, fallen leaves, twigs, flowers and fruit, and crop residues in agroforestry etc help to add organic matter and humus into the soil, which also increase microbial activities in the soil. Soil microorganisms are decomposers that break down organic matter into humus and plant available nutrients and cycle nutrients back to plants, starting the cycle over again.

Leguminous species such as *Leucaena* and *Gliricidia* grown in agroforestry system can yield large quantities of biomass and nutrient yield as compared to non legumes species plantation. Repeated additions of pruning materials can have a profound effect on soil properties. Agroforesty plots with *Leucaena* and *Gliricidia* have higher soil organic matter and nutrient status than non-legume plots (FAO, 1992).

Agroforestry farming also reduces runoff and soil erosion compared with mono-cropping plots. Runoff and erosion is reduced by the physical barrier of trees and crops, and also by the better physical condition of the soil under agroforestry system, resulting from higher faunal (earthworm) activity, which increases water infiltration.

Despite the high nitrogen yield from *Leucaena* and *Gliricidia* pruning materials, it is inefficiently used by the associated crop. It is estimated that the N contribution from pruning materials of these two species is about 40 kg ha^{-1} (FAO, 1992) to the associated maize crop.

Kang *et al*. (1985) have shown that maize and *Leucaena* hedgerows do not compete for soil moisture, as the hedgerows use moisture from lower depths in the soil than the crop. On non-acid soils in the humid zone, competition between the woody hedgerows and the crop is mainly for light (FAO,1992).

The below-ground interactions between crops and woody species are gradually receiving more attention. The effects of root turnover, water and nutrient competition in various soil types and climatic conditions need to be further researched. In agroforestry deep rooting legume trees are more suitable species to improve the productivity of the soil.

Finally, soil productivity in agroforestry system reduced when both trees and agriculture crops are nutrient exhausted or more nutrient absorber, and roots of both trees and crops are in same layers.

Slope Agriculture Land Technology (SALT)

This technology was first developed in the Philippines, where both agriculture and forestry are practiced on sloppy land, with slopes ranging upward from 18% (Ramos 1991).

SALT is a technology package of soil conservation and food production that integrates several soil conservation measures (Tacio 1988, Evans 1992). It is also an indigenous upland technology which combines the feature of soil and water conservation, enrichment of soil fertility, crop diversity and productivity improvement. It is example of alley or contour cropping.

Double hedge rows of legumes and shrub species help to prevent soil erosion. Legume species fix nitrogen and improve soil fertility. To cover soil permanently, cover crops are used following relay cropping practices. This is appropriate technology for small farmers with few tools and little capital. A frame is used to establish hedge row plantation.

Basically, the SALT method involves planting field crops and perennial crops in bands 3-5 m wide between double rows of nitrogen-fixing shrubs and trees planted along the contour. These minimize soil erosion and maintain the fertility of the soil. Field crops include legumes, cereals, and vegetables, while the main perennial crops are coffee, banana, citrus and fruit trees (MBRLC 1988).

SALT helps considerably in the establishment of a stable ecosystem. The single or double hedgerows of leguminous shrubs or trees prevent soil erosion. Their branches are cut every 30-45 days and incorporated back into the soil to improve its fertility (Palmer 1992).

The crop provides permanent vegetative cover which aids the conservation of both water and soil. The legumes and the perennial crops maintain soil and air temperatures at levels favorable for the better growth of different agricultural crops.

Steps of SALT

SALT is an improvement over existing technologies. It is a simple, effective method of farming uplands, without losing topsoil to erosion (MBRLC 1988). It consists of the following ten basic steps:

1. **Making the A-frame**

The A-frame is a simple device for laying out contour lines across the slope. It is made of a carpenter level and three wooden or bamboo poles nailed or tied together in the shape of a capital letter A with a base about 90 centimeters wide. A carpenter's level is mounted on the crossbar.

2. **Determining the contour lines**

One leg of the A-frame is placed on the ground, and the other leg is swung until the carpenter's level shows that both legs are touching the ground on the same level. A helper drives a stake beside the frame's rear (first) leg. The process is repeated across the field. The contour lines should be spaced 4-5 m apart.

3. **Cultivating the contour lines**

One-meter strips along the contour lines should be plowed and harrowed to prepare for planting. The stakes serve as a guide during plowing.

4. **Planting seeds or seedlings of different nitrogen fixing trees and shrubs**

Along each prepared contour line, one/two furrows should be laid out. Two to three seeds of Ipil-Ipil, Tanki, Koiralo, *Gliricidia sepium, Calliandra, Sebania sesban* etc are planted per furrow hill, with a distance of 12 centimeters between hills. The seeds should be covered firmly with soil. When the hedgerows are fully grown, they hold the soil and serve as a source of fertilizer.

When hedge rows are single and nitrogen fixing plants are planted wider space, seedlings of mulberry, badahar, and different fruits can also planted alternatively to nitrogen fixing trees and shrubs.

5. Cultivating alternate strips/alley

The space between the rows of nitrogen fixing trees on which the crops are to be planted is called a strip or alley. Cultivation is done on alternate strips (strips 2, 4, 6 and so on). Alternate cultivation prevents erosion because the unplowed strips will hold the soil in place.

6. Planting permanent crops

Permanent fruit crops such as coffee, banana, citrus and others of the same height may be planted when the nitrogen fixing species are sown. Only the spots for planting, however, are cleared and dug, and later only ring weeding is employed until the hedgerows are large enough to hold the soil in place. Permanent crops are planted in every third strip. Tall crops should be planted at the bottom of the farm while the short ones are planted at the top.

7. Planting short-term crops

Short and medium-term income producing crops (pineapple, ginger, sweet potato, peanut, melon, corn, upland rice, etc.) should be planted between the strips of permanent crops as a source of food and regular income while farmers are waiting for the permanent crops to bear fruit.

8. Trimming of nitrogen-fixing trees

Every 30 to 45 days, the growing hedgerows are cut to a height of 1.0 to 1.5 m from the ground. The cut leaves and twigs should be piled on the soil around the crops, where they serve as an excellent organic fertilizer. In this way, only a minimal amount of commercial fertilizer (about 1/4 of the total fertilizer requirements) is necessary.

9. Practicing crop rotation

A good way of rotating is to plant cereals such as corn or upland rice and other crops on strips where legumes were planted previously, and vice versa. This practice will help maintain the fertility and good condition of the soil. Other management practices in crop growing, such as weeding and pest control should be carried out regularly.

10. Building green terraces

To enrich the soil and effectively control erosion, organic materials such as straw, stalks, twigs, branches and leaves, and also rocks and stones, are piled at the base of the rows of nitrogen fixing trees. As the years go by, strong, permanent terraces will be formed which will anchor the precious soil in its right place.

Farming techniques for soil and water conservation

1. Farming system approach to development

The farming systems approach to development (FSD) is based on the farm-household focus of farming system research and emphasizes the central role the farmer plays in farming systems development for soil and water conservation. In addition, this approach incorporates an increased emphasis on the dissemination of improved farming systems based, in the process, on active involvement of those responsible for the policy/support systems.

The FSD approach is a more 'bottom-up' research work or planning exercises, which can help in facilitating and strengthening the linkages not only between farmers and station-based researchers but also with other 'actors, including those responsible for designing and implementing the policy/support system.

The main principle of farming system approach for soil and water conservation is that farmers could participate at all stages of technology selection, design, testing, and adoption. It is based on the development principles of **i)** improving productivity or soil fertility, **ii)** increasing profitability, **iii)** ensuring sustainability, and **iv)** guaranteeing an equitable distribution of the results of production.

It has two inter-related thrusts, which are as follows:

- Develop an understanding of the farm-household, the environment in which it operates, and the constraints it faces for soil and water conservation, together with identifying and testing potential solutions to those constraints.
- Dissemination of the most promising solutions to other farm households facing similar problems.

Farming system approach rapidly became popular and was strongly supported by many donor agencies. By the mid 1980s, about 250 medium- and long-term projects worldwide were carrying out by this type work. Now, many of those projects are being institutionalized within national programmes with considerable domestic financing (FAO reports).

The primary objective of this approach is to improve the well-being of individual farming families by increasing the overall productivity of the farming system in the context of both the private and societal goals, given the constraints and potentials imposed by the factors that determine the existing farming system.

Stages of the approach

- ***The Descriptive or Diagnostic Stage***, in which the actual farming system is examined in the context of soil and water conservation to identify constraints farmers face and to determine the potential flexibility in the farming system in terms of timing, unused resources, etc. An effort also is made to understand the goals and motivation of farmers that may affect their efforts to improve the farming system.

- ***The Design Stage***, in which a range of strategies is identified that are thought to be relevant in dealing with the constraints determined in the descriptive or diagnostic stage.

- The soil fertility loss, soil erosion and land degradation constraints are ranked according to their severity, and potential solutions (terrace improvement, crop rotation, cropping patter, tree and crop combination, fertilization etc) are identified after determining what flexibility exists in the farming systems currently practiced.
- An evaluation is made of the proposed solutions before putting them into practice.

- ***The Testing and Implementation Stage***, in which one or more promising soil fertility improvement and erosion control strategies, arising from the design stage, are examined and evaluated under term conditions to determine their suitability for producing desirable and acceptable changes in the existing farming system.

- ***The Dissemination and Impact Evaluation Stage***, in which the strategies that were identified and screened during the design and testing stages are extended to farmers.

2. Rainfed based agriculture

Rainfed agriculture systems have dominated our food production systems, but investment for water in rainfed agriculture has been found very low. Upgrading rainfed agriculture promises large social, economic, and environmental paybacks, particularly in poverty reduction and economic development.

Rainfed farming covers most of the world's cropland (80%) and produces most of the world's cereal grains (more than 60%), generating livelihoods in rural areas and producing food for cities.

Climate change-related drought in recent years has emerged as a source of household-level vulnerability in rainfed hill agriculture of Nepal. The farmers cannot grow crops when there is no rainfall during the cropping season. They have weak adaptive capacity against drought due to the poor asset base and low access to services and facilities provided by the government and other line agencies. Facilities and services provided by the government are also not sufficient to meet the needs of these farmers.

Constraints of rainfed agriculture

Major constraints of rainfed agriculture in Nepal generally fall into the following categories: biophysical, technical, economic, social and cultural, institutional and infrastructural, which are briefly discussed in following section:

i) Biophysical constraints

The major biophysical constraints are small and fragmented size land holdings with low soil fertility, limited or irregular water resources (insufficient rainfall, change in rainfall pattern due to the effects of climate change and lack of irrigation facilities) and limited arable land of suitable soil types and less leveled or hilly topography, lack of soil organic matter, improper use of chemical fertilizers, soil erosion and nutrients loss and weed problems.

ii) Technical constraints

The main technical constraints include the lack of technical knowhow to farmers on soil moisture management and cropping systems, poor extension support to farmers and low access of farmers to services and facilities.

iii) Economic constraints

The major economic constraints consists the poor farmers with small and fragmented land holdings, lack of money or credit facility, problem of products transportation and marketing, low access of rainfed farmers to the end markets (middle man gets most of the benefits), migration to cities and other countries for jobs and emigration opportunities, high cost of imported chemical fertilizers and other inputs, tourism opportunities in some areas, the relatively high value of agricultural lands in areas where transportation facilities are available, and commercial real estate uses of farmlands.

iv) Social constraints

The declining status of agricultural employment is the main social constraints to rainfed agriculture management in Nepal.

v) Cultural constraints

Land tenure systems characterized by fragmented land holdings and government policy on land use rights can be primary cultural constraints to commercial development of rainfed agriculture systems.

vi) Institutional constraints

There is no coordination mechanism between the Department of Agriculture and Livestock Services and other I/NGOs to provide technical and other supports needed for rainfed agriculture development and management in Nepal.

vii) Infrastructural constraints

Constraints posed by undeveloped infrastructure include lack of rural roads, and farm roads in mountain and high Himalayan regions of Nepal, scarcity of transportation from rural and outlying areas to central markets, and costly and problematic transportation to national markets.

Methods for improving soil and water conservation in rainfed or dry land agriculture systems

- Add more organic matter into the soil for making soil conditions favorable for crop growth.
- Improve rainfed irrigation systems collecting and conserving rain water into a pond system, and use that water for irrigation purpose.
- Green manuring crops should be grown to improve soil fertility.
- Mulching should be done during fallow season. Mulch is a layer of straw, leaves or sawdust, papers covering the soil that helps to reduce evaporation, conserve soil moisture, suppresses weed growth, enriches soil as it rots, and prevents runoff and hence erosion, and increase infiltration of rain water into the soil.

- Farmers should be made capable in soil moisture management and in growing alternate crops when there is no rainfall during the cropping season.
- Appropriate tree and grass species should be included in rainfed agriculture farming systems.
- Involve more farmers in rainfed agriculture land conservation and management groups. So that collective action for soil and water conservation can be carried out.

3. Cropping systems

A cropping system is a producer's map of their approach to crop production. It can be complex or simple system. A conventional tillage wheat-fallow system represents the simplest system. Growing of two or more crops together with proper rotational system is complex cropping system. The main cropping system of Nepal is given below:

a) **Multiple cropping**- growing of more than one crop on the same land in a year.

- **Intercropping** -growing of two or more crops together in the same land.
- **Relay cropping**-growing of another crop before harvesting the main crop. There is no need of tillage operation. Example: Paddy-lentil
- **Alley cropping-** Fast growing legume plants are planted in hedge rows and agriculture crops are grown in between hedge rows.
- Mixed cropping- Growing of two or more crops together at the same time in same land. Example: wheat + mustard, wheat + peas etc.

b) Strip cropping

It is a conservation practice mainly to grow crops in systematic strips or bands, which serve as barriers to water and wind erosion.

- **Contour strip**-two or more crops are grown along the contours in alternative strips.
- **Field strip cropping-** The alternative strips are uniform widths across the field and not necessarily curved to conform to the contour.
- **Wind strip cropping-** Tall wind resistant crops and normal crops are planted alternatively in narrow strips perpendicular to the direction of prevailing winds.

c) Cover cropping

Cover crops are close growing crops planted mainly for protecting soil between regular crops. The types of cover crops can be annual or perennial legume crops (beans, cow peas, peas, rahar) and grasses depending on actual needs of the farmers.

Case study of Hills and Terai

Case study is the process of finding the existing activities of any program in detail. It should be done in specific areas on basis of the objectives of the program. The following points should be covered in a case study:

- Introduction (background information-location, areas etc)
- Objectives of the program
- Methodology (how agroforestry program was conducted, and study methods)

- Result and discussion
- Conclusion and recommendations

Conservation farming (case study of Begnas Tal Rupa Tal Watershed Management Project-BTRT

It refers to the system which minimizes soil loss and conserves moisture. Therefore, it helps to sustain and increase crop production. It can be achieved planting fruit seedlings, trees, grasses etc, multiple cropping, green manuring, composting, cash crop production, home gardening and winter fallow utilization.

In steep hillside (usually on terrace bunds or risers) soil protection from erosion is obtained by growing broom grass, babiyo and other tree species. Thus vegetation in terrace and along the risers creates the special micro-environment in the upland. This makes the upland relatively cooler and moist compared to the surroundings.

Case study of income generation *(source: Agroforestry Systems Prospects and Problems: A Case Study of Begnas Tal Rupa Tal Watershed Management Propject, Kaski by Govinda Rimal)*

It is the case study of Ardha agroforestry farm managed by farmer groups Lekhnath Municipality of Kaski, District. Kharka, initially a grazing land of 3 ha has been now changed into diversified farms with crops like orange, banana, pineapple, coffee, cereal and vegetable crops, and fodder and fire wood species. The main objective of this program was to improve degraded grazing lands involving local farmers.

The land was completely fallow before 1992, and Begnas Tal Rupa Tal (BTRT) project formed farmer groups of eight farmers, and encouraged group members to plant trees and grow vegetable crops "says Hari Prasad Bastola of Lekhnath Municipality and Rishi Ram Bastola of Majhthana VDC.

They have planted 2050 fruit plants (citrus, banana etc), 363 coffee and 727 fodder and fire wood species, and earned Rs 40,000 per year from the sale of citrus fruits, pineapple and vegetables.

Unit 5: Diagnosis and Design of Agroforestry Systems

Field research techniques or methodology

For the design of AF project, field information needs to be collected using Participatory Rural Appraisal (PRA) tools and techniques.

What is Participatory Rural Appraisal?

PRA is a field information collection technique, in which field workers interact with local peoples aiming to facilitate local capacity to analyse, plan, resolve conflicts, monitor and evaluate, and take action according to a local agenda.

PRA is distinguished at its best by the use of local graphic representations created by the community that legitimize local knowledge and promote empowerment.

It is designed to facilitate interaction between the field workers and local peoples. In this process, field workers act as a facilitator in a process of collecting and sharing information to engage villagers in local planning and action. Villagers are empowered to analyse their own situation, and plan and take action according to their own agenda, rather than that of the field worker.

Dr. Robert Chamber is the founder of this approach, which emerges in the 1980s with proper builds on Rapid Rural Appraisal (RRA) but goes much further. To RRA it adds some more radical activist perspectives, deriving principally from South Asia. Its five central additional concepts are:

- **Empowerment**

  Knowledge is power. Knowledge arises from the process and results of the research that, through participation, come to be shared with and owned by local people. Thus the professional monopoly of information, used for planning and management decisions, is broken. New local confidence is generated, or reinforced, regarding the validity of their knowledge. "External" knowledge can be locally assimilated.

- **Respect**

  The PRA process transforms the researchers into learners and listeners, respecting local intellectual and analytical capabilities. Researchers have to learn a new "style". Researchers must avoid at all costs an attitude of patronizing surprise that local people are so clever they can make their own bar charts etc. A good rule of thumb is that when you can really understand the local jokes, poetry and songs, then you may feel you are starting to understand the people's culture.

- **Localization**

  The extensive and creative use of local materials and representations encourages visual sharing and avoids imposing external representational conventions.

- **Enjoyment**

  PRA should be fun. The emphasis is no longer on "rapid" but on the process.

- **Inclusiveness**

  Enhanced sensitivity, through attention to process; include marginal and vulnerable groups, women, children, aged, and destitute.

Characteristics of good PRA

- Build rapport with men and women, rich and poor, young and old, and different ethnic groups and dalits.
- Be aware of potential suspicions and take action to dispel them.
- Be friendly, interested, culturally sensitive, relaxed and open.
- Listen, analyse and probe.
- Take advantage of local events and activities.
- Avoid people’s expectations being raised too early.

- Make your conversations a two-way exchange of information.
- Leave space in conversations for additional comments.
- Learn from peoples don't lecture.
- Be patient but proceed at a moderate pace.
- Seek the views of the weaker, less powerful peoples or groups.
- Share information.
- Avoid placing peoples in situations in which they may feel uncomfortable.
- Give people time to communicate and consider ideas.
- Be self aware and self critical-learn from your errors.
- Cross-check the validity of information using at least three different sources.
- Frequently reflect on what information has been gained and where the gaps are.
- Identify and test assumptions.
- Be aware of your own biases-do not let them affect your work.
- Ask questions that invite explanations or points of view rather than yes or no answer.
- Schedule PRA activities so that they fit in as far as possible with seasonal and daily routines of local peoples.

Potential dangers and drawbacks of PRA

- Misused through superficial adoption of methods.
- Seen as a replacement for other form of investigation.
- Unreliable if rushed.
- Disruptive to social routines in the villages.
- Time consuming.

PRA tools and techniques

- Building rapport
- Information collection from secondary sources
- Semi-structure interviews
- Key informants and focus or interest group discussion
- Participatory resource and social mapping
- Participatory sketch mapping
- Participatory analysis of photographs
- Ranking
- Time chart (seasonal calendar)
- Semi-structure transect walk
- Direct observation
- Participatory human resource identification
- Participatory stakeholder identification
- Workshop and group meeting
- Cross-checking of information

Using PRA tools and techniques, following study should be carried out for designing appropriate agroforestry system:

Study of traditional and indigenous land use system

In both traditional and modern society there are many forms of lands. The traditional society had the characteristics of large land and sparse population density, and plentiful cultivable lands. Farmers in Nepal have their own tradition on the ownership and utilization of lands,

where trees are integrated with farming systems. Traditional types of lands are **1)** rice fields: the fields are flat cultivation land surrounded by borders or bunds to keep water, and are mainly used to grow rice. The fields have been cultivated for a very long time and have been an important source of income generation. Trees are planted on bunds and borders of these fields. Another land is **2)** dry fields or bari lands- are flat or slope cultivation land situated on high hills or near the foot of hills, oe plan areas of both Terai amd inner Terai also surrounded by borders but to limit soil erosion rather than to hold water. Most of terrace fields are reclaimed from former slopping field. In those fields, the main crops grown are maize, millet, wheat, potatoes, and vegetables in the form of intensively farming. Trees in these lands are planted along terrace bunds, borders and slopes to meet household needs on fodder and forage, fuel wood and timber in some extent.

Additional land is **3)** marginal lands or kharbari- generally these lands are only few slopping fields. They are less fertile cultivation lands on the high hills or on the slopes of mountains or plain areas. People in these lands grow grasses (Khar) and few fodder and timber trees. There are some **4)** gardens. In the gardens, people grow fruit trees, herbs, green vegetables and even fodder, fuel wood and timber trees.

The study of traditional knowledge and technology of farmers regarding their production environment cannot be over emphasized while reviewing the wide variety of application of agroforestry found in tropical, sub-tropical and temperate high lands. The best example of innovative indigenous management technique in high lands agroforestry system includes the following:

- Growing of multi varietal trees along terrace bunds, borders and slopes with agriculture crops.
- Planting of trees and grasses (bamboo) in gullies to conserve soil and to improve productivity of such highly degraded gully lands.
- Multi storey home gardens with shade tolerant under storey crops (ginger, turmeric, colocasia etc).

These traditional farming methods are developed over many generations of trial and error and refinement. Oldeman (1979) reported that indigenous agriculture is the combination of bio-climatic factors, soil, population density and technical ability of the farmers. Study of such traditional and indigenous technology or land use system will promote in better understanding of the system as it helps by diagnosis of the technology and ultimately in designing the appropriate system from these learning on species selection, tree and crop combination and planting techniques etc.

There are some common factors of land use system, which should also be studied before designing new project. These factors are:

- Resources such as land, labour and capital availability at the community or household level.
- Resource use right with respect to lands, trees, animals and water should be well understood.
- Alternative resources such as on farm and off-farm activities should also be understood.
- Management level associated with various production systems should also be studied.
- Performance (yields) in terms of meeting socio-economic priorities and criteria should also be measured.

Study indigenous Vs introduced technology

An agroforestry system may use

- Indigenous technology that farmers are familiar and such technologies are socially, economically and locally or environmentally adoptable and acceptable.
- Practice that has been modified or improved by farmers or outsiders.
- Practice introduced by outside researchers or extension agents.

Indigenous or existing knowledge and skills on tree and agriculture farming should be the basis for designing new agroforestry interventions. However, many projects introduced new exotic species and technologies, which have following risks:

- Introduced technology may not be socially and economically acceptable to local farmers.
- Introduced technology or species may not be ecologically sound (introduction of Ipil-Ipil on acidic soils because legume species cannot grow well in acidic soils).

Therefore, small scale on farm experiments with farmers should be carried out to test new species and technologies. Performance of such species and technologies should be evaluated before promoting in large scale.

3. Study of biophysical situation

a) Biological information

- **Flora** (types of vegetation cover, species-the most productive and useful indigenous and exotic trees, shrubs and herbs found in this localities, weeds, crop plants, endemic plants for agroforestry)
- **Macro and micro fauna** (wild and domestic animals especially destructive, insects, pests and pathogenic organisms etc)
- Problems of weeds and insects, pests and destructive animals such as monkey, pigs etc.

b) Physical data

- **Soil factors-** Physical properties (Texture, structure, depth, drainage, porosity, dryness, erodibility etc), chemical properties (nutrient content, soil pH, organic matter, salinity, cation exchange capacity etc) and biological properties (soil microorganisms)
- **Climatic factors-** Rainfall (amount, monthly distribution), temperature (maximum, minimum and monthly average etc), wind (intensity and direction), catastrophic events (storm and floods, fire frequency, intensity and seasonal occurrence etc).
- **Physiographic factors-** Elevation (altitude), exposure (aspect) and slope (gradient), general terrain, location relative to mountain ranges and water bodies etc.
- **Land use systems-** (history, present use, human activities of surrounding areas, potential alternate use of land, land capability class, size of farm, land tenure, accessibility and market)

c) Study of socio-economic environment

- **Endogenous factors-** these factors are under the control of individual farmers, which are land, labour and capital. The land potential for agroforestry is usually small in size, labour

is abundant, but there is shortage during peak season, and capital interms of cash and credit is very scarce.

- **Exogenous factors-** these factors are outside the control of the community or individual farmers, which are market structure and support system, extension services (technical, social, health and religious etc), financial institutions and policies (government policies on land use).
- **Gender, social equity and poverty** –information on men vs women, rich and poor and different ethnic groups and dalits should be collected.

Methods for agroforestry system planning and management

1. The ICRAF's Diagnostic and Design Methodology

1 Introduction

Diagnosis and Design (D&D) is a systematic methodology developed by ICRAF to initiate, monitor, and evaluate agroforestry programs. It is based on the philosophy that knowledge of the existing situation (diagnosis) is essential to plan, implement and evaluate meaningful and effective programs in agroforestry research for development. In the design of appropriate agroforestry systems following three criteria's are used:

- **Productivity** – high production of both agriculture and forest products.
- **Sustainability**- It is a pattern of resource development and use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for generations to come.
- **Adaptability**- Technology (species and techniques) recommended for agroforestry system development should be locally applicable.

Objectives or Purposes of D & D methodology:

- To describe and analyze existing land use systems with respect bio-physical and socio-economic condition
- To design appropriate agroforestry technologies or research work
- To develop technologies to solve farmers' problems in priority land use systems in specific eco-zones.

The basic unit of D&D analysis is the land use system that can be defined and analyzed at the level of a farming system, crop system, eco-zone or any other unit. The structure and function of any land use system are determined by climatic, physical, biological, technological, economic, social, and political factors. D&D focuses on the interactive effects these factors have on the land use system, and searches for opportunities for improved system development in the land use system.

There are six main steps in the process:

1. Level of D and D methods: Macro D&D (national and ecozone level) and Micro D&D (land use analysis at the production systems level)
2. Technology design
3. Component experimentation
4. Technology testing
5. Technology dissemination and adoption

Level of D&D Methods:

1. **Macro D&D**

It is a large-scale analysis of an eco-zone within a country. Macro D&D is important for deciding on national agroforestry research-and extension agenda at-the national level. It relies heavily on secondary data which are verified and complemented by quick field surveys using Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA) techniques.

The Objectives of Macro D&D

Macro D&D is an analysis of an ecozone within a country or group of countries. The four main objectives of the Macro D&D are:

- to identify broad issues and problems of all the land use systems of a given eco-zone.
- to identify and prioritize areas for potential agroforestry interventions
- to identify research priorities and formulate research programs
- to identify needs, opportunities, and mechanisms for coordination and linkages with various line agencies for technology development.

2. **Micro D&D**

It gives attention on one land use system within the larger eco-zone that has special priority for agroforestry intervention. Micro D&D involves a detailed analysis of households and production systems in the land use system. It leads to guidelines for research that will address the constraints of the prioritized land use system.

Objectives of Micro D&D

The objectives of micro D&D are similar to those of macro D&D. The major difference is that whereas macro D&D has a broad scope (i.e., an ecozone), micro D&D focuses on detailed analysis of one prioritized land use system. The three main objectives of micro D&D are:

- to describe and analyze a land use system in order to identify its constraints
- to design and evaluate agroforestry technologies to address the constraints
- to design and evaluate appropriate research programs aiming to develop these technologies.

The basic principles or steps for achieving these objectives are as in macro D&D. These steps are as follows:

There are seven steps in macro/micro D&D exercise:

- Identification of study eco-zone or household or land use system within eco-zone.
- Delineation of land use systems within the eco-zone or household or land use system

- Description of land use systems
- Analysis of land use system constraints and potentials
- Analysis of potential agroforestry technologies (species selection, spacing and plantation establishment and management techniques)
- Definition of agroforestry research needs, and
- Coordination and linkages with various line agencies for agroforestry technologies and techniques development, implementation, monitoring and evaluation, and technology dissemination and extension.

Following points should be considered while evaluating new technology:

- **Economic viability:** benefit/cost ratio, and cost effectiveness; net returns to land/labor/cash; risk and sensitivity analysis.
- **Sustainability:** analysis of the capacity of new technology to meet short -and long-terms objectives; analysis of expected changes and requirements related to soils, water, vegetation, management, and commercial input/output streams, and sustainability of achievements.
- **Farmer acceptability:** comparability analysis with respect to resources and management; also, social analysis with respect to defined rules and responsibilities within household obligations. It is essential to analyze who in the household makes decisions on the resources required, who has to do the work, and who will receive the benefit accruing from proposed changes.
- **Adoption potential:** analysis of technology impacts in terms of number of farmers, lateral adoption, institutional and infrastructural support systems.

2. Farming System Research and Development (FSRD) Approach

The FSRD approach is a relatively recent development in the field of agriculture system development and management. It was concept module in reaction to the traditional type of research which focuses mainly in an ideal farming environment. As such the result was found to be generally inappropriate to small scale farmers. The FSRD approach is small farmer centered and therefore, relevant to the overwhelming majority of upland farmers. It has four stages, which are given below:

- ***The Descriptive or Diagnostic Stage***, in which the actual farming system is examined in the context of total environment to identify biophysical and socio-economic information (see study of biophysical and socio-economic condition section above), and constraints farmers face (that may be shortage of fodder and forage, fuel wood and timber, and soil fertility loss and soil erosion, and land degradation etc) and to determine the potential flexibility in the farming system in terms of timing, unused resources, etc. An effort also is made to understand the goals and motivation of farmers that may affect their efforts to improve the farming system.

- ***The Design Stage***, in which a range of strategies is identified that are thought to be relevant in dealing with the constraints determined in the descriptive or diagnostic stage.

    - The constraints are ranked according to their severity (fodder and forage, fuel wood and timber supply and soil fertility loss, soil erosion and land degradation etc), and potential solutions are identified after determining what flexibility exists in the farming systems currently practiced.
    - An evaluation is made of the proposed solutions before putting them into practice.

- ***The Testing and Implementation Stage***, in which one or more promising strategies such as fodder, forage, firewood and timber, soil fertility improvement and soil erosion control, arising from the design stage, are examined and evaluated under term conditions to determine their suitability for producing desirable and acceptable changes in the existing farming system.

- ***The Dissemination and Impact Evaluation Stage***, in which the strategies that were identified and screened during the design and testing stages are extended to farmers.

On station agroforestry research methods

An agroforestry **research station** is a place which is built for the purpose of conducting scientific research on agroforestry. In such experiment station, ***applied*** research is usually undertaken from which new technologies are developed. In Lumle and Pakhribas Agriculture Research Centre, such applied research in agroforestry has been conducted. In these centers agroforestry research plots are designed using statistical methods such as split plot design, completely randomized block design etc. Various treatments are used to compare the results of the research work. Tree growth and production of all crops are measured seasonally. Trees are managed using silvicultural regimes. Data are analyzed using statistical methods. In most cases, farmers and their concerns are also listened during tree species and agriculture crops selection, research plot design and establishment, and measurement of production and productivity. Such station will also serve as training and extension centers, where farmers during training and study tour programme will be visited.

Unit 6: Agroforestry Project Development and Evaluation

An agroforestry project should be designed for making an innovative change, improving performance of a routine operation and trying something new. The project design and management criteria should be as follows:

1. **Clear mutual agreed upon the objectives**
   - Goal
   - Objectives
   - Outputs
   - Major activities

2. **Clear roles and responsibilities**
   - Person and agent's responsibility
   - Target

3. **Built in flexibility for solving problems**
   - Reporting system
   - Monitoring and evaluation system

4. **Accurate schedule and budget**

- Duration
- Budget

Basic information should be kept about all potential agroforestry projects, and these projects should be to solve the problems faced by the farmers. An agroforestry project should be:

- Technically simple
- Economically viable
- Socially acceptable
- Environmentally sound

Principles or consideration for agroforestry project design

1. **Productivity**

The productivity of recommended agroforestry system should be high production in both agriculture and forest products. Productivity should also be seen from the point of view of improved stability of the farming system, increased labour efficiency, reduction of inputs and improve the value of the land etc. There are different ways in improving the productivity of agroforestry systems. These are:

- Increase in tree products
- Improved the yield of associated crops
- Reduction of cropping inputs
- Increase labor efficiency
- Diversification of production
- Satisfaction of basic needs
- Other measures of socio-economic efficiency

2. Sustainability

It is a pattern of resource development and use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for generations to come.

The agroforestry model should be for its ability to provide sustained yield overtime. The system must be based on the principles of optimal production in order to consider the ecological principles.

Analysis of the capacity of new technology to meet short and long-terms objectives; analysis of expected changes and requirements related to soils, water, vegetation, management, and commercial input/output streams, and sustainability of achievements.

3. **Adaptability**

Technology (species and techniques) recommended for agroforestry system development should be socially and environmentally applicable in local situation for which it is designed.

4. **Economic viability**

The benefit/cost ratio, and cost effectiveness; net returns to land/labor/cash; risk and sensitivity analysis of proposed agroforestry models should be done for measuring economic viability.

5. **Farmer acceptability**

It is comparability analysis with respect to resources and management, and social analysis with respect to defined rules and responsibilities within household obligations. It is essential to analyze who in the household makes decisions on the resources required, who has to do the work, and who will receive the benefit accruing from proposed changes. Proposed technology should be beneficial to the women of all households involved in this program.

6. **Adoption potential**

Analysis of technology impacts in terms of number of farmers adopted this technology or lateral adoption, and institutional and infrastructural support system analysis should also be carried out while developing agroforestry projects.

7. Multiple function

The species selected for agroforestry system must give multiple benefits such as food security, income generation, soil fertility improvement and environment protection etc to the farmers.

8. Stratification

Design of planting schemes should consider the dimension of space and time. It must consider both horizontal as well as vertical perspectives

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Design of planting schemes should consider the dimension of space and time. It must consider horizontal as well as vertical perspectives.

Procedure for designing agroforestry project

There are 4 stages of agroforestry project design or procedures that are information collection, feasibility study or information analysis, technical designing of project and redesigning. These stages are described below:

1. Information collection

Information needed for agroforestry project design is bio-physical and socio-economic information. This information can be collected using primary (field survey and visit) and secondary sources (publication, report, papers etc.

2. Feasibility analysis

Information collected from the field and secondary sources should be analyzed. The main objectives of the feasibility analysis is to identify the advantage in economic and natural resource development, and to find out the existing problems or constraints of farmers, and potential of land use development based on the utilization of natural resources. Biophysical and socio-economic information will help to select best species and species combination, and spacing (Row to row, and plant to plant distance), target groups, agroforestry plot establishment methods and management policy for different biophysical condition and their development scale.

Site selection

Sites for agroforestry project implementation should be selected in consultation with farmers and other local and district level stakeholders (government office, I/NGOs and private sector) keeping in mind the following criteria:

- Availability of suitable lands (fertile soil and suitable climatic condition) needed for recommended agroforestry technology
- Solving farmer's constraints
- Farmer's needs and interest
- Beneficiary groups (poor, women, ethnic groups and dalits)
- Availability or potentiality for developing natural resources and their collection and trading place
- Motivated and interested people who wants to start agroforestry as a business
- Employment or just for meeting subsistence needs
- Government policy supporting agroforestry system
- Transportation access
- Have demonstration effects (high possibilities for farmer to farmer extension)
- Have communication facilities
- Market and market demand

Prioritization of agroforestry models

Different agroforestry models can be developed during feasibility analysis, and these models can be prioritized of using following criteria with score (1-5 score: very high - 5, high - 4, moderate - 3, poor - 2 and very poor – 1) in each criteria. Agroforestry models obtaining higher score will be selected as priority activities or model.

- Farmer's needs and interest
- Availability of lands
- Possibility of selected technology implementation
- Resource availability/investment probability
- Sponsorship/support available
- Technical aspects (farmer's skill and knowledge)
- Creativity and innovation
- Physical infrastructure (Road linkage)
- Beneficiaries groups (poor, dalits and women - 5, ethnic group - 3 and others - 1)
- Economic activities - Annual turnover, employment opportunity and profit level
- Market demand
- Government policy

Strategy or guidelines for designing and or implementing appropriate agroforestry systems

Strategy for designing appropriate agroforestry system in Terai, mid-hills and mountains of Nepal should be to improve livelihood of small land holders and how this system is related to food and income security; investigating whether livelihood systems can be improved which better meet the needs of a wider range of small farmers, women and disadvantaged groups and whether there is potential for incorporating those species which produce Non Timber Forest Products (NTFPs) into livelihood systems. However, the strategy for designing appropriate agroforestry systems in Terai, mid- hills and mountains of Nepal should be as follows:

- Agroforestry system designed for small farmers should be technically simple, economically viable, socially acceptable and environmentally sound.
- Empower farmers technically and socially
- Encourage coordination and linkages to implement agroforestry activities.
- Use those tree species, which reduce farmer's main problems or constraints related to fodder and forage/ fire wood/ timber shortage and soil and water conservation etc.
- Use mixture of different species to meet the needs of farmers. Tree and crop species having high demand and market value should also be included.
- Use legume trees, shrubs and grasses to maintain or improve soil fertility.
- Adopt mix cropping practice including legume and non-legume agriculture crops.
- Use fast growing and deep rooted trees.
- Plant trees, grasses and crops along contour or across the slope to control soil erosion.
- Pruned materials or leaf litter should be mixed in soil to add organic matter into the soil.
- Hedge rows should be pruned at 75-100 cms height to reduce shading effects of trees to under storey crops.
- Synchronize the tree pruning or lopping time with nutrient requirement of crop plants.
- Adopt crop rotation practice.

- Upper slope of farm lands should be developed as wood lots.
- Grow cover crops or green manure crops in fallow areas.
- Arrange 4-8 meters row to row, and 2-3 meters plant to plant distances depending on slope of the lands. Only 4-5 meters row to row distance should be in sloppy lands form soil conservation point of view.
- Trees should be managed using appropriate silvicultural regimes such as singling, pruning, and thinning for timber species, and lopping, pollarding and coppicing for fodder species for reducing the shading effects of trees to under storey crops.

3. Technical designing

It includes species selection and combination, vertical species arrangement, horizontal deposition and temporal structure design etc, which are discussed below:

3.1. Species selection and combination

Tree species and crops should be selected to meet the farmer's needs, and to improve the soil fertility and to increase productivity of both forestry and agricultural crops. The main principles of species combination should be as follows:

- Tree and agriculture crops intercropping
- Combine species for mutual relationship such as nitrogen fixation
- Select trees having less shading effects and root competition
- Understory crops should be shade tolerant
- Avoid species combination having **Allelopathic** effects.

3.2. Vertical species arrangement

Modern agroforestry should be multistory use of space and sunlight, diversity of the flow of materials, energy and outputs. Principally, it involves selection of species to be planted in different vertical strata according to their height and light or shade tolerant capacity. The following points should be considered while designing multistory agroforestry systems:

- Species selected for upper layer should be tall and deep rooted with light crown cover. In this layer, trees like coconut, nuts, eucalyptus, sissoo etc should be the best species.
- Middle layer species (fruits, and fodder-Ipil Ipil and fuel wood-bakaino species) should be partially shade tolerant species.
- Ground level species should be shade tolerant species (like coffee, tea, cardamom etc) and agriculture crops like ginger, turmeric, yam, sweet potato, colocasia, pineapple etc, and forage crops like desmodium and forage peanut. These species should also be shallow rooted.
- Legume species should also be included in all desgn.

3.3. Horizontal deposition

It means horizontal arrangement of trees and crop species, in which rational proportion of trees (row to row and plant to plant distances), and agriculture crops should be arranged for

better mutual relationship between trees and agriculture crops. Trees should be arranged in such a way that sunlight should be reached upto the understory crops.

During the design of an intercropping system with light loving agriculture crops in flat terraces, trees should be planted in North-South orientation with relatively wide space between trees rows, and plants.

3.4. Temporal structure

It means original design should be for some years, in which more trees should be planted initially, and later on this should be reduced by thinning operation to open canopy cover. In some cases, agriculture crops are grown for few years like in Taungya system.

3.5. Technical structure design

Technical structure of agroforestry includes the combination biotechnology (forest and agriculture technology) and engineering techniques, conventional and modern technology etc. In case of gully rehabilitation through agroforestry practice, engineering structure may be needed for the sustainability of silvi-pastoral system.

3.6 Regional model series design

It includes design agroforestry project for a community or region or a country, not only for a household or farm.

a) Formats for designing agroforestry project

Any activity that involves the use of resources during a specific time period for the purpose of producing a socio-economic return in the form of goods and services (NEDA, 1984) is known as project. For the design of such projects, following points need to be considered:

- Introduction or background information (including biophysical and socio-economic information)
- Purpose and goals - single (Specific) and multiple (Several)
- Objectives – to increase economic growth
  - to reduce poverty
  - to improve environment
- Outputs - Area or households to be covered by agroforestry practice
- Relation - Mutual relationship with other projects
- Methodology (Beneficiaries – small farmers, women and disadvantaged groups, working approach-group or individual household, time (strategic- long term and operational- short term), coordination and linkages for activities implementation, monitoring and evaluation etc.
- Activities – Seedling production, plantation establishment, capacity building etc.
- Financial requirement – budget

4. Redesigning

After designing agroforestry projects with proper trees and crop selection, planting methods (row to row distance, and plant to plant distance) and plantation and crop management prescriptions, this design should be presented and discussed with farmers and their

association, government line agencies, I/NGOs and private sectors for their comments and recommendation. After getting their suggestions, the project should be redesigned.

Project or program implementation

The step represents the opportunity to actually put the program into operation. The justification for maintaining the element of program implementation as part of the process is primarily that the plans made seldom match those which actually become implemented in the field. Factors that increase effectiveness in project implementation are:

- Detail planning
- Adequate resources
- Effective agent
- Effective communication
- Effective linkages
- Political will of local government unit
- National policy supportive to the program
- Commitment

Factors to consider in implementing agroforestry programs

- Bio-physical factors
- Population factors- gender and social equity
- Economic factors
- Communication , extension and education factors
- Ideological factors
- Institutional or organizational factors

Case study of Hills and Terai

Case study is the process of finding the existing activities of any program in detail. It should be done in specific areas on basis of the objectives of the program. The following points should be covered in a case study:

- Introduction (background information-location, areas etc)
- Objectives of the program
- Methodology (how agroforestry program was conducted, and study methods)
- Result and discussion
- Conclusion and recommendations

a) **Hills** *(source: Agroforestry Systems Prospects and Problems: A Case Study of Begnas Tal Rupa Tal Watershed Management Propject, Kaski by Govinda Rimal)*

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The land was completely fallow before 1992, and Begnas Tal Rupa Tal (BTRT) project formed farmer groups of eight farmers, and encouraged group members to plant trees and grow vegetable crops "says Hari Prasad Bastola of Lekhnath Municipality and Rishi Ram Bastola of Majhthana VDC.

They have planted 2050 fruit plants (citrus, banana etc), 363 coffee and 727 fodder and fire wood species, and earned Rs 40,000 per year from the sale of citrus fruits, pineapple and vegetables.

b) Terai *(Source: Agroforestry System and Practice in Nepal by Dr. S.M. Amatya, and Sagarnath Forestry Development Project reports)*

The Sagarnath Forestry Development Project is located in Sarlahi and Mahottari Districts of Nepal, which have planted 9143 ha until 1992. The major tree species planted in the project areas are *Eucalyptus camaldulensis, Dalbergia sissoo and Tectona grandis* and other few fire wood species. The row to row and plant to plant distances were 4 meters and 2 meters respectively. Villagers were involved to grow agriculture crops like Tori, vegetables, maize etc as Taungya planters for few years (3-5 years) until canopy cover is closed or dense.

The main objective of the project was to encourage farmers to intercrop agriculture crops in between trees in order to lower weeding costs, protect the young seedlings from animal grazing and fire, and enhance the tree growth and survival rates. It was experienced that the growth of Eucalyptus and Sissoo in intercropped areas was 3-4 times higher in comparison to the areas where intercropping has not been practiced. Some farmers involved in intercropping have also earned money from the sale of vegetables grown in Taungya plots.

The project development is the operational process for designing high-quality agroforestry development projects that respond to the realities in the field and the needs and aspirations of the project's partners - especially the poor, women and disadvantaged groups. Such project is developed for 1) social development through group empowerment, 2) forest and other natural resource development to meet farmer's needs, 3) maximum utilization of available lands, 4) improve productivity of lands and 5) income generation and livelihoods improvement of targeted groups.

Monitoring and Evaluation

Definitions:

After implementing field programs, monitoring and evaluation should be carried developing simple criteria and indicators for doing regular monitoring and evaluation works.

Monitoring - should be carried out periodically during program implementation based on the formats developed by the project. Participatory monitoring is defined as the process of measuring, recording, processing and communicating information to assist the project management and farmers concerned in decision making (Huizer, 1983). Mr Michael

Bamberger, defines monitoring as "an internal project activity designed to provide constant feedback on the progress of a project, the problems it is facing, and the efficiency with which it is being implemented".

The main objective of monitoring is to check if work is proceeding according to set targets and record this data in a systematic way so that it will allow control of project activities to achieve given goals.

Evaluation

Evaluation is defined as the periodic assessment of the performance of a project against its stated objectives (Fearnside,1992). An evaluation studies the outcome of a project (changes in income, housing quality, benefits distribution, cost-effectiveness, etc.) with the aim of informing the design of future projects. This work will be carried out after 2-3 years of project implementation or mid of the project period or after the project completion. For this, a set of criteria and indicators need to be developed.

Objectives of evaluation

- To check project achievements and impacts.
- To check the assumption that whether project inputs and objectives are achieved or not.
- To help the management in making decisions about the follow up projects or activities.

Types of evaluation

1. Formative and summative

The formative evaluation aims to determine whether the project is working or not as planned, and if not what can be done to improve it. Summative or terminal evaluation is done after the completion of the project. It measures the achievements of the project in terms of activities, outputs, effects and impacts.

2. External and internal

Internal evaluation is done by persons with in the project or institute, and external evaluation is carried out by people outside of the project or institute.

3. Informal and formal

Informal evaluations are the ones people ordinarily make about simple problem without much consideration of the principle of evaluation. Formal evaluation is scientific research based on statistical procedures.

4. Qualitative and quantitative

Qualitative evaluation uses non-numerical data, while quantitative evaluation uses numerical data.

Impact evaluation model

- Integrative model (social, economical and environmental impacts)
- Modifying the model- modify integrative model

Monitoring and evaluation systems can be an effective way to:

- Provide constant feedback on the extent to which the projects are achieving their goals.
- Identify potential problems at an early stage and propose possible solutions.
- Monitor the accessibility of the project to all sectors of the target population.
- Monitor the efficiency with which the different components of the project are being implemented and suggest improvements.
- Evaluate the extent to which the project is able to achieve its general objectives.
- Provide guidelines for the planning of future projects.
- Influence sector assistance strategy. Relevant analysis from project and policy evaluation can highlight the outcomes of previous interventions, and the strengths and weaknesses of their implementation.
- Improve project design. Use of project design tools such as the log frame (logical framework) results in systematic selection of indicators for monitoring project performance. The process of selecting indicators for monitoring is a test of the soundness of project objectives and can lead to improvements in project design.
- Incorporate views of stakeholders. Awareness is growing that participation by project beneficiaries in design and implementation brings greater "ownership" of project objectives and encourages the sustainability of project benefits. Ownership brings accountability. Objectives should be set and indicators selected in consultation with stakeholders, so that objectives and targets are jointly "owned". The emergence of recorded benefits early on helps reinforce ownership, and early warning of emerging problems allows action to be taken before costs rise.
- Show need for mid-course corrections. A reliable flow of information during implementation enables managers to keep track of progress and adjust operations to take account of experience.

Good monitoring and evaluation design during project preparation is a much broader exercise than just the development of indicators. Good design has five components:

- Clear statements of measurable objectives for the project and its components, for which indicators can be defined.
- A structured set of indicators, covering outputs of goods and services generated by the project and their impact on beneficiaries.
- Provisions for collecting data and managing project records so that the data required for indicators are compatible with existing statistics, and are available at reasonable cost.
- Institutional arrangements for gathering, analyzing, and reporting project data, and for investing in capacity building, to sustain the M&E service.
- Proposals for the ways in which M&E findings will be fed back into decision making.

Examples

1. Project objectives

Projects are designed to further long-term sectoral goals, but their immediate objectives, at least, should be readily measurable. Thus, for example, an agroforestry project might be designed to further the sectoral goals of a reduction in poverty but have an immediate, measurable objective of providing more equitable access to income generation. Objectives should be specific to the project interventions, realistic in the timeframe for their implementation, and measurable for evaluation.

2. Indicators

Input indicators are quantified and time-bound statements of resources to be provided. Information on these indicators comes largely from accounting and management records. Input indicators are often left out of discussions of project monitoring, though they are part of the management information system. A good accounting system is needed to keep track of expenditures and provide cost data for performance analysis of outputs. Input indicators are used mainly by managers closest to the tasks of implementation, and are consulted frequently, as often as daily or weekly.

Examples: vehicle operating costs for the crop extension service; levels of financial contributions from the government or cofinanciers; appointment of staff; provision of buildings; status of enabling legislation.

Process indicators measure what happens during implementation. Often, they are tabulated as a set of contracted completions or milestone events taken from an activity plan.

Output indicators show the immediate physical and financial outputs of the project: physical quantities, organizational strengthening, initial flows of services. They include performance measures based on cost or operational ratios.

Impact refers to medium or long-term developmental change. Measures of change often involve complex statistics about economic or social welfare and depend on data that are gathered from beneficiaries. Early indications of impact may be obtained by surveying beneficiaries' perceptions about project services. This type of leading indicator has the twin benefits of consultation with stakeholders and advance warning of problems that might arise.

Examples of beneficiary perceptions: proportion of farmers who have tried a new variety of seed and intend to use it again; percentage of women satisfied with the agroforestry service they receive.

3. Collecting Data and Managing Project Records

The achievement of project objectives normally depends on how project beneficiaries respond to the goods or services delivered by the project. Evidence of their response and the benefits they derive requires consultation and data collection that may be outside the scope of management. It is important to identify how beneficiaries are expected to respond to project services, because managers will need evidence of that response if they are to modify their activities and strategy. Indications that beneficiaries have access to, are using, and are

satisfied with project services give early indication that the project is offering relevant services and that direct objectives are likely to be met.

Exogenous indicators are those that cover factors outside the control of the project but which might affect its outcome, including risks (parameters identified during economic, social, or technical analysis, that might compromise project benefits); and the performance of the sector in which the project operates. Concerns to monitor both the project and its wider environment call for a data collection capacity outside the project and place an additional burden on the project's M&E effort.

Data collection from Project field records - Indicators of inputs and processes will come from project management records originating from field sites. The quality of record keeping in the field sets the standard for all further use of the data and merits careful attention.

Surveys and studies. To measure output and impact may require the collection of data from sample surveys or special studies (including, where appropriate, participatory methods). Studies to investigate specific topics may call for staff skills and training beyond those needed for regular collection of data to create a time series.

Special studies may be more manageable by a project unit directly, or subcontracted to consultants. If the special studies are to make comparisons with data from other surveys it is vital that the same methods be used for data collection. In the project plan, proposals to collect data for studies should include a discussion of: the objectives of the study or survey; the source of data; choices and proposed method of collection; and likely reliability of the data.

Data comparability - Some desired indicators of impact, such as seedling mortality rate or household income attributable to a project, may involve comparisons with the situation before the project, or in areas not covered by the project. Such comparisons may depend on the maintenance of national systems of vital statistics, or national surveys. Before data from such sources are chosen as indicators of project impact the designer needs to confirm that the data systems are in place and reliable and that the data are valid for the administrative area in question and for any control areas.

Participatory methods of data collection can bring new insights into peoples' needs for project planning and implementation, but are no less demanding on skills than questionnaire surveys. They are time-consuming and require substantial talent in communication and negotiation between planners and participants.

4. Institutional arrangements; capacity building

Good M&E should develop the capacity of the staff and build on existing systems. Capacity building is widely acknowledged to be important but is often poorly defined. It means: upgrading skills in monitoring and evaluation, which include project analysis, design of indicators and reporting systems, socioeconomic data collection, and information management; improving procedures, to create functional systems that seek out and use information for decisions; and strengthening organizations to develop skilled staff in appropriate positions, accountable for their actions.

5. How Monitoring and Evaluation Findings Can Be Fed Back into Decision Making

In projects where operating performance standards are quoted as an objective, or where decentralized processes call for localized capacity to plan and manage work programs and budgets, designers will need to describe how and when M&E findings will be used to shape work plans and contribute to program or policy development.

Annual plans are to be prepared for each component, including an element of institutional development, and these will form the basis of annual monitoring. The analysis of implementation will depend on the functioning of a central database about sub-projects, created in each state from standardized data sheets. The database will produce the reports required for the project approval procedures, giving an incentive to field staff to use the system. Results from the implementation database will be analyzed in order to target field reviews and a mid-term review. The project has no specific monitoring and evaluation unit. Instead, each management sub-unit responsible for technical oversight of a component is responsible for ensuring the quality and timeliness of data collection, and for producing and analyzing reports. These reports will be presented by project component and be used to help diagnose technical and institutional implementation issues, propose and conduct studies, and plan institutional development and training.