

FWM 314: PRINCIPLES OF AGROFORESTRY

LECTURE NOTE

BY

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INTRODUCTION

Agroforestry is an example of Multiple Land Use (MLU). What then is Multiple Land Use?. **MULTIPLE LAND USE** is the conscious and deliberate use of land for the simultaneous production of two or more goods or services using good combination.

- Take note of the words **CONSCIOUS** and **DELIBERATE** as against **ARBITRARY** and **HAPHAZARD** use of land. Such services may include timber production, grazing, recreation, wildlife, farming, water conservation, soil protection etc.

THE CONCEPT AND DEFINITION OF AGROFORESTRY

Agroforestry is an age-old land-use system that has been practised for thousands of years by farmers all over the world. Although in recent years it has been developed as a science that promises to help farmers increase the **PRODUCTIVITY**, **PROFITABILITY** and **SUSTAINABILITY** of production on their land, the science of agroforestry lags far behind the art of existing agroforestry practices.

Cultivating trees, agricultural crops and animals in close combination with one another is an old practice that farmers have used all over the world. Trees have always played an important role in mankind's survival. Originally, hunting and gathering was carried out in forested areas, which provided not only shelter but food, such as game, fruits and seeds. Early agriculturists also made use of forests with the practice of shifting cultivation or slash-and-burn agriculture. In this practice, they cut and burn relatively small forest plots and produce crops in the burned-over, taking advantage of the nutrients in the ashes of the burnt plants. After 2-3 years, the nutrients are depleted and weeds become a problem; so the farmers abandoned the plots for 10-20 years, permitting the re-growth of forest species. They move on to another forested plot, which they slash-and-burn and then crop for 2-3 years before this plot is abandoned as before. A farmer may shift in turn to 5-10 such small plots before returning to clear and burn trees in the first one that was idled (fallowed) 10-20 years previously. The steps are then repeated until another cycle is completed. This agricultural system is termed 'shifting cultivation', indicating the moving from one plot to another, or 'slash-and-burn' referring to the means of destroying the forest lands. Over a long period

of time, as population pressure has steadily increased, fallow periods have become shorter and shorter. Consequently, farmers have returned to abandoned fields before they have had enough time for fertility to be sufficiently restored.

Today's shorter fallow period is one of the reasons for a decline in per capital food production in Africa during the past decade. Most of the countries in Africa are faced with the problems of food and fodder shortage, degradation of non-renewable resources, and decreasing access to fuelwood supplies. With increasing realization of the World environmental crises and the worsening food situation in developing countries; more integrated outlooks have begun to emerge in the last decades. One of these is AGROFORESTRY.

This relatively young science known as agroforestry was brought from the realm of indigenous knowledge into the forefront of agricultural research a little over three decades ago, and was promoted widely as a sustainability-enhancing practice that combines the best attributes of forestry and agriculture. Growing trees along with crops and livestock was postulated to enhance crop yields, conserve soil and recycle nutrients while producing fuelwood, fodder, fruit and timber.

The KEY CONCEPTS of agroforestry are now well established; and it is generally accepted that agroforestry:

1. Is a collective name for land use systems involving trees combined with crops and /or animals on the same unit of land;
2. Combines production of multiple outputs with protection of the resource base;
3. Places emphasis on the use of indigenous, multipurpose trees and shrubs;
4. Is particularly suitable for low-input conditions and fragile environment;
5. Is more concerned with socio-cultural values than most other land-use systems;
6. Is structurally and functionally more complex than monoculture.

With the growing realization that agroforestry is a practical, low-cost alternative for food production as well as environmental protection, forestry departments of many countries are integrating agroforestry programmes with conventional silviculture.

DEFINITION OF AGROFORESTRY

Following its conceptualization as a land-use approach in the late 1970s, there was a surge of enthusiasm to define agroforestry. Since the word 'agroforestry' was coined in 1977 when deliberations for establishing the International Council for Research in Agroforestry (ICRAF) began, it has been variously defined.

As time passed, the definition proposed in the early 1980s by ICRAF (now known as the World Agroforestry Centre) gained wider acceptance. The definition, which was used from the early 1980s to the mid-nineties is as follows:

AGROFORESTRY is a collective name for land-use systems and practices where woody perennials (trees, shrubs, bamboos, vines etc) are deliberately integrated with crops and/or animals on the same land management unit. The integration can be either in spatial mixture or temporal sequence. There must be both ecological and economic interactions between the woody and non-woody components to qualify as agroforestry.

More simply put, agroforestry is any land-use involving planting of trees or deliberate retention of trees by farmers within the farm or homestead for a variety of purposes which include wood, fodder, fruits, medicine, shade, soil improvement, water conservation etc. Agroforestry is more than intercropping trees with food crops; it combines crop and livestock production with forestry activities to improve or prevent further degradation of ecosystems.

Based on the suggestion of Leakey (1996), the World Agroforestry Centre (ICRAF) now defines agroforestry as a dynamic, ecologically based natural resource management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land-users at all levels.

AIMS OF AGROFORESTRY

1. The science and practice of agroforestry aim to produce and maximize positive interactions between trees and agricultural crops.

2. Agroforestry is generally practiced with the intention of developing a more sustainable form of land-use that can improve farm productivity and the welfare of rural community.

ESSENTIAL FEATURES OF AN AGROFORESTRY SYSTEM

1. Agroforestry systems normally involve **two** or **more** species of plants (or plants and animals), at least one of which is a woody perennial;
2. An agroforestry system always has **two** or **more** outputs;
3. The cycle of an agroforestry system is always more than one year; and
4. Even the simplest agroforestry system is more complex; ecologically (structurally and functionally) and economically, than monocropping system.

THE GENESIS / ORIGIN OF AGROFORESTRY

Trees have been used in cropping systems since the beginning of agriculture. Throughout the world, at one period or another in its history, it has been the practice to cultivate tree species and agricultural crops in intimate combination. In much of the tropics, human beings underwent a transition from hunting/gathering to the use of domesticated plants and livestock. As a part of the process they cut down trees, cleared the debris by burning, and sowed crops in the ash-enriched soil. Thus was born slash-and-burn agriculture, a primary forerunner of the present day agroforestry and a practice that may have originated in the Neolithic period, around 7000 BC.

The combination of soil impoverishment arising from soil erosion and nutrient extraction through crop harvests and the invasion of aggressive and hardy weeds forces farmers to move to new sites to repeat the process in a system widely known as SHIFTING CULTIVATION.

In the 1960s and early 1970s there was increasing concern for the forested lands of the tropics. It was clearly recognized that they were under severe pressure. Some thought that commercial exploitation was

the problem; others believed that fuelwood needs were the culprit; while still others thought that shifting cultivation was the root cause. The President of the International Development Research Centre (IDRC), located in Ottawa, Canada, engaged in 1975 Mr. John Bene, a retired forest industrialist in Canada, to study the problem.

Bene assembled a small team in Canada; and called that the advisory committee, and recruited experts in the various continents, to prepare studies pertinent to their area. The culmination of these various activities, including extensive travel by Bene, was the publication in 1977 of a report titled:

Trees, Food and People: Land management in the tropics;

which is always cited as

Bene, J. G; H.W. Beall and A. Cote (1977) Trees, food and people: Land management in the tropics. Ottawa: IDRC.

The report had THREE major features:

1. A cataloguing of the problems associated with the disappearance and decline in tropical forests.
2. A recognition that the major problem devolved to one of land use exacerbated by the demands for land on which to grow food and fuel.
3. A recommendation that a special Council be established to deal exclusively with the problems of 'agroforestry', the term coined to identify the practice of having trees in the agricultural landscape – irrespective of whether one dealt with crops or livestock.

From the foregoing, it is clear that it was Bene/IDRC Project Report that for the first time recommended the creation of an internationally financed Council for research in agroforestry, to administer a comprehensive programme leading to better land use in the tropics.

The report went on to suggest that the OBJECTIVES of such a Council should be:

1. The encouragement and support of research in agroforestry,

2. The acquisition and dissemination of information on agroforestry systems;
3. The promotion of better land use in the developing countries of the tropics.

The internationally financed organization, then known as the International Council for Research in Agroforestry (ICRAF) was established in 1977 and started its work in The Hague. The organization moved to its present headquarters in Nairobi, Kenya in 1978. In 1992, it became an International Centre for Research in Agroforestry (ICRAF) when it joined the Consultative Group on International Agricultural Research (CGIAR). In 2002 the Centre's name was once again changed to World Agroforestry Centre in order to more fully reflect its global reach, as well as its more balanced research and development agenda. The Centre's legal name – International Centre for Research in Agroforestry (ICRAF) remains. Unchanged; and so its acronym as a Future Harvest Centre – ICRAF- likewise remains the same.

The World Agroforestry Centre (ICRAF) has since been involved in the promotion of national agroforestry research programs, with a heavy emphasis on Africa. Agroforestry research has accelerated rapidly since the early 1980s and has resulted in a greater understanding of the science of agroforestry. Much of this understanding has come from observation of existing practices and systems, although an increasingly important knowledge base is being established through designed agroforestry experiments.

Today, the potential of agroforestry for soil conservation is generally accepted. Indeed, agroforestry is fast becoming recognized as a system which is capable of yielding both wood and food and at the same time of conserving and rehabilitating ecosystems.

Presently, instead of agroforestry being merely the handmaiden of forestry, the system is being more and more utilized as an agricultural system, particularly for small-scale farmers.

CLASSIFICATION OF AGROFORESTRY SYSTEMS

After conceptualization and definition of agroforestry; evolving some broad-based and widely acceptable scheme for classification of agroforestry systems was the major issue in the process of understanding, evaluating and improving existing agroforestry systems and designing new ones.

Between 1982 and 1987, the World Agroforestry Centre (ICRAF) compiled an inventory of agroforestry systems and practices being used in the developing countries. This agroforestry systems inventory (AFSI) was partly financed by the United States Agency for International Development (USAID).

Several criteria can be used to classify and group agroforestry systems and practices. The most commonly used ones are:

1. Structure,
2. Function,
3. Ecological spread,
4. Socio economic nature.

- 1. Structure-** this refers to the composition of the components, including spatial arrangement of the woody component, vertical stratification and temporal arrangement of the different components.
- 2. Function-** refers to the major function or role of the system, mainly of the woody components (which can be productive, e.g. production of food, fodder, fuelwood, and so on; or protective, e.g. windbreak, shelterbelt, soil conservation hedges, etc.).
- 3. Socioeconomic nature** – refers to the level of inputs of management (low-input, high-input) or intensity on scale

of management and commercial goals (subsistence, commercial, intermediate).

- 4. Ecological spread** – this refers to the environmental conditions and ecological suitability of the systems on the assumption that certain types of systems can be more appropriate for certain ecological conditions (e.g. asset of agroforestry systems for arid and semi-arid lands, tropical highlands, lowland humid tropics, and so on.

CLASSIFICATION OF AGROFORESTRY SYSTEMS BASED ON THE TYPE OF COMPONENTS

There are THREE basic sets of components managed by man in all agroforestry systems. These components are:

- a) Woody perennials,
- b) Herbacious plants (agricultural/arable crops),
- c) Animals.

Depending on the combination of these agroforestry components, THREE major agroforestry systems have been identified; namely:

- i) **Agrisilvicultural systems** which consist of trees including shrubs and vines associated with crops;
- ii) **Silvopastoral systems** - these consist of trees, animals and/or pasture;
- iii) **Agrosilvopastoral systems** – these consist of trees, crops and animals or pasture;
- iv) **Other systems** – combination of woody component with biotic life like fish, bees and wildlife form this separate category. Examples are
 - 1. **Aquaforestry** which is the combination of fish production with trees. Trees have a considerable role in providing some of the nutrition required by fish.

2. **Apiculture**-this is the science of bees and beekeeping. Bee production is supported by many tree species.
3. **Sericulture**-(silkworm culture) the silkworms feed almost entirely on deliberately planted or retained mulberry trees (*Morus alba*).

There are various **agroforestry practices** under each of the **agroforestry systems** listed above. i.e. agrisilvicultural, silvopastoral and agrosilvopastoral systems.

AGROFORESTRY SYSTEMS AND PRACTICES

The words “systems” and “practices” are often used synonymously in agroforestry literature.

However, some distinction can be made between them:

1. An **agroforestry system**- is characterized by certain types of practices that, taken as a whole, form a dominant land-use system in a particular locality and determine its overall biological composition and management. In any one agroforestry system there can be more than one agroforestry practices.
2. An **agroforestry practice**- denotes a specific land management unit, such as a field, and a specific arrangement, temporally and/or spatially, of components. Another term that is also frequently used is
3. **Agroforestry technology**- This refers to an innovation or improvement, usually through scientific intervention, to either modify an existing system or practice, or develop a new one.

It should be noted that the distinction between systems and practices are vague, and even not very critical for understanding and improving them. Therefore, the words, systems and practices are used synonymously in agroforestry, as they are in other forms of land-use.

I . Agroforestry practices under the **agrisilvicultural systems** include:

1. Improved 'fallow' in shifting cultivation,
2. Alley cropping (Hedgerow intercropping),
3. Multispecies tree garden,
4. *Taungya*,
5. Scattered trees on farmland (Parklands),
6. Plantation and other crops,
7. Mixture of plantation crops,
8. Biomass transfer,
9. Shade trees for commercial plantation crops,
10. Trees for fuelwood production,
11. Shelterbelt, windbreak, Soil Conservation hedges etc,
12. Rotational woodlots,
13. Boundary markings.

II. Agroforestry practices under the **Silvopastoral systems** include:

1. Protein banks (fodder tree banks),
2. Trees and shrubs on rangeland or pastures,
3. Live fences of fodder trees and shrubs (Living fences),
4. Plantation crops with pastures and animals,
5. Integrated production of animals and wood products.

III. Agroforestry practices under the **agrosilvopastoral systems** are:

1. Homegardens (Homestead gardens),
2. Woody hedgerows for browse, green manure, soil conservation etc.,
3. Integrated production of crops, animals and wood (fuelwood, poles etc).

IV. **Other systems** include:

1. Aquaforestry,
2. Apiculture
3. Sericulture.

CLASSIFICATION OF AGROFORESTRY SYSTEMS BASED ON THE ARRANGEMENT OF COMPONENT SPECIES IN TIME (TEMPORAL CLASSIFICATION)

i) Simultaneous agroforestry systems – In simultaneous agroforestry systems the tree and crop components occupy the same land unit **at the same time**. There is significant overlap in the growth cycles of tree/crop components. As a result there is direct interaction between the two species. i.e. the tree and the crop species. Simultaneous agroforestry systems include alley cropping, parklands, fodder/protein banks, live fences, boundary markings and homegardens.

ii) Sequential agroforestry systems – are those in which trees and crops occupy the same land unit **at different times** and interaction between them is **indirect**. The growth of the crop and the tree components occur at different times even when both components may have been planted at the same time. One component species may grow rapidly, while the other grows slowly. Nutrient uptake peaks of the component species may also occur in a sequence, which makes the species complementary in the use of soil resources. Interactions

between tree and crop components are reduced with time in sequential agroforestry systems. Examples of sequential agroforestry systems are improved fallows and rotational woodlots.

In simultaneous agroforestry systems, management should aim at limiting interspecific competition while in sequential systems, the farmer utilizes the residual effects of the trees. Thus, in shifting cultivation the farmers pile the cut trees into smaller area, burn them and then plant a new crop, which depends on the accumulated ash. In improved fallows, nitrogen fixing trees are deliberately planted to improve soil physical conditions and soil fertility in general, which benefits subsequent crops grown after harvesting the trees.

Simultaneous and sequential agroforestry systems can also take various forms as shown in the figure overleaf.

SPATIAL ARRANGEMENT OF COMPONENTS IN AGROFORESTRY SYSTEMS

1. Trees along borders

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0 0 0 0 0 0 0 0 0 0
0
0
0
0 0 0 0 0 0 0 0 0 0
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2. Alternate rows

3. Alternate Strips or Alley cropping

4. **Random mixture**

FUNCTIONS OF AGROFORESTRY SYSTEMS

Agroforestry systems perform a multitude of services for farmers, for farms and for the environment as a whole: These services include:

1. Provision of food security,
2. Conservation of soils,
3. Enhancement of soil fertility,
4. Improvement of microclimates,
5. Provision of living fences for crops and fruit trees,
6. Demarcation of boundaries,
7. Carbon sequestration,
8. Watershed stabilization,
9. Protection of biodiversity
10. Reclamation of degraded soils,
11. Weed control.

DESCRIPTION OF DIFFERENT TYPES OF AGROFORESTRY PRACTICES UNDER THE VARIOUS AGROFORESTRY SYSTEMS

I. DESCRIPTION OF AGRISILVICULTURAL PRACTICES

i) **Biomass transfer** – This is the application of leafy biomass from hedges to crop fields to improve soil fertility. Leguminous trees are most frequently used as biomass transfer; but there is increasing evidence that non-leguminous shrubs may also accumulate high concentrations of nutrients in their biomass. One of such promising shrubs for biomass transfer in humid and sub-humid areas is *Tithonia diversifolia*, a non-nitrogen fixer. It is commonly found along field borders and roadsides at middle elevations throughout East Africa and South east Asia and has exceptionally high nutrient concentrations(3.5% N, 0.38% P and 4.0% K) in its leaf biomass. The P and K levels are higher than those of commonly used legumes in agroforestry. Fresh leaf biomass of *Tithonia diversifolia* decomposes rapidly and it is an effective source of N, P and K for maize. Application of tithonia biomass increased maize yield at a site that was both N and P deficient in Western Kenya.

ii) **Improved fallows** – Fallowing is defined as leaving land that is normally cultivated temporarily uncultivated. An improved fallow is defined as enrichment of a natural fallow with trees, shrubs or herbaceous legumes planted at high density to improve soil fertility. Improved tree fallows have the potential to increase crop yields while also providing wood. They are able to restore soil fertility more rapidly

than the traditional fallows and, hence, allow shortening of the required fallow period. Improved fallow is also known as enriched fallow. When established with only leguminous trees and/or shrubs, it could be called Leguminous fallow. That is, Leguminous fallows are natural fallows enriched with planted legumes to improve soil fertility.

iii) The *Taungya* system

The word *Taungya* is a Burmese word which literally means Hill (*Taung*) cultivation (*ya*). Originally it was the local term in Burma for shifting cultivation.

The *Taungya* system essentially consists of growing annual agricultural crops along with forest tree species during the early years of establishment of the forest plantation. In order words, *taungya* system is a forest plantation establishment system in which forest crops are raised in combination with temporary cultivation of field or agricultural crops.

The *taungya* system can be considered as another step in the process of transformation from shifting cultivation to agroforestry. Shifting cultivating is a sequential system of growing woody species and agricultural crops, whereas *taungya* consists of simultaneous combinations of the two components during the early stages of forest plantation establishment.

Although wood production is the ultimate objective in the *taungya* system, the immediate motivation for practicing it, as in shifting cultivation and other smallholder systems, is food production.

The *taungya* system was first used in Burma in 1862; and it was introduced to Nigeria in 1928 in a silvicultural experiment at Sapoba (Edo State). It is now a widely adopted agroforestry practice in the rainforest and derived zones of Nigeria. The system which has been modified in various parts of the tropics is essentially an adaptation of the traditional shifting cultivation whereby the farmers are able to raised food crops for at least one year in a forest land, usually a part of a forest reserve. The successive areas are then converted into plantations as the farmers shift their farming activities progressively to new reforestation areas.

At least THREE forms of *taungya* system have existed in Nigeria:

1. The ‘**traditional *taungya***’ which called ‘own your crop’ type. In this type, each farmer is allocated one or more plots and a plot area is about 0.5ha. Under this system, the farmers are responsible for site preparation for the tree planting, and in return for their labour, they are allowed to grow some food crops. E. g. maize, yams, cassava, etc; till the forest trees such as *Gmelina arborea*, *Tectona grandis*, *Terminalia* species interplanted by the Forestry Department close their canopy. Planting of the food crops can continue up to 3 years depending, among other things, on the species raised. This type of *taungya* is the most commonly practiced in the former Western Region (principally at Ogun, Ondo, Ekiti, Oyo, Osun, Edo and Delta States).
2. The second type of *taungya* known as **Departmental *taungya*** which is also called ‘farming for pay”, has been extensively practiced in the high forest areas of Cross River and Akwa Ibom states. Under this system, farming is practiced by the Forestry Department. The major difference between the two systems is that under the traditional *taungya*, the local farmers own only the food crops, whereas under the Departmental *taungya*, both tree and food crops belong to the government or the Forestry Department.

The third type, a ‘hybrid’ version of the two systems which had been tried in the old Bendel state (Edo and delta) implies that the local farmers under the traditional *taungya* assist the Forestry department in planting the tree crops.

iv) Alley Cropping (Hedgerow intercropping)

Alley cropping, also known as hedgerow intercropping,

Is a simultaneous agroforestry system where arable (food) crops are grown between hedgerows of planted shrubs and trees, preferably leguminous species, which are pruned periodically during the crop’s growth to provide green manure (which, when returned to the soil, enhances its nutrient status and physical properties) and to prevent shading of the growing crop(s).

The hedgerows are allowed to grow freely to shade the inter-rows when there are no crops. Alley cropping retains the basic restorative attributes of the bush fallow through nutrient recycling, fertility regeneration and weed suppression and combines these with arable

cropping so that all processes occur concurrently on the same land, allowing the farmer to crop the land for an extended period.

Trees used in alley cropping must have deep roots; so that they do not compete with food crops for water and nutrients. (2) They should be fast growing (3) they should be able to re-sprout easily after pruning*, coppicing** or pollarding*** (4) They should ideally be multipurpose, i. e capable of producing poles, wood, food, fodder, medicinal and other products. (5) They should preferably be leguminous; able to fix their own nitrogen, so they provide protein-rich leaves for livestock and nitrogen-rich organic matter for the soil.

*Pruning-The process of cutting back growth of plants, including roots, but more particularly, side branches of trees, or the sides and tops of hedges.

** Coppicing - cutting broadleaved trees close to the ground level to produce sprouts or regrowth. Trees are also coppiced if they are damaged.

***Pollarding – Cutting back in more or less systematic fashion the crown of a tree but leaving a main trunk to 1.5m or so, with the object of harvesting small wood and browse, of producing regrowth beyond the reach of animals or of reducing the shade cast by the crown.

Trees and shrubs in the alley cropping system have the following benefits:

1. Provision of green manure or mulch for companion food crops. In this way plant nutrients are recycled from deeper soil layers,
2. Provision of prunings, applied as mulch, and shade during the fallow to suppress weeds,

3. Provision of favourable conditions for soil macro- and microorganisms,
4. When planted along the contours of sloping lands, provide a barrier to control soil erosion,
5. Provision of pruning for browse (to feed livestock), staking materials and firewood, and
6. Provision of biologically fixed nitrogen to the companion crop(s).

The major advantage of alley cropping over traditional shifting cultivation and bush fallow systems is that the cropping and fallow phases can take place concurrently on the same land, thus allowing the farmer to crop for an extended period without returning the land to bush fallow.

Other beneficial effects that have been claimed for alley cropping include:

1. Improved crop performance due to the addition of nutrients and organic matter to the soil/plant system,
2. A reduction of the use of chemical fertilizers,
3. An improvement in the physical nature of the soil environment. The addition of mulch can lower soil temperatures, reduce evaporation, and improve soil fauna activity and soil structure resulting in better infiltration, reduced run-off and improved water use efficiency.
4. On sloping land, the tree rows act as a physical barrier to soil and water movement, resulting in significant reductions in erosion losses.
5. The provision of additional products such as forage, firewood or stakes when a multipurpose tree legume is used as the hedgerow,
6. An improvement in weed control. During the fallow period shading of the interspaces may reduce weed growth, while in the cropping phase, the mulch may inhibit germination and establishment of weeds.

By integrating small ruminant production with alley cropping, the International Livestock Centre for Africa (ILCA)* project in Ibadan,

Nigeria developed the ALLEY FARMING concept in which prunings from the hedgerows provide high-quality supplementary fodder.

So, ALLEY FARMING can be defined as the planting of arable crops between hedgerows of woody species that can be used for producing mulch and green manure to improve soil fertility and to produce high-quality fodder.

- ILCA is now known as ILRI i. e. International Livestock Research Institute (ILRI). Its headquarters is in Addis Abba, Ethiopia.

V) **Multispecies tree garden**

This system consists of a mixture of tree plantations of conventional forest species and other commercial perennial tree crops, especially tree species, lending a managed mixed forest appearance. As opposed to homegardens which surround individual houses, these tree gardens are usually away from houses, and are typically found on communally-owned lands surrounding villages with dense clusters of houses, as in Indonesia (Java and Sumatra).

The multispecies, multilayer dense plant associations are with no organized planting arrangements. The major group of components are different woody components of varying forms and growth habits. Herbaceous plants are usually absent; but the shade-tolerant ones are sometimes present. This agroforestry practice is adaptable to areas with fertile soils, with good availability of labour, and high human population pressure.

VI) **Scattered trees on cropland or farmland (Parkland agroforestry)**

Trees scattered haphazardly or according to some systematic patterns on bunds, terraces or plot/field boundaries, crop lands, pastures and rangelands. Some of the trees grow naturally from seed dispersed by birds and other wildlife. Such trees are retained by farmers during land preparation for agriculture, and are often randomly dispersed on the land. In the Sahel region of West Africa, scattered trees on cultivated or recently fallowed land form a characteristic land-use system commonly referred to as 'Parklands'.

The most important and dominant tree species in the parklands of the Sahel region include *Faidherbia albida* (syn. *Acacia albida*), Shea butter tree (*Vitellaria paradoxa*), *Parkia biglobosa*, *Adansonia digitata* (the

baobab tree), and *Tamarindus indica*. *Acacia tortilis* and *Prosopis* species are also often scattered on the farmlands. Through horticultural techniques, improved accessions of some of these species have been produced. These accessions mature faster and produce higher-quality products than the existing natural populations in the parklands.

Trees scattered on cropland offer a variety of benefits and these, together with the limitations of this agroforestry practice are listed below:

Benefits of scattered trees on farmland include:

1. Farmers consider such trees not to be competitive against food crops. *Faidherbia albida* is an example of such trees.
2. Trees, such as *Faidherbia albida*, provide shade for livestock during intense heat of the long dry season.
3. The trees diversify farmers' products and increase crop production, and the duration of cropping the land without fertilizer use.
4. Control of wind erosion when tree canopies in parklands intercept wind-blown soil.
5. Sale of non-timber products, such as charcoal, firewood, gum Arabica, wine, oil and fruits significantly increases income.

Limitations

1. Scattered trees are often not at the optimum density that would confer maximum benefits to the environment and crop production.
2. Reliance on naturally regenerating trees makes it difficult to improve the system through use of better germplasm.
3. Trees found in parklands, such as *Faidherbia albida*, are slow growing and so, benefits take long to accrue.
4. The trees are often browsed by livestock that are allowed to graze crop residues during the dry seasons.

Faidherbia albida, which is a prominent tree species in the parklands in the Sahel region of West Africa, exhibits reverse phenology.

Phenology is the partitioning in time of the events of a plant's life-cycle: seasonal changes in leaf bearing, leaf shedding, growth processes, flowering and seed production.

The reverse phenology exhibited by *Faidherbia albida* in the Sahel region of West Africa has made the species indispensable in the welfare of rural people in the Sahel. The species develops fresh green leaves

during the dry season when other livestock feeds are very scarce in that region.

Therefore, the green leaves produced by the species during the dry season is the major source of protein-rich fodder for the livestock of the Sahelian people during that season. When *F. albida* sheds its leaves during the rainy season; evapotranspiration and competition for water and light with the understorey agricultural crops will be reduced; at a time when the crops need these resources most. The leaves will decompose and also improve the soil nutrient status for the growing crops. This will subsequently contribute to an increase in the crop yield.

VII) Plantation and other crops (Tree intercropping with plantation crops)

Tea, coffee, cashew, oil palm, rubber, cocoa and coconuts are major sources of foreign exchange in the tropics. On large estates, these tree crops are grown in monoculture but on small-holdings, they often grown as intercrops. The reasons why intercropping in these perennial tree crops is possible or even desirable include:

1. There are large spaces between tree crops during the early stages of growth. In the case of cocoa + oil palm combination, the wide oil palm spacing of at least 9 – 10.5m reduces the amount of shade on cocoa.
2. The intercrops reduce soil erosion between widely spaced tree crops, especially during the early tree growth stages.
3. Roots of some tree intercrop combinations complement each other.
4. Shade tolerance of understorey crops such as cassava, favours growth under some plantation crops.
5. Complementary use of light .e.g. during the first 6 – 8 years and after about 25 – 28 years, coconuts allow a considerable amount of light to reach the intercrops. On the other hand, while oil palm has a high light requirement that is available in the upperstorey, cocoa in the understorey requires considerable shade, except at flowering stage.
6. Perennial tree crops intercropping during early growth period is economically viable while waiting for harvest of long maturity tree crops.

7. Some intercrops are compatible because of differing labour calendars.
8. Some tree crops require an intercrop to serve as a nurse crop during the early growth period. For instance, newly transplanted coffee seedlings benefit from the shade cast by taller intercrops, such as maize.

VIII) Mixture of plantation crops

Perennial crops such as cocoa, kola, orange and avocado (*Persea americana*) are planted together on the same piece of land.

IX) Shade trees for commercial plantation crops

Farmers often leave or plant trees to provide shade for plantation crops such as coffee and tea. Young cocoa plants also need shade in the nursery and for the first 2-3 years in the field. The shade moderates the micro-environment so that excessive moisture stress is avoided and also reduces wind damage.

The use of shade trees in coffee plantations is common in the tropics and legume trees are mostly used for this purpose. A major function of such trees is contribution of nutrients to low fertility soils wherever inorganic fertilizers are not used. Example of such shade trees are:

1. *Erythrina poeppigiana*
2. *Cordia alliodora*
3. *Gliricidia sepium*
4. *Leucaena leucocephala*
5. *Albizia chinensis* (syn. *A. stipulate*)
6. *Grevillea robusta*
7. *Ficus natalensis* (a common shade tree species for coffee and bananas in Central Uganda)

X) Trees for fuelwood production

It has been estimated that in the early to mid 1970s not less than 1.5 billion people in developing countries derived at least 90% of their energy requirements from wood and charcoal, and another billion people meet at least 50% of their energy needs this way. As a result of consistent harvesting of natural forests and woodlands for fuelwood and poles; these essential resources are seriously threatened, and the developing world is facing a critical firewood shortage as serious as the petroleum crisis.

Today there are alternative sources of fuel such as kerosene, gas and electricity. However, these require cash inputs and are not available to everyone. Every year about 3000 million cubic metres of wood are harvested and used all over the world. Of this amount, slightly more than half is burned as fuel for heating and cooking, most of it directly but some in form of charcoal.

In the last 20 years or more, fuelwood supplies have come under increased pressure in many parts of the world. Several measures have been recommended to address this problem, the most significant being the promotion of tree planting for fuelwood production. Rural people are been encouraged to integrate tree production for fuelwood into existing farming practices. Such fuelwood species can be interplanted on/or around agricultural lands. In Ghana, tree species such as *Albizia* species and *Celtis* species are good sources of fuelwood and poles in the forest zone. While in the savanna areas, species such as *Pterocarpus erinaceous*, *Daniella oliveri* and *Isobertina doka* constitute the bulk of the fuelwood and materials for poles. In northern Nigeria (especially Kano area), *Dalbergia sissoo* is a good fuelwood species.

XI) Windbreaks and Shelterbelts and/or affect carbon dioxide circulation.

Wind is air mass in motion. There are all kinds of winds. Some are local whereas others build up over great distance(maybe thousands of kilometers); they are hot or cold depending on the circumstances; they carry varying amounts of water vapour; they blow at altitude or, on the contrary, near the ground. They could be gentle or strong.

From the farmer's point of view, gentle winds are advantageous in that they can contribute to pollination of crops and seed dispersal. Strong winds, on the other hand, are damaging and could be detrimental to agricultural crops, human life and properties. Below are some of the effects of strong winds on crops:

1. Wind may increase transpiration rate, and this may exacerbate soil moisture deficits.
2. It can spread pests and diseases because disease-causing spores and insects are dropped whenever wind speed is reduced.

3. It can deform plants, cause crop lodging and/or affect carbon dioxide circulation.
4. It can increase loss of top-soil through rill erosion, which may impair seedling growth especially in semi-arid areas.
5. It can cause drifts during herbicide and insecticide spray; hence, leading to wasteful application and ecotoxicity.

Windbreaks

Windbreaks are narrow strips of trees, shrubs and/or grasses planted to protect fields, homes, canals, and areas from wind and blowing sand. Where wind is a major cause of soil erosion and moisture loss, windbreaks can make a significant contribution to sustainable production.

Shelterbelt

A shelterbelt is a wide strip of vegetation that slows wind speeds, thereby reducing wind erosion, evaporation and damage to towns, villages and adjoining farmlands by the wind. It is sometimes referred to as windbreak, although the latter often implies a single strip of trees and other vegetation.

A shelterbelt presents a mechanical barrier to the impact of the wind, and separates two zones; the windward and the leeward zones. The windward zone refers to the side from which the wind blows, whilst the leeward zone relates to the side where the wind passes. As a rule of the thumb, a belt protects a distance up to its height on the windward side and up to 20 times its height on the leeward side.

Belt design

(Check Dr. Ekwebelam's booklet)

Orientation of shelterbelts

As their main function is to protect agricultural lands against the hazards of wind and wind speed, shelterbelts are placed on the upwind side of the land to be protected. They are most effective when the shelterbelt is situated perpendicular (at right angles) to the prevailing wind direction.

If wind direction changes throughout the year, a chessboard pattern is the best possible way to plant shelterbelts.

(Check Ekwebelam's booklet for Wind direction and Orientation of belt)

Suitable species for shelterbelt establishment should as much as possible have the following characteristics:

1. Adaptability,
2. Growth rate,
3. Crown formation,
4. Increased land productivity. (Check Ekwebelam's booklet).

XII) Rotational woodlots

In rotational woodlots, multipurpose trees and shrubs are intercropped with food crops such as maize, sorghum and cassava for about 2- 3 years, when the trees are still too small to out-compete the food crops. This phase resembles the *taungya* system. In the subsequent phase, the trees are allowed to grow to maturity in pure stand. Therefore, the second phase resembles a fallow period; soil fertility may be improved if the trees fix nitrogen and add large amounts of organic matter to the soil. When the trees are harvested, crop production resumes and the crops benefit from the residual soil fertility built up during the 'fallow' period.

The main function of rotational woodlots is to produce both food crops and tree products and services such as fuelwood, poles, fodder and soil fertility improvement. In semi-arid parts of Tanzania, 4- and 5- years old woodlots with *Leucaena* and *Acacia polyacantha* produce up to 10 – 15 tonnes of wood per hectare. Because a woodlot keeps the soil surface covered, it is also a soil and water conservation measure. *Acacia auriculiformis*, *Senna siamea*, *Azadirachta indica*, *Dalbergia sissoo*, *Albizia lebbek*, *Gmelina arborea*, *Delonix regia*, *Anogeissus leiocarpus*, *Cassia fistula* etc are all excellent tree species for a woodlot.

XIII) Boundary markings

Certain multipurpose trees are used to mark farm boundaries. Unlike live fences, the trees on boundaries need not be closely spaced except when soil erosion control is also desired. Tree growing on farm boundaries requires agreement between neighbouring farm owners to avoid conflicts. There are difficult ways of sharing trees planted on a boundary. Sometimes two rows of trees are planted, one on each side of the boundary, and then each farmer grows and manages his own trees. A disadvantage of this is that it occupies more land than a single row.

Initially trees can be established at a close spacing (0.75 – 1.00m) and then later thinned for poles or firewood to a final spacing of 1.5 -3.0m. With double rows the spacing between the rows should not be less than 2m. The tree propagation method will depend on the species, but use of seedlings or transplanting of wildings is common. *Grevillea robusta* is commonly used for boundary planting in Central Kenya. Its use for this purpose (and also in other agroforestry systems) may be related to its restricted lateral root system. This makes it associate well with

neighbouring crops. In general, trees on boundaries offer several benefits and these, together with the limitations of this agroforestry practice, are highlighted below:

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II. DESCRIPTION OF AGROFORESTRY PRACTICES UNDER THE SILVOPASTORAL SYSTEMS

Silvopastoral systems are land-use systems in which trees and/or shrubs are combined with livestock and pasture production on the same unit of land. Integrating livestock production in the farming system promotes farm product diversification and improves food security. Shrubs and trees in silvopastoral production systems constitute the basic feed resource of more than 500 million out of the 660 million head of livestock in the tropics.

Within the broad category of silvopastoral system; there are several types of practices which can be identified depending on the role of the tree/shrub (sometimes collectively called “trub”) component. These include:

1. Protein banks (Fodder tree banks),
2. Trees and shrubs on rangeland or pastures,
3. Live fences of fodder trees and shrubs (Living fences),
4. Plantation crops with pastures and animals.

1. Protein banks (Fodder tree banks)

Protein banks are blocks of forage plants deliberately planted to alleviate fodder shortages in arid, semi-arid and mountainous regions; especially during the dry seasons. The forage plants may be leguminous trees and shrubs or herbaceous legumes, and they may be grown in combination with suitable grasses. The fodder trees are pruned regularly to feed zero-grazed livestock (animals that are kept in stalls). When based on legumes, the fodder banks become important sources of protein and are referred to as protein banks.

2. Trees and shrubs on rangelands or pastures

The primary use of trees in range and pasture land has been the provision of shade. Besides this vital function of trees on rangeland; they (trees) still provide other benefits to livestock and the herdsmen. They provide fodder and wood. Normally such trees are scattered at random and there is no need to be particular regarding any regular spatial arrangement. The number of species with potential for this practice is great. They include *Acacia nilotica*, *Acacia seyal*, *Acacia tortilis*, *Annona senegalensis*, *Calliandra calothyrsus*, *Combretum molle*, *Gliricidia sepium*,

Piliostigma thonningii, *Bauhinia* spp, *Salvadora persica*, *Cadaba farinosa*, *leucaena leucocephala* etc.

3. Live fences of fodder trees and shrubs (Living fences)

Live fencing means fencing composed of living plants. Living fences are lines of trees or shrubs planted on farm boundaries or on the borders of farmyards, pasture plots or animals enclosures. Sometimes they are also used around agricultural fields. They serve mainly as field boundaries, to keep animals on the farm and off adjacent crop fields or farm areas. They can be made of single or multiple densely planted rows. Alternatively, one row of living fenceposts can be planted, widely spaced, with wire, sticks or dead branches between the trees. Both kinds are made of permanent lines of shrubs or trees, that are regularly pollarded and trimmed. The fences provide shade, protection and privacy for the animals. The trees can also serve as windbreaks that produce wood and foliage products. The foliage can be eaten by animals. Legumes are especially valued as they usually have a high protein content.

The most important component in the living fence practice is the animal component – the main reason for establishing living fences and the primary motive in management of the fences is to control livestock movement. In arid and semi-arid zones, lives fences are often made of thorny species of the *Acacia* or *Prosopis* genera. In the humid and sub-humid tropics, leguminous species such as *Gliricidia sepium* and *Erythrina berteroana* or species of multipurpose Hibiscus or *Ipomea* hedges are used.

4. Plantation crops with pastures and animals

Plantation trees such as coconut could be planted in scattered form on pasture land. Cattle and small ruminants can graze in open and lightly shaded pastures under such coconut trees. This is common in South East Asia and South Pacific.

(Show the picture on page 4.1 of Pacific Agroforestry- An information Kit).

Other plantation crops such as cashew, mango etc can be on such pastureland.

This practices is beneficial to the animals in the following ways:

1. Pastures may grow more as trees bring up limiting nutrients from below pasture rooting depth.
2. Trees may improve quantity and quality (e. g. protein, minerals, energy) of forage available.
3. Some light shade may help pasture growth and quality in dry areas by improving soil surface microclimate.
4. Trees may maintain forage supply when insects have attacked other pasture species. E. g. Army worm on para or carpet grasses (this occurs in every South Pacific countries at the same time).
5. Forage tree leaves are less trampled than those of creeping or erect pasture grasses and legumes.
6. By having shade beef animals grow better and diary cows produce up to 3 litres more milk in the humid tropics.
7. Wind and cyclone protection is provided by the trees.
8. Animals can eat tree fruits and pods.

DESCRIPTION OF AGROFORESTRY PRACTICES UNDER THE AGROSILVOPASTORAL SYSTEMS

Examples of agroforestry practices under this system include:

1. Homegardens (tree-livestock-crop mix around homesteads)
2. Woody hedgerows for browse, green manure, soil conservation etc.
3. Integrated production of crops, animals and wood (fuelwood, poles etc).

HOMEGARDENS (Tree-livestock-crop mix around homesteads)

The word “homegarden” has been used rather loosely to describe diverse practices, from growing vegetables behind houses to complex multistoried systems. It is used here to refer to intimate association of multipurpose trees and shrubs with annual and permanent crops and, invariably livestock within the compounds of individual houses, with the whole crop-tree-animal unit being managed by family labour. These systems are common in all ecological regions in the tropics and subtropics, especially in humid lowlands with high population density. Many homegardens resemble those of Java or Southeastern Nigeria, with

an intensive combination of trees, crops and livestock. The average size of a homegarden is usually much less than 1ha, yet in many parts of the world the fruit, nuts, edible leaves and other foodstuff grown in homegardens provide a substantial part of the household food requirement. In some areas of Java, homegardens provide more than 40% of the total calorific intake of farming communities. Food production is the primary function and role of most, if not all, of the homegardens. An aspect of food production in homegardens is the almost continuous production that occurs throughout the year. The combination of crops with different production cycles and rhythms results in a relatively uninterrupted supply of food products.

In most cases, animals are kept in the home garden. The animals can browse there and rest in the shade. Cattle, like buffaloes, are mostly kept for diary products and land cultivation. Sheep, goats, chickens and fish are kept for household consumption. Products from animals or the animals themselves can of course also be sold in the market.

Structure of Homegardens

The layered configurations and combination of compatible species are the most conspicuous characteristics of all homegardens. Contrary to the appearance of random arrangement, the gardens are usually carefully structured systems with every component having a specific place and function.

In general terms, all homegardens consist of a herbaceous layer near the ground, a tree layer at upper levels, and intermediate layers in between. The lower layer can usually be partitioned into two, with the lowermost (less than 1m height) dominated by different vegetable and medicinal plants, and the second layer (1-3m height) being composed of food plants such as cassava, banana, papaya, yam and so on. The upper tree layer can also be divided in two, consisting of emergent, fully grown timber and fruit trees occupying the uppermost layer of over 25m height, and medium-sized trees of 10-20m occupying the next lower layer. The intermediate layer of 3-10m height is dominated by various fruit trees, some of which would continue to grow taller. This layered structure is never static; the pool of replacement species results in a productive structure which is always dynamic while the overall structure and function of the system are maintained.

Food production from homegardens

A conspicuous trait of the tree-crop component in homegardens is the predominance of fruit trees, and other food-producing trees. Apart from providing a steady supply of various types of edible products, these fruit and food trees are also compatible – both biologically and environmentally – with other components of the system. While fruit trees such as guava, mango and other food-producing trees such as *Moringa oleifera* and *Sesbania grandiflora* dominate the Asian homegardens, indigenous trees that produce leafy vegetables (*Pterocarpus* spp) fruit for cooking (*Dacryodes edulis*), and condiment (*Pentaclethra macrophylla*) dominate the West African compound farms.

Benefits and constraints of home gardens

Some of the benefits of home gardens are:

1. Production is very diverse and continuous; risk is minimized and there is a daily flow of products such as food, fuel, fodder, fruit, spices and wood for construction;
2. The protective function of home gardens is very high: soil protection, water retention and pleasant micro-climate for humans, animals and some plants;
3. The use of labour for the farm is very efficient due to proximity of the garden to the house; also the walking distances in the garden from job to job are short;
4. Valuable crops or animals in need of protection can be given extra care by the farm family (especially at night) because of the short distance from the house;
5. Home gardens ensure a pleasant living environment; shade, windshelter and provision of privacy; they can also satisfy aesthetic values and open patches often serve as family or village gathering places.

Constraints of home gardens:

A specific constraint encountered in practising home gardens is that; because of the high diversity of ecological niches, a home garden can provide a habitat for species that can become pests or introduce diseases, like snakes, insects and fungi.

2. During tree harvesting other plants are often damaged.

3. Proximity to homesteads makes houses prone to damage from falling branches and extensive lateral roots from trees.

IV OTHER SPECIAL AGROFORESTRY SYSTEMS

These other agroforestry systems; which are sometimes referred to as minor agroforestry technologies include aquaforestry, apiculture, sericulture etc.

1. **Aquaforestry** – This is a practice that links trees with aquaculture. Other terms that have been used for this practice are silvipisciculture, silvo-aquaculture and aquasilviculture. Trees can be linked to fish culture in the following ways:

- a) Fodder
- b) Fuelwood for processing
- c) Planting trees around the pond
- d) Tree branches for small pond constructions
- e) Other practices, e.g. ponds providing water and nutrients for trees that are planted around.

2. Apiculture with trees

Apiculture is the science of bees and beekeeping. Beekeeping is the breeding and care of bees. Apiculture has continued to gain considerable attention in many developing countries due to the increasing importance of bees and honey. It is not just that bees and trees rhyme well, bees and trees are interdependent, and have been perfecting their relationship over the last 50 million years or so; literally millions of years before man appeared on the scene. Bees benefit trees and trees in turn provide series of benefits to bees.

Beekeeping – is the breeding and care of bees. In some regions it is the only source of sugar. Beekeeping is a rewarding branch of agriculture. The gain can be very high for subsistence farmers because the production from a few hives of bees can sometimes give them higher income than they can earn by a full-time occupation. Not much work is needed to look after the bees and all family members can all take part in it. Developing countries of the subtropics have become the main source of honey, exporting at least 150,000 t per year to the world market.

3. **Sericulture** – is the culture of silkworms. Mostly, these silkworms are fed leaves of mulberry tree (*Morus alba*). Silkworms produce

silk and several by-products, which can be used for many purposes: textile, fibre, soap, vitamins, medicine and others.

Silkworms depend upon tree leaves for their normal growth and development. Mulberry (*Morus alba*) leaves are excellent food.

The mulberry tree is a small deciduous tree which tolerates drought and heat but prefers moist climates and can be grown up to 2000 m. They adapt well and can grow not only in warm areas but also in cold regions.

The mulberry is not only useful for sericulture. The mulberry tree itself gives a fine wood. Its branches can be used to make farm tools and its bark to make high-grade paper and artificial fibre. The fruit is edible and can be used to make wine. Every part of the mulberry tree is of medicinal value. The tree can also produce fuelwood, vegetable and fodder. It also provides shade and can be used as ornamental plant. It is useful for windbreaks, soil conservation, soil stabilization, hedgerow planting, bee-forage and live fence.

TREE – CROP INTERACTIONS IN AGROFORESTRY

When trees and crops are grown together on the same piece of land there will be interactions between the two components, which may have positive or negative results. INTERACTION is defined as the effect of one component of a system on the performance of another component and/or the overall system.

Different types of interactions have been recognized between trees and crops in agroforestry systems; namely:

1. Complementary,
2. Supplementary,
3. Competitive and,
4. Allelopathic.

1. **COMPLEMENTARY INTERACTION** exists **if the presence of one crop increases production of another crop**. An example of complementarity in cropping is the positive effect of one crop on the other crop. *Cordia alliodora* and several *Erythrina* species are used as shade trees for coffee and cocoa. Trees moderate the intensity of sunlight and wind, and maintain higher humidity. Crops under or between the trees are protected from sudden changes in climate. Species of *Acacia*, *Leucaena*, *Gliricidia* and other legumes are often interplanted with crops in agroforestry systems, because the nitrogen fixed by these plants increases soil fertility and benefits the crop plants.

Interplanting trees and crops as in the *taungya* system often results in a mutual benefit. Weeding carried out by cultivators benefits both the crops and the trees in that it

reduces competitions for nutrients and water. The cut weeds represent a source of readily available nutrients to the crops and trees, if used as a mulch. The crops and weeds, and their litter when they are cut provide a mat over the soil which lessens erosion and reduces evaporation

2. SUPPLEMENTARY INTERACTION- This occurs if the presence of one crop **does not influence** the production of other crop(s). This is an independent relationship. This relationship occurs if the different crops draw on resources at different times of the year, or from different parts of the environment .e.g. different soil depth for nutrients. In *taungya*, crop plants occupy space between tree seedlings, and use light, nutrients and water that presumably otherwise would be wasted. During the first growing season, tree seedlings are so small that crops usually grow well despite their presence. The relationship between trees and crops during the first year of *taungya* appears in most cases to be supplementary.

The next two types of interactions between trees and crops in agroforestry systems are negative in nature; namely:

1. Competition,
2. Allelopathy.

1. COMPETITION

The component plants in a mixed system vie for essential resources. Although agroforestry is envisaged as a system of plant species that benefit each other mutually or unilaterally, it is too optimistic to assume that all types of competition can be eliminated in these systems, especially in areas with poor soils and scanty rainfall. Agroforestry systems lose some of the

assimilated nutrients in the form of grain, wood, fodder, etc, at each harvest, thus reducing reserves, unlike natural forests where recycling of nutrients occurs.

Ideally, the relationship between crops and trees should be of a 'complementary' nature. However, this is not always the case. In many situations where trees and crops are grown together, they may compete for water, nutrients and solar energy. The situation is obvious when the canopies of trees begin to close over the tops of crops such as upland rice.

In Indonesian *taungya* (Tumpangsan) teak is often interplanted with giant *Leucaena leucocephala* and with cassava as a cash crop. The *Leucaena leucocephala* is beneficial in that it produces shade and green manure. The side-shading results in good form for the teak. However, competition can be deleterious when teak is enclosed by two rows of *Leucaena leucocephala*. Competition between trees and crops is a long-term problem in plantations when the crop species is a perennial.

2. ALLELOPATHY

Allelopathy is an interaction between plants or between plants and microorganisms in which substances (allelochemicals) produced by one organism affect the growth of another (usually adversely).

The term allelopathy was coined in 1937 by Molisch to refer to biochemical interactions between all types of plants including micro-organisms. Allelopathy means plant-plant biochemical interactions that have detrimental effects, i. e. certain plants release into the environment toxic chemicals that are injurious to other plant(s) in their vicinity. Such toxic chemicals may be

injurious to microbes and even to the seedlings of those plants releasing them.

Recent studies have shown that the organic compounds released this way are often phytotoxins which are released into the environment as leaf leachates or root exudates by certain plants. The effects of the chemicals may result in complete inhibition of growth or in stunted or retarded growth. When complete inhibition occurs; this may be noticed in the form of bare areas around the trees which exude the chemicals.

When the toxic exudates of the adult trees of a particular species suppress and eventually kill their seedlings; then the phenomenon is called AUTOALLELOPATHY.

Allelopathic situation has been found around *Callitris intratropica* in Northern Australia. Grevillea's poor performance in Australian tree plantations may be due to autoallelopathy.

Researchers have shown that water-soluble extracts from roots of adult trees suppress and eventually kill their seedlings. This could prevent trees from growing well when closely spaced in pure stands.

Allelopathic compounds (allelopathic chemicals or allelochems) may be released into the environment by:

1. Volatilization,
2. Leaching from living or dead tissues,
3. Exudation from roots and decay of plant tissues

Allelopathic interactions between trees and crops have been investigated in *taungya* plantations.

Some Southeast Asian scientist (Susech and Vinaya Rai) in 1987 reported on effects upon Sorghum, Cowpea and Sunflower by *Eucalyptus tereticornis*, *Casuarina equisetifolia* and

Leucaena leucocephala. The crops, grown in topsoil taken from beneath the trees, had decreased seed germination rate, decreased root growth and decreased dry matter production compared with crops grown in control soils.

Presently, most of the allelochems known fall into FIVE chemical classes:

1. Phenolic compounds,
2. Aldehydes,
3. Coumarins,
4. Glucosides and
5. Terpenes.

MECHANISMS OF ACTION OF ALLELOCHEMICALS

The mechanism of action of allelochems are diverse and include:

- i) Inhibition of cell division and elongation;
- ii) Inhibition of gibberellins – or indoleacetic acid induced growth;
- iii) Reduction of mineral uptake;
- iv) Retardation of photosynthesis;
- v) Inhibition or stimulation of respiration;
- vi) Inhibition or stimulation of stomatal opening;
- vii) Inhibition of protein synthesis and changes in lipid and organic acid metabolism.