Agroforestry Series: Volume III

AGROFORESTRY

CLASSIFICATION OF SYSTEMS AND CHOICE OF SPECIES

By

Sahibzada Mohammad Hafeez

Punjab Forestry Research Institute
Faisalabad
Pakistan
1998

With Compliments

Hafeez

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PREFACE

Agroforestry is receiving more and more attention from governments and development organizations around the world. These groups are finding that agroforestry has the potential to address several environmental and development problems at the same time. Developing countries are finding that agroforestry may be one important way of dealing with problems affecting their citizens.

Agroforestry is a way of managing land. Agroforestry is the term used to describe the deliberate growing of trees and shrubs together with agricultural crops or livestock. Agroforestry is known as a strategy which attempts to reduce land use conflict and increase what the land can produce.

Our approach to agroforestry is aimed at encouraging farmers to practise agroforestry on their lands so that the benefits/outputs are directly related to their needs and lives.

In view of high importance and potential of agroforestry and scarcity of literature on this comparatively new subject, a modest effort has been made to compile a series of booklets on various aspects of Agroforestry and make these available to the officers of Punjab Forest Department, students, teachers, and other interested persons for their study, concept clearance, practical use and further extension of this knowledge to other staff and persons.

The Volume-I of this series deals with the definition, concept, historical background, need and potential of agroforestry, its importance in Pakistan and its role in rural development.

Volume-II: It describes ecological, economic, social and institutional aspects of agroforestry in a concise form.

Volume-III: It gives classification of agroforestry systems alongwith its purpose and criteria. The role of woody perennials, their arrangement and interaction with other components in some agroforestry systems is also indicated. An important item of choice of species for agroforestry is also included in it.

Volume IV: The existing agroforestry systems in Pakistan have been described briefly. Existing agroforestry systems and practices in different parts of the tropics and sub-tropics the world-over have also been given.

Volume-V: Design, establishment and management of an agroforestry system has been given in this.

Volume-VI: This contains the procedure for financial analysis of an agroforestry system with some other useful and practical information. It has been compiled by Malik Muhammad Khan, C.F. who has got advanced training on the subject from USA.

This series of volumes on various aspects of agroforestry has been compiled by the authors on the basis of available literature on agroforestry most of which have been published by ICRAF. No originality is, therefore, claimed in these. A list of reference has been added at the end of each volume, which have been freely used in the preparation of these booklets. Authors are grateful to the previous writers whose publications provided a sound base for compiling this series.

Sahibzada M. Hafeez
Director
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1 DEFINITION OF SOME COMMON TERMS

Agroforestry (AF) represents an approach of integrated land-use that involves deliberate retention or admixture of trees and other woody perennials in crop/animal production fields to benefit from the resultant ecological and economic interactions (Nair, 1985 a, Nair, 1985; Raintree, 1984). After explaining the concept of the term agroforestry and describing its ecological and socio-economic potential and constrains in land-use parlance, now the question to be answered is one step further in detail 'What type of agroforestry'? This not only implies the multitude of AF systems and practices, but also underscores the importance of having a set of classification schemes for AF.

AF System

The words 'system', 'sub-system' and 'practice' are very commonly used in AF literature. In systems analysis language, a system refers to a group of physical components, i.e. an assemblage of objects, connected or related in such a manner so as to form and/or act as an entire unit; an ecosystem consists of living organisms and their non-living environment with which they are inseparably inter-related (Arnold, et al, 1976; Wit, et al, 1974). In land use terms, a system refers to a type of land use specific to an area and described according to its bio-technical or socio-economic aspects. For example, an agricultural system, or a forestry system denotes a type of agricultural or forestry land use of the locality, described in terms of its main components, level of management, nature of output, and so on. The term agroforestry system as used in the AF literature corresponds to specific or generalized AF land utilization types (Young, 1984), the basis for defining and demarcating the various such systems being not only biological or technical, but also economic or social. Thus, from the point of view of distinguishing and classifying AF systems, an AF system can be considered as a type of AF land use that is specific to a locality and described according to its biological composition and arrangement, level of technical management, or socio-economic features (Nair, 1985 a).

AF Sub-System

The other commonly used expression in AF literature is sub-system. Semantically it indicates a lower order hierarchy of the system. A system can well be conceived to be composed of various sub-systems, or compartments, each with definable boundaries, though being unable to exist independently; it is in this way that the term is used in a physical sense in the systems analysis language. But in AF literature the sub-system refers to a part of the system with a more restricted role, content and complexity than the system itself. Depending on the criteria used for defining or designating the system (biological, socio-economic, and so on), the types of sub-system can also vary. For example an agrisilvicultural system can have several types of sub-systems according to the type of arrangement of its constituent components; but another way of looking at it is based on the system's output, this is, to consider a system to be composed of several sub-systems, each producing a defined 'basic need' as its major output so that there can

be a food sub-system, an energy sub-system, a shelter sub-system, a cash sub-system, and so on (Raintree, 1984).

AF Practice

An agroforestry practice usually denotes a specific land management operation of an agroforestry nature on a farm or other management unit. Several such practices will be involved in the constitution and maintenance of an AF system. Commonly these practices include the arrangements of components in a space and time vis-a-vis the major functions of the tree component. Alley cropping (hedgerow intercropping), boundary planting of trees, trees and shrubs as shelterbelts and windbreaks, use of woody perennials in soil conservation, tree gardens, woodlots on agricultural lands, etc., are all commonly-found AF practices. Any of these practices becomes an AF system when it is developed or spread to such an extent in a specific local area so as to form a definite land utilization type in that area (Nair, 1985 a). One essential point to note here is that an AF practice can be found to exist even in a non-agroforestry land use system. An example is the practice of growing rows of *Sesbania grandiflora* on the bunds of rice paddies in Java, Indonesia. This woody species is harvested for its leaves as green manure, its flowers are eaten as a vegetable, it provides firewood and it adds to the fertility of the soil underneath through biological fixation of atmospheric nitrogen. Thus the woody species interacts ecologically and economically with the crop (rice) production system; in other words, it is an AF practice in a crop production system.

Hierarchically, the system, the sub-system and the practice form different levels of organization of the components, i.e., a system to consist of several sub-systems and each sub-system to consist of several practices. Depending on the degree of 'evaluation' and the level of physical spread, these terms also represent different extents to which they are adopted in a given locality, a system being widely practised to form a land utilization type of the locality, a practice being a definite management operation involving the components and a sub-system falling in between (Nair, 1985 a).

AF Technology

Another term that is commonly used in all land use systems including agroforestry is "technology" and it is usually used in combination with a particular production system or land use system as the prefix thus, agricultural technology, wood production technology, agroforestry technology, and so on. The word or suffix "technology" in this sense indicates an improvement or innovation, usually through scientific intervention, that can be applied with advantage in the management of the system or practice concerned. The inputs that are used for developing such technologies can sometimes be the most significant aspects, and these are called input technologies; e.g., improved varieties of plants, agrochemicals, and so on.

Most, if not all, of the AF practices need to be improved scientifically and developed into modern agroforestry technologies. The success potential of an AF practice (and, therefore, an AF system) depends on the extent to which such technologies have been perfected, and made use of in the management of the practice (or the system).

2 PURPOSE AND CRITERIA OF CLASSIFICATION

Most of the existing information concerning AF systems is descriptive. The descriptions and data can be assembled in several ways to facilitate their storage, retrieval and, to some extent, comparison. However, such an assemblage of data is only an essential first step in developing a practical and realistic framework for analysing the systems and development of AF. The purpose of classification should essentially be to provide such a framework. But depending on the focus and emphasis of such strategies and action plans, the structure of the framework will also vary. Essentially any classification scheme should:

- include a logical way of grouping the major factors on which production of the system will depend;

- indicate how the system is managed (pointing out possibilities of management interventions to improve the system's efficiency);

- offer flexibility in re-grouping the information; and

- be easily understood and readily handled (practical) (Nair, 1985 a).

The complexities of these requirements suggest that just a single classification scheme cannot satisfactorily accommodate all of them. A series of classifications will be needed, and each one has to be based on a definite criterion to serve a different purpose. Lundgren (1982) points out that the most commonly used criteria so far have been spatial and temporal arrangement of components, relative importance and role of components, production aims/output from the systems and social and economic features. While some of the classification schemes have been based on only one of the criteria, for example, role of components (King, 1979), temporal arrangement of components, some others have tried to integrate several of these criteria in hierarchical schemes in rather simple ways (Torres, 1983 a) or more complex ones (Wiersum, 1980). An assessment of the various criteria (to be)) used in classifying AF indicates that they refer to the system 'structure, function (output), socio-economic nature, or ecological (environmental) spread. The characteristics also denote the most common purpose to be served in classification schemes. Therefore, most AF systems (including sub-systems and practices as well) can be categorized/grouped according to the following sets of criteria (Nair, 1985 a):

1. Structural basis - refers to the composition of the components, including spatial admixture of the woody components, vertical stratification of the components.

2. Functional basis - refers to the major function or role of the system, mainly of the woody components (these can be productive, e.g. production of food, fuelwood and so on, or protective, e.g. windbreak, shelterbelt, soil conservation and so on).

3. Socio-economic basis - refers to the level of inputs of management (low-input, high-input) intensity or scale of management and commercial goals (subsistence, commercial, intermediate).

4. Ecological basis - refers to the environmental condition and ecological suitability of systems, on the assumption that certain types of systems can be more appropriate for certain ecological conditions: thus there can be a set of AF systems for arid and semi-arid lands, tropical high-lands, low-land humid tropic, and so on.

These broad basis of classification of AF systems are by no-means independent or mutually exclusive. Indeed it is obvious that they have to be interrelated because the structural and functional basis relate to the woody components in the system whereas the socio-economic and ecological stratification refer to the organization of the systems according to certain defined conditions (socio-economic or ecological). And in any defined socio-economic or ecological situation, the systems should still have specific structure (composition and arrangement of components) and function/role. Thus the complexity of AF classification can considerably be reduced if the structural and functional aspects are taken as the primary considerations in categorization of the systems and socio-economic and agro-ecological/environmental (as well as any other such physical or social) factors taken more as a basis for stratifying or grouping the systems for definite purposes, than for classifying them. These approaches for classification of AF systems are summarized in the Table 1.

Table 1: Major approaches in classification of agroforestry systems (and practices)

Categorization of systems (based on their structure and function)			Grouping of systems (according to their spread and management)	
Structure (Nature and arrangement of components, especially woody ones)		.Function (Role and/ or output of components especially woody ones	.Agro-ecological/ environmental adaptability	Socio-economic & management level
Nature of components	Arrangement of components			
1.Agrisilviculture (crops and trees shrubs/trees crops and trees	In space (spatial) Mixed dense (e.g. home garden)	Productive function Food Fodder	System in/for Lowland humid tropics	Based on level of technology input Low input (Marginal)
2.Silvopastoral (pastyre/animals & trees)	Mixed sparce (e.g.:most systems of trees in pastures)	Fuelwood Other woods	Highland humid above 1200 m a.s. 1:e.g.:Andes,India, Malaysia)	Medium input High input
3.Agrosilvopastoral (crops,pasture/ animals and trees)	Strip (Width of strip to be more than one tree	Other products	Lowland subhumid (tropics e.g savanna zone of Africa, Carrado of South Ameriica)	Based on cost/benefit relations Commercial Intermediate
4.Others (multipurpose tree lots,apiculture with trees, aquaculture with trees, etc.)	Boundry (trees on edges of plots/fields)	Protective function Windbreak, Shelterbelts Soil conservation, Moisture conservation, Soil improve-ment Shade (for crop,animal, and man)	Highland submid tropics (tropical highlands e.g in Kenya, Ethiopia)	Subsistence
	In time(Temporal) Coincident Concomitant Overlapping Sequential(separate) Interpolated			

3 CLASSIFICATION OF AGROFORESTRY SYSTEMS ON STRUCTURAL BASIS

Structure of the system can be defined in terms of components (constituents) and the expected roles or functions of each (manifested in terms of outputs). It is not only the nature (type) of components that is important, but also their arrangement.

Based on the nature of components

In AF land use systems there are three basic sets of elements or components that are managed by man, namely, the tree (woody perennial), the herb (agricultural crops including pasture species) and the animal. In order for a land use system to be designated as an AF system, it should always have the first one, i.e., the woody perennial. In most systems, the second one (the herbaceous species) is also involved, the notable exceptions could be apiculture with trees and aquaculture (pisciculture) in mangroves areas with trees. The third set of components (animals) is present in some AF systems. This leads to a simple classification of AF systems as given below (Nair, 1985):

1. Agrisilvicultural system (crops and trees including shrubs/vines/tree crops and trees)

This system involves the conscious and deliberate use of land for the concurrent production of agricultural crops including tree crops and forest crops.

Based on the nature of the components this system can be grouped into various forms:

(i) Improved fallow species in shifting cultivation
(ii) The Taungya system
(iii) Multispecies tree gardens
(iv) Alley cropping (Hedgerow intercropping)
(v) Multipurpose trees and shrubs on farmlands
(vi) Crop combinations with plantation crops
(vii) Agroforestry fuelwood production
(viii) Shelterbelts
(ix) Wind-breaks
(x) Soil conservation hedges etc.

2. Silvopastoral system (pasture/animals/and trees)

The production of woody plants combined with pasture is referred to as a silvopastoral system. The trees and shrubs may be used primarily to produce fodder for livestock or they may be grown for timber, fuelwood, fruit or to improve the soil. A silvopastoral system is needed in dry areas, in particular to help meet wood and fodder demands throughout the year. This system is again classified into three categories:

(i) Protein bank
(ii) Living fence of fodder trees and hedges
(iii) Trees and shrubs on pasture

3. Agrosilvopastoral system (crops, pasture/animals and trees)

This system has been grouped into two sub-groups:

(i) Home gardens
(ii) Woody hedgerows for browse, mulch, green manure, soil conservation

4. Other systems

Additionally there are a few systems such as multipurpose woodlots (that interact economically and ecologically with other land use production components and hence fall under the purview of AF definition), apiculture with trees and aquasilviculture. In the absence of a better term to encompass these forms of AF, they can be grouped together under 'others'.

This categorization of AF systems into three major types is so fundamental that any one of these can conveniently be used as a prefix to other terms emanating from other efforts to classify/group AF systems in order to explicitly express the basic composition of constituents of any such system. For example, there can be an agrisilvicultural system for food production, a commercial silvopastoral system for fodder and food production in lowland sub-humid (or dry) tropics, an agrisilvopastoral system for food production and soil conservation in highland humid tropics, and so on. Therefore, it seems logical, compatible and pragmatic to accept the nature of components as the basic criterion in the hierarchy of AF classification (Fig-1).

There can be several other criteria of the lower order to demarcate sub-systems and practices. In addition to the functional categorization of sub-systems as the food sub-system, the fodder sub-system, and so on, there can be structural categorization too. For example, the various sub-systems and practices in agrisilviculture include hedgerow intercropping (alley cropping), use of improved 'fallow' species in shifting cultivation, multistorey combinations of multispecies plant communities, multipurpose trees and shrub on farm lands, shade trees for commercial plantation crops, agroforestry fuelwood production, shelterbelts and windbreaks on crop production fields, and so on. Silvopastoral systems include animal production systems in which multipurpose woody perennials provide the fodder (protein bank) or function as living fences around grazing land or are

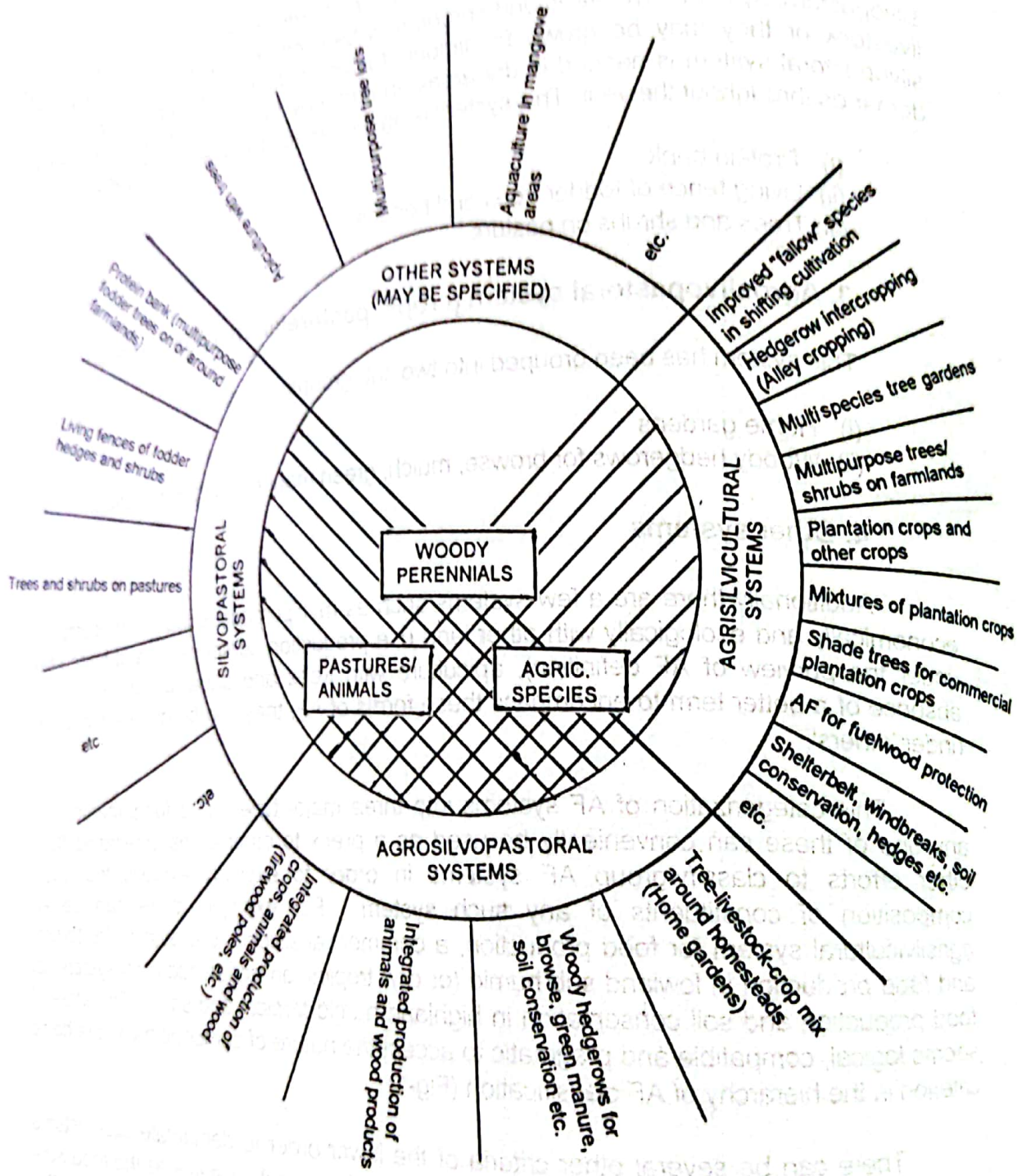

Fig-1: CATEGORIZATION OF AGROFORESTRY SYSTEMS BASED ON THE NATURE OF COMPONENTS (WITH EXAMPLES OF COMMON SUB-SYSTEMS/ PRACTICES UNDER EACH SYSTEM)

retained as commercial shade/browse/fruit trees in pasture lands. Examples of agrosilvopastoral systems include the use of woody hedgerows for browse, mulch and green manure as well as for soil conservation, the crop/tree/livestock mix around homestead (home gardens), and so on. More field examples of each category of system shall be presented in a latter section.

It may be noted that the term agrisilviculture (rather than agrosilviculture) is used to denote the combination of trees and crops, whereas agrosilvopastoral (rather than agrisilvopastoral) is used for crops + animals/pasture + trees. The intention here is to limit the use of the word agrisilviculture only to those combinations involving agricultural crops and trees. The word agrosilviculture can encompass all forms of agriculture (including animal husbandry) with trees, and thus be another word for agroforestry. That again is the reasoning behind the use of the all inclusive 'agro' prefix to agrosilvopastoral. It is worth mentioning in this context that during the process of evolution of the word 'agroforestry', some opinions had been expressed that the proper usage of the term(from the linguistic point of view) should be agriforestry and not agroforestry (Stewart, 1981). But the word agroforestry has become so firmly implanted that it would now be very confusing if another word were to be popularized to encompass the same concept. After all, one can find several other usages in technical languages that may not strictly satisfy the niceties of conventional linguistic usage (Nair, 1985).

Based on the arrangement of components

Arrangement of components refers to plant components of the system. Even in AF systems involving animals, the management of such animals according to a definite plan, such as, say, a rotational grazing scheme, is in consideration more of the plants than of the animals. Such plant arrangements in multispecies combinations can involve dimensions in space and time.

Spatial Arrangement

Spatial arrangements of plants in AF mixtures can result in mixed dense stands (as in home gardens) or in mixed sparse stands (as in most systems of trees in pastures). Moreover, the species (or species mixes) can be in zones or strips of varying widths. There can be several forms of such zones varying from microzonal arrangement (such as alternate rows) to macrozonal ones. A commonly mentioned example of the zonal pattern is the hedgerow intercropping (alley cropping) (Ssekabnembe, 1985). An extreme form of the zonal planting is the boundary planting of trees on edges of plots and fields for a variety of purposes and outputs (fruits, fodder, fuelwood, fencing and protection, soil conservation/ windbreak, and so on). It is also important to note that extreme forms of macrozonal arrangements can lead to sole cropping systems; but the interactive association of different components can be used as the criterion to decide the limits between zonal AF and sole crop (component) plots (Nair, 1985 a).

Temporal Arrangement

Temporal arrangements of plants in AF can also take various forms. An extreme example is the conventional shifting cultivation cycles involving 2-4 years of cropping cycle and more than 15 years of fallow cycle, when a selected woody species or mixtures of species could be planted. Similarly, some silvopastoral systems may involve grass lees in rotation, with the same species of grass remaining on the land for several years. These temporal arrangements of components in AF has been described by terms such as coincident, concomitant, overlapping (of which the extreme case is relay cropping), separate, interpolated, and so on (Huxley, 1983 a) (Kronick, 1984). These terms are more easily explained, than defined, as in next figure.

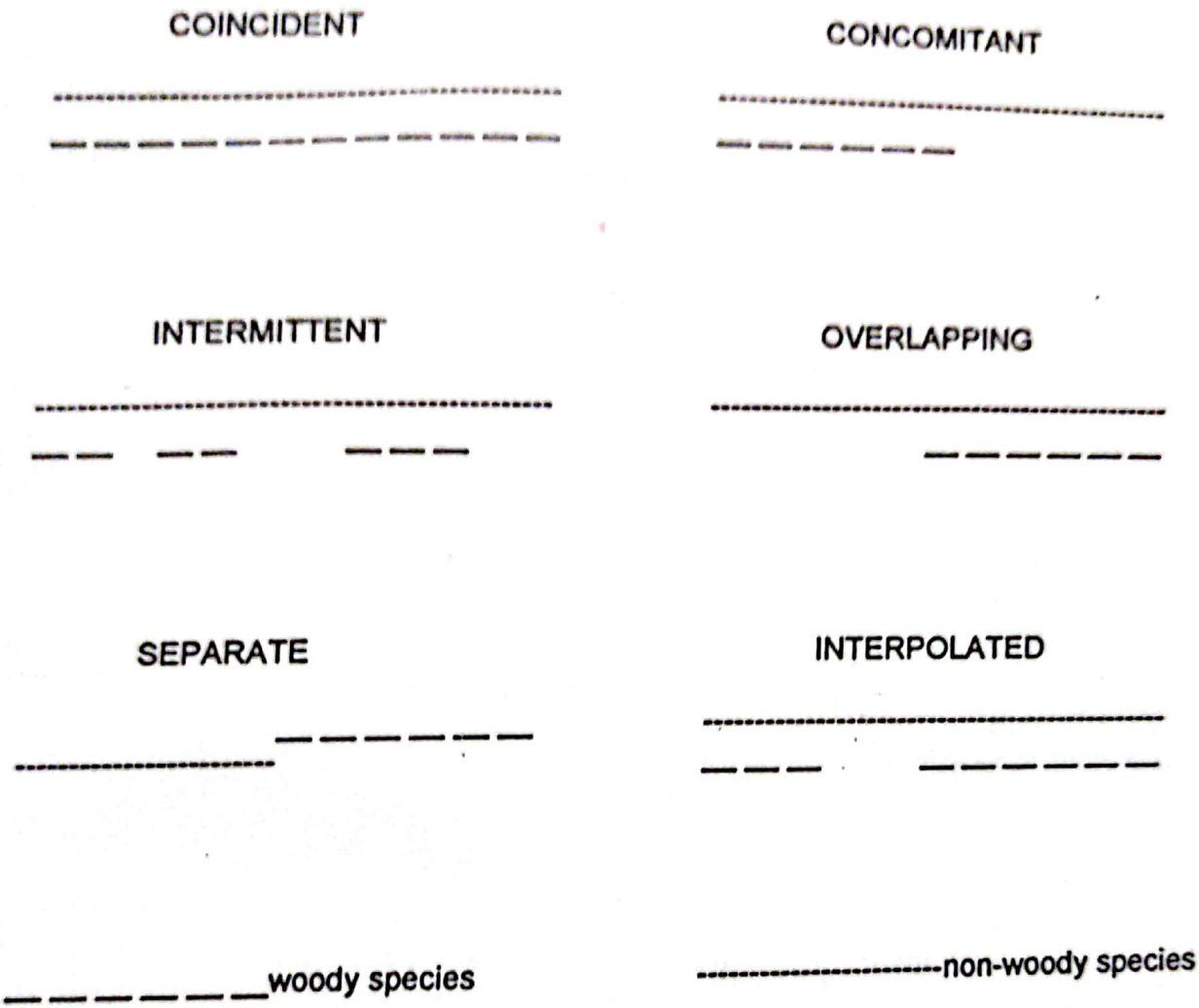

Fig-2: TEMPORAL ARRANGEMENT OF COMPONENTS IN AGROFORESTRY SYSTEMS

4 FUNCTIONAL CLASSIFICATION OF AGROFORESTRY SYSTEMS

Two fundamental attributes of all AF systems are productivity and sustainability. This clearly indicates that AF systems have two functions, i.e.,

(a) Productive functions (producing one or more products)

The various productive functions of AF systems are:

(i) Food
(ii) Fodder
(iii) Fuelwood
(iv) Other woods
(v) Other products

(b) Protective functions (protecting and maintaining production systems)

The protective functions of AF systems are:

(i) Windbreak
(ii) Shelterbelt
(iii) Soil conservation
(iv) Moisture conservation
(v) Soil improvement
(vi) Shade (for crop, animal and man)

Raintree (1984) argues that any land use system, regardless of its degree of commercialization, can be described and evaluated in terms of the outputs of relevant basic needs such as food, energy, shelter, raw materials, cash, and so on. This is the strategy which underlines the basic needs approach within the methodology for AF diagnosis and design development by ICRAF (1983 a). According to this approach, the service roles of woody perennials are also taken as factors contributing to the production of one or more of these basic needs. For example, soil conservation affected by appropriate AF practices can be expressed in terms of its contribution to augmenting the sustainability of crop production; amelioration of microclimate through well designed arrangements of trees and crops (e.g. shelterbelts) can be evaluated in terms of its effect on crop yield, and so on.

However, this emphasis on production of outputs places an undue importance on this attribute at the cost, if not exclusion, of the other important attribute, viz; sustainability. Although production is a very important consideration in AF, it is the sustainability aspect

that makes it different from other approaches to land use. Moreover, all AF systems will be producing more than one basic need output (largely so because of the multipurpose nature of the associated woody perennial component). Therefore, all AF systems have both the productive and protective roles, though to varying degrees of magnitude. Depending on the relative dominance of the particular role, the system can be termed as productive or protective as indicated in Table 2 (Nair, 1985).

This summary table (which also indicates the spatial arrangement of woody components and the nature of their interaction with other components) shows the inadequacy of choosing the production of a particular basic-need output as the sole criterion for classifying AF systems. However, if production of an output, or for that matter any such other aspect, may be chosen as the basic for undertaking an evaluation of available AF options with a view to selecting the most appropriate ones to fulfill the stated objective (Nair, 1985).

Table:2 *The role of woody perennials, their arrangement and interaction with other components in some agroforestry systems.*

System	Sub-system/ practices	Role of woody	Arrangement	Nature of interaction
Agrisilvi-cultural	Hedgerow intercropping (Alley cropping)	Protective (Soil Productiviy)	s: Zonal (strip) t: Concomitant	Spatial
	Improved fallow	Protective (soil Productivity) and productive	t: Sequential (time-dominant)	Temporal
	Multistorey crop combination	Productive	s: Mixed, sparce t: Coincident	Spatial & Temporal
	Multipurpose tree on farmlands	Productive	s: Mixed, dense t: Interpolated	Spatial
	Shade tree for commercial plantation crops	Protective and productive	s: Mixed (scattered) or Zonal t: Interpolated	Spatial and Temporal
	AF fuelwood production	Productive	s: Zonal (strip/ boundary) t: Coincident	Temporal and Spatial
	Shelterbelts and windbreaks	Protective	s: Zonal (boundary) t: Coincident/ interpolated)	Spatial

Silvopastoral	Protein bank	Productive (and protective)	s: Zonal t: Coincident/ interpolated	Temporal
	Living fence	Protective	s: Zonal/boundary t: Coincident	Spatial
	Trees over pastures	Productive (and protective)	s: Mixed sparce t: Coincident	Spatial
Agrosilvo-pastoral	Woody hedgerows for browse, mulch, green manure and soil conservation	Productive and protective	s: Mixed or zonal (strip) t: Coindicent	Temporal and Spatial
	Tree-crop-Livestock mixed around homelands	Productive and protective	s: Mixed t: Coincident/ intermittent	Spatial and temporal
	Agrisilvicultural to silvopastoral	Productive	s: Mixed t: Overlapping to separate	Temporal and spatial

5 ECOLOGICAL AND SOCIO-ECONOMIC GROUPING OF AGROFORESTRY SYSTEMS

Ecological grouping of AF Systems

Several enumerations of AF practices have been presented from various geographical regions to a large number of seminars, workshops, etc. during the past over two decade.

Based on the major agroecological zones, agroforestry systems are grouped into the following categories:

(a) Humid/sub-humid lowlands
(b) Semi-arid/arid lands
(c) Tropical Highlands

Most of these AF systems documentation pertain to specific ecological situations from different geographical regions. It is thus easy to find several descriptions on AF systems in say, highland sub-humid tropics (or tropical highlands as popularly known) for example; the Chagga system in Mount Kilimanjaro in Tanzania (Fernandes, et al, 1984), hill farming in Western Nepal (Fonzen, et al, 1984), and multipurpose tree integration on the highland of Rwanda (Neumann, 1983). Similarly a large number of system descriptions can be found for various other ecological regions too.

Descriptions of existing systems as well as recommendations of potential AF technologies for specific agroecological zones include a mixture of various forms of AF(in terms of the nature as well as arrangement of components). Thus there can be agrisilvicultural, silvopastoral or agrosilvopastoral systems in any of the ecological regions. Young (1984) analyzed the AF potential for sloping lands using the primary data collected by ICRAF's AF System Inventory Project and others for eight systems in sloping lands in various parts of the world. It shows that all the three basic categories of AF system (Agrisilvicultural, silvopastoral and agrosilvopastoral) can be seen in this particular land form. This is true for other agroecological zones also.

Socio-economic grouping of AF Systems

Socio-economic criteria such as scale of production and level of technology input and management have been used as criteria for classifying AF systems. Lundgren (1982 b) thus groups systems into three categories:

(a) Commercial
(b) Intermediate and
(c) Subsistence systems

Commercial Systems

The term commercial is used where the production of the input, usually a single commodity, for sale is the major aim of the system; scale of operations is often medium to large and land ownership may be government, corporate or private; labour is normally paid or otherwise contracted. Examples include commercial production of agricultural plantation crops such as rubber, oil-palms and coconut, with perennial underplantings of food crops, other crops, or pasture/animals; commercial production of shade tolerating plantation crops like coffee, tea, and cacao under overstorey shade trees; rotational timber/food crop systems in which a short phase of food crop production is used as a silvicultural method to ensure establishment of the timber species (various forms of taungya); commercial grazing and ranching under large scale timber and pulp plantations: etc.

Intermediate AF Systems

' Intermediate' AF Systems are those that are intermediate between commercial and subsistence scales of production and management. Production of perennial cash crops and subsistence crops is undertaken on medium to small sized farms where the cash crops cater for the cash needs, and the food crops meet the family's food needs. Usually farmers who either own the land, or have long term tenancy right to land, reside and work themselves on the land, supplemented by paid temporary labour. The main distinguishing features of the intermediate system from those of the commercial system on the one end and subsistence system on the other are holding size and level of economic prosperity. Several AF systems in many parts of the world can be grouped as intermediate systems, especially those based on plantation crops such as coffee, cacao, coconut, etc. Similarly there are also several intermediate AF systems based on large number of fruit trees, especially in the Asia-Pacific region (Nair, 1985) and short rotation timber species such as *Albizzia falcataria* in the Philippines (Pollisco, 1980) and Indonesia (Nair, 1985)

Subsistence AF Systems

Subsistence AF systems are those where the use of land is directed toward satisfying the basic needs, and managed mostly by the owner/occupant and his family. Cash crops, including sale of surplus production of commodities may well be a part of these systems, but are only supplementary. Most of the AF systems practised in various parts of the developing countries come under the subsistence category. All forms of traditional shifting cultivation found throughout the tropics are the most wide spread example. However, all forms of subsistence AF systems are not as 'undesirable' or resource depleting as traditional shifting cultivation, for example, the integrated, multi-species system (Atmosoedaryo, et al, 1980 and Wiersum, 1980). Similarly several commendable systems of a subsistence nature can be found in many other regions also (Nair, 1985).

Grouping of AF systems according to these socio-economic and management criteria is yet another way of stratifying the systems for a purpose oriented action plan. In development efforts, for example, such an approach will be useful. However, there are some drawbacks if these criteria are accepted as the primary basis for classifying the systems. First, the criteria in defining the various classes are not well-quantifiable; the standards set for such a differentiation will reflect the general socio-economic situation of the locality. What is considered as 'subsistence' level in one set of situations may well fall under 'intermediate' or even a higher category in another set of situations. Secondly, these class boundaries will also change with time. A good example is the gum-arabic production system of the Sudan. It used to be a flourishing 'intermediate' system consisting of a planned rotation of *Acacia senegal* for gum production for 7-12 years. *Acacia senegal* also provided fodder and firewood and improved soil fertility. But with the advent of artificial substitutes for gum arabic, the *Acacia senegal* millet system has now regenerated into a subsistence system (Nair, 1985).

Therefore, these socio-economic factors that are likely to change with time and management conditions cannot rigidly be adopted as the satisfactory primary basis for an objective classification scheme, but they can be employed as a basis for grouping the systems for a defined objective or action plan. These approaches for classification of AF systems are summarized below:

Major approaches in classification of AF systems

a: Categorization of AF systems:

(Based on their structure and function)

1. Structural basis

i. Nature of components.

1. Agrisilviculture -Crops and trees including shrub
2. Silvopastoral -Pasture/animals and tree.
3. Agrosilvopastoral-Crops, pasture/animals and trees
4. Others -Multipurpose tree lots, apiculture with trees, aquaculture with trees, etc.

ii Arrangement of components

(1)Spatial(In space) -Mixed dense (as in home garden)
Mixed sparce
Mixed scattered
Zonal
Strip
Boundary

(2) Temporal(In time) -Coincident
-Concomitant
-Overlapping
-Sequential(separate)
-Interpolated
-Intermittent

2. Functional basis

(i) Productive function:
-Food
-Fodder
-Fuelwood
-Other woods
-Other products

(ii) Protective function
-Windbreak
-Shelterbelt
-Soil conservation
-Moisture conservation
-Soil improvement
-Shade (for crop, animal and man)

b: Grouping of AF Systems:

(According to their spread and management)

1. Agroecological/environmental adaptability:
System in/for:
-Lowland humid tropics
-Highland humid tropics (1200 m a.s.l)
-Lowland sub-humid tropics
-Highland sub-humid tropics

2. Socio-economic and management level:
(i) Based on level of technology input
-Low input (Marginal)
-Medium input
-High input

(ii) Based on cost/benefit relations:
-Commercial
-Intermediate
-Subsistence

A framework for classification of agroforestry Systems based on these considerations is given in Table 3 (Nair, 1985)

Table 3 Framework for a purpose-oriented classification of agroforestry systems.

First step	Subsequent step(s) Criteria	Major areas of application
Classification based on the nature of components	.Arrangement of components	Research on plant management for optimizing interactions
-Agrisilviculture -Silvopastoral -Agrosilvopastoral -Others (specify)	-in time -in space	Development projects for exploiting agroforestry
	.Function/role of components -Productive -Protective (service)	Land-use planning, regional development
	.Agroecological zones and other specified land forms	R & D programmes, Socio-economic analysis of agroforestry potential, resource utilization plan
	.Socio-economic aspects	

6 CHOICE OF SPECIES FOR AGROFORESTRY

Introduction

The most important factor deciding the success of agroforestry is the choice of suitable species of economic plants that can be grown together. The more important among such plants are usually considered to fall under either of the two broad categories of agricultural and forestry crops (Nair, 1980). Agroforestry involves the more or less intimate association of different plants components, always including woody ones, on the same unit of land. Whether the plant components are arranged zonally or in mixture they will be associated closely enough to interact with one another in some way. As mainly dominant over-storey plants, trees and shrubs play a key role in agroforestry systems (Huxley, 1983 c).

Agroforestry land use practices can be at various levels of scale. Conceptually we need only three components: two different plant species (one at least woody), and man. Some agroforestry systems can, additionally, include animals of course. In practice any small patch of land with these three (or four) components that is providing multiple outputs in the form of products and/or environmental benefits may be considered the basic agroforestry unit for purpose of study. Next in the hierarchy is the complete holding or farm. Then any aggregation of land use systems with some common feature (a complete watershed, for example). Finally, the region or , better still, agro-ecological zone. The problems and potentials of agroforestry will require attention at all four of these levels (Huxley, 1983).

Characteristics of Trees for Agroforestry

The key to understand what is agroforestry is the appreciation that we start with the environmental and biological processes which occur at the interface between two or more plant components, one of which at least is a woody perennial. In order to do this satisfactorily it is necessary to have an understanding of the relevant characteristics of the various plant components. Those relating to trees and shrubs are given in the form of a list of points in tabular form to consider concerning germplasm, propagation, planting out, the juvenile phase of growth, mature growth and senescence and replanting; all in relation to technical, managerial and socio-economic considerations (Huxley, 1983 c).

Role of woody perennials in agroforestry

In general, the role of woody perennials - including the leguminous one - in agroforestry can be termed as productive and/or protective depending upon the dominant function (s) of such species.

PROPAGATION -What methods of propagation are available? (and see above)	-What facilities are there for establishing nurseries and distributing plants?	-what are the relative cost advantages of direct planting vs using nurseries (transplants and container grown plants)? -What propagating method best suits the land user?
-Seeds; cutting; budding and grafting; tissue culture, etc.	What types of nursery are best? Central, village school, commercial etc.	
	-What skills/labour/materials are there for setting up nurseries and distributing plants? And what national organizations and/or infrastructure can help? Are the facilities(labour and skills) available?	-What will the costs be of using different methods? Will the land user easily/understand the requirements?
-What are the specific environmental requirements for germinating seeds and/or rooting cuttings, etc. and for early seedling growth?		
-Are there requirements for seed inoculation (rhizobium, mycorrhizal fungi)?	Will this be done ,on-farm, or for issued seeds?	Will seed be sown in time, and with care, so that inoculation is effective?
-Are there specific pests and diseases in the nursery phase?	-Are special procedures involving materials and skills required?	Will the land user suffer severely from a failure to control these properly?
-What is the likely (and optimum) duration of the nursery phase?	Can the nurseries supply plants -When the farmer wants them, and -for as long as he wants them in sufficient quantities and of a type which will survive the distribution and planting systems available?	What are costs of seedlings? What are the costs of maintaining unsold/undistributed plants?
PLANTING OUT -What are the soil/environmental conditions needed? What is the best season? And are there special soil conservation requirements in this phase?	What site preparation problems are there?	How does it fit in with labour availability and other family needs?

Table:4 *Some characteristics of Trees (and other Woody Perennials) for consideration in Agroforestry*

Technical	**Managerial**	**Socio-economic**
GERMPLASM *-Is this species outbreeding and the germplasm therefore heterozygous?*	-Does a mixture of genotype matter? -Is germplasm easily and cheaply available? And through what sources?	Can the land user collect and/or distribute his own seed? Or does he have to buy it?
-Are there seed viability problems?if so, does it pay and are there facilities to nvestigate them?	Will someone have to carry out seed testing? If so, are the necessary skills and equipment available?	Can a farmer easily store seed? Does this put up the cost of seed?
- Are there seed dormancy problems? if so, does it pay and are there facilities to nvestigate them?	Is any special equipment or technology required to break seed dormancies?	Does this hinder adaptation?
-Are seeds commonly attacked by pests and/or diseases?	Are special storage facilities or conditions required?	Will this be a major hindrance to issuing farmers with seed?
- Are there specific seed borne diseases?	-Is any special treatment of the seed required?	Will the land user need special help or service? And will this be effective and/or costly?
	-Will the land user have to watch out to eradicate these diseases or treat young seedlings?	
If tree seeds are not the best or most convenient method of propagation, then what other materials can be tried?	-Are the skills and equipment available for collecting and storing propagules (cuttings, bud wood, etc). Will there be problems associated with using clones, for example, viruses?	What are the comparative costs? And does the farmer already have experience in handling cuttings etc.? (And see next section).

Is the tree palatable? what is the need for animal production?

-What are the plants' requirements and responses to shade/shelter, watering, fertilizing, weeding?

-What is the duration of the time to flowering/fruiting? is the species being grown for fruits?)

-How susceptible is this tree species to pests and diseases?
-What is the phenology of this species?
-How does this affect the associated crop plants?

MATURE GROWTH PHASE AND PERIOD OF MATURITY

-What are the morphology and branching habit?

-What is the phenology? shoot dormancies and growth regulation .leaf flush/leaf fall sequences .flowering and fruiting cycles .general source-sink relationships

-Are there any effects on animal production if browsing is restricted?
-Are people, methods, etc. available for animal protection measurements?

What materials, labour and skills are available?

What management procedures can be adopted to induce early flowering?

What materials and skills are required?

How do the time-of-planting restraints and/or other management factors affect the overall management especially with regard to the agricultural crop?

-Are skills/labour available to deal with training/pruning?

-What are the tree/crop interactions implicit in the tree's morphology/phenology and cropping sequences?

-What are the land user's habits with regard to his(or other's)browsing animals?
-What are the ,costs, of protecting the trees from animals

-What are costs/benefits?
-What is the likelihood of adaptation of these techniques? what will happen if this isn't done?
How does this affect incentives to plant?

-Will a failure to control these end in disaster?
How does all this fit with labour availability and social needs?

-Are there any land user preferences?

-What effects are there on the land user's immediate environment(does he want shade/shelter)?

-What is the optimum plant size, and condition, at planting out?(See also above)

-Is shelter/support required for the young plants?

-Do the young plants need watering, fertilizing or mulching?

-Are pests/diseases/weed likely to be a problem (and animals/birds)?

JUVENILE PHASE

-What is the morphology and early growing habit of the species?

-How does it respond to training/pruning, and what growth responses are there from buds of different kind?

-Is the species slow or fast growing in its early stages?(see also above)

-What are the rooting characteristics of the tree species?

Are proper handling facilities available, and the necessary skills?

What is the easiest to arrange? For example, what local materials are available?

Can it be provided?

-Are special chemicals or protective methods needed?

-Does this affect crops growing nearby? What are the tree/crop interactions?

-What training is possible and desirable?
-Are plant training skills available?

If slow growing will this increase the burden of management operation

-How does this affect management practices(watering, weeding, fertilizing)?
-Do early, deep-rooting characteristics affect associated crops and what are the tree/crop interactions at below ground level?
Will this affect choice of site?

-can the necessary care be given?

Will the farmer bother? Can he afford it? Will he maintain and manage it and finally remove it?

What is the cost and likelihood of the land user adopting these procedures?

What cost? How does it fit with labour requirements and available skill?

Will the land user understand what is required?

What are the costs of training vs not training?

-Will a slow growing species be acceptable, however useful and productive later?

Is the land user prepared to allocate a special site to the trees if needed?

What is the duration of this phase and its effects?	-Especially on associated agricultural crops and farm management	What are the effects of declining productivity? -Is there a need for credit/help or alternative sources of income?
-What are the options for technical solutions to final harvesting sequences and/or tree removal	-What are the effects on adjacent crops and on the soil?	Are there alternative choices of how to dispose of the trees?
-Are there pests/diseases associated with cutting down trees(including general and specific replant problems)?	-Is the knowledge of what to look for available?	-Is there a willingness to take care?
-What land preparation is required for replanting?	-What place does this occupy in the whole farming programme? -What is the availability of labour for this?	What costs are there?
-What crop/soil management is required in the transition period before replanting trees?	-What labour/resources are needed, especially for soil conservation in this period?	-Is there a willingness to adopt a sound plan? -Are there any extra costs?

Competitiveness(from morphology, etc., above)	*What possible operations (for example, lopping) might reduce this and what are the timings?*	-What does the land user see as his needs to control the tree? -What are the costs/benefits of doing so? How does this fit into social requirements or market opportunities?
Harvestability (single, terminal harvest/ sequential harvests).	How does this fit in with weed control timing and methods for the agricultural crop?	What method are best suited?
Needs for weed control	-Is the necessary labour/ equipment available? -How does this fit in with weed control timing and methods for the agricultural crop?	-Will the land user adopt some form of weed control? What is the cost/benefit to him?
Soil management and soil conservation	-Is the necessary labour/equipment available? -How does this fit in with weed control timing and methods for the agricultural crop?	-Does the land user perceive a need? -Will the land user adopt the appropriate soil management? -What is the cost/benefit to him?
Pests and/or diseases	-Is the necessary labour/ equipment available? -How does this fit in with weed control timing and methods for the agricultural crop? Can advice be obtained?	-Does the land user perceive a need? -What is the cost/benefit to him? Will there be a disaster if he neglects pest control with these species combinations?
Biennial (seasonal) bearing -for fruiting crops	-Are the necessary skills and understanding available to obviate this?	-To what extent do variations in seasonal output affect the land user/markets?
SENESCENCE AND REPLANTING PREPARATIONS		
-What is likely time of onset of ageing/senescence?	-What decisions have to be taken on how to remove trees?	How will the land user perceive the need to remove trees?

(i) Productive role

The productive role includes production of food, fodder, firewood and various other products from the wood perennials in agroforestry systems. One of the most promising technologies of this kind that is applicable in a wide range of situations is the hedgerow intercropping in crop production fields. The practice involved growing arable crops in the spaces of alleys between such hedgerows; the woody species is pruned periodically during the cropping season to prevent shading and to provide green manure to the arable crop. Promising results have been obtained from this type of studies at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (Silson and Kang, 1981), where the practice is called alley cropping. The most promising system based on those trials is *Leucaena leucocephala* - maize alley cropping. IITA studies showed that leucaena tops maintained maize grain yield at a reasonable level even with no nitrogen input on a low-fertility sandy Inceptisol, the nitrogen contribution by leucaena mulch on maize grain yield being equivalent to about 100 kg ha^{-1} for every 10 t ha^{-1} of fresh prunings (kang, et al, 1981).

The hedgerow intercropping system offers the advantage of incorporating a woody species with arable farming system without impairing soil productivity and crop yields. The potential of nutrient (N) contribution by several candidate species of woody legumes suggests that a wide range of such species could be integrated into crop production systems. Spacing of inter-row woody species can be adjusted and the trees can be cut back and kept pruned during the cropping period and leaves and twigs applied to the soil as mulch and nutrient sources, and bigger branches used as stakes or firewood (Nair, at al., 1984).

Integration of trees in crop production fields is an essential part of traditional farming systems in the dry regions also. Two typical examples are the extensive use of *Acacia albida* in the ground-nut and millet production areas of sub-Saharan, Africa and the dominant role of *Prosopis cineraria* in the arid North-Western parts of India (Mann and Saxens, 1980). The role of woody perennials on farmlands for producing fuelwood is another example of the productive role of the species in agroforestry. Several fast growing firewood crops, most of them legumes, suitable for different environmental conditions, have been identified (NAS, 1980), and most of them combine well with conventional agricultural crops.

In the 'animal agroforestry' systems, the woody components could be used either as a source of fodder to improve livestock productivity or to obtain another commodity such as fuel, fruit, or timber. Based on this ' productivity objective', silvopastoral systems can be grouped into browse grazing and forest/plantation grazing systems. The role of woody perennials in these systems has been reviewed excellently by Torres (1983 b).

(ii) Protective role

The protective role of woody perennials in agroforestry stems from their soil improving and soil conserving functions. There are various avenues through which the leguminous woody perennials could improve and enrich soil conditions; these include

fixation of atmospheric nitrogen, addition of organic matter through litterfall and decaying roots, modification of soil porosity and infiltration rates leading to reduced erodibility of soil and improving the efficiency of nutrient cycling within the soil plant system (Nair, 1984). However, the main protective function of woody perennials is in physical conservation of the soil.

The soil conservation benefit of woody perennials can conveniently be exploited in agroforestry if the chosen species can provide additional benefits and outputs such as fodder, fuel, wood, food, etc. The long tradition of planting leucaena leucocephala in contour hedges for erosion control and soil improvement in south-east Asia, especially Indonesia, is a typical example. Lopping and prunings from such hedgerow species could also provide mulch to aid in preventing sheet erosion between trees (Neumann, 1983). The potential role of agroforestry in soil conservation lies not only in woody perennial acting as a physical barrier against erosive forces, but also in providing mulch and/or fodder and fuelwood at the same time. Other protective functions of woody perennials in agroforestry include their role as live fences, shelterbelts and windbreaks. Use of trees and other woody perennials to protect agricultural fields from tresspassing as well as the adverse effects of wind is a widespread practice in many agricultural systems. Very encouraging results on shelterbelts and windbreaks have been obtained at the Pakistan Forest Institute, Peshawar (Sheikh and Chima, 1976; Sheikh and Khalique, 1982) besides many other places in the world.

Leguminous woody perennials for agroforestry

From the foregoing, it is evident that legumes are not the only woody species that have potential role in agroforestry. However, the Leguminosae offer by far the maximum range of choice of woody species for agroforestry in terms of their economic uses as well as ecological adaptability. Compared with the multipurpose woody perennials that are useful in agroforestry, the legumes have the added advantage because of their capability for nitrogen fixation. Although legumes are not the only nitrogen fixers (others include, for example, the genera Alnus and tropical Casuarina), and all legumes are not necessary N-fixers, there is a general tendency, albeit erroneously, to equate N-fixation with legumes (Nair, et al., 1984).

Plants, especially woody species, that have hitherto been very little studied may prove themselves to be very valuable for agroforestry. Prime candidates will be species that can grow well with other species, that can thrive in environments that are too harsh for most other species, that simultaneously yield several products (food, fuel, fodder), that enrich the micro-site such as by nitrogen fixation, efficient nutrient cycling or addition of organic matter to the soil through litterfall and root exudates and decay. Growth habits of such species with respect to their above ground and below ground parts will also be of considerable significance. With this long list of attributes it would be possible to prepare a check-list o characters to look for, or suggest some ideotypes of woody plants for agroforestry. For expediency we can look for some of these characters in the trees that are commonly found to exist in agricultural land - either mixed with agricultural crops or otherwise retained deliberately.

Multipurpose trees and shrubs in agroforestry

Threes and shrubs occur in a wide variety of land use systems. For simplicity these systems can be grouped into 11 major categories.

i. Natural Vegetation Management

Although considerable research has been undertaken on the management of tropical rain forests, relatively little attention has been given to the natural tree and shrub associations of drier zones. Nevertheless, these communities offer a significant and often the sole source of plant materials, especially for fuel and fodder; often they contain species that could have great potential as planted exotics for other sites. Generally there is more information and experience of tropical and subtropical trees than shrubs from the points of view of ecology, distribution, inventory, use and management.

ii. Industrial plantations

These are large areas created and managed intensively, usually with exotic species, for the production of timber to supply sawmills, pulpmills, veneer factories, chipboard plant, etc. The plantations are usually owned and managed by state enterprises.

iii. Community woodlots

These are small areas of 5-10 ha created for the benefit of village or town communities (where they are often referred to as "peri-urban plantations"), often by the state, and more recently by the communities themselves in some form of social forestry. They may be on state or community land and may yield timber, poles and fuelwood plus occasionally fruit, fodder and other products. There are often difficulties of management, protection and distribution of benefits.

iv. Farm woodlots

These are small plantations of less than 10 ha, often much less, that are established by the individual farmer for the production of poles, fuel, fodder and possibly other products; multipurpose trees are thus desirable. The products supply the farmer's own needs with excess for sale and such woodlots may be established on unused or degraded land with a view to rehabilitating it.

v. Trees in crop land

Individual trees may be left or planted randomly at wide intervals in productive agricultural land to supply wood, fuel, fodder, fruit, honey and shade.

vi. Alley farming

In this group of systems, one or more rows of trees are planted alternately with several rows of agricultural crop plants and the trees are hedged, coppiced or pollarded frequently. The decline in value of crop yield caused by the loss of land occupied by trees should be compensated or exceeded by the fertilizing effect of the tree leaves and other ways of soil improvement by trees, and by the value of tree products (poles and fuel). This is becoming the most widely recommended agroforestry system.

vii. Linear planting

This includes the planting of one or more rows of trees, with or without subsequent management, along farm borders, river or stream banks, or along roads, railways or canals. They can provide the usual services and benefits.

viii. Shelterbelts

These are belts/blocks consisting of several rows of trees established at right angles to the prevailing wind. They are also known as windbreaks and have significant effects on micrometeorological factors up to several times their height away from the edge. The species, age composition, canopy density, height and profile are all important determinants of their effectiveness. They also produce valuable by-products.

ix. Sequential cropping

Trees and agricultural crops may follow each other on the same piece of land in planted "fallow" systems in which the trees restore the soil fertility. Taungya is a system whereby trees are planted, often at close industrial spacing, together with intercrops of agricultural species, the agricultural crops being grown for upto three or four years.

x. Silvopastoral systems

Silvopastoral systems involve the incorporation of tree and shrub management and animal husbandry. The trees may be used for fodder production, shade and pasture improvement. Intensity of the operations can vary from extensive range management in dry zones to intensive trees-over-pasture in areas of higher rainfall.

xi. Protection forestry, land rehabilitation, reclamation

The use of trees in these roles encompasses many technologies. Protection forestry generally requires the management, through natural regeneration, of existing indigenous vegetation, which requires protection from grazing and damaging exploitation above-all. For the reclamation and rehabilitation of degraded land the function of trees is primarily for soil conservation or improvement, coupled with production of (mainly) wood and fodder. The arrangement of the planted trees (which can be combined in agroforestry systems) should follow these major objectives.

For virtually all these systems a multipurpose plant would be considered more useful than a species fitted for only one purpose. In fact there can be very few species that, if they are used at all, are not used for several purposes, products, benefits and services. There has been considerable discussion of the definition of multipurpose trees but the concept is now well established, largely as a result of the interests and activities of ICRAF. The common abbreviation is MPTS, which can imply "Multipurpose Tree Species" or "Multipurpose Trees and Shrubs".

The attention to MPTS has developed in parallel with the growth of social forestry programmes and the research and development of agroforestry systems that can be used to meet the objectives of social forestry and integrated rural development programmes. The incorporation of MPTS into land use systems requires significant changes in the attitude, understanding and cooperation of professional foresters, horticulturists, agronomists and various groups of extension workers.

Characteristics of MPTS Suitable for Agroforestry

1. Adaptability to local climatic conditions.
2. Light open crown that lets sunlight through.
3. Ability to resprout quickly after pruning, coppicing or pollarding.
4. Productive capacity that includes poles, wood, food, fodder, medicinal and other products.
5. Good leaf litter making nutrients available at appropriate times in the crop cycle.
6. Few and shallow lateral roots (or prunable).
7. Ability to assist in nitrogen fixation.
8. Resistance to drought, flooding, soil variability and other climatic hazards.
9. Deep thrusting taproot system.
10. Easy to manage.
11. Cheap to establish.
12. Higher demand and better value for the produce.

Benefits from trees and shrubs

The products and services derived from trees and shrubs are manifold and vary between societies and environments, but they can be summarized simply as follows.

Products

Wood

Unprocessed	- fencing or building poles
Processed, solid	- sawn timber
Reconstituted	- veneers, paper, chipboard
Bark	- raw and processed for various uses

Energy

Solid, raw	- firewood
Solid, processed	- charcoal
Fluid	- liquid and gaseous fuels and feed-stocks
Chemical stem	- resins, oils, paints,extractives varnishes, pharmaceuticals
Leaf products	- thatch, fibre, fodder, extractives, oils, silk, smoking material, medicines
Fruit/seed products	- food, fodder, oils, drinks, medicines
Flower products	- drinks, medicines, honey, dyes, food
Root products	- fuelwood, chemical extractives, dyes

Environmental benefits

Climatic moderation (macro-and-micro)
Soil stabilization
Soil improvement
Water-flow moderation
Wildlife habitats
Boundary demarcation
Pest and weed control
Use or rehabilitation of degraded land, improving downstream environments

Socio-economic benefits

Amenity and tourism
Employment generation - especially for the landless
Income generation - including foreign exchange
Import substitutions
Public education
Rehabilitation of abandoned and degraded land, increasing production
Counter seasonality
Risk reduction
Labour saving in some situations
Improved human and animal nutrition and health

Choice of Agricultural Crops

The agricultural crop components in any existing agroforestry system, or in any newly postulated one, will be largely restricted to species which satisfy existing consumer and market preferences in any particular region. Introducing completely new food or cash crops is generally a lengthy business. An exception to this might be in relatively infertile,

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Improved human and animal nutrition and health

Choice of Agricultural Crops

The agricultural crop components in any existing agroforestry system, or in any newly postulated one, will be largely restricted to species which satisfy existing consumer and market preferences in any particular region. Introducing completely new food or cash crops is generally a lengthy business. An exception to this might be in relatively infertile,

semi-arid ecozones where agricultural cropping is not generally considered viable, yet possibilities of nutrient transfer and improved water economy exist if trees are planted and the litter and mulch materials from them are carried to support agricultural crops (Huxley, 1983 a). In some areas the possibilities would be almost unlimited, covering vegetables, wine crops, fodder crops, grazing, etc., whereas in other areas there may be only one or two obvious alternatives.

It is important to carefully select agricultural crops which neatly tie in with the overall management of the system. Early in the establishment phase, for example, crops which can be successfully grown and harvested between the trees, without the possibility of damaging them, are the most suitable. As the trees develop, grazing may be introduced and it is important that the stock used do not cause damage to the trees.

Shading of the understorey is an important factor affecting the suitability of many agricultural crops for developed agroforestry systems. It would be worthwhile investigating the relative shade tolerance of various agricultural crops under consideration for agroforestry system. The availability of soil moisture under the trees, especially in the top-soil, is crucial for pasture and crop growth. Research trials in Western Australia and New Zealand involving various stockings of *Pinus radiata* growing on pasture have shown that soil moisture levels in the top soil actually increase with increasing tree density thus allowing pasture to stay greener over summer (Reid & Wilson, 1985).

Soil nutrient status is another important factor influencing the choice of the agricultural component within an agroforest. The farmer has great potential of achieving a valuable level of agricultural productivity from his agroforest with consistent fertilization if he allows for some degree of shading and carefully manages the site to prevent excessive tree damage (Reid and Wilson, 1985).

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