TROPICAL AGROFORESTRY SYSTEMS AND PRACTICES

By

P.K.R. Nair

International Council for Research in Agroforestry (ICRAF)

P O Box 30677 Nairobi Kenya

Chapter No. 14

In: Furtado, J.I. and Ruddle, K.(Eds)

TROPICAL RESOURCE ECOLOGY AND DEVELOPMENT

John Wiley, Chichester, England

June 1984

SUMMARY

Agroforestry is a new field of organized scientific pursuit although the practice encompasses some age-old land use activities. It involves elements of agriculture and forestry, wherein woody perennials are deliberately mixed or retained with crop or animal production units.

A global overview of the current agroforestry situation indicates that there are several examples of agroforestry systems and practices in different ecological and geographic regions of the world, especially the tropics. Depending on the dominant components, these systems can broadly be classified into agrosilvicultural, silvopastoral and agrosilvopastoral. Prominent examples of each are given from different parts of the tropics.

The role of woody perennials in agroforestry systems can be both productive (producing food, fodder, fuel, wood, etc.) and protective (soil conservation, windbreaks and shelterbelts, etc.).

Although agroforestry has the most apparent potential in marginal lands, it can equally be effective in high-potential areas too. In both types of areas, it can have a special role in situations where socio-economic or physical constraints force farmers to produce most of their basic needs from their own land. However, there are several scientific, institutional, developmental and extension constraints and impediments facing the development of agroforestry.

While developing management approaches in agroforestry, special emphasis has to be given to the overall performance of the system, and components may be viewed from such a perspective. Some fundamental aspects relating to the two major disciplinary components of land use systems -- plant and soil -- are also examined in the light of these considerations.

decades in tropical agriculture, forestry, ecology, soil management and rural socioeconomics. Increasing dependence of modern agricultural technology on high-value inputs on the one hand, and the deteriorating economic situation of most of the developing countries on the other, have caused a renewed awareness about the potentials of age-old conservation farming technologies. At the same time, the seriousness of forest destruction and its alarming consequences are also being increasingly realized. The major cause of deforestation is now recognized to be man's search for more and more areas to produce food to meet the ever-increasing demand for this basic need. Thus, in the wake of the mounting pressures of food and fuel shortage, and the serious environmental problems associated with deforestation, it is no longer prudent to ignore the conservation benefits and the potential for sustained yields provided by agroforestry farming systems based on or involving trees and other woody perennials, some forms of which have been in existence for a long time in various parts of the world.

How to find a definition for agroforestry embodying all these concepts and encompassing all the complexities? Certainly there is no concensus of opinions. Many definitions have been proposed (see Agroforestry Systems 1, 7-12, 1982). Some have even gone to the extent of exaggerated and presumptuous claims that agroforestry, by definition, is a superior and more successful approach to land use than others. The definition that is adopted by ICRAF reads as follows:

Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management unit as agricultural crops and/or animals, either on the some form of spatial arrangement or temporal *sequence. In agroforestry systems there are both ecological and economical interactions between the different components.*

This definition implies that:

i) agroforestry normally involves two or more species of plants (or plant and animals), at least one of which is a woody perennial;

ii) an agroforestry system always has two or more outputs;

iii) the cycle of an agroforestry system is always more than one year; and

iv) even the most simple agroforestry system is more complex, ecologically (structurally and functionally) and economically, than a monocropping system.

(Readers interested to know more about these concepts and principles may contact the Information/Documentation Services of ICRAF, P.O. Box 30677, Nairobi, Kenya).

3. VARIETY OF AGROFORESTRY SYSTEMS AND PRACTICES

3.1. Classification of Agroforestry Systems

Whatever the definition of agroforestry, it is now generally agreed that it represents an approach to land use involving deliberate retention of trees and other woody perennials in the crop/animal production fields (Lundgren and Raintree, 1983; Nair, 1983 a; b). If we look at the existing land use systems keeping such a broad concept of agroforestry in mind, we find that several of them can be considered to ecnompass the principles of agroforestry.

Attempts have been made by various authors to classify the different agroforestry systems. Obviously, a classification scheme will depend upon the purpose for which it is to be used. On a global basis, there can be geographical considerations, and within each geographical region there can be ecological factors that determine the type of systems in a locality. Social factors, especially demographic, coupled with economic background of the population can add another dimension to it. However, the baisc structure of a system is decided primarily by the type and arrangements of its components. Therefore, one of the primary criteria in classifying agroforestry systems is the components that constitute the system.

Following the definition mentioned in section 2, the basic groups of components in an agroforestry system can be two or three: woody perennials, herbaceous crops and/or animals. Since the woody perennial forms the common denominator in all agroforestry systems, a component-based classification scheme will logically have to be based on this predominant component. Here again, the criteria, as pointed out by Torres (1983 a), can be several: the *type* of woody perennial, its *role and function* in the system, the nature of *interaction* between the woody and other components, and so on. All component-based classification schemes of agroforestry systems have so far considered the type of woody perennials as the first step in the exercise, and based on that, three broad subdivisions have been proposed by Nair (1983 d): agrosilvicultural, silvopastoral and agrosilvopastoral.

The agrosilvicultural system combines the production of tree crops (forest-, horticultural-, or agricultural plantation-) with herbaceous crops, in space or time, to fulfill productive or protective roles within the land management systems. Examples can be hedgerow intercropping (alley cropping), improved "fallow" species in shifting cultivation, multistorey multipurpose crop combinations, multipurpose trees and shrubs on farm lands, shade trees for commercial plantation crops, integrated crop combinations with plantation crops, agroforestry fuelwood production systems, shelterbelts and windbreaks and so on. The silvopastoral systems integrate woody perennials with pasture and/or livestock. Examples include animal production systems in which multipurpose woody perennials provide the fodder (protein bank), or function as living fences around grazing land or are retained as commercial shade/browse/fruit trees in pasture lands. The agrosilvopastoral systems, as the name implies, combine trees and herbaceous crops with animals and/or pastures. The use of woody hedgerows for browse, mulch and green manures and for soil conservation, the crop/tree/livestock mix around homesteads, etc. are good exmples of this system. It is also a common practice in some places to have sequential patterns (integration in time) of agrosilvicultural phase followed by a silvopastoral one so that initially trees and crops are established, and later on, the crops are replaced with pasture, and animals are brought in.

3.2. Field Examples of Agroforestry Systems in the Tropics

ICRAF is currently undertaking a global inventory of agroforestry systems and practices that exist in the tropics and subtropics. The basic document that was prepared for the project included a preliminary overview of the situation as a "Systems Overview Table" indicating the most prominent examples found in different geographical regions. An up-dated version of the Table is presented as Table 1.

TABLE 1 HERE

The ICRAF survey collects information pertaining to the functioning of these systems, as well as analyzes their merits, weaknesses and constraints with a view to identifying research needs and extending the system to other areas. A summary account of some of these extensively practised agroforestry systems and practices is given in Table 2. (For a more detailed account of the woody species involved, see Nair, 1983 d and Nair et al., 1984). Without going into the details, suffice it to say that there are several extensively practised land use systems which though not known by the name agroforestry, do encompass the agroforestry approach to land use.

TABLE 2 HERE

4. PRODUCTIVE AND PROTECTIVE ROLES OF AGROFORESTRY

The field examples of agroforestry systems and practices presented in Table 2 show that they are not only widespread in different ecological regions, but are also important in terms of the role of woody perennials in producing the basic needs and/or protecting and prologing the sustainability of the system. These primary roles (productive/protective) of the woody perennials,the type of their interactions (temporal/spatial) with the other major components and the spatial arrangement of the components (mixed/zonal) in the major agroforestry systems are summarized in Table 3.

TABLE 3 HERE

4.1. Productive Role

The productive role of the woody perennials in agroforestry systems includes production of food, fodder, firewood and various other products. One of the most promising technologies of this kind that is applicable in a wide range of situations is the hedgerow intercropping (alley cropping) in crop production fields. Promising results have been obtained from this type of studies conducted at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (Wilson 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 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 (Nair, 1984; Nair *et 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 groundnut and millet production areas of sub-Saharan Africa (Felker, 1978) and the dominant role of *Prosopis cineraria* in the arid North-Western parts of India (Mann and Saxena, 1980).

The role of woody perennials on farmlands for producing fuelwood is another example of the productive role of species in agroforestry. The seriousness of the fuelwood situation has been well recognized all over the world, so that several initiatives and studies on this aspect are currently being undertaken. Several fast-growing firewood crops, most of them legumes, suitable for different environmental conditions, have been identified (NAS, 1980); most of them combine well with conventional agricultural crops (Nair, 1980).

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 either browse grazing or forest/plantation grazing systems. The role of woody perennials in these systems has been reviewed excellently by Torres (1983 b).

4.2. 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 dead 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 long tradition of planting *Leucaena leucocephala* in contour hedges for erosion control and soil improvement in Southeast Asia, especially Indonesia, is a typical example. Indirect terraces are also formed when the washed-off soil is collected behind the hedges. Loppings and prunings from such hedgerow species could also provide mulch to aid in preventing sheet erosion between trees (Zeuner, 1981; Neumann, 1983). The presence of more plant cover on the soil, either alive or as mulch, also reduces the impact of raindrops on the soil and thus minimizes splash and sheet erosion. Therefore, as pointed out by Lundgren and Nair (1983), the potential role of agroforestry in soil conservation lies not only in woody perennials 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 trespassing or against the adverse effects of wind is a wide-spread practice in many agricultural systems. For example, a large number of multipurpose woody perennials are being used as effective live fences at CATIE (Centro Agronomico Tropico de Investigacion y Ensenanza), Turrialba, Costa Rica (Budowski, 1983). Similarly, very encouraging results on shelterbelts and windbreaks have been obtained at the Pakistan Forestry Research Institute, Peshawar (Sheikh and Chima, 1976; Sheikh and Khalique, 1982), as indicated in Table 2.

5. CONSTRAINTS AND POTENTIALS

5.1. Constraints

There are several scientific, institutional, developmental and management constraints and impediments to be overcome before scientifically sound agroforestry technologies can be developed and adopted in areas where other land use systems are breaking down.

Scientifically, agroforestry has no distinct identity or separate existence of its own as yet. By its very nature, it is an integrated and multidisciplinary approach encompassing complex systems. Existing land use research institutions, both national and international, are mostly oriented to specific commodities, disciplines or ecological regions so that they are poorly equipped to handle complex topics such as agroforestry. The scientists themselves are mostly too discipline-oriented (such as specialists in one or the other branch of agriculture, forestry, animal husbandry, etc.) so that it is not an easy task to persuade them to relegate and reorient their disciplinary pursuits to the interdisciplinary needs of a multidisciplinary team. Moreover, the experimental methods and procedures that have been developed over the decades for specific disciplines and components will have to be modified to make them applicable and relevant to integrated and complex systems, which by no means, is an easy task.

Institutional constraints to agroforestry development are also equally complex. As mentioned in the introductory section of this paper, rigid boundaries often separate departments dealing with different aspects of land use, leading to increasing competition for scarce developmental resources at governmental and administrative levels. As pointed out by Lundgren and Raintree (1983), even in places where formal agroforestry programmes exist, they fall under the forestry departments with very little knowledge of, let alone interaction with, the agriculture departments (which, usually, are more 'prestigious' and 'powerful' than the respective forestry departments). The situation is much the same in the international sphere too. Thus there exists a sort of vicious circle: on the one hand agroforestry has not developed to earn a separate identity in terms of resources allocation, and, such a respectability and identity can, on the other hand, be achieved only by research investments for development.

The transfer of technology to the masses is another big step involved in the adoption of such land use practices. The majority of the farmers in the tropics are preoccupied by their efforts to find the current basic needs of food, fuel, shelter, etc. so that they cannot easily be bothered about the merits of long-term approaches and investments. Thus, it may be relatively easy to introduce short-term technologies such as new species or better varieties of agricultural crops, or to make marginal improvements in the management of existing tree components. But, it will be considerably more difficult and challenging to convince farmers about incorporation of tree components over existing crop or animal enterprises, especially if land tenure is uncertain and success of the system is not guaranteed. The problem is compounded by poor and inadequate extension services that can seldom handle complex problems such as those of agroforestry.

Management constraints of agroforestry are also several and of varied nature. Special skills and sustained efforts are needed for undertaking the various management aspects of trees, about which many crop or livestock farmers may not be aware of. Interaction between components, especially the hypothetical adverse effects of trees on crops, is an area about which farmers who are not experienced with such systems are very apprehensive, and researchers are not equipped enough to allay such apprehension. It is interesting to note in this context that a survey on the extent of intercropping in coconut lands in Sri Lanka identified seven important problems/constraints that are faced by the farmers in expanding their intercropping activity (Liyanage *et al.*, 1984). These, in order of their relative importance, were: drought, lack of funds, price instability, lack of technical know-how, problems of timely availability of labour, availability of planting materials, and thefts. On an average, each intercropper faced at least three of these problems, their nature and extent being dependant on the size of holding and type of intercrop.

5.2. Potentials

Notwithstanding the above-mentioned constraints, agroforestry has great potential over vast areas of land. As indicated earlier, the most apparent potential for agroforestry exists in areas where soil fertility is low and is dependent mainly on soil organic matter fraction, and where erosion hazards are high. And such "marginal lands" cover a majority of land areas in the tropics. Proper integration of appropriate woody species in the land use systems in these areas can enhance both land productivity and sustainability.

However, the potential of agroforestry is, by no means, confined to such "marginal" lands; it is equally applicable to high-potential lands. Indeed, we can find indigenous agroforestry systems wherever there has been a history of population pressure and a long-standing need for efficient management of scarce resources (Lundgren, 1982). Some of the most successful smallholder systems mentioned in Table 2 are, in fact, found on high-potential, fertile soils where such integrated systems are often superior and preferred to other forms of land use. In both low-potential and high-potential areas, agroforestry can have a special role in situations where land tenure system or infrastructural limitations (road, transport, markets, etc.) make it imperative for the farmers to produce most of their basic needs (food, fuel, building poles, etc.) from their own land resources.

The potential role of agroforestry in production systems producing food, fodder, fuelwood, poles, etc. and in protecting the environment through soil conservation, wndbreak, etc. has already been indicated in section 4.2. Agroforestry approaches have also been suggested as alternatives to resource-depleting shifting cultivation (Nair, 1983 d) as well as in other specific environments (Nair, 1983 c). It has also a special role in combating desertification and deforestation because the primary reason for forest destruction is man's ever-increasing demand for more land for producing food and agroforestry offers possibilities for producing food and wood at the same time from the same piece of land (King, 1979; Nair, 1982).

6. MANAGEMENT APPROACHES FOR DEVELOPMENT OF AGROFORESTRY SYSTEMS

Basically, there are two approaches in the study of an entity. First, to consider the different components and study them individually, paying particular attention to their cause-effect relationships. Most of the agricultural research conducted in the past has been of this nature, and these studies have helped us to improve our knowledge considerably. However, problems often arise when we try to put the pieces together and predict the behaviour of the system, which often consists of something more than the individual components. The second approach is to study the system in its totality -- a system will, of course, be considered to consist of different sub-systems.

In agroforestry, the individual components to be studied and their interactions are many. Moreover, the studies are normally of a very long-term nature. Inadequate planning and uncoordinated data-gathering without a central theme, as is likely to occur in individual disciplinary experiments, might lead to the drawing of incorrect conclusions with respect to the system as a whole. In addition, the extrapolation of results obtained from such piece-meal research might be extremely dangerous. Therefore, the technological assessment in agroforestry research should concentrate less on types of component analyses, in which the factors and organisms are treated as if they were independent entities, but focus more on approaches in which the interactive, integrative, and emergent properties are also included.

This is, however, not to suggest that approaches aiming at gathering basic information on the components of the system are not required. In fact, when the land use system is examined in its totality certain aspects of the components that need to be studied in detail to produce the expected technologies will come to the fore. In most cases, such technologies and management approaches that will require immediate attention will be related to plant and soil components.

6.1. Plant Aspects of Agroforestry

Because of the newness of agroforestry, there are no conventional plant species that can be categorized as "agroforestry species". All species that can grow well in combined production systems fall under the domains of "agricultural, "forestry", "horticultural", or other established classes. Therefore, what is important is to examine the "suitability" of economic plant species to agroforestry, no matter whether it is known to belong to any of the conventional disciplinary groups. Nair (1980) examined the "agroforestry potential" of several of the better-known as well as lesser-known "agricultural" and "horticultural" species and found that most of them can grow and produce reasonable yields under combined production systems.

When considering integration of trees on farmlands where some agricultural species are already being grown, it is assumed that there will be little or no change in the type of such herbaceous species: they will continue to be limited to what the local population or established markets require. On the other hand, the compatability and complementarity of the woody perennial with such herbaceous species will be the important consideration. In addition to the genotype of the woody species as such, its resource-sharing capabilities, potential micro-site enrichment capability, and environmental amelioration are also or prime importance. Thus, appropriate management measures (pruning, lopping, pollarding, browsing, time of sowing in the case of herbaceous species) have to be practised in order to optimize the benefits in combined production systems. Peculiar phenological characteristics of economically useful species may become very convenient in some contexts. A typical example is the tree *Acacia albida,* which produces leaves prior to the onset of rains and shed the leaves during rainy season, so that millet and groundnut can be grown close to the tree in the rainy season without being shaded, and at the same time they can benefit by the micro-site enrichment by the tree (Felker, 1978).

Plants, especially woody species, that have hitherto been very little studied and understood may prove themselves to be very valuable for agroforestry. Prime candidates will be species that can grow well with other species, that thrive in environments that are too harsh for most other species, that simultaneously yield several products (food, fuel, fodder), that provide environmental amelioration (e.g. soil conservation) and that enrich the micro-site, such as by nitrogen fixation or nutrient cycling. Luckily, a few species have been identified that possess some, if not all, of these attributes (NAS, 1975; Ritchie, 1979), and they are now receiving scientific attention.

Arrangement of component plant species in space and time is also an important but difficult factor in agroforestry because of the many variations in the types of agroforestry practices and the conditions under which they are practised. The motivation for most of the various kinds of smallholder agroforestry systems that are prevalent throughout the world (Tables 1 and 2) has been to find plants that provide multiple products and that can be grown on the available land. When attempting to improve such systems or to devise new ones, it therefore is necessary, to know about both the short-term productivity of the plants and the long-term sustainability of the system. Thus depending on whether the tree-crop interaction is favourable or not,plant arrangements have to be devised to maximize the beneficial interactions and minimize the undesirable ones. There are also several other factors to be taken into account. Examples include: growth habits and growth requirements of the component species when grown near other species, simplicity of management procedures for the whole system, and realization of additional benefits like soil conservation. These plant aspects of agroforestry were brought out in considerable detail in an expert consultation organized by ICRAF (Huxley, 1983).

6.2. Soil Aspects of Agroforestry

State-of-the-art of soils aspects of agroforestry was brought out in an ICRAF Consultation in 1979 (Mongi and Huxley, 1979). Since agroforestry is particularly suitable for farmers with limited resources in marginal areas, where sedentary agriculture or forestry systems may not be the most feasible and desirable, the system must be self-maintaining. This means that the system should attain maximum efficiency in inputs and maintain productivity of soil with a strong emphasis on resource conservation. In view of the importance of the self-sustaining and resource-conserving attributes of agroforestry, the likely effects of agroforestry on long-term productivity of soil have been examined using existing knowledge derived from similar land use systems (Nair, 1984). This involved an evaluation of soil productivity changes under shifting cultivation, taungya, plantation forestry, integrated systems involving plantation crops and multiple cropping. It also entailed an assessment of the role of trees in soil productivity and protection.

The analysis revealed that several advantages in terms of soil productivity and protection could be anticipated by proper incorporation of appropriate woody species in land use systems. Some expedient soil management technologies of a general nature were also suggested based on these considerations.

In conclusion, agroforestry has generated a lot of enthusiasm among various groups of people. There are several types of agroforestry systems and all of them are very complex in nature. The scientific approach to the study of these complex systems is difficult, time-consuming and needs multidisciplinary input. Most of the hypothesis concerning the potential as well as management approaches of agroforestry are still in the hypothetical and speculative stage. In order to validate the hypotheses and devise sound management technologies, research has to be undertaken on these various aspects in a systematic manner in different agro-ecological situations. While interpreting results from such research and trying to extrapolate them to other situations, the overall systems perspective of agroforestry has to be given adequate attention.

ACKNOWLEDGEMENTS

ICRAF's Agroforestry Systems Inventory project, some results of which are included in this paper, is funded partially by the United States Agency for International Development (USAID). Mr. Erick C.M. Fernandes, my colleague in the project has contributed substantially to the paper, especially Tables 1 and 2.

REFERENCES

Alvim, R. and Nair, P.K.R. (1984). Agroforestry practices involving agricultural plantation crops in southeast Bahia, Brazil, No. 9 of AF System Description Series, *Agroforestry Systems* (In Press).

Ambar, S. 1982. Overview of the results of traditional agroforestry study in Ci-Tarum river basin, West Java. Paper presented to *The Regional Seminar-Workshop in Agroforestry.* 18-22 October, 1982. SEARCA, College, Laguna, The Philippines.

Bene, J.G., Beall, H.W. and Côté, A. (1977). *Trees, Food and People - Land Management in the Tropics*, IDRC 084e, International Development Research Centre, Ottawa.

Boonkird, S.-A., Fernandes, E.C.M. and Nair. P.K.R. (1984). Forest villages - an agroforestry approach to rehabilitating forest lands degraded by shifting cultivation in Thailand, No. 2 of AF System Description Series, *Agroforestry Systems* (In Press).

Bourke, M. (1984). Food, coffee and Casuarina: an agroforestry system from the Papua New Guinea highlands, No. 6 of AF System Description Series, *Agroforestry Systems* (In Press).

Budowski, G. (1983). An attempt to quantify some current agroforestry practices in Costa Rica, in *Plant Research and Agroforestry* (Ed. Huxley, P.A.), pp. 43-62, ICRAF, Nairobi.

De las Salas, G. (Ed). (1979). *Proceedings of the Workshop on Agroforestry Systems in Latin America.* CATIE, Turrialba, Costa Rica.

Evans, P.T. and Rombold, J.S. (1984). Paraiso *(Melia azedarach* var. "Gigante") woodlots: an agroforestry alternative for the small farmer in Paraguay, No. 5 of AF System Description Series, *Agroforestry Systems* (In Press).

Fernandes, E.C.M., O'King'ati, A. and Maghembe, J. (1984). The Chagga home-gardens: a multi-storied agroforestry cropping system in Mt. Kilimanjaro, N. Tanzania, No. 1 of AF System Description Series, *Agroforestry Systems* (In Press).

Felker, P. (1978). *State of the Art: Acacia albida as a complementary intercrop with annual crops,* Univ. California, Berkeley, California (Grant No. AID/afr C-1361; mimeographed report).

Fonzen, P. and Oberholzer, E. (1984). Use of multipurpose trees in hill farming systems in western Nepal, No. 4 of AF System Description Series, *Agroforestry Systems* (In press).

Getahun, A., Wilson, G.F. and Kang, B.T. (1982). The role of trees in the farming systems in the humid tropics, in *Agroforestry in the African Humid Tropics,* (Ed. MacDonald, L.H.), pp. 28-35, UNU, Tokyo.

Hecht, S.B. (Ed). (1982). *Amazonia: Agriculture and Land Use Research,* CIAT, Cali, Colombia.

Heuveldop, J. and Lagemann, J. (Eds). (1981). *Agroforestry: Proc. of a seminar held at CATIE,* 23 February - 3 March, 1981, CATIE, Turrialba, Costa Rica.

Huxley, P.A. (Ed). (1983). *Plant Research and Agroforestry, Proceedings of an Expert Consultation,* ICRAF, Nairobi.

Indian Council of Agricultural Research. 1979. *Proceedings of the National Seminar on Agroforestry, May 1979.* ICAR, New Delhi.

Johnson, D.V. (1983). *Agroforestry Systems in Northeast Brazil,* Report of the Special Consultant, ICRAF, Nairobi (unpublished).

Johnson, D.V. and Nair, P.K.R. (1984). Perennial crop-based agroforestry systems in northeast Brazil, No. 8 of AF System Description Series, *Agroforestry Systems* (In press).

Kang, B.T., Wilson, G.F. and Sipkens, L. (1981). Alley cropping maize and leucaena in southern Nigeria, *Plant and Soil,* 63, 165-179.

Kundstadter, P., Chapman, E.C. and Sabhasri, S. (Eds). (1978). *Farmers in the Forest: Economic Development and Marginal Agriculture in Northern Thailand,* East-West Center, Honolulu, Hawaii.

Little, E.L. (1983). *Common Fuelwood Crops: A Handbook for their Identification*, McClain Printing Co., Parsons, West Virginia.

Liyanage, M. de S., Tejwani, K.G. and Nair, P.K.R. (1984). Intercropping under coconuts in Sri Lanka, No. 7 of AF System Description Series, *Agroforestry Systems* (In press).

Lundgren, B.O. (1982). Agroforestry approaches to land use in the tropics, *Fourth International Congress of INTERFORST,* Munich.

Lundgren, B.O. and Nair, P.K.R. (1983). Agroforestry for soil conservation, *Second International Conference on Soil Erosion and Conservation,* Honolulu (Proc. in press).

Lundgren, B.O. and Raintree, J.B. (1983). Sustained agroforestry, in *Agricultural Research for Development: Potentials and Challenges in Asia* (Ed. Nestel, B.), pp. 37-49, ISNAR, The Hague.

Mann, H.S. and Saxena, S.K. (Eds). (1980). *Khejri (Prosopis cineraria) in the Indian Desert,* CAZRI Monograph No. 11, Central Arid Zone Research Institute, Jodhpur, India.

Mongi, H.O. and Huxley, P.A. (Eds). (1979). *Soils Research in Agroforestry - Proceedings of an Expert Consultation,* ICRAF, Nairobi.

Nair, P.K.R. (1979). *Intensive Multiple Cropping with Coconuts in India: Principles, Programmes and Prospects,* Verlag Paul Parey, Berlin (West).

Nair, P.K.R. (1980). *Agroforestry Species: A Crop Sheets Manual,* ICRAF, Nairobi.

Nair, P.K.R. (1982). Agroforestry: a sustainable land-use system for the fragile ecosystems in the tropics, *Malay. Nat. J., 35, 109-123.*

Nair, P.K.R. 1983 a). Multiple land-use and agroforestry, in *Better Crops for Food, CIBA Foundation Symposium 97,* pp. 101-115, Pitman Books, London.

Nair, P.K.R. (1983 b). Tree integration on farmlands for sustained productivity of smallholdings, in *Environmentally Sound Agricultural Alternatives,* (Ed. Lockeretz, W.), pp. 333-350, Praeger, New York.

Nair, P.K.R. (1983 c). Some promising agroforestry technologies for hilly and semi-arid regions of Rwanda, in *Report of a Seminar on Agricultural Research in Rwanda: Assessment and Perspectives.* (Ed. Chang, J.), pp. 93-99, ISNAR, The Hague.

Nair, P.K.R. (1983 d). Alternative and improved land use systems to replace resource-depleting shifting cultivation, *Expert Consultation on Strategies, Approaches and Systems for Integrated Watershed Management,* Forest Resources Division, FAO, Rome.

Nair, P.K.R. (1984). *Soil Productivity Aspects of Agroforestry,* ICRAF, Nairobi.

Nair, P.K.R., Fernandes, E.C.M. and Wambugu, P.N. (1984). Multipurpose leguminous trees and shrubs for agroforestry, *Agroforestry Systems* (In press).

NAS (1975). *Underexploited Tropical Plants with Promising Economic Value,* National Academy of Sciences, Washington, D.C.

NAS (1980). *Firewood Crops: Shrubs and Trees for Energy Production,* National Academy of Sciences, Washington, D.C.

Neumann, I. (1983). Use of trees in smallholder agriculture in tropical highlands, in *Environmentally Sound Agriculture,* (Ed. Lockeretz, W.), pp. 351-374, Praeger, New York.

Okafor, J.C. (1982). Promising trees for agroforestry in southern Nigeria, in *Agroforestry in the African Humid Tropics,* (Ed. MacDonald, L.H.), pp. 103-107, UNU, Tokyo.

Panday, K. (1982). *Fodder Trees and Tree Fodder in Nepal,* Swiss Devpt. Corp., Berne, and Swiss Federal Inst. of Forestry Research, Birmensdorf., Switzerland.

Richardson, S.D. (1982). Agroforestry education in the south Pacific - opportunities and constraints, *International Workshop on Professional Education in Agroforestry,* December 1982, ICRAF, Nairobi (Proceedings in press).

Ritchie, G.A. (Ed). (1979). *New Agricultural Crops,* Selected Symp. No. 38, American Assoc. Adv. Sci., Westview Press, Colorado.

Sheikh, M.I. and Chima, A.M. (1976). Effect of windbreaks (tree rows) on the yield of wheat crop, *Pakistan Journal of Forestry, 26(1),* 38-47.

Sheikh, M.I. and Khalique, A. (1982). Effect of tree belts on the yield of agricultural crops, *Pakistan Journal of Forestry, 32,* 21-23.

Singh, R.V. (1982). *Fodder Trees in India,* Oxford and IBH Pub. Co., New Delhi.

Stewart, P.J. (1981). Forestry, agriculture and land husbandry, *Commonw. For. Rev., 60(1),* 29-34.

Torres, F. (1983 a). Agroforestry: concepts and practices, in *Agroforestry Systems for Small-scale Farmers,* (Eds. Hoekstra, D.A. and Kuguru, F.M.), pp. 27-42, ICRAF/BAT, Nairobi.

Torres, F. (1983 b). Role of woody perennials in animal agroforestry *Agroforestry Systems 1:* 131-163.

von Maydell, H.-J. (1984). *Agroforestry Systems and Practices in the Arid and Semi-Arid Parts of Africa,* Report of the Special Consultant, ICRAF, Nairobi (unpublished).

Wiersum, K.F. (1982). Tree gardening and taungya in Java: examples of agroforestry techniques in the humid tropics, *Agroforestry Systems 1,* 53-70.

Wilken, G.C. (1977). Integration of forest and small scale farm systems in middle America, *Agro-Ecosystems 3,* 291-302.

Wilson, G.F. and Kang, B.T. (1981). Developing stable and productive biological cropping systems for the humid tropics, in *A Scientific Approach to Organic Farming,* (Ed. Stonehouse, B.), pp. 193-203, Butterworth, London.

Yandji, E. (182). Traditional agroforestry systems in the Central African Republic, in *Agroforestry in the African Humid Tropics,* (Ed. MacDonald, L.H.), pp. 52-55, UNU, Tokyo.

Zeuner, T.H. (1981). An ecological approach to farming: some experiences of the agro-pastoral project, Nyabisindu, Rwanda, in *Kenya National Seminar on Agroforestry* (Ed. Buck, L.), pp. 329-353, ICRAF, Nairobi.

TABLE 1. SOME EXAMPLES OF PROMINENT AGROFORESTRY SYSTEMS AND PRACTICES IN THE DEVELOPING COUNTRIES

SYSTEMS		EXAMPLES FROM DIFFERENT GEOGRAPHIC REGIONS*						
Major Systems	Sub-Systems/Practices	Pacific	Southeast Asia	South Asia	Middle East and Mediterranean	East and Central Africa	West Africa	American Tropics
AGROSILVICULTURAL SYSTEMS	Improved "Fallow" (in shifting cultivation areas)		Forest villages of Thailand; Various fruit trees & plantation crops used as "fallow" species in Indonesia	Improvements to Shifting Cultivation; several approaches e.g. in the north-eastern parts of India		Improvements to Shifting Cultivation e.g. gum gardens of the Sudan	*Acioa barteri*, *Anthonotha macrophylla*, *Gliricidia sepium*, etc. tried as "fallow" species	Several forms
	The Taungya System	(e.g. Taro with *Cedrella* and *Anthocephalus* trees)	Widely practised; Forest villages of Thailand is an improved form	Several forms, several names		The 'Shamba' System	Several Forms	Several forms
	Tree Gardens	Involving fruit trees	Dominated by fruit trees	In all ecological regions	The Dehesa system; "Parc arboré"			e.g. "Paraiso Woodlot" of Paraguay
	Hedgerow Intercropping (Alley Cropping)		Extensive use of *Sesbania grandiflora*, *Leucaena leucocephala* and *Calliandra callothyrsus*	Several experimental approaches e.g. Conservation Farming in Sri Lanka		The Corridor System of Zaire	Experimental systems on alley cropping with *Leucaena* and others	
	Multipurpose Trees and Shrubs on Farmlands	Mainly fruit or nut trees (e.g. *Canarium*, *Pometia*, *Barringtonia*, *Pandanus*, *Artocarpus altilis*)	Dominated by fruit trees; also *Acacia mearnsii* - cropping system, Indonesia	Several forms both in lowlands and highlands e.g. Hill Farming in Nepal; 'Khejri' - based system in the dry parts of India	The Oasis system; Crop combinations with the Carob tree; The Dehesa system; Irrigated systems; Olive trees + cereals	Various forms; The Chagga system of Tanzanian highlands; The Nyabisindu system of Rwanda	*Acacia albida*-based food production systems in dry areas; *Butyrospermum* + *Parkia* systems; "Parc arboré"	Various forms in all ecological regions
	Crop Combination with Plantation Crops	Plant. crops and other multipurpose trees: e.g. *Casuarina* and coffee in the highlands of PNG; also *Gliricidia* and *Leucaena* with cacao	Plant. crops + fruit trees; smallholder systems of crop combinations with plantation crops; plantation crops with spice trees	Integrated production systems in smallholdings; shade trees in plantations; other crop mixtures including various spices	Irrigated systems; Olive trees + cereals	Integrated production; shade trees in commercial plantations; mixed systems in the highlands	Plantation crop mixtures; smallholder production systems	Plantation crop mixtures; shade trees in commercial plantations; mixed systems in smallholdings; spice trees
	AF Fuelwood Production	Multipurpose fuelwood trees around settlements	Several examples in different ecological regions	Various forms		Various forms	Common in the dry regions	Several forms in the dry regions
	Shelterbelts, Windbreaks, Soil Conservation Hedges	*Casuarina oligodon* in the highlands as shelterbelts and soil improver	Terrace stabilization in steep slopes	Use of *Casuarina* spp. as shelterbelts; several windbreaks	Tree spices for erosion control	The Nyabisindu system of Rwanda	Various forms	Live fences, windbreaks especially in highlands
SYLVOPASTORAL SYSTEMS	Protein Bank (Cut-and-carry Fodder Production)		Very common, especially in highlands	Multipurpose fodder trees on or around farmlands especially in highlands		Very common	Very common	Very common
	Living Fence of Fodder Trees and Hedges		*Leucaena*, *Calliandra*, etc. used extensively	*Sesbania*, *Euphorbia*, *Syzigium* etc. common		Very common in all ecological regions		Very common in the highlands
	Trees and Shrubs on Pastures	Cattle under coconuts, pines and *Eucalyptus deglupta*	Grazing under coconuts and other plantations	Several tree species being used very widely	Very common in the dry regions; the Dehesa system	The *Acacia* dominated system in the arid parts of Kenya, Somalia and Ethiopia	Cattle under oil palm; Cattle and sheep under coconut	Common in humid as well as dry regions; e.g. Grazing under plantation crops in Brazil
AGROSILVOPASTORAL SYSTEMS	Woody Hedges for Browse, Mulch, Green Manure, Soil Conservation, etc.	Various forms: *Casuarina oligodon* widely used to provide mulch and compost	Various forms	Various forms especially in lowlands			Very common	
	Home Gardens (involving a large number of herbaceous and woody plants with or without animals)		Very common; Java Home Gardens often quoted as good examples	Common in all ecological regions	The Oasis system	Various forms (The Chagga homegardens; the Nyabisindu system)	Compound farms of humid lowlands	Very common in the thickly populated areas
OTHER SYSTEMS	Agro-Silvo-Fishery ('Aquaforestry')		Silviculture in mangrove areas; trees on the bunds of fish-breeding ponds					
	Various forms of Shifting Cultivation	Common	e.g. Swidden Farming	Very common; various names		Very common	Very common in the lowlands	Very common in all ecological regions
	Apiculture with Trees	Common	Common		Common	Common	Common	-

TABLE 2. FIELD EXAMPLES OF SOME COMMON AGROFORESTRY SYSTEMS AND PRACTICES IN THE TROPICS

Sub-system/ Practice	Country/ Region	Some examples of the woody species involved	Remarks/ Major references
I.A. AGROSILVICULTURAL SYSTEMS - Humid/Sub-humid Lowlands			
Improved "Fallow" (in shifting cultivation areas)	Indonesia	*Aleurites molucana* *Erythrina* spp. *Styrax* spp.	Kunstadter et al. (1978)
Woody species planted and left to grow during the "Fallow phase"	Nigeria	*Acioa barteri* *Anthonotha macrophylla*	Getahun et al. (1982)
Tree Gardens Multilayer, multi-species plant associations with no organized planting arrangement	Nigeria	*Daniellia oliveri* *Gliricidia sepium* *Parkia clappertoniana* *Pterocarpus africana*	Getahun et al. (1982)
	Pacific Islands	*Inocarpus edulis* *Morus nigra* *Spondias dulce*	Richardson (1982)
	India, Sri Lanka	*Areca catechu* *Artocarpus* spp. *Cocos nucifera* *Mangifera indica*	Coconut intercropping: Nair (1979; 1983); Liyanage et al. (1984)

TABLE 2 (CONT'D)

	Paraguay	*Melia azedarach*	The Paraiso woodlot (Evans and Rombold, 1984)
	SE Asia	*Albizia falcataria* *Artocarpus* spp. *Bambusa* spp. *Durio zebethinus* *Nephelium lapaceum*	Ambar (1982) Forest Villages of Thailand (Boonkird et al., 1984)
Hedgerow intercropping (Alley cropping)	SE Asia	*Calliandra callothyrsus*	
Woody species in hedges; agri. species in between hedges (alleys)	Nigeria	*Leucaena leucocephala*	Wilson and Kang (1981)
Multipurpose trees and shrubs on farmlands Trees scattered haphazardly or according to some systematic patterns	Brazil	*Cassia excelsa* *L. leucocephala* *Mimosa scabrella*	
	India	*Derris indica* *Emblica officinalis* *Moringa oleifera* *Tamarindus indica*	NAS (1980)
	Kenya	*Anacardium occidentale* *Ceiba petandra* *Mangifera indica* *Manilkara achras*	

TABLE 2 (CONT'D)

	SE Asia	*Acacia mangium* *Artocarpus* spp. *Durio zibethinus* *Gliricidia sepium* *Sesbania grandiflora*	
Crop combinations with plantation crops 1) Integrated production of plantation crops and other crops in intimate plant associations 2) Mixtures of plantation crops e.g. coconut and cacao 3) Shade trees for commercial plantation crops		<u>Plantation crops</u> *Anacardium occidentale* *Camellia sinensis* *Cocos nucifera* *Coffea arabica* *Elaeis guineensis* *Hevea brasiliensis* *Piper nigrum* *Theobroma cacao*	
	Brazil	*Bertholletia excelsa* *Copernicia prunifera* *Cordia alliodora* *Inga* spp. *Orbignya* spp. *Samanea saman*	Hecht (1982) Alvim and Nair (1984)

TABLE 2 (CONT'D)

	Costa Rica	*Cordia alliodora* *Erythrina poeppigiana* *Gliricidia sepium* *Inga* spp.	Budowski (1983) Heuveldop and Lagemann (1981)
	India	*Albizia* spp. *Cassia* spp. *Erythrina* spp. *Grevillea robusta*	Coconut intercropping (Nair, 1979; 1983; Liyanage et al., 1984)
	SE Asia	Various fruit trees	
	West Indies	*Inga vera*	
	Western Samoa	*Erythrina variegata* *Gliricidia sepium* *Leucaena leucocephala*	Richardson (1982)
AF for fuelwood Production Interplanting fire-wood species on or around agricultural lands	India	*Albizia* spp. *Cassia siamea* *Derris indica* *Emblica officinalis*	ICAR (1979) NAS (1980)
	Indonesia	*Albizia falcataria* *Calliandra callothyrsus* *Sesbania grandiflora* *Trema orientalis*	NAS (1980)

TABLE 2 (CONT'D)

Shelterbelts, windbreaks, soil conservation hedges	India	*Casuarina equisetifolia* *Syzygium cuminii*	NAS (1980)
Planting around agricultural lands as windbreaks and shelterbelts; planting along contours for terrace stabilization and soil conservation	Indonesia (and other parts of SE Asia)	*Gliricidia sepium* *Leucaena leucocephala* *Sesbania grandiflora*	NAS (1980)

I. B. AGROSILVICULTURAL SYSTEMS - Tropical Highlands

Multipurpose trees and shrubs on farm-lands	India	*Albizia* spp. *Bauhinia variegata* *Dalbergia sissoo*	NAS (1980)
	Kenya	*Ceiba petandra* *Eriobotrya japonica* *Grevillea robusta*	
	Nepal	*Bauhinia* spp. *Erythrina* spp. *Ficus* spp. *Litsea polyntha*	Hill farming in Nepal (Fonzen and Oberholzer, 1984)

TABLE 2 (CONT'D)

	Paraguay	*Melia azedarach*	The Paraiso woodlot (Evans and Rombold, 1984)
	Tanzania	*Albizia* spp. *Cordia africana* *Croton macrostachys* *Trema guineensis*	The Chagga system (Fernandes et al., 1984)
Crop combinations with plantation crops	Brazil	*Alnus acuminata* *Enterolobium contorsiliquum* *Erythrina velutina*	
	Costa Rica	*Alnus acuminata* *Erythrina poeppigiana* *Inga* spp.	Budowski (1983)
	India, Sri Lanka	*Albizia* spp. *Grevillea robusta*	
	Kenya	*Grevillea robusta*	
	Papua New Guinea	*Casuarina olygodon*	Bourke (1984)
	Philippines	*Trema orientalis*	
	Rwanda Tanzania	*Albizia* spp. *Cordia africana* *Grevillea robusta* *Trema guineensis*	Fernandes et al. (1984) Neumann (1983)

TABLE 2 (CONT'D)

AF Fuelwood Production	India, Nepal	*Albizia stipulata* *Bauhinia* spp. *Grewia* spp.	ICAR (1979) NAS (1980)
Shelterbelts, Windbreaks, Soil Conservation Hedges	(same as in lowlands)		
I.C. AGROSILVICULTURAL SYSTEMS - Arid and Semi Arid Regions			
Multipurpose Trees and Shrubs on Farm-lands	Brazil	*Caesalpinia ferrea* *Prosopis juliflora* *Zizyphus joazeiro*	Johnson (1983)
	Central African Republic	*Adansonia digitata* *Balanites aegyptiaca* *Borassus aethiopium*	Yandji (1982)
	India	*Cajanus cajan* *Derris indica* *Prosopis cineraria* *Tamarindus indica*	NAS (1980)
	Kenya	*Acacia* spp. *Balanites aegyptiaca* *Cajanus cajan*	

191

TABLE 2 (CONT'D)

	Tanzania	*Acacia* sp. *Combretum* spp.	
AF Fuelwood Production	Chile India	*Prosopis tamarugo* *Albizia lebbek* *Cassia siamea* *Prosopis* spp.	NAS (1980) Little (1983) ICAR (1979)
	Sahel	*Acacia albida* *A. senegal* *A. tortilis*	von Maydell (1984)
Shelterbelts and Windbreaks	India, Pakistan	*Azadirachta indica* *Cajanus cajan* *Cassia siamea* *Eucalyptus* spp. *Pithecellobium dulce* *Populus* spp.	Sheikh and Chima (1976), Sheikh and Khalique (1982)

TABLE 2 (CONT'D)

II. SILVOPASTORAL SYSTEMS - Humid/Sub-humid Lowlands			
Protein Bank (Multi-purpose Fodder Trees on or around Farmlands)	India, Nepal, Sri Lanka	*Artocarpus* spp. *Anogeissus latifolia* *Bombax malabaricum* *Cordia dichotoma* *Dalbergia sissoo* *Eugenia jambolana* *Samanea saman* *Zizyphus jujuba*	ICAR (1979) Pandey (1982) Singh (1982)
Living Fences of Fodder Trees and Hedges	Costa Rica	*Diphysa robinoides* *Gliricida sepium*	
	Ethiopia	*Erythrina abyssinica*	
	SE Asia	*Sesbania grandiflora*	
Trees and Shrubs on Pastures (similar to multipurpose trees on farmlands)	Brazil	*Acacia* spp. *Anacardium occidentale* *Cedrela odorata* *Cordia alliodora*	Hecht (1982) Johnson and Nair (1984)
	Costa Rica	*Enterolobium cyclocarpum* *Erythrina poeppigiana* *Samanea saman*	De las Salas (1979)

TABLE 2 (CONT'D)

	India	*Derris indica* *Emblica officinalis* *Psidium guajava* *Tamarindus indica*	Singh (1982)
II. SILVOPASTORAL SYSTEMS - Tropical Highlands			
Protein Bank	Indian subcontinent	*Albizia stipulata* *Bauhinia* spp. *Ficus* spp. *Grewia oppositifolia* *Morus alba*	
Living Fences	Costa Rica Ethiopia East Africa	*Gliricidia sepium* *Erythrina abyssinica* *Dovyalis caffra* *Euphorbia tirucalli* *Iboza multiflora*	
Trees and Shrubs on Pastures	Brazil	*Desmanthus varigatus* *Desmodium discolor*	
	Costa Rica	*Alnus acuminata*	
	Indian subcontinent	*Albizia stipulata* *Alnus napalensis* *Grewia* spp.	

TABLE 2 (CONT'D)

II. C. SILVOPASTORAL SYSTEMS - Arid and Semi-arid Regions			
Protein Bank	India	*Acacia nilotica* *Ailanthus excelsa* *Opuntia ficus indica* *Prosopis* spp. *Rhus sinuata*	Singh (1982)
Living Fences	East Africa	*Acacia* spp. *Commiphora africana* *Euphorbia tirucalli* *Zizyphus mucronata*	
Trees and Shrubs on Pastures	India	*Acacia* spp. *Prosopis* spp. *Tamarindus indica*	
	Middle East and Mediterranean	*Acacia* spp. *Ceratonia siliqua* *Haloxylon* spp. *Prosopis cineraria* *Tamarix aphylla*	

TABLE 2 (CONT'D)

III. AGROSILVOPASTORAL SYSTEMS			
Woody Hedgerows for Browse, Mulch, Green Manure and Soil Conservation	Indian subcontinent (Humid lowlands), SE Asia	*Erythrina* spp. *Leucaena leucocephala* *Sesbania* spp.	
Tree-Crop-Livestock Mix around Homestead (known as Home Gardens, these associations are found in almost all ecological regions and several countries; only some examples are given)	South and SE Asia (Humid lowlands)	Fruit trees and some plantation crops mentioned under Agro-silvicultural systems	.g. Home Gardens of Java (Wiersum, 1982)
	Nigeria (Humid lowlands)	*Cola acuminata* *Garcinia kola* *Irvingia gabonensis* *Pterocarpus soyauxii* *Treculia africana*	
	Latin American countries	Several species mentioned under Agrosilvicultural systems	Wilken (1978)
	Tanzania (Highlands)	*Albizia* spp. *Cordia africana* *Morus alba* *Trema guineensis*	Chagga Home-gardens (Fernandes et al., 1984)

TABLE 3. THE ROLE OF WOODY PERENNIALS, THEIR ARRANGEMENT AND INTERACTION WITH OTHER COMPONENTS IN SOME COMMON AGROFORESTRY SYSTEMS

Systems	Sub-systems/ Practices	Primary role of woody perennials	Arrangement of components	Nature of interaction between major components
Agrosilvicultural	Hedgerow intercropping (Alley cropping)	Protective (soil productivity)	Zonal	Spatial
	Improved fallow	Protective (soil productivity and productive)	Zonal	Temporal
	Multistorey crop combination	Productive	Mixed	Spatial and temporal
	Multipurpose trees on farmlands	Productive	Mixed	Spatial
	Shade trees for commercial plantation crops	Protective and productive	Mixed or zonal	Spatial and temporal
	AF fuelwood production	Productive	Zonal	Temporal and spatial
	Shelterbelts and windbreaks	Protective	Zonal	Spatial

TABLE 3. CONT'D

Systems	Sub-systems/ Practices	Primary role of woody perennials	Arrangement of components	Nature of interaction between major components
Silvopastoral	Protein bank	Productive (and protective)	Zonal	Temporal
	Living fence	Protective	Zonal	Spatial
	Trees over pastures	Productive (and protective)	Mixed and zonal	Spatial
Agrosilvopastoral	Woody hedgerows for browse, mulch, green manure and soil conservation	Productive and protective	Mixed	Temporal and spatial
	Tree-crop-livestock mix around homesteads	Protective and protective	Mixed	Spatial and temporal
	Agrosilvicultural to silvopastoral	Productive	Mixed	Temporal and spatial