Classification of Agroforestry Systems

3

Contents

Abstract

The main purpose of a classification scheme is to provide a practical framework for the synthesis and analysis of the information about existing agroforestry systems (AFS) and the development of new and promising ones. During the early stages of AF development in the tropics, a substantial database was generated from a global inventory of tropical AFS. Using that database, a classification scheme was developed based on the system's structure (nature and arrangement of components) as the primary criterion, and three major categories of AFS were identified: agrisilvicultural, silvopastoral, and agrosilvopastoral systems. Other criteria such as the system's function (major role or output), ecological distribution (rainfall, elevation), and socioeconomic characteristics (subsistence, commercial) were then used to group the systems in a purpose-oriented manner: for example, a silvopastoral system in tropical savannas, an agrisilvicultural system for soil conservation, and so on. In situations where such a detailed classification is not relevant or needed as in the

P. K. R. Nair et al., *An Introduction to Agroforestry*, https://doi.org/10.1007/978-3-030-75358-0_3

temperate regions, classification has been limited to the identification of the major practices. Thus, during the late 1990s to early 2000s, alley cropping, silvopasture, forest farming, riparian buffer, and windbreaks were recognized as the major agroforestry practices in North America. Almost identical terms with slight modifications were adopted to designate the AF practices in Europe too. These terms have subsequently been modified and expanded in both North America and Europe.

3.1 Introduction

If we look at the existing land-use systems using the broad definition and concepts of agroforestry given in Chapter 2, we find that various types of agroforestry combinations abound in all ecological and geographical regions of the world, but most distinctively in the tropics. Several descriptions of promising land-use systems involving integrated production of trees and crops, as well as innovative scientific initiatives aimed at improving such systems, have been reported without the label of "agroforestry" before the arrival and acceptance of such a new word. To understand and evaluate the existing agroforestry systems and to develop action plans for their improvement, it is necessary to classify them according to some common criteria.

The main purpose of classification should be to provide a practical framework for the synthesis and analysis of information about existing systems and the development of new and promising ones. Besides, a classification scheme will aid in the transfer and application of knowledge gained from one location to another. Depending on the focus and emphasis of strategies for the development of improved systems, the nature of a given framework will vary. Therefore, 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 for management interventions to improve the system's efficiency)
- Offer flexibility in re-grouping the information, and
- Be easily understood and readily handled.

The complexities of these requirements suggest that a single classification scheme may not satisfactorily accommodate all of them; perhaps a series of classifications will be needed, with each one based on a definite criterion to serve a different purpose.

3.2 Early Efforts in Classification

In the early stages of agroforestry development, several attempts were made to classify agroforestry systems (AFS). These were mostly focused on concept development rather than on evaluation and data-based analysis of the systems. While some of them were based on only one criterion such as the role of components (King 1979) or temporal arrangement of components, others tried to integrate several of these criteria in hierarchical schemes in rather simple ways (Torres 1983) or more complex ones (Combe and Budowski 1979; Huxley 1983). The most organized effort in understanding the systems has been a global inventory of agroforestry systems and practices in developing countries undertaken by ICRAF between 1982 and 1987. That activity involved systematically collecting, collating, and evaluating data on numerous such land-use systems around the world (Nair 1987). It assembled, for the first time, a substantial body of information on AFS including their structures and functions, and their merits and weaknesses. As that activity progressed, it became increasingly clear that a classification scheme was necessary to compile and process the information that was being gathered. At the same time, the comprehensive and broad-based nature of the inventory provided a substantial database for developing a widely-applicable classification scheme. That scheme was based on the notion that the most obvious and easy-to-use criteria for classifying AFS

systems would be the spatial and temporal arrangement of components, the importance and role of components, the production aims or outputs from the system, and the social and economic features. These attributes correspond to the systems' structure, function (output), socioeconomic nature, or ecological (environmental) spread, respectively, and represent the main purpose of a classification scheme. Thus, the following sets of criteria were adopted in the classification proposed by Nair (1985).

- ***Structural basis:*** refers to the nature of the components, including spatial arrangement of the woody component, vertical stratification of all the components, and temporal arrangement of the different components.
- ***Functional basis:*** refers to the major function or role of the system, usually furnished by the woody components. These can be of service- or protective nature as well, e.g., windbreak, shelterbelt, soil conservation, shade trees, and the like. Apart from these service benefits, the woody components also provide one or more direct forms of production such as logs for building construction, furniture making, peeler logs (e.g., plywood), chip or particleboard, round timber posts or poles, fuelwood, fodder, or green manure, fruits or nuts, besides the production of chemicals such as gums, resins, and dyes.
- ***Ecological basis:*** refers to the environmental condition and ecological suitability of systems, based on the assumption that certain types of systems can be more appropriate for certain ecological conditions; i.e., there can be separate sets of agroforestry systems for arid and semiarid lands, tropical highlands, lowland humid tropics, etc.
- ***Socioeconomic basis***: refers to the level of inputs of management (low input, high input) or intensity or scale of management and commercial goals (subsistence, commercial, intermediate).

While proposing this classification, the author emphasized that the broad foundations upon which it is based are by no means independent or mutually exclusive and that indeed they are interrelated. The structural and functional bases often relate to the biological nature of the woody components in the system, whereas the socioeconomic and ecological stratification refers to the organization of the systems according to those local conditions. It was further proposed that the complexity of agroforestry classification could be considerably reduced if the structural and functional aspects are taken as the primary considerations in the categorization of the systems and socioeconomic and agroecological/ environmental (as well as any other such physical or social) factors are taken as a basis for stratifying or grouping the systems for defined purposes (Table 3.1).

3.3 Classification Based on the Structure of the System

The structure of the system can be defined in terms of its components, their arrangement, and the expected role or function of each.

3.3.1 Nature of Components

In AFS, three basic sets of elements or components are managed by the land user, namely, the tree or woody perennial, the herb (agricultural crops including pasture species), and the animal. As we have seen in Chapter 2, for a land-use system to be designated as an AFS, it must have a woody perennial. In most AFS, the herbaceous species are also involved, the notable exceptions being apiculture and aquaculture with trees, and shaded perennials systems involving shade-tolerant woody perennials such as coffee, cacao, and tea under the shade trees. Animals are only present in some AFS. This leads to a simple classification of AFS as given below and depicted in Figure 3.1.

Agrisilviculture – crops (including shrubs/vines) and trees
Silvopastoral – pasture/animals and trees
Agrosilvopastoral – crops, pasture/animals, and trees

Table 3.1 Major agroforestry practices in the tropics.

Agroforestry practice	Brief description
Tropical agroforestry	
Alley cropping (hedgerow intercropping)	Fast-growing, preferably leguminous, woody species grown in crop fields; the woody species pruned periodically to a low height (<1.0 m) to reduce shading of crops; the prunings applied as mulch into the alleys as a source of organic matter and nutrients, or used as animal fodder.
Homegardens	Intimate multistorey combinations of a diverse and large number of trees and crops in homesteads; livestock may or may not be present.
Improved fallow	Fast-growing, preferably leguminous, woody species planted and left to grow for short periods (2–3 years) of fallow between cropping periods for soil fertility enhancement; woody species may yield economic products.
Multipurpose trees (MPTs) on farms and rangelands	Fruit trees and other MPTs scattered haphazardly or planted in some systematic arrangements in crop or animal production fields; trees provide products such as fruits, fuelwood, fodder, and timber.
Silvopasture: • Grazing systems • Cut and carry system (Protein banks)	Integration of trees in animal production systems: o Cattle grazing on pasture under widely spaced or scattered trees. o Stall-feeding of animals with high-quality fodder from trees grown in blocks on farms.
Shaded perennial-crop systems	Growing shade-tolerant species such as cacao and coffee under or in between overstorey shade-, timber-, or other commercial tree crops.
Shelterbelts and windbreaks	Use of trees to protect fields from wind damage, sea encroachment, floods, etc.
Taungya	Growing agricultural crops during the early stages of establishment of forestry (timber) plantations

Source: Nair (2012)

Figure 3.2 presents a more comprehensive scheme than Figure 3.1 showing classifications based on not only the nature of components but function (products and services) and geographical/ecological distribution of systems. As mentioned above, there are also a few other systems, such as multipurpose woodlots (that interact economically and ecologically with other land-use production components and hence fall under the purview of agroforestry definition), apiculture with trees, and integration of trees and shrubs with fish production (*aquasilviculture*?) that do not fall into these categories. In the absence of a better term to encompass these, they are grouped under "others."

This categorization of AFS into three major types is somewhat fundamental; one of these types can conveniently be used as a prefix to other terms emanating from other classification schemes to explicitly express the basic structure/composition of any system. For example, there can be an agrisilvicultural system for food production in the lowland humid tropics at a subsistence level of production, a commercial silvopastoral system for fodder and food production in lowland subhumid (or dry) tropics, an agrosilvopastoral system for food production and soil conservation in highland humid tropics, and so on. Therefore, it seems logical, compatible, and pragmatic to accept the components as the basic criterion in the hierarchy of agroforestry classification. The classification scheme developed by Nair (1985) was perhaps the first such effort based on a comprehensive database from the above-mentioned inventory of agroforestry systems in the tropics.

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 agrisilvipastoral) 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 would thus be

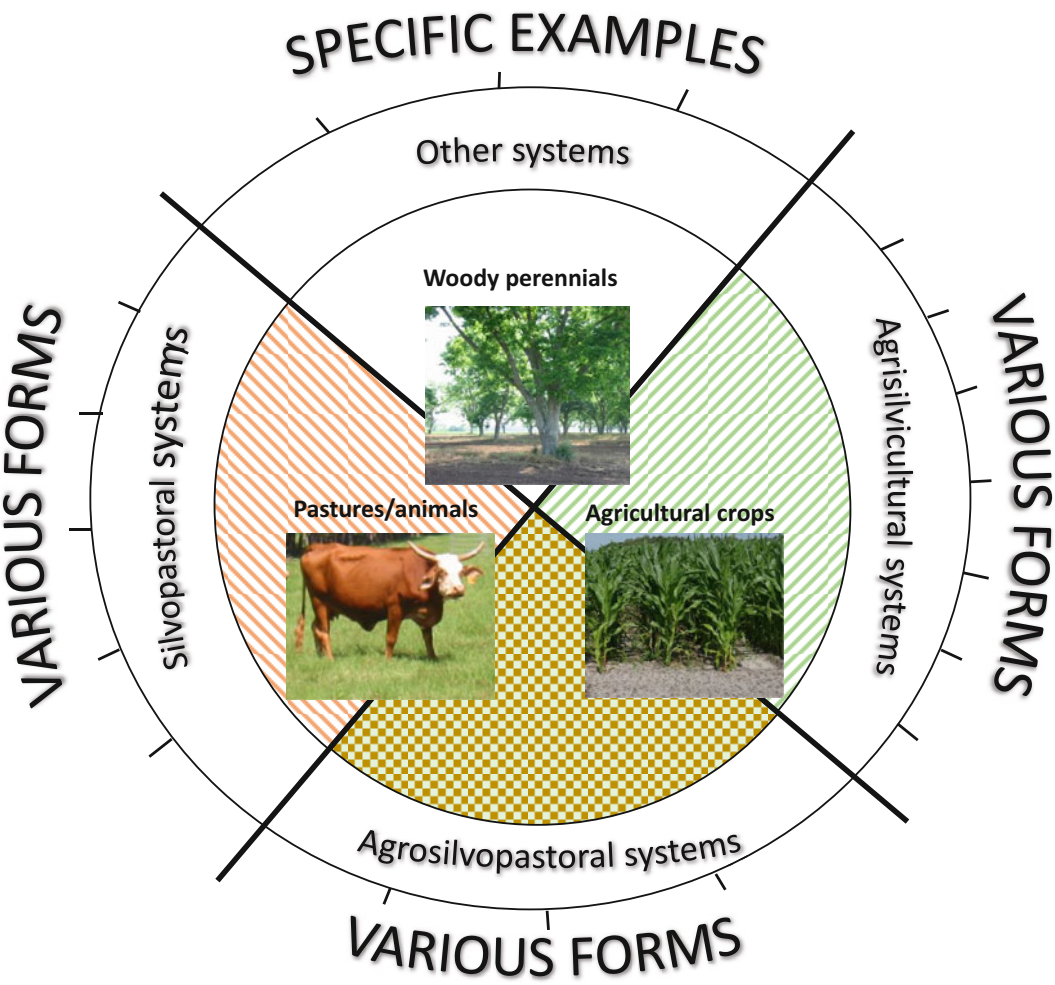


Figure 3.1 Classification of agroforestry systems based on the nature of components. Source: Nair (1993)

another word for agroforestry. That again is the reasoning behind the use of the all-inclusive "agro" prefix in agrosilvopastoral. During the process of evolution of the word agroforestry, there was an argument as noted in Chapter 2 that the proper nomenclature from the linguistic perspective for a term that combines agriculture and forestry should be "agriforestry" and not agroforestry. After all, several other usages can be found in technical languages that may not strictly satisfy the niceties of conventional linguistic usage.

3.3.2 Arrangement of Components

The arrangement of components refers to the plant components of the system (especially if the system involves plant and animal components). Such plant arrangements in multispecies combinations can involve the dimensions of space and time. Spatial arrangements of plants in agroforestry mixtures in the tropics vary from dense mixed stands (as in homegardens) to sparsely mixed stands (as in extensive silvopastoral grazing systems and extensive tree-intercropping

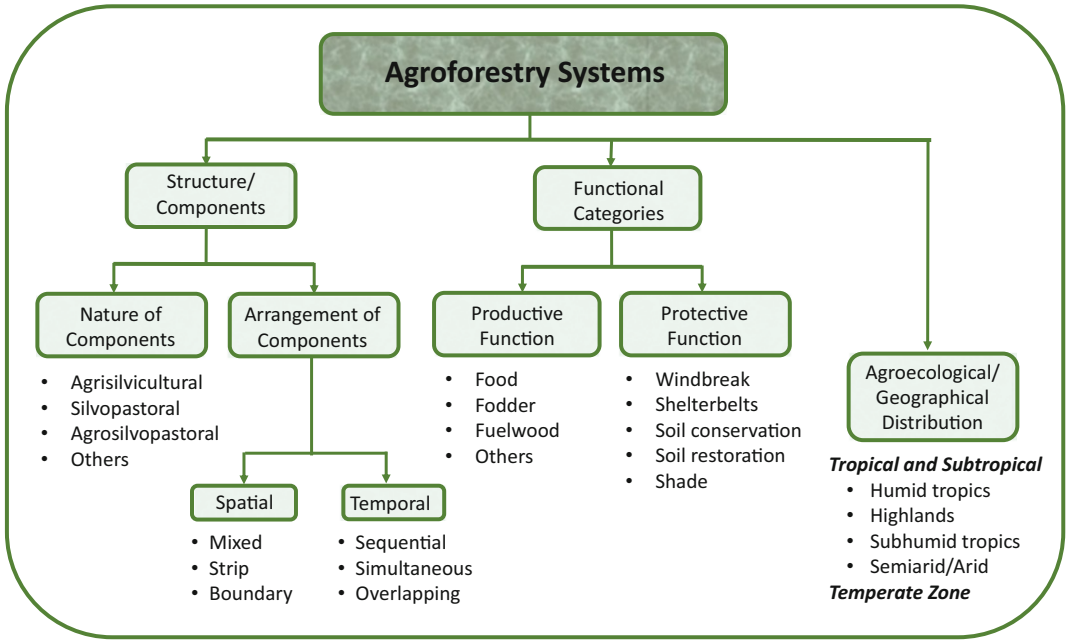


Figure 3.2 Classification of agroforestry systems based on the structure and function of components

systems such as the parkland systems: see Chapter 9, Section 9.4.1). Moreover, the species can be in zones or strips of varying widths in several scales of zones varying from microzonal (alternate rows) to macrozonal arrangements. A commonly mentioned example of the zonal pattern is hedgerow intercropping (alley cropping: Chapter 6). An extreme form of 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 be construed as sole cropping systems; the extent of interactive association of different components, however, can be used as the criterion to decide the limits between macrozonal agroforestry and sole crop systems.

Temporal arrangements of plants in agroforestry can also take various forms. An extreme example is the conventional shifting cultivation cycles involving 2 to 4 years of cropping followed by more than 15 years of fallow when a selected woody species or a mixture of species is planted or allowed to regenerate naturally (see Chapter 5, Figure 5.2). Similarly, some silvopastoral systems may involve grass leys in rotation with woody species with the same species of grass remaining on the land for several years during the grass phase. These temporal arrangements of components in agroforestry have been described by terms such as coincident, concomitant, overlapping (of which the extreme case is relay cropping), sequential, interpolated, and so on a shown in Figure 3.3 (Huxley 1983; Kronick 1984; Nair 1993). The Coincident systems represent simultaneous crop combinations in which different crops occupy the land together. For example, tea/coffee + shade trees or pasture under trees. In a Concomitant system, different crop components occupy the land together for some period, e.g., *Taungya* (Chapter 5). Agroforestry systems, in which annual crops are grown under woody perennials may be described as Intermittent. In situations where different crops occupy the land at different times, as in homegardens, the temporal arrangement can be described as Interpolated. When the components occupy the land at different times, such systems may be

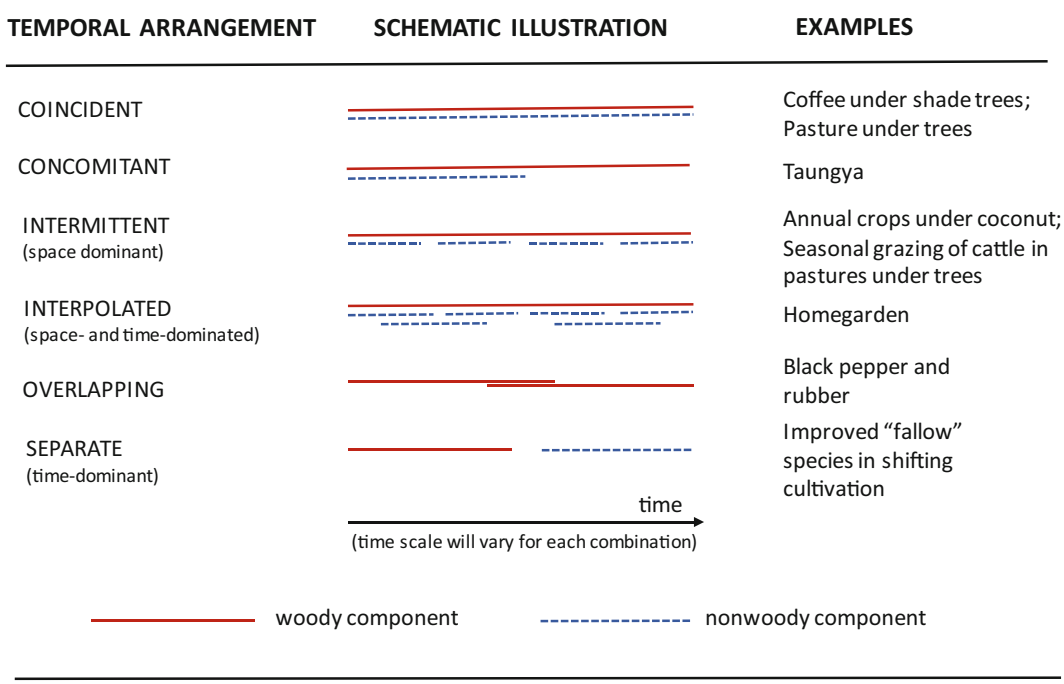


Figure 3.3 Temporal arrangements of woody and nonwoody components in agroforestry systems

classified as Sequential systems (e.g., improved fallows). Overlapping systems represent those in which two or more woody perennials occupy the land continuously, e.g., specialty spice trees (see Chapter 13, Section 13.4.1) interplanted with other usually taller trees such as coconut palms or timber species).

3.4 Based on the Function of the System

Production and conservation (which are the cornerstones of sustainability) are two fundamental attributes of all AFS as explained in Chapter 2. This implies that all AFS have a productive function yielding one or more products that usually meet basic needs, as well as a service role (i.e., protecting and maintaining the production systems). This approach recognizes the service roles of woody perennials as factors contributing to the production of one or more of these basic needs. For example, the soil conservation benefit of agroforestry practices can be expressed in terms of their contribution to augmenting the sustainability of crop production. Similarly, amelioration of microclimate through well-designed arrangements of trees and crops (e.g., shelterbelts) can be evaluated in terms of its effects on crop yields; however, the climate-change mitigation benefits of AFS, particularly through soil carbon sequestration is a long-term benefit (see Chapter 20), the value of which cannot be assessed in short-term studies.

The emphasis on the production of outputs should not diminish the importance of sustainability. Although production is a very important consideration, it is the sustainability attribute that makes AFS different from other approaches to land use. Moreover, all AFS produce more than one basic-need output (largely because of the multipurpose nature of the associated woody perennial component). Therefore, all AFS have both productive and protective roles, though to varying degrees. Depending on the relative dominance of a specific role, the system can be termed productive or protective. Production of a specific output should not, therefore, be used as the sole criterion for classifying AFS. The production of output, or for that matter any other aspect, may be

chosen as a basis for undertaking an evaluation of available agroforestry options.

3.5 Based on Ecological Characteristics

During the late 1970s and early 1980s, several enumerations of agroforestry practices were presented from various geographical regions at seminars and workshops. Notable among them are the group discussions held at CATIE, in Turrialba, Costa Rica (de las Salas 1979); at ICRAF, in Nairobi (Buck 1981; Chandler and Spurgeon 1979; Huxley 1983); and at IITA, Ibadan, Nigeria (McDonald 1982). Several compilations on specific systems were also available such as the *Acacia (Faidherbia) albida* system in West Africa (Vandenbeldt 1992), and the *Prosopis cineraria* system in western India (Mann and Saxena 1980). Additionally, country- or regional overviews were undertaken, such as reviews of agroforestry in francophone Africa (FAO 1981a), the Indian subcontinent (FAO 1981b), and Latin America (Montagnini 1986; Padoch and de Jong 1987). Several other notable overviews have been published (Lundgren and Raintree 1982; Nair 1983b, 1983c, 1984). The Agroforestry System Description Series in *Agroforestry Systems*, which was a major output from ICRAF's Agroforestry Systems Inventory Project (Nair 1987), was the most coordinated effort in describing such existing systems.

Most of these AFS characterizations pertained to specific ecological conditions of different geographical regions in the tropics. It was thus easy to find several descriptions of AFS in, say, the highlands, subhumid tropics (or the tropical highlands, as they are popularly known): for example, the *Chagga* system on Mount Kilimanjaro in Tanzania (Fernandes et al. 1984), hill farming in western Nepal (Fonzen and Oberholzer 1984), multipurpose tree integration in the highlands of Rwanda (Neumann 1983), and casuarina and coffee system in Papua New Guinea (Bourke 1984). Recommendations on agroforestry practices had also been suggested for specific agroecological regions, for example, the hilly regions of Rwanda (Nair 1983a), and for areas with common physical features such as sloping lands (Young 1989) or soil constraints such as acidity (Benites 1990).

Descriptions of existing systems, as well as recommendations of potential agroforestry technologies for specific agroecological zones, include a mixture of various forms of agroforestry: there could be agrisilvicultural, silvopastoral, or agrosilvopastoral systems in any of the zones. For example, based on an analysis of the agroforestry potential for sloping lands in various parts of the world, Young (1989) reported that all three basic categories of agroforestry (agrisilvicultural, silvopastoral, and agrosilvopastoral) could be found in sloping lands.

Various system characterizations and descriptions such as agrisilvicultural systems for fuelwood production in semiarid lands, silvopastoral systems for animal production in sloping lands, multistrata homegardens in humid tropics, etc., are common in agroforestry literature. Moreover, descriptions of existing systems, as well as recommendations of potential agroforestry technologies for specific agroecological zones include a mixture of various forms of agroforestry in terms of the nature and arrangement of components, and several agroforestry systems can be found within the same ecological regions. Thus, in general, for any specific agroforestry practice, agroecological zonation alone cannot be taken as a satisfactory criterion for classification. Agroecological characteristics could, however, be used as a basis for designing agroforestry systems, because similar ecological regions can be found in different geographical regions and the agroforestry systems in similar ecological zones in different geographical regions are structurally (in terms of the nature of species components) similar. The bottom line is that several types of AFS are relevant to any major agroecological zone; the emphasis of the practice will also vary depending on the special conditions of a zone.

3.6 Based on Socioeconomic Criteria

Socioeconomic criteria such as the scale of production and level of technical input and management have also been used as a basis for classifying agroforestry systems. Three such categories have been proposed: commercial, intermediate, and subsistence. In general, they are characterized by low, medium, and high levels of technical input and management. Subsistence farmers consume most of what they produce (or, produce most of what they consume), whereas commercial farmers sell most – if not all – of what they produce on their farm or enterprise. The intermediate group comes in between these two categories. Most AFS practiced in various parts of the developing countries come under the subsistence category. Shifting cultivation, which is still prevalent in many parts of the tropics although not much talked about lately (see Chapter 5), is a common form of this category. All subsistence AFS, however, are not as resource-depleting as traditional shifting cultivation. For example, the integrated, multi-species homegarden system is an ecologically sound AFS (Wiersum 1980; Michon et al. 1986; Kumar and Nair 2006: Chapter 7). Similarly, reports on several sustainable systems of a subsistence nature from many other tropical regions can be found in the early literature of agroforestry, for example, from Latin America (Wilken 1977), arid West Africa (von Maydell 1979, 1987; Le Houerou 1987), humid West Africa (Getahun et al. 1982), and India (ICAR 1979).

Grouping agroforestry systems according to these socioeconomic and management criteria may offer a purpose-oriented action plan; however, there are some drawbacks too. The criteria for defining the various classes are not easily quantifiable; the standards set for such differentiation will reflect the general socioeconomic situation of a given locality. What is considered a "subsistence" system in one locale may well fall under the "intermediate" or even a higher category in another setting. Moreover, these class boundaries will also change with time. A good example is the gum-arabic production system of Sudan. It used to be a flourishing "intermediate" system consisting of a planned rotation of *Acacia senegal* tree for gum production for 7–12 years. The tree also provided fodder and fuelwood and improved soil fertility (Seif-el-Din 1981). But with the advent of artificial substitutes for gum arabic, the *Acacia senegal*/millet system has now degenerated into a shrinking, subsistence system. Therefore, socioeconomic factors that are likely to change with time and management conditions cannot be rigidly adopted as a satisfactory 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.

3.7 Other Approaches to Classification of Tropical Agroforestry Systems

The component-based classification of AFS explained above (Figures 3.1, 3.2 and 3.3) have been used somewhat widely in tropical agroforestry literature. Over the years, however, the relevance and application to all different forms of AFS have been questioned. Torquebiau (2000) argued that the three broad categories (agrisilviculture, silvopasture, and agrosilvopasture) are either too vague or restrictive; he argued that agrisilviculture could almost be a synonym for agroforestry covering hundreds of practices, and the distinctions among the three categories could be faint when considering systems involving all three major components of crops, trees, and animals. Another weakness of that classification system is that it does not recognize that the components of a system could be arranged in time (sequentially or simultaneously) or space (mixed or zonal) patterns. Furthermore, that classification gives more emphasis to the tree component compared with the other components (crops or animals). Based on such considerations, some attempts at classifying agroforestry systems more robustly have since been reported. Torquebiau (2000) suggested a classification with six categories: crops under tree cover, agroforests, agroforestry in a linear arrangement, animal agroforestry, sequential agroforestry, and "minor" agroforestry techniques.

It has not, however, been established how this categorization would overcome some of the problems associated with the earlier classification scheme. Other classification schemes of agroforestry systems have also been proposed (e.g., Sinclair 1999); but, essentially, they all are based on the criteria and concepts described in Chapter 2. Various other terms are also used in agroforestry literature to refer to specific types of associations, notably in India where terms such as *silvi-pasture, agri-horti, horti-agri, silvi-horti, horti-silvi*, and so on, are found in local literature without a clear explanation of the basis for such categorizations. *Integrated Crop-Livestock-Forestry Systems* is a relatively new term that has sprung up, primarily in (or, for application in) Brazil (Bungenstab and Almeida 2014). The intent seems to be to make silvopasture as a "stand-alone" field distinct from the rest of the agroforestry applications (see Chapter 9, Section 9.6).

Tropical Agroforestry System Subgroups. To streamline the agroforestry systems nomenclature and reduce the number of major groups, Nair (2012, 2014) arranged the systems into five major subgroups based primarily on the nature of system components (multistrata systems, tree intercropping, silvopasture, protective systems, and agroforestry woodlots) with major types of agroforestry systems identified under some of them (Table 3.1; see also Chapter 4, Table 4.3). The total number of categories (nine) is still high – which also indicates how diverse agroforestry systems are.

3.8 Agroforestry Systems and Practices

The words "system" and "practice" are used commonly, and often synonymously, in agroforestry literature, adding to the confusion surrounding the classification of agroforestry. This is particularly so in the tropics, where agroforestry is more diverse, complex, and rooted in traditions and culture, than in the temperate regions. A distinction can be drawn between the two words system and practice: a *system* connotes the many parts, arrangements, and interactions created by integrating these parts, whereas *practice* is the customary, habitual, or expected procedure or way of doing something. Thus, an *agroforestry practice* denotes a distinctive arrangement of components in space and time and the actual application or use of an idea, belief, or method. An *agroforestry system* is a specific local example of a practice, characterized by environment, plant species and their arrangement, management, and socioeconomic functioning. Although hundreds of agroforestry systems have been recorded in the tropics, they all consist of a few (less than 20) distinct agroforestry practices. In other words, the same or similar practices are found in various systems in different situations. Table 3.2 lists the most common agroforestry practices that constitute the diverse agroforestry systems throughout the tropics and their main characteristics. It may be noted that both the systems and the practices are known by similar names, but the systems are (or ought to be) related to the specific locality or the region where they exist, or other descriptive characteristics that are specific to it. Nevertheless, the distinction between systems and practices is vague, and even not very critical for understanding and improving them; therefore, the words are used synonymously in agroforestry, as they are in other forms of land use too. As explained in the following section, however, the use of the word *practice* rather than *system* is better established in North America (the USA and Canada) and Europe, where agroforestry systems and practices are relatively few and are based on agricultural traditions.

Another term that is also frequently used is *agroforestry technology*. It refers to innovation or improvement, usually through scientific intervention, to either modify an existing system or practice or develop a new one. Such technologies are often distinctly different from the existing systems/practices; so, they can easily be distinguished and characterized.

Table 3.2 Major tropical agroforestry practices

Agroforestry Practice	Brief description (of arrangement of components)	Major groups of components	Agro-ecological adaptability
Agrisilvicultural systems (crops-including shrub/vine/tree crops – and trees)			
(1) Improved fallow	Woody species planted and left to grow during the fallow phase	w: fast-growing preferably leguminous h: common agricultural crops	In shifting cultivation areas
(2) Taungya	Combined stand of woody and agricultural species during early stages of establishment of plantations	w: usually plantation forestry spp. h: common agricultural crops	All ecological regions (where taungya is practiced); several improvements possible
(3) Alley cropping (hedge-row intercropping)	Woody species in hedges; agricultural species in alleys in between hedges; microzonal or strip arrangement	w: fast-growing, leguminous, that coppice vigorously h: common agricultural crops	Subhumid to humid areas with high human population pressure and fragile (productive but easily degradable) soils
(4) Multilayer tree gardens	Multispecies, multilayer dense plant associations with no organized planting arrangements	w: different woody components of varying form and growth habits h: usually absent; shade tolerant ones some-times present	Areas with fertile soils, good availability of labor and high human population pressure
(5) Multipurpose trees on crop lands	Trees scattered haphazardly or according to some systematic patterns on bunds, terraces or plot/field boundaries	w: multipurpose trees and other fruit trees h: common agricultural crops	In all ecological regions esp. in subsistence farming; also commonly integrated with animals
(6) Plantation crop combinations	(i) Integrated multistorey (mixed,dense) mixtures of plantation crops (ii) Mixtures of plantation crops in alternate or other regular arrangement (iii) Shade trees for plantation crops; shade trees scattered (iv) Intercropping with agricultural crops	w: plantation crops like coffee, cacao, coco- nut, etc. and fruit trees, esp. in (i); fuel-wood/fodder spp., esp. in (iii) h: usually present in (iv), and to some ex- tent in (i); shade-tolerant species	In humid lowlands or tropical humid/sui>- humid highlands (depending on the plantation crops concerned); usually in small- holder subsistence system
(7) Homegardens	Intimate, multistorey combination of various trees and crops around homesteads	w: fruit trees predominate; also other woody species, vines. etc. h: shade tolerant agricultural species	In all ecological regions, esp. in areas of high population density
(8) Trees in soil conservation and reclamation	Trees on bunds. terraces, raisers, etc. with or without grass strips; trees for soil reclamation	w: multipurpose and/or fruit trees h: common agricultural species	In sloping areas, esp. in highlands, reclamation of degraded. acid, alkali soils, and sand-dune stabilization
(9) Shelterbelts and wind breaks, live hedges	Trees around farmland/plots	w: combination of tall-growing spreading types h: agricultural crops of the locality	In wind-prone areas
(10) Fuelwood production	Interplanting firewood species on or around agricultural lands	w: firewood species h: agricultural crops of the locality	In all ecological regions

(continued)

Table 3.2 (continued)

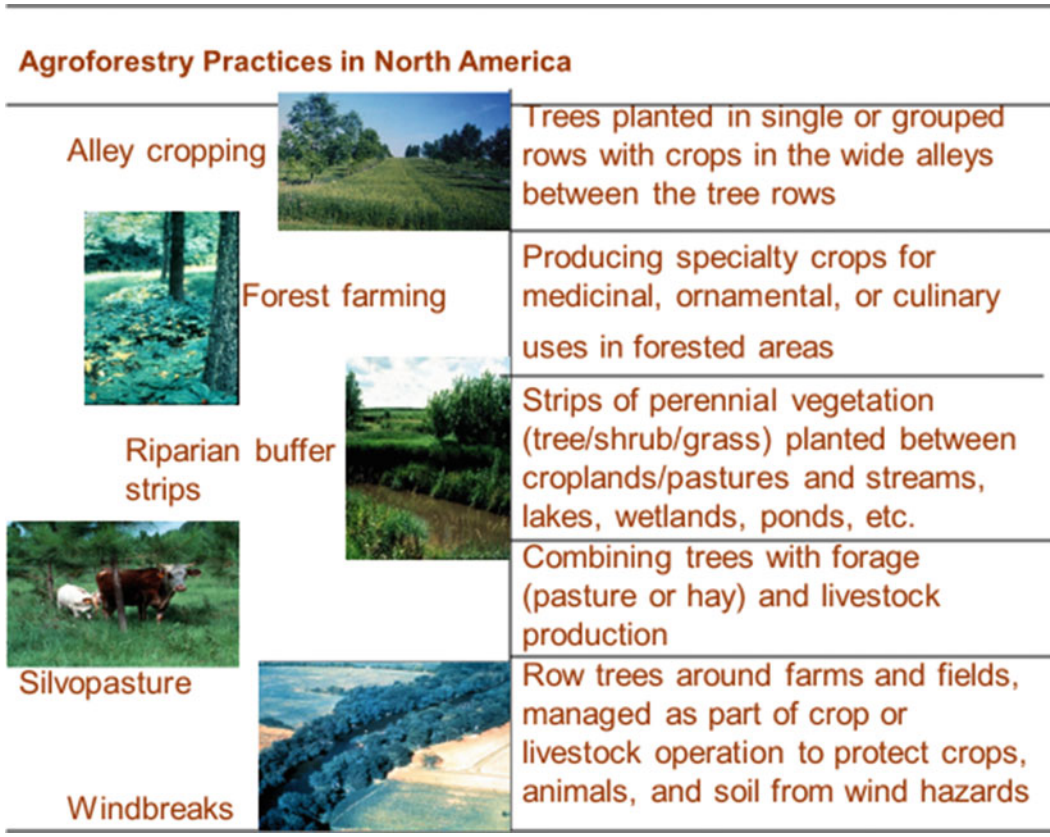
Agroforestry Practice	Brief description (of arrangement of components)	Major groups of components	Agro-ecological adaptability
Silvopastoral systems (trees+pasture and/or animals)			
(11) Trees on rangeland or pastures	Trees scattered irregularly or arranged ac- cording to some systematic pattern	w: multipurpose; of fodder value f: present a: present	Extensive grazing areas
(12) Protein banks	Production of protein-rich tree fodder on farm/ rangelands for cut-and-carry fodder production	w: leguminous fodder trees h: present f: present	Usually in areas with high person: land ratio
(13) Plantation crops with pastures and animals	Example: cattle under coconuts in southeast Asia and the South Pacific	w: plantation crops f: present a: present	In areas with less pressure on plantation crop lands
Agrosilvopastoral systems (trees+ crops+ pasture/animals)			
(14) Homegardens involving animals	Intimate, multistorey combination of various trees and crops, and animals around homesteads	w: fruit trees predominate: also other woody species a: present	In all ecological regions with high density of human population
(15) Multipurpose woody hedgerows	Woody hedges for browse, mulch, green manure, soil conservation, etc.	w: fast-growing and coppicing fodder shrubs and trees h: (similar to alley cropping and soil conservation)	Humid to subhumid areas with hilly and sloping terrain
(16) Apiculture with trees	Trees for honey production	w: honey producing (other components may be present)	Depending on the feasibility of apiculture may be present)
(17) Aquaforestry	Trees lining fish ponds, tree leaves being used as 'forage' for fish	w: trees and shrubs preferred by fish (other components may be present)	Lowlands
(18) Multipurpose woodlots	For various purposes (wood, fodder, soil protection, soil reclamation, etc.	w: multipurpose species; special location specific species (other components may be present)	Various

Note: w = woody; h = herbaceous; f = fodder for grazing; a = animals

3.9 Classification of Agroforestry Practices in the Temperate Regions

Agroforestry practices and systems in the temperate zone are less diverse and complex compared to those in the tropics. Gold and Garrett (2009) have perceived agroforestry in the United States and Canada as based on agricultural traditions, in which an agricultural production system is an aggregation of various practices. This perception led to the development of a definition of agroforestry in the context of the USA and Canada (Chapter 2: Table 2.1), and recognition of five distinct North American agroforestry practices. Following considerable deliberations, the definition and the set of practices were adopted by the Association for Temperate Agroforestry (AFTA). The five practices are: alley cropping, forest farming, silvopasture, riparian buffer, and windbreaks (Table 3.3); experiences and advances in the application of the practices are summarized in Chapter 10. In addition to these five agroforestry practices, *Urban Food*

Table 3.3 Agroforestry practices in North America (USA and Canada)



Source: AFTA (Association for Temperate Agroforestry), www.aftaweb.org (accessed 12 Feb 2019)

Forests (UFF) is now being recognized as a sixth addition to the N. American AF practices (Jose 2019): see Chapter 10, Section 10.3.5. In Europe too, where agroforestry efforts have gathered considerable momentum since the early 2000s, the North American model has been adopted by identifying distinct agroforestry practices instead of following any detailed classification of systems. The European Agroforestry Federation (EURAF) too has recognized five agroforestry practices that are comparable to the North American pattern: alley cropping, silvopasture, silvoarable, riparian buffer, homegardens or kitchen gardens, and forest farming (Table 3.4). The practices are described in Chapter 10. Figure 3.4, originally proposed by den Herder et al. (2015) for Europe and modified by Bentrup et al. (2017) for adaptation to the US and Canada, is a schematic presentation of agroforestry as a continuum among trees, crops, and livestock within the land management unit (field or pasture) in the temperate regions.

3.10 Concluding remarks: A Framework for Classification of Agroforestry Systems

The foregoing analysis shows that there is no universally applicable or acceptable scheme for the classification of agroforestry systems. Several models and schemes have been suggested, each of them usually for specific situations; therefore, each has limitations too for universal applicability. It

Table 3.4 Spatial agroforestry practices in Europe (Modified from Association for Temperate Agroforestry (AFTA 1997; Alavapati and Nair 2001; Nair 1994, Alavapati et al. 2004; Mosquera-Losada et al. 2009)

Agroforestry practice	Description	
Silvopasture		Combining woody with forage and animal production. It comprises forest or woodland grazing and pastoral land with hedgerows, isolated/scattered trees or trees in lines or belts
Homegardens or kitchen gardens		Combining trees/shrubs with vegetable production in urban areas, also known as part of "trees outside the forest"
Riparian buffer strips		Strips of perennial vegetation (trees/shrubs) natural or planted between croplands/pastures and water sources such as streams, lakes, wetlands, and ponds to protect water quality. They can be combined with arable lands (silvoarable) or grasslands (silvopasture) but are signified by its role in preserving water streams
Silvoarable		Widely spaced woody vegetation inter-cropped with annual or perennial crops. Also known as alley cropping. Trees/shrubs can be distributed following an alley cropping, isolated/scattered trees, hedges and line belts design
Forest farming		Forested areas used for production or harvest of natural standing specialty crops for medicinal, ornamental or culinary uses, including those integrating forest and agricultural lands

seems that John Saxe's famous description of "six blind men describing an elephant" (described in Chapter 1, Section 1.4.1) that has been used to express the uncertainties in characterizing global forestry can very well be applied to agroforestry too.

The complexity of the problem can be reduced if the structural and functional aspects of the system are taken as the criteria for categorizing the systems. Since there are only three basic sets of components that are managed by the land user in all agroforestry systems (woody perennials, herbaceous plants, and animals), a logical first step in classifying agroforestry should be based on the structure (nature and arrangement) of these components. As discussed previously, there are three major categories: agri-silvicultural, silvopastoral, and agrosilvopastoral. Having done such a preliminary categorization, the system can be grouped according to any of the purpose-oriented criteria mentioned above. Each

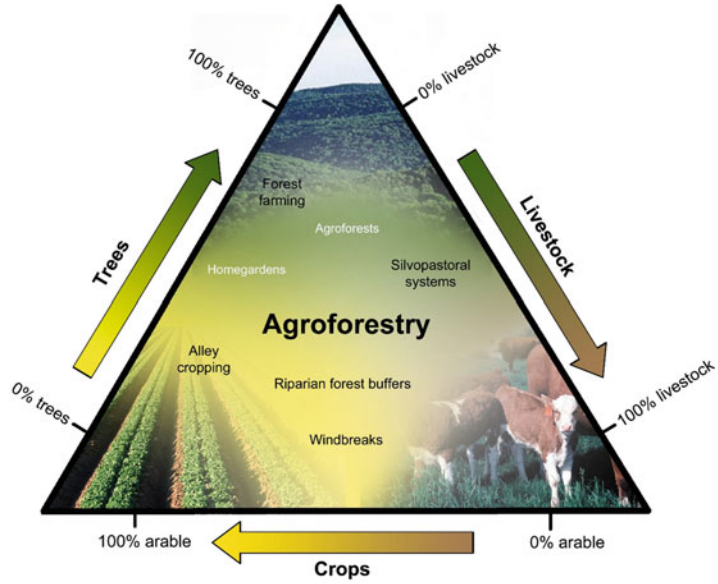


Figure 3.4 Agroforestry landscape continuum in North America
Agroforestry represents a fluid continuum among trees, crops, and livestock, ranging from a few trees established with a field or pasture to multistory forests managed for a variety of products and services. Source: USDA/National Agroforestry Center

of the resulting groups can have any one of the above three categories as a prefix, for example, a silvopastoral system for cattle production in tropical savannas; and agrisilvicultural systems for soil conservation and food production in tropical highlands. Such an approach seems a logical, simple, pragmatic, and purpose-oriented way to classify agroforestry systems. In situations where such a detailed classification is not relevant or needed as in the temperate regions, classification could be limited to the identification of the major practices.

References

AGFORWARD (2015) (This report is also cited in the literature as "den Herder et al. (2015)"

Benites JR (1990) Agroforestry systems with potential for acid soils of the humid tropics of Latin America and the Caribbean. For Ecol Manage 36:81–101

Bentrup G, Schoeneberger M, Patel-Weynard T, Jose S, Karel TH (2017) Introduction. In: Agroforestry: enhancing resiliency in U.S. agricultural landscapes under changing conditions. USDA Forest Service Ge. Tech. Report WP-96, pp 1–6

Bourke RM (1984) Food, coffee and casuarina: An agroforestry system from the Papua New Guinea highlands. Agrofor Syst 2:273–279

Buck L (ed) (1981) Proceedings of the Kenya National Seminar in Agroforestry, November 1980. ICRAF/University of Nairobi, Nairobi

Bungenstab DJ, de Almeida RG (eds) (2014) Integrated crop-livestock-forestry systems: a Brazilian experience for sustainable farming. Embrapa, Brasilia, 282 pp

Chandler T, Spurgeon D (eds) (1979) International cooperation in agroforestry. Proceedings of ICRAF/DSE conference. ICRAF, Nairobi

Combe J, Budowski G (1979) Classification of agroforestry techniques. In: de las Salas G (ed) Proceedings of the Workshop on Agroforestry Systems in Latin America. CATIE, Turrialba, pp 17–47

de las Salas G (ed) (1979) Proceedings of the Workshop on Agroforestry Systems in Latin America. CATIE, Turrialba

den Herder M, Burgess PJ, Mosquera-Losada MR et al. (2015) Preliminary stratification and quantification of agroforestry in Europe. Milestone Report 1. 1 for EU FP7 Research Project: AGFORWARD 613520, 57 p. (Also cited as AGFORWARD 2015)

FAO (1981a) Agroforesterie Africaine. FAO, Rome

FAO (1981b) Agroforestry: India and Sri Lanka. FAO, Rome

Fernandes ECM, O'Kting'ati A, Maghembe J (1984) The Chagga home gardens: a multistoried agroforestry cropping system on Mt. Kilimanjaro (N. Tanzania). Agrofor Syst 2:73–86

Fonzen PF, Oberholzer O (1984) Use of multipurpose trees in hill farming systems in Western Nepal. Agrofor Syst 2:187–197

Getahun A, Wilson GF, Kang BT (1982) The role of trees in the farming systems in the humid tropics. In: MacDonald LH (ed) Agroforestry in the African

Humid Tropics. United Nations University, Tokyo, pp 28–35
Gold MA, Garrett HE (ed) (2009) Agroforestry: nomenclature, concepts, and practices. In: Garrett HE (ed) North American agroforestry: an integrated science and practice, 2nd edn. Amer Soc Agron, Madison, pp 45–55
Huxley PA (1983) Comments on agroforestry classification with special references to plants. In: Huxley PA (ed) Plant research and agroforestry. ICRAF, Kenya, pp 161–171
ICAR (Indian Council of Agricultural Research) (1979) Proceedings of the National Seminar on Agroforestry, May 1979. ICAR, New Delhi
Jose S (2019) Environmental impacts and benefits of agroforestry. In: Oxford encyclopedia of agriculture and environment. Oxford University Press, New York. https://doi.org/10.1093/acrefore/9780199389414.013.195
King KFS (1979) Agroforestry and the utilization of fragile ecosystems. For Ecol Manage 2:161–168
Kronick J (1984) Temporal analysis of agroforestry systems for rural development. Agrofor Syst 2:165–176
Kumar BM, Nair PKR (eds) (2006) Tropical homegardens: a time-tested example of sustainable agroforestry. Springer, Dordrecht
Le Houerou HN (1987) Indigenous shrubs and trees in the silvopastoral systems of Africa. In: Steppler HA, Nair PKR (eds) Agroforestry: a decade of development. ICRAF, Nairobi, pp 139–156
Lundgren BO, Raintree JB (1982) Sustained agroforestry. In: Nestel B (ed) Agricultural research for development: potentials and challenges in Asia. ISNAR, The Hague, pp 37–49
Mann HS, Saxena SK (eds) (1980) Khejri (*Prosopis cineraria*) in the Indian Desert. CAZRI monograph no 11. Central Arid Zone Research Institute, Jodhpur
McDonald LH (ed) (1982) Agroforestry in the African Humid Tropics. United Nations University, Tokyo
Michon G, Mary F, Bompard J (1986) Multistoried agroforestry garden system in West Sumatra, Indonesia. Agrofor Syst 4:315–338
Montagnini F (ed) (1986) Sistemas Agroforestales: Principios y Applicaciones en los Tropicos. Organización para Estudios Tropicales, OTS and Centro Agronómico Tropical de Investigación y Enseñanza, CATIE; San José, Costa Rica.
Nair PKR (1983a) Some promising agroforestry technologies for hilly and semiarid regions of Rwanda. In: Chang J (ed) Report of a seminar on agricultural research in Rwanda: assessments and perspectives. ISNAR, The Hague, pp 93–99
Nair PKR (1983b) Agroforestry with coconuts and other plantation crops. In: Huxley PA (ed) Plant research and agroforestry. ICRAF, Nairobi, pp 79–102
Nair PKR (1983c) Tree integration on farmlands for sustained productivity of smallholdings. In: Lockeretz W (ed) Environmentally sound agricultural alternatives. Praeger, New York, pp 333–350
Nair PKR (1984) Soil productivity aspects of agroforestry. Science and Practice of Agroforestry 1. ICRAF, Nairobi
Nair PKR (1985) Classification of agroforestry systems. Agrofor Syst 3:97–128
Nair PKR (1987) Agroforestry systems inventory. Agrofor Syst 5:301–317
Nair PKR (1993) An Introduction to agroforestry. Kluwer (Springer), Dordrecht, The Netherlands.
Nair PKR (2012) Climate change mitigation and adaptation: A low hanging fruit of agroforestry. In: Nair PKR, Garrity DP (eds) Agroforestry: the future of global land use. Springer, Dordrecht, pp 31–67
Nair PKR (2014) Agroforestry systems and practices. In: Van Alfen N (ed) Encyclopedia of agriculture and food systems, vol 1. Elsevier, San Diego, pp 270–282
Neumann I (1983) Use of trees in smallholder agriculture in tropical highlands. In: Lockeretz W (ed) Environmentally sound agriculture. Praeger, New York, pp 351–374
Padoch C, de Jong W (1987) Traditional agroforestry practices of native and Ribereno farmers in the lowland Peruvian Amazon. In: Gholz HL (ed) Agroforestry: realities, possibilities and potentials. Martinus Nijhoff, Dordrecht, pp 179–194
Seif-el-Din AG (1981) Agroforestry practices in the dry regions. In: Buck L (ed) Proceedings of the Kenya National Seminar on Agroforestry. November 1980. ICRAF, Nairobi, pp 419–434
Sinclair F (1999) A general classification of agroforestry systems. Agrofor Syst 46:61–180
Torquebiau (2000) A renewed perspective on agroforestry concepts and classification. CR Acod Sci Poris, Sciences de la vie / Life Sciencê sciences/Éditions scientifiques et médicales Elsevier SAS 323 (2000):1009–1017
Torres F (1983) Agroforestry: concepts and practices. In: Hoekstra DA, Kuguru FM (eds) Agroforestry systems for smallscale farmers. ICRAF/BAT, Kenya, pp 27–42
Vandenbeldt RJ (ed) (1992) *Faidherbia albida* in the West African Semi-Arid Tropics. ICRISAT\ICRAF, Hyderabad\Nairobi
von Maydell HJ (1979) The development of agroforestry in the Sahelian zone of Africa. In: Chandler T, Spurgeon D (eds) International cooperation in agroforestry. ICRAF, Nairobi, pp 15–29
von Maydell HJ (1987) Agroforestry in the dry zones of Africa: past, present, and future. In: Steppler HA, Nair PKR (eds) Agroforestry: a decade of development. ICRAF, Nairobi, pp 89–116
Wiersum KF (1980) Observations on agrofrestry in Java, Indonesia. Forestry Faculty, Gadjah Mada University, Indonesia, and Department of Forest Management, University of Wageningen, The Netherlands.
Wilken GC (1977) Integration of forest and small-scale farm systems in middle America. Agro-Ecosyst 3:291–302
Young A (1989) Agroforestry for soil conservation. ICRAF\CABI, Nairobi\Wallingford