CHAPTER 12

Agroforestry species: the multipurpose trees

The emergence of agroforestry as an important land-use activity has raised the issue of "agroforestry species," i.e., which species to use as well as what constitutes an agroforestry species. Many of the species used in traditional agroforestry systems are well known as conventional agricultural or forestry plants, or as plants with other economic benefits. If we examine the history of the development of agriculture and forestry as separate disciplines, we notice that most of the species that were cultivated with considerable managerial attention and were harvested at frequent intervals for their economic produce - either through repeated generations of the same short-duration species, or by repeated harvesting from the same plant - were classified as agricultural (for this discussion, horticulture is considered as a part of agriculture). Those species that were planted and usually managed less intensively, and then harvested after a long production cycle, often for their wood products, were grouped under forestry (Nair, 1980). There were also a few less important and relatively underexploited plants that did not clearly conform to agricultural or forestry classifications. Agroforestry has brought a different perspective into discussions on plant typologies based on suitability for land-use systems. The most important characteristic that determines the place of a species in agroforestry is its amenability to integrated combination cultures (i.e., intercropping), not whether it is labelled as an agricultural, forestry, or any other type of species. Many of the relatively underexploited and lesser-known species - both woody and herbaceous - often times satisfy this criterion much better than many of the well known species. Several indigenous agroforestry systems involve a multitude of such species that are not widely known or used in conventional agriculture and forestry. Undoubtedly, one of the major opportunities in agroforestry lies in making use of, or "exploiting the potential"[1] of these lesser-known and

[1] The word "exploitation" is often used, as Burley (1987) has stated, "in a pejorative sense to indicate the utilization of a person or object for one's own selfish ends. But, indeed, human use of multipurpose trees and shrubs (MPTs) is usually utilitarian; species that can provide diverse benefits in various land-use systems are selected and used. The word 'potential' is taken to indicate the possible values of these benefits; their exploitation requires a knowledge of hitherto hidden values."

underexploited species. Furthermore, agroforestry places a special emphasis on making use of such lesser-known woody species, because they are (arguably) more numerous and less exploited (and therefore they offer greater scope for success in a variety of situations) than herbaceous species, and because woody perennials are central to the concept of agroforestry as we have seen in Chapter 2. Thus, the term "agroforestry species" usually refers to woody species, and they have come to be known as "multipurpose trees" (MPTs) or "multipurpose trees and shrubs" (MPTS). (Henceforth, we will use the abbreviation MPT [or MPTs as plural] to denote all multipurpose trees, shrubs, and other woody perennials.) Important woody perennial groups in agroforestry include fruit trees, fodder trees, and fuelwood species, but the term MPTs encompasses all these, especially the fodder and fuelwood trees.

It is incorrect, however, to assume that agroforestry species consist only of MPTs; indeed, the herbaceous species are equally important in agroforestry. Many of these species are conventional agricultural species, and there are several textbooks that describe them. The study of these species is an essential part of agricultural curricula. On the other hand, most of the MPTs used in agroforestry are neither described in conventional forestry or agricultural textbooks, nor do they form part of such curricula. Therefore, the MPTs are given special emphasis here.

12.1. Multipurpose trees (MPTs)

All trees are said to be multipurpose; some, however, are more multipurpose than others. In the agroforestry context, multipurpose trees are understood as "those trees and shrubs which are deliberately kept and managed for more than one preferred use, product, and/or service; the retention or cultivation of these trees is usually economically but also sometimes ecologically motivated, in a multiple-output land-use system." Simply stated, the term "multipurpose" as applied to trees for agroforestry refers to their use for more than one service or production function in an agroforestry system (Burley and Wood, 1991). As mentioned earlier, the MPT can be said to be the most distinctive component of agroforestry, and the success of agroforestry as a viable land-use option depends on exploiting the potential of these multipurpose trees, many of which are relatively little known outside their native habitat.

Quite a lot of information is now available about MPTs that are commonly used in agroforestry. The notable information sources include:

- The U.S. National Academy of Sciences (NAS) publications on Firewood Crops (NAS, 1980; 1983) and individual publications on some taxa such as *Leucaena, Acacia, Casuarina,* and *Calliandra calothyrsus;*
- A compilation of information on the most important MPTs in dryland Africa (von Maydell, 1986);
- The ICRAF Multipurpose Tree and Shrub Database (von Carlowitz *et al.,* 1991), a comprehensive compendium on the subject based on extensive field

surveys, and available as 12 microcomputer floppy disks; and

- A compendium on MPTs used in Asia, prepared by Winrock International (Lantican and Taylor, 1991).

Table 12.1 (pp. 187-190) is a compilation of the important characteristics and uses of about 50 MPTs that are commonly used in agroforestry systems around the world. Additionally, brief descriptions of individual species are provided at the end of this chapter. The list of species included in the table or described individually is not exhaustive; it merely represents some MPTs that have received research attention and are therefore more widely known than others, as well as some lesser-known species that seem particularly promising. Publications consulted for this compilation include Hensleigh and Holoway (1988), ICRAF (1988), Johnson and Morales (1972), Lamprecht (1989), Little (1983), NAS (1980; 1983), NFTA (1983; 1983-1991), Teel (1984), von Maydell (1986), and Webb *et al.* (1984). Fodder trees and fuelwood species, and sometimes fruit trees, are terms that are widely used in agroforestry literature; they represent important groups of MPTs.

12.1.1. Fodder trees

A large number of tropical trees and shrubs are traditionally known and used for their fodder; for example: Panday (1982) reported several such species from Nepal, and Singh (1982) from India. A state-of-the-art account of the "trub" (a collective name for tree and shrub: see Chapter 10) species in Africa is given by Le Houerou (1980), who suggested that technologies based on permanent feed supply from fodder trubs could transform pastoral production systems into settled agropastoral systems. An extensive review by Ibrahim (1981) presents one of the most comprehensive treatments of factors affecting dry-matter yield, palatability, nutritive value, and utilization of fodder trubs, including recommendations for further research and development. Torres' (1983) review of the subject includes extensive information on trub species, and their productivity, and nutritive value under different conditions. He concluded that protein supply was the main nutritive role of tropical trubs, but that the value could be limited by low levels of intake due to animal preferences. Nevertheless, the tropical trubs are very valuable because of their presence during dry seasons when grasses may be lacking or in states of extremely low nutritive value. Additionally, pod-producing trubs may become a very useful source of energy and protein concentrate (Felker, 1980; Le Houerou, 1987). Silvopastoral systems involving these fodder trees are discussed in Chapter 10 (section 10.1).

In recent times, a lot of interest has been generated regarding the possibility of exploiting the fodder value of tropical trubs for improved silvopastoral management, special attention being given to nitrogen-fixing species (Robinson, 1985; Blair *et al.,* 1990; Gutteridge and Shelton (forthcoming)). Table 12.2 gives the nutritive value of some of the common tree and shrub species used regularly as feed sources in these systems. Brief descriptions of most of these and other commonly-used tropical tree and shrub fodder species

Table 12.2. Chemical composition (% dry matter basis) of some tree- and shrub fodder.

SPECIES	COUNTRY/ LOCATION	<%DM	CP	NDF	ADF	CF	LGN	DMD	SOURCE*
Acacia mangium	Indonesia		12.0	61.9	61.0		42.2	...	Blair era/., 1989
Acacia nilotica	Ethiopia	85.0	13.6	31.6	22.5	...	5.3	...	Tanner *et al.*, 1990
Acacia tortilis	Ethiopia	89.4	13.0	32.4	24.2	...	4.8	—	Tanner *et al.*, 1990
Albizia lebek	Thailand	—	22.1	44.2	—	...	...	—	Akkasaeng *et al.*, 1989
Albizia (Samanea) saman	Thailand	...	22.8	52.7	—	...	...	...	Akkasaeng *et al*, 1989
Artocarpus heterophyllus	Sri Lanka	29.3	14.2	46.9	46.9	3.4	1.4	50.8	Rajaguru, 1989
Azadirachta indica	Nepal	36	15.0	—	...	13.8	...	...	Bajracharya *et al*, 1989
Cajanus cajan	Malaysia	90.0	21.7	...	—	30.2	...	...	Devendra, 1979
Cassia siamea	Indonesia	...	12.4	45.6	43.5	...	25.3	...	Blair *et al*, 1989
Dalbergia sissoo	Nepal	40	16.6	—	...	22.2	...	...	Bajracharya *et al*, 1989
Desmanthus variegata	Philippines	53	14.6	...	—	19.5	...	...	Brewbaker, 1985
Erythrina poeppigiana	Central America	—	32.0	...	—	...	...	44.0	Pezo *et al*, 1989
Erthyrina variegata	Sri Lanka	18.6	25.7	50.6	39.1	4.8	0.9	52.5	Rajaguru, 1989
Faidherbia (Acacia) albida	Ethiopia	88.0	14.3	37.4	27.9	...	4.5	...	Tanner *et al*, 1990
Gliricidia septum	Sri Lanka	19.9	27.6	36.1	27.8	5.3	2.1	61.5	Rajaguru, 1989
Grewia paniculata	Malaysia	...	13.2	—	...	28.1	...	...	Devendra, 1979
Leucaena leucocephala	Philippines	69	22.0	...	—	18.3	...	...	Brewbaker, 1985
Paraserianthes (Albizia) falcataria	Indonesia	...	24.0	37.0	...	...	...	...	Rangkuti *et al*, 1989
Prosopis cineraria	India	...	13.9	...	...	17.8	...	...	Raghavani, 1989
Robinia pseudoacacia	China	...	20.7	49.0	...	19.4	...	...	Zaichun, 1989
Sesbania grandiflora	Thailand	...	26.9	45.1	...	...	...	...	Akkasaeng *et al*, 1989
Sesbania sesban	Thailand	...	26.4	38.7	—	...	...	...	Akkasaeng *et al*, 1989
Terminalia arjuna	Sri Lanka	40.7	10.0	51.1	48.9	7.0	16.7	26.3	Rajaguru, 1989
Zizyphus nummularia	India	...	14.0	...	—	17.0	...	...	Raghavan, 1989

NDF = Neutral Detergent Fiber = hemicellulose + cellulose + lignin
LGN = Lignin
ADF = Acid Detergent Fiber = cellulose + lignin
CP = Crude Protein
DMD = Dry Matter Digestibility (in vitro)
CF = Crude Fiber

*Please refer to Devendra (1990) for the full bibliographic citations of these references.

are included in the MPT-summary table (12.1) and in the species descriptions at the end of this chapter. Detailed individual descriptions on some of the important species are available in various special publications such as those of the U.S. National Academy of Sciences (e.g. on *Leucaena, Calliandra, Acacia mangium),* Nitrogen Fixing Tree Association (NFTA)[2] (e.g., Macklin and Evans, 1990, on *Sesbania;* Withington *et al.,* 1987, on *Gliricidia sepium),* and others (e.g. Evans and Rotar, 1987, on *Sesbania).* Readers are advised to refer to these various publications for detailed information on specific aspects of such species and the systems in which they are found.

12.1.2. Fuelwood trees

A large number of woody species have been identified as fuelwood crops. It could be argued that any woody material can be a fuelwood, and therefore any woody plant can be a fuelwood species. But the term "fuelwood (or, firewood) crops" as used in the swelling literature refers to plants suitable for deliberate cultivation to provide fuelwood for cooking, heating, and sometimes lighting (Nair, 1988). For the preparation of the earlier-mentioned two-volume publication *Firewood Crops* (NAS, 1980, 1983), an international expert panel was constituted in the late 1970s by the Board on Science and Technology for International Development of the U.S. National Academy of Sciences. The panel identified more than 1200 species as fuelwood species, of which about 700 were given top ranking, signifying that they were potentially more valuable than others. Eighty-seven of them were described in detail in the two volumes (NAS,

[1] NFTA (1010 Holomua Road, Paia, Hawaii 96779-6744, U.S.A.) has a large number of publications on various leguminous multipurpose trees. The Association also publishes occasional flyers called *MPT Highlights* on selected MPTs, and these are a good source of condensed information on such species.

Footnotes to Table 12.2

1. *In vitro* DMD will differ from *in vivo* DMD, especially when many different species are compared.
2. Intake is not always well correlated with NDF, ADF, or lignin contents; hence it may be misleading to rank fodder quality based on these figures. However, high values of NDF will mean lower digestibility. The most important aspect of NDF is chemical composition, i.e., the ratios of cellulose: hemi cellulose: lignin. Species with same NDF values may differ in digestibility because one species may contain less lignin or a different type of lignin which will always affect digestibility differently.
3. Most analyses are not complete and they use different methods; therefore, comparison of figures is difficult.
4. Animal performance is the ultimate test of fodder quality; but there are few *in vivo* digestibility data in relation to animal performance.
5; The results will depend on several factors such as the stage of maturity of sample, leaf: twig ratio, and whether the sample was dried before analysis or was fresh. These details are nog given in most of these reports; therefore, it is very difficult to compare the different results.

1980; 1983). In preparing these reports, special considerations were given to plants that:

- have uses other than providing fuelwood;
- are easily established and require little care;
- adapt well to different ecological conditions, including problem environments such as nutrient-deficient or toxic soils, sloping areas, arid zones, and tropical highlands; and
- have desirable characteristics such as nitrogen-fixing ability, rapid growth, coppicing ability, and wood that has high calorific value and burns without sparks or toxic smoke.

Many of these commonly used or promoted fuelwood species are included in Table 12.1, and in the species descriptions at the end of this chapter; the role of agroforestry in fuelwood production is reviewed briefly in Chapter 10 (section 10.2). Again, readers are advised to refer to the publications listed earlier for detailed information on individual fuelwood species.

12.1.3. Fruit trees

The indigenous farming systems of many developing countries often include several fruit- and nut-producing trees. These are common components in most homegardens and other mixed agroforestry systems; they are also integrated with arable crops either in intercropping mixtures or along boundaries of agricultural fields. These fruit trees are well adapted to local conditions and are extremely important to the diet, and sometimes even the economy, of the people of the region, but they are seldom known outside their common places of cultivation. For example, an inventory of the commonly cultivated plants in mixed agroforestry systems in Tome' Acu, near Belem, Brazil listed 32 fruit-producing species, a majority of which were indigenous trees virtually unknown outside the region (EMBRAPA, 1982; Subler and Uhl, 1990). Examining the biological and socioeconomic attributes of fruit trees and their role in agroforestry systems, Nair (1984) concluded that fruit trees are one of the most promising groups of agroforestry species. A summary account of the occurrence of the common fruit trees in tropical agroforestry systems and their condensed crop profiles are given in Table 12.3 (pp. 191-198). This table gives only some general information on some species: there are many more fruit tree species that are either already present in existing agroforestry systems, or could potentially be used in agroforestry combinations. Detailed descriptions of several of the better-known fruit trees are available (e.g., Morton, 1987); once again, readers are advised to refer to these specialized publications for details.

12.1.4. Other underexploited woody perennials

The history of agroforestry development, albeit short, is dominated by the emphasis and focus on a few (about 50) species of trees and shrubs (as shown in Table 12.1 and the species descriptions at the end of this chapter). Some of these have received considerably more attention than others. Considering that worldwide agricultural efforts are concentrated on about 25 plant species, the emphasis of agroforestry on twice that number of multipurpose tree and shrub species may not appear to be extraordinary. Nonetheless, in many developing countries, rural populations derive a significant part of their food and other basic requirements from various indigenous trees and shrubs that are seldom "cultivated." In addition to food, these species provide a variety of products such as fiber, medicinal products, oils, and gums, which play a critical role in meeting the basic needs of local populations. Some examples of such indigenous multipurpose trees used as food sources in parts of Africa are given in Table 12.4 on p. 199(Nair, 1990). Many of these species occur naturally in forest environments that are currently under pressure as the demand for agricultural land increases.

Furthermore, these species are often complementary to agricultural crops and animal products. They may serve as emergency supplies in times of drought and they are usually consumed at production points with only a fraction of the products entering the local markets. Therefore, the variety and value of products that are derived from such trees are seldom appreciated, and, consequently, no efforts have been made for their domestication, improvement, or exploitation.

Various publications from FAO and other sources list information about the various indigenous food- and fruit-bearing trees and shrubs in different parts of the tropics (e.g., FAO/SIDA, 1982; FAO,1983a; 1983b; 1984; 1986a; 1986b). As discussed in Chapter 7, tropical homegardens and multistory tree gardens contain a large number of such locally adapted woody perennials. For example, Fernandes and Nair's (1986) analysis of homegarden systems in 10 selected countries identified about 250 woody perennials of common occurrence in these homegardens. Similarly, Michon *et al.* (1986) and Okafor and Fernandes (1987) reported the presence of many such species in Indonesia and Nigeria respectively. Some of these are relatively better known fruit trees described in Table 12.3. A vast majority of these species, however, are quite restricted in their distribution and are virtually unknown outside their usual range. There are also a large number of emergency food plants that are not usually eaten, but are consumed as food in times when natural calamities cause failure of common food crops. FAO (1983a) has identified 700 such species that are used as emergency food sources, a vast majority of them being woody perennials. Many of these underexploited woody perennials are components of existing indigenous agroforestry systems.

The U.S. National Academy of Sciences publication (NAS, 1975) and Vietmeyer (1986) list several other underexploited species with promising value, and some of these are multipurpose woody perennials that can be incorporated into agroforestry systems. ICRAF's computerized MPT database contains close to 1,100 species entries based on literature searches and actual field reports (von Carlowitz *et ah,* 1991). Even species like the Brazil nut tree *{Bertholletia excelsa),* guarana *(Paullinia cupana),* passion fruit *(Passiflora edulis),* cupuacu *(Theobroma grandiflorum),* and durian *(Durio zibethinus),* which are very common in specific parts of the tropics, are not fully exploited despite their tremendous potential. In the dry regions there are also a number of multipurpose woody species, the most notable being the various *Prosopis* spp., that can be incorporated into agroforestry (especially silvopastoral) systems. Undoubtedly, one of the most promising opportunities in agroforestry lies in making the best use of this vast range of underexploited species.

An important group of multipurpose woody species with tremendous potential in agroforestry is palms. Several prominent agroforestry systems have been developed in different parts of the world based on some species of palms, namely the coconut palm *(Cocos nucifera)* in India (Nair, 1979), Sri Lanka (Liyanage *et al.,* 1984), other parts of Southeast Asia (Nair, 1983), the Pacific (Vergara and Nair, 1985), and Northeast Brazil (Johnson and Nair, 1984); the arecanut palm *(Areca catechu)* in India and Southeast Asia (Bavappa *et al.,* 1982); the babassu palm *(Orbignya martiana)* in Brazil (May *et al.,* 1985; Anderson *et al.,* 1991); the carnauba wax palm *(Copenicia prunifera)* in Northeast Brazil (Johnson and Nair, 1984); and the pejibaye palm, *Bactris* (syn. *Guilielma) gasipaes,* in Central and South America (Clement, 1986; 1989). Johnson (1984) classified and assessed the multipurpose nature of palms with respect to their suitability for incorporation into tropical agroforestry development projects, and identified a total of 52 such species.

12.1.5. Improvement of MPTs: the ideotype concept

It has generally been accepted that the main scientific foundation of agroforestry is the multipurpose tree. It is therefore only natural that MPT improvement is one of the major scientific efforts in agroforestry. Collection, screening, and evaluation of MPT germplasm are by far the most common aspect of such efforts (Nair, 1992) and several MPT improvement programs of various scales and dimensions are under way in different places around the world (see Chapter 20).

Most of these efforts are directed towards identifying the species, varieties, provenances or cultivars of MPTs that are most promising and appropriate for a given set of conditions and objectives. One of the difficulties encountered in these efforts arises from the very reason for choosing an MPT: they have multiple uses and roles; the focus on, or management for, one product or service may affect or even contradict the output of other products and services. For example, leaf production will be an important attribute of an MPT developed or selected for its green-manure value; the same species, if improved or developed for fuelwood production should produce a higher proportion of its biomass as shoots. Therefore, for each species, the screening and selection criteria will have to be specific depending on the objectives and locations.

Thus, in reality nothing approximates an "ideal" MPT for agroforestry for all locations. The key to the fulfillment of the role of the MPT in an agroforestry system can perhaps be clarified through the ideotype concept. First developed by CM. Donald in a now classic paper (Donald, 1968), the term literally means "a form denoting an idea." In its broadest sense, an ideotype is a biological model which is expected to perform in a predictable manner within a defined environment. Thus, an ideotype specifies the ideal attributes of a plant for a particular purpose. The formulation of the ideotype is a practical step, because it provides a clear, workable goal to which plant breeders can aspire.

The ideotype concept was originally developed for agricultural crops, using the conventional "selection for yield" approach (Donald, 1968). The concept has been adopted in the crop breeding programs for many agronomic crops (Adams, 1982), but it has not become a major operational part of most tree breeding programs (Dickmann, 1985).

While the selection of an ideotype may be a feasible approach in monocultural forestry (Dickmann, 1985), it is likely to be much more complex in agroforestry. As Wood (1990) has pointed out, in agroforestry, the environmental conditions have to be extended to include such management

Table 12.5. Example of an ideotype specification for *Acacia tortilis* for agroforestry use in semiarid zones.

Design Needs
- *Products and services required* (given in order of importance): fodder, fuelwood, food, windbreaks, poles and posts, shade
- *General selection criterion:* vigor
- *Ancillary information required:* nitrogen-fixing or not, chemical composition (fodder value) of leaves and pods

Ideotype Description
- *Stem:* as straight as can be found in a population; multistem phenotypes acceptable but long boles important
- *Crown:* fairly rounded, medium diameter (crown-bole ratio, 25:1 or less) with many branches and positioned high up the stem; foliage medium to dense
- *Roots:* geotrophic angled rather than horizontally extending lateral roots
- *Pods:* large pods (on average 6010cm long and > 8mm wide) in large quantities
- *Thorns:* as few and as small as can be found
- *Response to management:* prolific regrowth after pollarding and individual branch pruning; reliable coppicing response
- *Deciduousness:* low period of dry season leaflessness in comparison with the average tree of a population

Discussion
When fodder is a priority, pod and leaf production is of foremost importance. Consequently, selection of an appropriate ideotype should concentrate on tree attributes that support this. A fairly rounded crown with a larger surface exposed to the light is likely to increase flowering and fruit setting. A delayed leaf drop increases leaf fodder production for an extended period. Prolific regrowth after pollarding of shoots with fewer and smaller thorns provides additional and better digestible fodder for a longer period during the dry season. Straighter stems at least 4 m long favor the production of poles and posts of better quality. The opportunity to collect fuelwood as a byproduct is increased by selecting more intensely branching crowns. A deep root system is less prone to cultivation damage and is likely to be less competitive with adjacent grass or crops.

Source: Wood (1990); Burley and Wood (1991).

practices as regular cutting and partial harvesting of trees, as in the management of hedgerows and lopped fodder trees. This implies that structural, physiological, phenological, and management characteristics should be included in any description of the ideotype for a specified situation. An example of a desired ideotype of *Acacia tortilis* for agroforestry in a semiarid environment (Table 12.5), suggested by Burley and Wood (1991), illustrates the complexities involved in conceptualizing ideotypes of MPTs for agroforestry. Furthermore, as we have already seen, the interest in a particular MPT may lie in several of its attributes, and these may behave in quite different or even opposing ways in relation to changes in desired products of the species, or even sites. Table 12.6, adapted from von CarIowitz(1986) and Wood (1990), indicates the interrelationships among tree attributes that may be evaluated in MPT screening and selection trials for the service and productions expected of them.

Detailed accounts of MPT selection criteria and breeding strategies are beyond the scope of this book. Readers are directed to specific reference manuals, e.g., Burley and Wood (1991). Major MPT breeding programs currently under way include those for species/genera such as *Leucaena* spp., *Gliricidia sepium, Erythrina* spp., *Acacia mangium* and *Sesbania* spp. (see section 12.1.1). Additionally, Budelman (1991) has examined the desirable characteristics of woody species that could be used as stakes to support yams (*Dioscorea* spp.), an agroforestry practice that is very common in West Africa, Southwest India, and Jamaica (Figure 12.1).

Figure 12.1. Yam staking: staking yams on poles and other dead or live woody materials is a common aspect of yam *(Dioscorea alata)* cultivation in the Carribbean (as in this picture from Jamaica shows), and the humid lowlands of West Africa and Southeast Asia.

Table 12.6. Multipurpose tree characteristics and agroforestry systems.

Tree attributes	Relationship to performance in agroforestry systems
Height	Ease of harvesting leaf, fruit, seed and branchwood; shading or wind effects
Stem form	Suitability for timber, posts and poles; shading effects
Crown size, shape and density	Quantity of leaf, mulch and fruit production; shading or wind effects
Multistemmed habit	Fuelwood and pole production; shading or wind effects
Rooting pattern (deep or shallow, spreading or geotrophic)	Competitiveness with other components, particularly resource sharing with crops; suitability for soil conservation
Physical and chemical composition of leaves and pods	Fodder and mulch quality; soil nutritional aspects
Thorniness	Suitability for barriers or alley planting
Wood quality	Acceptability for fuel and various wood products
Phenology (leaf flush, flowering and fruiting) and cycle (seasonality)	Timing and labor demand for fruit, fodder and seed harvest; season of fodder availability; barrier function and windbreak effects
Di = or monoeciousness	Sexual composition of individual species in community (important for seed production and pollen flow)
Pest- and disease-resistance vigor	Important regardless of function; biomass productivity, early establishment
Site adaptability and ecological range	Suitability for extreme sites or reclamation uses
Phenotypic or ecomorphological variability	Potential for genetic improvement, need for culling unwanted phenotypes
Response to pruning and cutting management practices	Use in alley farming, or for lopping or coppicing
Possibility of nitrogen fixation	Use in alley farming, planted fallows, or rotational systems

Source: Wood (1990) *adapted from* von Carlowitz (1986).
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However, none of these efforts is comparable (in scale or magnitude) to the massive breeding and improvement programs of preferred agricultural species such as cereals, or forestry species such as eucalypts and pines. This is not surprising given the complexity of the factors involved, the multiplicity of species, and the relative newness of the concepts of agroforestry and the MPT.

Finally, in the context of the discussion on MPT improvement, it is important to refer to the controversy that prevails in many countries about exotic versus indigenous tree species. Despite the fact that a greater part of agricultural production in these countries depends on introduced species such as maize, wheat, or potatoes, there is vehement and powerful opposition to introduction of exotic trees. Often times, the opposition is exacerbated by linking it with sensitive issues such as national pride. Certainly, large-scale monocultures of any species, especially little-known exotics, run the risk of pests, diseases, and site incompatibility. Nonetheless, these are not reasons to enforce an outright ban on all exotic species. We should realize that many of the currently popular species in most countries were introduced as exotics at one time or another; gradually they became naturalized. Therefore, as Wood (1990) has aptly stated, the overriding principle should be to *select the most suitable tree for the farmer and the land,* regardless of whether it is native or not. This is not to imply that the indigenous species, especially the underexploited ones, should continue to be neglected. It has been sufficiently emphasized in this book that one of the greatest opportunities in agroforestry lies in exploiting the vast potentials of such indigenous trees and shrubs.

12.2. Herbaceous species

In the history of agricultural domestication and improvement of plants, attention has focused on nearly 30 species that have come to comprise most of the world's human diet (Borlaug and Dowswell, 1988). Understandably, the selection and improvement programs of these species have mostly been oriented towards those traits and characteristics that would render the improved cultivars most suitable to maximal production under sole crop conditions. Agroforestry settings, however, offer sub-optimal conditions for the growth of these plants with regard to resources such as light, moisture, and nutrients. Thus, we are in a difficult situation with regard to compatible agricultural species for agroforestry. On the one hand, an important measure of success of agroforestry is its ability to satisfy the farmers' expectations and aspirations regarding production of their most basic need (i.e., food); this implies that some of these nearly 30 preferred crop species should be produced in a given agroforestry system. On the other hand, crop improvement efforts have not addressed the need to select or breed varieties of these species which can thrive in low-input and mixed culture conditions. The situation has not been made easier with the emphasis on MPTs almost at the exclusion of agricultural species.

The agroforestry potential of the traditional agricultural species is different from their commonly-perceived production potential. Based on the knowledge of the ecophysiological requirements of different groups of plants in general, and the individual species or cultivar in particular, some predictions can be made with reasonable accuracy about optimal conditions for their best growth. It is also possible to predict the ability of the species to produce a reasonable yield under conditions of reduced supply of basic growth factors such as light, nutrients, and water. Furthermore, from the practical point of view, the ease of management of the species, its ability to withstand adverse climatic and management conditions, and its adaptability to low-input systems are important considerations. Predictions regarding compatibility and agroforestry potential of common agricultural crops could be made based on the information about their performance under diverse agroforestry systems, as well as available knowledge about their growth requirements.[3] Some preliminary efforts were initiated in this direction by Nair (1980); a list of species included in this compilation is given as Table 12.7 (p. 200). Unfortunately, this type of work has not been seriously advanced. While rectifying this deficiency, attention should also be given to other relatively underexploited herbaceous species of potential value in agroforestry.

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[3] There are several well known books that describe the botany and agronomy of cultivated plants. For example, Purseglove's books (Purseglove, 1968; 1972) give a very comprehensive treatment of the subject.

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