Agroforestry Systems 2: 145–163.

Multipurpose leguminous trees and shrubs for agroforestry*

P.K.R. NAIR, E.C.M. FERNANDES and P.N. WAMBUGU

International Council for Research in Agroforestry (ICRAF), P.O. Box 30677, Nairobi, Kenya

Abstract. There are various ways in which farmers deliberately incorporate trees and shrubs on farm production fields. Many of the species so incorporated are legumes. The role of such woody perennials in agroforestry systems can be productive and/or protective. Legumes offer by far the maximum range of choice of woody species for agroforestry in terms of their economic uses as well as ecological adaptability. In addition to the several leguminous woody species that are well known in agroforestry, there are many more whose potentials have not yet been fully understood. An evaluation is presented of the agroforestry potentials of a few leguminous species from the point of view of their growth characteristics, ecological adaptability, combining ability with other species and uses/functions. The science of agroforestry is still in its infancy. There exists no research data on the various management aspects of these potentially promising group of plants. ICRAF, in its capacity as an international research council, has assembled several multipurpose leguminous trees and shrubs of agroforestry potential at the Council's recently-established Field Station in Machakos, Kenya, primarily for demonstration and training purposes. Initial results from these trials are presented in the paper.

Introduction

Integrated land use systems that have now come to be called agroforestry have been in existence since very early times, in some form or other, in different parts of the world. But such systems and practices had hitherto been bypassed, if not neglected, by researchers and other experts and consequently have not been a part of the resource-rich farming. However, the trend is now changing, and these systems are now receiving scientific attention. Increasing dependance 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 productive and protective value of trees, and the realization of the potentials of age-old conservation farming technologies.

In spite of the tremendous amount of interest on agroforestry, quite a bit of confusion and ambiguity prevails as to 'what is agroforestry?'. Various definitions have been suggested for agroforestry Systems, vol. 1, pp. 7–12, 1982). However, as opined by Nair (1983a), it is generally agreed that agroforestry represents an approach to integrated land use involving deliberate mixture or retention of trees and other woody perennials in the crop/animal

*Adapted from a paper presented at the International Symposium on Nitrogen Fixing trees in the Tropics, 19–24 September, 1983 Rio-de-Janeiro, Brazil.

production fields. The concepts and principles of agroforestry are now fairly well elucidated (for example, Lundgren 1982; Lundgren and Raintree, 1983; Torres, 1983a; and so on). Similarly, the potential role of agroforestry in diverse situations has also been highlighted by various authors; for example, in the fragile or marginal environments (King, 1979; Chandler and Spurgeon, 1980); in soil conservation (Lundgren and Nair, 1983); in high-potential lands (Budowski, 1983); in areas with insufficient rural infrastructure (Lundgren and Raintree, 1983); in combating deforestation and forest destruction (King, 1980) and so on.

Agroforestry systems and woody perennials

State-of-the-art

If we look at the existing land use systems keeping the broad concept of agroforestry as outlined earlier in mind, we find that several types of agroforestry systems abound around the world (Nair, 1979; 1980; 1983b). The International Council for Research in Agroforestry (ICRAF) is currently undertaking a global inventory of such existing agroforestry systems and practices. As a basic document for the project, a preliminary overview of the agroforestry situation in the developing countries was prepared, indicating the most prominent examples found in the different regions. An abstract of that document, including the summary Table of agroforestry systems can be found in the project announcement that appeared in 1983 in several international journals, including Agroforestry Systems (1(3), pp. 269–273). Though based on the existing knowledge prior to the commencement of the formal survey phase of the project, the Table shows the diversity of agroforestry systems and practices. Without going into the details, suffice it to say that there are several ways in which farmers deliberately incorporate different types of woody perennials in their crop/animal production fields; see, for example, Okigbo (1977); Huxley (1983); Neunhaeuser (1983); Torres (1983a).

A closer examination of the woody perennials so used reveals that most of them are legumes. Based on the literature survey conducted by ICRAF for the earlier-mentioned global inventory of agroforestry systems, some of the most prominent examples of leguminous (and other nitrogen fixing woody perennials) that are currently used in agroforestry systems in the tropics and subtropics are given in Table 1.

Role of woody perennials in agroforestry

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

Productive role. The productive role includes production of food, fodder, firewood and various other products from the woody perennials in agroforestry systems. One of the most promising technologies of this kind that is applicable in a wide range of situations is the hedgerow intercropping in crop production fields. The practice involves growing arable crops in the spaces or alleys between such hedgerows; the woody species is pruned periodically during the cropping season to prevent shading and to provide green manure to the arable crop. Promising results have been obtained from this type of studies 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 no nitrogen input on a low-fertility sandy Inceptisol, the nitrogen contribution by leucaena mulch on maize grain yield being equivalent to about 100 kg ha^{-1} for every 10 t ha^{-1} of fresh prunings (Kang et al., 1981) The hedgerow intercropping system offers the advantage of incorporating a woody species with arable farming system without impairing soil productivity and crop yields. The potential of nutrient (N) contribution by several candidate species of woody legumes suggests that a wide range of such species could be integrated into crop production systems. By adjusting the inter-row spacing of the woody species, mechanized equipments could be used, wherever deemed desirable, for various field operations connected with cropping. Moreover, the trees can be cut back and kept pruned during the cropping period and leaves and twigs applied to the soil as mulch and nutrient sources, and bigger branches used as stakes or firewood. Research on these various aspects of hedgerow cropping system is in progress in various places around the world.

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 the 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 aspects are currently being undertaken. Several fast-growing firewood crops, most of them legumes, suitable for different environmental conditions, have been identified (NAS, 1980), and most of them combine well with conventional agricultural crops.

In the 'animal agroforestry' systems, the woody components could be used either as a source of fodder to improve livestock productivity or to obtain another commodity such as fuel, fruit, or timber. Based on this 'productivity objective', silvopastoral systems can be grouped into browse grazing and

Table 1. Some leguminous woody perennials currently used in tropical/subtropical agroforestry

Species	System/practice	Major eco-zone	Countries
Dalbergia sissoo	(SP) cut and carry fodder prod.	tropical highlands	India, Nepal
Derris indica	(AS) multipurpose trees on farms	arid/semi-arid	India
	(SP) cut and carry fodder prod	arid/semi-arid	India
Diphysa robinoides	(AS) livefences/shelterbelts	humid/sub-humid	Costa Rica
Enterolobium cyclocarpum	(SP) shade/browse trees in pasture	humid/sub-humid	Costa Rica
Erythrina abyssinica	(SP) livefences/shelterbelts	tropical highlands	Ethiopia
	(SP) cut and carry fodder prod.	tropical highlands	Ethiopia
	(ASP) crop/tree/livestock mix around homesteads	tropical highlands	Ethiopia
Erythrina poeppigiana	(AS) shade for commercial crops	humid/sub-humid	Costa Rica
		tropical highlands	Costa Rica
Gliricidia sepium	(AS) shade for commercial crops	humid/sub-humid	Brazil, Costa Rica
			Philippines
	(AS) livefences/shelterbelts	humid/sub-humid	Costa Rica, Indonesia
	(AS) tree gardens	humid/sub-humid	Indonesia
	(SP) cut and carry fodder prod.	humid/sub-humid	Panama
	(ASP) crop/tree/livestock mix around homesteads		
Inga edulis	(ASP) crop/tree/livestock mix around homesteads	humid/sub-humid	American tropics
Inga jinicuil	(AS) shade for commercial crops	humid/sub-humid	Mexico
Inga vera	(AS) shade for commercial crops	humid/sub-humid	Puerto Rico, West Indies
	(AS) agroforestry fuelwood prod.	humid/sub-humid	West Indies
Lespedeza bicolor	(AS) multipurpose shrub on farmlands	humid/sub-humid	Korea
	(AS) agroforestry fuelwood prod.	humid/sub-humid	Korea
	(SP) cut and carry fodder prod.	humid/sub-humid	Korea
Leucaena leucocephala	(AS) shade for commercial crops	humid/sub-humid	Nigeria, Papua N. Guinea
	(AS) agroforestry fuelwood prod.	humid/sub-humid	Philippines
	(AS) hedgerow (alley) cropping	humid/sub-humid	Nigeria
	(SP) cut and carry fodder prod.	humid/sub-humid	Philippines
	(ASP) woody hedgerows for browse, mulch, green manure and soil conservation	humid/sub-humid	Philippines
Leucaena esculenta	(AS) shade for commercial crops	humid/sub-humid	Mexico

Mimosa scabrella	(AS) multipurpose trees on farmlands	humid/sub-humid	Brazil
	(AS) agroforestry fuelwood prod.	tropical highlands humid/sub-humid	Brazil
Parkia biglobosa	(AS) tree gardens – multispecies multipurpose associations	tropical highlands humid/sub-humid	Brazil Central African Repub.
Acacia albida	(ASP) crop/tree/livestock mix around homesteads	arid/semi-arid	Ethiopia, Niger
	(AS) agroforestry fuelwood prod.	arid/semi-arid	Niger, Senegal
	(SP) multipurpose fodder trees	arid/semi-arid	Ethiopia, Senegal
Acacia auriculiformis	(AS) agroforestry fuelwood prod.	humid/sub-humid	Papua New Guinea
Acacia mearnsii	(AS) agroforestry fuelwood prod.	tropical highlands	Indonesia, Kenya
	(AS) multipurpose trees on farmlands	tropical highlands	Indonesia
Acacia senegal	(AS) agroforestry fuelwood prod.	arid/semi-arid	Sudan
	(SP) multipurpose fodder trees	arid/semi-arid	Kenya, Sudan
	(SP) shade/browse trees in pasture	arid/semi-arid	Kenya, Sudan
Acacia seyal	(AS) agroforestry fuelwood prod.	arid/semi-arid	Sudan, Upper Volta
	(SP) multipurpose fodder trees	arid/semi-arid	Kenya, Sudan
	(SP) shade/browse trees in pasture	arid/semi-arid	Senegal, Sudan
Acacia tortilis	(AS) agroforestry fuelwood prod.	arid/semi-arid	India, Kenya, Sudan
	(SP) shade/browse trees in pasture	arid/semi-arid	Kenya, Senegal, Sudan
	(SP) multipurpose fodder trees	arid/semi-arid	India, Kenya, Sudan
Albizia falcataria	(AS) tree farms	humid/sub-humid	Philippines
Albizia gummifera	(AS) shade for commercial crops	humid/sub-humid	Cameroun
Albizia lebbeck	(AS) shade for commercial crops	humid/sub-humid	India
	(SP) cut and carry fodder prod.	tropical highlands	India
Albizia stipulata	(SP) cut and carry fodder prod.	humid/sub-humid	India
Alnus acuminata	(AS) shade for commercial crops	tropical highlands	Nepal
	(SP) shade trees in pasture	tropical highlands	Brazil, Costa Rica
Andira inermis	(AS) shade for commercial crops	tropical highlands	American tropics
Cajanus cajan	(AS) multipurpose shrub on farmlands	humid/sub-humid	Brazil, Costa Rica
		arid/semi-arid*humid/ sub-humid	India
	(AS) livefences/shelterbelts	arid/semi-arid	India
	(AS) agroforestry fuelwood prod.	arid/semi-arid	India

Table 1. (continued)

Species	System/practice	Major eco-zone	Countries
Calliandra calothyrsus	(AS) agroforestry fuelwood prod.	humid/sub-humid	Indonesia
	(AS) multipurpose trees on farmlands	humid/sub-humid	Indonesia
	(ASP) woody hedgerows for browse, mulch, green manure and soil conservation	humid/sub-humid	Indonesia
	(SP) cut and carry fodder prod.	humid/sub-humid	Indonesia
Cassia siamea	(AS) tree gardens-multispecies, multipurpose species ass.	humid/sub-humid	Cameroun
	(AS) agroforestry fuelwood prod.	humid/sub-humid, arid/semi arid	Sudan
	(ASP) crop/tree/livestock mix around homesteads	humid/sub-humid	Nigeria
Ceratonia siliqua	(SP) shade/browse trees in pasture	arid/semi-arid	Middle East
Colophospermum mopane	(SP) multipurpose fodder trees	arid/semi-arid	Zambia, Zimbabwe
Parkia clappertoniana	(AS) tree gardens-multispecies, multipurpose	humid/sub-humid	Nigeria
Parkia speciosa	(AS) tree gardens	humid/sub-humid	Indonesia
Pithecellobium dulce	(AS) livefences/shelterbelts	arid/semi-arid	Philippines
	(SP) shade/browse trees in pasture	arid/semi-arid	Hawaii
	(SP) cut and carry fodder prod.	arid/semi-arid	Philippines
Prosopis africana	(AS) tree gardens – multipurpose. multispecies associations	humid/sub-humid	Nigeria
Prosopis chilensis	(SP) shade/browse trees in pastures	arid/semi-arid	Bolivia, Chile, Peru
Prosopis cineraria	(AS) multipurpose trees on farmlands	arid/semi-arid	India
	(AS) agroforestry fuelwood prod.	arid/semi-arid	India
	(SP) cut and carry fodder prod.	arid/semi-arid	India
	(SP) shade/browse trees in pastures	arid/semi-arid	India
Prosopis juliflora	(AS) agroforestry fuelwood prod.	arid/semi-arid	Haiti
	(SP) shade/browse trees in pasture	arid/semi-arid	Middle East
Prosopis tamarugo	(AS) agroforestry fuelwood prod.	arid/semi-arid	Chile
	(SP) shade/browse trees in pasture	arid/semi-arid	Chile
Pterocarpus soyauxii	(AS) tree gardens – multipurpose multispecies associations	humid/sub-humid	Nigeria
	(ASP) crop tree livestock mix around homesteads	humid/sub-humid	Nigeria

Samanea saman	(SP) shade/browse trees in pasture	humid/sub-humid	American tropics
	(ASP) tree/crop/livestock mix around homesteads	humid/sub-humid	Nigeria
Sesbania bispinosa	(AS) multipurpose trees on farmlands	humid/sub-humid	India, Vietnam
	(AS) agroforestry fuelwood prod.	humid/sub-humid	North Pakistan
	(SP) cut and carry fodder prod.	humid/sub-humid* arid/semi-arid	India, Pakistan
	(ASP) woody hedgerows for browse, mulch, green manure,* soil conservation	humid/sub-humid	India, Pakistan, Vietnam
Sesbania grandiflora	(AS) livefences/shelterbelts	humid/sub-humid	Indonesia
	(AS) tree gardens	humid/sub-humid	Indonesia
	(AS) shade for commercial crops	humid/sub-humid	Malaysia
	(SP) shade/browse trees in pasture	humid/sub-humid	Indonesia
	(SP) cut and carry fodder prod.	humid/sub-humid	Indonesia
	(ASP) woody hedgerows for browse mulch, green conservation	humid/sub-humid	Indonesia
	(ASP) crop/tree/livestock mix around homesteads	humid/sub-humid	Indonesia
Tamarindus indica	(AS) multipurpose trees on farmlands	humid/sub-humid	India
Trema orientalis	(AS) shade for commercial crops	humid/sub-humid	Philippines
	(AS) agroforestry fuelwood prod.	humid/sub-humid* tropical highlands	Indonesia

AS = Agrosilviculture; SP = Silvo-pastoral; ASP = Agro-silvo-pastoral

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

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.

Tree planting along contours is widely recommended both to reduce runoff and protect terraces wherever such physical soil conservation measures are adopted (for example, see Wenner, 1980). This soil conservation benefit of woody perennials can conveniently be exploited in agroforestry if the chosen species can provide additional benefits and outputs such as fodder, fuel, wood, food, etc. The long tradition of planting *Leucaena leucocephala* in contour hedges for erosion control and soil improvement in 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 as well as 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). Darnhofer (1982) examined the physical, ecological and biological considerations involved in the design of agroforestry shelterbelts and felt that the design has to be site-specific depending on a large number of factors such as major components of farming systems (crops/livestock), desired pattern of windbreak (simple, multiple (successive), network system (with or without secondary hedgerows) and so on.

Leguminous woody perennials for agroforestry

From the foregoing, it is evident that legumes are not the only woody species that have potential role in agroforestry. However, the family Leguminosae offers by far the maximum range of choice of woody species for agroforestry in terms of their economic uses as well as ecological adaptability. Compared with other multipurpose woody perennials that are useful in agroforestry, the legumes have the added advantage because of their capability for nitrogen fixation. Although legumes are not the only nitrogen fixers (others include, for example, the genera *Alnus* and tropical *Casuarina*), and all legumes are not necessary N-fixers, there is a general tendency, albeit erroneously, to equate N-fixation with legumes. As pointed out by Brewbaker and Ta Wei Hu (1981), the 18000 species of the family Leguminosae include the vast majority of important nitrogen fixing trees. Out of the species tested by the authors, a high proportion of the mimosoids (92%) and papilionoids (94%) were able to fix nitrogen, contrasted with caesalpinioids (34%). For a detailed discussion on the role of woody legumes in agroforestry vis-à-vis N-fixation, see Nair 1984).

Plants, especially woody species, that have hitherto been very little studied may prove themselves to be very valuable for agroforestry. Prime candidates will be species that can grow well with other species, that can thrive in environments that are too harsh for most other species, that simultaneously yield several products (food, fuel, fodder), that enrich the micro-site such as by nitrogen fixation, efficient nutrient cycling or addition of organic matter to the soil through litterfall and root exudates and decay. Growth habits of such species with respect to their above-ground and below-ground parts will also be of considerable significance. With this long list of attributes it would be possible to prepare a check-list of characters to look for, or suggest some ideotypes of woody plants for agroforestry. Although such approaches are certainly useful in the long-term selection process, expediency demands that we look for some of these characters in the trees that are commonly found to exist in agricultural lands – either mixed with agricultural crops or otherwise retained deliberately. Several such studies have recently been initiated in various places (G. Poulson, 1981: personal communication – about 100 woody species that are potentially suitable for agroforestry in Kenya; NAS, 1975; 1979; 1980; Hecht, 1982; etc.). However, such studies are often not necessarily limited to legumes, although legumes dominate all the lists, as mentioned earlier. Some such studies are also being undertaken exclusively on economically important nitrogen fixing tree species (for example, Vergara, 1982; Brewbaker et al., 1983).

In addition to the nitrogen-fixing capability, many of the leguminous woody perennials have other multiple output nature and functions as described elsewhere in this article, which make them eminently suitable for agroforestry. A summary of characteristics and descriptions of a few such woody leguminous species and their potential role in different agroforestry

Table 2a. Characteristics and uses of some leguminous and other nitrogen fixing woody

Major ecological zone	Species	Ecological adaptability			
		Altitude (m.a.s.l.)	Rainfall range (mm/yr)	Maximum dry period (months per year)	Soil conditions
Arid/semi-arid	*Acacia albida*	up to 1200 m	300–800	6–8	Sandy/silty well drained soils. Good tolerance to salinity
	A. senegal	up to 1700 m	200–800	8–11	Sandy/well drained soils. pH 5–8 poor tolerance to waterlogging.
	A. tortilis	up to 1500 m	100–1000	10–12	Alkaline and sandy soils. Good tolerance to salinity
	Albizia lebbeck	up to 1600 m	500–2000	4–5	Prefers drained loams. Good tolerance to salinity.
	Cajanus cajan	up to 3000 m	400–2500	5–6	Light sandy soils and loams. Poor tolerance to waterlogging.
	Cassia siamea	up to 1200 m	500–1000	4–5	Most soils including limestone & laterite Poor tolerance to waterlogging.
	Cordeauria edulis	300–1000 m	200–500	10–12	Sandy soils. pH 7–8.5; very poor tolerance to frost.
	Pithecellobium dulce	up to 1500 m	400–1600	4–5	Most soils including clay. Good tolerance to salinity and waterlogging.
	Prosopie chilensis	300–2900 m	200–600	8–11	Most soils. Good tolerance to salinity
	Prosopis cineraria	up to 1000 m	75–850	8–10	Sandy/rocky soils. Tolerates pH 9, salinity and waterlogging.

Species	Functions/uses														
	Food						Fodder				Wood				
	Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiment (C)	Leaves	Fruit/Pods/Seeds	Shoots	Dee Forage	Fuel Wood	Charcoal	Building Material	Wood for Utensils & Tools	Sawn Timber
Arid/semi-arid															
Acacia albida							**	*			*		*	*	
A. senegal		*					**	**			***	**			
A. tortilis							**	**	*	**	***	**	**	**	
Albizia lebbeck							**		*	**	**		*		**
Cajanus cajan		**	**				*	**	*		r.				
Cassia siamea							*	*	*		***				**
Cordeauxia edulis		***		**	**		**								
Pithecellobium dulce	*			*			**	**		**	*		*		*
Prosopis chilensis		*					*	*		*	*		**	*	
P. cineraria							**	**		*	***	**	*	*	

* fair; ** good; *** excellent

perennials with agroforestry potential

Growth form	Management aspects					
	Establishment	Seed treatment	Care	Coppicing ability	Special features
Tree to 30 m	Seedlings	Hot water (80 C) & soak 24 hours	Weedings	poor	leafless in rains
Tree 5 to 15 m	Seedlings	Hot water (80 C) & soak 24 hours	Weeding	good	Browse susceptible
Tree flat top 4 - 30 m	Seedlings	Hot water (80 C) & soak 24 hours	Weeding	good	Bruchids eat seeds
Tree 20 - 30 m spreading crown	Direct seeding, root/shoot cuttings	Boiling water & cool & soak 24 hrs	Weeding	good	Browse susceptible
Shrub, 1 - 4 m	Direct seeding	None. Use fresh seeds.	Weeding for first 4 - 6 weeks	good at 0.15 m	Shade intolerant
Tree 15 - 20 m. Dense crown	Direct seeding	Hot water (80 C) & soak	Weeding for first 2 years	good	Browse susceptible
Shrub 1 - 3 m	Direct seeding	None. Short and viability (3 mths)		–	frost sensitive
Tree, 15 - 20 m	Seedlings or cuttings	None. 6 month seed viability	Very good tolerance to weeds	Very good	Insects eat seeds
Tree, 8 - 15 m	Seedlings	Hot water (80 C) & soak 24 hours	Weeding in first year	?	frost susceptible
Tree, 5 - 9 m Open crown	Seedlings or root suckers	Scarified & boiling water & soak	Good tolerance to weeds	good	tolerates slight frost

Functions/uses

Services								Miscellaneous									
Windbreak	Live Fence	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Mulch	Others	Waxes	Essential Oils	Tannins (T) Dyes (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual	Social	Ornamental	Other	Other remarks
		**		**	**					(T) *						*		Combines well with agric. crops
		**	*	*							***	**	*					Yields Gum arabic
		**	**	*												*		Widely used for livestock pens. Termite resistant
		**		**	*						*					*		fast growing
		**		***							*					*		sericulture/shellac
**		**			**													very toxic to pigs
		*		*						(D) *								Subsistence food
*	**			*						(T) *	*					*		presscake makes good stock feed
		**		*														high biomass yielder
		**	**	**														combines well with agric. species

Table 2b. Characteristics and uses of some leguminous and other nitrogen fixing woody

Major ecological zone	Species	Ecological adaptability			
		Altitude (m.a.s.l.)	Rainfall range (mm/yr)	Maximum dry period (months per year)	Soil conditions
Humid/sub-humid	*Acacia auriculiformis*	up to 600 m	1000–1800	6–8	Wide range including Uranium and tin mining spoils. pH 3–9
	Calliandra calothyrsus	up to 1500 m	1000–2000	3–4	Wide range of soils. Very good tolerance to flooding
	Casuarina equisetifolia	up to 1500 m	200–5000	6–8	Most soils except clay. Tolerant to salinity and waterlogging
	Derris indica	up to 1200 m	500–2500	4–6	Most soils including limestone. Very good tolerance to salinity
	Gliricidia sepium	up to 1600 m	2300	2–3	Moist or dry soils even when very alkaline
	Leucaena leucocephala	best below 500 m	250–1700	5–6	Poor growth on acid soils (< pH 5). Poor tolerance to waterlogging
	Mimosa scabrella	up to 2400 m	1000–2000	?	Most well drained soils. Poor tolerance to waterlogging
	Samanea saman	up to 1000 m	600–2500	5–6	Wide range of soils
	Sesbania bispinosa	up to 1200 m	550–1100	5–6	Most soils. Very good tolerance to alkalinity, salinity and waterlogging
	Sesbania grandiflora	up to 800 m	1000–2000	2–3	Wide range of soils. Good tolerance to waterlogging

Humid/sub-humid	Species	Functions/uses														
		Food						Fodder				Wood				
		Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiment (C)	Leaves	Fruit/Pods/Seeds	Shoots	Bee Forage	Fuel Wood	Charcoal	Building Material	Wood for Utensils & Tools	Sawn Timber
	Acacia auriculiformis											**	**			
	Calliandra calothyrsus							**			*	**				
	Casuarina equisetifolia											***	***	**	**	
	Derris indica							**				**			*	
	Gliricidia sepium							**			**	**				
	Leucaena leucocephala							***		**	**	**	**	*		
	Mimosa scabrella											**				
	Samanea saman	*							**						**	**
	Sesbania bispinosa							**				*				
	Sesbania grandiflora	*		**				**	**			*				

* fair; ** good; *** excellent

perennials with agroforestry potential

Growth form	Management aspects				
	Establishment	Seed treatment	Care	Coppicing ability	Special features
Tree, 30 m	Direct seeding or seedlings	Boiling water & soak for 24 hours	Weeding	poor	shallow roots
Shrub, 5 -10 m	Direct seeding or seedlings	Boiling water & soak 24 hours	Good tolerance to weeds	excellent	1 -2 year rotations
Tree, 30 - 50 m	Seedlings	Ant repellent on seed	Weeding	poor	N-fixing Actinomycete
Tree, 5 - 8 m Deciduous	Direct seeding/ cuttings	None	Good tolerance to weeds	good	shade tolerant
Tree, 5 -10 m Open crown	Seedlings or large cuttings	Hot water (80 C) & soak 24 hours	?	good	Deciduous
Shrub/tree, 5 - 20 m	Direct seeding or seedlings	Hot water (80 C) & soak 48 - 72 hours	Weeding	good	frost sensitive
Shrub/tree 10 - 12 m	Direct seeding	?	?	?	3 - 4 year rotations
Tree, 30 - 40 m Spreading crown	Seedlings	Feed pods to cattle	Good tolerance to weeds	?	shallow roots
Shrub like, 4 m	Direct seeding	None	Very good tolerance to weeds	-	An annual
Tree, 10 m	Direct seeding/ seedlings/cuttings	None	Little maintenance	good	frost sensitive

Functions/uses

Services								Miscellaneous							
Windbreak	Live Fence	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Mulch	Others	Waxes	Essential Oils	Tannins (T) Dyes (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual Social	Ornamental	Other	Other remarks
		**		**						(T) *	*				**		outgrows Imperata cylindrica
		**		**	**										*		combines well with agric. species
***		**	**	*						(T) *							fire sensitive
		**	**	*					*			*	*				insecticide properties
**	***	**		*	**												coffee/cocoa shade
**		**		**	***												combines well with agric. species
	**			*	**										**		coffee shade
				**							*				**		pasture shade
*		**		**	**							**					combines well with agric. species
**		**		**	***					(T) *	*		*				combines well with agric. species

Table 2c. Characteristics and uses of some leguminous and other nitrogen fixing woody

Major ecological zone	Species	Ecological adaptability			
		Altitude (m.a.s.l.)	Rainfall range (mm/yr)	Maximum dry period (months per year)	Soil conditions
Tropical highlands	*Acacia mearnsii*	up to 2000 m	500 - 1200	4 - 6	Wide range except calcareous soils
	Albizia stipulata	2000 - 3000 m	500 - 2500	3 - 5	Well adapted to infertile and shallow soils
	Alnus acuminata	1200 - 3200 m	1000 - 3000	3 - 5	Well drained loams and loamy sands. Also on gravelly and clayey soils
	A. nepalensis	300 - 3000 m	500 - 2500	3 - 5	Wide range. Best on alluvial loams and loamy sands.
	Casuarina oligodon	up to 2300 m	700 - 4000	6 - 8	Most soil types
	Erythrina poeppigiana	up to 2000 m	1000 - 3000	3 - 5	Most soils; dry to wet
	Gleditsia triacanthos	up to 1500 m	500 - 2500	6 - 8	Most soils; acid to alkaline, sandy to clay
	Inga jinicuil	up to 1400 m	500 - 3000	5 - 6	Most soils including limestone
	Lespedeza bicolor	up to 2000 m	500 - 2500	3 - 5	Most types including infertile rocky soils
	Trema orientalis	up to 2000 m	1000 - 3000	3 - 4	Wide range including denuded infertile soils

	Species	Functions/uses															
		Food						Fodder				Wood					
		Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiment (C)	Leaves	Fruit/Pods/Seeds	Shoots	Bee Forage	Fuel Wood	Charcoal	Building Material	Wood for Utensils & Tools	Sawn Timber	Others
Tropical highlands	*Acacia mearnsii*											***	**				pl
	Albizia stipulata							***									
	Alnus acuminata											**		**	**	*	pl
	Alnus nepalensis							*				*			**		
	Casuarina oligodon											***	**	**			
	Erythrina poeppigiana							**							*		
	Gleditsia triacanthos	*						**	**			**		**	**	*	
	Inga jinicuil											*		**			
	Lespedeza bicolor							**			**	**					
	Trema orientalis							**				**	**	**			pl

* fair; ** good; *** excellent

perennials with agroforestry potential

Growth form	Management aspects				
	Establishment	Seed treatment	Care	Coppicing ability	Special features
Tree to 25 m	Direct seeding	Immerse in boiling water	good tolerance to weeds	poor	mod. frost tolerant
Tree 15–20 m	Seedlings, root/ shoot cuttings	None	weeding	good	Highlands–Nepal
Tree 15–40 m	Seedlings or root cuttings	None. 2–3 weeks seed viability	weeding	good	Actinomycete Frankia sp.
Tree 30–40 m	Seedlings/cuttings	None	good tolerance to weeds	fair	shade tolerant
Tree 20–35 m	Seedlings	Ant repellent	weeding	?	mod. frost tolerant
Tree 10–15 m	Seedlings/cuttings	?	?	good	–
Tree to 45 m flat topped	Seedlings/cuttings	Immerse in hot water (80 °C)	good tolerance to weeds	good	frost tolerant
Tree 10–20 m	Seedlings	short seed viability	?	good	termite susceptible
Shrub 2–3 m	Direct seeding or seedlings	None	good tolerance to weeds	good	Korean species
Tree 10–15 m	Seedlings/cuttings	Refrigerate 2 °C for 3–4 months	good tolerance to weeds	good	shade intolerant

Functions/uses

Services								Miscellaneous									
Windbreak	Live Fence	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Mulch	Others	Wazes	Essential Oils	Tannins (T) Dyes (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual Social	Ornamental	Other	Other remarks
		***		**	***					(T) ***							combines well with agric. species
				**	**						*				**		coffee/tea shade
		***		**	*												pasture trees
		***		**											*		outgrows and suppresses most weeds
***		**		*													common fuelwood in Papua New Guinea
	**	**		**	**	*											coffee shade
**		**													*		could become a weed
		**		***	**												coffee shade
		***		**	**												nurse/fallow species
		**		?													cacao/coffee shade

systems under various ecological conditions is compiled in Table 2 as an indicative example. The possible uses and functions of the species are also indicated in the Table. This Table along with the previous one (Table 1) gives a good indication of the potential role of woody leguminous species in agroforestry systems under diverse ecological conditions. In addition to the trees and shrubs on which such information is available, there are also many other species which have not thus far been studied. Undoubtedly, one of the most promising opportunities in agroforestry lies in tapping this hitherto unexploited potentials of this large number of multipurpose trees and shrubs.

ICRAF's field trials on leguminous trees and shrubs for agroforestry

There is an understandable but unfortunate tendency in the present 'enthusiasm and awareness' stage of agroforestry development to exaggerate the supposed benefits of agroforestry systems and components such as multipurpose trees and shrubs. In fact, these benefits have to be *achieved* through development of sound technologies based on research, rather than being merely *ascribed* to any land use practice that can fit itself into the broad definition and concept of agroforestry, or any tree or shrub that can be considered to be having a potential role in agroforestry. But in addition to the difficulty caused by the lack of adequate quantitative information on agroforestry systems and its components, there is also the problem of non-existence of appropriate methods to assess their suggested advantages and potentials in comparison with other systems and components.

However, there is only very little that ICRAF can do in this task of undertaking specific technology-generating research. ICRAF is a research *Council* with a global mandate to promote and catalyze research in agroforestry, but with no resources to undertake elaborate research on its own accord. Nevertheless, in view of ICRAF's unique position as the sole international agency that has been set up exclusively for agroforestry research, it was felt inevitable for the Council to have a small field station of its own, which could be used for demonstration and training purposes. With the cooperation of the Government of Kenya which provided a suitable piece of land free of cost, such a station is now being established in Machakos, 70 km away from Nairobi. The site, situated about 1500 m above m.s.l., has a semi-arid climate with an average (bimodal) rainfall of 700 mm per annum, a typical savanna vegetation comprising perennial grasses, shrubs and low trees, and good but erodible soils. As one of the first activities on the station, about 40 species of multipurpose trees have been planted on the station starting from October 1981. Growth characteristics of a few leguminous ones among them are presented in Table 3.

Though the primary objective of assembling the plants on ICRAF's Field Station is to aid in the Council's demonstration and training activities, the results are also of immense value from the point of view of their suitability

Table 3. Some growth characteristics of a few multipurpose leguminous woody perennials at ICRAF's Field Station, Machakos, Kenya

Species	Date of planting	Number of plants measured	1. Height (m) (± S.D.)	2. Crown diameter (m) (± S.D.)	3. Stem diameter (cm) (± S.D.)	
					at base	1 m above ground
Acacia albida	28.10.81	45	1.77 (0.62)	1.24 (0.45)	4.09 (1.78)	2.12 (1.24)
Acacia cyanophylla	9.11.81	12	3.00 (0.62)	2.39 (0.51)	8.61 (1.88)	3.99 (1.48)
Acacia nilotica	9.11.81	12	1.66 (0.34)	2.57 (0.39)	6.46 (1.09)	1.87 (0.96)
Cassia alata	14.11.81	8	1.74 (0.67)	1.62 (0.41)	3.82 (1.63)	2.17 (1.43)
Cassia siamea	7.12.81	12	2.28 (0.46)	2.05 (0.42)	7.23 (1.42)	2.25 (0.70)
Casuarina equisetifolia	5.4.82	8	1.52 (0.46)	0.66 (0.23)	1.94 (0.83)	0.61 (0.40)
Erthryna abyssinica	11.12.82	12	0.82 (0.34)	1.09 (0.28)	4.36 (0.94)	–
Leucaena leucocephala (Cunn.)	9.11.81	12	2.40 (0.26)	2.03 (0.31)	6.78 (1.36)	2.93 (0.93)
Leucaena leucocephala (K8)	12.11.81	66	3.02 (0.59)	2.29 (0.42)	6.95 (1.14)	4.70 (1.15)
Leucaena leucocephala (Peru)	13.11.81	36	2.55 (0.52)	2.02 (0.40)	6.09 (1.19)	3.86 (1.09)
Parkinsonia aculeata	29.10.81	11	1.74 (0.23)	2.51 (0.25)	5.12 (0.40)	2.19 (0.38)
Prosopis juliflora	27.10.81	59	2.29 (0.53)	1.92 (0.55)	4.98 (1.29)	1.74 (0.78)
Prosopis palida	29.10.81	9	2.00 (0.37)	1.77 (0.59)	3.45 (0.94)	1.49 (0.70)
Sesbania grandiflora	19.4.82	42	2.40 (0.44)	1.61 (0.41)	10.15 (1.65)	3.83 (0.93)

Date of measurement: First week of July, 1983

1. Height was measured with a heightpole and/or metre ruler.
2. Crown diameter was measured using a measuring tape. At least two measurements at right angles to one another were taken and an average obtained.
3. Stem diameter was measured using vernier calipers. Two readings at right angles to one another were averaged. For multi-stemmed trees the average diameter of each stem was converted to basal area. The basal area of all the stems were summed and the corresponding diameter calculated.

for agroforestry in similar conditions elsewhere. Moreover, it is hoped that the plants will be made use of for developing methodologies for evaluating multipurpose trees and shrubs for agroforestry.

Conclusions

Several of the existing land use systems and practices in different parts of the world encompass the concepts and principles of agroforestry. Multipurpose leguminous trees and shrubs form an important group of components in most of such systems and practices. However, various gaps exist in our knowledge on these plants and their eventual use in such systems. In order to realize the potentials offered by agroforestry in a wide variety of situations, and to exploit the multiple benefits of the leguminous trees and shrubs, systematic research has to be undertaken on a global scale.

References

Brewbaker JL, Halliday J and Lyman J (1983) Economically important nitrogen fixing tree species. Nitrogen Fixing Tree Research Reports vol 1, pp 35–40

Brewbaker JL and Ta Wei Hu (1981) Nitrogen fixing trees of importance in the tropics. Paper for the US National Academy of Sciences Workshop, September, 1981

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

Chandler TM and Spurgeon D (eds) (1980) International Cooperation in Agroforestry. ICRAF/DSE, Nairobi, 469 p

Darnhofer T (1982) Shelterbelts: some remarks on the micro-climate effects and design considerations on shelterbelts. ICRAF, Nairobi, Mimeo, 16 p

Felker P (1978) State of the Art: Acacia albida as a Complementary Permanent Intercrop with Annual Crops. University of California, Riverside, Mimeo, 143 p

Hecht SB (ed) (1982) Amazonia: Agriculture and Land Use Research. CIAT, Cali, Colombia, 428 p

Huxley PA (ed) Plant Research and Agroforestry. ICRAF, Nairobi, 619 p

Kang BT, Wilson GF and Sipkens L (1981) Alley cropping maize and Leucaena (*Leucaena leucocephala* LAM) in southern Nigeria. Plant and Soil 63: 165–179

King KFS (1979) Agroforestry and the utilisation of fragile ecosystems. Forest Ecol Management 2: 161–168

King KFS (1980) Agroforestry and the development of tropical forestry. UNEP Expert Meeting on Tropical Forestry, 1980. UNEP, Nairobi

Lundgren B (1982) Introduction. Agroforestry Systems 1: 3–6

Lundgren B and Nair PKR (1983) Agroforestry for soil conservation. Paper presented at the Second International Conference on Soil Erosion and Conservation. January 16–22, Honolulu, Hawaii (Proc in press)

Lundgren B and Raintree JB (1983) Agroforestry: In: Nestel B (ed) Agricultural Research for development: Potentials and Challenges in Asia. ISNAR, The Hague, pp 37–49

Mann HS and Saxena SK (eds) (1980) Khejri (*Prosopis cineraria*) in the Indian Desert. CAZRI Monograph No. 11. Central Arid Zone Res Inst, Jodhpur, India, 77 p

Nair PKR (1979) Intensive Multiple Cropping with Coconuts in India: Principles, Programmes and Prospects. Verlag Paul Parey, Berlin, 149 p

Nair PKR (1980) Agroforestry Species: A crop Sheets Manual. ICRAF, Nairobi, 336 p,

Nair PKR (1983a) Multiple land use and agroforestry. In: Better Crops for Food: CIBA Foundation Symposium 97, pp 101–115. Pitman Books, London

Nair PKR (1983b) Tree integration on farmlands for sustained productivity of small-holdings. In: Lockeretz W (ed). Environmentally Sound Agriculture, pp 333–350. Praeger, New York

Nair PKR (1984) Soil Productivity Aspects of Agroforestry. Science and Practice of Agroforestry No 1. ICRAF, Nairobi (In press)

National Academy of Sciences (1975) Underexploited Tropical Plants with Promising Economic Value. NAS, Washington, DC 189 p

National Academy of Sciences (1979) Tropical Legumes: Resources for the future. NAS, Washington, DC 331 p

National Academy of Sciences (1980) Firewood Crops: Shrub and Tree Species for Energy Production. NAS, Washington, DC 237 p

Neumann I (1983) The use of trees in smallholder agriculture in tropical highlands. In: Lockeretz W (ed). Environmentally Sound Agriculture. Praeger, New York, pp 351–374

Neumhaeuser P (1983) Appropriate Land Use Systems for Smallholder Farms: A survey of ecological and socio-economic conditions in the Machakos District (Kenya). Studien Reihe IV/39, SLE, Tech Univ, Berlin, 187 p

Okigbo BN (1977) Neglected plants of horticultural importance in tradional farming systems of tropical Africa. Acta Horticultura 53: 131–150

Sheikh MI and Chima AM (1976) Effect of windbreaks (tree rows) on the yield of wheat crop. Pakistan Journal of Forestry, 26(1): 38–47

Sheikh MI and Khalique A (1982) Effect of tree belts on the yield of agricultural crops. Pakistan Journal of Forestry 32: 21–23

Torres F (1983a) Agroforestry: Concepts and practices. In: Hoekstra, DA and Kuguru FM (eds). Agroforestry Systems for Small-Scale Farmers. ICRAF/BAT, Nairobi, pp 27–42

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

van Gelder B and Poulson G (1982) The Woodfuel Supply from Trees outside the Forests in the Highlands of Kenya. Report of a study for the Beijer Institute. Nairobi (Mimeo)

Vergara NT (1982) New Directions in Agroforestry: The Potential of Tropical Tree Legumes Parts I and II. Environment and Policy Institute, East-West Center, Honolulu, Hawaii, 52 p

Wenner CG (1980) Soil Conservation in Kenya. Ministry of Agriculture, Nairobi, Mimeo, 191 p

Wilson GF and Kang BT (1981) Developing stable and productive biological cropping system for the humid tropics. In: Stonehouse B (ed). Biological Husbandry: A Scientific Approach to Organic Farming, pp 193–203. Butterworth, London

Zeuner TH (1981) An ecological approach to farming: some experience of the agro-pastoral project, Nyabisindu, Rwanda. In: Buck L (ed). Proceedings of the Kenya National Seminar on Agroforestry, ICRAF, Nairobi, pp 329–335