Fodder trees and shrubs in range and farming systems in tropical humid Africa

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INTRODUCTION

In many developing countries, sustained and high population growth rates, combined with limited and rapidly diminishing land for food and forage production, have created a need to intensify agricultural production in order to bridge the gap between requirement and supply of food and ensure proper human nutrition. Intensification, in the context of ruminant production systems, means a broadening of the feed resource base to compensate not only for the shrinking of rangeland and natural grasslands but also for the low quality and seasonal nature of this major feed resource.

Some of the alternate feed resources that could complement natural forages include cultivated leguminous and non-leguminous pastures, crop residues, fodder trees and shrubs. The choice of alternate feed resource should not be restrictive but must fit within the existing farming systems, and be adapted to the economic realities of the farmer.

Fodder trees and shrubs have been used for generations as multipurpose resources (food, fibre, fodder, timber, wood and live fences) across all of the agro-ecological zones of Africa.

FARMING SYSTEMS IN TROPICAL HUMID AFRICA

Tropical Africa, which lies between 23.5°N and 23.5°S of the Equator, can be divided into 5 major agro-ecological zones whose main characteristics are shown in Table 1. Tropical humid Africa in this context is taken to include all areas receiving over 900mm of rainfall annually, i.e. both the humid and sub-humid zones.

TABLE 1.
Main characteristics of agro-ecological zones in tropical Africa

	Zone*			
Characteristics	Humid	Sub-humid	Semi-arid	Arid
Rainfall (mm/yr)	>1500	900-1500	600-1000	<600
Growing season (days)	270	180-270	180	
Vegetation	Moist ever-green with trees dominant	Guinea-savannah with trees and shrubs	Sudan Savannah with scattered bushes/low trees	Steppe with scattered grasses
Farming/land use systems	Arable cropping Cash cropping Mixed crop-small ruminant farming	Arable cropping Agro-pastoralism Ranching	Nomadic, Pastoralism, Perennial arable cropping	Nomadic Pastoralism

* The fifth zone - Highlands - varies according to altitude and latitude

In the humid zone, the predominant farming activity or land use system is that of tree crop cultivation (cocoa, oil palm, kola nut, etc.), in conjunction with a shifting cultivation-bush fallow system of growing food crops (cassava, yams, maize, cowpea, etc.). Dwarf sheep and goats, which are not well integrated into the cropping system, are the predominant livestock species raised on a free roaming, low input, subsistence system.

In the sub-humid zone, on the other hand, livestock (predominantly cattle but with a large small ruminant population) are more important and better integrated into the shifting cultivation-bush fallow system by settled agro-pastoralists who cultivate mainly cereals and grain legumes. In both zones, trees and shrubs play an important role in the maintenance and regeneration of soil fertility, thus enhancing crop production (Atta-Krah *et al.*, 1986). Fodder from these trees and browse from fallow lands provide high quality feed for livestock production.

These feed resources have hitherto not been systematically exploited for strategic year-round feeding of livestock. However, efforts have been intensified recently to characterise the agronomic features, management requirements and feed value of some promising species, particularly introduced, exotic ones, so that they could be used in appropriate feeding systems for improved livestock productivity.

INVENTORY OF FODDER TREES AND SHRUBS

Trees are the dominant natural vegetation in the humid zone, while short trees and shrubs predominate in the drier sub-humid area. A large number of trees and shrubs, both leguminous and non-leguminous are listed in the literature as being suitable for feeding livestock (Le Houérou, 198O; Brewbaker, 1986; Atta-Krah, 1989). Amongst the several hundreds listed in the literature, only a small number apparently have a real feed value. According to Brewbaker (1986), the 5000 known nitrogen fixing woody species could be selectively reduced to 80 of acknowledged fodder value, out of which only 5 could be described as good.

This reflects a lack of knowledge of the value of many of the trees and shrubs indigenous to tropical Africa, rather than an intrinsic poor fodder value, and highlights the need to evaluate some of these materials. The list of fodder trees and shrubs in humid tropical Africa shown in Table 2 has therefore been limited to species whose fodder value is more universally acknowledged.

AGRONOMIC FEATURES OF SOME OUTSTANDING SPECIES

Some of the desirable characteristics of trees and shrubs cultivated for fodder production have been summarised by several authors (Wilden, 1986; Atta-Krah *et al.*, 1986; Ivory, 1989). These include:

- easy establishment and rapid early growth in order to compete effectively against weeds,
- thornlessness and perenniality,
- high productivity under repeated cutting, grazing or browsing,
- resistance to local pests and diseases,
- high seed production ability or reliable vegetative propagation,
- little or no fertiliser requirement,
- high production of good quality forage in terms of protein and mineral contents, palatability and digestibility.

TABLE 2.
Trees and shrubs of known fodder value in tropical humid Africa

Botanical name	Common name	Fodder value*
Acacia sieberiana **	-	High
Acioa barterii	-	Medium
Afzelia africana **	Haemorrhage plant	High
Albizia ferrunginea **	-	Medium
Albizia lebbeck **	Woman's tongue	Medium
Alchornea cordifolia	Xmas bush	Low
Anacardium occidentale	Cashew	Low
Anthonata macrophylla	-	Low
Baphia nitida	Camwood	Medium
Baphia pubescens	-	Medium
Bridelia spp.	-	Low
Butyrospermum paradoxum	Sheabutter	Medium
Cajanus cajan **	Pigeon pea	High
Calliandra spp.**	Kaliadra	Low
Canarium schwenfurti	-	Medium
Ceiba pentandra	Cotton tree	Medium
Chlophora excelsa	Iroko	Low
Citrus spp.	Orange	Low
Creistis ferruginea	-	Low
Cussonia barterii	-	
Cyclicodiscus gabunensis	-	Medium
Dacryodes edulis	Pear	Low
Daniella oliveri **	-	High
Desmodium spp.**	-	Medium
Dialium guineense	Velvet Tamarind	Low
Dichrostachys cinerea **	Kakada	Low
Elaies guineensis	Oil palm	Medium
Ficus elasticoides	-	High
Ficus exasperata	-	Medium
Ficus thonningii		High
Gardenia erubescens	-	Low
Glifforia simplicifolia	-	Low
Gliricidia sepium	Madre de cacao	High
Gossypium barbadense	Cotton plant	Medium
Grewia mollis	-	Low
Glyphaea brevis	-	Medium
Harungana madagascariensis	-	Medium

Botanical name	Common name	Fodder value*
Hymenodictyon pachyantha	-	Medium
Leucaena leucocephala	Ipil-ipil	High
Mangifera indica	Mango	Low
Manihot utilissima	Cassava leaves	High
Musa sapientum	Plantain/banana	Medium
Newbouldia laevis	-	Low
*Pentachethra macrophylla***	Oil bean	Medium
*Piliostigma thonningii***	-	Low
Psidium guajava	Guava	Low
*Prosopis africana***	-	Medium
*Pterocarpus erinaceus***	African Rose Wood	Medium
Rauwolfia vomitoria	-	Low
Ricinodendron heudelotii	African wood oil tree	Low
Sesbania sesban	Sesban	High
Spondias mombin	-	High
Sterculia tragacantha	-	Medium
Strychonos spinosa	-	High
Treculia africana	African breadfruit	Medium
Waltheria indica	-	Low

* Fodder value based on published information on palatability, intake and digestibility
** Leguminous fodder

Some efforts are currently being made in Africa to select and evaluate trees and shrubs that meet these requirements, but with little success to date because of the long growth cycle of these fodder plants. Atta-Krah *et al.* (1986) reported that efforts to screen 22 native browse species in Nigeria were abandoned after two years of observations, redirected and limited to *Gliricidia* and *Leucaena* because none of the former species could match the productivity of the introduced species. It is not surprising therefore that information available in the literature on agronomic features such as establishment, yield, and management are limited to such species as *Leucaena leucocephala, Gliricidia sepium, Sesbania sesban* and *Cajanus cajan*.

ESTABLISHMENT

Trees and shrubs can be propagated either from seeds or stem cuttings, although certain species like *Leucaena* have traditionally been cultivated from seeds. *Gliricidia*, on the other hand, is easily established from cuttings or seeds. Conditions for high striking (i.e., germination) percentages of stem-cutting established *Gliricidia* have been extensively investigated.

Willis (1980), Chadhokar (1982) and Falvey (1982) suggested using mature stakes (six-month-old or more), 1 to 1.5m long and 3 to 5cm in diameter, planted about 15cm deep. Stem sections should be planted fresh within 3 days after cutting and the exposed ends should be waxed or covered with vaseline, mud or polythene to minimise evaporation. There is no consensus as to the angle at which the planted end should be cut. Chadhokar (*loc. cit.*) recommended an oblique angle in order to increase the terminal bark area from which the roots emerge, while Willis (*loc. cit.*) preferred a straight or right angled cut to minimise the area exposed to rot.

Stake establishment of *Gliricidia* has two disadvantages. The plant develops a shallow root system that does not go deep enough to tap deep water sources during the dry season when it could suffer water stress and could easily be knocked down by animals browsing it. Secondly, a large amount of material may be required. According to Reynolds and Atta-Krah (1986), about 25 tons of stakes were needed to establish 1 ha of alley farm with tree rows 4m apart.

The latter problem prompted the ILCA team to investigate seed collection and drying techniques as well as optimum spacing for seed-established *Gliricidia*. The results summarised by Atta-Krah *et al*. (1986) showed that seeds of *Gliricidia*, which would otherwise be dispersed from the pods on drying, could be collected from fresh green pods and sun-dried without affecting seed viability. An 8 cm spacing of seeded trees, which gave 25,000 trees/ha, appeared most suitable for high yield. In other words, seed-established shrubs and trees are more suitable for fodder production.

Certain precautions need to be taken, however, to maximise this advantage. Many leguminous species such as *Leucaena* have hard seed coats that need to be treated prior to planting to enhance water imbibition and germination. *Leucaena* seeds are usually treated with hot water, acid or mechanical scarification. Vegetative domination of slow growing seedlings by weeds may result in high plant mortality. Transplanting nursery raised plants may therefore be preferable to direct drilling.

YIELD

Regardless of the production systems of fodder trees and shrubs (hedgerow planting or intensive production), foliage yield is affected by such factors as plant density and harvesting management, i.e., age at first harvest, height and frequency of cutting and season of harvest (Ivory, 1989). Biomass production figures available in the literature vary from 2 to 20 tons of dry matter/ha for *Leucaena* (NAS, 1984) 2-10 tons/ha for *Gliricidia* and *Sesbania* and 4-10 tons for *Cajanus cajan*. According to Hedge (1983) and ILCA (1988), higher yields of 30-50 tons/ha are possible for *Leucaena* under intensive monocultural production systems with tree populations of over 200,000 plants/ha.

The effect of planting densities on leaf yield has been investigated by several workers (Kang and Reynolds, 1986; Ella, 1988) who reported that, for *Leucaena, Gliricidia, Calliandra* and *Sesbania*, leaf yield per unit area increased with increasing planting density. In other words, when high leaf yield is targeted for fodder production, high planting densities are recommended. Although various planting densities ranging from 1 to 13 trees/m^2 have been assayed, optimum planting densities have rarely been recommended because of the confounding effects of such factors as season, rainfall and plant spacing. Ivory (1989) concluded that it may be difficult to define optimum planting densities for intensive production systems based on existing information. Nevertheless, an optimum planting density of 1O-15 trees/m^2 was recommended for *Leucaena* by Hedge (1983) and 25 trees/m^2 for *Gliricidia* by Atta-Krah *et al*. (1986).

HARVESTING MANAGEMENT

Management factors that affect not only fodder yield per unit area but also total long-term productivity include age at first harvest, harvesting frequency and height and season of harvest. Chadhokar (1982) indicated that frequent fodder harvest in the early years of *Gliricidia* establishment may reduce biomass yield in later years and recommended that, during the first to three years of establishment, foliage be harvested only once or twice a year. According to Ivory (1989), the older the tree at first cutting, the higher the rates of regrowth and biomass yield, since older trees would have thicker stems, more carbohydrate reserves and a deeper more extensive root system.

On the basis of experiments carried out on five-year old *Gliricidia* plants, harvested for two years at varying intervals of 2, 3, 4, 5 and 6 months, Chadhokar (1982) suggested that *Gliricidia* be harvested once every 3 months to maximise foliage yield.

Less categorical recommendations were made by Ivory (1989), following a review of studies on pruning frequency and biomass yield. The variable results reported were attributed to the modifying effects of factors such as intra-row spacings, fodder species, climate (wet or dry), production system (wood or leaf), etc. Thus ILCA (1988) reported a fall in *Leucaena* yield from 30.4 tons/ha, when cut at 12 weeks interval, to 10.3 tons per ha when harvested at intervals of 6 weeks, with an accompanying higher plant mortality. The same workers demonstrated the effect of intra-row spacings on *Leucaena* yield which fell from 41 tons/ha at 0.5m to 30 tons/ha at 1 to 2m intra-row spacing. In general, it could be concluded that, in humid climates where emphasis is on fodder production, short cutting intervals of 8-10 weeks appear suitable, while the longer interval of 12-14 weeks is recommended for the drier environment.

Although *Gliricidia* and *Leucaena* remain green all year round, particularly when pruned regularly, foliage growth and retention appear lower during the dry season, demonstrating a seasonal effect. Oakes and Skov (1962) obtained monthly dry matter yields of 0.99 tons of *Gliricidia* dry matter/ha during the dry season with an average rainfall of 55 mm/month, compared to 1.48 t/ha during the wet season (114 mm/month rainfall).

This demonstrable seasonal effect on regrowth and total biomass yield, calls for some management strategy that will ensure adequate all-year round supply of fodder for livestock feeding. In general, a pruning interval of 8 weeks during the wet and 12 weeks during the dry season may achieve this. Where the shorter pruning interval produces foliage in excess of livestock requirements, harvesting may be delayed to carry larger amounts as protein stores into the dry season.

FEED VALUE

The feed value of a forage is a function of its nutrient content and digestibility, its palatability (which determines its consumption level) and the associative effects of other feeds. An interplay of these factors determine the effective utilisation or feed value of the material.

Sufficient data exist in the literature on the nutrient content of several fodder trees and shrubs, including the usually neglected local species. Some of the published data are summarised in Table 3 and suggest that, on average, fodder trees and shrubs are richer in protein and lower in fibre and ash than tropical grasses. The differences are even more striking when dry season values are compared. Crude protein content of dry, mature tropical grasses often falls below the minimum 6% required for maintenance, while most fodder trees remain green with high protein contents. In a review of the nutritive value of browse in West Africa, le Houérou (198O) concluded that browse contains double the amount of energy of dry grass owing to its lower content of fibre.

There is less data available in the literature on the mineral concentrations in fodder trees and shrubs, particularly the local species. Available data for the favoured species like *Gliricidia* (Table 4) and some local species suggest that, except for a disproportionately high Ca:P ratio in leguminous species, most browses contain adequate levels of macrominerals to cover animal requirements and that this should be better exploited. More studies are, however, required to fully characterise trace mineral contents of these fodder resources.

TABLE 3. **Nutrient content of selected fodder trees and shrubs (compared to *Panicum maximum*)**

Fodder species	% OF DRY MATTER					
	Organic Matter	Crude Protein	Crude Fibre	Acid Detergent Fibre	Neutral Detergent Fibre	Total Ash
Albizia lebbeck	85.0	21.7	36.6	24.6	35.4	7.3
Afzelia africana	85.0	17.8	27.8	26.0	-	13.0
Cyclicodiscus gabunensis	95.0	15.8	21.0	23.0	-	5.0
Ficus exersperata	90.5	14.8	22.0	25.0	-	7.0
Gliricidia sepium	90.0	23.0	20.7	28.7	42.8	9.7
Leucaena leucocephala	89.0	22.4	13.0	28.9	42.0	9.4
Sesbania grandiflora	88.2	23.5	-	21.7	27.1	10.0
Panicum maximum	88.4	12.0	30.0	55.9	76.0	13.0

TABLE 4. **Mineral content of *Gliricidia sepium*.**

Mineral	Range	Mean
Calcium (% DM)	0.6 - 2.5	1.3
Phosphorus (% DM)	0.1 - 0.3	0.2
Calcium-Phosphorus Ratio	3.7 - 9.3	6.2
Magnesium (% DM)	0.2 - 0.6	0.3
Sodium (% DM)	0.1 - 0.5	0.3
Potassium (% DM)	2.4 - 3.4	3.3
Zinc (mg/kg)	22.0 - 37.0	26.0
Iron (mg/kg)	259.0 - 362.0	207.0
Manganese (mg/kg)	40.0 - 90.0	69.7
Copper (mg/kg)	4.0 - 7.7	5.8

The high variability in the nutrient content of fodder trees and shrubs often encountered in the literature could be attributed to within species variability due to factors such as plant age, plant part, harvesting regimen, season and location. These factors should be considered when chemically evaluating fodder trees. Even so, laboratory analyses may be of limited value in assessing fodder nutritive value because they do not indicate the availability of cell wall constituents. The nutritive value of fodder trees can therefore not be accurately determined without an indication of their digestibility.Unfortunately, there is even a greater dearth of data on the digestibility of fodder trees and shrubs native to tropical humid Africa.

Some of the available data are summarised in Table 5. In general, fodder trees and shrubs not only degrade fairly well and rapidly in the rumen, supplying soluble carbohydrates and fermentable nitrogen to the rumen (Smith and Van Houtert, 1987) but also are well digested post-ruminally, often at a higher level than tropical grasses, and should therefore improve the intake and digestibility of the latter.

It is also well known that digestibility values may not be a good indicator of the feed value of fodder because of such factors as palatability, associative effects of other feeds and metabolic principles which may reduce intake or bind up nutrients. An evaluation of the feed value of these materials should therefore be completed by feeding trials using practical feed combinations offered at realistic levels. It has been recommended that, when used as supplements, the optimum dietary level of fodder trees and shrubs should be about 30 to 50% of the ration on dry matter basis, or 0.9-1.5kg per 100kg body weight (Devendra, 1988). Table 6 shows some available data on the potential feed value of fodder trees.

TABLE 5. **Digestibility of selected fodder trees and shrubs (compared to *Panicum maximum*)**

Fodder species	*In vivo* Organic Matter Digestibility (%)	*In vitro* Organic Matter Digestibility (%)
Albizia lebbeck	53.2	59.5
Afzelia africana	-	45.5
Ficus exasperata	-	45.5
Gliricidia sepium	53.9	-
Leucaena leucocephala	64.9	57.5
Sesbania grandiflora	61.8	66.7
Panicum maximum	53.2	37.0

TABLE 6. **Potential feed value of fodder trees and shrubs**

Basal feed	Fodder supplement	Response	Livestock species	Reference
Rice straw	*Leucaena* (50% of ration)	Significant increase in organic matter digestibility (9%), energy intake (86%), and nitrogen retained (256%)	Sheep	Devendra (1983)
Gliricidia	*Leucaena* (50% of ration)	Significant increase in digestible dry matter intake (12%) and growth rate (55%)	Goats	Ademosun *et al.* (1985)
Guinea grass hay	*Gliricidia* (30g/kg $W^{0.75}$)	Doubling effect on digestible dry matter intake	Goats	Ademosun *et al.* (1985)
"	*Leucaena* (30g/kg $W^{0.75}$)	66% increase in digestible dry matter intake		

PRODUCTION SYSTEMS OF FODDER TREES AND SHRUBS

A number of fodder production systems designed to produce sufficient foliage for livestock feeding particularly during the dry season are currently being evaluated and refined.

Two examples of such cultivation systems are alley farming and intensive feed gardens (IFG). Both systems are varieties of the same theme - that of cultivating suitable trees and shrubs either as pure monoculture stands, or mixed with herbaceous forages (IFG) or arable crops (alley farming). Biomass yields from both systems are usually high. Atta-Krah and Reynolds (1989) reported a yield of over 20 tons of dry matter/ha in an IFG of *Gliricidia* and *Leucaena* mixed with *Panicum maximum*. The tree hedgerows were established 2.5m apart with two rows of grasses. In the *Leucaena-Gliricidia* plots only, 30 tons of foliage dry matter/ha was harvested. A more extensive treatment of both systems is given later in this publication.

TOXINS AND ANTI NUTRITIVE FACTORS

Fodder trees and shrubs may contain high levels of deleterious compounds that make them unpalatable or harmful to livestock when consumed in large amounts. Particularly well documented in the literature are the harmful effects of mimosine, or its metabolite 3-hydroxy-pyridone (DHP), on livestock consuming large quantities of *Leucaena*, which may contain concentrations of 0.3 to 7.1% of mimosine depending on the variety and plant part. Levels of 2 to 2.3% of tannins have also been reported in *Gliricidia* and *Albizia* spp.

A number of methods are used by farmers to overcome or reduce palatability or toxicity problems caused by these compounds. Wilting, drying and dilution of the problem feed with other feeds are common. Wilted *Gliricidia* leaves are more readily consumed by cattle than the fresh leaves which have an offensive odour and the feeding of *Leucaena* at a level not exceeding 50% of ration to ruminants lacking the specific DHP detoxifying rumen bacteria is recommended. The less well studied indigenous fodder trees and shrubs that have high potential feed value should be characterised by their contents of potentially toxic compounds.

CONCLUSION

Trees and shrub fodder play important roles within the farming systems of tropical humid Africa, contributing significantly to soil maintenance and fertility, as well as livestock production, particularly as dry season feed resources. The full potential of several species native to this region has not been systematically and fully exploited because of the benign neglect they have hitherto suffered in terms of research efforts which have been concentrated on a few introduced species. While research efforts should continue on such species as *Leucaena, Gliricidia* and *Sesbania*, emphasis needs to be gradually shifted to the local species currently being exploited by farmers. Adoption of technologies based on these species may be more rapid and widespread.

Research efforts should be directed towards:

a) Agronomic evaluation including seed production and storage techniques for promising local species.
b) Nutritional characterisation of these species under practical feeding systems.
c) Year-round feed utilisation systems that will maximally exploit improved biomass yields resulting from a better understanding of agronomic features.

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