Nitrogen Fixing Trees for Fodder Production

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R. T. Paterson, NRI, Chatham, U.K. Seconded to ICRAF, KARI/KEFRI/ICRAF National Agroforestry Research Project, P. O. Box 27, Embu, Kenya; **B. H. Dzowela**, SADC/ ICRAF Agroforestry Research Project, P. O. Box 594, Causeway, Harare, Zimbabwe; **E. Akyeampong**, ICRAF Headquarters, P.O. Box 30677, Nairobi, Kenya; **A. I. Niang**, KEFRI/KARI/ICRAF Agroforestry Research Centre (Maseno), P.O. Box 25199, Kisumu, Kenya; and **R. M. Otsyina**, SADC/ ICRAF Agroforestry Research Project, P.O. Box 797, Shinyanga, Tanzania.

A review of ICRAF work with fodder trees in Africa

Abstract. The International Centre for Research in Agroforestry (ICRAF) has worked with fodder trees in many sub-Saharan countries. It operates within existing agroforestry research networks in the bimodal highlands, the unimodal plateau, and the semiarid lowlands of Africa. The work, aimed at smallholder farming systems, addresses constraints identified in diagnostic surveys. Farmers have consistently noted among their most pressing problems, the poor quality and limited quantity of dry season feed. Across the regions, *Calliandra calothyrsus*, *Leucaena* spp. (*L. leucocephala* before the appearance of the leucaena psyllid; *L. diversifolia*, *L. esculenta*, and *L. pallida* since), and *Gliricidia sepium* often produce the highest yields. *Acacia angustissima* is promising in Southern Africa, as is *Mimosa scabrella* above 2,000 m altitude. While species may be similar, niches for tree planting vary with the farming system. Contour bunds can be stabilized and made productive by the planting of fodder trees. Fodder species are sometimes planted under upper-storey trees along farm boundaries. In Tanzania, seasonal drainage lines can be used for fodder banks when protected by live fences. Agronomic studies have addressed wet season management for dry season fodder yields. The quality and productivity of indigenous trees are compared with exotics. Tree fodder acceptance by livestock and animal performance levels are evaluated.

Introduction

In 1991 the International Centre for Research in Agroforestry (ICRAF) was formed, evolving out of the council with the same acronym. At that time, it became a full member of the Consultative Group on International Agricultural Research (CGIAR) with a mandate to "mitigate tropical deforestation, land depletion and rural poverty through improved agroforestry systems." The change in the status of the institute brought with it the responsibility to act as a focal point for both strategic and applied agroforestry research on a global scale (ICRAF, 1992).

Although collaborative research projects were started in Latin America and Asia in 1992, these activities were initially directed toward farming systems where livestock were of limited importance. The bulk of ICRAF work on fodder and animal production has, therefore, been carried out in the countries of sub-Saharan Africa.

In the days when ICRAF was a council, a logical sequence of events for farmer-participatory research in agroforestry had been conceptualized, starting with macro and micro diagnosis and design (Raintree, 1986) and leading on to the design and on-farm testing of interventions in an iterative manner. This process was initiated in a number of African countries (e.g., Minae and Nyamae, 1988, for Kenya; Ngugi and Saka, 1988, for Malawi), where almost inevitably, livestock was identified in farmer surveys as an important component of the diverse farming systems. A major constraint to animal production, as perceived by farmers in most areas, was shortage of fodder, both in quantity and quality, particularly during the dry seasons. The problems of farmers, summarized for 67 sub-Saharan Africa diagnosis and design surveys by Raintree (1987), are shown in Figure 1.

In view of the potentially high nutritive value of tree foliage, it was reasoned that deeply rooted, woody plants could help overcome these problems. Collaborative research into tree fodders was therefore initiated with national scientists in 13 countries in the East and Central African Highlands (ECAH); the Central and Southern Africa Plateau (SADC); and in both the semiarid (SALWA) and humid lowlands of West Africa (HULWA). In each of these four regions, the work was coordinated through the formation of an Agroforestry Research Network for Africa (AFRENA), which was designed to provide technical and logistical support to the partners in the networks. This paper summarizes the results obtained under these collaborative programs.

Species screening

The geographical area encompassed by the four networks is vast, covering more than 2 million km^2. It includes a wide diversity of climatic and edaphic conditions, ranging from sea level in West Africa up to more than 2,500 m in Rwanda and Burundi. In attempts to identify suitable fodder trees for these varying conditions, many species have been screened at a number of sites. The most important woody genera assessed include *Acacia*, *Albizia*, *Cajanus*, *Calliandra*, *Chamaecytisus*, *Flemingia*, *Gliricidia*, *Leucaena*, *Mimosa*, *Prosopis*, and *Sesbania*.

In many parts of the region with relatively neutral soils, *Leucaena leucocephala* (leucaena) was the most productive fodder species and was becoming popular with farmers before the arrival of the leucaena psyllid (*Heteropsylla cubana*) into the region. This pest first appeared on the African mainland just

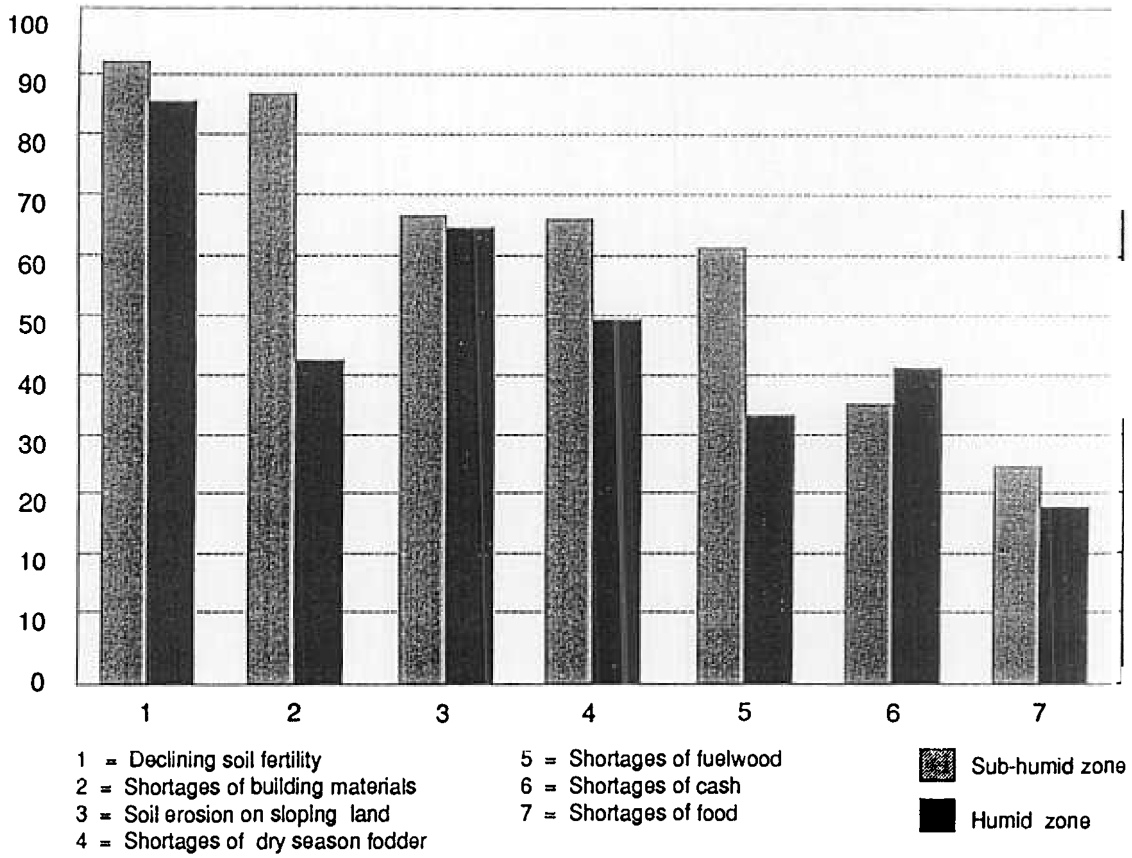

Figure 1. Frequency distribution of problems affecting land use systems in the humid and sub-hum tropics (Raintree, 1987).

north of Mombasa (Kenya) in August 1992 (Reynolds and Bimbuzi, 1993). Although it has not yet appeared in Zimbabwe, its presence in neighboring countries suggests that it will become endemic in the whole region before long. It remains to be seen whether natural or introduced predators will be able to control it in the long run. Other species such as *L. diversifolia*, *L. esculenta*, and *L. pallida*, together with a number of composites and inter-specific hybrids, have shown some degree of tolerance to the psyllid (Dzowela et al., 1994; Otsyina et al., 1994a, 1994b). But work with them is of recent inception and more local experience will have to be gained before these species and lines can be recommended to farmers.

Another species to show early promise was *Sesbania sesban*, but most accessions died out after a few cuts, seldom lasting for much more than two years when managed as a hedgerow under frequent cutting (ICRAF, 1992; Niang et al., in press). Although this species may not be suitable for fodder production, it is currently attracting much attention as a tree for improved fallows because of its prolific growth and positive effect on the yield of subsequent crops (ICRAF, 1993).

Of the exotic leguminous species tested, those with the widest general potential across the region appear to be *Calliandra calothyrsus* where the annual rainfall exceeds 1,100 mm and *Gliricidia sepium* if the rainfall is around 700 mm (ICRAF, 1993, 1994). On acid soils in Zimbabwe, the cold tolerance of *Acacia angustissima* makes it a very promising species (Dzowela, 1994; Dzowela et al., 1994). At altitudes above 2,300 m, on extremely acid soils (pH below 4.0) in Rwanda, *Mimosa scabrella* has outperformed most other species (ICRAF, 1994; Niang, 1994).

Although selection work with indigenous fodder trees is not as well advanced as with exotic species, they are not ignored by ICRAF programs. Trees that are valued by farmers as sources of fodder include both legumes and non-leguminous species. In the SALWA region, *Prosopis africana*, a native to the Sahel, is a priority species for tree improvement research aimed at evaluating existing genetic variation and developing recommendations for management and conservation of the resource base (ICRAF, 1994). *Pterocarpus* spp. are under investigation as fodder trees in Mali; *Acacia nilotica, Balanites aegyptica*, and *Zizyphus mauritiana* are showing promise in a number of dry areas as species for live fences and fodder (ICRAF, 1994).

In the bimodal highlands of Kenya, farmers value the local species *Trema orientalis* and *Sapium elipticum*. The naturalized species *Morus alba*, which is commonly recognized as a source of feed for silkworms, also shows potential for the feeding of ruminant livestock (Thijssen et al., 1993b). The current research focus is on propagation techniques and the animal production potential of these species.

In Eastern Zambia, the local species *Zizyphus abyssinica* and *Diplorynchus condylocarpon* have shown promise as supplements for goats fed on a basal diet of poor quality roughage (Phiri et al., 1992, 1994). In Tanzania, *Margaritaria discoides* is showing similar promise for goats (Otsyina et al., 1994b). The aim is to extend the range of useful fodder species by evaluating both exotic and local species within the prevailing farming systems.

Planting niches

Since the ICRAF mandate includes the aim of reduction of rural poverty, many of its activities are centered on small-scale, resource-poor farmers. Although farmers in some areas have access to communal grazing, the total area under direct, long-term control of a farm family is usually less than 1.5 ha. In such circumstances, farmers are seldom able to set aside an area specifically for the block planting of fodder trees. Much of the work, therefore, is aimed at the identification of niches on the farm where fodder trees, either alone or in close combination with other species, can produce feed for livestock without a serious reduction in the production of other crops.

Where possible, the trees should also serve other functions such as boundary demarcation, soil conservation, and fuelwood production to make the technique more attractive to farmers. Readily identifiable niches that can be potential sites for fodder trees or hedgerows vary from country to country, depending upon the prevailing farming systems. Some common examples are described below.

Scattered trees in croplands. At densities below 625 trees/ha, the slight reduction in maize yield caused by competition from trees such as *Gliricidia sepium* may be offset by the value of the fodder produced (ICRAF, 1992).

Below upper-storey tree species along boundary lines. It has been observed at a number of sites that growth of *L. leucocephala* and *C. calothyrsus* is not reduced by the presence of taller species such as *Grevillea robusta* or *Casuarina equisetifolia* planted in the same line for timber and fuel production, although the growth of the upper-storey species may be reduced by competition from the fodder species (ICRAF, 1993).

Hedges around the farm compound. Commonly, hedges are used to ensure privacy and to prevent dust from blowing into the compound. In many parts of the continent, as typified by the Embu region of Kenya, they are often formed of species such as *Cupressus lusitanica*, *Euphorbia tirucalli*, or *Lantana camara* (Thijssen et al., 1993a). The opportunity exists to replace these relatively unproductive species with hedgerows that can yield high quality fodder. Similarly, internal divisions that are presently often formed by low-value bushes (ICRAF, 1994) could be replaced by productive fodder species.

Terrace edges on sloping land. The fodder hedges help to stabilize the sloping face of the terrace riser with little adverse effect on the neighboring crop.

Permanent contour bunds. Bunds are a common feature of gently sloping areas in many parts of Central and Southern Africa. At present, they conserve the soil but contribute little toward the direct income of the farmer (Dzowela et al., 1994). They can be made more productive by the inclusion of fodder trees.

Intercropping with grasses. *Pennisetum purpureum* below 2,000 m altitude or *Trypsacum laxum* at higher altitudes can be grown with fodder legumes in fodder banks. In this way, the grass provides the bulk and the associated hedge gives increased feeding quality from the same piece of land.

Tree /hedgerow management and fodder production

Management practices will vary according to the growth conditions at the site under consideration. Studies in Kenya and Rwanda showed that, as may be expected, fodder yields from trees increased with increasing cutting height from 10 to 130 cm. Conversely, the yield of adjacent rows of grass fell as the pruning height increased (ICRAF, 1992). Experience suggests that the best compromise for most situations lies in the range of 60 to 100 cm (Niang, 1994; Niang et al., 1994). In the bimodal rainfall regime at Embu in Kenya, when *L. leucocephala* was pruned at intervals of about three months to a consistent height of 100 cm, initial leaf yields were highest when side branches were pruned back to the main stem. Annual cumulative yields were increased, however, by cutting the side branches at about 20 cm from the stem. The yields could be slightly increased by hand stripping of the remaining leaves after the pruning, but the extra labor involved may not be justified by the small increase in dry matter (DM) production (Thijssen, 1994; ICRAF, 1994).

In areas with a unimodal rainfall and a long dry season, moisture stress and leaf senescence can lead to the loss of fodder material unless cutting times are chosen judiciously. If the aim is to maximize the yield of fodder at the height of the dry season in August, the final wet season cut should be made six months earlier in February (Akyeampong and Muzinga, 1994). Earlier cutting caused an increase in leaf senescence, whereas later cutting resulted in inadequate time for recovery before the onset of the dry season.

In a situation where a range of species is grown in a number of different planting arrangements under varying conditions of altitude, climate, and soil fertility and under differing management systems, it is difficult to generalize about fodder yields. Some typical results from experimental linear plantings are presented in Table 1.

At Embu in Kenya, an experiment was established late in 1992 to study fodder yields in block plantings. Treatments were arranged as a substitution series with a total of 20,000 plants (or sets)/ha, these being either pure grass (*Pennisetum purpureum* cv. Bana), pure tree hedgerow (either *C. calothyrsus* or *L. leucocephala*), or combinations of 1:1 and 4:1 grass to legume. On average, after the initial establishment period, the grass was cut at intervals of two months and the trees at three months. This is designed as a five-year study and results so far are very preliminary. They show that the highest cumulative fodder yields over the first seven cuts have come from the 4:1 grass to legume combination. The cumulative yield

Table 1. Typical yields of fodder from hedgerows in double rows along contour bunds (kg DM/m of bund)

Country	Altitude	Rainfall	Tree species	DM yield (kg/m)
Burundi[a]	1600	1100	*C. calothyrsus*	1.3
			C. calothyrsus/T. laxum	
Kenya[b]	1500	1736	*C. calothyrsus*	2.7
			C. calothyrsus/ P. purpureum	8.2
			L. leucocephala/ P. purpureum	8.0
Rwanda[c]	2300	1257	*C. calothyrsus*	3.8
Zimbabwe[d, e]	1500	895	*A. angustissima*	1.7
			C. calothyrsus	0.8

a. Akyeampong and Dzowela (in press).

b. Otieno et al. (1993).

c. Niang et al. (in press).

d. Dzowela et al. (1994)

e. Four rows on the bund, spaced at 0.5 x 0.5 m.

of crude protein (CP) is much greater from all of the combinations than from any of the species grown alone (O. Z. Nyaata, unpublished data). Similar results were obtained in Maseno (Kenya) where a 3:1 ratio of Napier to *L. leucocephala* produced the highest yields (H. J. O. Otieno, unpublished data). On-farm work in Embu showed that these tree species can be successfully introduced into existing stands of Napier or Bana grass (O'Neill, 1994). There is potential to increase fodder production through the introduction of trees into existing grass plots.

Animal production

The activities of ICRAF and its collaborators in animal production are aimed largely at goats and dairy cattle because these are the most common animals found in the priority production systems in the farms of sub-Saharan Africa. ICRAF has concentrated so far on the acceptability and productivity of the most promising fodder trees. Studies will be initiated shortly that will address more comprehensively aspects of feed quality and anti-nutritive factors. Some typical examples of animal responses are given below.

In Rwanda, *Mimosa scabrella* has consistently shown CP contents of about 25%. Young local goats of about six months of age fed on a basal diet of *Setaria splendida* (7–10% CP) consumed more than 400 g/day dry matter (DM) of the fresh tree fodder, resulting in an increase in the total DM intake, with little substitution of the additive for the grass. In a separate experiment where similar animals were fed mixtures of the grass and the tree fodder, they gained weight at some 50 g/day compared with 31 g/day on grass alone (ICRAF, 1994; Niang et al., 1994; Niang et al., in press). In Zimbabwe, animals maintained on a basal diet of native pasture hay and fed 110–160 g DM/day of a range of tree fodders, including dry pods of leucaena, exhibited similar growth trends (Dzowela et al., 1994). Sheep, on the other hand, accepted only *Calliandra* fodder, rejecting other woody species such as *Cajanus cajan* and *Acacia holosericea.*

In central Tanzania, separate groups of local goats with an average initial age of 8.8 months were allowed to graze daily on natural range for two wet and two dry seasons. They were supplemented at night with *ad libitum* sun-dried leaves and small twigs of either *Cajanus cajan*, leucaena, or *Sesbania sesban*, the mean intakes of which were 82, 81, and 76 g/day, respectively. Supplemented animals gained weight faster than the unsupplemented controls in both dry and wet seasons. Therefore, at least in the miombo woodlands of Tanzania, the natural range is incapable of producing optimum growth rates in local goats. There were no significant differences in animal growth rates between the tree species, although *Sesbania* consistently produced slightly poorer results than the other two species (Karachi and Zengo, in press).

The effect of tree fodder as a supplement for oxen in the latter part of the dry season will be the focus of a recently initiated study in Shinyanga in Tanzania. Early indications are that 2.0 kg/day of fresh *L. leucocephala* can result in a notable improvement in the body condition of the animals. It is expected that better physical condition should result in improved ability to perform heavy work during the critical period of land preparation (R. Otsyina, personal communication).

Research on dairy cattle at Maseno has shown that *Calliandra calothyrsus* can be successfully used as a concentrate for milking animals (van der Veen, 1993). In Embu, the replacement value of the fodder within the normal range of feeding of commercial concentrates (2.0–4.0 kg/day) is in the region of 3.0 kg of fresh material (0.8–1.0 kg DM) equivalent to 1 kg of dairy meal with 16% CP. Normal milk yields are about 10 l/d from grade Friesian or Ayrshire animals receiving a ration based on Napier grass, maize stover, and banana pseudostems. There was an indication ($p = 0.08$) that the tree fodder resulted in a slight increase in the butterfat content of the milk (R. T. Paterson, unpublished data). In contrast, linear programming models for local Ankole cattle in Rwanda showed that there would be little advantage to offering them tree foliage in view of their low productivity and lower demand for high quality fodder (Niang et al., in press). It is, therefore, clear that the use of tree fodder must be adjusted according to the nutritional needs of the animals involved.

Economics

An established market for fodder does not usually exist among small farmers except where bush fodder is cut and offered for sale. Fodder has a value only when it is fed to livestock, and the value will depend on the productivity of the animals. While ICRAF has been conducting research into tree fodder production for some years, work on the effects of tree foliage on animal performance is recent and incomplete in many instances.

Few attempts have so far been made at economic evaluations of tree fodder production systems. An ex-ante comparison was made of the relative merits of using leucaena foliage as a substitute for inorganic fertilizers in maize production or as a protein supplement for dairy cows (ICRAF, 1993). The assumptions made in the analysis were taken from either ICRAF results or from the international literature, and costs and returns were those obtaining in Kenya in 1992. On the basis of nitrogen content alone, the substitute fodder value of leucaena leaves (in comparison with commercial dairy meal) was calculated at seven times the substitute fertilizer value compared with calcium ammonium nitrate.

In terms of end product analysis, the value of milk produced from 1.0 kg of leucaena fodder would be three and a half times the value of maize grown from the same amount of green manure. If the value of the brown manure produced from feeding the foliage to animals were to be taken into account, the differences in favor of feeding would be even greater. While the assumptions used in any ex-ante analysis can be open to debate, the magnitude of the economic advantage is such that the conclusions from this study are unlikely to change as a result of minor adjustments to the assumed figures.

At Maseno in Western Kenya, either 8.0 kg of fresh *Calliandra* or 6.0 kg of fresh leucaena was fed to dairy cows, either in addition to, or as a replacement for commercial concentrate. The fodder trees were planted in rows within the Napier grass that formed the basal diet (van der Veen, 1993; van der Veen and Swinkels, 1993). The net benefit was negative in the first year, as a result of the cost of establishment of the trees, but became positive in the second year. Where currently used dairy meal was replaced by the tree fodder, an internal rate of return of 61% was calculated. The profitability of feeding leaves in addition to concentrates was more variable, depending on the loss of grass resulting from the growth of the trees within the same block. This limitation could be removed by planting the trees in alternative niches that do not require the removal of some of the grass.

Future plans

Future ICRAF work should concentrate on intensive management systems (Otsyina et al., 1994a). Even where animals are kept under extensive communal grazing, the opportunity exists for intensive fodder production in specific niches on the land controlled by the farm family. The high feeding quality of the fodder produced from these areas needs to be used strategically, for selected stock, to have the maximum effect on the farm economy. Work on the effects of the fodder on differing classes of livestock should be intensified to define the most cost-effective utilization strategies for the tree foliage across the region. Species screening and evaluation should include both exotic and indigenous trees managed under systems that are socially acceptable to the residents in the target areas.

As the programs of the center gather strength and move into other farming systems in Latin America and Asia, it may become necessary to address the use of trees for livestock in these areas. While there are no specific plans for such activities in the immediate future, ICRAF is aware of the possibility and the situation will be kept under constant review. With the current moves toward rationalization and consolidation in the CGIAR system, as epitomized by the recent amalgamation of ILCA and ILRAD into the new International Livestock Research Institute (ILRI), it is to be expected that future ICRAF work in animal production will be conducted in close collaboration with ILRI, CIAT (Centro Internacional de Agricultura Tropical), and other international centers.

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