The potential for tree forage supplements to manipulate rumen protozoa to enhance protein to energy ratios in ruminants fed on poor quality forages.

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INTRODUCTION

It is probable that there are large numbers of forages with secondary plant compounds that may manipulate digestive function in the rumen to the benefit of the animal. There is a need to survey such forages as they could represent cost-effective supplements for ruminants on poor quality pastures/crop residues. The first priority is to balance the rumen to allow an effective use of the basal diet which requires fermentative digestion. The main point to be emphasised is the need to extract, by microbial digestion, the maximum nutrients from the basal diet. At the same time, the growth efficiency of the rumen microbes must be optimised to provide the animal with a high protein (amino acids) to energy ratio (P/E ratio) in the nutrients absorbed. This can be achieved by supplementation with a combination of non-protein nitrogen and minerals. Once this has been achieved then the animal appears to need a small amount of extra supplementary protein that escapes to the lower tract to optimise the P/E ratio in the nutrients absorbed and maximize the animal's efficient use of the diet. The major problem for most developing countries is the availability of the resources needed to provide these supplements. Tree forages, and in addition seeds and pods, are potential sources of supplements that could provide an array of minerals and soluble nitrogen for the rumen microorganisms. The same materials can potentially also provide the bypass protein either naturally, when they contain tannins, or when induced by simple processing.

The P/E ratio in the nutrients absorbed by ruminants on forage-based diets depends largely on the microbial growth efficiency in the rumen and on the amount of bypass protein supplement included in the diet.

It has been demonstrated recently that the presence of rumen protozoa reduces the protein to energy ratio in the nutrients absorbed (Bird, 1991) through:

- their predation of bacteria in the rumen decreasing the flow of bacterial cells to the intestines (Coleman, 1975).
- their apparent retention in the rumen (only 30% of the protozoal cells actually move to the intestines) (Weller & Pilgrim, 1974; Leng, 1982).

- their ability to digest particulate protein in the rumen and thus convert protein and amino acids to VFA with a net loss of dietary protein (Ushida and Jouany, 1986). Bird (1991), in a recent review article, summarised the beneficial effects of removal of protozoa and maintenance of the unfaunated state on rumen production as follows:

"With respect to the protein economy of the animal the advantages of removing the protozoa from the rumen and maintaining the defaunated state are:

- increased utilisation of protein nitrogen in the rumen
- increased availability of dietary protein for intestinal digestion.
- an increased yield of microbial protein from rumen fermentation.
- an increased proportion of the pool of rumen microbes flowing to the intestines (a reduced loss of microbial protein through degradation in the rumen)."

It appears that it can now be stated definitely that there will be more microbial and dietary protein available to the ruminant when protozoa are absent from the rumen. It follows therefore that in the absence of protozoa in the rumen there is an increase in the total protein available relative to the VFA produced and absorbed from the rumen. The improved P/E ratio will benefit the animal where it is fed diets low in true protein. In such a feeding situation, the increased P/E ratio will increase the efficiency of nutrient utilisation by the animal. Thus removal of protozoa or a decrease in protozoal density in the rumen can be expected to increase ruminant production under most feeding conditions pertaining to roughage fed ruminants (Leng, 1990).

Following considerable research that tested the above statements, research began about 1980 to seek natural defaunating agents.

THE SEARCH FOR ANTI-PROTOZOAL FORAGES

Research commenced with the establishment of a bioassay system to assess the effects of various additives on the viability of rumen protozoa in culture medium.

Culturing and maintaining protozoa *in vitro*

A stock culture protozoa isolated from the rumen was maintained *in vitro* in caudatum-type salt media using techniques of Coleman (1978) as follows:

Four Hungate roll tubes containing 3 ml of fresh media were prepared. To each tube of fresh media a mixed protozoal population was added. The cultures were fed daily with 0.1mg dry ground lucerne and 0.05 ml of corn starch suspension, 1.5% (w/v), the tubes were gassed with CO_2, sealed tightly with a rubber bung and incubated at 39°C. After three days, 3ml of fresh media was added to each tube, and culturing was continued for a further 4 days. After this time, cultures were examined for protozoal growth and were transferred to 50 ml conical flasks with 25ml fresh media. The daily amount of feed was increased to 1.5mg lucerne and 0.2ml of the starch suspension.

Four stock cultures were maintained in this way. These cultures were found to consist of mixed *Entodinia* spp., as other genera present in the original rumen fluid rapidly disappeared from the mixed culture.

From this point onward each stock culture was maintained by removing 15ml of the culture media every three days and replacing this with fresh media.

Anti-protozoal assay

60ml of protozoal culture was available twice a week for assaying material for potential anti-protozoal toxins. Protozoa were fed with the starch suspension and a mixture of the test forage and lucerne.

Assay of anti-protozoal effects of forages

A number of forages were obtained; these had been dried at 60°C and ground through a 1mm sieve. All samples were assayed, mixed with the lucerne and the nutrients added to the cultures daily. In most cases, the test forages were at levels to replace 1, 10 or 100% of the lucerne.

Fresh caudatum-type salt media was prepared and 8ml of media was added to each of a number of Hungate roll tubes which were incubated at 39°C for at least 1 hour prior to inoculation. To each tube, 2ml of well mixed stock culture was injected and fed with 0.1mg of the mixture of lucerne and test forage and 0.1ml starch (1.5 (w/w) suspension. The tubes were incubated at 39°C for three days. On the fourth day, a 1ml sample of well mixed culture was taken and added to 1ml of formal saline (10% (v/v) formaldehyde; 0.9% (w/v) NaCl), with a few drops of iodine solution. This solution (0.1ml) was placed on a microscopic slide and all the protozoa present were counted using a dissecting microscope at 40x magnification. The protozoa count multiplied by 20 gave the number of protozoa in 1ml of the original culture.

Results of the anti-protozoal assay

The number of protozoa cultured, when starch plus a fibre source of either 100% lucerne or 100% *Leucaena leucocephala* was included, were similar (3.5×10^3 respectively).

In preliminary studies, a sample of powdered leaves of *Lotus pendunculatus* and also *Acacia dealbata* showed anti-protozoal activity. The numbers of protozoa in culture were depressed by increasing the *Lotus* proportion of the forage source in the growth medium. *Lotus pendunculatus* foraget at 100% of the forage apparently killed all protozoa in the medium.

Anti-protozoal properties of forages

The results of assays of forages which showed anti-protozoal activity are shown in the following tables. Forages that stimulated protozoal growth, had no effect on the number of protozoa in culture, or inhibited protozoal growth are shown in Tables 1, 2 and 3 respectively.

TABLE 1. **Forages that apparently promote protozoal growth**

Name of plant	**Forage substitution rate for lucerne leaf powder in the substrate added to incubation medium**	
	1%	**10%**
	protozoa numbers as % of control	
Acacia leveocloala	121	109
Brachychiton australis	111	113

Casuarina cunninghamia	114	130
Albizia lebbeck	112	102
Commersonia bastramia	124	106
Desmanthus unantiem	112	114
Gliricidia sepium	113	138
Samanea saman	110	114
Casuarina cunninghamiana	123	130
Cajanus cajan	126	104
Desmanthus virgatus	112	108
Soya bean (Glycine max)	118	122
***Desmodium intortum* (green leaf)**	139	114
Centrosema viaginium	110	142
Macroptilium atropurpureum	112	121
Macroptilium lathyroides	111	114
Cassia brewsteria	112	115
Gejera parviflora	122	111

TABLE 2. **Forages with no effects on protozoal growth**

	Forage substitution rate for lucerne

Name of plant	leaf powder in the substrate added to incubation medium	
	1%	10%
	protozoa numbers as % of control	
Casuarina cristata	107	128
Alphitonia excelsa	108	123
Acacia excelsa	91	85
Acacia harpophylla	109	113
Brachychiton populeus	109	98
Acacia salicina	94	88
Acacia glavocarpa	109	143
Acacia bidwilli	107	108
Alphiltonia petriei	106	124
Albizia chimensis	108	90
Acacia harpophylla	102	110
Desmanthus virgatus	96	99
Sesbania sesban	107	130
Indigofera schemperi	98	97

Macroptilium lathyroides	95	73
Arachis hypogea	106	117

Identification of a potent anti-protozoal component in *Enterolobium cyclocarpum* leaf

Enterolobium cyclocarpum **was identified as the most likely forage to be used as a rumen manipulator. It was quickly established that all ruminants would consume the leaf materials after an initial introductory period. Over the next 6 years, a series of trials were carried out to test the value of *Enterolobium* spp. as a potential rumen anti protozoal agent and the response of animals to consumption of small quantities.**

PRODUCTION TRIALS USING ANTI-PROTOZOAL LEAF FORAGES

The following experiments illustrate the potential usefulness of this material in small quantities to stimulate ruminant productivity.

TABLE 3. **Forages with apparent anti-protozoal properties at 1% and 10% substitution rate for lucerne pasture of the in a culture medium**

Name of plant	**Forage substitution rate for lucerne leaf powder in the substrate added to incubation medium**

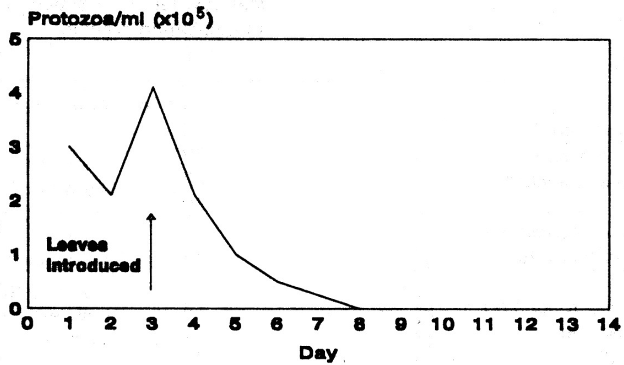
	1%	10%
	protozoa numbers as % of control	
Acacia deanei	38	79
Acacia crassa	38	74
Acacia semilunata	72	77
Acacia spectabilis	56	73
Acacia chinchillensis	75	103
Desmanthus intortum	63	73
Centrosema pubescens	78	84
Casuarina ronophlora	79	111
Black wattle	51	8
Fern leaf	81	97
Indigofera	75	75

schemperi		
Macroptilium lathyroides	88	100
Leucaena leucocephala	69	99
Vigna parteri	55	86
Lotononis bainesii	75	78
Desmodium uncinatum	78	108
Aeschynomena falcata	82	99
Cassia rotundifolia	88	106
Enterolobium cyclocarpum	0	0
Enterolobium timbouva	0	0

Enterolobium cyclocarpum: Anti-protozoal activity *in vivo*

Four rumen fistulated buffaloes in Indonesia (Batan) (350kg LWt) were fed cut/carry grass with minerals. Samples of rumen fluid were removed daily through the rumen cannula for 3 days prior to the commencement of feeding the leaf forage. The buffaloes were then given 500 g of fresh leaves (30% DM) daily for seven days. The effects of feeding the leaf material is shown in Figure 1. Although rumen protozoa were markedly depressed over the 7 days when these leaves were provided, protozoa were not removed totally and rapidly returned to normal densities in rumen fluid following cessation of feeding of the leaf material.

FIGURE 1. The effects of feeding 500g of fresh leaves from the tropical tree *Enterolobium cyclocarpum* to buffaloes given cut and carry grass in Indonesia



In India (CIRB, Hisar), a trial was conducted feeding young buffaloes on chopped wheat straw based diets. Dried leaves (375g) of *Enterolobium timbova* fed for 3 days apparently totally removed protozoa from the rumen but defaunation was not complete (or security failed) as periodically protozoa appeared in the rumen within one week after the cessation of feeding the leaf materials. In Australia, fistulated sheep were fed small amounts of *Enterolobium cyclocarpum* leaves at various rates in a diet of oaten chaff. The results on protozoal densities in the rumen indicated that *Enterolobium* leaf materials at 75 g/d could reduce protozoal numbers in rumen fluid to negligible numbers but that it was most difficult to remove them entirely and they returned to normal population densities within 4 days of cessation of feeding the leaf-meal. It was concluded that it was unlikely

that defaunation in ruminants would be effected by feeding the leaf meal from this tree.

Effects of leaf forage defaunation in buffaloes on productivity

No research has been reported of the effects of the presence of protozoa in the rumen of large ruminants fed poor quality forages. The potential for manipulating rumen protozoa and stimulating productivity is illustrated by research undertaken in the Central Institute for Research in Buffaloes, Hisar, India, which was carried prior to using the leaf meal as a potential rumen modifier.

Forty-eight Murrah buffalo heifers (average 105 kg live weight) were allocated to one of eight treatments (4 diets x 2 fauna states). Feed intake and live weight changes were monitored over a 106-day period. A basal diet of urea ensiled wheat straw, fresh green cut/carry grass (3 kg/day) and minerals was supplemented with groundnut cake (GNC) at four levels (g/day); 0, 250,500 and 750. The buffalo were defaunated by dosing with a surface active agent.

The fauna-free condition which was created by drenching the animals with a surface active agent (Bird and Leng, 1978) increased live weight gain and

improved feed conversion efficiency of heifers on all diets with the response being greatest in animals receiving the most GNC supplement (Table 4). Supplementing the basal diet with 750 g/day GNC increased the growth rate of the faunated animals from 220 g/day to 400 g/day (82%) and the growth rate of the defaunated animals from 263 g/day to 477 g/day (82%). A combination of defaunation and supplementation with 750 g/day GNC increased the growth rate of heifers from 220 g/day to 477 g/day (117 %).

TABLE 4. **Growth rate (g/day) and feed conversion (FCE) of faunated (+F) and defaunated (-F) buffalo given straw-based diets.**

Diet	Total DM intake (kg/day)		Growth rate (g/day)		FCE g DMI/g gain	
	+F	-F	+F	-F	+F	-F
Basal[a]	3.13	2.57	220	263	18.2	11.1
Basal + GNC[b] (250g/d)	3.16	3.08	277	370	12.9	9.8
Basal + GNC (500g/day)	3.50	3.24	360	434	10.1	8.2
Basal + GNC (750g/day)	3.48	3.14	400	477	9.8	7.2

[a] Basal ration: urea-ensiled wheat straw, green fed 3kg, minerals.

[b] GNC = Groundnut cake.

Continual re-infection with protozoa during the study period meant it was necessary to drench each heifer (on average) four times during the 106-day period. During each drenching treatment (2–3 days), feed was not offered and animals took several days to regain full appetite following treatment. Regular drenching therefore greatly reduced feed intake of the heifers in the fauna-free group indicating that the differences reported may be minimal.

Results from these studies clearly show that defaunation can improve ruminant production from straw-based diets. Unfortunately there is no satisfactory method currently available for defaunating animals under field conditions. In these studies a detergent (sodium lauryl diethoxy sulphate) drenched directly into the rumen was used to defaunate animals. This method is not suitable for commercial use. The application of this technology is therefore dependent upon the development of a specific anti-protozoal agent. An alternative approach using leaf material is still being tested. However, the testing has been restricted to sheep because of the quantities

of leaf material necessary to feed cattle.

Production of sheep given low quality forages supplemented with *Enterolobium* leaf material.

Cross-bred lambs, 10–11 months of age were dye-branded (technique for determining wool growth) while still in the paddock and then were individually penned in an animal house for 3 weeks prior to the experimental period. A pre-experimental rate of wool production was determined for all animals. Animals were divided into four dietary groups according to weight. The basal diet was oaten chaff (*ad lib*.), 1% urea and a mineral and vitamin mix. The experimental diets were:

1. **Basal diet (oaten chaff + 1% urea)**
2. **Basal + 125 g/d lupins (cracked)**
3. **Basal + 110 g/d lupins + (25 g/d) *Enterolobium cyclocarpum* (E.C.) leaves**
4. **Basal + (90 g/d) lupins + (75 g/d) *Enterolobium cyclocarpum* (E.C.) leaves (diets 2,3,4 were iso-nitrogenous)**

Bodyweight change was monitored over an 8 week period and wool growth over the last 6 weeks of the experimental period. There were 9 animals in dietary groups 1 and 2 but only 4 animals in groups 3 and 4 (there was

insufficient E.C. leaves to feed 9 animals/group). The results are shown in Table 5.

TABLE 5. **Effects of feeding *Enterolobium cyclocarpum* leaves (EC) on the rate of live weight gain and wool growth of lambs.**

	Dietary Group			
	Urea	**Lupins**	**Lupins + 25g/d EC**	**Lupins + 75g/d EC**
initial weight	35	35	34	34
Final weight	39	40	41	41
Oaten chaff intake (g/d)	876	853	909	901
Total intake (g/d)	896	894	1029	1021
Growth rate (g/d)	63	93	103	115
FCR (g feed/g gain)	14.3	10.6	10.0	8.9
Wool growth* (clean wool) (g/d)	6	7	7.5	8.8
Rumen protozoa popn. � 10^5/ml	3.1	202	2.6	3.1

* **Wool growth rates have been adjusted using pre-experimental wool growth as a covariate.**

Discussion of results with sheep

Supplements of EC leaves were readily accepted by sheep. There was no apparent detrimental effects of EC leaves on rumen function even to the extent that protozoal numbers in the rumen did not change. Intake of oaten chaff increased with the addition of leaf.

Supplements of EC leaves significantly increased the rate of body weight gain (24%) and wool growth (27%). These responses appear to be due largely to an improved efficiency of feed utilisation and therefore probably represent a change in the protein to energy ratio in the nutrients absorbed. The supplements (25 and 75 g/d) of EC leaves did not apparently alter the numbers of protozoa in the rumen, so it appears that the leaf had either altered the behaviour of the protozoa (making them more efficient) or affected some other (unknown) aspect of rumen function. This is an area that requires considerable further study to determine whether there are other effects of the leaf meal on the rumen protozoa.

DISCUSSION

Studies over a period of 15 years at the University of New England have shown that, on low true protein forage based diets in particular, removal of protozoa from the rumen of sheep and cattle and preservation of the fauna free state has improved animal productivity (see Bird *et al*., 1990; Bird, 1991). The increased productivity appears to be associated with a greater supply of essential amino acids from microbial protein but, where the basal forage is high in protein, extra dietary protein escapes the rumen for digestion in the intestines in fauna free ruminants (Ushida and Jouany, 1986). The increased amino acid supply appears to stimulate productivity of traits that are limited by amino acid supply such as body weight gain, wool growth and milk production. The improved P/E ratio in the nutrients absorbed increases the efficiency of feed utilisation for production.

The identification of a naturally occurring anti-protozoal forage that is relatively easily obtained in tropical countries or can be grown as a crop would open up new potential strategies for increasing animal productivity from poor quality forages.

In the research presented here, only a small range of the forages that are potentially available in tropical countries have been examined and there is a real need for a survey of different groups of plants. At the present time, the active ingredient in the forage has been identified and is being prepared as a single compound for use in many intensive animal production systems.

One of the important aspects of study concerns protozoal ecology in the rumen. It is apparent that many factors in the feed affect the capacity of protozoa to lower the P/E ratio in the nutrients absorbed. Perhaps protozoal activity can be modified by inclusion of other compounds in feed that have been identified through research. Bentonite, a clay mineral, has an overall effect similar to defaunation when added to the diet of sheep in small quantities (15–20g/d) (Fenn and Leng, 1990). In the studies now presented, sub-optimal levels of this anti-protozoal compound in the diet were almost as effective as the defaunated state in stimulating protein availability to sheep and increasing productivity.

SECONDARY PLANT COMPOUNDS IN TREE FORAGES

Secondary plant compounds are chemicals produced by plants that create an advantage for that plant in the ecosystem within which it has evolved. They are produced as protective agents in a number of plants to modify, limit or prevent damage to the plant against consumption or attack by insects, fungi bacteria, protozoa or grazing animals, and also may be produced to

reduce competition by other plants.

In recent times it has been suggested that some plants respond to invasive actions in stimulating an increased synthesis of particular secondary plant compounds which then decrease consumption of the plant by graziers.

It would be surprising that the wide variety of secondary plant compounds produced by a diversity of tree forages were all detrimental to ruminants. It could also be expected that, where forages have been components of the diet of ruminants, microbial diversity and genetic selection would provide the rumen microorganisms with the ability to modify or degrade these secondary compounds.

In the same way, with plants seldom consumed by ruminants because of location of growth, growth habit or taste, it would be surprising if they did not affect selectively or totally the growth of microbes in the rumen and that, where intake of such plants/compounds is controlled, there is great potential to manipulate rumen function.

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The role of multi-purpose trees in integrated farming systems for the wet tropics
by T.R. Preston

INTRODUCTION

Multipurpose trees play a critical role in the intensive integrated farming system based on sugar cane and developed by CIPAV (Preston and Murgueitio, 1992; Figure 1) in close cooperation with local farmers in the Cauca valley in Colombia. This system recognises that renewable biomass is the only sustainable source of fuel, feed and food, and that additionally it can be a medium for reversing environmental degradation.

The system is based on sugarcane which provides the carbohydrate feed (the juice and tops) and also fuel (the bagasse). Multi-purpose trees and water plants supply the protein and the trees play other important roles such

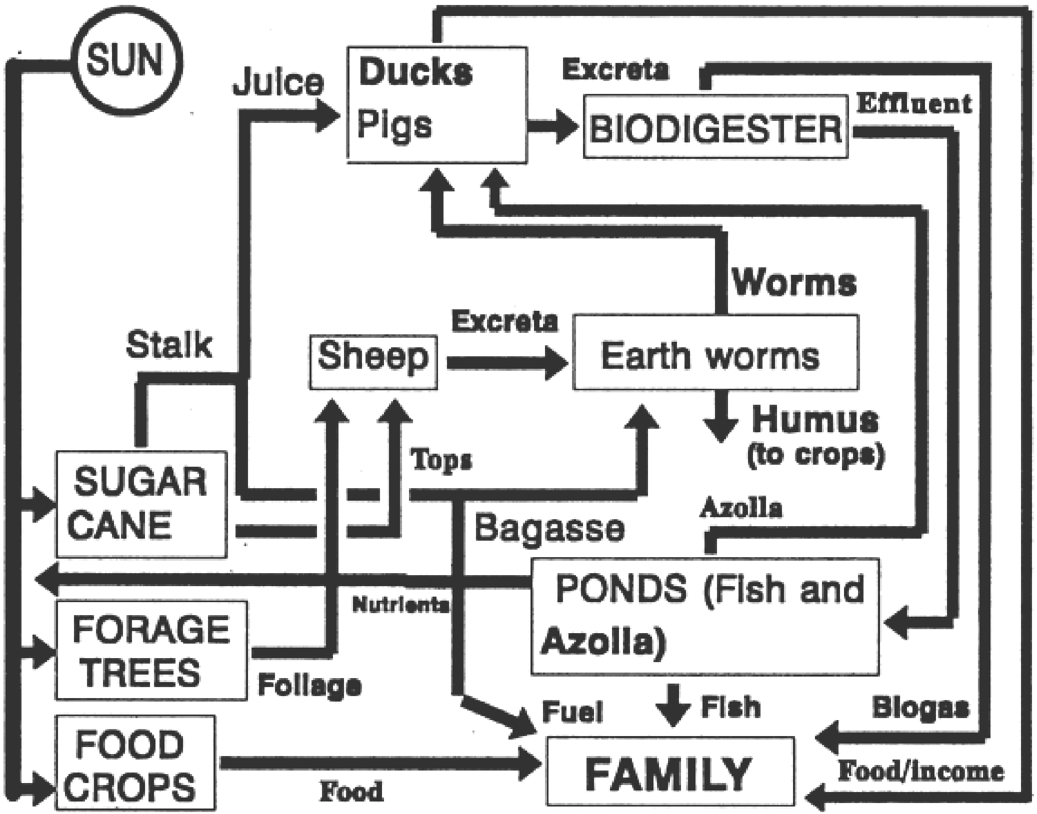
as controlling erosion, providing sinks for carbon dioxide (the standing biomass) and methane (at the interface between the decaying fallen leaves and the soil) and as a source of biodiversity. Sugar cane and trees have well developed systems of biological pest control, require minimum synthetic chemical inputs and are easily separated into high and low fibre fractions as required for the different end uses of feed for monogastric and ruminant animals and fuel.

The trees which have had most farmer impact are *Gliricidia sepium*, *Trichantera gigantea*, *Erythrina glauca* and *edulis.* The foliage from *Trichantera gigantea* is consumed by pigs; that from the other trees is more appropriate for ruminants.

The preferred animal species are pigs and ducks which adapt readily to the "non-conventional" high-moisture feed resources (cane juice, tree leaves and water plants) and have a high meat: methane production ratio. They are complemented by African hair sheep which derive most of their feed from the cane tops and tree foliage. Buffaloes and/or triple purpose cattle supply draught power as well as meat and milk. All the livestock are managed in partial or total confinement to minimize environmental damage and to maximise nutrient recycling to the crops.

The CIPAV model is flexible as witnessed by the increasing acceptance of many of the elements in the model by both resource-poor and entrepreneurial farmers.

FIGURE 1. The CIPAV Farming System.



THE ROLE OF MULTI-PURPOSE TREES

The role of multipurpose trees in this mixed farming system is as:

- **Sources of protein for pigs, ducks, sheep and buffaloes (the leaves)**
- **Substrate for gasification (the trunks and branches)**
- **As sinks for CO_2 (the standing biomass)**
- **Sinks for CH_4 (the decaying organic matter from fallen leaves and unused branches)**
- **As media for synthesis of ammonia through the action of symbiotic microorganisms attached to, or in free-living associations with, the root layer.**
- **To control erosion**
- **To provide construction material and firewood.**
- **The characteristics of multipurpose trees that are sought by farmers relate to the need to minimize inputs and maximise outputs. They require:**
- **High yield**
- **Ease of harvesting**
- **Resistance to pests and diseases>**
- **Animal response to minimal inputs**
- **Ease of establishment and management**

- **Availability of different species**

Monogastric animals

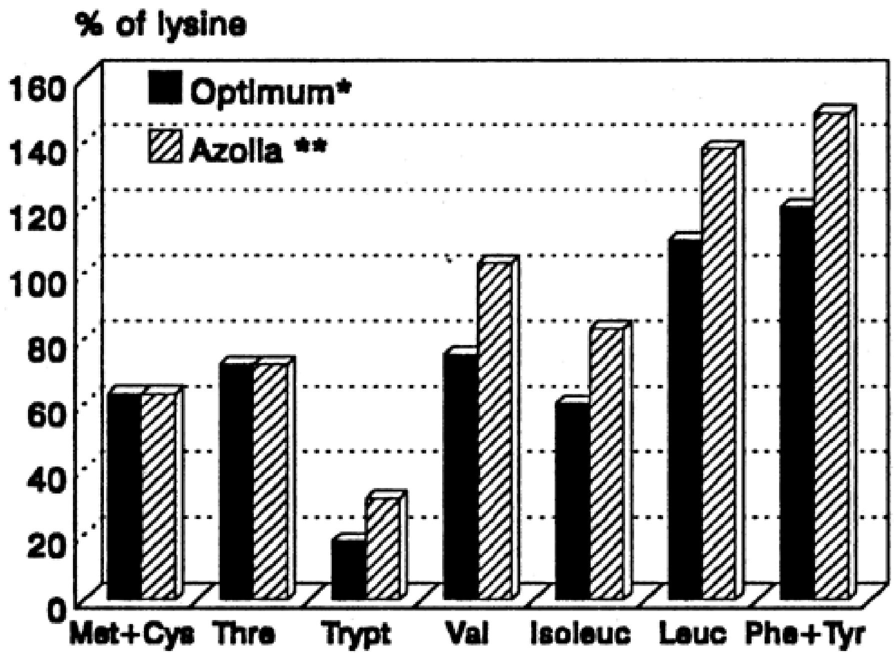
When monogastric animals are fed basal diets derived from tropical feed resources such as sugar cane, cassava, bananas, sweet potatoes or oil palm, the supplementary nutrients that are needed are protein, lipids, minerals and vitamins. The usefulness of tree foliages for these species will therefore be a function of their capacity to supply some or all of these nutrients.

The total protein needs of monogastric animals are reduced considerably when low-protein basal diets are fed. This is because the ratio of essential (EAA) to non-essential amino acids in protein supplements such as oilseed meals and tree foliages is close to the optimum. In contrast, when cereal grains are the basis of the diet, there is an inevitable over-supply of non-essential amino acids, and total protein supply must be higher in order to provide the required amounts of EAA.

The new approach to assessing the suitability of a protein supplement for a basic diet low in protein, is to calculate the ratios of each essential amino acid as a function of the amount of lysine, and to compare this with the

optimum determined from studies with synthetic amino acids (Wang and Fuller, 1989). On this basis, the aquatic plant *Azolla filiculoides* has an excellent balance of amino acids (Figure 2).

FIGURE 2. Amino acids in *Azolla*: comparison with optimum



Source: * Wang and Fuller (1989)
** Buckingham *et al.* (1978)

For ruminant animals, the need is for trees with high production of biomass and high content of protein in a form that will escape the rumen

fermentation. Thus the presence of moderate concentrations of tannins could be important as a means of 'insolubilizing' the protein. If the desired tree species is low in tannins, then another approach is to mix with it a species which has a high content of these substances. In order to achieve acceptable intake, tree forage is normally limited to 30% of the diet DM. High digestibility, good balance of essential amino acids and minerals and vitamins are also required from the forage.

Six species are presently being used in ruminant diets. They are:

- ***Gliricidia sepium***
- ***Trichantera gigantea***
- ***Erythrina glauca***
- ***Erythrina edulis***
- ***Acacia mangium***
- ***Prosopis juliflora***

The choice of a particular tree will be decided by climatic and soil considerations. Thus *Erythrina glauca* is specifically adapted to acid soils with a high water table, and a propensity to flooding. *Acacia mangium* is especially tolerant of acid soils saturated with aluminium. *Leucaena leucocephala* is not normally used as it is least tolerant of all the species to

acid soils. Where leucaena can be grown, it is outyielded by gliricidia, which is also more resistant to insect attack and is more easily harvested. The latter is important in "cut and carry" systems which is the usual practice on small farms.

GLIRICIDIA SEPIUM

The traditional way of establishing *Gliricidia* as a 'live' fence is by planting a stake in the ground. However, when the aim is to produce forage for intensive harvesting it is essential to develop it from seed. Survival of trees established from seed is much higher than when stakes are used (Figure 3). Production of biomass is higher when *Gliricidia* is established from seed (Figure 4). Biomass yields of *Gliricidia* are consistently high, especially when established at high plant densities. However, in practice, with only 50 cm between rows, harvesting is made difficult and present recommendations are to plant at 1 m between rows and 50 cm between plants.

It seems that the origin of *Gliricidia sepium* is in Guatemala. Certainly, there are differences among provenances according to where the seed was collected. The provenances from Guatemala and from Colombia seem to be the highest producers in the series of trials carried out in Colombia, using seed collected and provided by the Oxford Forestry Institute, UK (Figure 5).

FIGURE 3. Effect of plant density of method of establishment on survival of *Gliricidia sepium*

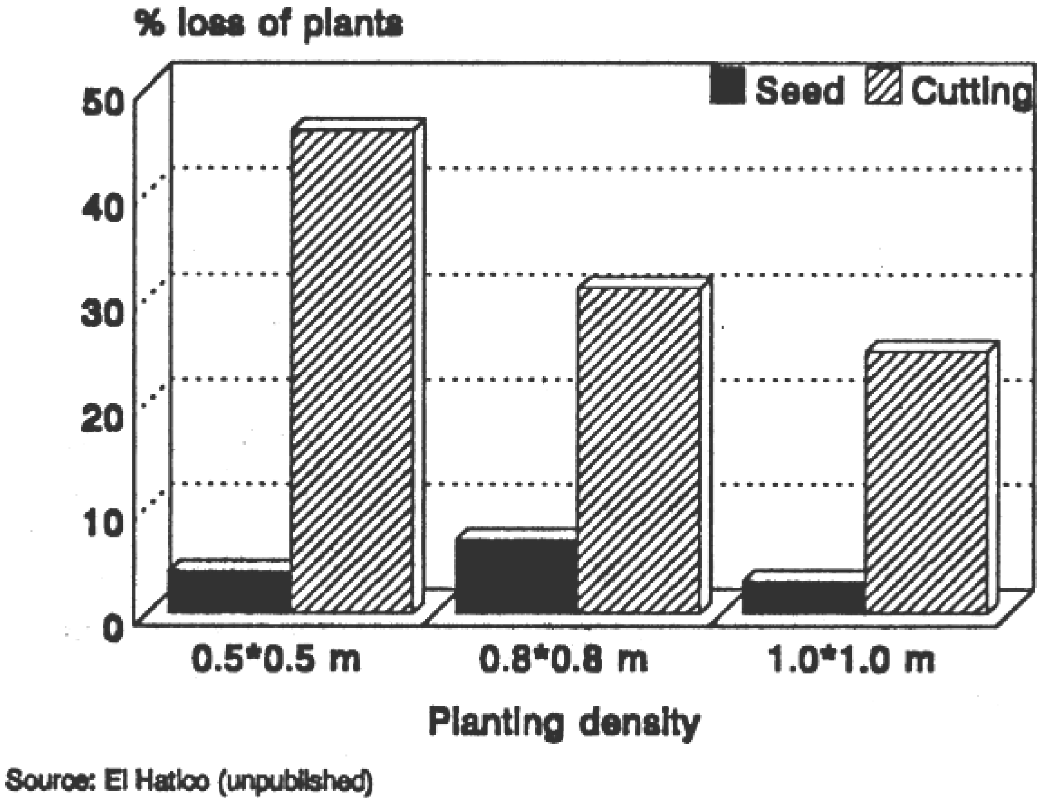
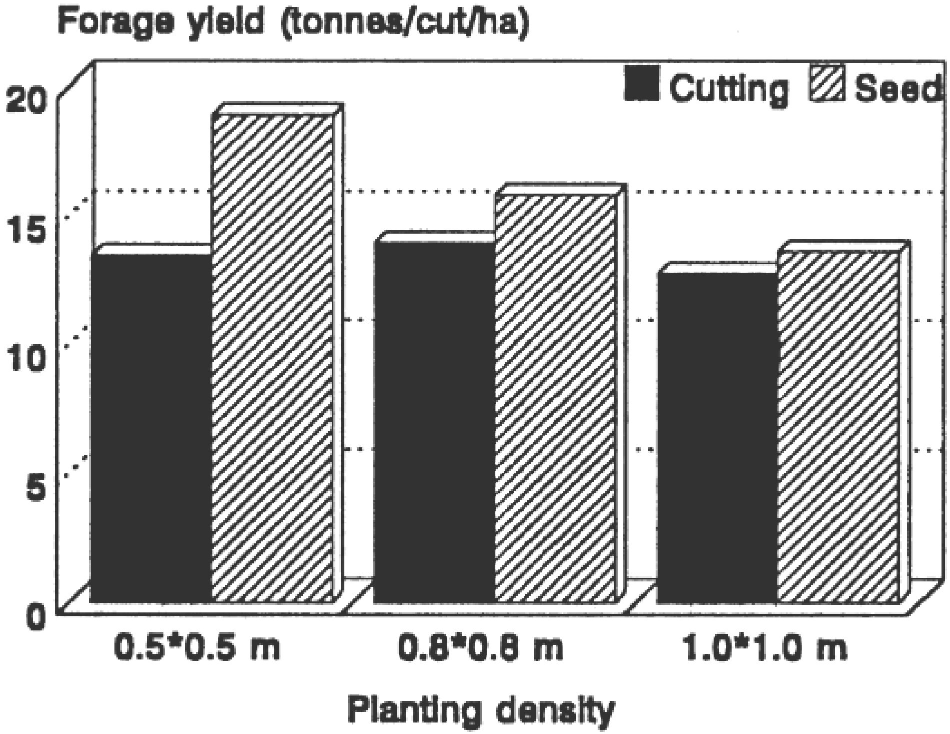


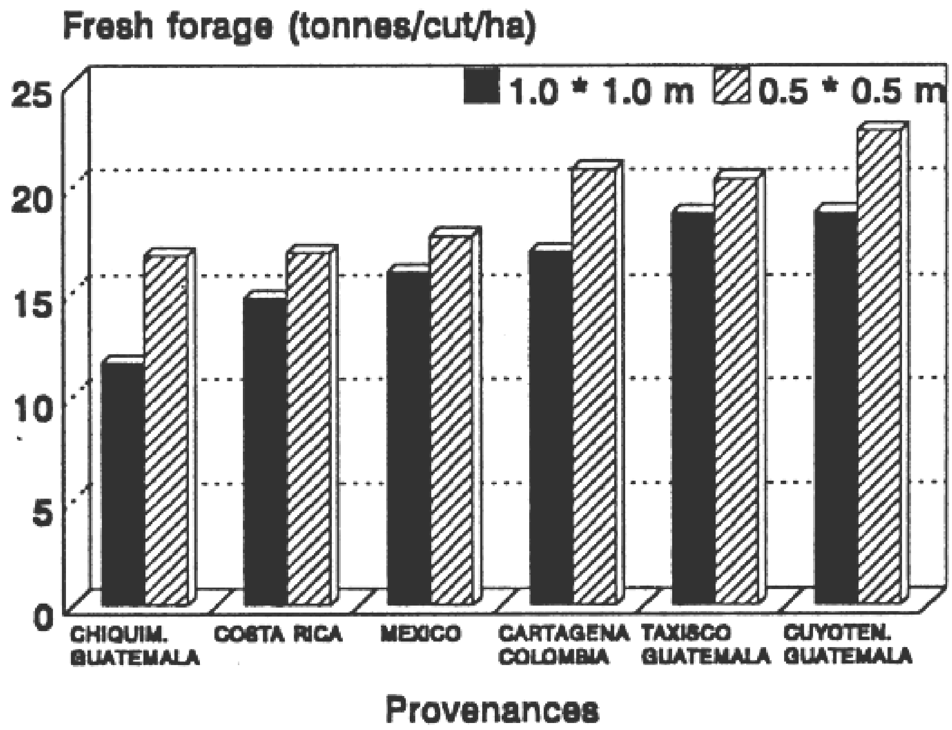
FIGURE 4. Effect of plant density of method of establishment on survival of

Gliricidia sepium



Source: El Hatico (unpublished)

FIGURE 5. Edible forage yield of six provenances of *Gliricida sepium* (total of 10 cuts at 3 month intervals).

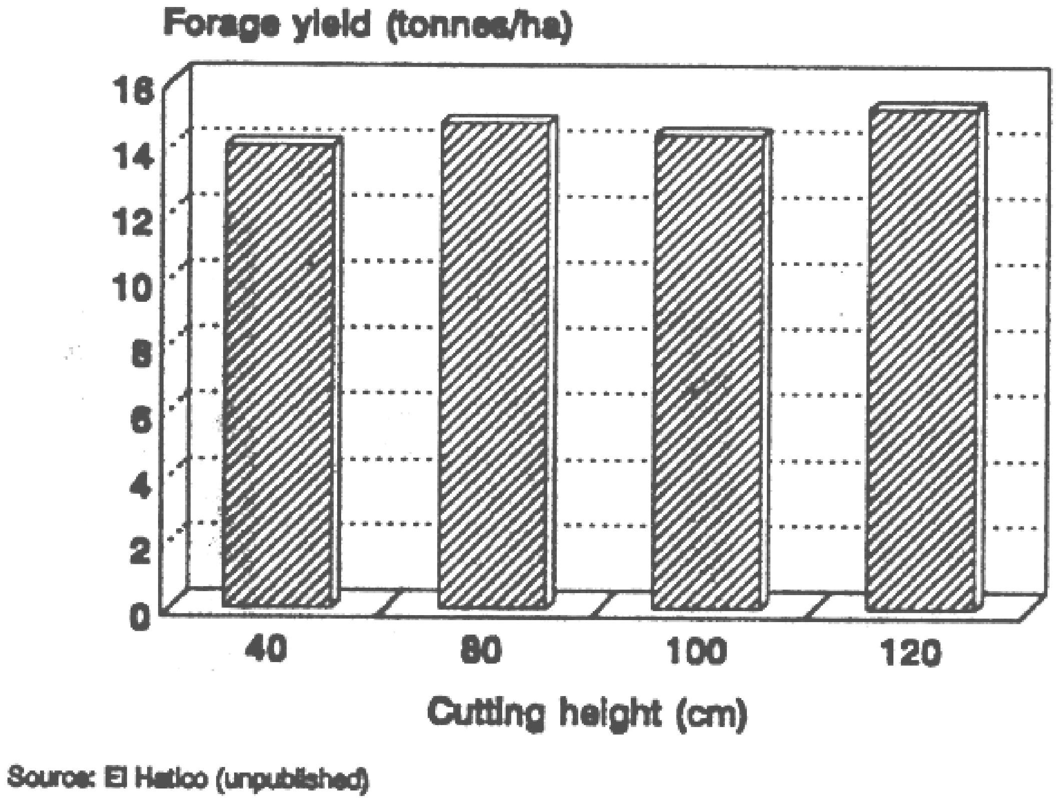


Source: El Hatico (unpublished)

The height above ground level at which *Gliricidia* is harvested has little

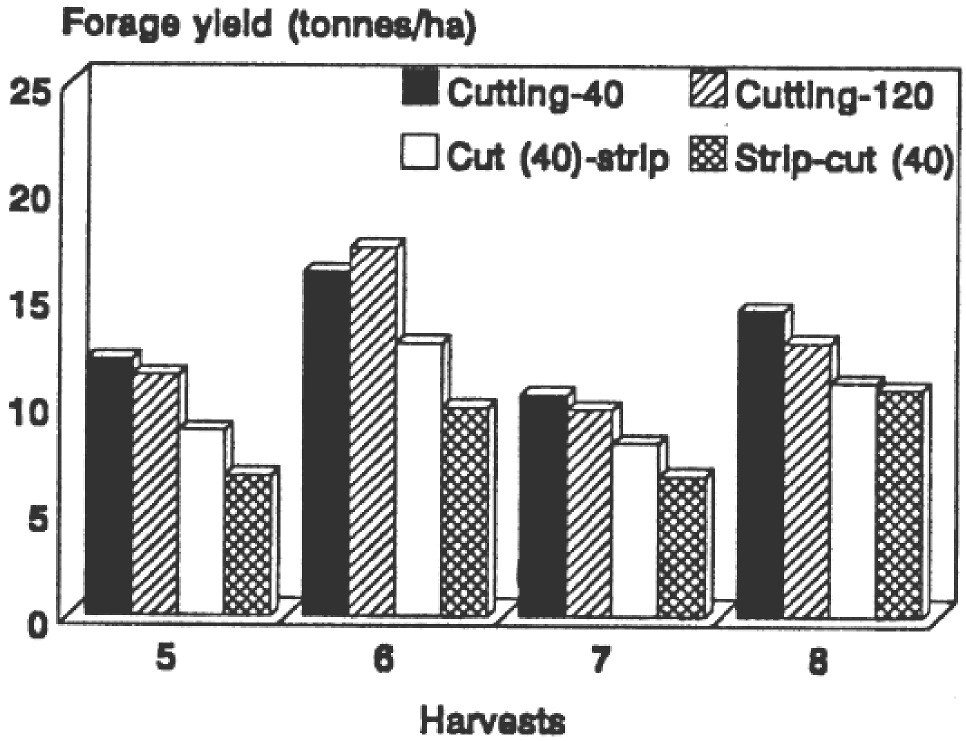
effect on biomass yield. However, it has been observed that cutting at about 1.2 m gives better weed control and is also more convenient for the person doing the harvesting (Figure 6). There are two ways of harvesting the foliage from *Gliricidia*. One is by cutting the branches with a knife or machete; the other is to strip by hand the leaves and petioles from the stems. The former is recommended as it stimulates the appearance of more buds which in turn results in a higher biomass yield (Figure 7).

FIGURE 6. Effect of cutting height on forage yield of *Gliricidia sepium.*



Source: El Hatlco (unpublished)

FIGURE 7. Effect of harvesting method (cutting vs. stripping) on forage yield of *Gliricidia sepium.*



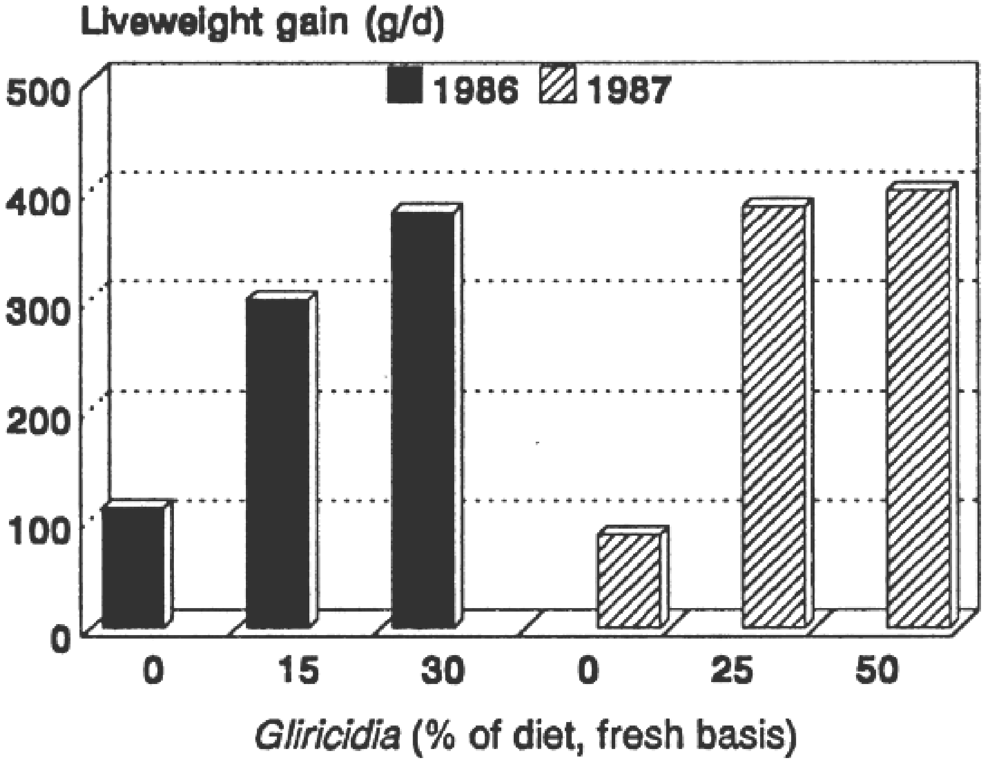
Source: El Hatloo (unpublished)

Nutritive value

Foliages from multi-purpose trees play a dual role in ruminant feeding. They help to provide an improved ecosystem in the rumen, which is reflected in increased microbial activity which in turn leads to an increased rate of digestion of the fibrous basal diet. In certain cases, especially when tannins are present in moderate amounts, the protein in the leaves may partially escape the rumen fermentation and contribute amino acids directly at the level of the intestine.

Gliricidia **foliage appears to provide bypass protein since there is a marked stimulation of growth rate when it is fed as a supplement to a basal diet of low digestibility, in this case King grass harvested during the dry season. In the experiment shown in Figure 8, growth rate of recently weaned calves responded to** ***Gliricidia*** **levels in the diet equivalent to 5% of liveweight.**

FIGURE 8. Growing steers on a King grass diet supplemented with ***Gliricidia*** **foliage.**



Source: ICA (see Preston and Leng, 1987)

Gliricidia **has proved to be an excellent supplement to a basal diet of sugar**

cane tops for African hair sheep managed in total confinement (Table 1). Levels of performance of the sheep fed cane tops, *Gliricidia* foliage and a mixture of poultry litter and rice polishings (9:1) together with urea-molasses blocks have been highly satisfactory (Table 2).

TABLE 1. **Mean values for the feed intake of a flock of tropical hair sheep (July to December 1990).**

Diet components	Fresh basis (kg/d)	Dry basis (%)
Gliricidia	0.777	9.3
Sugarcane tops	5.640	72.4
Multinutrient block	0.121	6.2
Poultry litter	0.204	10.6
Rice polishings	0.021	1.0
Total dry matter* (kg/d):		1.735
(proportion of live weight):		(0.045)

*** For a sheep unit (1 ewe of 25 kg and 1 lamb of 14 kg)Source: Mejía *et al.* 1991.**

TABLE 2. **Productivity and reproduction of the flock of African hair sheep**

(December to March 1991)

	Mean	Standard deviation	n
Live weight (kg)			
Birth	2.32	0.52	167
Weaning	14.90	2.62	84
Weight gain to weaning (g/d)	106	33.6	84
Age at weaning (days)	129	45.5	84
Lambing interval (days)	284	85.3	44
Litter size*	1.16		44
Lambs per ewe per year**	1.49		44
Mortality (% of all births)			
Perinatal	5.5		
Birth to weaning	10.4		

*** Number of lambs born per parturition**

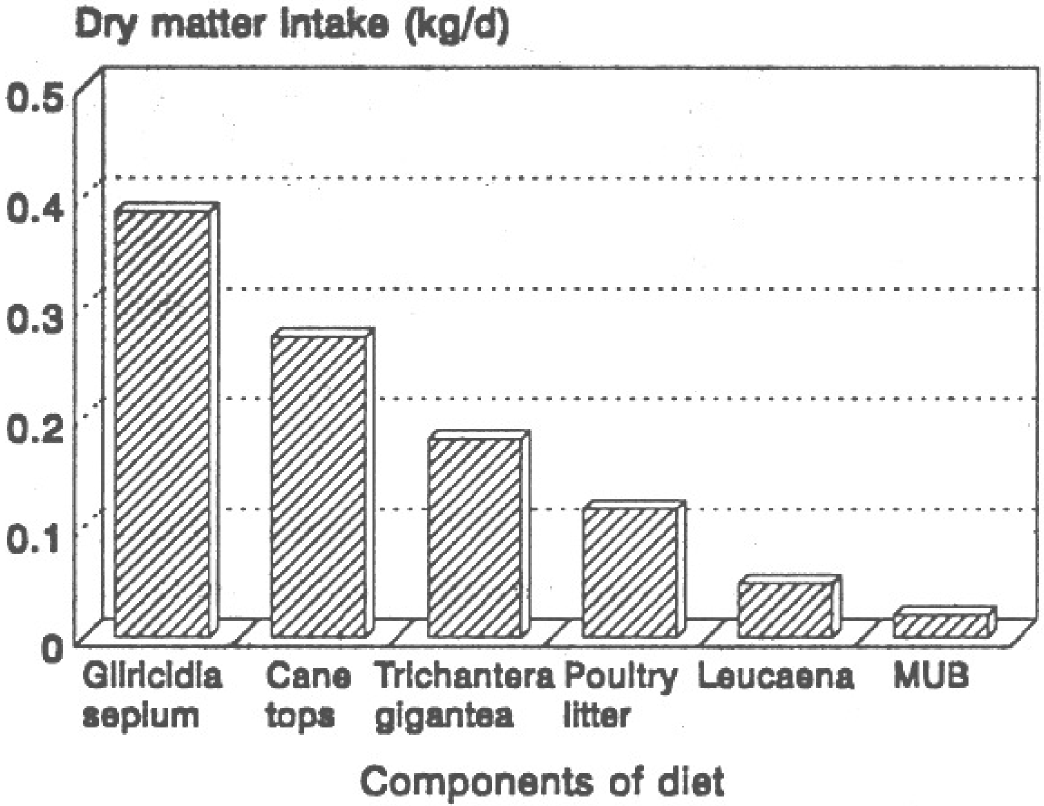
**** Mean number of lambs born per ewe per yearSource: Mejía *et al.* (1991)**

It is sometimes reported that *Gliricidia* is not very palatable even to ruminants because of the presence of secondary plant compounds. In this

trial with sheep, admittedly accustomed to previously to consuming *Gliricidia*, it was selected in preference to all the other feeds including *Leucaena*.

FIGURE 9.

Diet preference by sheep. (Cafeteria trial; 3 groups; 21 days).

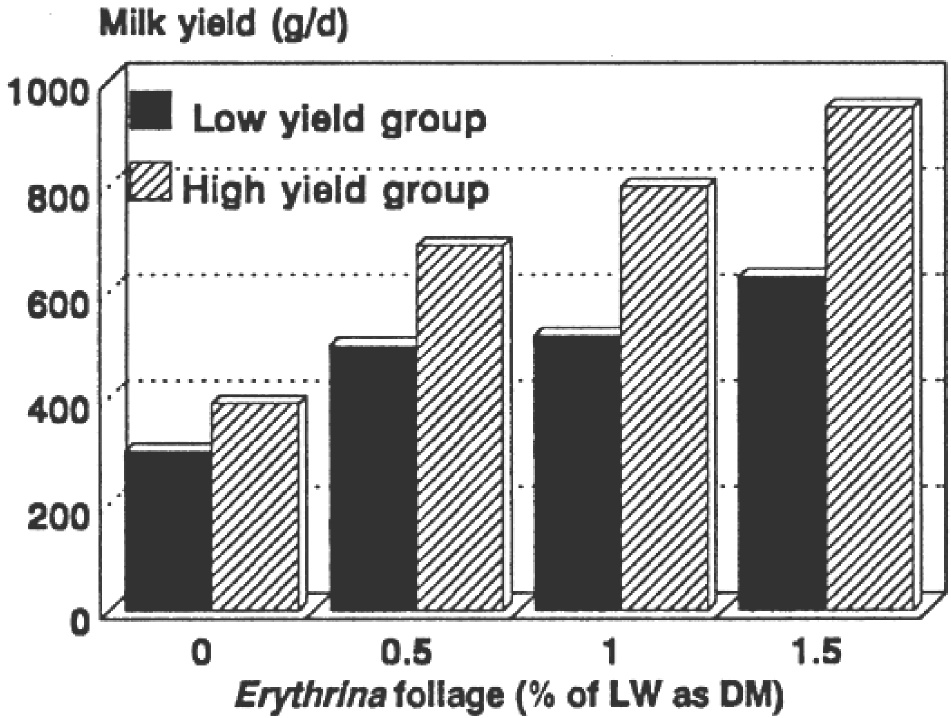


Source: Mejia et al. 1991

ERYTHRINA POEPPIGIANA

Goats fed a basal diet of King grass and reject banana fruit responded with linear increases in milk production when offered increasing levels of foliage of *Erythrina poeppigiana* (Figure 10).

FIGURE 10. Milk production of goats fed King grass. Effect of giving *Erythrina* tree foliage.



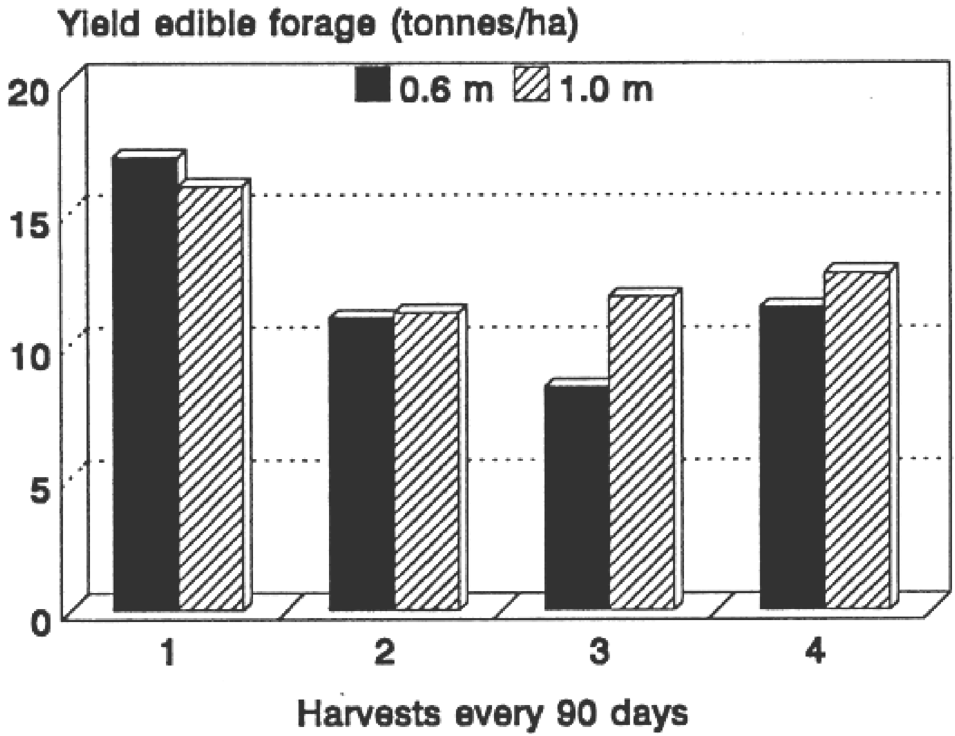
Source: Esnaola and Rios (1990)

TRICHANTERA GIGANTEA

This tree is native to the Andean foothills in Colombia. It is not a legume but its vigorous regrowth even with repeated cutting and without fertilizer applications indicates that nitrogen fixation occurs in the root zone either through the action of mycorrhiza or other organisms. Nacedero (*Trichantera gigantea*) responds in a similar way to height at cutting. The yield is slightly higher when it is harvested at about 1-1.2 m above ground level (Figure 11).

The advantage of this tree is that the leaves are consumed quite readily by pigs. Results from replacing 75 % of the soyabean meal in cane juice diets for pregnant sows have been very encouraging (Figure 12). Results with growing pigs have been less satisfactory. Performance was reduced at all levels of substitution of soyabean meal by *Trichantera* (Figure 13).

FIGURE 11. Cutting height and biomass (edible forage) yield of *Trichantera gigantea.*



Source: Gomez and Murgueitio (1991)

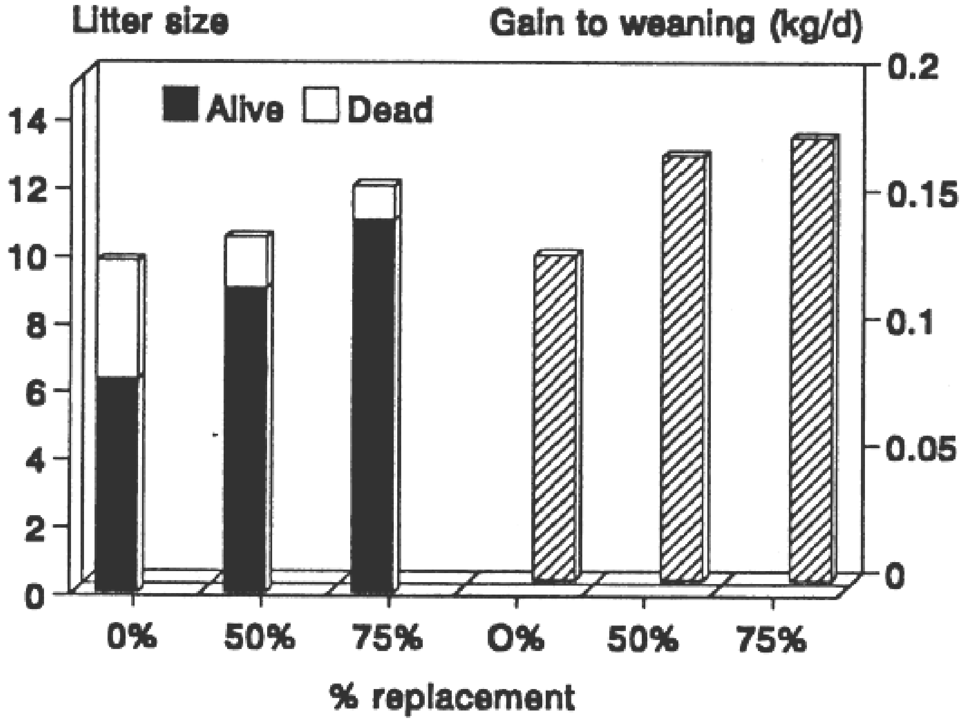
CHEMICAL TREATMENT OF TREE FOLIAGE

There are interesting possibilities for improving the digestibility of tree foliages by simple methods of chemical treatment. Ensiling with acetic acid has given promising results when applied to the foliage of *Trichantera* (Figure 14).

Ensiling can be used to neutralize other secondary plant compunds, as in this case the cyanogenic glucosides in the leaves of cassava (Table 3).

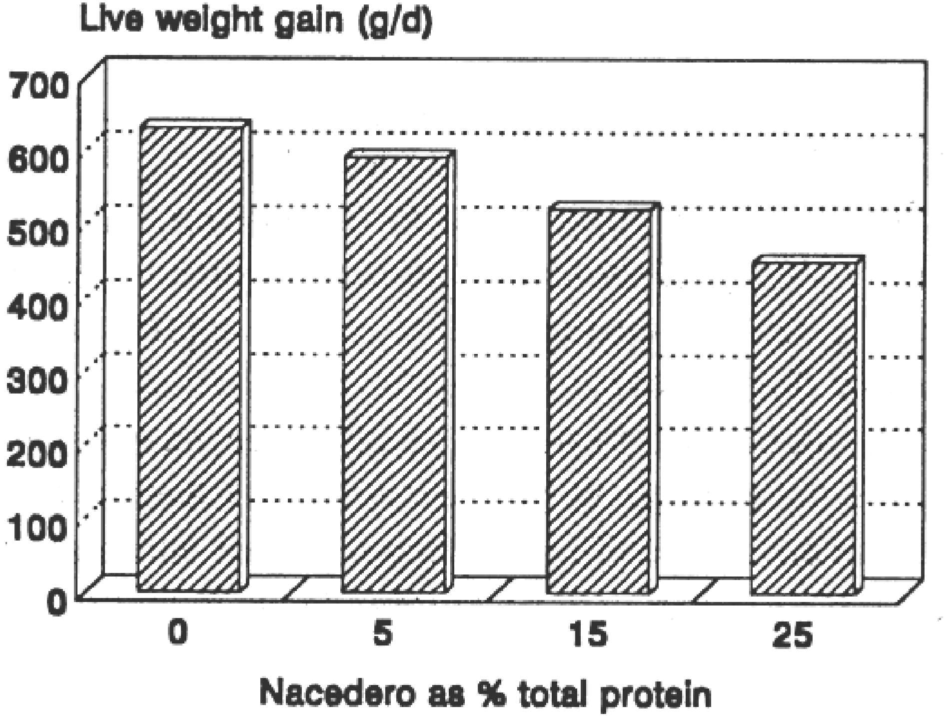
The treatment of tree foliage to improve their nutritive value, to remove secondary plant compounds and to enable the longer term storage of feed material is now a high priority for future research.

FIGURE 12. Foliage of *Trichantera gigantea* as replacement for soyabean meal in cane juice diets for pregnant sows.



Source: Sarria *et al.* (1991)

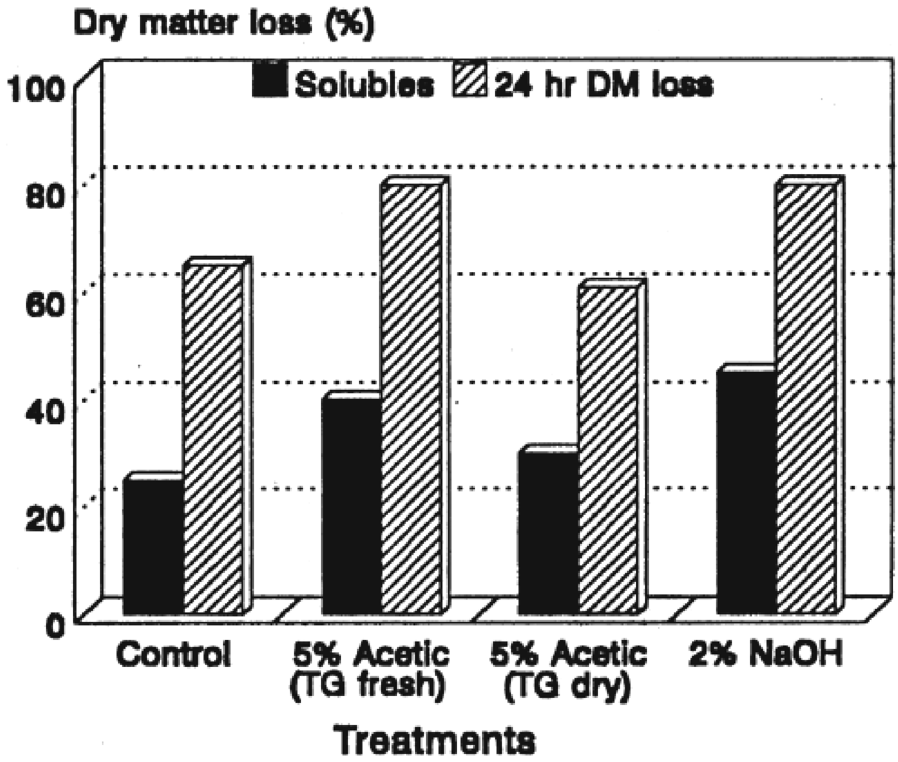
FIGURE 13. Foliage from Nacedero (*Trichantera gigantea*) as replacement for soyabean meal in growing pig rations.



Source: Sarria *et al.* (1991)

FIGURE 14. Effect of acetic acid and sodium hydroxide on degradability of

***Trichantera gigantea* (*in situ* rumen nylon bags).**



Source: CIPAV (unpublished)

TABLE 3. **Effect of ensiling or drying cassava leaves on HCN content**

TABLE 5. Effect of ensiling or drying cassava leaves on HCN content.

	HCN content (mg/kg DM)
Fresh cassava leaves	863
Cassava silage	33
After sun-drying for 4 hours	261
Sun-drying 4 hours then ensiling	32
After drying 2 days in shade	274
Drying 2 days in shade then ensiling	34
Dried cassava leaf meal	80

Source: Chinh *et al.* (1991).

CONCLUSIONS

Multi-purpose trees play an important role in an integrated system based on sugarcane, developed in Colombia. They provide feed for pigs, ducks and small ruminants (sheep and goats). Buffalo and triple purpose cattle are preferred to single-purpose beef or dairy cows. The use of renewable biomass also supplies a sustainable source of fuel and reverses environmental degradation.

The species include the legumes *Gliricidia sepium, Erythrina poeppigiana, E. glauca* and *E. edulis*, and *Trichantera gigantea* (family: *Acanthaceae*).

Plant survival and biomass production were highest when *Gliricidia* was established from seed, planted at 50 cm spacing with 1 m between rows. A number of provenances have been tested, of which the seed from Guatemala and Colombia were most productive. Cutting at a height of 1.2 m is recommended as the method of harvesting.

Gliricidia provides bypass protein for ruminants and is fed as a supplement to low-digestibility basal feeds (King grass and cane tops). Contrary to reports elsewhere, there were no problems of acceptability of *Gliricidia* to animals and sheep showed preference for this feed in a cafeteria trial. Good animal performance has been obtained with cattle and sheep.

Similarly, milk production of goats responded to the inclusion of *Erythrina* foliage in a diet of King grass and bananas.

Trichantera gigantea is a new candidate for inclusion in integrated systems and grows well with repeated cutting and without fertilizer input. Its particular value is as a protein supplement for monogastrics (pigs) and it has replaced up to 75% of soyabean meal in pregnant sow diets.

A future priority is the treatment of tree foliage to improve the nutritive value and remove secondary plant compounds.

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Role of fodder trees in Philippine smallholder farms
by F.A. Moog

INTRODUCTION

The majority of livestock in Asia are found on smallholder farms. In the Philippines, it is estimated that 80 percent of the cattle population is raised by smallholders while over 90 percent of buffalo and goats are also in the hands of small farmers. Dairy production remains underdeveloped but the small number of cattle and buffalo being milked are raised by smallholders, who individually sell their produce to milk buyers or through a government assisted milk-collection program. The sheep population is small (about 30,000) but interest in the animal is growing with a high level of acceptability on both small and large farms. The feeding of livestock on small farms depends primarily on forages which consist of weeds, crop by-products and tree fodder.

SMALLHOLDER FARMS

Table 1 and 2 show the limited resources available on smallholder cattle farms: farmers operate a small parcel of land and most of them cultivate less than 2 hectares. A very small proportion own more than 2 hectares. Animal holdings are few, with the majority of the farms keeping one head of cattle. Larger landholdings and animal holdings were observed in the village Pacifico, a sugarcane growing area, compared to other villages.

A survey by Alviar (1987) of 1,867 buffalo producers showed that 76% of them had farm areas of 3 hectares and below while only 24% had more than 3 hectares. In terms of animal holdings, 52, 29 and 19% own 1, 2 and 3 or more buffalo, respectively.

TABLE 1. **Farm size distribution (%) in four Philippine villages**

Area (hectare)	Village			
	Luyos	Galamay-Amo	Pacifico	Matipunso
Less than 1.0	42	22	33	40
1 – 1.9	42	48	48	14
2 – 2.9	6	20	15	15
3 or more	-	10	4	0

Sample farms (No.)	63	100	81	71

TABLE 2. **Cattle holding distribution (%) in four Philippine villages**

Village No. of Head	**Luyos**	**Galamay-Amo**	**Pacifico**	**Matipunso**
1	42	92	48	74
2	54	8	26	23
3 or more	4	-	36	3

TABLE 3. **Trees and shrubs species used as fodder on smallholder farms.**

Species		**Parts Used as Fruit/Feed**	**Other Economic Uses**
Common Name	**Scientific Name**		
1. Madre de Cacao (Kakawati)	***Gliricidia sepium* (Jacq.) Kunth ex Welp**	**Leaves**	**Shade, post, timber, hedge, fuelwood, driftwood for orchids**
2. Ipil-ipil	***Leucaena leucocephala* (Lmk) de Wit**	**Leaves**	**Shed, post, hedge, fuelwood**
3. Katuray	***Sesbania grandiflora***	**Leaves**	**Hedge, fuelwood, seed for handicrafts**
4. Acacia	***Samanea saman***	**Leaves and pods**	**Shade, timber for furniture**

(Rain tree)	(Jacq.) Merr.	Leaves and pods	and handicraft
5. Dapdap	*Erythrina* spp.	Leaves	Post, hedge
6. Malunggay	*Moringa oleifera*	Leaves	Vegetable
7. Nangka (Jackfruit)	*Artocarpus integra*	Unripe off-size/ small fruits; ripe fruit peelings	Fruit
8. Saging	*Musa paradisiaca* L.	Leaves/trunks and fruit peelings	Fruit (Banana)
9. Kadyos	*Cajanus cajan* (L.) Huth	Leaves, empty pods	Fuelwood, vegetable
10. Cowpea	*Desmanthus virgatus*	Leaves	Hedge
11. Bignay-pugo	*Antidesma* spp.	Leaves	Fruit for wine manufacture
12. Bignay-kalabaw	*Antidesma bunius* (L.) Spreng.	Leaves	Fruit for wine manufacture
13. Kalios	*Streblus asper*	Leaves	

13. Kalios	Lour.	Leaves	
14. Anunang	*Cordia dichotoma* Forst.	Leaves	Glue (fruit)
15. Niyog (Coconut)	*Cocos nucifera* L.	Frond stalks and leaflets	Juice (Young coconut), oil timber, broom, and fuelwood rum, vinegar
16. Palsahingin	*Canarium asperum* var. sementis Bth.	Leaves	

COMMON FODDER TREES

Fodder trees are grown naturally on smallholder farms and are an integral part of the farming system. Most of the identified fodder tree species are not primarily grown for fodder but for other purposes. Table 3 lists the tree species commonly found and used (some of them occasionally) as fodder in the Philippines. Most of the species had economic values other than fodder but being grown for such purposes makes them readily available for livestock feeding. Utilization of these species is still very limited and is confined to areas of livestock concentration and intensive crop production

systems. In most areas, they are hardly used as a source of fodder. Ipil-ipil (*Leucaena leucocephala*) has been the most popular of the fodder. tree species but its extensive use as fodder is confined in Batangas province. *Gliricidia* is more versatile than Ipil-ipil in terms of actual farm use, particularly as shade for black pepper, coffee and cacao. It has a wider distribution than any of the other species. Its major drawback is that it is not highly acceptable to cattle but, for sheep and goats, such a limitation is not observed. *Sesbania grandiflora* is commonly found in rice growing areas of Central Luzon. It is grown on roadsides and the perimeter of gardens. It is more popular for its inflorescence, which is used as a vegetable, than for its value as source of fodder. *Sesbania* is one of the species identified as an alternative to Ipil-ipil and has been introduced into upland areas of Batangas where psyllids have caused serious damage. It cannot be compared to Ipil-ipil in terms of palatability to cattle, but farmers report that it is relished by goats. (Most farmers in Batangas prefer raising cattle to goats).

The rain tree (*Samanea saman*) is commonly grown for shade but it is also grown on rice farms where, every year during the dry season, it is cut for fuelwood but not fodder. In Batangas, its leaves and pods are used for cattle feeding during the dry season.

The use of *Erythrina* is almost confined to live fence-posts. It is highly palatable to goats.

***Moringa oleifera* is popular for its leaves as vegetables. The tree is pruned regularly (30–45 days) and the leaves are sold in the market. The leaves are cooked for soap and highly recommended for nursing mothers because it is claimed to be very nutritious. One advantage of this species over the rest is that it is easily propagated from stem cuttings (as well as from seed) with a very high survival rate; it is relished by sheep and goats.**

The rest of the species are seldom used but when feed shortages are encountered they have their own value. Except for coconuts, which are found on most farms, other species are just allowed to grow without consideration of due agronomic management practices.

UTILIZATION OF FODDER TREES

In general, the value of fodder trees in the villages are confined during the dry season. Table 4 shows the months when high and low utilization of fodder trees occur under different upland cropping systems.

TABLE 4. **Periods of high and low utilization of fodder trees in different**

cropping systems and villages (Philippines).

Cropping system/village	High utilization		Low utilization	
	Months	Componentin feeds(% daily)	Months	Component in feeds (% daily)
Batangas Province				
Rice/Corn (Galamay-Amo, San Jose)	March to June	27.2	July to Feb.	4.6
Rice/Corn/ Sugarcane	March to July	21.6	August to Feb.	15.6
(Luyos, Tanauan)				
Sugarcane (Pacifico, Sta. Teresita)	April to May	17.2	June to March	5.4
Quezon Province				
Coconut	December to June	36.9	July to November	3.1

(Matipunso, San Antonio)	to June		November	

In rice/corn growing areas, fodder from trees is valuable from March to June, at the height of the dry season, during the planting season and the onset of the rainy season. Less fodder from trees is used in sugarcane cropping areas compared to the other 3 cropping systems. This is explained by the availability of sugarcane tops in the area where harvesting of cane occurs just before and during the dry season. Increased use of fodder trees occurs in April and May, at the end of the cane harvest period. With a combined cropping system, utilization of fodder trees is more uniform throughout the year and is less during the dry season compared to that of the rice/corn cropping system.

Fodder trees are even more valuable in coconut growing areas. A greater amount of tree fodder (36.9%) is fed for a longer period (seven months). Less biomass is available under coconuts for feeding livestock, compared to areas planted to cultivated annual crops.

Tree fodder as a supplement to crop by-products

For more than a decade, a lot of studies have been carried out on *Leucaena*.

Marbella *et al*. (1979) reported that feeding cattle on rice straw with 50% Ipil-ipil gave an average gain of 520g/day, while supplementation of 40% Ipil-ipil and 10% concentrate produced 720g/day. However, considering the cost of the concentrates, the value of the extra 200g is not enough to pay for the cost of the concentrates and Ipil-Ipil supplementation alone is more economic.

Observations in Batangas showed that farmers feed their cattle with 5 to 20kg of Ipil-ipil. Estimates indicate that those feeding 15 to 20kg of Ipil-ipil, plus fresh grasses obtained an average daily gain of 800–900g.

A recent study by Medrano (1991) showed that farmers feed intake and live weight gain (LWG) of sheep increased with increasing levels of *Gliricidia*. Sheep fed 80% *Gliricidia* + 10% rice straw + 10% *Setaria* gave the highest adjusted LWG (49.7g) which was significantly better than those receiving lower levels of *Gliricidia* and 20% concentrate. The lowest LWG (20.4g) was obtained in sheep fed concentrate + 70% rice straw + 10% *Setaria* (Table 5). A ration containing 80% *Gliricidia* had the highest efficiency.

TABLE 5. **Live weight gain and feed efficiency of sheep fed varying levels of *Gliricidia* in combination with rice straw and setaria.**

	TREATMENT/RATION

PARAMETER	A 20% CON 70% RS 10% SS	B 20% GLI 70% RS 10% SS	C 40% GLI 50% RS 10% SS	D 60% GLI 30% RS 10% SS	E 80% GLI 10% RS 10% SS
Number of animals	4	4	4	4	4
Feeding duration, days	63	63	63	63	63
Initial weight, kg	12.2	11.6	11.5	12.9	13.1
Final weight, kg	13.5	12.7	13.2	15.3	16.6
Live weight gain					
Total gain kg	1.27^{cd}	1.10^{d}	1.76^{c}	2.41^{b}	3.43^{a}
LWG g/day	20.2^{c}	17.5^{c}	28^{b}	38.3^{b}	54.4^{a}
Adjusted LWG g/day	20.35^{b}	21.15^{b}	32.32^{ab}	34.82^{n}	49.70^{a}
Feed Efficiency (FE)	20.7^{b}	22.1^{ab}	16.2^{ab}	12.7^{ab}	10.7^{a}
Adjusted FE	20.67^{b}	20.31^{ab}	14.13^{ab}	14.27^{ab}	12.89^{a}

Means in the same row with different superscripts are significantly different ($P<0.01$).

Legend:
CON - Concentrate
GLI - *Gliricidia*
RS - Rice Straw
SS - *Setaria splendida*
Source: Medrano (1991)

Recent study in the BAI (Navarro, unpublished) showed that sheep fed sugarcane tops (*ad lib.*), supplemented with 500g fresh Kakawati leaves + 100 grams copra meal had an average daily gain of 35g.

SUMMARY AND CONCLUSIONS

A range of fodder trees is available on smallholder farms but their value and utilization is limited to areas of high livestock concentration. Fodder from trees is very valuable in upland farming systems particularly during the dry season. The use of tree fodder is quite limited in sugarcane farming systems, except after the end of cane harvesting. A larger amount and longer period of fodder tree utilization is observed in coconut farming system.

Better animal performance is observed with increasing levels of tree fodder

in animal ration. The use of other fodder trees may have limitations in terms of palatability for cattle but not for sheep and goats.

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Feeding systems based on the traditional use of trees for feeding livestock

by D.V. Rangnekar

INTRODUCTION

The critical role of trees and shrubs in livestock production in developing countries is now well recognised by the scientific community, (Nagarcenkar, 1983; Devendra, 1989; Swaminathan, 1989). A large number of species have been evaluated and work in India has been reviewed by Singh (1984).

Trees and shrubs have acquired a special place in semi-arid and rainfed areas due to their better tolerance of unfavourable soil-moisture conditions. We find species of *Prosopis, Acacia, Salvadora*, etc., remaining green during long dry spells, as well as withstanding several weeks of flooding.

Rajasthan, Madhya Pradesh and Gujarat states, where the studies under discussion were carried out, are bordered by a range of hills with forest cover (most of which is denuded) on one side and large semi-arid areas on the North western side, with high salinity and alkalinity. The hilly areas are inhabited by tribal people described in colonial times as “sons of forest”. This community used to sustain itself on the forest products in the past and

the people have a strong affinity for trees, which have provided them with shelter, fuel, fodder, food and fruits. Many parts of north Gujarat and west Rajasthan have large semi-arid areas where there is a large population of traditional cattle breeders, comparable to pastoralists in other countries. They keep large herds of cattle or goat and sheep and many are typically nomadic. Crop production is not reliable due to frequent rain failures. Farmers also keep larger herds maintained on crop residues, trees and bushes. Amongst the tree species only a few species thrive.

It is no wonder that trees have a special place in the socio-cultural structure of our society, besides being an important resource. The teachings in our ancient scripts, like Upanishadas (Ishavasya or the Dashavaikalika Sutra of Jains), emphasise the importance of trees. During the Indus valley period, from 4000–3000 B.C., we find official seals showing the worship of tree divinities. Reverence for trees is expressed in various observances, which involve the worship of trees of *Ficus* species (*religiosa* and *bengalensis*). The trees have also been linked with penance, education and religious activity. Trees feature predominantly in paintings of Gods like Shiva, Krishna and of Buddha. The story of Bishnois, from the plains of Rajasthan, resisting the felling of *Prosopis cineraria* by the king is famous in India. The tribal people from the hills of Gujarat, Madhya Pradesh and Maharashtra States

will not cut *Bassia latifolia* (local name Mahuva). Linking anything useful with religion is typical of Indian culture.

TRADITIONAL PRACTICES AND FARMER-ORIENTED DEVELOPMENT PROGRAMMES

Livestock development is one of the major rural development programmes in India. However, many have pointed out that its impact in underdeveloped areas and with backward communities have been very limited (Mishra and Sharma, 1990; Vaidyanathan, 1989). Such communities change slowly, since cannot afford to take risks, subsistence is their priority and they have strong faith in traditional methods, which have been tested over time. Crop scientists have already realised the need to study and understand traditional methods and farmer perceptions but very limited efforts have been made by animal scientists in this regard. McCorkle *et al.* (1989) and Nolan *et al.* (1989) have reported useful studies of indigenous knowledge and traditional practices in development and extension programmes.

Through various development programmes, more productive livestock are being provided or the existing livestock changed by cross-breeding. There is a need to develop farmer-friendly and beneficial extension and training programmes in order to help livestock owners to get best out of the

improved animals. It was therefore decided to critically study the following aspects to obtain a clearer understanding of the overall situation:

1. **Traditional management and feeding systems for dairy animals.**
2. **Productivity of dairy animals.**
3. **Involvement of women in dairy production.**
4. **Farmer perceptions, views, indigenous knowledge and real objectives regarding livestock.**
5. **Feed resources.**

The traditional feeding systems, particularly in tribal areas, make maximum use of local resources like crop residues, tree leaves, pods, seeds, etc. (Pradhan *et al.* 1991). Milking animal are provided with somewhat better quality feeds. Feed mixtures are usually offered after soaking or cooking. Feeding of animals is invariably by women and they are well aware of the habits of each animal (Rangnekar S.D. *et al.*, 1991a and b). The farmers have identified feed materials which are claimed to be beneficial for improving the quantity and quality of milk. Farmers classify feed as very good, average or bad, on the basis of its palatability and visible effects on quality and quantity of milk, unlike researchers who look mainly at chemical analysis (Rangnekar, 1991). The traditionally preferred materials like cotton seed, cotton seed

cake and coconut cake are now recognised as sources of undegradable protein. Thus some of the traditional systems are comparable to the so-called modern approaches of strategic supplementation, rumen manipulation, etc. (Rangnekar D.V. *et al.*, 1991).

Animal owners traditionally use tree leaves, bushes and creepers for feeding animals. Besides the leaves, they make extensive use of the flowers, pods and seeds of some trees as feed supplements. The use varies with season, depending on availability. In some cases the choice of tree varies with species of animal (see Tables 1 and 2).

TABLE 1. **Relatively uncommon plant species traditionally used by livestock owners in tribal and semiarid belt in north east and north of Gujarat.**

Plant species	Area	Nature of Plant	Parts used	Crude Protein content (% DM basis)
Ailanthus excellsa	North Gujarat	Large tree	Leaves	16 to 19
Alangium salvifolium	East Gujarat	Medium size tree	Leaves	20 to 22
Anogeissus latifolia	East Gujarat	Medium size tree	Leaves	9 to 11

Bassia latifolia	East Gujarat	Large tree	Leaves, flower & fruit cover.	8 to 10
Dichrostachys cinerea	East Gujarat	Medium size tree	Leaves to cattle	17.0
Diospyros melanoxylon	East Gujarat	Medium size tree	Leaves	7.8 to 8.0
Maytenus emerginata	East Gujarat	Medium size tree	Leaves	7.8
Morinda tomentosa	East Gujarat	Evergreen large tree	Leaves	22.9
Salvadora oleoides	North Gujarat	Large tree	Leaves	10.0
Salvadora persica	North Gujarat	Large tree	Leaves	11.0
Tinosperma cordifolia	East Gujarat	Creeper	Leaves Stem	8.5
Ventilago denticulata	East Gujarat	Creeper	Leaves	12.0

(Well known species of *Acacia, Albezia, Azadirachta, Prosopis*, etc. not

included)

Many tree leaves, flowers and pods are identified as useful for improving milk production, milk fat, body condition and for the induction of oestrus. Table 2 lists such material and only such claims as made by a large number of farmers from many villages are considered. These have been observed and recorded by extension staff over a period of 2–3 years. Some of these approaches are comparable to strategic supplementation recommended by Devendra (1988).

TABLE 2. **Use of uncommon plant species in traditional feeding: season of use and benefits claimed for livestock production.**

Plant species	Season of maximum use	Type of Animal	Benefit claimed
Ailanthus excelas	All year round	Goat Cattle	Improvement in milk production
Alangium salvifolium	December to June	Cattle Buffalo	Improvement in milk yield & fat%
Bassia latifolia (flower)	April to June	Cattle Goat	Improves milk yield
Morinda tomentosa	November to June	Cattle Buffalo	Improves milk yield

Maytenus emerginata	February to June	Cattle Buffalo	Improves fat % in milk
Prosopis cinereria (leaves & pods)	Whole of the year	Cattle Buffalo Goat	Improves/maintains milk production
Tinosperma cordifolia (creeper)	July to November	Cattle Buffalo	Improves milk production
Ventilago denticulata (creeper)	July to November	Cattle Buffalo	Improves milk production

In some areas of Rajasthan and Gujarat, there is an established tradition of preparing leaf meal from *Prosopis cinereria* and conserving it for use in summer. Flowers of *Bassia latifolia*, commonly known as Mahuva, are dried and stored for feeding bullocks and milk producing animals. These flowers are rich in energy and are also used as human food in times of scarcity. Conservation methods are adopted by farmers wherever they are found useful.

Two creepers, *Ventilago denticulata* and *Tinosperma cordifolia* were found to have widespread popularity because of their beneficial effect on milk production. They are specially gathered and sold in small towns for use as supplements for milk producing animals.

Pods and seeds of trees species of *Prosopis* and *Acacia*, are used as supplements or as part of concentrate mixtures. The pods are known to be rich in protein and energy.

DEVELOPING FEEDING SYSTEMS

Conventional approaches of advising livestock owners to use balanced concentrates, cultivate high quality fodder crops and feed according to recommended standards have not been very successful. We learnt through experience and various studies that small changes in traditional systems, using familiar materials and methods are more readily acceptable. Traditions are based on long experience and farmers have more confidence on their own experience. It was therefore decided to try to develop feeding systems on the basis of what we learnt from farmers, taking a participatory approach and studying there methods whenever necessary. Some of the aspects have been reported earlier by Rangnekar *et al.* (1991). The steps can be described as:

- i. **Detailed study of the system (already described above).**
- ii. **Identification of beneficial material (Table 1 and 2) and selection after validation of claims.**
- iii. **Literature search for available information and study material (including**

favourable and anti-nutritional factors) which may be scanty or lacking.

iv. Study of feed resources - home grown, community resource, purchase and quantities fed and animal productivity.
v. Work out nutritional status on the basis of information gathered.
vi. Suggest changes in feeding on basis of the finding giving preference to local material and in consultation with farmer.

Initial results of the attempts at developing farmer friendly and farmer beneficial feeding system. The results of studies in different districts are summarised in Table 3. They indicate protein availability to be the major constraint.

TABLE 3. **Intake and availability of nutrients.**

Centre	Season		Marginal			Small	
			CP	TDN		CP	TDN
Asind	M		1.0	7.0		0.96	6.5
			(1.1)	(5.1)		(0.94)	(4.6)
	S		0.7	5.1		0.79	5.1
			(1.0)	(5.0)		(1.05)	(5.0)
	W		0.69	4.8		0.72	4.8

				(1.00)	(4.9)	(0.99)	(4.8)
Shahpura		B		S		M	
		CP	TDN	CP	TDN	CP	TDN
	M	1.1	5.3	1.1	5.2	0.69	4.6
		(1.3)	(5.6)	(0.96)	(4.6)	(0.72)	(3.7)
	S	1.1	4.9	0.81	4.8	0.61	4.4
		(1.4)	(5.9)	(0.98)	(4.7)	(0.70)	(3.6)
	W	0.79	6.3	0.70	4.8	0.66	4.7
		(0.90)	(4.4)	(0.79)	(4.0)	(0.67)	(3.5)

M = Monsoon,
S = Summer,
W = Winter
Source: Rangnekar *et al.* (1991).

The protein deficiency is marginal for low producing nondescript cows during 8 to 9 months of the year and for crossbreds during 4 months of rainy season. In such cases additional feeding of protein rich tree leaves (*Alangium* or *Morinda* spp.) is recommended. Majority of animal owners do not feed tree leaves in the rainy season, since grass is available. In some cases, urea addition by spraying on roughage, treating straw or through feed

mixtures is being tried in addition to use of tree leaves.

TREE PLANTING PROGRAMMES

Agroforestry has been promoted through the introduction of selected species (*Alangium*, *Morinda*, *Acacia* and *Leucaena* spp). Trees with large canopies are to be avoided and lucerne and *Leucaena* hedges have been introduced to augment the leguminous resources.

Some of native species are not generally included in tree planting programmes (e.g., *Prosopis cinereria, Bassia latifolia* and Morinda tomentosa). It took some time to persuade the authorities concerned to agree to include these along with other tree species. They would help to augment the feed resources, particularly during dry spells.

ON-FARM RESULTS

Initial results from some centres, involving more than 150 families, indicate immediate beneficial effects on milk production in all the cases (milk recording is carried out with 50 families only). The response is better in the case of crossbreds (about 2 litres/day), as expected. Acceptance is better in villages where milk fetches a good price and where trees are available

nearby.

Table 4 summarizes various observations made before and after intervention. Pre-experimental observations are based on an average of four weekly records and the post-experimental results are from 6 weekly records. Animals were mostly in the 2nd or 3rd month of lactation. Observations on reproduction and health are being made and are yet to be analyzed.

TABLE 4. **On-farm results of introducing tree forage.**

Centre Nos.	Type of cow	Nos.	Average milk yield per day(l) Initial period	Type of Intervention	Post experiment-mental milk yield/day (l)
1	Nondescript	12	3.5	Tree leaves	4.25
	& crossbred	8	7.0	& creeper	9.5
2	Nondescript	16	4.0	Tree leaves	4.5
	& crossbred	5	7.5	& creeper	9.0
3	Nondescript	15	5.0	Tree leaves	6.0
	& crossbred	12	8.5	+ Urea	10.0

4	Nondescript	8	4.5	Tree leaves	6.0
	& crossbred	10	8.0	+ Urea	10.0

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Heteropsylla cubana: impact on feeding systems in southwest Asia and the Pacific

by F.A. Moog

INTRODUCTION

In the seventies and early eighties, *Leucaena* became widespread and popular worldwide. Although in some cases the local or common varieties are considered weeds, in many situations it is an important plant with its improved varieties purposefully introduced for varied uses. No other tree

legumes had been given as much attention as *Leucaena*. Most feeding trials, reforestation, agroforestry and soil conservation projects made use of or made reference to *Leucaena*. Too much emphasis was placed on *Leucaena* and it was looked on as a panacea species. This bias has now proved inadvisable because the psyllid or jumping lice (*Heteropsylla cubana* Crawford) problem arrived and still persists.

The *Leucaena psyllid* problem has been reviewed by NFTA (1988) and Napompeth (1989). Various authors have reported the extent of the psyllid damage and solutions being offered in different countries and locations.

***Leucaena* psyllids, *Heteropsylla cubana* Crawford, are tiny insects (1–2 mm) in the family *Psyllidae (Homoptera)*. The eggs are yellow, found primarily on young terminal leaves, and hatch in 2–3 days. Nymphs, which resemble aphids, undergo five instars over 8–9 days. Adults are two to three times the size of the largest nymphal instar. Their reported colour has ranged from green to brown to whitish. They use stout legs to jump before taking flight when disturbed. Females begin laying eggs 1–3 days after becoming adults (NFTA, 1988).**

The *Leucaena* psyllid is native to the Caribbean, Mexico and Central and South America. Moving as uninvited passengers on aircraft or in high

altitude winds, they arrived in Hawaii in 1984. They were first found in Taiwan in 1985, causing serious damage in 1986 and 1987 (Jiunn-Fuh, 1989) and were reported to be present in Cebu, Philippines in August 1985 (Moog and Sison, 1986). By 1986, they were reported in Australia, the Pacific Islands and Southeast Asia (Thailand, Malaysia, Indonesia, Vietnam). In 1987, they arrived in Sri Lanka, making their way to Burma, China and India in 1988.

DAMAGES CAUSED BY PSYLLIDS

Damage brought about by the psyllid to established *Leucaena* plantations in different countries is presented in Table 1. Damage ranges from physical effects on the plant by defoliation to indirect, adverse effects on companion crops and reduced biomass for animal feeding, resulting in instability of the production system and financial loss. The socio-economic impact of the infestation is alarming.

IMPACT OF PSYLLID IN THE PHILIPPINES

The psyllid has affected the more intensive smallholder beef producer, where *Leucaena* is the most valuable component of the animal feeding system. A survey in Malimatoc, a village in the town of Mabini, Batan-gas province, where cattle raising is the primary enterprise in the villages and with

***Leucaena* as the main crop for animal feeding showed the following results (Moog and Sison, 1986).**

The foremost problems caused by the infestation were stunted growth and death of plants and feed shortage. The infestation resulted in reduced feed supply so farmers resorted to feeding other plant materials such as banana leaves and trunks, corn stover, coconut fronds, etc. However, with the lower feeding value of these substitute materials, most of the animals became weak and susceptible to diseases. About 74% of farmers reported that their animals became sick and four of them reported death of animals. The majority of the farmers (83.9%) reported loss of profit (Table 2).

TABLE 1. **Damage/impact and research concern/control/action taken on psyllid in different countries**

Country	Role/Use of *Leucaena*	Psyllid Damage/ Impact	Research Concern/ Control/Action Taken
AUSTRALIA Bray *et al.* (1989)	Pasture	Production reduced by 50 %	Resistant varieties Alternative species Predator Parasites

INDIA Veeresh (1989)	Fodder	Plantation Devastated	Natural enemies: Coccinalids, praying manthids, mirids and chrysopids, staphylivid beetle, white muscardine fungus, anthacorid bug
Krishnamurthy *et al.* (1989)	Fodder/ Alley crop	Fodder yield reduced	Resistant species/cultivars
INDONESIA Malessy (1987)	Fodder	Fodder production decreased Farmers stopped fattening cattle. Reduced cattle sales resulting in reduced local government income	
Mangoendihardjo *et al.* (1989)	Shade	35 to 50 percent loss in harvest of coffee. Loss in income from sale of Leucaena seed	Spraying with insecticide Use of predator *Curinus coerulus*

Oka (1989)	Shade tree Fodder Reforestation Charcoal/firewood green mixture, timber leaf meal, veg.	Economic loss	National Task Force for Psyllid Control was created Released of predator *Curinus coeruleus*
Oka *et al.* (1987)		Millions of trees died Hampers reforestation and soil reclamation programmes	Systemic insecticide (monocrotophos); *Curinus*adults was introduced and being multiplied
Hollenbeck (1987)	Shade Re-greening Feed Fuelwood	Reduced crop (cacao, coffee, black pepper and cardamon) yield and income Less feed resulting to use of low-quality feed materials. Greater soil loss and instabi- lity of water tables to regenerate quickly	Wide spectrum insecticide (expensive) Lady bugs (*Curinus coeruleus*) *Olla abdominalis* Resistant varieties/alternative

			species
Piggin and Parera (1987)	Soil stabilization Fodder	50 % of trees affected Losses in exports of live-stock, coffee, cocoa and vanilla	Cutting and burning both infested and uninfested trees and spraying diagmon and injection of azodrin
MALAYSIA Lim *et al.* (1989)	Fodder	Trees defoliated	Resistant varieties
PHILIPPINES Sanchez (1989)	Fuelwood Fodder Alley crop	50 % loss in production Leaf meal production reduced Price of fuelwood rose Farmers became reluctant to plant	Biological studies on psyllid Resistant varieties
De Guzman (1987)	Feed/fodder reforestation Soil conservation Green manure Nurse trees	Mortality of plants reduced animal holding Reduced farmers' income Weakened link between rural people and government	Resistant alternative species
			Annual cropping

SRI LANKA Gunasena *et al.* (1989)	Fodder Leaf meal Fuelwood Alley crop Shade Compost	Most farmers shifted to *Gliricidia*	between alleys of *Leucaena* Pruning and burning of leaves Resistant species
TAIWAN Jiunn-Fuh (1989)		Serious damage	Replaced by other tree species Spraying insecticides by airplane Resistant species Natural enemies: -Parasitic wasp -Coccinelids -Bugs -Entomopogous fungi
THAILAND Napompeth	Vegetable Fodder Alley crop	Young shoots disappeared in the market Plantation abandoned, ploughed up and replaced	Ecology, evaluation and introduction of natural enemies and entomopathol-

(1989)	Agroforestry	by other crops Farmers could not supply leaves to feed mills	ogens, IPM Covering young top shoots
VIETNAM Ich and Tru (1989)		Defoliation of trees	Coccinelids as predators
WESTERN SAMOA	Weed Cocoa shade	75 % of infested plants died	Spraying Demettonte (Perfecthion) Grow cocoa under coconuts using Sesbania grandiflora as shade

TABLE 2. **Problems encountered by farmers due to ipil-ipil infestation**

Problems	**Respondents (31)**	
	Frequency	**Percent**
Stunted/Poor growth of Ipil-Ipil	31	100
Death of Ipil-Ipil	31	100
Feed shortage	31	100
Animals became susceptible to	9	29

diseases/animals got sick		
Thinning of animals	23	74.2
Death of animals	4	12.9
Profit loss	26	83.9

TABLE 3. **Animal holding before and during infestation**

Before Infestation			**During Infestation**					
Animal Holding	**No. of Farmers**	**No. of Animals***	**Animal Holding/No. of farmers**					**No. of Animals***
			0	**1**	**2**	**3**	**4**	
8	2	16	1	-	1	-	-	2
7	3	21	-	-	1	-	2	10
6	2	12	-	1	-	-	1	5
5	3	15	-	1	1	1	-	6
4	4	24	1	1	1	-	1	10
3	3	9	-	1	2	-	-	5
2	9	18	2	2	5	-	-	12
1	1	1	-	1	-	-	-	1
0	2	0	1	1	1	-	-	2
TOTAL	31	116						53

*** Animal holding multiplied by number of farmers**

The 31 farmer respondents were raising a total of 115 animals before infestation occurred. However, due to the severe damage suffered by *Leucaena*, the number of animals was reduced to 50 percent (Table 3). Three quarters of the respondents reduced the number of animals they raised. One of the two farmers raising 8 head totally stopped raising cattle, while the other reduced it to 4.

Psyllid in Cebu province

The infestation also affected the feed milling industry which utilized it as a source of xanthophyll and carotene in mixed feeds. Likewise, it also affected the smallholder farmers who grow, harvest and sell the leaves to merchants and feedmills. A survey in Cebu showed the effects of the infestation on the smallholder farms and on the export of pelleted ipil-ipil leaf meal.

Table 4 shows the effects of psyllid infestation among the three ipil-ipil farmers' associations involving 770 members in Cebu. Each association used to harvest 6–8 tonnes of dried ipil-ipil leaves per month. Their Ipil-ipil plantations were totally infested and, when the infestation occurred, they reported no harvest. Some farmers who raised cattle stopped raising animals

or reduced the number of animals they raised. It was observed that the infestation had also brought down livestock sales and transaction in the nearby livestock market. Dumanjug Cattle Raisers' Association reported that animal holdings of its members were reduced from 495 to 250 head, a reduction of about 50% (similar to the observations in Batangas). In the absence of ipil-ipil, they used banana leaves and trunks, leaves of rain tree (*Samanea saman*) and whatever grasses were available as animal feed.

Annual export of ipil-ipil from 1983 to 1985 ranged from 6,400 to 8,900 tons (Table 5). Although the quantity of exports in 1985 was higher than that of 1984, the amount of ipil-ipil exported went down during the months of October, November and December 1985 when the infestation occurred (Moog and Sison, 1986). Exports from October to November 1985 was only 24% of that for the same months in 1984. No exports were recorded from 1986 to date.

TABLE 4. **Effect of psyllid infestation on 3 farmers groups in Cebu, Philippines.**

ITEM	CATMON Ipil-Ipil Planters	DUMANJUG Cattle Raiser's Association	ALOQUINSAN Ipil-Ipil Planters'

	Ass'n.		Ass'n.
No. of Members	113	557	65
Area (ha) planted to ipil-ipil	113	557	100
Main Use of Ipil-ipil	Firewood	Feeds & Firewood	Feeds & Firewood
% Infestation	100	100	No data available
Data when pest first observed	August 1985	2nd week of October 1985	2nd week of October 1985
Leaf production per month			
Before infestation	6–7 tons	8 tons	6 tons
During infestation	0	0	0
No. of animals fattened Before infestation	no available data	495	no available data
During infestation	-do-	250	-do-
		Mostly grasses, banana leaves &	

Substitute feeds	-do-	trunks & other legumes such as *Samanea* and *Gliricidia*	-do-

Source: Department of Agriculture, Cebu City

TABLE 5. **Exports of ipil-ipil, 1983–1986 (tons).**

Year	1983	1984	1985
January	594	727	549
February	687	449	103
March	725	549	885
April	965	549	1123
May	892	545	989
June	879	720	1004
July	914	630	669
August	107	627	342
September	798	586	148
October	40	391	142
November	501	347	48
December	723	274	50
TOTAL	8894	6393	8252

Source : Animal Feed Control Division, BAI

CONCLUSIONS

Too much emphasis has been placed on *Leucaena* and its infestation with *H. cubana* is a catastrophe. The principles of ecology are that the more diverse the community is, the more stable will be. Organized evaluation trials on psyllid-resistant *Leucaena* species and cultivars are in progress but results may not be forthcoming in the short-term. Meanwhile, there is a pressing need to change the reliance on *Leucaena*. The tropics are imbued with numerous tropical fodder legumes like *Sesbania, Erythrina* and *Gliricidia* and their potentials should be tapped and enhanced.

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Alley farming and protein banks for tropical Africa

by O. B. Smith

INTRODUCTION

The main traditional land use system for food production in tropical humid Africa is the shifting cultivation-bush fallow system. Long fallow periods, ranging from 5–10 or more years, depending on the crops cultivated and available land, were the normal practice. With such long fallow periods, full vegetation regeneration and soil fertility restoration were possible and the system was ecologically balanced and sustainable.

With rapid population growth and increasing demands for food and other competing land uses, fallow periods are continually being reduced, with a resultant decline in soil fertitility and productivity. In addition, a greater area of cultivated land has been used in response to the increased requirements for crops.

Both the reduction in the fallow period and the expansion of cultivated land have resulted in an ecological imbalance and land degradation which, according to FAO (1982), are responsible for excessive “savannization” and “grassification” in the sub-humid zones. Efforts are therefore being made to develop more sustainable and productive land use systems to restore and

maintain the ecological balance and soil fertility on a long-term basis.

Agroforestry techniques which involve intercropping of leguminous or non-leguminous trees and shrub species with food and forage crops have been particularly exploited for this purpose. Alley cropping for food crop production and alley farming for both crop and animal production are two such agroforestry technologies.

In the drier savannah zones, three types of farmers are in competition for a limited and dwindling land resource: the pastoralists who migrate in and out of the zone and therefore appear to have unlimited grazing, albeit of poor quality; the cultivators who are not only expanding their cultivated areas but are also degrading the land through reduced fallow periods; and the agro-pastoralists who have limited grazing resources for their large livestock herds. The last of these (agropastoralists) have no tradition of fodder cultivation and their livestock therefore suffer from qualitative as well as quantitative feed shortages, particularly during the long dry season, with resultant weight loss and poor productivity. The fodder bank concept was developed to alleviate this constraint and improve livestock performance.

DEFINITIONS

Alley cropping

According to Kang *et al.* (1984), alley cropping (also known as hedgerow intercropping or avenue cropping) is an agroforestry system in which food crops are grown in alleys formed by hedgerows of trees and shrubs, preferably legumes. The hedgerows are cut back at planting and periodically pruned during cropping to prevent shading and to reduce competition with the associated food crops, but allowed to grow freely to cover the land when there are no crops. The system has been described as an improved bush-fallow system, as it retains the basic features of the latter but is improved in the sense that the cropping and fallow phases take place at the same time and on the same land, thus allowing more intensive cropping for a longer period of time. A summary of other differences is shown in Table 1.

Alley farming

The alley cropping system extended to include livestock by feeding a portion of the hedgerow foliage to animals was described as alley farming by Okali and Sumberg (1985). Both systems are similar, except that hedgerow management differs when the purpose includes animal feed production. Alley farming in its purest form essentially promotes croplivestock integration and the production of a mulch for improved crop production is still one of its

objectives. In alley farming most of the hedgerow foliage is used as mulch during the wet, crop growing season, particularly during the early growth phase, while a higher amount goes for animal feed during the dry fallow period. Thus foliage pruning must be strategically managed to satisfy both requirements.

A field data-based model developed by Sumberg *et al.* (1985) adequately demonstrates the crop-livestock integrating purpose of alley farming. The authors reported that about 80 kg mulch nitrogen would be required to maintain a base maize yield of 2t/ha, decreasing annually by 20% because of soil infertility. A one hectare alley farm producing 6 tons dry matter of foliage would supply this with 2.8 tons of dry foliage at 2.9% N. The surplus 3.2 tons would be sufficient to supplement 29 goats for one year, at the rate of 300g of foliage/day.

TABLE 1. **Differences in management between traditional bush fallow and the alley croppign system**.

BUSH FALLOW	ALLEY CROPPING
- Mixed native woody species	- Selected woody legumes
-Irregular planting pattern	- Planted in hedgerows
- Trees and shrubs cut back and burned	- Periodic pruning of trees and shrubs

before cropping to release nutrients	for use as mulch and green manure
- Growth controlled by fire	- Periodic hedgerow pruning
- Allows short-term cropping following fallow	- Allows continuous cropping

Source: Kang *et al.* (1986)

ALLEY FARMING MANAGEMENT

Legumes are usually prefered as hedgerow material for alley farming, although some non-leguminous tree species could also be used. The more important factor is the suitability of the plant to the agro-ecological and soil conditions. According to Kang *et al.* (1984), results of several trials conducted in the humid and sub-humid lowland areas indicate that *Leucaena* and *Gliricidia* are the most suitable species for alley farming in these zones. Others (Wildin, 1986) have suggested that *Gliricidia* should be limited to the humid areas only, while *Sesbania grandiflora* can be incorporated into alley farming in both the humid and sub-humid areas. Other species that have been tested and found suitable for other agro-ecological zones and soil conditions are: for humid highlands, *Sesbania sesban* and *Cajanus cajan;* for semi-arid highlands, *Casia spectabilis* and *Calliandra;* and for humid

lowlands with acid soils, *Acioa barterii* and *Ingas edulis* (Kang *et al*., 1984).

Hedgerow management

In the alley farming system, food crops such as maize and cassava are grown in 4-metre alleys between established trees which are pruned at various times to prevent shading of the crops. The prunings are applied as green manure and mulch to improve crop production. Okali and Sumberg (1985) suggested that, since the primary objective of the smallholder farmers is to obtain satisfactory crop yields, only 25 % of the prunings should be fed to livestock and the rest used as mulch. Evidence exists, however, that the crop response varies with the stage of growth at the time of application of the mulch. Results from IITA suggest that prunings applied close to planting maize, for example, gave greater yield responses than those applied after tassling. Hence, as suggested by Kang *et al*. (1984), while all pre-planting prunings of alley trees should be used as mulch, all or a large part of later prunings could be fed to livestock without markedly depressing crop yields. In other words, a greater proportion of the foliage than suggested by Okali and Sumberg (1985) could be used as feed. Indeed most of the dry season prunings, when they are not needed for crops, could be used as fodder.

Studies need to be carried out to determine more precisely the optimum

partitioning of alley farm prunings for use as mulch or fodder. The role of manure from animals should be quantified, together with the relative advantages of using tree foliage directly as mulch, or indirectly through animal manure.

Intensive feed gardens.

Alley farms could also be managed for fodder production only, by planting trees alone or in tree-grass combinations, in the intensive feed garden system. According to Atta-Krah (1989), this system is especialy suitable for livestock farmers willing to invest in pasture production.

In the tree-grass version, tree rows are spaced 2.5 or 4 metres apart with 2 or 4 rows of grass respectively in the alley. Yields of 20 tons of dry matter were reported for *Leucaena-Panicum maximum* combinations in the humid zone (Atta-Krah and Reynolds 1989). The productivity of tree-only plots, which allow more management flexibility, depends on interrow spacing and cutting frequency. Atta-Krah (1989) reported an annual yield of 30t dry matter/Ha from a combination of 0.5 m interrow spacing with a cutting interval of 12 weeks for *Leucaena*-only plots in the humid zone.

The intensive feed garden system has been evaluated by the ILCA Humid

Zone Programme in East and Western Nigeria, where the average sheep and goat holding per household is about 3–4. It was reported that fodder from tree-only intensive feed gardens with an average size of 0.01 ha could provide sufficient browse in a cut and carry feeding system to meet 12.5% of the daily dry matter requirement of the animals.

BENEFITS AND PROBLEMS ASSOCIATED WITH ALLEY FARMING

Some of the documented benefits of alley farming include:

a. ***Soil improvement and conservation*. Being deep rooted, alley trees extract nutrients from deep layers and return them to the surface in the litter. In addition to this beneficial nutrient recycling, legume species improve soil fertility through nitrogen fixation. Several workers (Kang *et al*., 1984; Onim *et al*., 1990) have shown that the addition of hedgerow mulch has favourable effects on soil physical characteristics (moisture infiltration and retention), chemical (high organic matter and nutrient status) and biotic (increased earthworm activity) properties. Surface soil cover with hedgerow prunings reduces runoff and soil erosion and woody hedgerow species planted on sloping land improve soil and water conservation (Lal, 1975).**
b. ***Increased crop yield*. Comparisons of crop yields under alley farm or**

traditional cultivation systems often show a yield advantage to alley crops (Table 2). Poor management of the hedgerow in terms of timing and utilisation of pruning in relation to crop growth cycle may, however, nullify this advantage.

c. ***Weed control*. An often reported advantage of alley farming is weed control and suppression, through mulch cover (Lal, 1975) and shading. Jama *et al.* (1991) reported a 90% reduction in weed growth in alley plots of maize and *Leucaena*.**

d. ***Improved animal productivity*. Proper management of hedgerow plants, as indicated earlier, will ensure that browse is available for animal feeding during critical periods of scarcity. This fodder could be used as a supplement to poor quality grasses, crop residues and by-products. Evidence suggests that it could even be used as the sole feed for goats which have been shown to thrive on. *Gliricidia* or *Gliricidia-Leucaena* combinations (Ademosun *et al*., 1988). A summary of interesting results on the use of trees and shrub fodder for livestock feeding was presented by Smith in this volume.**

TABLE 2. Crop yield response to hedgerow mulching

CROP	TREE SPECIES MULCH	RESPONSE %INCREASE OVER CONTROL	REFERENCE

Maize	Pigeon Pea	63.1	Onim *et al.* 1990
	Sesbania	75.5	
	Leucaena	68.2	
	Maize stover	38.1	
Maize	*Leucaena*	76	Jama *et al.* 1991
Maize	*Leucaena*	52	Akonde *et al.* 1986
	Gliricidia	43	
	Cajanus	35	

Labour requirements

The major problem with alley farming is the high labour input required to prune trees and incorporate mulch into the soil. ILCA workers estimated a labour requirement for pruning of 18 days/ha, which is higher than traditional labour requirements. Incorporation of a livestock component in a cut and carry system will further increase the daily labour requirement. Nevertheless, some data exist which show that labour required for clearing fallow land on

alley farms is lower than that for fallow in the traditional farm. It is also claimed that, although more labour is required in alley farming, less fertilizer and herbicides are required. In other words, alley farming may indeed be economically viable in certain circumstances. Proper cost-benefit analyses are therefore essential.

FODDER BANKS

Fodder banks are enclosed areas of forage legumes reserved for dry season supplementary grazing of cattle (Saleem and Suleiman, 1986). The concept was developed in the humid zone of Nigeria by ILCA scientists and has been mainly tested in this area with some measure of success. The main objective of fodder banks is to overcome the protein deficiency of the grass which is of low quality in this zone and fluctuates seasonally, with protein content often going below the 6% required for adequate intake.

It is argued that including forage legumes in the diet of livestock would be of value here. Legumes were chosen because they are usually higher in protein and minerals, consumed better and have a higher digestibility than associated grasses at similar stages of growth. The legumes of choice relied on to date has been *Stylosanthes guianensis* cv. Cook and *S. hamata* cv. Verano. The guidelines worked out for establishing and managing a fodder

bank, according to Saleem *et al.* (1986) are:

a. **Fence a 4 ha piece of land. The land area was determined on the basis of earlier studies which showed that average herd population in the target area is 50, with 15 to 20 cows. With a yield of 4 to 5 t/ha of Stylo dry matter, it was calculated that this would supply enough supplementary feed for the more needy cows during the critical 6-month period of the dry season.**
b. **Prepare the seed bed by confining cattle overnight in the plot prior to the onset of the rains or by grazing down for 1 to 2 weeks after broadcasting seed or by harrowing if possible.**
c. **Broadcast scarified stylo seeds.**
d. **Control rapidly growing grasses and other weeds by grazing early in the growing season.**
e. **Allow forage to bulk up by deferring further grazing until the dry season.**
f. **Graze pregnant and lactating animals at a stocking rate of about 5 per ha for 2.5 hours per day, after the cattle return from bush grazing.**
g. **Ensure sufficient seed drop and enough stubble to remain for regeneration in the following season.**

The fodder bank is usually located close to the homesteads to ensure proper

management and minimise misuse.

Management of fodder banks

Fodder banks should be managed to ensure high productivity and dominance of the legume at the end of the growing season, as well as its persistence. Some of the factors identified as being important for long-term persistency of stylo in the fodder banks include: grazing pressure, soil fertility and fertilizer application, nitrogen output to the soil/plant system, other fodder species in the pasture and time of first rains (Saleem *et al.*, 1986).

Under controlled experimental conditions, these factors were addressed, and the productivity, quality and persistence of the legumes were satisfactory. During the testing and validation phase managed by the agro-pastoralists, certain changes were made to the proposed management package in order to reflect the realities of the terrain.

Some of these changes listed by Saleem *et al*. (1986) include:

a. **Reluctance to confine cattle to the targeted plot for land preparation by trampling, as they were needed at the same time to manure crop fields.**

This resulted in poor seedbed preparation and hence lower yield.

b. **The reluctance to graze cattle on freshly manured plots, to avoid worm infestation, resulting in a smothering of stylo by tall grasses.**
c. **The grazing of not just the pregnant and lactating animals in the herd as recommended but other animals in the herd that are equally stressed nutritionally, and for longer than recommended periods. The resultant overstocking led inevitably to lower persistence of the fodder bank.**
d. **The strategic change in the period of exploitation of the fodder bank from the dry season, as recommended, to the rainy season, to ensure that the animals entered the dry season with enough reserves to guarantee survival.**

The results of these changes, which were rational to the farmer, were reflected in the reduced quantity, quality and persistence of farmer-managed fodder banks (Table 3).

TABLE 3. Effect of management on the yield, composition and persistence of stylo fodder banks.

PARAMETERS	AGE OF BANK (YRS)	STATION MANAGEMENT	FARMER MANAGEMENT
Total yield (kg			

DM/ha)	1	6824	7111
	2	7350	5278
	3	4748	-
	4	6546	-
Stylo yield (% total)	1	56	68
	2	55.4	64.5
	3	62	-
	4	61	-
Seeds recovered/m^2	1	941	1529
	2	2839	1372
	3	2745	1824
	4	3102	-

This experience stimulated ILCA scientists to initiate remedial research. According to Saleem (1991), some of the new elements introduced to accomodate farmers concerns include: alternative land preparation methods to alleviate the fear of worm infestation; a search for productive disease-tolerant legume species to suit different ecological niches within the sub-

humid zone, in order to ensure longer persistence; introduction of nitrogen-demanding cereal crops to alternate with years of legume growth to take advantage of and reduce soil nitrogen and reduce fertilizer input; the development of mini fodder banks of 0.25 ha adapted to small ruminant production by smallholders.

FUTURE PROSPECTS

Although the fodder bank concept has been shown to be a feasible, the rate of adoption by farmers has not been impressive. Perhaps not because of technical viability but due to socio-economic constraints such as land tenure insecurity and lack of infrastructural support. The technology was developed for the sub-humid zone and its central element, the Caribbean stylo, does not permit its extension outside the zone without further refinement. The length of the growing period in the drier areas is too short to support the generation cycle of the plant and, in the wetter areas, the challenge of anthracnose is too high. These limitations must be addressed in order to adapt the fodder bank concept to other regions.

CONCLUSION

The increasing demand for food in tropical Africa will continue to stimulate

competition for the limited available land for crop and livestock production. An attractive solution to this problem is to encourage crop-livestock integration. Alley farming, intensive feed gardens and fodder banks provide for this integration and ensure a more rational and efficient use of the limited land resources. All three techniques have been shown to benefit the soil-plant-animal complex and should be exploited. Problem areas highlighted need to be examined and solutions found for adapting the systems to the different ecological regions.

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The genus *Prosopis* and its potential to improve livestock production in arid and semi-arid regions

by F. Riveros

INTRODUCTION

The genus *Prosopis* has become one of the important plant genetic resources which may offer new alternatives and options for the development

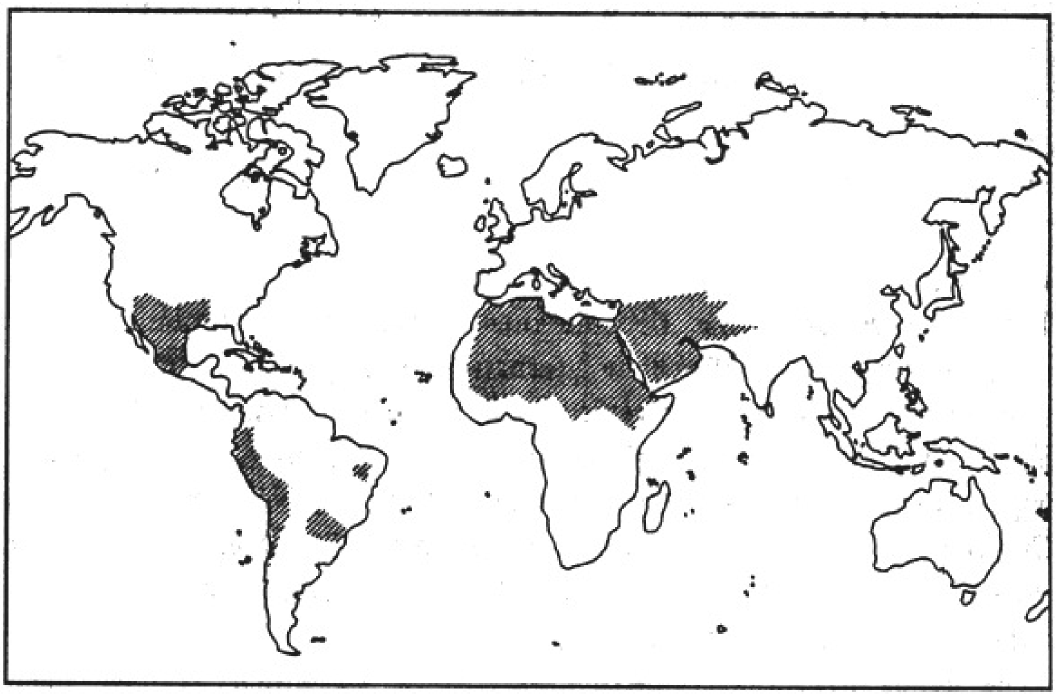
of arid and semi-arid regions. In the past, *Prosopis* spp. had an important role in the traditional agriculture practised by indigenous populations in Latin America, Africa and Asia. Now the Grassland Group of FAO has developed a programme to enhance the use of *Prosopis* spp. in those areas where it can be integrated into the current farming and livestock production systems.

The genus *Prosopis* comprises 44 species, of which 32 have been referred to by Burkart (1952) in Argentina. Although the genus *Prosopis* presents no difficulty of identification, individual species are difficult to determine in view of the large variability which is further complicated by the ease of hybridization among species. The genus is widely distributed in South, Central and North America, Africa and Asia. In the Chaco region of Argentina, many species are found and this area is recognized as a centre of biodiversity.

In spite of apparent optimism for its use, there are still a number of questions and doubts about the use of *Prosopis* species. It may become an invader when not managed adequately, resulting in widespread panic in some countries where it is considered a weed. Baumer (1990) suggests that "one should clearly distinguish between the rich pastures in temperate regions where the concept of 'invader' species is prevalent and the

frequently very degraded drylands of the Third World, especially in Africa, where one would be happy to find an invading plant which has as many good properties as offered by the *Prosopis* genus".

FIGURE 1. Dispersion of the genus *Prosopis* in the continents.



The problems resulting from long drought periods in Africa, the interest in agro-forestry and the potential role of trees in the development of sustainable agriculture have resulted in an increased interest by international and national institutions which have organized workshops, conferences and

seminars, and commissioned detailed studies on various aspects of fodder trees which have been published.

This paper will concentrate on the description of the use of three *Prosopis* species which are now well established and being utilized at a commercial level by local people. However, special attention and efforts in research, development and training are required to solve the many problems associated with the efficient utilization of these better known *Prosopis* spp.

PROSOPIS TAMARUGO IN CHILE

A comprehensive review on this subject was made in Chile at the First Round Table on *Prosopis tamarugo* held in Arica in 1984. The example of *Prosopis tamarugo* is important in the sense that it shows the possibilities that do exist for the rehabilitation of a degraded ecosystem where preference is given to a species adapted to that degraded environment, in contrast to the common practice of trying to adapt plants to difficult environments.

The Tamarugal Pampa is a plain stretching from latitude 19°33' to 21°50' south where the climate is classified as desert, characterized by almost total lack of rainfall and wide variations in day and night temperatures; mean maximum is 30.9°C, mean minimum is 16.7°C, relative humidity is 52% and

average annual rainfall is 0.7mm. The groundwater table is located between 1 and 10m deep but, in certain sectors, it is found at 60m. *P. tamurugo* grows on soils with a thick salt layer.

Studies carried out in Israel (Gindel, 1966) have reported that the Negev soils in which *P. tamarugo* grows had a high moisture content. This is a result of the water intake by leaves which occurs with certain plants under arid and semi-arid conditions and which allows a discharge of small amounts of water into the soil through the roots, enabling the plant to stay alive (Slatyer, 1967). The possibility of inverted potentials during periods of high humidity has been carefully studied; this is a way to enable the plant to absorb atmospheric water, either as liquid or gas. Studies have shown that the *P. tamarugo* opens its stomata during the night and that the percentage of opened stomata is in direct relation to relative humidity (Sudzuki, 1985).

The development of commercial plantations in the Tamarugal Pampa was initiated in 1961 through the National Livestock Development Programme. Here, an area covering 1.5 million hectares was cut for timber and fuel at the turn of the century to supply fuel for local mining operations. Today, mining for nitrate of soda has almost ceased and, of several thousand former inhabitants in the Tamarugal Pampa, only a few hundred are left who are

involved in agriculture (lucerne combined with *Prosopis)*, which is now the only source of wealth in this region. In the relic forest of the Tirana oasis, species have been found up to 400 years old.

The basic concept and idea of the development of the *Prosopis tamarugo* plantation was to rehabilitate and transform the desert into an ecosystem whereby agro-forestry would have a key role in the economic and social development. The tentative conclusions reached after five years of this work can be summarized as follows:

1. **The *P. tamarugo* tree is easy to propagate and established well when adequately planted from seedlings.**
2. **It is advisable to plant where ground water level is found between 2–10m; this reduces costs as little initial watering is required.**
3. ***P. tamarugo* can be planted in ground covered by a salt crust that varies in thickness from 10–60cm, although it does not appear to be as salt tolerant as *Propsopis juliflora*. It can also grow in soils with no salt cover, clay or sandy soils. *P. tamarugo* presents no problem in the Tamarugal Pampa and its tap-root develops well.**
4. ***P. tamarugo* has a highly specific physiology. Under conditions of pronounced atmospheric humidity above 80%, the plant absorbs water**

through its foliar system, transports it along the root system and deposits it in the microrhizosphere where it is re-absorbed as water (Sudzuki, 1985). This explains its adaptation to where ground-water lies at 40m deep.

5. **Carrying capacity of a fully productive hectare (8th year plantation) exceeds that of natural grassland in many arid and semi-arid ecosystems (Table 1). Best adaptation is seen with Angora goats.**
6. **The nutritive value of *P. tamarugo* is good; it contains approximately 5% digestible crude protein (DCP) and 55% total digestible nutrients (TDN) (Table 2).**

TABLE 1. **Projected annual yield of *P. tamarugo* fruit by age and ground area covered; yield estimated per tree and per hectare.**

Age in years	**Area covered (m^2)**	**Fruit and leaves (yield per tree)kg.**	**Fruit and leaves* (yield per ha) T.**
5	12	-	-
10	33	79.2	4.4
15	50	120.0	6.6
20	67	160.8	8.8
25	84	201.6	11.1

30	100	240.0	13.2
35	113	271.2	14.9
40	125	300.0	16.5

***Based on 55 trees per hectare**

TABLE 2. **Nutritive value of *P. tamarugo* dry leaves and fruit.**

Components	**Leaves**		**Fruits**	
	Composition %	**Digestible nutrients %**	**Composition %**	**Digestible nutrients %**
Dry matter	90.53		96.66	
Crude protein (N × 6.25)	9.98	1.27	11.14	6.07
Crude fibre	10.72	2.70	31.45	16.22
Ether extract	1.90	0.90	1.62	0.81
Nitrogen free extractives	45.91	17.45	48.18	35.72
Ash	22.02		4.27	
Calcium	2.82		0.28	

Phosphorus	0.91		1.44	

Source: Lanino (1966)

TABLE 3. **Average composition of various *P. tamarugo* components for cattle feed.**

Plant component	**Dry matter %**	**Crude protein %**	**Ether extract %**	**Crude fibre %**	**NFE %**	**Ash %**
Whole fruit*	94.4	13.3	1.4	34.2	44.8	6.4
Fruit without seed*	87.3	13.3	1.0	31.7	44.8	9.3
Seed*	90.8	27.3	5.3	10.8	50.5	6.1
Dry leaves without						
rachis*	91.7	13.6	1.7	9.9	52.6	22.2
Dry leaves*	91.4	9.0	1.8	22.3	55.4	11.5
Rachis of dry leaves*	88.2	11.3	1.8	16.0	50.7	20.3
Green leaves*	43.7	35.7	3.0	31.6	1.4	28.4
Dry leaves with rachis*	90.5	11.0	1.1	11.8	50.7	24.3
Fruit**	96.7	11.5	1.7	32.5	49.9	4.4

*** Unpublished data from Gonzales and Haardt, Univ. of Chile, School of Veterin. Medicine (1966).**

**** Lanino (1966)**

Source: Lamagdelaine (1972)

***Tamarugo* fruit is considered a good feed for sheep and cattle, as can be seen from Tables 2, 3 and 4. The FAO publication *Prosopis tamarugo: fodder tree for arid zones* (Habit *et al*., 1981) is the only published information on animal production and can be summarized as follows:**

1. **The fruit of *P. tamarugo*, when not attacked by insects, has a low concentration of nutrients as compared to concentrates but it can be compared favourably to good quality hay.**
2. ***P. tamarugo* fruit intake seems to be high when consumed freely and compares favourably with that of other high-quality fodders.**
3. **In feeding trials with sheep which received 2kg (60% leaves, 40% fruit), it was found that production was significantly lower than that of grazing sheep; addition of lucerne made a significant difference. Supplementation with mineral salts has a marked effect and it appears**

that cobalt, iron and manganese are of major importance.

4. **Table 5 provides an estimate of carrying capacity according to the age of the trees.**

TABLE 4. **Comparison of results from early-maturing French Merino sheep in the Tamarugal Pampa, fed with leaves and fruit, lucerne hay and grazing freely in *P. tamarugo* forest (Lanino, 1966).**

Variables	Leaf hay & fruit (2kg/day)	Lucerne hay (1.5kg/day)	Free grazing in forest
Weight at weaning:			
Ewe lamb	15.0kg	21.5kg	26.7kg
Ram lamb	14.0kg	25.0kg	29.6kg
Fleece weight	2.8kg	3.2kg	3.77kg
Fibre length	5.9mm	6.4mm	-
Ratio lambing:symptoms of			
pregnancy	48%	63%	111%

TABLE 5. **Estimated carrying capacity (sheep/ha) by age of *P. tamarugo* forest (Cadahia, 1970).**

Age of forest (years)	Carrying capacity (sheep/ha)

1–6	Unused
7	0.5
8	0.75
9	1.5
10	2.0
11	3.0
12	4.0
13	5.0
14	6.0
15	8.0
16	10.0

Estimates of the potential of the Tamarugal Pampa have shown wide discrepancies. It is felt that 200,000 ha can be planted, with a potential carrying capacity of 800,000 sheep in the 12th year, increasing up to 2,000,000 sheep at the 18th year. At the present time, there are approximately 23,000 ha. No planting has been done during the last 8 years, other than the experimental area which the FAO Grassland Group is developing in order to test different management techniques.

The development should include those areas where the water table is not too deep (10–15m), followed by comprehensive feasibility studies in order to assess the economics of such a development programme. It is already felt that individual areas should not be smaller than 500 ha, otherwise the development costs are not justified.

PROSOPIS JULIFLORA IN BRAZIL

The north-east region of Brazil covers an area of over 1.5 million km^2 and extends over tropical and equatorial latitudes from 1 ° to 18 °S. It represents 18% of the country and contains 125 million people, approximately 30% of the population.

***Prosopis juliflora* (Swartz) is a thorny, large-crowned evergreen to semi-evergreen tree with a deep tap-root and a well developed lateral root system. It grows up to 10–15m high, depending on the type of soil, in arid and semi-arid conditions. It is adapted to a rainfall range from 250– 800mm.**

***Prosopis juliflora* was introduced into the north-east of Brazil from Piura, Peru in 1942. It is now found throughout the dry, semi-arid region, showing its economic potential as a multi-purpose tree. In recent years, due to**

recurrent drought periods affecting this vast region, it is becoming an important alternative to annual crops in marginal areas.

Planting *Prosopis juliflora* requires a source of high quality viable seed, which is the first problem to solve as seeds are difficult to extract from pods. Pods can be cut lengthwise with a knife or across between the seeds. Other systems consist of feeding the whole pod to animals; the digestion of the pod allows the seed to come free and can be easily separated from the faeces. The seed suffers no change through the digestion process, sugar being dissolved. Trees can vary their pod production from a few kilograms to over 400kg. Seeds are not true to their origin because of cross pollination.

It is now accepted that pruning is essential in the establishment phase of *Prosopis juliflora* in order to permit easy access for collecting pods from the ground and to allow grazing before the pods drop.

Vegetative reproduction by cuttings has not been common thus there is a need for further research on this subject, the main purpose being to to exploit the possibility to increase certain ecotypes which have a high pod production. At present, a comprehensive programme on the vegetative multiplication of *Prosopis juliflora* and on the possibility of grafting certain *Prosopis* spp. is underway in the University of Cordoba with funds from FAO.

The grafting of *Prosopis* spp. would permit the use of fast growing tutors combined with heavy pod production. This work appears to be quite promising and, from preliminary results, there is a strong indication that certain species of *Prosopis* would develop a more efficient production system.

The development of a factory to process *Prosopis juliflora* pods in Iparaiba, with a capacity of 15 tonnes per day, has provided an incentive to local farmers to increase their interest in planting *P. juliflora.* Production of *P. juliflora* pods can be tripled or quadrupled if occasional or strategic irrigation can be provided during the 2 months period of flowering. Yields per hectare of over 15 tonnes have been obtained when trees were watered (6001 per tree) every fortnight. Planting near a water course or dam should therefore be encouraged, considering that during 1991 the price of pods was equal to that of maize. Water available in the region is not sufficient to cover the overall requirement for maize.

***Prosopis juliflora* pod production varies according to the soil type and rainfall has an important effect, although production may continue even after 2–3 years of drought. In the north-east, yields of 2–3t/ha are obtained on shallow stony soils in gently rolling country. These soils have no agricultural**

value and the vegetation is typical of semi-arid regions, with little herbaceous production but nevertheless containing some browse species. *P. juliflora* is planted following strip clearing or total clearing, depending on the predominant vegetation.

On agricultural land with relatively high fertility, *Prosopis juliflora* planted at 10 x 10cm spacing can yield 6 tonnes of pods per ha after the 4th year, compared to an average of 400kg maize per ha. It is therefore easy to understand why farmers are encouraged to plant *P. juliflora*.

Processing and use

Pods of *Prosopis juliflora* are harvested from the ground as they fall freely when ripe and are taken to the factory. Pods contain approximately 17–19% moisture and are stocked in a well-ventilated building. Processing starts by passing them through a standard hammer-mill and then the broken pods are subjected to a process of drying for approximately 4 hours, lowering the moisture content to 6–8%. The drying has initially been done in converted coffee roasters and, more recently, a rotary oven has considerably simplified the operation. The following step consists of grinding the broken pods through a modified feed mill in which 16–18% of the product is considered to have long fibres and is utilized directly for feeding ruminants. The remainder

goes into feed mixtures for both ruminants and monogastrics, mainly pigs and poultry.

In West Africa, it is claimed that pods can be dried in the sun, reducing the moisture from 9% to 5.5%, and down to 4.5% when passed through a hammer-mill. However, the problem of inhibitors remains when pods are not subjected to heat. Research is underway on this important subject.

Several trials to evaluate the potential of *Prosopis juliflora*-based supplements in livestock production have shown positive results. However long-term experiments with livestock under current local management conditions are necessary in order to be able to extrapolate results to the potential use by farmers.

***Prosopis juliflora* has a high carbohydrate content and acceptable protein level, as shown in Tables 6 and 7.**

In the north-east of Brazil, as in other tropical regions of the world, wheat bran constitutes an important component of rations not only for poultry but also for other animals. Wheat bran is generally-imported and therefore its price fluctuates considerably according to the season and local availability. This has stimulated research on alternatives to the use of bran and other

imported feedstuffs. It is fortunate that *P. juliflora* and other *Prosopis* spp. pods are available during the dry season which makes it possible to use these pods during critical times of the year.

TABLE 6. **Analysis of seeds and flour of *P. juliflora* as % in DM (Baiao, 1987).**

Component	Seeds	Pod flour
Moisture	11.6	10.8
Crude protein	35.8	59.0
Ether extract	4.5	8.9
Ash	3.7	4.9
Crude fibre	6.1	1.7
NFE	38.3	15.0
Reducing sugars	1.7	1.9
Non-reducing sugars	5.1	5.8
Starch	1.0	3.6

TABLE 7. **Amino acid composition of *P. juliflora* pod flour (Baiao, 1987).**

Amino acid	Amino acids in fresh material %	Amino acids g/16g N	Amino acids per 100g amino acids recovered
Lysine	1.71	3.96	4.43
Histidine	1.15	2.67	2.98

Arginine	5.72	13.27	14.83
Aspartic acid	3.24	7.54	8.43
Threonine	1.02	2.37	2.64
Serine	1.72	4.01	4.49
Glutamic acid	7.73	17.94	20.04
Proline	2.47	5.73	6.40
Glycine	1.91	4.43	4.95
Alanine	1.70	3.94	4.41
Cystine	0.51	1.18	1.32
Valine	1.50	3.48	3.98
Methionine	0.41	0.95	1.06
Isoleucine	1.17	2.71	3.03
Leucine	2.83	6.57	7.34
Tyrosine	0.99	2.30	2.57
Phenylalanine	1.51	3.50	3.91
Tryptophane*	0.46	1.07	1.19

* **Determined separately by enzymatic hydrolysis.**

In the Animal Husbandry Department of the Universidade Federale de Perambuco, experiments with chickens (Table 8) showed that wheat flour could be 100% replaced by *P. juliflora* bran (whole pod). The total ration contained ground maize, soyabean, bonemeal, calcium premix and methionine. Normally, the ration contained 7.5% wheat flour which was replaced with 7.5% *P. juliflora* bran. The replacement of up to 35% of maize in lactating sow rations in the north-east of Brazil also clearly demonstrated the value of *Prosopis* flour.

TABLE 8. **Replacement of wheat bran with *Prosopis juliflora*flour in rations for chickens (Universidade Federale de Pernambuco).**

Treatment	W* 100% Pj** 0%	W 67% Pj 33%	W 33% Pj 67%	W 0% Pj 100%
Mean daily ration intake g.	107.8	106.5	107.1	107.5
Mean egg weight g.	58.8	59.5	59.0	59.3
Feed conversion rate	1.58	1.62	1.57	1.55
Ration intake/kg egg weight	2.22	2.28	2.20	2.18

*** Wheat bran**

**** *Prosopis juliflora* pod flour**

The importance of *Prosopis juliflora* in silvo-pastoral systems is the subject of a research programme in the semi-arid NE of Brazil and in the Argentinean Chaco. It is known that the canopy of trees has a beneficial effect on the soil; it protects it from the direct effects of raindrops, reduces water run-off, etc. Of major importance is the recycling of nutrients which maintains or increases the fertility level, in particular through the accumulation of litter and through nitrogen fixation. It is also known that the canopy may reduce evapotranspiration, thus favouring overall moisture levels and increasing plant growth. It is important to highlight the fact that *P. juliflora* is sensitive to competition from grasses at the seedling stage.

Studies of the value of *Prosopis juliflora* and other *Prosopis* spp. in the dry Chaco in Argentina suggest that stability of this degraded ecosystem may be achieved by the intelligent use of indigenous *Prosopis* spp. The dry Chaco has high temperatures in the summer and moderate temperatures in the winter, with occasional frosts 5–10 times per year. 70 % of the rainfall is concentrated in the summer, during the 4 warmest months, and there is hardly any rain at all during winter. Annual rainfall ranges from 300mm in the west to 500mm in the east. Productivity is very low at 4–10 kg beef per ha and 15–20 ha per head (Diaz and Karlin, 1984). As much as 300kg/ha has been obtained under intensive experimental conditions. A comprehensive

study of the effects of *Prosopis nigra* on the vegetation under the canopy shows that higher production results from improved nutrient supply, higher organic matter and favourable water balance (Table 9). Further research is required in this area.

TABLE 9. **Production and soil characteristics under canopy of *Prosopis nigra* and in the open.**

		Under canopy of *P.nigra*		**In the open**
Acc. production of *C. ciliaris* (Buffel grass Texas 4464) planted 1976				
Output	14.4.83	4300		2000
(kg/DM/ha/year)	10.4.84	3900		2600
kg DM/ha/year		control (no fertilizer)		2500
	50 kg N		2900	
	100 kg N		3700	
(Cleared Feb 1983, collected April 1983)		3900		2000
Crude protein % in *C. ciliaris* (1976)				
	9.4.84	8.6		4.8

	5.7.84	6.9		3.9
	18.9.84	6.7		3.7
Crude protein % in native grasses				
Setaria spp.		13.7		8.8
Trich. pluriflora		10.9		9.3
Dig. californica		10.0		8.3
Soil OM%	superficial	1.83		0.90
	2–10cm	1.57		0.94
	20–40cm	0.70		0.70
Soil Nitrogen %	superficial	0.26		0.13
	2–10cm	0.26		0.13
	20–40cm	0.05		0.06
Saline soil values				
Sample depth (cm)		0–10		0–10
Organic matter (%)		1.00		0.55
$CaCO_3$ (%)		0.12		0.37
pH hydrolitic		7.60		9.00
CE sat. extr. (mmho/cm)		1.80		0.40

PROSOPIS CINERARIA (KHEJRI)

***Prosopis cineraria*, locally known as Khejri, has an important place in the economy of the Indian desert. In the arid zone of Rajasthan, camels, goats, donkeys and mules, which make up about 40% of the 19 million head of livestock in the region, depend on browsing to meet their nutrient requirements.**

Khejri is well adapted to the very dry conditions in India and is found in zones with annual rainfall ranging from 150–500 mm; the optimum density is seen between 350–400 mm range. This plant produces its leaves, flowers and fruit during the extreme dry months (March-June) when all other species adapted to arid zones are leafless and dormant. It is this characteristic which deserves greatest attention as the tree offers a new forage resource for extreme arid zones.

Khejri is a slow growing tree in its early stages, requiring 10–15 years to develop to a height of 6m, compared 12–15m in 4–5 years for *Prosopis juliflora*. Recent work at the Central Arid Zone Research Institute (CAZRI) in Jodhpur is showing the potential that exists for the selection of fast-growing lines. This research should benefit greatly from the use of micropropagation of tissue culture in order to obtain large populations of uniform, high-yielding

and fast-growing trees.

Growth of natural pastures under *Prosopis cineraria* is significantly higher (1.1–1.5 t/ha) than under *Acacia senegal* (0.6–0.7 t/ha). Maximum production of 2.6 t/ha has been obtained during 1973 with 27 rainy days and 641mm of rainfall, clearly showing the advantage of a tree canopy in the semi arid conditions found in Rajasthan (Ahuja, 1980).

***Prosopis cineraria* is lopped for firewood and its productivity is greatly reduced when lopping is carried out every year; ideally, a rest of four years will result in 200% more leaf production (Saxena, 1980).**

Khejri trees are ready to provide animal feed from the 10th year onwards and, if properly managed, may be kept in production for 2 centuries. An average tree yields 25–30kg of dry leaf forage per year. Tables 10 and 11 provide data of interest on the nutritional value of *Prosopis cineraria* leaves (Bohra and Ghosh, 1980). Dry matter intakes of 685 and 1306g/day are quoted for sheep and goats respectively.

TABLE 10. **Percentage (DM basis) proximate components of *P. cineraria* leaves (Bohra and Ghosh, 1980).**

	Patel		Ganguli *et al.*	Gupta	Mathur

Component/Source*	**(1961)**	**Sen & Ray (1964)**	**(1964)**	**(1967)**	**(1976)**
Crude protein	15.4	15.3	13.9	14.1	11.9
Ether extract	4.5	3.1	±	3.9	2.9
Crude fibre	13.4	17.5	20.3	15.6	17.5
NFE	56.8	54.1	59.2	54.8	43.5
Ash	-	9.9	6.5	11.5	8.1
Phosphorus	0.18	0.24	0.20	0.93	0.38
Calcium	1.92	2.65	1.50	2.50	2.10

* **References quoted by Bohra and Ghosh (1980)**

TABLE 11. **Digestibility and balances of different nutrients of winterlopped *P. cineraria* leaves in sheep and camels**.

Trait/type of animal	**Sheep**	**Camel**
A. Digestibility (%)		
Dry matter	38.9 ± 0.55	44.7 ± 1.62
Crude protein	7.2 ± 1.75	74.8 ± 1.93
Ether extract	31.5 ± 2.14	72.5 ± 0.69
Crude fibre	25.9 ± 1.19	49.3 ± 1.46

NFE	57.9 ± 1.38	60.6 ± 1.00
B. Nutrient balance (g/day)		
Nitrogen balance	-0.57 ± 0.22	8.33 ± 0.06
Calcium balance	-0.27 ± 0.03	17.66 ± 1.01
Phosphorus balance	-0.22 ± 0.04	6.96 ± 0.67
C. Nutritive value (%)		
Digestible crude protein	1.01	8.93
Total digestible nutrients	39.83	48.66

The importance of *Prosopis cineraria* is well recognized by farmers as it provides an extra source of revenue, acts as an insurance against drought and increases the sustainability of production systems in this drought-prone fragile ecosystem. An average, fully-developed tree provides green fodder worth Rs 20, twigs Rs 16 in the form of fencing and fuel material and Rs 6 as a vegetable, giving a total revenue per tree of Rs 42. According to CAZRI, in dry regions an average of 40 trees per ha is common, resulting in Rs 16,800 additional income per ha (1 US$ = 25 Rs). This income may be at least doubled if trees are planted 12m apart and the soil below the canopy is managed to favour water collection.

Prosopis cineraria is an important feed resource in the Sultanate of Oman, where large forests can still be found. In view of its important role in the environment and as a source of feed to livestock, a comprehensive study is underway.

RECOMMENDATIONS FOR FUTURE PROGRAMMES

It is felt that, although the value of this genus is recognized, there is a great number of questions that arise as to their real potential in terms of incorporation into production systems.

1. **With respect to _Prosopis tamarugo_:**

    a. **It is important to review the economic factors that could lead to an extension of the present area planted, in particular considering the new approaches to the management of trees.**
    b. **It would be advisable to look at the possibilities that exist to test _Prosopis tamarugo_ in those environments that appear similar to the conditions found in the Pampa del Tamarugal, e.g. coastal areas of Oman, Somalia and Sudan.**
    c. **Selection of fast-growing and high pod production trees should be studied.**

2. **Concerning *Prosopis juliflora*, there is a need to investigate the following aspects:**

    a. **The problems caused by enzyme inhibitors and the practical solutions, e.g. use of heat treatment of feedstuffs.**
    b. **research into micropropagation/tissue culture of high yielding lines.**
    c. **The advantage of grafting different species to combine favourable production attributes.**
    d. **The importance of nitrogen fixation and means to increase its efficiency.**
    e. **Nutritional aspects and feeding systems based on *Prosopis juliflora*.**
    f. **Management of plantations.**
    g. **Processing systems for feed and food production.**
    h. **Economic aspects, including irrigation practice.**

3. **Regarding *Prosopis cineraria*:**

    a. **Selection of fast growing types must take priority.**
    b. **Nutritional aspects.**
    c. **Selection of ecotypes for different ecological zones, particularly for very low rainfall conditions.**
    d. **Economics of the incorporation of *P. cineraria* into arid regions.**

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Acacia nilotica: a traditional forage species among the Afar of Djibouti

by J. Audru, M. Labonne, H. Guerin and A. Bilha

INTRODUCTION

The study of vegetation and grazing potential, financed by the European Development Fund and carried out in 1986, very quickly revealed that practically the whole of the area of Djibouti, with some exceptions, was composed of low quality steppe with the following average production:

- **grassland: 20–200kg DM/ha/year**

- **trees and shrubs: 20–50kg DM/ha/year**

For the maintenance of goats alone, normally reckoned as 0.1 TLU (Tropical Livestock Unit), the necessary annual stocking rate is 1.5–2ha per head on average and 5–9ha per head in the extreme. In such a situation, it is difficult to impose control or to institute a rotational management system. Every hectare is continuously used and all the resources are exploited.

The Government of Djibouti and the Department of Livestock wanted to develop the country's livestock production and it was necessary to provide extra available forage without encroaching on the existing production area. In order to do this, the intention was to improve the vast alluvial plains which are flooded once or twice a year and currently totally devoid of vegetation. Studies had shown that these areas were not sterile, so they required the reintroduction of a stable mixture of forage plants, resistant to uncontrolled grazing, of use to the stockbreeders and adapted to flooding.

The existence of natural populations of *Acacia nilotica* on similar sites and the interest of the grazers in this species made it desirable to find out more about this tree. Similar considerations showed that *Sporobulus helvolus* could be used to establish grass cover.

ORIGIN AND DISTRIBUTION

Acacia nilotica **L. Willd. (family: *Mimosaceae*) is one of the most common and widespread of the *Acacia* species in dry tropical Africa, the Middle East and the Indian subcontinent. Ross (1979) has distinguished seven sub-species:**

- **subsp. *adstringens* (Schumach. and Thonn.)**
- **subsp. *nilotica***
- **subsp. *tomentosa* (Benth.)**
- **subsp. *indica* (Benth.)**
- **subsp. *subulata* (Vatke)**
- **subsp. *biocarpa***
- **subsp. *kraussiana* (Benth.)**

There are numerous local names and the sub-species are seldom defined in West or Central Africa.

Distribution of sub-species

Subsp. *nilotica* is common in the Nile Valley in Egypt and in the Sudan. It is also found in Nigeria, Niger, Mali and Chad and, in the east, in Ethiopia

(including Eritrea).

Subsp. *tomentosa*, very abundant in India and Pakistan, is also widespread in Senegal, Mali, Ghana, Nigeria and, in East Africa, in Sudan and Ethiopia. It is the sub-species found in Djibouti.

Subsp. *adstringens* is relatively common in west sahelian Africa, as far as Sudan in the east. It is also found in the northern Sahara, Libya and Algeria. The sub-species *tomentosa* and *adstringens* are quite often planted in the sudanese region and *nilotica* has been introduced into Qatar.

Subsp. *indica* is of Indian origin but has been grown in Africa. It has been introduced into Egypt, Ethiopia, Tanzania and Angola. Subsp. *subulata* is found in the south of Sudan, in Ethiopia, Uganda, Kenya and Tanzania. Subsp. *biocarpa* exists in Somalia, Kenya and Tanzania. Subsp. *kraussiana* occupies the area in the south of Tanzania, as far as Natal and is also found in Angola and Southwest Africa.

ECOLOGY

The three following sub-species are very important, from the point of view of biology, sylvo-pastoral use and economic value, and are very different in

these respects. The subsp. *tomentosa* is most often found in pure stands on alluvial soils that are periodically flooded, sandy-clays and non-saline clay soils. It is resistant to temporary flooding and can grow in waterlogged soils for long periods. It is certainly one of the *Acacia* species most adapted to wet areas and is referred to as hydrophillic.

The subsp. *adstringens*, more adapted to dry conditions than the previous one, is only found widely dispersed and in dry areas. In the delta of Senegal, it is found on the edge of flood zones where populations of *tomentosa* have established.

The subsp. *nilotica* frequently forms dense tree belts around permanent or semi-permanent pools. It also grows along the banks of the Nile.

ACACIA NILOTICA SSP. *TOMENTOSA IN DJIBOUTI*

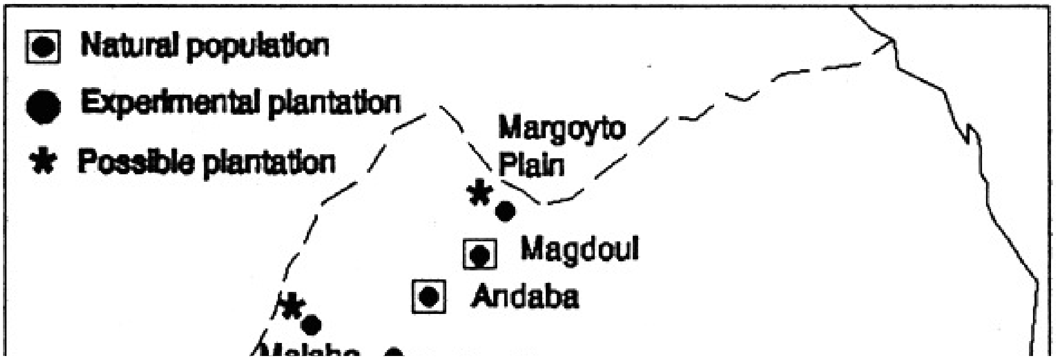
***Acacia nilotica tomentosa* is the only sub-species found in the Republic of Djibouti and is known locally in Afar as *Kassal-to* (pl. *Kassal*) and in Somali as *Xarmuku*. It naturally occupies the lowest, temporarily flooded parts of three valleys: Andabba, Madgoul in the north-west and Ginnibad on the Dakka plateau in the south-west (Figure 1). Elsewhere it is planted in the gardens of the local inhabitants throughout the country, everywhere where it can be**

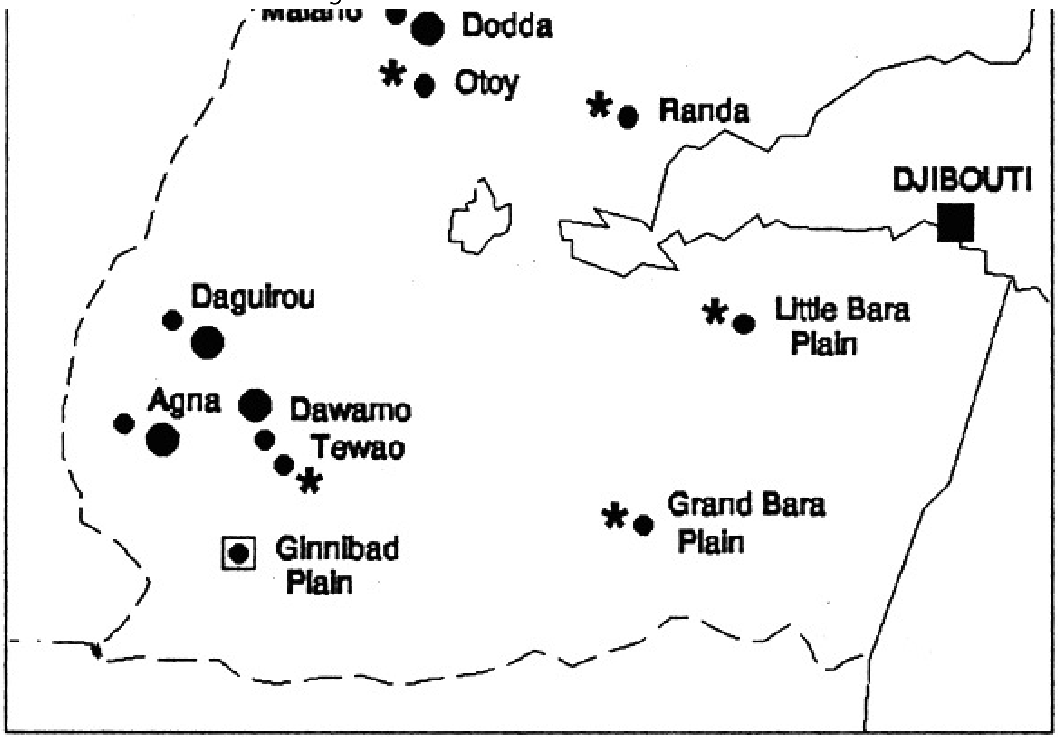
watered. Experimental plantations exist at Dodda, Dagguirou, Agna and Dawano, established at the request of the farmers. There are other sites in the Republic of Djibouti (in particular, Petit Bara and Grand Bara) where its introduction does not pose any major technical problems.

General characteristics and botanical composition of natural sites

***Acacia nilotica tomentosa* is found in pure or nearly pure stands, associated with some *Ziziphus abyssinica*. In a broken circle round the edge of the valley and on the slopes of the hills, *Acacia ehrenbergiana* is associated with some *Salvadora persica* thickets. The soil is silty-clay on all the sites.**

FIGURE 1. Distribution of sites of *Acacia nilotica*ssp. *tomentosa.*





Flooding, which is of longer duration in the Andabba and Madgoul valleys, allows the development of an aquatic field of *Aponogeton nudiflorus*. In the lowest areas which are therefore the most flooded, one notes some pockets

of *Cyperus rotundus* and, in isolated patches, *Echinochloa colona*. In the less wet areas, such as the valley of Ginnibad, one finds some patches of *Citrullus colocynthis, Chrozophora plicata* and *Coldenia procumbens*.

Evolution of the flora

The tree population is in a relatively good state at Ginnibad and Madgoul but declining at Andabba, following too frequent and severe lopping. The herbaceous layer is poor and of low grazing value. However, it is reported that the small tubers of *Aponogeton nudiflorus* are consumed by man.

According to old people, grass existed forty years ago. Its disappearance occurred at the same time as a very great flood which happened after a very long period of drought. When the flood went down, all the herbaceous growth had disappeared. *Sporobolus helvolus, Echinochloa colona, Cyperus rotundus* and *Panicum turgidum* (on the edge) are still remembered as being there. All these species still exist in similar regions, often enough in a scattered state. They will be used to reestablish the grass cover.

Ecology

The soils of these valleys, alluvial in origin, are silty-clays with low organic

matter, except in the Madgoul valley. These soils are quite regularly flooded and the limits of the flooding are very variable. It ranges from simple waterlogging to complete flooding which makes the valley inaccessible for 2–3 months. The sub-species resists waterlogging quite well, even for a long period. At the same time, it is very resistant to drought.

Experimentally, it can be transplanted into areas very different to those where it is normally found, with the only condition being to ensure the recovery of the transplant. A simple pit, a few metres deep, watered occasionally, will ensure the recovery and survival of the plant. The result is an improvement in the potential of the soil for water retention which allows growth to take place even in the absence of water for more than a year.

Finally, this species resists low levels of salinity.

IMPORTANCE OF THE TREE TO THE STOCKBREEDERS OF THE MADGOUL VALLEY

General land use

The Afar society is composed of tribes (*kedo*) and each of these is divided into family groups (*gulub*). The entire grazing areas are the property of the

tribes but there are those that they can be freely used by everyone, whatever the season, including the families of other tribes who may use these areas with the same rights as the ‘owners’; others are not free and access must be requested of the chief of the group or tribe. This request is generally granted. These grazing units are called *desso* and this is the usual practice of the Assayamara, the tribe of Madgoul.

This *desso* is a sort of traditional form of control that implies ownership of the land and maintains a certain quality of pasture. It involves, when the water rises after a flood or rains, forbidding all access by animals to an area of land where the plants have not yet flowered, which is a way of obtaining a maximum level of biomass of good quality.

The *desso* quite often implies the exclusivity of the pasture to one species of animal. Such land is destined for cattle with the exclusion of all other species, essentially for the cattle of breeders belonging to the family groups of the proprietary tribe. Finally, it sets a date for turning out to pasture.

As far as it goes, the principle is good but where the problem comes is that there isn't any regulation concerning the stocking rate and the end of grazing. The stockbreeder removes his animals only when he finds another favourable area of pasture.

This method of land use, although still not perfect, is at the same time relatively positive in the context of development projects aimed at improving or establishing pastures.

The existence of a land tenure system and the social organization of the Afar suggests that it is possible to collaborate more easily with them in a development programme. One may also state that all action to improve the pasture on the common land will subsequently be managed within the *desso* system.

Family ownership of the trees

On the common land or in the areas controlled by the *desso* system, the tree layer is not differentiated from the herbaceous layer. This is quite different to the situation in certain tree populations which are judged of value to the farmers, such as *Acacia nilotica* or species like *Ziziphus mauritania, Ficus vasta* and *Ficus sycomorus*. In these cases, the trees are the property of family groups or of the families which make them up.

In the Madgoul valley, given the existence of a herbaceous component, it is subject to the controlled management but excluding the trees. The tribe of Assayamara comprises six family groups forming, in this way, six grazing

units involved in using the trees.

The use of trees by the stockbreeders

The breeders of Madgoul are essentially goatkeepers; some possess fattailed sheep and some dromedaries. *Acacia nilotica tomentosa* is a forage tree *par excellence*, as well as being a reserve for security of fodder supply. The leaves are cut and the pods and flowers are also collected. But the vegetative production obtained is extremely variable from one year to the next, depending on climatic conditions, which can be summarized as the presence or absence of water on which growth is directly dependant, and individual variability between trees in the same stand.

CLIMATE AND TREE DEVELOPMENT

The performance of the tree is variable and a function of the climatic conditions. In semi-arid areas, water determines the phenology. In the area inhabited by the Afar, the annual climate pattern is as follows:

Dec-Mar	*Guilal* (cool season)	Rain possible
	Daddaa (unique to the Godas	
	and Mablas regions)	

Mar-Jul	*Sougoum*	Rain possible
Jun-Jul	*Kamsin*(50 day wind)	
Jul-Nov	*Hagay*	*Karma* rains
		(summer rains of Ethiopia)

The pattern shows three possible periods of rain, of which the most certain is *Karma*. These rains fall, or don't fall, on the Madgoul valley, but fall on the surrounding region, flooding the valley, which serves as a catchment for the neighbouring hills.

The development of the tree is as follows: *Foliage growth.* At Madgoul, the trees generally stay in leaf throughout the year, provided that the interval between two floods or two periods of rain does not exceed 10–12 months.

***Flowering.* At the beginning of each season, the smallest amount of rain provokes flowering. It is therefore possible to have three flowerings in the same year.**

***Fruit setting.* Regardless of the number of flowerings in the year, there will only be one lot of fruit. This fruiting time is always after a flowering in October-November. The pods, which are slightly marcescent (mature without**

falling off), start to ripen from February to March.

Individual variation

Within the same natural stand, individual variability is another element of the variation in vegetative production. In natural regeneration and in the conditions of an unmanaged area, the sub-species always produces a very spiny juvenile form, with very few leaves and sterile until the differentiation of a shoot that produces branches and twigs, with few spines but with leaves, that is fertile.

When the young tree grows in favourable conditions of water supply, this juvenile form does not occur and all the functions of the tree are found to be modified. For example, it is reported, on the basis of a one year period of growth including the time in the nursery, that untimely flowerings were occasionally observed. Systematic recording of trees under different environmental conditions is going to be undertaken starting in 1992. This will provide better information on growth and development.

One thing that cannot be explained at present in certain older individuals is the maintenance of the very spiny stage over the whole of the top of the tree whether or not it has been pruned. The most curious thing is that these trees are sterile, just like the young form. They do not flower or produce pods. The foliage is less abundant, the ends of the leaves cannot so easily be touched and the tree is of much less value for cutting. The farmers have observed this difference and the absence of flowers and pods but cannot explain the phenomenon. By monitoring some trees, perhaps an explanation will be found.

We also need to know the percentage of these sterile trees in natural populations and reafforested areas.

PRODUCTS AND USES

Foliage

The foliage is much sought after by small ruminants and camels. The camels, even when they are young, go for the ends of the shoots after browsing by the goats and sheep.

The trees are lopped in rotation every 18–24 months in the dry, cool season (*Guilal*) and, if the rains known as *Dadaa* don't fall, the lopping continues during the season called *Sougoum* (3 months). If it rains during *Sougoum*, the cutting is abandoned while other grazing is available. In every case,

cutting is also stopped during *Sougoum* when the trees are defoliated, which is generally during May.

Cutting may be total or only partial. In any case, even when total, the farmers, concerned with the survival of the tree, leave one or two branches entire. When the crown has reformed, these branches are either left or cut, if they are still in leaf.

The best time for use is during *Guilal*, when the branches have plenty of leaves and are bearing pods at different stages of maturity.

The actual production has still not been established. It is known by the farmers that the complete foliage of an adult tree provides for the maintenance of 100 goats for one or two days, if feed supply is difficult.

Flowers

There may be three flowerings in the year but only the flowering at the end of *Hagay* (October) produces pods. The inflorescences which have fallen to the ground are the basis of feeding of young weaned goats from 1–11/2 months.

The Afar, like others in desert regions, have adapted the management of their flock to the progressive poverty of the rangeland. The management of the livestock is essentially dominated by the need to obtain goat-milk production, sufficient for all the family and throughout the year. This is achieved by slaughtering young male goats between 8 and 15 days and the early weaning of young females.

Each production of flowers, which is difficult to quantify, is reserved exclusively for young goats and young lambs of both sexes which do not follow the flock during the 1–2 months after weaning.

The pods

The maturing of the pods is spread out like the flowering. The first ones are ripe at the end of January and the remainder carry on until the end of March/beginning of April. Quite often, part of the production is lost by the pods falling in the water or into the mud when the valley is still flooded.

The production of pods, which on average reaches 80–100kg per adult tree, is only partly collected by the women and children. Many of the pods are gleaned directly by the animals. They are somewhat marcescent and there are differences in humidity between day and night and gusts of wind which

make them fall.

Stored in bags, they are fed, lightly crushed, at the end of *Guilal* (February-March) and the beginning of *Sougoum* (March-April), and the following months if the dry season persists. They are reserved for the remaining goats that are kept in the proximity of the camp during difficult periods to provide milk for the very young children. The milking camels also benefit during the same periods. While the camels consume the whole pod, goats only eat the casing and reject the grains.

NUTRITIVE VALUE

The results from IEVMT relating to the laboratory analysis of various edible parts of *Acacia nilotica* are summarized in Table 1. They have been obtained from samples collected in Burkina Faso, Senegal and Djibouti. The leaves have been collected from August to April but the stage of development is not given. It has been assumed that the youngest leaves were gathered in September in Senegal, given the fact that the protein content diminishes with age. The inflorescences came from Djibouti and have been gathered in October. The pods and grains have been picked up or acquired from October to May in the three countries.

The organic matter content (100–ash) is of limited significance because the ash may include mineral matter of exogenous origin (sand, etc.). The enzymatic degradability of organic matter (DOM) was 65–80% for the majority of samples, except for the young leaves (25–30%). The low digestibility of the latter may be related to the high content of tannins because it is not explained by the chemical composition (protein content, cell wall constituents, etc. - see below). As a result, the energy value was between 0.6–0.9 UFL (6.8 and 10.3 MJ ME/kg DM) for the older leaves, inflorescences, pods, envelopes and grains, and between 0.2–0.3 UFL (2.3 and 3.4 M/D) for the young leaves. For each component, the variation is probably related to the tannin content and, as for all forages, to the cell wall contents.

The protein contents (N × 6.25) were between 9 and 24%. The measurement of solubility and fibre-associated protein (CP-ADF) allows the respective determination of the quantities rapidly degraded by the rumen microorganisms and the undegradable fraction. These fractions are quite variable in the leaf samples (older leaves) but, on the other hand, quite homogenous for the pods. The variation is quite small compared to between-species differences (Kone *et al*., 1989a; 1989b).

TABLE 1. Chemical composition, enzymatic degradability and estimates of the nutritive value of various component parts of *Acacia nilotica* analyzed at IEVMT.

Part	Green leaves			Inflorescences	Pods	Pod	Seeds
Stage of development	**Young**	**Intermediate**	**Adult**	**fallen to ground**	**entire**	**envelopes**	
Number of samples	**1**	**2**	**12**	**1**	**6**	**1**	**3**
CHEMICAL COMPOSITION							
Organic matter (%DM)	78	88	83–94	84	95	93	94
Protein							
Total protein (%DM)	27	16	11–15	9	9–14	9	18–23
N-solubility (% protein)	21	18	13–23	24	30	54	27–58
(Durand. In Verité and Demarquilly, 1978)							
Residual protein in ADF (% protein)	33		7–13	10	5	9	4–8

CELL WALL CONSTITUENTS							
Neutral Detergent Fibre - NDF (% DM)			13–23	17	25*	28	32–44
Acid Detergent Fibre - ADF (%DM)	35		10–18	15	19*	22	25–32
Acid Detergent Ligin - ADL (%DM)	26		5–9	6	6*	8	3–4
ENZYMATIC DEGRADABILITY							
of Organic Matter (%)	25	29	64–69	80	67	76	67–74
(pepsin-cellulase)							
(Aufrère and Demarquilly, 1989)							
of protein by							

pronase - 1 hour (%)		24	24–33	31		61	35–64
(Aufrère *et al.*, 1989)							
of protein by HCl-Pepsin (%)	18	18	68–74		79*		4–8
NUTRITIVE VALUE							
(examples of estimates from the analysis)							
Energy value (UFL/kg DM)1	0.2	0.3	0.77–0.83	0.81	0.7	0.77	0.6–0.9
(MJ ME/kg DM)	(2.3)	(3.4)	(8.8–9.5)	(9.2)	(8.0)	(8.8)	(6.8–10.3)
Digestible Crude Protein (g DCP/kg DM)	50	50	60–100	40	40–90**	50	60–140

*** 1 sample only**

** depending on the number of seeds

[1] UFL = Unité Fourragère Lait : 1700 Kcal NE for milk

About a third of the protein is associated with the ADF in young leaves and, as a result, the enzymatic degradability is very low (18–25%). For the older leaves and other components, the degradability can reach 65– 80% but, for the same sample, the results vary according to the method of enzyme digestion; the measurement of degradability by pronase appears to estimate the degradation of protein in the rumen, whilst HCl- pepsin digestion simulates post-ruminal digestion.

The order of magnitude of the levels of digestible protein are given; they have been estimated from the variations in chemical and enzymatic criteria and from some results obtained *in sacco* and *in vivo* for other species of tree forage. They are provisional.

The cell wall constituents are characterized by the Van Soest fractionation method. The total level of cell wall is a little high (NDF < 45% of DM) but a third or more of the lignocellulose (ADF) is composed of lignin (ADL).

Conclusions

The estimates of energy and protein value may be improved by the results obtained in the course of measuring *in vitro* and *in vivo* digestibility (Project CEE-DG XII 5TD2 –215: Nutritive value of ligneous forages), as well as by the study of the kinetics of enzymatic digestion (1– 24 hrs) and the nylon bag method (6–48 hrs in the rumen) for protein.

The variability of results obtained so far shows that it is essential, in order to extrapolate to other samples, to define precisely the nature of the components collected, the stage of development of the tree, etc.

The first estimates of the nutritive value confirm, except for young leaves, the value of *Acacia nilotica* for young animals, lactating females, etc.

Palatability and intake are other parameters associated with forage value. The fallen flowers, with a high energy value, are highly palatable. The value of the pods is partly related to the content of seeds but the latter are less palatable to goats. The leaves, if they have a low tannin level, can have a high nutritive value but their consumption may require adaptation. As the basal feed for the small ruminants of the Afar, the leaves are consumed only at the rate of 25g DM/kg $W^{0.75}$ (about 1kg DM/100kg LWt) by sahelian sheep adapted to herbaceous forages.

OTHER USES

Medicines

Pods, ground up in water, are used as a drink for diabetics and people with ulcers.

Wood

The wood is not used for heating or other purposes. The cut branches remain on the soil and rot where they are with successive floods. Some farmers use them to protect young trees against animals. The dead trees are also left onthe ground.

If a system can be organized, the wood could be a source of revenue for the farmers as wood is scarce in the towns of Djibouti.

Tanning materials

The sub-species is tanniferous. The pods are rich in tannin and contain 20–30% in the DM. They are used by the stockbreeders of Madgoul to tan the hides of goats to make water-containers. The skin is filled with crushed, wet

pods for 48 hours.

CONCLUSION

Re-establishment of the pastoral environment is a priority in the Republic of Djibouti and this objective must be approached within the limitations of the existing botanical composition of the degraded or lost land, so as not to cause problems for the stockbreeders.

The proposed system of forage management is simple. It consists of:

- **100 plants/ha of *Acacia nilotica tomentosa*. This is the optimum density observed in the undegraded natural populations at Madgoul. It is also the density which allows the maximum spread of the tree crowns; this is required when they are used for cutting.**
- **625 plants/ha of *Sporobulus helvolus*. The grass is stoloniferous The growth of stolons is 70cm/month during the 2 months after flooding and grass cover is formed in 2 1/2–3 years.**

Save for the *Acacia*plants that are too young to be exploited, the first results for green biomass obtained at the flowering stage, after the first flooding following the planting, vary between 3000 and 3200kg DM/ha. At a rate of 1kg

DM/goat/day, this level of DM production will support 12 goats/ha for 81/2months; the remaining 31/2 months are the time when the plain is inaccessible during the floods.

The resulting herbaceous cover can be expected to nearly double this production as has occurred at Dodda in the north-west of the country where the plain is flooded twice a year on average.

***Sporobolus helvolus*, in fact, provides the grazing (that no longer exists at Madgoul), while *Acacia nilotica* remains the reserve of forage to provide security in case of drought. It remains to find a pasture legume to improve the grass component.**

These results have led to the establishment of two projects:

- **livestock development project in the north-west of the Republic of Djibouti, financed by the French Fund for Aid and Cooperation, for the creation of 3000–3500ha of pasture over 4 years**
- **project for the restoration and improvement of palm groves and development of animal production in the district of Yoboki, financed by FED, to put in place 2000–2500ha over 3 years.**

There are other sites in Djibouti currently being studied and which are amenable to the same approach and techniques.

In conclusion, the creation of grazing will also permit:

- **the safeguarding of the land currently in use and stopping the further reduction in value of large valley areas**
- **an improvement of the income of farmers by increasing the productivity of the herds that is made possible by the new available forage resources**
- **an increase in the contribution of livestock, and small ruminants in particular, to the national economy.**

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Use of fodder trees and shrubs as protein supplements to ruminants and as a means of soil stabilization. The Nepalese case.

by N.P.Joshi

INTRODUCTION

Fodder trees and shrubs are used in Nepal as protein supplements in ruminant diets during the long dry period (October - May). It is estimated that 12% of the total digestible nutrients (TDN) come from fodder tree and shrub leaves (New Era, 1990). The major source of leaf fodder is from the forest. MPFS (1988) estimates the contribution from the forest is about 24% of the total TDN supply, mainly as fodder leaves. In some areas of the hills of Nepal up to 90% of the feed come from the forest (Metz, 1987).

The total TDN supply is estimated at 6.3 million tonnes (Joshi and Panday, 1991), of which 1.5 million T comes from forest resources. The share of tree leaves comes to about 0.75 million T. The ruminant population of Nepal is estimated at about 15.5 million (DFAMS, 1991), of which about 70% is

concentrated in the hills and mountains. The TDN requirements has been estimated at about 8.8 million T TDN (Panday, 1982; Joshi, 1988). Hence the deficit is about 2.5 million T TDN (28% of the requirement).

Much of the forest below 2300m above sea level (a.s.l.) have been over-extracted, resulting in loss of ground cover, exposing soil to degradation and erosion (MPFS, 1988). Nepal is rich in biodiversity. There are more than 100 species of trees and shrubs that are being used as sources of animal fodder (Panday, 1982; Howland and Howland, 1984; Amatya, 1990; Neil, 1990).

LOCATION, PHYSIOGRAPHY AND LAND USE PATTERN

Nepal is a Himalayan kingdom located between India and China at 80°04' to 88°12'E and 26°22' to 30°27'N. It has an area of about 14.7 million ha, of which more than 80% of the land area is occupied by rugged hills and mountains. Although Nepal is a small country, because of its dramatic changes in altitude within short distances, climate ranging from tropical to tundra types occurs. Physiographic divisions are presented in Table 1. Land utilization patterns for the 5 physiological regions are given in Table 2.

TABLE 1. **Physiographic divisions**

Region	Elevation (m a.s.l.)	Area '000 ha	Area %
High Himal	>4200	3350	23
High Mountain	2000–4200	2960	20
Middle Mountain	1500–2000	4442	30
Siwalik	300–1500	1886	13
Terai	60–300	1110	14
Total		14748	100

Source:LRMP (1986)

TABLE 2. **Land use pattern (10^3 ha).**

Region	Culti- vated land	Non cul- tivated land	Forest land	Shrub land	Grass land	Other	Total
High Himal	8	1	155	67	885	2234	3350
High Mountain	244	148	1639	176	508	245	3960
Middle Mountain	1223	667	1811	404	278	59	4442
Siwalik	269	59	1438	29	16	75	1886

Terai	1308	123	475	30	58	116	2110
Total	3052	998	5518	706	1745	2729	14748
(%)	21	7	37	5	12	18	100

Source: LRMP (1986)

RUMINANT POPULATION AND DISTRIBUTION

Ruminant population of Nepal is estimated at 15.5 million (DFAMS, 1991). It's ecological distribution is given in Table 3 where, for simplicity, physiological divisions are grouped into 3 ecological zones: mountains (high himal and high mountain), hills (middle mountain and Siwaliks) and the Terai.

The livestock sub-sector contributes about 25% of agricultural GDP or 15% of the national GDP (CBS, 1991). Ruminants supply milk, meat, wool and draught power for cultivation of land. Besides these, they provide manure to the extent of 49.3 million T/yr. Large ruminants supply 100% of farm power, 85% of soil nutrients and 94 % of meat (DFAMS, 1991). They also act as the vital link between forests and crop production, by converting forest leaf litter to compost. Ruminants provide uncontrolled manure and urine to the forest, where they browse and graze. Bedding material (leaf litter) mixed with urine

and manure make compost. Compost is the major source of fertilizer to replenish soil nutrients and sustain crop production.

TABLE 3. **Ruminant population and ecological distribution (10^3).**

Region	Cattle	Buffalo	Sheep	Goat	%	Total
Mountain	806	303	366	808	14.8	2296
Hills	3242	1772	404	3089	54.9	8503
Terai	2243	928	125	1395	30.3	4690
Total	6255	3044	906	5295	100.0	15489

Source: DFAMS (1991)

FEED RESOURCES

The total TDN supply from different sources are given in Table 4. The major sources of nutrients provided to the ruminants are mainly from straws (51 %), green grasses (30%), fodder tree leaves (12%) and concentrates (7%) (New Era, 1990). However, earlier estimates for tree and shrubs as fodder were as high as 35% of the total available TDN (Panday, 1982; Brewbaker, 1984; LRMP, 1986; MPFS, 1988). Forest resources are by far the most important source of fodder tree and shrub leaves. Projection of fodder

supply from various sources are estimated at 6.7, 7.4 and 8.3 million T TDN for the years 1990/91, 2000/01 2010/11 respectively (MPFS, 1988). The feed and fodder balance sheet is presented in Table 5.

TABLE 4. **TDN supply from different sources (10^3 Tonnes)**

Source	Amount	%
Grassland	670	10.6
Forest	1010	16.0
Shrubs/burnt forest	530	8.4
Fallow grazing	240	3.8
On-farm fodder	120	1.9
Raisers/bunds	330	5.2
Crop by-products and residues	3424	54.1
Total	6324	100.0

Source: ANZDEC/APROSC (1986), MPFS (1988) adjusted for change in crop production figures 1988/89.

TABLE 5. **Feed balance sheet (10^3 T TDN)**

	Mountains	Hills	Terai	Total

Feed required	930	4985	2949	8864
Feed available	1056	2228	3040	6324
Feed balance	126(+)	2757(-)	91(+)	2540(-)
% deficit/surplus	113(+)	55(-)	103(+)	29(-)

Source: Joshi and Panday (1991)

There are big variations in the estimates of feed requirements. MPFS (1988) estimates the feed TDN requirements at 6.35 million T, which is much lower than estimates reported by several authors (Panday, 1982; Joshi, 1988). The variations may have been due to the differences in the assumed body weights used to calculate the livestock standard unit (LSU).

FOREST RESOURCES

The forest area of Nepal is estimated to be about 5.5 million ha or 37.4% of the total area of the country, of which about 100,000 ha is deforested each year (Brewbaker, 1984). In the quest for fuel and fodder, man has over-exploited forest resources, making them incapable of supporting the growing need for fuelwood and fodder.

Most of the remaining forests in the hills and mountains of Nepal are temperate, subalpine and alpine forests dominated by *Quercus, Pinus, Tsuga, Abies, Rhododendron, Lyonia, Symplocos, Acer, Juniper* and *Lauraceae* (Metz, 1987). The natural vegetation is grouped under the following categories according to altitude (MPFS, 1988):

a. **Tropical forest (< 1000m), predominantly *Shorea robusta, Acacia catechu* and *Dalbergia sissoo.***

b. **Subtropical forest (1000–2000m), predominantly *Pinus roxburghii, Schima wallichiana, Castanopsis* spp., *Alnus nepalensis, Albizia* spp. and *Toona* spp.**

c. **Lower temperate forest (2000–2700m) predominantly *Pinus wallichiana, Quercus* spp.**

d. **Upper temperate forest (up to 3100m) predominantly *Pinus wallichiana, Quercus* spp. and *Acer* spp.**

e. **Subalpine forest (3000–4200m), predominantly *Abies spectablis, Betula utilis* and *Rhododendron*.**

f. **Alpine zone (up to 4500m), predominantly shrubs specially *Rhododendron* and junipers.**

Hardwoods are the most extensive forest component, comprising about 60% of the total. The distribution of different forest types are presented in Table 6.

In last 10 yrs, about 120,000 ha has been brought under afforestation (CBS, 1991). Thus far, most plantation species have been pines, which are of little value for livestock feeding. The reason for this is their ability to stabilize soils in exposed, landslide-prone areas. There is growing awareness among Nepalese hill farmers that deforestation and soil erosion have negative effects on their livelihood.

TABLE 6. **Nepal's natural forest (10^3 ha).**

Region	Conifers	Hardwoods	Mixed	Total	%
Hill Himal	54	18	83	155	3
High Mountain	492	560	577	1729	30
Middle Mountain	344	990	421	1762	33
Siwalik	37	1187	209	1433	26
Terai	0	445	0	445	8

Total	927	3200	1290	5524	100

Source:MPFS (1988)

There are useful native species which can establish themselves on difficult exposed sites and can begin the process of natural succession to establish forest covers. For example, *Alnus nepalensis* is a multipurpose, nitrogen-fixing tree which establishes on landslide-prone, exposed soils (Thapa and Budathoki, 1987). This species should be exploited to check soil erosion and for the rehabilitation of degraded forests.

IMPORTANT FODDER TREES AND SHRUBS

Extensive lists of trees and shrubs used as animal fodder in Nepal are reported elsewhere (Panday, 1982; Howland and Howland, 1984; Neil, 1990). Jackson (1987) describes in more detail the tree species found in natural vegetation, together with their silvicultural practices and chemical compositions.

Chemical composition of fodder trees and shrubs

The chemical composition of some important fodder trees are given in Table

7. More extensive lists are reported elsewhere (PAC, 1982; Panday, 1982; Bajracharya *et al*., 1985; Joshi and Singh, 1989; Panday, 1990). Variations are found in chemical composition reported by several authors for the same species (e.g., *Ficus roxborghii*: CP 13.1-18.3%).

TABLE 7. **Chemical composition of some important fodder trees in the hills of Nepal**

Species	DM%	N%	Ash%
Albizia mollis	50	2.8	6.9
Artocarpus lakoocha	41	2.2	14.7
Bauhinia purpurea	57	2.8	11.2
Budleja asiatica	31	3.4	9.9
Castanopsis hystrix	44	2.0	3.8
Celtis australis	69	1.8	28.8
Dendrocalamus strictus	48	2.4	14.2
Dalbergia sissoo	40	2.6	8.6
Eurya acuminata	40	1.3	6.9
Erythrina arborescens	37	2.7	19.6
Ficus nemoralis	30	2.4	12.2

F. roxburghii	34	2.1	12.0
Grewia tiliafolia	35	3.1	11.9
G. oppositifolia	71	2.3	10.8
Litsea polyantha	40	2.1	8.9
Michalia champaca	49	2.2	4.5
Machilus odoratissima	43	1.8	4.4
Prunus cerasoides	41	2.6	6.3
Quercus lamellosa	66	1.9	4.1
Q. semicarpifolia	69	1.4	3.1
Salix spp.	52	3.0	10.2
Saurauia napaulensis	40	0.9	8.6
Schima wallichii	59	1.2	4.6

Source: PAC (1982); Bajracharya *et al.* (1985); Panday (1990).

Species preferred by farmers There is a great variation in farmers' preference for different multipurpose tree species for fodder, fuel and timber. The preferred species in one region may not be the same in another region. Generally, in the hills of Nepal, *Artocarpus lakoocha, Ficus spp., Saurauia napaulensis* are the most preferred species. In the mountains, the

most preferred species are *Salix* spp. and *Quercus* spp. (Brewbaker, 1984). Promising indigenous fodder tree species need to be characterized in terms of their nutritional value and proper canopy management for optimum fodder yield. Among them *Budleja asiatica, Grewia tiliafolia, Ficus* spp. and *Salix* spp. are the most promising ones. *Alnus nepalensis* needs special mention as it establishes very fast in the exposed, degraded soil. Since it is a nitrogenfixing tree, it should be explored in combination with other broad-leaved trees. Some other tree species used by the farmers are given below:

Hills (1000–1500m):

Bassia butyraceae
***Bauhinia* spp.**
Erythrina arborescens
Celtis australis
Litsea polyantha
Machillus gamblei
Prunus serasoides
Alnus nepaleneis

Mountain (3000m):

Castanopsis tribuloides Machillus odoratissima

SOIL EROSION AND ENVIRONMENTAL DEGRADATION

Nepalese mountains are geologically young and natural mass wastage and soil erosion rates are therefore high. Forest degradation, deforestation, uncontrolled grazing, cultivation of marginal lands and other improper land use practices are responsible for accelerating the rate of soil erosion. It is estimated that 20–2000 t/ha annual soil losses occur from poorly managed sloping terraces and degraded rangeland (MPFS, 1988).

Any reduction in biodiversity and/or a reduction in the ability of the land to meet the needs of the current and future population on a sustainable basis can be considered as environmental degradation. The environmental crisis is closely associated with the exploitation of forest resources by a rapidly increasing population. Much of the land has been cleared to meet the growing demand for food and livestock (ANZDEC/ APROSC, 1991). These higher forests are extremely important both for controlling erosion and associated environmental problems, and for providing essential products to the people living below.

CURRENT STRATEGIES FOR AFFORESTATION AND WATERSHED

MANAGEMENT

Strategies are needed to arrest degradation and allow rehabilitation of degraded forests with community participation. HMGN, through the Ministry of Forest and Environment and the Ministry of Agriculture and their constituent Departments, are undertaking several projects in this area, with the support from various bilateral and multilateral agencies.

In this context special mention of the Community Forestry Development Project (CFDP) is appropriate. Started in 1976/77, the approach encompasses the interests of the community in meeting their long-term needs for forest products on a sustainable basis, using participatory forest management practices. This approach helps in linking forest resource utilization with farming practices. Community forestry is considered as the most effective strategy for restoring and managing the forests, especially in the hills of Nepal.

One success story in community forestry is worth mentioning: that of Nala, a hamlet 30 km east of Kathmandu. The community of Nala faced severe shortage of fodder and fuelwood in the '40s. Realizing the importance of forests for their livelihood, they formed a community group in 1952 and later received help from the Department of Forest and the Nepal-Australia

Community Forestry Program. Now the community is enjoying a surplus of fodder, fuelwood and other forest products from what is now called Nalako Thulo Ban. It is considered to be a good model for broad-leaved plantations in other parts of the country.

In 1988, a long term forest resource management program was developed in what is now known as the Master Plan for Forest Sector (MPFS).

Along with the forest management programs, various watershed management programs have been undertaken to check soil erosion (including Bagmati, Tinau and Phewa watershed projects). These are basically integrated projects for afforestation and control of soil erosion.

There are also several integrated projects that have agricultural crops and livestock as major components. Integration of forest, livestock and crop agriculture in any development project in Nepal, especially in the hills, is essential for the success of the project.

There are 42 different agencies involved in research related to afforestation. However, there is a lack of coordination. Effort has been initiated by the Forest Research Division (FRD) of the Department of Forestry by creating a Forest Research and Information Centre (FRIC). Research thus far has been

focussed on the silvicultural practices of indigenous and exotic species and chemical composition of fodder trees and shrubs. Most of the research is being conducted in the lower hills of Nepal (< 1000 m) but it is argued that the research conducted here may not be appropriate for the middle hills.

CONCLUSIONS AND RECOMMENDATIONS

The constraints to livestock production is mainly due to feed and fodder scarcity. The scarcity is seasonal, from October to May, and during this long dry period fodder trees and shrubs are the major source of green fodder. Forestry is the major source of leaf fodder and bedding material for livestock in the hills.

Forestry plantations have been thus far limited to pines, because of easiness in establishment. Private plantations are limited to the richer farmers who have extra land but the community approach to forest management is becoming more popular.

Research thus far has been on silvicultural practices of indigenous and exotic species but there is still a dearth of information on the nutritive value of fodder tree species. Little information is available on the antinutritional substances present in the fodder tree leaves.

Planting of broad-leaved species should be encouraged in place of conifers in plantation forestry, to meet the demand for fodder, fuelwood and timber. Grasses/legumes can be incorporated along with plantation species to maintain ground cover and avoid soil erosion while the trees are growing. Indigenous as well as exotic tree species, like *Leucaena, Gliricidia, Sesbania*, etc., should be used to stabilize the exposed and degraded soils and help regenerate natural succession. Species should be selected which require less root depth and are frost tolerant, shed tolerant and less susceptible to browsing by livestock.

Farmers should be educated on the benefits of agroforestry to encourage private plantating of multipurpose tree species. A participatory approach can be used to identify the farmers' preferred species for forest or private plantation.

Stall feeding practices for livestock should be encouraged. Help can be given to the farmer to prepare a fodder calendar, depending upon the size of the herd. On-farm research is required to determine the optimum level of fodder leave supplementation. Further research is also needed on the nutritive value of fodder tree and shrub leaves and to standardize the chemical analysis.

We need to identify a few, promising fodder tree species and establish their

sivilcultural practices, propagation techniques, lopping techniques and measure their chemical composition (including anti-nutritional factors) and feeding value.

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Fodder trees as a renewable energy source for biomass gasification by D.V. Rangnekar

INTRODUCTION

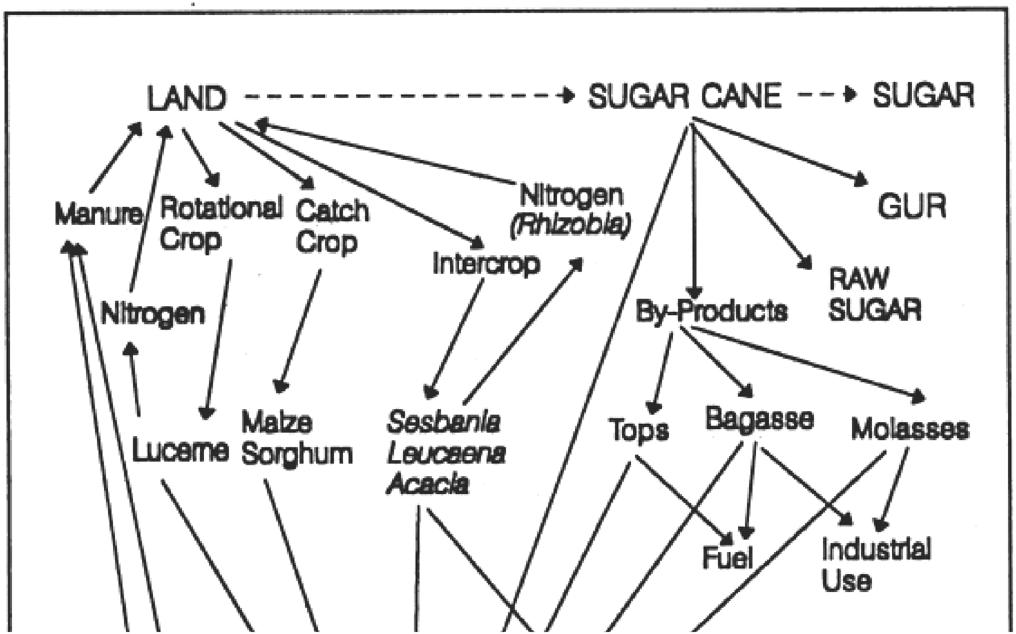
In countries like India with rising energy requirements and dependence on imports of fossil fuel, considerable stress is being placed on developing renewable energy sources. There have been a series of workshops and seminars in India on this issue and three major aspects are generally discussed (Chandrashekar & Bowander, 1982):

1. **Which are the major renewable sources of energy relevant to India?**
2. **Which of these are now ready for adoption?**
3. **What new resources can be developed or what available technology can be modified to realize these resources?**

It has been realised that, unlike conventional fossil fuel, the renewable or non-conventional energy resources cannot be put to use directly (except when they are used as fuel for household use). They need transformation into a suitable form of energy or the equipment needs to be changed to make use of them.

The National Commission for Agriculture, appointed in the 1980's to look into agricultural production as well as related aspects like availability of fuel and requirement for energy, had already pointed out the need to take up an

intensive programme of augmenting renewable energy resources like biomass. The Government of India subsequently established a Department of Non-conventional Energy Sources (DNES) and also Energy Development Agencies in each state. These organisations identify suitable approaches for different states and promote research and development activities to enable the proper utilisation of renewable energy sources.



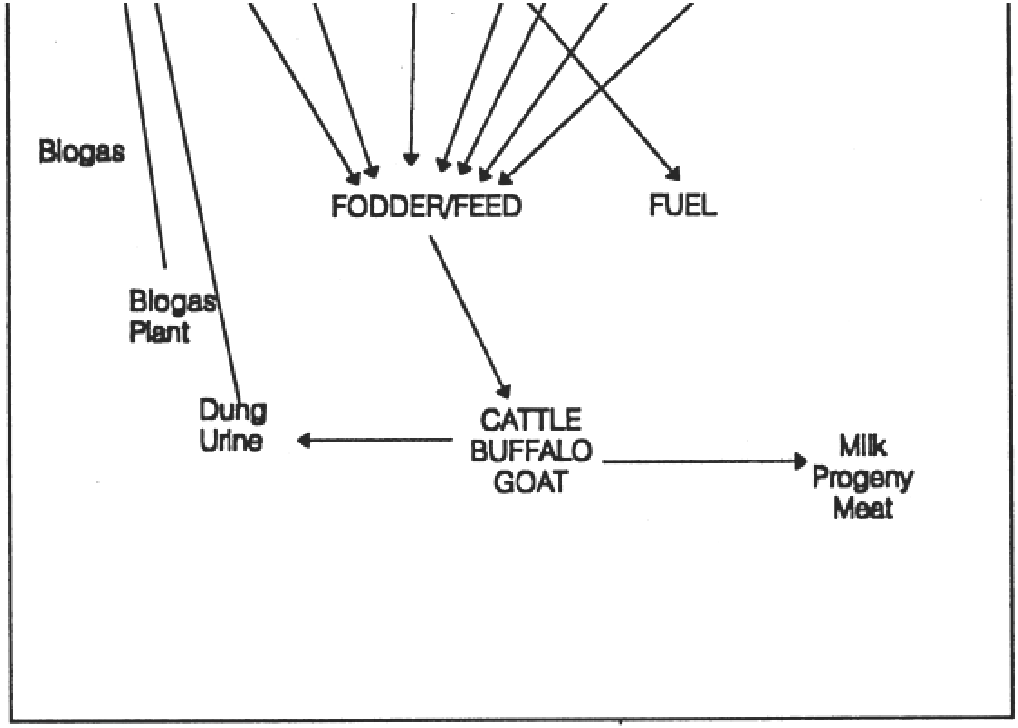


FIGURE 1.Integration of sugar and milk production for optimizing land use.

Biogas use is one such renewable energy resource which integrates well with livestock production and which is of importance to the BAIF programme,

in view of the fact that cattle development activity is our major area of involvement. Figure 1 shows how well the biogas system has integrated into the total farming system in the sugarcane growing regions of South Gujarat, western Maharashtra and Karnataka, the three main areas where BAIF is involved. Similar integration has developed with other crop production systems like fruit and food crops.

BIOMASS PRODUCTION IN BAIF'S DEVELOPMENT PROGRAMMES

Rural energy demand patterns indicate that the requirement for cooking and heating account for 80% of the total need and that firewood and crop residues emerge as the main sources of fuel. The second major requirement is for agriculture operations, i.e., for irrigation, and draught power (Gujral and Vasudevan, 1982).

A variety of activities and approaches are under trial to augment biomass resources and their utilisation. They range from tree plantations to gathering and densification of tree leaves, aquatic weeds and agroindustrial waste. Development of equipment for their proper utilisation, which ranges from smokeless wood stoves to bricketing and gasification of wood, is also in progress.

In the BAIF development activities, the use of renewable energy sources is considered as having multiple objectives. Tree planting programmes, either on individual farms or on community land and degraded forest, is a useful source of employment, income, fuel and fodder, as well as for soil water conservation. In many remote areas, irrigation is hampered by a shortage of power and diesel. Some of these aspects are discussed by Rangnekar (1982) and Sohoni (1987).

From the farmers viewpoint, the major resources are land and animals (Rangnekar, 1982). The animals provide food and energy, as well as the draught power for agriculture operations, transport, etc. The land is the major source of food, feed and fuel. We have been exploring the pos sibilities of augmenting this resource to meet the requirements of the family. There is a sizable population in rural areas who have very limited land or are landless. They have to depend upon bigger farmers or community resources to meet their energy requirement. For this purpose, a different approach of developing community lands and wasteland has been taken up, so that it serves as a source of employment and income, as well as for fuel and fodder (there by saving the drudgery of women and children gathering fire wood). There is also need to take cognizance of the farmer preference for multipurpose trees or a com bination of species.

BIOMASS PRODUCTION TRIALS FOR SPECIES EVALUATION

In Gujarat and Maharashtra states, trials were organised to study biomass production from local and introduced species under a variety of soil moisture conditions. Species tested were *Acacia nilotica, Azadirachta indica*, *Albizia lebbeck, Prosopis juliflora, Leucaena leucocephala, Pithecololium dulcei, Casuarina equisetifolia*, and *Eucalyptus* hybrid. These trials were organised on regional farms, as well as on farmers' fields. The results indicate that *A. indica, P. juliflora, A. nilotica* and *P. dulcei* amongst the local species, and *L. leucocephala* and *Eucalyptus* amongst the introduced species, were most promising (Mohatkar and Relwani, 1985).

***L. leucocephala* has attracted attention because of its adaptability to saline-alkali soils and brackish water, as well as for its multipurpose utility. The studies demonstrated the possibilities of developing plantations for fodder, fuel and timber in agro-forestry with food crops and, in silvipastoral systems with grasses. *P. juliflora* adapts well to saline-alkali soils but has no value for other purposes and experience in Gujarat indicates that it destroys grass cover. The suitability of various tree species for salt-affected soils has been well reviewed by Yadav (1989). *Leucaena* plantations in saline-alkali soils produced an average of 40–70 tonnes of green forage and 80–100 tonnes of**

wood. Some plots have shown higher productivity, yielding 175 tonnes of wood/ha with 10,000 plants/ha (Relwani *et al*., 1985).

The planting of tree species like *L. leucocephala, Acacia*, etc., are part of integrated Tribal development programmes. In South Gujarat, where the programme now involves more than 4000 families (over a period of 8–9 years of involvement), interesting combinations have emerged. These can best be described as fodder+fuel production, food crop+fodder+fuel production and fruit+fodder+fuel production. The programme involves the development of 1 hectare of land by each family, with rainwater harvest and lift irrigation by a group of families. Each family has to plant trees on 0.4 hectare with 1×1 m. spacing (4000 trees) and another 1500 plants along the bunds and in plots. These include some fruit trees, as well as fodder and fuel species.

GASIFIER SYSTEM TRIALS

One of the approaches being tried for the utilization of fuelwood is biomass gasification. As indicated earlier, gasifiers are being tried as a part of integrated projects which subsequently involved fruit planting, dairy cattle development, etc. Most of these projects are in remote, underdeveloped, tribal areas where the power supply is very irregular and timely supply of water for irrigating the crops becomes difficulty. The alternative of using

diesel engines often faces the difficulty unavailability of diesel oil. Moreover, it is difficult to operate submersible pumps with the diesel engines. The gasifier system is being tried in areas where tree planting is well established and uses small branches and twigs after the main trunk is cut for sale.

In the BAIF projects, the gasifier system is being tried in two ways: (i) using the gas directly to operate engines, and (ii) a gasifier with a generating set to produce electricity which can provide energy for a series of pumps. Reports by Sohoni (1987) may be referred to for details. Initial trials involved 5 engine pump sets connected to five C-25 gasifier models. The pump set were powered by 5 hp AND 8 hp engines. Each pump set-gasifier system is used by a group of families. One caretaker family is chosen by the group and trained in the operation and maintenance of the gasifier system and pumpset. Each family contributed about 30kg of wood to operate the gasifier system and this had to be supplemented with wood chips (available locally). After about two years, the plantations produced enough wood to meet the requirements. The wood requirement was about 3kg per hour and average diesel substitution rate of 50% was observed which was lower than expected. With experience and improvements in the working system, it was possible to get higher replacement rate for diesel. The wood consumption was found to increase to about 6kg/hr with 60 to 70% replacement of diesel. Frequent

cleaning of the unit, inconsistent flow rate of the gas and air and slow movement of wood were some of the problems which needed to be rectified. The operators had also to be trained to ensure use of dry wood (less than 20% moisture) cut to the right size.

At four locations, gasifier-generating set units have been tried with mixed results. These units, which have a capacity of 20–30 kW, need 14–15kg of wood per hour. They are placed on farms with large plantations located in remote areas of Maharashtra and Gujarat. One of the units has given good performance with a satisfactory diesel replacement rate of over 60%. The other two units initially showed low replacement rates (35%) which improved subsequently to about 60%.

Technically the systems seems to be feasible but the same problems are faced as stated earlier. The need for training is also critical.

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Fodder trees and fodder shrubs. Socio-economic aspects and government policies.

by P. Amir

INTRODUCTION

Broadly speaking, animal agriculture can be classified as commercial and non-commercial. The bulk of commercial animal agriculture is based on modern animal production techniques, as seen in poultry, swine, dairy and beef production. These intensive production system are based on adequate supplies and economic usage of feed to ensure profitable returns to producers. Seldom do trees and shrubs form the major source of the diet for commercially produced animals. Perhaps the one exception is production on

rangelands which is predominantly based on trees and shrubs.

Many mixed crop-livestock systems involve supplementing diets with trees and shrubs. Although the final produce may enter the market for sale, these systems are seldom intensive and rarely run on modern commercial lines. Furthermore, the owners are resource-poor smallholders who often operate at the subsistence level. Land ownership amongst these groups is also limited: many are tenants or operate as nomads. The socio-economic profiles of these groups include women farmers, with considerable child labour used for herding, watering and other animal husbandry chores. Cash inputs are limited to the purchase of medicines and feed supplements during periods of hardship. Fodder prices vary with season and so does the form of payment. In many countries like Pakistan, India and Nepal, fodder is exchanged for labour operations. Since livestock serve as a buffer against risk and a form of insurance/convertible stock, small farmers have a great stake in its upkeep.

Besides growing fodder on owned land, landless classes also have access to common lands. Trees and shrubs have a dual role as fuel and fodder but seldom do trees and shrubs enter the market. On ranges and owned land, trees are picked and shrubs browsed directly, often without any

compensation to the landowner. Therefore attaching economic values becomes problematic.

TREES AND SHRUBS AND THEIR SOCIO-ECONOMIC SIGNIFICANCE

The economic significance of trees and shrubs can be determined from the fact that they are hardy and can provide year-round fodder to be used as a supplement in lean periods. With proper management and propagation techniques, this fodder can be a viable feed resource to supplement the income of small and landless farmers. In mixed farming systems, trees and shrubs can have a stabilizing effect on prices as farmers have a longer holding capacity and are not forced into selling animals in periods of drought (Knipscheer *et al*., 1987). Both trees and shrubs also provide multiple benefits (fuel, wood for furniture and other uses, leaves and shoots for use by animals, etc.). In addition, they also help to stabilize the soil and improve the environment. In harsh environments, particularly those of Africa and parts of Asia, there is considerable scope to encourage the use of trees and shrubs by further educating farmers (Winrock International, 1991).

POLICY FRAMEWORK

Policies to promote the use of trees and shrubs for fodder seldom exist on

paper. However forest and range laws do tend to regulate utilization patterns, where they can be implemented at low cost. Little attention is given to analyze how trees and shrubs can be promoted for the benefit of farmers or even how their use can be encouraged on private farms. LDC government policies mostly conform to the norms and customs of the locality. Power and authority often determine the rights of the users. In some cases, policies are announced prior to political events (i.e., elections), to gain support, and their implementation is subsequently ignored, depending on which group benefits or gets hurt in the process. To adequately design a macro policy it is prudent that the analyst clearly understands the system relationships and in particular the interactions which determine overall performance of the system. A generalized model giving an illustration of such an analysis can be found in Amir and Knipscheer (1987).

A useful way to look at likely policy impacts is to consider three facets of trees and shrubs development:

a. ***Environment*. The technical, socioeconomic and political domain in which tree and shrub growing takes place. Factors influencing productivity, use, distribution etc.**
b. ***Behaviour*. This component of the model includes the behavioral**

assumptions, for example, rules and regulations, forest/range grazing laws, property rights, fencing, pastoral treaties, etc.

c. *Performance*. This would include the impact of the environment and behaviour on animal productivity, joint products (fuel, fodder and meat), total contribution to fodder, carrying capacity, etc.

It is clear that for policy purposes we must fully understand the environment and behaviour norms of the key players (grazers, animals, marketing functionaries, buyers and sellers). By modifying the environment and behaviour patterns, we can establish the desired performance criteria. Below are some of the important questions that policy makers must ask:

1. What are the desired performance goals from animals fed on different types of trees and shrubs? These would include average weight gains, mortality, carrying capacity and seasonal availability. Technical scientists must provide policy analysts with this information.
2. If we are to realistically change performance we must spell out desired goals that are to be achieved. Once the output level is clear, policy alternatives that either influence the environment or change the behaviour pattern must be spelled out in concrete terms. Hypothetical examples are:

i. **increase livestock numbers by 30–40% within 2 years and reduce mortality by 50 %.**
ii. **increase farmer income by say 40 % within 5 years by promoting use of trees and shrubs**
iii. **increase on-farm fodder availability by 25 % and reduce area under fodder crops by 15 %.**

The above are examples of explicit targets which should be in the minds of development planners, extension workers and scientists who aim to design plans and programmes. The direct and indirect cost and benefits should also be clearly spelled out. Policy analysts should then proceed to implement programmes where minimum risks are taken during the first phase of the project. National programmes should also receive appropriate consideration when development programmes are launched.

As farmers show willingness to adopt new tree and shrub species for fodder, new components such as mineral supplements and health coverage can also be provided. The main goal should be to get higher productivity with limited expenditure on cash inputs.

A significant factor which limits farmer participation in tree and shrub fodder technologies is the lack of knowledge and unavailability of germplasm suited

to local conditions. Similarly, lack of storage techniques also hampers farmers' ability to store leaves and branches in conditions conducive to later use.

Whereas technical information on the nutritive value of most trees and shrubs exists, there is less information on utilization patterns at the farm level. Nor do we have good data which collates farmers' responsiveness to feeding different species. Health implications of various trees and shrubs are also not clear. To develop a long term planning strategy whereby trees and shrubs become an integral part of small and large farming systems, it is important that further information on microvariables relating to use, labour patterns, prices for various trees and shrubs, animal performance on various fodders at farm level and effects of farmer education be collected.

Policy makers desire more information on likely impacts of alternative land use patterns, watershed benefits and measures of changes in welfare by following a particular course of action, etc. (Pereira, 1989; Simpson, 1988). Macro-economic analysis would benefit from information on border prices of livestock products and different types of feeds. Similar ly, if there is cross-regional migration of animals, it would be useful to know the number of animals that cross the border to indirectly assess the true value of animals

raised on trees and shrubs.

FREE GOOD PROBLEMS

The economic problem of trees and shrubs is classified under the ‘Free Good’ and ‘Tragedy of the Commons’ cases. Given difficulties in clearly identifying ownership of common lands, excessive and uncontrolled grazing severely depletes rangelands. Even where controls are exercised (e.g., Maslakh range in Baluchistan), it becomes extremely costly to police the area. A simple solution is to encourage the leasing of such lands to farmers who pay a nominal fee and the government provides the needed support to re-green the area. Distributing some form of property rights obviously has its political and institutional implications which have been evaluated separately. Nevertheless, more attention should be given to quantifying the benefits arising out of the use of trees and shrubs under different feeding systems. Costs associated with maintenance of trees and shrubs for environmental improvement, fuel and feed should then be estimated along with the associated benefits.

When considering the role of trees and shrubs in watershed improvement, care must be taken to look at total biomass generation of the system. Where possible, quantification should be carried out to determine the opportunity

cost of not growing trees.

EDUCATION AND AWARENESS

Education, technology transfer and creating general awareness amongst the public will be key factors in successful promotion of sustainable trees and shrubs. Little information is available to farmers on the choice of species, care and management, levels of utilization, time of harvest, etc. Free grazing is often practised with little regard to suitability of species or carrying capacity of the land. It has been observed in the Baluchistan province of Pakistan that an NGO working at the grass root level to motivate small farmers can play an important role in educating them. Motivation alone is not sufficient; clearly demonstrated benefits and long term implications for livestock development must be shared with the farming community. The roles of printed media, radio and television should be further developed to allow a farmer participatory development agenda.

ON-FARM TESTING OF SPECIES AND PERFORMANCE

Socio-economic constraints and opportunities are best studied during onfarm testing of new technologies. It is prudent that researchers directly work with farmers to ensure that trees and shrubs get evaluated under

representative conditions. The guidelines for such technology testing have been laid out by Amir and Knipscheer (1989).

Livestock, range management, watershed and forestry projects must clearly recognize the potential of trees and shrubs as a feed resource. Integrated projects which recognize the multiple use of trees and shrubs and facilitate the utilization of these species through increased farmer awareness programmes are more apt to affect the lives of poorer segments of the population. Furthermore evaluation of projects should clearly specify the contribution of trees and shrubs to increasing farm income. Perhaps a key limitation of such analysis is the lack of prices and values of trees and shrubs under range conditions.

MARKET STUDIES

A programme should be launched to study the marketing of trees and shrubs for use as fodder. This would include studies to determine the seasonal fluctuation of prices for different species. This study should be conducted on a regional basis with the objective of determining the price of various trees and shrubs species, marketing channels, utilization patterns, trading arrangements (i.e., cash *vs*. barter), impacts of various regulations on tree and shrub usage, etc. Efforts should be devoted to shadow pricing various

species of trees and shrubs in order to estimate the value of this type of fodder *vis a vis* other feed sources. Socioeconomic factors entering the production-marketing-consumption chain need to be understood.

INTERNATIONAL EXPERIENCE

The use of trees and shrubs is common in Asia, Africa and Latin America. Extensive research has been conducted in Indonesia, the Philippines and India to show the merits of feeding *Leucaena* (Ipil-Ipil) to ruminants with encouraging results. Species of *Acacia arabica* and *Dalbergia sissoo* are commonly fed to goats in the Indian sub-continent. Throughout the middle east, farmers graze their animals on shrubs and small trees. Goats relish trees and shrubs more than any other species. Trees are commonly utilized by camels in desert areas. Research in the uplands of Indonesia has clearly demonstrated that trees and shrubs can safely form part of cattle and small ruminant diets, provided mineral supplements are regularly added. Farmers' main apprehensions are the possible toxicity problems which may result in decreased performance or mortality amongst grazed animals.

On-farm implications of the use of different tree and shrub species for fodder need further research. Similarly, utilization patterns when multiple benefits are derived (wood, fodder, shade, etc.) need to be studied to design

improved systems. The three-strata forage systems practised in Bali clearly demonstrate the superiority of fodder trees over the traditional grazing system.

INTER-AGENCY ACTION TO FACILITATE LIVESTOCK PRODUCTION

A major constraint limiting the success of livestock and forestry interventions at the farm level is the lack of inter-agency collaboration. In many countries, departments of livestock and forestry or rangelands belong to different ministries. This limits the success of tree and shrub planting campaigns. Analysts often do not recognize this institutional limitation and build projects with the assumption that there will be coordination amongst various line agencies.

Inter-agency networking is required:

1. **to initiate an institutional network to encourage information sharing amongst different countries and agencies,**
2. **to encourage National Agricultural Research Systems to devote more attention to fully realize the potential of trees and shrubs in their livestock development strategy,**
3. **to provide resources for germplasm sharing and intensification**

programmes,

4. to educate users of trees and shrubs in sound principles of conservation and provide needed back-stopping when incorporating trees and shrubs into feeding systems, and
5. to provide training opportunities directly relevant to on-farm technology design.

CONCLUSION

The paper looks into factors that limit the use of trees and shrubs in feeding systems especially amongst resource poor farmers. It outlined a policy framework whereby environment and behavioral variables can be manipulated to obtain desired changes in the performance of animals. To date, experience in several Asian, African and Latin American countries shows that trees and shrubs can play an important role in fulfilling the dietary requirements of ruminants during drought periods. However more efforts are needed to integrate the existing knowledge base and to promote technologies that facilitate the use of trees and shrubs amongst farming communities.

The multiple benefits of trees and shrubs will facilitate mass adoption, provided inter-agency collaboration can be secured and government policies

clearly encourage large scale planting on private and public lands. Careful resource use must be a part of the broader policy guidelines.

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Conclusions and recommendations

The conclusions and recommendations were prepared at the end of the meeting by the participants divided into three working groups according to the three main subject areas covered as follows:

I.	The Resource Base:	
	Chairman (in session)	R.A. Leng

	Rapporteurs	M. Baumer
		C.P. Chen
	Members	A. El Aich
		R.A. Halim
		F. Riveros
II.	Main fodder trees and fodder shrubs, both legumes and non-legumes, as protein sources for livestock. The Nutritional Aspects:	
	Chairman (in session)	D.V. Rangnekar
	Rapporteurs	C. Devendra
		M.S. Dicko
	Members	F.D'Mello
		M. Kass
		R.A. Leng
		Ravindra Kumar
III.	Harvesting and Feeding Systems. Regional and Country Case Studies:	
	Chairman (in session)	F.D'Mello

	Rapporteurs	T.R. Preston
		F.A. Moog
	Members	P. Amir
		N.P. Joshi
		D.V. Rangnekar
		O.B. Smith

Conclusions and recommendations elaborated by each group were discussed, amended and adopted by all participants at the final session. This last session was the concluding plenary session. It was chaired by the FAO officer in charge of the consultation.

In order to plan the debates and help from conclusions and recommendations, the following themes of discussion were suggested in advance to the three groups:

A. **What is the established knowledge on the subject and what can be applied immediately?**
B. **What research should be done locally concerning the technologies which are to be introduced?**

C. **What fundamental research is needed for further development of technologies? This fundamental research is supposed to be done in established research institutes.**
D. **What kind of training is needed in developing countries to ensure good research and transfer inside the country?**
E. **How can the technologies be transferred?**

The participants were obviously free to introduce other themes of discussion, if necessary.

SESSION I. THE RESOURCE BASE

Trees and shrubs contribute, *inter alia*, to sustainable agriculture and provide a high value fodder for livestock. Their browse production role within livestock systems should be considered in close liaison with all their other roles and within the global context of the environment. Development is for the benefit of man. The target is to gain a greater understanding of how to use trees and shrubs for improved livestock production.

A. Established knowledge and application

Trees and shrubs have multiple functions, especially for livestock

production. A large number of trees and shrubs are eaten by livestock, wildlife and various animals (silkworms, fish, honeybees, agoutis etc…); a short list of the main ones could be established for each ecological zone but only a few species have been studied and often with insufficient scientific definition.

The role of trees and shrubs varies with the climate: the more arid the climate, the greater the use of trees and shrubs, even to the point where animals depend exclusively on them. Within each climate zone, trees and shrubs are more important in the dry seasons. They can be used as basal feeds or as protein supplements.

A lot of nutritional data exist but these were often obtained with different methodologies on materials of uncertain provenance, age or definition and on a limited number of species.

The feeding value of trees and shrubs depends on factors such as digestibility and deleterious compounds which are often not considered in most nutritional studies. Seasonal variation in nutritive value has also been ignored in nutritional evaluation.

B. and C. Local and fundamental research

1. **Research should be strengthened.**
2. **Technical validity, social acceptability and economical viability should be considered on the establishment, protection and increasing use of fodder trees and shrubs.**
3. **The knowledge of local people should be more often and more fully taken into consideration. Communication between concerned people and scientists should be increased.**
4. **A global data bank proposed by ICRAF should be adopted to allow rapid access to information. The list of useful species of economic importance should be enlarged in each ecological zone.**
5. **Selection of fast growing and high yielding varieties has still to be done.**
6. **Standardization of methodology for evaluation of trees and shrubs is also still required. At least in arid zones, carrying capacity, stocking rate and other similar concepts should be replaced, if possible, by concepts describing the grazing pressure and patterns of utilisation, as they do not take into account the animal owners' strategies.**
7. **Interactions between trees and shrubs, animals, crops and environment, within the feeding systems should be studied.**
8. **Research on processing technologies, on allelopathy, on deleterious factors and on technology for processing fodder should also be developed.**

D. Training

A multidisciplinary and systems approach should be taken into consideration within training programmes dealing with trees and shrubs. Animal scientists should be more aware of sociological, agronomical and forestry aspects and *vice versa*.

Livestock owners and farmers should be fully associated in an integrated manner to participate in research and development programmes.

E. Technology transfer

Technologies for planting and management of trees and shrubs should be adopted in each zone and in relation to potential demand and possible success.

Germplasm exchanges, creation of tree and shrub fodder banks and creation of botanical conservatories should come first and should include whenever possible the utilisation of a few specimens of endangered trees and shrubs species for germplasm conservation.

Based on ecological zoning, working groups on trees and shrubs should be

formed, with FAO and other international organizations' support, to exchange experience and information.

SESSION II. NUTRITIONAL ASPECTS

The main conclusions and recommendations within this session were the following:

- **The value of trees should be considered as multipurpose.**
- **There is a need to set up systems which involve the use of multipurpose fodder trees taking into consideration humans, animals, and the environment and the interaction between them. Potential areas where such work needs to be undertaken are North western India (Rajasthan) and also parts of semi-arid and arid Africa (Kenya, Mali and Senegal, for instance).**
- **In ruminant feeding, considerable evidence exists of beneficial responses to production due to the use of some tree fodder supplements in terms of live weight gain and milk production. There is a need for a wider application of these research results in large scale on-farm trials. Continuing research is necessary to focus on other fodder trees on which there is inadequate information.**
- **In non-ruminant nutrition, considerable potential exists for partial**

replacement of conventional protein sources, with the benefit of reduced cost of feeding in small farm systems.

- **On-farm research and development activities necessitate strengthening of research-extension linkages in participatory work with farmers involving efficient delivery systems.**
- **Research and development activities need to ensure that the use of these supplements are cost effective and economically justified in all production systems.**
- **Many of the fodder trees and shrubs have, as toxic or deleterious factors: mimosine, cyanogens, lectins and tannins. Practical and costeffective methods need to be demonstrated to overcome problems associated with their use. Tannins are to be considered as the most important deleterious principles in tree fodder and shrubs. It is recommended that more research be undertaken to determine appropriate methods of alleviating these deleterious effects in order to upgrade the quality of the protein supplements made with these feeds.**
- **In *Enterolobium cyclocarpum*, there exists an antiprotozoal substance that demonstrated reduced protein requirements and good perform ance in sheep. There is a need to explore more fully similar forages and inherent substances which could provide low cost supplements for ruminants in developing countries.**

- **Increased informal training is recommended for technicians in undertaking fundamental research, for instance tannins analysis, and for promoting the utilization of research results.**
- **There is also a concurrent need to accelerate information exchange on the subject as well as to promote increased contact between scientists working in this field within and between regions in the developing countries. This can be achieved through meetings and also exchanging visits.**

SESSION III. HARVESTING AND FEEDING SYSTEMS. REGIONAL AND COUNTRY CASE STUDIES

A. State of knowledge and what can be applied

a) Role of trees and shrubs

Trees and shrubs play a critical role in integrated farming systems because:

- **The leaves are sources of protein for both ruminant and monogastric animal species**
- **Stems and branches can be used as firewood or as fuel in gasifiers**
- **They control erosion**

- **Most species, even non-leguminous ones, are associated with organisms which fix atmospheric nitrogen**
- **The decaying organic matter on the soil derived from the fallen leaves acts as a mulch and sink for oxidation of methane**
- **The standing biomass is a living sink for carbon dioxide**
- **The provide shade, are windbreaks and conserve soil moisture**
- **Most trees and shrubs are deep-rooted and resistant to drought and unfavourable soil conditions. They are particulary valuable as supplements and sources of fuel in such regions**
- **They are also the cheapest feed resource for resource-poor farmers**

b) Farming systems

Five major farming systems have been identified where trees and shrubs are being used extensively. Examples are taken from specific countries, but the practices are widespread in the regions and subregions in all major continents. In addition, two other systems which relate to North Africa and the Middle East must also be considered.

1. Systems for rehabilitating arid and semi-arid regions using *Prosopis* spp.

***Prosopis tamarugo* was established on some 26,000 ha of the Tamarugal**

Pampa in Chile in the decades of the 60s and 70s. This region is a desert, characterised by almost complete lack of rainfall (average is 0.7 mm annually) and temperatures varying from 16 to 31°C with 52% relative humidity. Carrying capacity with sheep has risen from 1 animal/ha in the early years to 6–10/ha after 15 years. At this stage the productivity (leaves and fruit) from the forest is assessed to be 6,600 kg/ha (55 trees/ha).

***Prosopis juliflora* was introduced into N East Brazil in 1942, from Peru, and has spread extensively throughout the region. In this semi-arid region average yields of pods are 2–3 tonnes/ha/year; however, on soils of slightly higher fertility, yields up to 6 tonnes/ha/year (comparable yields of maize are 600 kg) can be obtained with 100 trees/ha while, with irrigation during flowering (600 litres/tree every two weeks), yields as high as 16 tonnes/ha have been reported. The feeding value of the pods (50% sugars) is only slightly inferior to that of cereal grain, when heatprocessed to neutralise non-nutritional compounds.**

***Prosopis cineraria* has an important place in the economy of the Indian desert where annual rainfall is from 150 to 500 mm. It produces flowers and fruit in the driest months when all other species are leafless and dormant. With 40 trees/ha, income from fodder, timber and fuel wood can reach US$**

500.00/year. The tree is an important feed resource in Oman where large forests are still found.

2. Agroforestry systems such as alley farming in West Africa

This system was derived from "alley cropping" or avenue cropping, in which food crops are grown in 4–5m wide alleys between hedgerows of trees and shrubs, preferably legumes. The hedges are trimmed at planting and during crop growth and the prunings used as mulch and fertilizer. In alley farming, part of the hedgerow material (about 25% is the recommended proportion) is fed to livestock especially small ruminants. *Gliricidia* and *Leucaena* have been the most widely used trees in the humid and semi-humid lowlands in conjunction with food crops such as maize and cassava. Alley farming can also be managed to provide larger quantities of fodder for livestock in trees-only or tree-grass plots.

3. Farm forestry in Nepal and India

In India, trees are planted along the bunds, water channels or on community lands. In Nepal forests they are integrated with crop production on terraces.

In India, commonly used species are *Acacia* spp., *Albizia* spp., *Ficus* spp.,

Sesbania **spp.,** ***Prosopis*** **spp.,** ***Ailanthus*** **spp.,** ***Ziziphus*** **spp.,** ***Hardwikia*** **spp.,** ***Pithecellobium*** **spp.,** ***Erythrina*** **spp.,** ***Enterolobium*** **spp.,** ***Azadirachta indica*** **and** ***Dalbergia*** **spp.**

Most of these species are found also in Pakistan and Nepal, as in the sub-continent in general. Additionally in Nepal, there is widespread use of ***Artocarpus lakoocha, Leucaena, Quercus, Salix, dendrocalamus, Budleja asiatica, Grewia ophra, Bauhinia*** **spp.,** ***Litsea polyantha, Castanopsis*** **and** ***Morus alba*****. There are three systems of usage:**

- **Extensive, by pastoralists completely dependent on livestock who depend on tree foliages and shrubs almost exclusively during the dry season.**
- **In rain-fed cropping areas where livestock are an integral feature of the economy. In times of drought livestock are the major source of income and this is when trees and shrubs are most used.**
- **Intensive cropping in irrigated areas where stress is on cash crops and trees are essential supplementary feeds especially for livestock owned by landless labourers who work in these areas. In all cases the trees and shrubs are considered as an important source of fuelwood and of timber. In many cases they also provide fruit for human consumption.**

The above pattern generally reflects usage of trees and shrubs in the subcontinent as a whole. In the high elevation areas, trees and shrubs are the major feed resource during the dry season.

4. Trees and livestock in upland cropping systems

In the Philippines, trees are integrated with many farming systems. In Batangas, *Leucaena* has had a major impact being used in intensive fattening while in Cebu a prosperous export trade was developed in leaf meal. However, many other species are commonly used: for example *Gliricidia, Sesbania, Moringa oleifera* and *Cocos nucifera* during the dry season.

5. Intensive integrated production of livestock and fuel from sugarcane, multipurpose trees and water plants in the wet tropics

In this intensive integrated system for the wet tropics, sugarcane is fractionated into juice for pigs and ducks, the tops for hair sheep and the bagasse for fuel. The leaves of *Trichantera gigantea* are used to replace 75% of the soyabean-based supplement for the pigs during pregnancy. The foliage of *Gliricidia sepium* provides almost all the protein for the hair sheep flock whose basal diet is the cane tops and a molasses-urea block. Net yields exceeding 4,000 hg/ha have been reported and methane: meat ratios are less

than 0.1, compared with 1.0 for typical pastoral systems.

6. Halophytic steppe and desert farming systems

This system integrates livestock, especially dromedaries and goats, and fodder trees and shrubs that are drought resistant and salt tolerant. It is largely represented by a belt starting in North Africa and continuing to the Middle East (more than 1.5 millions km^2). Rehabilitation of these desertic lands with species such as *Salsola spp, Suaeda spp, Traganum nudatum, Atriplex halimus, Acacia raddiana* and *Tamarix spp* is of a great value for the dromedary which is gaining a lot of interest. Such rehabilitation helps to decrease the desertification risk.

7. Artemisia Steppe farming system

This shrub is widely distributed in North Africa and the Middle East, i.e., it covers more than 11 million hectares just in North Africa alone. This fodder is highly palatable and well adapted to the arid environment. Sheep holders found *Artemisia* very useful as shrub. Improvements of the range lands dominated by *Artemisia* can be achieved through a proper grazing management. Association of *Artemisia* with other fodder trees and shrubs

such as *Acacia cyanophyla, Atriplex mummularia* and *Prosopis* spp. lead to an increase in animal production in a sustainable manner.

It is stressed that much of the experience with trees and shrubs is derived from farmers' experience and has long been a part of the culture of the farming communities in the different ecological zones.

With a more critical understanding of the role of trees and shrubs and of the factors influencing their nutritive value and productivity, the impact of these different systems could be increased considerably.

It is also stressed that it is the multipurpose role of trees, and especially their use as fodder, which is rendering this practice increasingly attractive in mixed farming systems.

B. On-Farm Research

There is a need for:

- **Socio-economic surveys to evaluate the role of multipurpose trees in mixed farming systems and especially their role as sources of fodder. Diagnostic studies should pay particular attention to the technical,**

political, and socio-economic aspects of incorporating multipurpose trees in farming systems.

- **A data base which describes traditional practices, ongoing research, resource persons, technology options and sources of information.**
- **Establishment of networks in equatorial regions of the three major continents. These should serve to promote activities in research, training and communication with respect to the use of trees and shrubs.**
- **Research on multi-purpose trees and shrubs must be interdisciplinary, since it involves forestry, agronomy, animal science and socio-econ omics. Support should be given preferentially to established groups that have such an interdisciplinary approach.**
- **Research is required in the following area:**
- **The balance between crops, trees and pastures.**
- **Evaluation of yield of pods and flowers on an individual tree and area basis, harvesting procedures and the utilization of these in practical feeding systems.**
- **Establishing response curves relating inputs of foliages and animal performance on different basal diets (e.g., crop residues).**
- **Use of mixtures of leaves from different species to optimise tannin contents and thus improve bypass protein characteris tics.**
- **On-farm processing of leaves (e.g., acid and alkali treatment) to aid**

conservation and to improve nutritive value especially for monogastric species.

- **Evaluation of gasification as a means of obtaining fuel from low-density ligno-cellulosic material.**

C. Problem-orientated Research on-station and at international Centres

- **Evaluation of local species of trees and shrubs, currently used widely by farmers, but for which there is negligible information.**
- **More precise information on secondary plant compounds, their effect on the animal, which of these are useful, and, if they are toxic, what kind of treatment is required for them to be neutralized. The approach should relate to the contrasting needs of ruminant and monogastric animals.**
- **In view of the dramatic improvements that can be obtained by defaunating ruminant animals fed tropical feed resources and the demonstrated anti-protozoal effects of tree species such as *Enterolobium cyclocarpum*, there is a need for more comprehensive testing of other species. This should be linked with known farmers' experience concerning the benefits of specific tree species on animal performance.**
- **Development of methods for conserving leaves, flowers and pods for**

use in lean periods.

- Studies on tree management for animal feeding.
- Studies on the effects of trees and shrubs on animal health over long periods.
- Studies on development of simple tools to facilitate harvesting of branches and pods.
- Design of gasifiers adapted to using low-density ligno-cellulosic material.
- Development of interactive "expert systems" software based on the ICRAF model and specifically directed to the needs of technology transfer, the aim being to provide information on appropriate species and management for specific ecological zones and farming systems.

D. Training

As with research so with training, the approach should be multidisciplinary and in-service. There is a need for postgraduate programmes which include socio-economics, forestry, agronomy and animal production. Short courses (1 to 2 weeks) are a valuable means of broadening the perspectives of professionals from specific disciplines, and for initiation of advisers involved in rural development (e.g., workers from NGO's). At the farmers' level, visits to regions where technologies are being applied is the most effective way of

technology transfer. There should also be incorporation in high school curricula of the importance of trees and shrubs as components of sustainable low-input farming systems. There should be a greater involvement of women both as teachers and trainees, and in the development of training materials directed at women.

Study tours to promote exchanges among countries with similar ecological zones (TCDC approach) should be encouraged. Regional training courses are also effective means of technology transfer.

E. Transfer of technologies

Ensure the "farmer first" approach at all levels. Identify successful farmers and then publicize their experiences through audio-visual aids and techniques. Emphasis should be on the role of trees and shrubs in the overall development process especially as this relates to protection and enrichment of the environment.

It must be noted that at the end of the presentation by the session's rapporteur, Dr: Preston, of the conclusions and recommendations elaborated within Group III, there was a general and very supportive agreement from the participants to consider this very comprehensive and attractive presentation

as the final text of the experts' conclusions and recommendations.

Nevertheless, the participants insisted, with regard to this text, on the necessity to include, besides the five major farming systems identified, the halophytic steppe and desert farming system as well as the Artemisia steppe farming system identified in North Africa and the Near East.

Participants also insisted on the necessity to clearly take into account the following:

- marketing aspects (foliage, bark, pods, seeds etc…);
- well defined objectives for research and projects formulation;
- women role and involvement in research and development;
- attention to be also focused on wastelands;
- involvement of governments and NGOs in development.

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