



1.1 The Role of Forage Tree Legumes in Cropping and Grazing Systems

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Introduction

Legumes have been used in agriculture since ancient times. Legume seeds or pulses were among the first sources of human food and their domestication and cultivation in many areas occurred at the same time as that of the major cereals. Nutritionally they are 2-3 times richer in protein than cereal grains and many also contain oil. Leguminous mulches have always been used as a source of nutrient-rich organic matter and nitrogen for crops. In more recent times, legumes have become important as high quality forages for livestock both in cultivated pastures and in naturally occurring associations.

Of all plants used by man, only the grasses are more important than the legumes but it is the legumes that show the most promise for future exploitation and development.

The legumes are the third largest group of flowering plants comprising over 18,000 species in 650 genera which are well distributed in most environments throughout the world. Taxonomists have divided the legumes into three families:

- The **Caesalpiaceae** contains about 2,800 species, most of which are trees of tropical savannahs and forests of Africa, South America and Asia (Williams 1983).
- **Mimosaceae** also contains about 2,800 species. These are predominantly small trees and shrubs of semiarid tropical regions of Africa, the Americas and Australia. *Acacia* species are the best known examples of this family.
- **Fabaceae** contains over 12,000 species, mainly herbs and small shrubs distributed worldwide, and includes the well-known grain legumes such as beans and peas.

Legumes in agriculture

Nitrogen is the most limiting element in agricultural production, and deficiency reduces the productivity of crops, pastures and animals. There are several potential sources of nitrogen to overcome this shortfall, namely:

- N from the mineralisation of soil organic matter,
- N from artificial fertilisers,
- N from biological nitrogen fixation in legumes, and
- N from organisms associated with tropical grasses.

Of these, N from soil is often insufficient for plant growth especially in most tropical soils which are low in organic matter. N from organisms associated with grasses is a minor source. Fertiliser N and N fixed by legumes are the largest potential sources with the latter being the cheapest source. Biologically fixed N is transformed into leguminous protein and this may be consumed directly by animals to meet their protein requirements and the excess returned to the soil via animal wastes. Alternatively, N may be returned directly to the soil as organic mulch.

Since few other plant families include species with a nitrogen fixing ability, legumes produce most biologically fixed nitrogen and are therefore crucial to maintaining the N-balance in nature. In Australia, Steele and Vallis (1988) estimated annual use of 35,000 t of artificial fertiliser N on pastures compared with 1.2 Mt of N derived from biological nitrogen fixation. Very high yielding leguminous crops can add up to 500 kg of nitrogen to the soil per hectare per year (NAS 1979) although inputs of 100-300 kg N/ha/year from good quality legume-based pasture would be a more realistic expectation (Steele and Vallis 1988). Legume associations are therefore vital to sustaining soil nitrogen fertility over long periods. The practice of shifting cultivation, traditional in many countries, is heavily dependent on the leguminous component of the primary and secondary forest cover for fertility restoration.

Another advantage of legumes is their high quality for animal production. The nutritive value of legumes is measured in terms of the potential intake of digestible dry herbage and, in general, legumes have both higher digestibility and higher intake than grasses and their nutritive value tends to remain higher as plants mature.

Tree legumes

Until recently, tree legumes were largely neglected by researchers because their utilisation and management fell between the disciplines of forestry and pasture agronomy. They are now receiving increased research attention because of their multipurpose value and some distinctive features which set them apart from herbaceous legumes. Their special characteristics may be summarised as follows:

Tree legumes

- are usually long-lived and low maintenance, and therefore enhance the sustainability of farming systems,
- provide high quality forage for feeding of livestock,
- stabilise sloping lands against erosion because of their deep-rooted habit,
- supply N-rich mulch for cropping systems,
- can be used to colonise and rehabilitate adverse environments, e.g. saline or arid locations,
- provide a source of timber and firewood for either domestic or industrial use,
- are used in farming systems as living fences, as shade trees for plantation crops, and as living trellises for climbing crops, and

- are a source of fruit and vegetables for human consumption (Figure 1.1.1).

Tree legumes can therefore be regarded as truly multipurpose trees for agriculture. These features of tree legumes will now be discussed separately.

[Fig. 1.1.1. Pods of tree legume sold for human consumption in Indonesia.](#)

Tree Legumes as Forage for Animals

The role of browse in natural grazing systems

Trees and shrubs have provided valuable forage to man's herbivorous animals probably since the time of their domestication (Robinson 1985). At least 75% of the shrubs and trees of Africa serve as browse plants and many of these are leguminous (Skerman 1977).

The overall importance of browse was summarised in the Commonwealth Agricultural Bureaux statement (1947) 'more animals feed on shrubs and trees or on associations in which shrubs and trees play an important role than on true grasslands'. McKell (1980) pointed out that shrubs and trees are the most visible plant forms in many landscapes, yet have been neglected in most scientific research. Much research effort has concentrated on methods for their eradication. In some arid and semiarid climates, livestock would not exist without browse species to supply feed.

Browse has been defined as the leaves, shoots and sprouts including tender twigs and stems of woody plants which are cropped to a varying extent by domestic and wild animals. It should be extended to include the fruit, pods and seeds which provide valuable feed, especially if the tree is deciduous.

Many tree legume species have evolved in semiarid regions alongside herbivorous animals and therefore have developed means of protection against browsing or grazing. Among the protective devices are thorns, toxins, fibrous foliage and height of tree crowns (Brewbaker 1986). Thorns characterise many woody legumes and are particularly prevalent on juvenile plants. Toxins are of two general types, those which deter feeding and those which poison the animal.

The nutritional quality of tree legumes varies from excellent (*Leucaena leucocephala*) to quite poor (most Australian *Acacia* species). Poor quality can be due to tannins which reduce the digestibility of both herbage and protein. The presence of tannins is often evident as brownish, reddish tinges in juvenile growth. Another reason for poor quality is that some species have phyllodes (expanded and flattened leaf petioles) instead of compound pinnate or bipinnate leaves which are very high in fibre and therefore of low digestibility, e.g. the Australian acacias.

Forage from tree legumes is often used as a buffer to overcome feed gaps that arise from seasonal fluctuations in the productivity of other feed sources. For example, grasses and other herbs may die when upper soil layers lose their moisture but the deep-rooted trees exploit moisture at depth and continue to grow. During the dry season or in times of drought, trees provide green forage rich in protein, minerals and vitamins while the herbaceous cover provides only poor quality straw.

The use of naturally occurring browse species is a vital component of livestock production systems in many regions of the world. In the Sahelian savannahs in Africa from Senegal to the Sudan, *Faidherbia albida* is a native leguminous species which is extremely important both in providing forage for livestock and in enhancing soil fertility for crops. *Prosopis* species provide forage for the sheep and cattle industries of the arid subtropical plains of Brazil, Argentina, Uruguay and Northern Chile. *Prosopis chilensis* contributes regular cattle feed in northwest Argentina and

central Chile while *P. tamarugo*, a native of Chile's northern plateau, is the only tree that survives on the arid salt flats producing the only available forage, timber and fuelwood in that region. In southwestern Queensland and northern New South Wales, mulga (*Acacia aneura*) occurs naturally often in monospecific stands and is used as a drought reserve for grazing sheep (see Section 7.1).

Under natural conditions, a large proportion of the foliage of tree species will be out of reach of grazing animals so utilisation can be manipulated by cutting or lopping to make it available when needed. Sometimes natural leaf fall through senescence is an important day-to-day component of the diet of some grazing animals. In Africa, goats thrive on the leaf fall of *Acacia melliflora* (Dougall and Bogden 1958).

Tree legumes as planted forage in cropping and grazing systems

As well as naturally occurring stands, tree legumes are often planted specifically for forage both in extensive grazing systems and in association with crops.

In many of the more intensive agricultural areas of Asia and Africa, where livestock are raised in small numbers by smallholder farmers, tree legumes are planted as 'forage banks' on unused land along field borders or fence lines, on rice paddy bunds or in home gardens. These areas are usually harvested under a 'cut-and-carry' system and are a principal source of high quality forage used to supplement low quality roughages such as crop residues. Productivity from these areas can be quite high. In the Batangas region of the Philippines, a 2 ha area of *Leucaena leucocephala* grown in association with the fruit tree *Anona squamosa* was able to supply the forage requirements of 20 growing cattle over a 6 month period (Moog 1985). At Ibadan in Nigeria, Reynolds and Atta-Krah (1986) suggested that the surplus foliage produced over a year from 1 ha of *Leucaena leucocephala* and *Gliricidia sepium* planted at 4 m intervals in an alley cropping system could be used as a supplement to provide half the daily forage requirements for 29 goats.

In many of these intensive cropping areas, tree legumes are planted not only for their forage but also for firewood, green manure and other uses.

In the more extensive grazing areas of Australia, southern Africa and South America, tree legumes are increasingly being planted in association with improved grasses to increase carrying capacity and productivity of grazing cattle. In central Queensland, over 20,000 ha have been sown to *Leucaena leucocephala* in the past 10 years. The leucaena is sown in wide spaced rows 4-10 m apart and an improved grass such as green panic (*Panicum maximum* var. *trichoglume*), Rhodes grass (*Chloris gayana*), buffer grass (*Cenchrus ciliaris*) or signal grass (*Brachiaria decumbens*) sown between the leucaena rows. A high stocking rate (up to 3-4 animals/ha) and liveweight gain (up to 1 kg/head/day) can be achieved with this system. A record liveweight gain of 1,442 kg/ha for cattle grazing a grass/legume pasture was achieved on an irrigated leucaena/pangola grass mixture in the Ord River District of north Western Australia (Jones 1986).

Other tree legume species that are being investigated for use in extensive grazing systems include *Calliandra calothyrsus* (Section 2.4), *Albizia chinensis*, *Cajanus cajan*, *Gliricidia sepium* (Section 2.2) and *Sesbania sesban* (Section 2.3).

Tree Legumes and the Environment

Degradation of natural systems

Unfortunately, due in large part to over-exploitation by both people and livestock, valuable tree and shrub resources over vast areas in arid and semiarid regions have been destroyed in the last few decades. In these areas, it is important that management practices are adopted which foster the wise use of diminishing tree and shrub resources. Livestock access should be restricted, and pruning and

harvesting of products performed on a rotational basis, to ensure time for regeneration.

In some cases, the presence of tree legumes has contributed to the degradation of the landscape. Animals can be maintained long after the loss of palatable perennial grass species due to drought or overgrazing, by feeding the foliage of hardy tree species. Vast areas of southwestern Queensland and East Africa have been degraded in this way.

Soil reclamation and erosion control

The restoration and maintenance of soil fertility is a basic and critical environmental problem. It is especially serious in tropical and subtropical regions where many soils lack plant nutrients and organic matter and intense rainfall erodes vulnerable top soil.

The nitrogen fixing ability of tree legumes allows them to grow on difficult sites subject to erosion, low fertility or other adverse soil conditions. Once established, they can create conditions favourable for the growth of other species leading to a balanced plant ecosystem. Tree legumes are a good source of organic matter for green manure. Their dry foliage contains 2.5-5.5% N and leaf material incorporated into the soil improves fertility, moisture and nutrient retention and general filth. At the same time, by improving soil structure, erosion can be retarded.

The extensive root systems of tree legumes enable them to adapt to steeply sloping sites unsuited to conventional cropping or grazing thus stabilising the sites from erosion and providing a measure of production which would not otherwise exist. The Sloping Agricultural Land Technology (SALT) developed in the Philippines (Tacio *et al.* 1987) is a prime example of the use of tree legumes in substantially reducing soil erosion and restoring moderately degraded hilly lands to a profitable farming system (see Section 7.5).

Tree Legumes for Fuelwood

It has been estimated (Eckholm 1975) that at least half the timber cut in the world is used as a fuel for cooking and heating. Approximately 2 billion people derive at least 90% of their energy requirements from wood and charcoal while a further 1.5 billion meet at least 50% of their requirements this way.

This essential resource, however, is seriously threatened. If the pace of tree planting around the world is not greatly accelerated, at least 500 million people will be without fuelwood for their minimum cooking and heating needs by the end of the century.

Tree legumes offer a partial solution to the fuelwood crisis. Of the 88 species recommended for fuelwood production by the National Academy of Sciences (1980, 1983), almost half were tree legumes. Tree legumes also meet many of the characteristics which are considered desirable in fuelwood species which include:

- rapid growth,
- nitrogen fixing ability,
- ease of establishment,
- ability to coppice,
- wood of high calorific value,
- wood which burns without sparks or toxic smoke,
- ability to grow well in a wide range of environments including difficult sites,
- multipurpose nature.

Tree legumes have been used successfully in sustained fuelwood production

systems. In the early 1920s, in the Paliparan area of the Philippines, *Leucaena leucocephala* was planted over a large area of unproductive *Imperata cylindrica* grassland. Since then it has yielded on average 20 m³ of fuelwood per hectare per year and is still the main source of fuel for the city of Laguna (NAS 1980) although recent damage by the leucaena psyllid (Section 6.1) has reduced the production of wood.

Other tree legumes that are highly regarded as fuelwood species include *Acacia auriculiformis*, *A. saligna*, *A. senegal*, *A. tortilis*, *Calliandra calothyrsus*, *Cassia siamea*, *Pithocellobium dulce* and *Prosopis* spp.

Conclusions

Tree legumes have an important role in many agricultural production systems throughout the world. They can be used in a multitude of ways including providing high quality forage to animals, contributing rich organic mulches to improve cropping land, stabilisation, of sloping landscapes from erosion, rehabilitation of degraded or saline lands, providing firewood or poles for construction, or as living plants for shade or fence lines.

Most of these topics are covered in greater detail in the following chapters of this book

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Plant Genetic Resources of Forage Crops, Pasture and Rangelands. C. Batello R. Brinkman L. Mannetje A. Martinez. J. Suttie. 3.3.1 Mediterranean and temperate forage legumes 3.3.2 Sub-tropical and tropical species. 4. grassland and forage genetic resources. 4.1 Pasture species selection and cultivar development 4.1.1 Temperate species 4.1.2 Tropical species 4.1.3 Vegetatively propagated pasture grasses. 6.1 Extensive grazing systems 6.1.1 Commercial extensive grazing systems 6.1.2 Traditional grassland systems 6.1.3 Mobile grazing systems. 6.2 Mixed farming systems and rotations 6.2.1 Intensive grassland production in north-western Europe (Wilkins 2000). Legume fixing trees and shrubs play a crucial role in biodiversity dynamics. From the ecological point of view, their introduction in cropping systems may contribute to reduce the use of chemical fertilizers and to ecosystems stability. 2. Description and functioning. 3. Importance and role in agroforestry tropical systems. Most tree and shrub legumes are resilient to extreme environments, e.g. erosion, low fertility, salinity, drought, fire and other adverse conditions [33, 34, 35, 36]. Such abilities seem to be innate and enhanced by the symbiosis with N-fixing rhizobia [30, 37].