

Application of agroforestry to African crop–livestock farming systems

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SUMMARY

THE VALUE OF tree legumes and constraints to their production in the different agro-ecological zones of Africa are assessed. Considerable research effort is required to solve the problems of germplasm availability and adaptation. Management issues, such as the identification of suitable entry points, are emphasised as the key factors determining the contribution of woody legumes to African farming systems. Depending on ecological conditions and the farming system, different management strategies can be adopted, including alley or terrace farming, fodder banks or intensive feed gardens, compound planting and plantation farming.

INTRODUCTION

ILCA's interest in agroforestry is limited to its application to mixed farming systems in which animals are important (Gryseels and Getachew Asamenew, 1985). Two of its basic agroforestry-related activities are acquisition and evaluation of tree germplasm and screening of fodder trees for nutritional factors, including both anti-nutritive and anti-dietary. The third is on-farm application of an alley farming model with *Leucaena leucocephala* and *Gliricidia sepium* in the humid zone, designed to improve animal feed supplies and soil fertility. The use of leguminous trees in mixed crop–livestock systems has recently been reviewed by Torres (1983).

The potential of leguminous trees to increase crop–livestock production in sub-Saharan Africa is discussed. Key management issues influencing tree introduction and contributions to these systems are described, followed by a detailed account of the management techniques suitable for different agro-ecological zones.

THE ROLE OF LEGUMES

The main constraints to plant and animal production in sub-Saharan Africa are nutrient shortages, particularly N and P, and water. Legumes can play various roles in improving the soil nutrient status, which in turn can positively affect the water constraint.

Soil nitrogen deficiency may be overcome through the use of fertilizer, manure or biological N fixation (BNF) by leguminous plants. BNF is an economical method to improve soil fertility that leads to a more active soil biology, which in turn improves nutrient cycling and soil physical conditions, such as bulk density, water infiltration and water-holding capacity (R. Lal, IITA, pers. communication). Legumes thus have two clear functions in mixed farming systems: they build soil fertility, thereby improving crop and forage yields, and enhance forage quality for animal production (Tothill, 1986).

The level of dietary forage intake by animals is determined by the quality and quantity of protein. Another factor influencing the rumen function is the level of tannins, which varies in different types of forage plants, particularly the woody species (van Soest, 1982). ILCA's animal feeding trials using browse and herbaceous legumes to supplement low-quality, straw-based diets demonstrated considerable differences in animal productivity between different species of leguminous fodder plants (ILCA, 1986a).

POTENTIAL OF TREE LEGUMES

Advantages

Because of the beneficial effects of legumes on plant and animal production, serious consideration has recently been given to the value of these plants to African farming systems. The woody species or multipurpose trees (MPTs) appear to have considerable potential for use in crop–livestock systems. Their advantages are:

- *Multipurpose use.* Forage, fertilizer (crop mulching), fuel, poles, building timber, shade, shelter from wind, soil conservation, fencing and forage conservation are all possible uses.
- *Perennial habit.* Most tree legumes are medium- (> 2 years) to long-term (> 10 years) perennials.
- *Deep-rooting habit.* Most trees are deep-rooted and can access soil water and nutrients that are out of reach of most crop and forage species. This enables them to produce or retain high-quality green forage even during the dry season. By tapping soil nutrients inaccessible to other plants, trees may also act as 'nutrient pumps'. Topsoil fertility is enhanced if tree cuttings are returned to the soil, either directly as mulch or indirectly as animal residues.
- *Dietary quality.* Because of the often prolonged production of green material, the dietary quality of prunings, usually determined by protein content, can remain high for most or all of the dry season. The effects of secondary polyphenolic compounds such as tannins, which tend to be more prevalent in tree legumes, can protect protein to various levels from rumen digestion. This may be used to both advantage or disadvantage in the overall digestion process.

Availability of germplasm

The use of leguminous trees in many African farming systems depends on the availability of exotic germplasm. This is because few vegetation systems are naturally endowed with adequate populations of leguminous trees, and germplasm availability is inadequate over all agro-ecological zones. ILCA is presently assembling germplasm from a wide variety of environments; other organisations and individuals are collecting MPT germplasm in Africa, Southeast Asia and Central and South America. Table 1 shows the present MPT germplasm holdings in ILCA's genebank.

Table 1. *Woody species germplasm in ILCA's genebank, September 1986.*

Genus	No. of species	No. of accessions	Agro-ecological zone ¹
<i>Acacia</i>	64	113	A to SA
<i>Aeschynomene</i>	9	94	H to SH, HL
<i>Albizia</i>	5	16	H to SH, HL
<i>Altriplex</i>	17	35	SH to SA
<i>Cajanus</i>	1	106	SH to SA
<i>Cassia</i>	9	14	H to SH
<i>Casuarina</i>	7	11	SH to SA
<i>Chamaecytisus</i>	2	30	SH, HL
<i>Desmanthus</i>	7	105	SA to SH
<i>Erythrina</i>	10	49	H to SH, HL
<i>Gliricidia</i>	1	87	H to SH
<i>Leucaena</i>	11	126	H to SH
<i>Prosopis</i>	7	14	A to SA
<i>Sesbania</i>	11	59	H to SH, HL
32 other genera	92	135	

¹ A = arid, SA = semi-arid, SH = subhumid, H = humid, HL = highlands (>1500 m a.s.l.).

Germplasm adaptation

A tentative assessment of germplasm adaptation to African agro-ecological zones indicates that problems occur in all zones except the humid:

- *Humid zone.* There is adequate germplasm available for this zone and adaptation is facilitated by ecological conditions.

- *Subhumid zone*. Because of acid soils (pH <5.5 and high aluminium content) and the widespread occurrence of a hard pan which impedes drainage and prevents root penetration, most legume trees establish and grow poorly in this zone.
- *Semi-arid zone*. The main problem in this zone is that selection for increased drought tolerance leads to decreased productivity. Thus, the management strategy must be oriented much less to optimising mulch or forage production than to maintaining reserves of forage for strategic feeding of certain animal classes.
- *Arid zone*. The relationship between tolerance and productivity is even more inversely proportional than that outlined for the semi-arid zone.
- *Highlands*. Locating woody browse species for the highland areas is also difficult, presumably because of the low temperature and high radiation. Since most temperate zones are in the higher latitudes, day-length control over plant phenology and function may be an adaptational barrier.

A more comprehensive account of MPTs is given by Burley (1985). Germplasm availability is limited partly due to inadequate germplasm exploration and definition of germplasm requirements. This applies particularly to *Acacia albida* which, despite its pan-African distribution and known genetic variability, has not been systematically collected for agroforestry¹.

¹The workshop on "Tree improvement in the Sahel", held in Nairobi from 27 February to 5 March 1987 by the International Union of Forestry Research Organisations (IUFRO) for the 16 Sahelian countries, confirmed that substantial *A. albida* germplasm is available in the semi-arid to arid zones. In these zones forestry and agroforestry have similar objectives.

Okigbo (1986) and others have reported that a large number of indigenous legume trees are already used by farmers for various purposes. A greater knowledge of these plants, their uses and potential in managed agricultural systems is needed to enable their complementary use with exotic species.

MANAGEMENT ISSUES

Some woody legumes have been used by man for a long time, and their potential to increase plant or animal production has been studied for many years. Why then has their adoption in crop–livestock farming systems been so slow? Probably because such management issues as practical ways to incorporate or use legume trees in these systems have not been researched.

Grass and tree balance

Where naturally occurring woody and herbaceous plants both contribute to the agricultural productivity of the system, as in the pastoral areas, an important management issue is to maintain the balance between the two components of the system. Either grass or tree species may dominate due to such factors as soil type, rainfall seasonality, grazing pressure, species type, fire etc. The factor(s) causing deviations from the desired balance must be identified and corrective measures introduced to ensure long-term productivity and sustainability of the system.

The introduction of additional forage elements, such as crop residues or herbaceous legumes, may, in certain situations, also upset the desired balance. For example, increased grazing pressure on species that are not adapted to high levels of defoliation may lead to the loss of one (e.g. the grass) component.

Entry points

Perhaps the most important management issue in agropastoral areas is the identification of points at which agroforestry technology can be introduced into the farming systems.

Traditional agricultural systems have two distinct phases: the fallow phase and the crop phase. During the fallow phase land is left to bush or grass for a period of time to rebuild soil fertility. Planting leguminous trees as a replacement for natural fallow will accelerate the rejuvenation process, and is thus a suitable entry point. The introduction of legume trees into the crop phase improves soil fertility and allows crop production to continue either indefinitely or for a considerably longer time than before.

Even though sensible entry points and apparently appropriate interventions can be defined, it is necessary that they should be tested in on-farm trials. The experience gained from these trials and feedback to researchers teach important lessons for technology adoption (Atta-Krah and Francis, 1986).

Mulch or fodder

If forage trees are planted in crop fields, a quantitative relationship has to be developed between the amount of foliage needed to maintain or restore soil fertility and that which could be harvested for animal feed.

Free-ranging livestock

Management of communal grazing lands poses another problem for which there is too easy solution. Agroforestry cannot be successfully implemented unless some communal management strategy is adopted (such as the livestock exclusion zones in Ethiopia) to prevent free-ranging animals from damaging seedlings and young trees. Goats can be particularly damaging.

Tree establishment

Finally, establishment is a critical management issue in agroforestry: most tree species are relatively slow to establish, require protection from animals and considerable labour input for weeding. Many agroforestry projects fail at this stage for lack of attention.

MANAGEMENT STRATEGIES

Different tree management strategies are suitable to different agro-ecological situations.

Arid and semi-arid zones

ILCA's East African rangelands programmes in Kenya and Ethiopia aim to exploit the more favourable environmental conditions in pastoral areas for the opportunistic production of crops and forages. This opportunity comes from the increased sedentarisation of the pastoralists and their realisation that supplementary calf feeding can substantially increase calf survival while maintaining milk offtake from dams. An appropriate strategy for growing legume trees in this zone is alley or terrace farming.

Alley or terrace farming. Under this technique hedgerows of leguminous trees are grown either in parallel rows or along a succession of contours; the intervening space is used to grow crops which are mulched with prunings from the hedges.

International Institute of Tropical Agriculture in Ibadan, Nigeria, pioneered alley cropping with *Leucaena leucocephala* and *Gliricidia sepium*, using 4-m hedgerow spacing (Kang et al, 1981). ILCA expanded on this work by introducing an animal feed component to the on-farm application of the technology, to test dry-season feeding of small ruminants (Atta-Krah et al, 1986).

The technique has also been adopted in Ethiopia's semi-arid zone (mid-altitude and lower highland areas) for terrace farming with *Sesbania sesban* on slightly sloping, easily erodible Vertisols (ILCA, 1986b).

Subhumid and humid zones

In the mixed smallholder farming systems of the more humid areas, a number of management strategies can be applied:

Fodder banks. These are small, densely sown stands of tree legumes providing high-quality fodder for dry-season feeding with natural forage or crop residues. Fodder banks with stylosanthes are being tested by ILCA's Subhumid Zone Programme (Mohamed-Saleem and Suleiman, 1986).

Intensive feed gardens (IFGs). This is specialised feed production on small plots of land. Fodder trees are grown either in pure stands or in combination with other forages such as herbaceous legumes and productive grasses. The gardens can provide high-quality supplementary feed for smallholder livestock (usually sheep and goats); the technique is being tested by ILCA's Humid Zone Programme (Atta-Krah et al, 1986).

Both fodder banks and IFGs may allow optimum use of light, manure or fertilizer in small areas, and perhaps also water through simple impounding. In the East African semi-arid zone, environmentally favoured areas are being selected for opportunistic cropping and, potentially, also for IFGs.

Compound planting/live fencing. Woody plants can be used in and around housing compounds and farm lands. Such fence and compound trees could supply fruits, vegetables, construction poles, fuelwood and fence poles. Moreover, small ruminants left around the housing area would greatly benefit from a regular supply of good-quality forage.

Fencing both the compound and cropland is usually important in the more humid zones. The fence can be made of spaced poles with wire strung between or as a close-planted barrier. Live fences tend to be more termite-resistant than dead fencing materials. Multipurpose trees such as leucaena, gliricidia, ficus and erythrina have all been used in fence development, the last three mainly for pole cuttings.

Water-point development. Because animals regularly congregate around water points, these areas are often heavily overgrazed or become denuded. Depending on the nature of the water point and the intensity of its use, forage banks with tree legumes could be developed at such sites. In the drier zones, many of the trees may require only a small amount of water in the establishment year, after which they have access to deep-soil water. However, the ever present threat of premature browsing is likely to be greater around water points.

Agroforestry development around water points can provide shade and shelter, and windbreaks to minimise soil erosion. These are being considered as companion developments to ILCA's pond development scheme for the southern Ethiopian rangelands.

Plantation farming. Under this technique a woody plantation crop is underplanted with a herbaceous ground crop and/or forage material. ILCA's Forage Agronomy Section has been investigating herbaceous leguminous forages suitable for underplanting coffee on smallholder mixed farms, but the technique can be used with other tree crops as well. Underplanting with forage legumes provides extra fodder while replacing weeds.

CONCLUSIONS

Fodder trees can play an important role in livestock farming systems in the tropics. However, research in this area is limited, as are genetic resources, particularly in tropical highland, dryland and acid soil situations. Useful species such as *Acacia albida*, found naturally in the subhumid and semi-arid zones of Africa, represent an enormous reservoir of genetic diversity, but have not been widely collected and evaluated. A further problem is the habitual cutting or pollarding of trees for fuel and fodder.

Management is likely to be different in an agroforestry-based system, and it is notable that such promising species as leucaena have had a long and chequered adoption career, mainly for management reasons.

Tree legumes can be grown under various agro-ecological conditions and managed for a variety of purposes or products. Thus they have a great potential for use in African small-scale farming systems, particularly those where fuelwood and forage resources are reduced.

Various types of MPT-based feed packages have been designed and tested, mainly in the humid zone. However, there is a considerable potential to introduce such packages also in the other zones, provided that germplasm identification, collection and acquisition for particular packages is closely coordinated with on-farm implementation and management.

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