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Alley Farming in the Humid and Subhumid Tropics

Proceedings of an international workshop held at Ibadan, Nigeria, 10–14 March 1986

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Alley Farming in the Humid and Subhumid Tropics

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Editors: B.T. Kang and L. Reynolds

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Abstract / Résumé / Resumen

Abstract — An urgent challenge facing scientists working on upland food-crop production in many parts of the humid and subhumid tropics is the need to find viable, sustainable, and environmentally sound alternatives to the ancient shifting cultivation and bush-fallow, slash-and-burn cultivation systems. As a food-cropping and livestock-production technology, alley farming requires a low level of inputs and helps conserve soil resources while sustaining long-term farm productivity. This publication presents the results of an international workshop on alley farming in the humid and subhumid tropics. Held in Ibadan, Nigeria, 10–14 March 1986, the workshop was attended by 100 participants from 21 countries. The theme of this workshop was the development of more productive, sustainable farming methods with low inputs in the humid and subhumid tropics using alley farming techniques. This book reviews the present state of alley farming research and its application, discusses the use of woody species in tropical farming systems, highlights training and research needs, and proposes the establishment of channels for collaborative research.

Résumé — Les scientifiques s'intéressant aux cultures vivrières en zones d'altitude dans de nombreuses régions des tropiques humides et sub-humides doivent répondre à un besoin urgent : trouver des solutions de rechange viables, soutenables et environnementalement saines aux anciennes méthodes de rotation des cultures et mise en jachère et de culture sur brûlis. A titre de technique de culture et d'élevage, l'agriculture en couloirs ne nécessite que peu d'intrants et contribue à conserver les sols, tout en favorisant la productivité agricole à long terme. Cette publication présente les résultats d'un atelier international sur l'agriculture en couloirs dans les tropiques humides et sub-humides qui s'est tenu à Ibadan, au Nigéria, du 10 au 14 mars 1986 et qui a réuni 100 participants de 21 pays. L'atelier portait sur la mise au point de méthodes culturales plus productives et plus durables ne nécessitant que peu d'intrants pour les régions des tropiques humides et sub-humides, grâce aux techniques de l'agriculture en couloirs. Le livre fait le point sur la recherche actuelle en matière d'agriculture en couloirs et ses applications, discute de l'utilisation des arbres dans les systèmes agricoles en milieu tropical, met en lumière les besoins en matière de formation et de recherche et propose l'établissement de canaux aux fins de la recherche en collaboration.

Resumen — Un reto urgente al que se enfrentan los científicos que realizan investigaciones sobre la explotación de cultivos de montaña en muchas zonas húmedas y subhúmedas de los trópicos, es la necesidad de encontrar alternativas viables, sustentables y correctas desde el punto de vista del medio ambiente, al antiguo método de cultivos migratorios y a los sistemas de cultivo en barbecho y de corte y quema. Como tecnología utilizada para cultivos alimentarios y la producción ganadera, la agricultura de pasillo o entresurcos necesita pocos medios y ayuda a conservar los recursos del suelo en tanto mantiene la productividad agrícola a largo plazo. Esta publicación presenta los resultados de un grupo de trabajo internacional sobre agricultura de pasillo o entresurco en las zonas húmedas y subhúmedas de los trópicos, celebrado en Ibadán, Nigeria, del 10 al 14 de marzo de 1986, y al que asistieron 100 participantes de 21 países. El tema de este grupo de trabajo fue el desarrollo de métodos de cultivo más productivos y sostenidos con pocos recursos en las zonas húmedas y subhúmedas de los trópicos, utilizando técnicas de agricultura de pasillo o entresurco. Este libro revisa la situación actual de la investigación sobre la agricultura de pasillo o de entresurco y su aplicación, discute el uso de especies maderables en sistemas de cultivo tropicales, subraya la necesidad de realizar investigaciones y dar cursos de capacitación y propone la creación de canales para la investigación conjunta.

Contents

Trees in forage systems

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Abstract—*Native trees in dense stands can be serious competitors to herbaceous pastures. With appropriate densities and management, however, trees can exploit an expanded biotic environment in forage systems and high economic gains can be achieved. This paper outlines the attributes of useful trees in forage systems and discusses the retention of valuable native trees on grazing lands. Selection of trees of immediate use in forage systems must rely on past experiences in the target region and similar environments throughout the tropics and subtropics. Fast-growing, multiple-use, nitrogen-fixing trees are considered most important in forage systems.* Leucaena leucocephala, Gliricidia sepium, *and* Sesbania grandiflora *are quick-growing leguminous trees already used throughout the humid tropics in cropping and forage systems. Selected forage types of* Cajanus cajan *can be undersown with crops. These trees can be put into farm use quickly, especially in alley cropping and alley grazing.* Leucaena *in alley grazing systems in Australia is discussed. The diversity of agroecological conditions in the tropics can impose severe constraints on crop, forage, and animal production. Research will identify better adapted nitrogen-fixing trees to suit this wide environmental range.*

Introduction

Trees and shrubs in tropical forests and savannas have provided people with shade, shelter, fuel, food, and fodder for their animals. Population and economic pressures have led to more intensive land use. This, in turn, has resulted in native trees being harvested or cleared for their economic products (e.g., building timber and fuel), the establishment of economic tree and annual crops, and the intensification of herbage forage production. In many countries, food production has not kept pace with human population growth, with drastic consequences to the stability of the environment. Special farming and forage systems are needed to increase livestock production within the ecological and socioeconomic constraints of each locality.

The development of farming systems involving both trees and crops (agroforestry) offered a means of optimizing land use. More importantly, the management practices involved in agroforestry were compatible with the cultural practices of the local population. In contrast to the shifting cultivation practices in the wet tropics, appropriate tree–multicrop systems offer a means of increasing production under a stable and rewarding environment for the farmers concerned (Watson 1983).

This paper addresses the value of trees in forage systems, the retention of useful native trees on grazing lands, and the selection of exotic trees. Alley cropping and alley grazing using *Leucaena* and other nitrogen-fixing trees are the main focal points.

Value of trees in forage systems

Trees expand the biotic environment by occupying a greater volume of the aerial and edaphic space and thereby offer protection to water catchment areas and regeneration of degraded farmlands. Trees also give shade and protection against the vagaries of the climate and, thus, create a more equitable microclimate near the ground for the benefit of food and forage crops, livestock, and humans. The canopy cover and ground mulch dissipate the energy of raindrops, increase water infiltration, and reduce moisture loss. The deep root systems tap a moisture source even in times of drought and recycle plant nutrients from depths inaccessible to crops and pastures. Nitrogen-fixing trees with highly nutritious foliage have several benefits. They add valuable nitrogen to the system as well as provide higher quality forage.

Competition for soil resources between trees and herbaceous crops and forages are minimal once the trees are well established because of the different environmental strata they occupy. There are tree species available that successfully exploit adverse environments (i.e., acid soils, saline conditions, waterlogged situations, long dry seasons, heavy clays, and deep sands) and provide economic products directly or indirectly. The economic value of the trees alone can be considerable because they may supply a variety of products such as fruit, vegetables, poles, firewood, building materials, salable timber, gum, high-value forage, and mulch. Because trees play a dominant role in plant communities, they can be integrated easily into cropping and grazing systems. Fodder trees also have the advantage of remaining productive during the dry season, when herbaceous forages dry out and decline in quality.

Native trees in forage systems

Native trees and native pastures

Pastoralists and scientists have observed useful browse plants and fodder trees in native grasslands (Everist 1969; Skerman 1977; Askew and Mitchell 1978; Le Houerou 1980; Cisse and Wilson 1985). These browse trees have been regarded as reserve forages for use during drought and the annual dry season. Generally, the quality of this "top" feed or browse is not high (Askew and Mitchell 1978), but they are useful for livestock survival. In some situations, native trees may have economic significance not only for high-quality forage but also for uses such as fuelwood, poles, and traditional medicines (Cisse and Wilson 1985). In the development of some scrub and woodland areas in Australia, for example, desirable trees such as *Brachychiton australe*, *B. rupestre*, and *B. populnea* have been preserved for drought feeding purposes.

Belts of indigenous trees have been preserved in native pastures to control erosion (Houghton 1984) and salinity (Hughes 1984), for livestock shade (Daly

1984), wildlife corridors, windbreaks, firebreaks, and other physical attributes for the long-term benefit of the environment and the domestic livestock (Burrows 1985; Burrows et al. 1986). Steep landscapes can be stabilized by the preservation of native trees in grazed and ungrazed situations. In monsoonal woodlands, moisture is not limiting during the wet season for tree and grass growth; however, lack of soil moisture in the long dry season is a serious limitation for grass growth (Mott et al. 1985). Even a low density of native trees in hot, monsoonal environments is of greater benefit to livestock than having no trees at all. In many of these native pastures, soils are grossly deficient in plant nutrients, especially nitrogen and phosphorus. The trees can act as nutrient pumps, recycling nutrients from soil depths to the surface layers. Nutrient accumulation under the tree canopy may allow nutrient-demanding grasses to establish and persist (Ebersohn and Lucas 1965).

Another excellent example of native trees enhancing the growth and persistence of a forage grass is that of lancewood (*Acacia shirleyi*) on the native lancewood grass (*Calyptochloa gracillima*) growing on the edge of lateritic red-earth tablelands in Queensland, Australia. The soil is very infertile and erodible when cleared. The *Acacia–Calyptochloa* combination is the most productive use of this land because the two species occur naturally on such soils and cattle relish the grass. The nutrients transferred to the grass and the shade from the nitrogen-fixing *Acacia* maintain a suitable environment for *Calyptochloa*, which may grow almost exclusively under the shade of the *Acacia*. The response may be similar to that of Texas bristle grass, which grows almost exclusively under trees and shrubs and generally has twice as much crude protein as other grasses (Everist and Alaniz 1982); shading may even enhance its crude protein content (McEwen and Dietz 1965).

Native trees and introduced pastures

In many countries, farms can still be found that have areas of standing native forest on shallow, infertile soils generally considered to have little potential for crop production. These areas usually are left as sources of fuelwood, farm timber, and salable timber, or are cleared completely for tree crops or pasture development. The importance of retaining trees to minimize problems of salt seepage and in preserving a timber supply has often been overlooked in agricultural development. Developing a forage system in such areas is possible and it can be of substantial benefit to the whole farming enterprise. An example of a native forest developed at minimal cost to improve pasture under the trees is the use of *Eucalyptus maculata – E. acmenoides* on a steep slope with shallow infertile soils at Gympie, Queensland. An improved pasture of Hamil grass (*Panicum maximum*) and *Archer axillaris* (*Macrotyloma axillare*) was successfully established from aerial broadcasting. The growth of the millable hardwoods was enhanced and the cattle benefited considerably, especially in the dry season, from the high-quality forage (Cook and Grimes 1977; Cook et al. 1984).

The rain tree (*Samanea saman*) is native to the humid rain forests of northwestern Venezuela. During the development of forest for improved pastures, the rain trees were preserved. These trees have been largely responsible for maintaining the high quality of the planted guinea grass (*Panicum maximum*) for milk and beef production (through the transfer of nitrogen) and the supply of nutritious pods for the animals. The use of tree legumes to enhance the production and quality of forage has been extended to forage systems in plantation crops (Gregor 1972; Thomas 1978; Watson 1983).

Plantation trees in forage systems

Improved pastures under plantation crops grown for food or industry have had benefits beyond that of supplying forage for livestock either in grazing management or in cut-and-carry systems. In the plantation-establishment years, forage management is such that the crops are not harmed by livestock or seriously set back by competition from the planted forage. Generally, cut-and-carry systems of harvesting the forage in the early years allow for flexible management so that crops and forage can be established rapidly. Grazing begins when the tree crops cannot be damaged by the livestock. Plantation crops and forage species can be combined in numerous ways and many have been reported (e.g., Thomas 1978; Humphreys 1978; Watson 1983). Tree crops supplying food and food products may be grown in enterprises ranging from small, self-sufficient farms to large commercial organizations. Other trees are grown for industrial products such as timber, pulpwood, fibre (kapok), oil, rubber, and medicines (e.g., *Dubosia* in Australia).

Nonleguminous trees have been used for mulch and forage; discussion here, however, is centred on nitrogen-fixing legumes that are usually associated with plantation crops. These plants offer a cheap source of protein for the livestock and nitrogen for crop fertilizer. Herbaceous and tree legumes alone or in combination can be incorporated into such forage systems. Nitrogen-fixing trees serve several purposes, including forage. When selecting such trees in a forage system, the needs of the farming–pastoral community, other socioeconomic factors, desirable features of the available tree legumes, and the urgency to implement programs using them in cropping and forage systems must be carefully considered.

Selection of tree legumes

There are many multipurpose tree legumes that could be incorporated into cropping and forage systems, ranging from small shrubs to tall trees. Attributes of tree legumes recognized as useful in forage systems are given by MacMillan (1935), Purseglove (1968), Gray (1969), Brewbaker et al. (1972), Skerman (1977), NAS (1979, 1980, 1983a, b, c, d), Brewbaker et al. (1982), Craswell and Tangendjaja (1985), Reid and Wilson (1985), and Brewbaker (1986). Several characteristics of tree legumes are considered highly desirable when establishing forage systems. Thornlessness and perenniality are prerequisites. The trees should produce high yields of edible material with rapid regrowth after cutting and be good-quality forage in terms of protein and mineral content, palatability, and digestibility. They should also retain leaf and edible plant parts of high quality in the dry season. Finally, the tree legumes should be relatively easy to establish and exhibit rapid, early growth.

Trees in a single tier

From past work and the availability of planting material, several tree legumes come to the fore for immediate use. The first is *Leucaena leucocephala*, which has been researched widely. There is a wide range of *L. leucocephala* cultivars, from shrubby forms to upright trees. Cultivar selection depends on the proposed management system. Because the tiny insect, *Leucaena* psyllid (*Heteropsylla* sp. poss. *incisor* [Sulc]) is a threat, resistant cultivars, such as the Hawaiian Giants (cv. K-527, K-538, K-584, K-591, K-636, K-658), are important (J.L. Brewbaker, personal communication). *Gliricidia sepium* is another tree legume used widely throughout the humid tropics for which much information is already available. *Leucaena* and *Gliricidia* have already been selected for the humid zone of Nigeria by Atta-Krah et al. (1985), who concluded from their studies that both these tree legumes are highly productive, contain significant amounts of nitrogen, establish well under tropical environments, and, therefore, are immensely suitable for the improvement of farming systems through maintaining soil fertility for crop production and increasing the availability of high-protein feed for small ruminants. The rapid early growth and other attributes of *Sesbania grandiflora* reported in Indonesia (Craswell and Tangendjaja 1985) and elsewhere (Skerman 1977; NAS 1979, 1980) make this tree legume worthy of immediate consideration for inclusion in forage systems research and development in both the humid and subhumid tropics.

The vigorous, tall-growing cultivars of pigeon pea (*Cajanus cajan*) are other forage legumes worthy of evaluation. Pigeon pea is a common crop throughout the tropics where it is used as food, forage, windbreak, ground cover, and fuel (Skerman 1977; NAS 1980). Although grown and used as an annual or biennial for pulse production, it can be maintained for up to 5 years for mulch and forage. Pigeon pea has been planted in rows between crops or sown mixed with the main crop. Because of its slow initial growth and suppression by shading, it is often sown with summer crops, such as maize and sorghum, to produce pulse and forage after the main crop has been harvested. Inoculation is not needed and some cultivars tolerate soils with excess salt, soluble aluminum, or manganese (NAS 1980). Pigeon pea has all the desirable attributes of a shrub legume for forage and mulch, but it is short lived. Rapid early growth of pigeon pea can be advantageous when it is planted with other, slower growing tree legumes. Planting a combination of tree legumes can also provide insurance against disease or pest damage that might attack one particular species.

Leucaena has been used widely in alley cropping in Indonesia, the Philippines, and many African countries. The management of *Leucaena* in alley cropping may differ slightly between countries and between farms. In the Philippines, *Leucaena* hedges are 4 m apart and pruned at 1 m every 6 to 8 weeks. The soft foliage and stems are used both as mulch for the companion crops and as livestock feed away from the crop area.

Whereas *Leucaena* could receive priority as permanent trees in alley systems for both the humid and subhumid areas, *Sesbania grandiflora* also deserves attention for similar areas. *Gliricidia sepium* is likely to be important for humid areas only.

Trees in multiple tiers

A high tier of tall tree legumes at densities of no more than 20/ha could be incorporated into long-term cropping and forage systems. Local trees may be preferred by farmer–pastoralist groups, as with *Acacia albida* in Malawi (Casey 1983). *Acacia auriculiformis*, *Erythrina poeppigiana*, *Samanea saman*, *Albizia falcataria*, and *Pterocarpus indicus* could serve useful roles as upper-story nitrogen suppliers to the cropping–forage systems.

For more intensive forage systems using leguminous trees, alley grazing and protein banks for supplementary grazing have been very successful. Again, *Leucaena leucocephala*, *Gliricidia sepium*, *Sesbania grandiflora*, and other quick-growing tree legumes have been used. The experiences with *Leucaena*, however, can be used as models for cultivated tree legume forage systems, which vary considerably from protein banks to alley grazing systems.

Leucaena in forage systems

In the tropics and subtropics, *Leucaena* has been used in many different ways in forage systems. Each system has strengths and pastoralists can choose the forage system best suited to their particular situation. System names may differ between countries, often because of the systems' flexibility. Sometimes systems can overlap or change with the seasons depending on the associated crop stage or forage requirement.

Intensive forage systems

Intensive forage systems involve dense stands of *Leucaena*, often irrigated, where intensive management is an essential element. The size of the operation may differ between countries and even between farms but the three following basic models are common.

Forage and protein banks

Naturalized *Leucaena* and high-density plantings have been used in cut-and-carry systems in many countries to supplement other forages available for intensive stall or corral feeding of livestock. Generally, harvesting continues throughout the year.

Livestock may also have access to all or a portion of the *Leucaena* paddock for grazing for short periods on a rotational basis with other forages. Native grass (Foster and Blight 1983) or sown grass pastures usually supply the major part of the feed requirement. Although this rotational grazing may continue throughout the year, *Leucaena* supplementation becomes more important during critical nutritional stress periods. Deferred use for such times is often practiced.

Leucaena–grass mixtures

Leucaena is established by broadcasting at relatively high seeding rates (5–10 kg/ha) with a companion grass (1–2 kg/ha). Rotational grazing to suit the *Leucaena* regrowth is used. A similar system has been used by researchers at the

Central Mindanao University in the Philippines where *L. leucocephala* cv. Hawaiian Giant K-8 was established as seedlings at 2-m spacing on the square, within a *Panicum maximum* stand. Set rotational grazing was practiced.

Irrigated *Leucaena*

Leucaena planted in rows 3–4 m apart with pangola grass between the rows has been used under irrigation and rotational grazing at the Kimberly Research Station in western Australia. The pasture, grazed at 4–5 steers/ha throughout the year, has given high animal production levels (D. Pratcheet, personal communication; Wildin et al. 1986).

Another irrigated *Leucaena* system in eastern Queensland involves high-density plantings at 1 to 1.5 m row spacings. The *Leucaena* can be machine harvested every 8–10 weeks for green feed or dried meal production. Intensive rotational grazing may also be practiced. In Australia, grazing such intensive *Leucaena* pastures demands that the ruminants be inoculated with 3-hydroxy-4 (IH) pyridone (DHP) with the detoxifying bacteria found in ruminants grazing *Leucaena* in Hawaii and Indonesia (R.J. Jones, personal communication; Partridge and Adams 1985).

Alley systems

Alley systems involve *Leucaena* or other forage tree legumes in defined rows with crops or other forages planted between the rows. There are four general alley systems.

Alley cropping

Leucaena is established in rows 4–20 m apart, depending on soil type, rainfall, associated crop, and farming practices. Crops are grown between the rows. Permanent tree crops may be involved; however, the discussion here focuses on annual cropping. In central Queensland, Australia, rows as wide as 20 m have been established with grain sorghum planted between the rows. The row spacing allows extensive cropping with wide planting and harvesting machinery while the *Leucaena* is becoming established. A grazed fallow is practiced and when the *Leucaena* is at least 3 m tall, perennial grasses are established between the rows and alley grazing is then practiced.

In the humid and subhumid tropics, *Leucaena* is planted in single or close double rows that are spaced 4–8 m apart. Annual crops are planted between these permanent *Leucaena* hedges. Generally, prunings are used as mulch–fertilizer. Some of the prunings are removed for livestock feeding away from the crop area (see Kang et al., this volume).

Some alley cropping systems have no fallow period because a following crop is established before the earlier crop is harvested. The crop stubble is used for mulch or removed for livestock feeding supplemented with *Leucaena* prunings. In other alley farming systems, livestock is allowed to graze on crop stubble, undersown legumes, and *Leucaena* rows during the fallow period.

Grazed fallow

Livestock access to the cropping area depends on the fallow period between crop plantings. The grazed fallow can be a matter of a few weeks to several years. The contribution of the grazed fallow to soil stability and fertility and to crop and livestock production is being studied (Atta-Krah et al. 1985). During the grazed fallow, one of the alley grazing systems is adopted.

Alley grazing – hedgerow system

In the alley grazing – hedgerow system, *Leucaena* is managed so that all forage on the bushes is completely accessible to the grazing livestock. For long-term alley grazing, a grass is established between the *Leucaena* rows. During the dry season, continuous grazing may be practiced; however, during the main growing period, rotational grazing is essential to allow a rest period for the *Leucaena* to recover from severe defoliation. A suitable rotation would be 2 weeks grazing and 6 weeks rest. More intensive grazing of shorter duration may be practiced but a minimum of 4 weeks rest is essential; 6–8 weeks is preferable. Intervals between grazing could be lengthened during periods of slow growth. Sometimes the pasture is rested to accumulate a bulk of high-quality forage for the beginning of the dry season.

When the interrow spacing is less than 5 m, *Leucaena* should be prevented from growing too tall so that grass and herbaceous pasture legumes growing between the rows receive sufficient light. When there is excessive shading, pruning or lopping will bring the *Leucaena* back to a manageable grazing height.

Alley grazing – tree system

In the alley grazing – tree management strategy, *Leucaena* is encouraged to grow into a multistemmed tree. This system is generally not associated with a cropping fallow but with permanent pastures established between the rows. The favoured cultivars are Peru and Cunningham, shrubby cultivars that naturally branch at the base. Row spacings should be at least 7 m to allow sufficient light to penetrate for vigorous grass growth. The amount of *Leucaena* forage from the trees and seedlings may not be as high as in the hedgerow system; however, this system is productive and stable, and provides highly nutritious feed, shade, and organic fertilizer (Wildin 1986) compared with other sown pastures that demand higher management inputs for persistence and productivity.

The alley grazing – tree system has allowed rapid commercial adoption of *Leucaena* in Australia, especially in semiintensive and extensive enterprises (Wildin 1981, 1986). *Leucaena* offers high-quality forage in the critical dry season. It can play an important role in augmenting low-quality native pastures (Miller et al. 1986) in savannas with distinct dry seasons. The management in such systems can be quite varied; at the drier end of its range, wide-row alley grazing between *Leucaena* growing as trees would be most appropriate.

Animal production

Improved animal production from planted forages is usually expressed in terms of higher stocking rates and higher live-weight gains per animal per year than those obtained on native pastures. Planted forages complement or supplement other available forages. The value to livestock of the high-quality forage from *Leucaena* and other fodder tree legumes in the dry season is well recognized. For beef cattle, high stocking rates and daily live-weight gains up to 1 kg/head have been achieved on *Leucaena* pastures in central Queensland, Australia (Foster and Blight 1983; Wildin 1986). Breeding cows have grazed on *Leucaena* as a supplement to native pastures during the dry season. The benefits are difficult to assess in terms of improved breeding performance because no comparative work has been done. *Leucaena* is known to improve the live weight of cows at the end of the dry season. This suggests that the cows would be gaining weight quickly early in the wet season and conception rates would be high. In this respect, *Leucaena* could give further gains to animal production over that gained from native pastures.

Conclusions

Indiscriminate forest clearing in the world, occurring at the rate of 10 to 20×10^6 ha/year, will make native fodder trees a thing of the past for many countries (Brewbaker et al. 1982). The Americas and Indonesia will have most of the remnants, a mere 25% of the forests that covered the tropics a century ago. However, the addition of legume shrubs and trees could have a major impact in fodder intake and nutritional value for the vast grazing and cropping areas of the natural and induced savannas of this zone. Multipurpose legume trees that provide fodder and fuelwood and have beneficial effects on the environment, humans and their livestock will be of value. Where adapted, *Leucaena* (especially the psyllid-resistant cultivars), *Gliricidia*, *Sesbania grandiflora*, and the forage types of *Cajanus cajan* can be immediately incorporated into alley grazing systems. The many advantages of tree legumes have been recognized, and they deserve more research and development.

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