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Cover Crops in West Africa
Contributing to Sustainable Agriculture

Plantes de couverture en Afrique de l'Ouest
Une contribution à l'agriculture durable

Edited by/sous la direction de
D. Buckles, A. Etèka, O. Osiname, M. Galiba and/et G. Galiano

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Smallholders' use of *Stylosanthes* for sustainable food production in subhumid West Africa[1]

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Abstract

The subhumid zone of West Africa has 180–270 growing d and receives 900–1 500 mm of rainfall. The zone is covered mainly with ferruginous tropical soils that have very low levels of N and P and a low cation exchange capacity. The common farming system is crop–livestock, with a predominance of cash crops wherever these have been introduced. The genus *Stylosanthes*, which originated mainly in South America, was tested in West Africa as early as the 1940s in an attempt to improve livestock nutrition and soil fertility. Some of the major attributes explaining the success of this genus are tolerance to the fungal disease anthracnose, adaptation to infertile soils, drought resistance, ability to fix N without special *Rhizobium* inoculum, and high seed yield.

Integration of *Stylosanthes* into the West African farming systems intensified with the opening of the International Livestock Centre for Africa's subhumid research site in Kaduna, Nigeria, in 1978, and since then the genus has been exploited to suit the domestic needs of various countries.

The management systems included sole crops of *Stylosanthes* ("fodder banks") to supplement natural range or improved grass–legume and legume–legume associations. *Stylosanthes* has also been successfully integrated in crop rotations as an intercrop and relay crop.

Tremendous variation occurs in the research–development efforts and diffusion of *Stylosanthes* in the West African region. For instance, in Nigeria, this legume is exploited by smallholders for agropastoral herds, small ruminants, and crop production. More recently, the concept of mixed cover crops involving *Stylosanthes* was introduced, and evidence suggests that such a management system leads to more profitable and sustainable crop–livestock production systems. In Cameroon, a lot of potential exists for the

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expansion of *Stylosanthes*-based enterprises into agropastoral herds, but the smallholders have not fully exploited such benefits. This is mainly because on-farm research and extension are in their infancy in this region. In Côte d'Ivoire, the use of *Stylosanthes* has been geared toward the dairy industry through the Eco-farms Project, a scheme jointly sponsored by the African Development Bank, Gesellschaft für Technische Zusammenarbeit (organization for technical cooperation), and the Ivorian government. The aim has been to enable smallholders to generate incomes equivalent to those of their counterparts in the cities. In Mali, *Stylosanthes* could improve cereal production and the performance of traction animals.

Some constraints to adoption, such as lack of labour and capital, plant disease, insufficient quantities of seed, and the expense of fencing, cut across all the four countries studied; other problems are specific to individual countries. The land-tenure constraint affecting agropastoralists, for instance, is more acute in Nigeria. In Côte d'Ivoire, pasture management is a serious problem in the Eco-farms where *Stylosanthes* is grown in association with aggressive grasses. Also, the scheme is too capital intensive. In Cameroon, the weak support for on-farm research and extension is unique, whereas in Mali, the successful cotton industry is providing capital for *Stylosanthes* adoption.

The potential of *Stylosanthes* for feed improvement, land reclamation, and control of noxious weeds should be further exploited by integrating the legume in crop rotations and promoting it to farmers with more profitable enterprises, such as those involving beef cattle, dairy cattle, traction animals, and cotton.

Other measures recommended for the long-term sustainability of *Stylosanthes* systems include the establishment of an adequate seed supply, identification of highly productive and disease-resistant varieties, use of live poles (for example, *Ficus*) for fencing, and the use of draft power. Government policies that promote loan schemes and protect land rights are also needed.

Résumé

La zone subhumide de l'Afrique occidentale se caractérise par une pluviométrie de 900 à 1 500 mm par année et par une période de croissance allant de 180 à 270 jours. Cette zone est principalement couverte de sols ferrugineux tropicaux qui ont un niveau très bas de N, de P et de capacité d'échange cationique. Le système d'exploitation agricole habituel est l'exploitation culture–élevage où prédominent les cultures commerciales là où celles-ci ont été introduites. Le genre *Stylosanthes*, qui provient surtout de l'Amérique du Sud, a été mis à l'essai en Afrique occidentale dans les années 1940, afin d'améliorer le fourrage ainsi que la fertilité des sols. Certaines des qualités essentielles attribuées au succès du genre *Stylosanthes* sont une tolérance à la maladie fongique, l'anthracnose, une adaptation aux sols infertiles, une résistance à la sécheresse, une capacité fixatrice de N sans inoculant rhizobien particulier, et un rendement grainier élevé.

L'intégration des *Stylosanthes* dans les systèmes d'exploitation agricole de l'Afrique occidentale s'est accrue depuis l'ouverture du site de recherche subhumide du Centre international pour l'élevage en Afrique à Kaduna, au Nigeria, en 1978. Depuis, le genre a aussi été exploité pour répondre aux besoins locaux de divers pays.

Les pratiques de gestion utilisées comprenaient les cultures de rangée de fourrage de *Stylosanthes* seules pour compléter la gamme naturelle ou les associations améliorées herbe–légumineuse et légumineuse–légumineuse. Les *Stylosanthes* ont aussi connu un succès dans leur intégration aux rotations de cultures comme culture intercalaire ou culture de relais.

Les efforts de recherche et de développement ainsi que les efforts de diffusion liés aux *Stylosanthes* en Afrique occidentale sont nombreux et variés. Par exemple, au Nigeria, cette légumineuse est cultivée par de petits exploitants pour la production de bovins, de petits ruminants et de cultures. Plus récemment, le concept de cultures de couverture mixtes utilisant les *Stylosanthes* a été introduit et semble démontrer qu'un tel système de gestion favorise une exploitation culture–élevage plus profitable et durable. Au Cameroun, il existe un grand potentiel pour l'expansion d'entreprises utilisant les *Stylosanthes* pour les troupeaux de pâturage, dont les petits exploitants n'ont pas encore complètement tiré parti. La raison principale est que la recherche en ferme et la vulgarisation en sont encore à leur début. En Côte d'Ivoire, l'utilisation des *Stylosanthes* est dirigée vers l'industrie laitière au moyen du Projet de fermes écologiques, une entreprise conjointement appuyée par le Groupe de la Banque africaine de développement, le Gesellschaft für Technische Zusammenarbeit (agence allemande de coopération technique) et le gouvernement ivoirien. Le but était de permettre aux petits exploitants de générer des revenus équivalant à ceux de leurs homologues des villes. Au Mali, les *Stylosanthes* offrent la possibilité d'améliorer le rendement des animaux de trait et celui de la production céréalière.

Les contraintes liées à l'utilisation de la légumineuse, telles que le manque de main-d'œuvre et de capitaux, les maladies des plantes, le manque de semences et les coupures imposées aux quatre pays à l'étude, s'ajoutent aux problèmes spécifiques de chacun des pays. Par exemple, la contrainte de la tenure qui nuit aux agropasteurs fulanis est typique du Nigeria. En Côte d'Ivoire, l'exploitation des pâturages est un sérieux problème pour les fermes écologiques, où les *Stylosanthes* poussent aux côtés d'herbes envahissantes. De plus, la structure fonctionne à trop forte intensité de capitaux. Au Cameroun, il existe peu de soutien pour la recherche en ferme et pour la vulgarisation, alors qu'au Mali, le succès des nouvelles technologies dans l'industrie du coton nuit à la popularité des *Stylosanthes*.

Il est recommandé d'exploiter davantage les possibilités que représentent les *Stylosanthes* pour l'amélioration alimentaire, la récupération des terres et le désherbage, en intégrant la légumineuse dans les rotations des cultures et en visant les entreprises plus rentables telles que le bœuf, les bovins laitiers, les animaux de trait et le coton.

Pour favoriser la durabilité des systèmes utilisant les *Stylosanthes*, il est également recommandé de s'approvisionner suffisamment en semences, d'utiliser des variétés hautement productives et résistantes à la maladie et de recourir à des intrants à moindre coût, tels les engrais, pour le billonnage cloisonné, en plus d'utiliser une puissance de traction, des politiques gouvernementales favorables aux systèmes de prêts et axées sur la protection des droits terriens.

Introduction

Subhumid West Africa

The West African subhumid zone (SHZ) covers Burkina, Benin, Cameroon, Côte d'Ivoire, The Gambia, Ghana, Guinea, Liberia, Nigeria, Senegal, Sierra Leone, and Togo. The SHZ has a single growing season (180–270 d) and covers 45% of sub-Saharan Africa (SSA). The common farming system is crop–livestock In some areas, cash crops predominate. The SHZ offers the greatest potential in SSA for growing crops and producing livestock, both of which are currently in crisis.

A major constraint to meeting the food demands in the SHZ is that SSA is experiencing substantial land degradation, leading to decreasing total agricultural productivity (Lal 1989). Marginal lands are increasing, as a result of land pressure from rapid population growth. Traditional grazing lands are acquired for cultivation, and the long fallow periods (crucial for regenerating the soil's fertility) have become unfeasible (Ruthenberg 1980). Recent studies suggest that the population of SSA (0.5 billion in 1990) will reach 1.2 billion by 2025 (Winrock International 1992). The studies also predict a demographic shift, with urban dwellers increasing from 29% to 55% of the population, implying that the rural sector will have to produce more food to feed the urban population.

Some technical developments have improved the crop–livestock production systems in the region. An example is the dual use of *Stylosanthes* as feed for starving animals and as an amendment for poor soils. Over the years, West African countries have developed various scenarios for exploiting the potential of this genus, based on their own needs. For instance, in Nigeria and Cameroon, *Stylosanthes* is used mainly for agropastoral herds, small ruminants, and crop production. In Côte d'Ivoire, the legume is used to boost the dairy industry; in Mali, to improve soil fertility and the performance of traction animals.

This paper provides a synthesis of the ways *Stylosanthes* is used in four West African countries — Nigeria, Cameroon, Côte d'Ivoire, and Mali — and the constraints to adoption of the technology. We selected these countries because they are known to use *Stylosanthes* at all levels and stages, from research through to on-farm adoption. We discuss the critical points and future opportunities for the long-term sustainability of *Stylosanthes*-based systems in subhumid West Africa. To obtain information, we reviewed the existing literature, made field visits, and held detailed discussions with smallholder farmers, researchers, and extension workers. This information is probably applicable to other countries in subhumid West Africa.

Brief history of *Stylosanthes*

Stylosanthes, a genus of the subtribe Stylosanthinae, tribe Aeschynomenae, subfamily Papilioniodae, family Leguminosae, occurs naturally in the tropical, subtropical, and temperate regions of the Americas, tropical Africa, and southeast Asia (t'Mannetje 1984). The major centres of diversification are the southern neotropics, particularly Brazil; a secondary centre is in the Mexican–Caribbean basin (Stace and Cameroon 1984). About 45 species and subspecies belong to the genus; these are classified into two sections, *Stylosanthes* and *Styposanthes*. *Stylosanthes* is self-fertile and predominantly self-pollinating. The range of photoperiod response in the genus is wide: short day, long day, day neutral, and long–short day. *Stylosanthes* spp. differ from most tropical pasture legumes in other genera because of their nonclimbing growth habit. Growing points are often close to the ground, and this is advantageous under grazing. Another rare feature of *Stylosanthes* is its single seed in an indehiscent pod, which helps to regulate germination and improve seed survival (Gardener 1975). *Stylosanthes* is the genus that has received most attention in the search for tropical pasture legumes, and this has resulted in the release of a wide range of commercial cultivars, as summarized in Table 1.

Overall, the genus is adapted to the tropics and subtropics. The natural habitats of *Stylosanthes* are usually areas of low soil fertility, especially where the soil has a low P content and an acidic nature, although forms adapted to alkaline soils are common in the Caribbean, Central America, and Mexico.

Stylosanthes has been shown to perform well under both drought and waterlogged conditions (Edye and Grof 1984). In contrast to most other tropical pasture species, *Stylosanthes* usually exhibits a high N content, combined with a very low P content, and the P content decreases as the plants age, especially under water stress. Although the amount of P is inadequate for the nutrition of grazing animals, other minerals seem to be available in sufficient amounts. In addition to improving natural rangeland and animal performance, *Stylosanthes* spp. have shown particular promise for inclusion in ley systems and as a cover crop in plantation agriculture (McCowan et al. 1986; Tarawali 1991).

Table 1. Released *Stylosanthes* cultivars.

Country and species	Common name	Cultivars	Year of release	Country of origin
Australia				
S. guianensis var. *guianensis*	Common stylo	Schofield	—	Brazil
		Cook	1971	Colombia
		Endeavour	1971	Guatemala
		Graham	1979	Bolivia
S. guianensis var. *intermedia*	Fine-stem stylo	Oxley	1965	Argentina
S. hamata (2*n* = 40)	Caribbean stylo	Verano	1973	Venezuela
		Amiga	1991	—
S. humilis	Townsville stylo	Common type	—	Australia
		Gordon	1968	Australia
		Lawson	1968	Australia
		Paterson	1969	Australia
S. scabra	Shrubby stylo	Seca	1976	Brazil
		Fitzroy	1979	Brazil
Brazil				
S. guianensis	Alfalfa de Nordeste	IRI 1022	1966	Brazil
S. guianensis var. *pauciflora*	Tardio stylo	Bandeirante	1983	Brazil
S. macrocephala		Pioneiro	1983	Brazil
China				
S. guianensis		Pia Hua Dou = CIAT 184 = Pulcallpa	1987	Colombia
Colombia				
S. capita		Capica	1982	Brazil
Peru				
S. guianensis		Pulcallpa = CIAT 184	1985	Colombia
Thailand				
S. humilis	Khon Kaen stylo	Khon Kaen	1984	Venezuela

Source: Peters (1992).

The response to inoculation with *Rhizobium* varies largely among and within species; the N-fixation efficiency presumably depends on the environmental conditions of the collection sites. There is some evidence that tetraploid and allotetraploid plants of *Stylosanthes* tend to be of the promiscuously nodulating type, whereas diploid species collected from alkaline soils are more specific. In glasshouse studies, *Stylosanthes* has shown positive reactions to inoculation with *Rhizobium* (Saif 1987). However, infection with native strains of *Rhizobium* is likely to occur under most field conditions; therefore, inoculation is usually unnecessary (Howeler et al. 1987).

The most damaging disease, and thus one of the major constraints to propagation of the *Stylosanthes*, is the fungal disease anthracnose, caused by *Colletotrichum gloeosporioides*. An extensive pathogenetic specialization and variation for virulence can be found among strains of *C. gloeosporioides*. *Stylosanthes* shows some field resistance, although this varies widely between accessions and agroecosystems.

Major attributes of *Stylosanthes hamata*

The genus *Stylosanthes* has provided ample germplasm for a wide variety of agroecological situations in the tropics. *Stylosanthes hamata* cv. Verano was found to be particularly adaptable in agropastoral farming systems in the SHZ of West Africa. This could be attributed to the following characteristics (de Leeuw and Mohamed-Saleem 1994):

- Rapid germination of seeds (50–80% within 2 d);
- Requirement for high temperatures (>50°C) to break dormancy (which means that out-of-season rainfall does not cause a problem);
- Rapid root growth, leading to deep penetration and high soil-water extraction at an early age;
- Fast aboveground growth rates during periods of high soil-water content and high temperatures (>25°C);
- Facultative-perennial nature (some plants survive into the next growing season, further assuring sustained seed production in most growing seasons);

- Species indeterminacy (nonselective defoliations during flowering and seed setting have no serious effects on subsequent seed yield);
- Efficient seed-dispersal mechanisms (herbivores ingest seeds, which are then spread by feces and transported by ants and termites);
- High anthracnose tolerance; and
- Low relative palatability (compared with grass) early in the growing season, but high levels in the late rainy and early dry seasons.

The subhumid zone of Nigeria

Climate and soils

The studies were mainly conducted in the SHZ of central Nigeria (Figure 1), which has an average annual rainfall of 1 200 mm (more than 95% of this falls between April and October) and a growing period of 180–270 d. It has a long, 6-month dry season (October–April). The soils are essentially ferruginous, with low C and N contents, poor drainage, and a low cation exchange capacity (CEC).

The herbaceous cover of the SHZ of Nigeria consists mainly of annual grasses (*Andropogon*, *Hyparrhenia*, *Pennisetum*, *Loudetia*, etc.), with a low percentage of native legumes (*Alysicarpus*, *Tephrosia*, etc.) and trees such as *Daniellia oliveri* and *Isoberlinia doka*.

Socioeconomic conditions and cultural features

In the Nigerian SHZ, *Stylosanthes* interventions target three major categories of livestock and crop farmers (Waters-Bayer and Taylor-Powell, 1986):

- *Pastoralists* — Full-time livestock keepers, ranging from those with no consistent association with a particular area (nomads) to those based at one site (pure pastoralists);
- *Agropastoralists* — Livestock keepers who practice some cropping but as an enterprise subsidiary to animal husbandry:
    - Transhumant agropastoralists — those who grow crops at one site but seasonally move all or some of their cattle to other grazing areas;

- Sedentary agropastoralists — those who keep cattle year-round close to the site of their cropping activities; and

- *Crop farmers* — Mostly indigenes who keep some livestock, mostly small ruminants, but as an enterprise subsidiary to cropping.

The agropastoralists are Fulani who no longer consider it necessary to move their small herds. These Fulani have settled close to farming communities, which provide markets for their meat, milk, and manure. In addition, they value the presence of public services, such as schools and dispensaries.

The settled Fulani live year-round at one site but shift every few years to another a few kilometres away, in contrast to the transhumant Fulani, who come into central Nigeria from the north each dry season. The influx of transhumant herds creates competition for grazing resources. The homesteads of settled Fulani

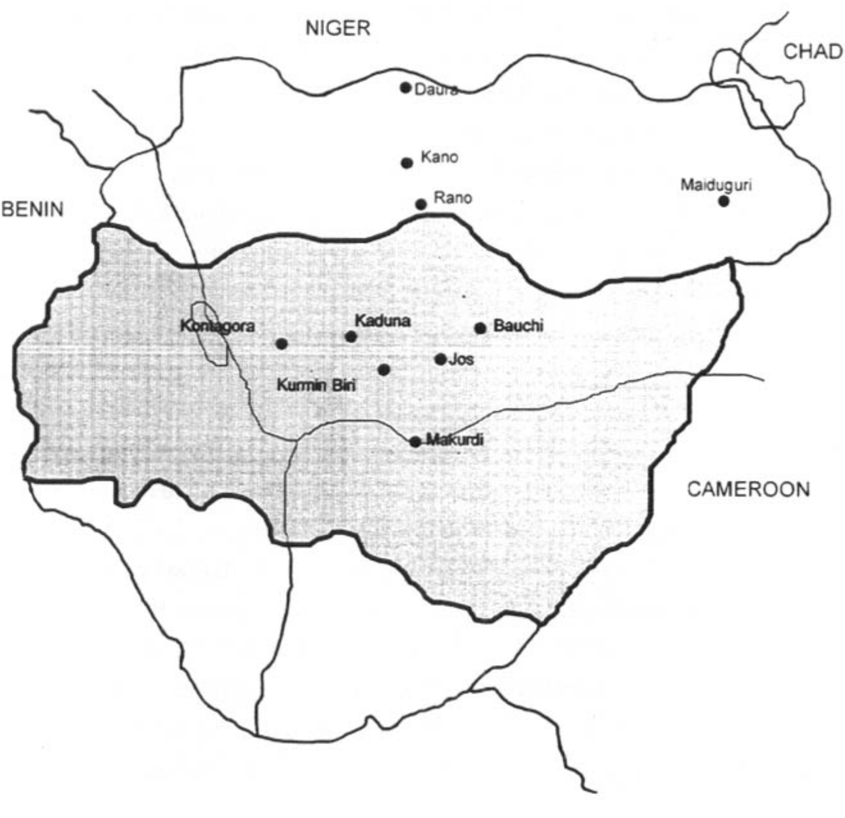

Figure 1. The subhumid zone of Nigeria, showing research–extension sites.

are generally on marginal lands bordering hamlet areas and on fields that farmers have left fallow for several years. The Fulani own no land in central Nigeria and have no certificates of occupancy.

Most of the crop farmers in central Nigeria are from the Kaje, Kamantan, Ikulu, Aten, and Hausa ethnic groups. Their main crops are sorghum, millet, maize, cocoyam, and yam, and the animals they raise include cattle, sheep, goats, pigs, and poultry (Ingawa 1986).

Average household size is nine persons, who contribute virtually all the labour. Peak labour demands occur in May to August (cultivation) and in November (harvest). Seasonal labour shows some age- and gender-related differences.

Farming systems and *Stylosanthes* management

Adopting a farming-systems research approach and promoting the use of *Stylosanthes* in the region, the International Livestock Centre for Africa (ILCA, now the International Livestock Research Institute [ILRI]) identified animal diseases, poor nutrition, and difficulties arising from land-tenure systems as the main constraints affecting the livestock industry in the SHZ (ILCA 1979). Serious cattle diseases, such as rinderpest and contagious bovine pleuropneumonia, can be fairly well controlled with available vaccines and techniques. The land-tenure issues tend to be site specific and highly political; the best approach is therefore thought to be to accept this limitation and work with it. ILCA considered malnutrition, especially in the dry season, the area in which some improvement could be made.

Productivity-monitoring of traditionally managed herds in the SHZ revealed that poor nutrition leads to low milk offtake per lactating cow (700 mL d^{-1}), long calving intervals (2 years), drastic weight losses (15–20%) in the dry season, high calf mortality (30%), and low fecundity (50%), a result of nutritional anestrus (Mani et al. 1988; Rege, von Kaufman, and Mani 1993; Rege, von Kaufman, Mwenya et al. 1993). Obviously, the natural vegetation cannot adequately support the existing cattle population. The accepted minimum level of 7.5% crude protein (CP) in the ruminant diet (Crowder and Chheda 1982) is attained only from June to September, and the digestibility of the natural forage is also low.

Farmers in Nigeria try to overcome this feed constraint by providing the cattle with crop residues after harvest (mostly of maize, sorghum, millet, and rice), at the beginning of the dry season. In the late dry season, the animals browse and graze forage resources on *fadama* (lowland areas where residual moisture permits plant growth throughout the dry season). Agropastoralists also supplement their animals' diets with agroindustrial by-products and local salt lick (*kanwa*). Although the agropastoralists take advantage of this wide variety of feed resources, these measures are still inadequate, as the productivity of their cattle remains low.

Recently, it was found that the crop farmers' traditional practice of tethering goats in the wet season to prevent them from damaging crops creates feed stress. This feed stress leads to undernutrition and weight losses in breeding females, with consequent low reproductive performance (ILCA 1991), which poses a new problem for crop farmers who are landowners but have no interest in livestock other than small ruminants.

Crop yields per unit of land and per unit of labour are low mainly because fertilizers are not readily available to smallholders. For instance, average grain yields in farmers' fields were 1 800 kg ha^{-1} for maize, 1 420 kg ha^{-1} for sorghum, and 700 kg ha^{-1} for millet (Powell 1984).

The poor nature of savanna soils contributes to the poor quality and low productivity of the herbage and crops in the SHZ. Any attempt to promote livestock production in the SHZ should, therefore, consider a program for maintaining soil fertility, as well as improving the nutritional value of the pasture. Herbaceous legumes offer an attractive option in this context, as they can provide both fodder for livestock and N to the soil.

Extension agents recommended the use of agroindustrial by-products — such as cottonseed cake, groundnut meal, urea, and molasses — to improve the productivity of lactating and pregnant cows. However, supplies of these products are not readily available, and prices are escalating. Similarly, a recommendation to use chemical fertilizers to boost crop production is problematic, as supplies of these chemicals are irregular. The fertilizers are too expensive for the small-scale farmer, and they also create environmental concerns.

In view of these ecological and financial constraints, ILCA considered a sustainable enterprise, such as planted forage legumes ("fodder banks"), as a more appropriate long-term option for improving cattle nutrition and soil fertility. This is because leguminous plants, such as *Stylosanthes*, can maintain a CP content of more than 8% in the dry season and the associated *Rhizobium* can fix N. It is against this background that low-input techniques have been developed for establishing *Stylosanthes* on natural range (Otsyina et al. 1987) and in cropped areas (Mohamed-Saleem 1985) to improve forage quality and soil fertility.

Stylosanthes on natural range

Sowing forage legumes can improve the nutritive value of the natural vegetation in rangelands. The low-input guidelines developed by ILCA (Otsyina et al. 1987) for the establishment, management, and use of these pastures are as follows:

Establishment

- Select an area close to the homestead (often 4 ha is adequate for an average-sized herd [40–50 animals per household]);
- Fence the area, using either metal or live poles, to prevent communal or untimely grazing;
- When the rains commence in April or May, prepare land for planting by confining animals as long as necessary or by using animal traction;
- Sow scarified seeds (10–12 kg ha^{-1}) after mixing with Single Superphosphate™ (SSP) at a rate of 150 kg ha^{-1};

Management

- Control grasses by early-season grazing, slash any shrubs, and destroy termite mounds;
- Leave forage to bulk up;
- Construct fire breaks at the beginning of the dry season; and
- Control dry-season grazing to ensure sufficient seed drop and adequate stubble for *Stylosanthes* regeneration in subsequent seasons.

ILCA's recommendation aims at feeding 15–20 lactating and pregnant cows for about 2–3 h d^{-1}, but herd owners tend to prefer strategic "survival feeding" for the whole herd.

Stylosanthes fallows in cropped areas

The undersowing technique is considered the most feasible method for introducing *Stylosanthes* into crop mixtures in the year before a piece of land is left to lie fallow. The understorey of stylo increases the nutritional value and quantity of the succeeding crop residue and improves soil fertility faster than a natural fallow. Undersowing exploits the land preparation primarily done for the crop and does not affect the cultural practices of the agropastoralists and farmers because it is based on intercropping, which is already the most common practice. When undersowing sorghum with *Stylosanthes*, a farmer must sow the legume 3–6 weeks after planting sorghum to avoid competition between the two crops (Mohamed-Saleem 1985).

Stylosanthes in legume–legume mixtures

Earlier evaluation work had identified several accessions of legumes that grew well in the West African SHZ, including *Aeschynomene histrix*, *Centrosema brasilianum*, *Centrosema pascuorum*, *Centrosema pubescens*, *Chamaecrista rotundifolia*, *Stylosanthes guianensis*, and *S. hamata* (Peters et al. 1994a, b). Tests made on collections of these species to identify material best adapted to the agroecological zone showed that none of these species is ideal. *Centrosema pascuorum* establishes well but soon disappears from a pasture. *Centrosema brasilianum* and *C. pubescens* establish slowly but stay green in the dry season. *Aeschynomene histrix*, *S. guianensis*, and *S. hamata* establish well and can persist for several seasons but do not stay green throughout the dry season. Individually, none of the legumes is ideal, but in the right combination, they might provide sustainable year-round grazing.

Therefore, our research efforts focused on developing legume–legume mixtures to replace the more commonly used grass–legume mixtures. A large-scale grazing trial was established to evaluate selected legume mixtures (such as *C. pascuorum* + *S. guianensis* + *C. pubescens* and *C. pascuorum* + *S. guianensis* + *Centrosema macrocarpum*) as supplementary pastures for young heifers (Tarawali et al. 1996).

Stylosanthes capitata, identified in similar environments in South America as a highly productive, drought- and disease-tolerant species adapted to soils with low fertility (Thomas et al. 1987), was evaluated for its potential in subhumid West Africa. This legume failed to nodulate in preliminary trials. However, later observations on abandoned plots in the same area revealed that several years after introduction, *S. capitata* nodulated and produced higher yields than *S. hamata*, the most widely used forage legume in subhumid Nigeria. An on-farm trial was therefore initiated to study the effects of *S. capitata* and *S. hamata* in various mixtures on forage and subsequent crop yields.

Animal evaluation

An on-farm study was conducted for 10 years (1977–87) at four locations in the SHZ of Nigeria (Mani et al. 1988). Fifty-eight herds of Bunaji cattle were involved, each with about 40–50 animals. In each herd, the animals were divided into two groups: those allowed to graze on *Stylosanthes* pastures for 2–3 h d^{-1} during the dry season (October–March), in addition to grazing on natural pasture; and those grazing strictly on natural pasture all year round. Calves were weighed every 2 weeks until they were weaned, and adult animals were weighed periodically. All births, deaths, and milk yields were recorded for statistical analysis. Cattle with access to forage legumes in the dry season produced more milk, lost less weight, and had shorter calving intervals and a better rate of calf survival (Table 2).

A similar study, involving West African Dwarf goats in 32 flocks owned by 45 smallholder farmers, was carried out for 30 months (Tarawali and Ikwuegbu 1993). At the beginning of the wet season, the goats were allowed to graze freely on one of two main treatments: natural vegetation and *Stylosanthes* pasture (miniature fodder bank). Animal performance was measured in terms of birth weights, deaths, stillbirths, abortions, etc. Weights were recorded fortnightly; the kids were weighed within 24 h of birth and weaned at about 5 months. A comparison of the wet-season liveweight (LW) changes of nonpregnant adults showed that those grazing on the *Stylosanthes* pastures had reduced ($P < 0.05$) weight losses (Figure 2). The kids' survival rate was also improved ($P < 0.05$) by legume supplementation (Ikwuegbu and Ofodile 1992).

In experiments with legume–legume mixtures (Tarawali et al. 1996), the differences between heifers grazing on the legume mixtures and those grazing on unimproved pasture were dramatic. For instance, in the 1994/95 dry season, the former gained an average 140 g d^{-1}, whereas the latter lost an average 58 g d^{-1}

Table 2. Effect of dry-season dam supplementation on the productivity of Bunaji cattle.

Variable	Grazing only	Fodder bank [a]	Improvement (%)	Significance (*P*)
Cow survival (%)	92.2	96.0	4.7	NS
Calving (%)	53.8	58.1	8.0	NS
Calf survival (%)	71.8	86.3	20.2	0.05
Calf weight at 1 year (kg)	98.1	103.4	6.6	0.05
Total milk yield (kg)	300.2	312.5	4.1	NS
Productivity index	51.5	69.1	34.2	NS

Source: Mani et al. (1988).
Note: NS, not significant.
[a] Planted forage legumes.

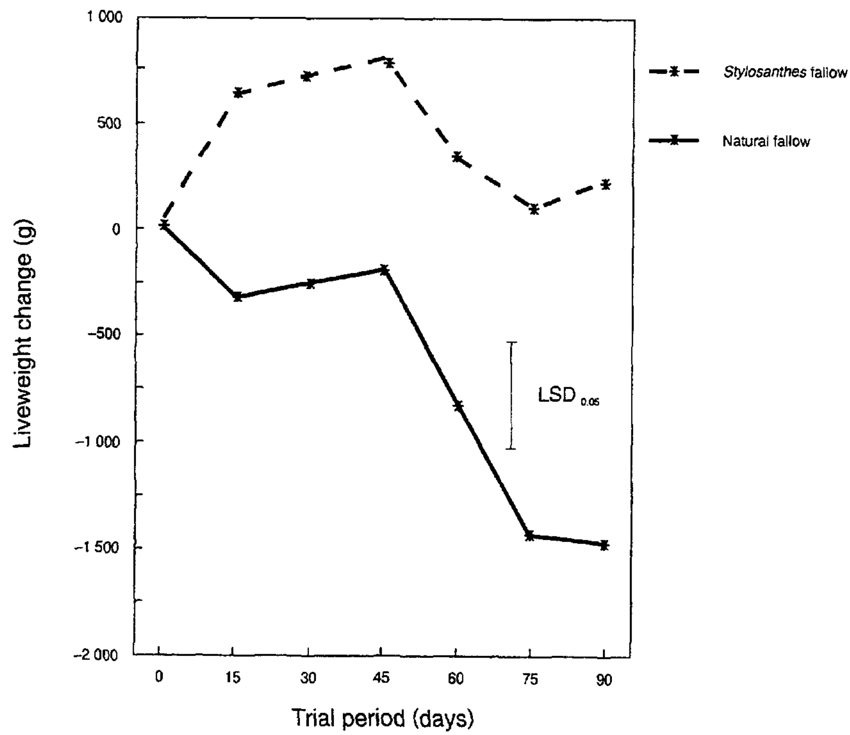

Figure 2. Liveweight changes of West African Dwarf goats grazing on *Stylosanthes* and natural pasture. Source: Tarawali and Ikwuegbu (1993).

(Figure 3). The trial, which ran for two dry seasons (1994/95 and 1995/96) and one wet season (1995), compared the performance of heifers (three per treatment) grazing on one of two legume mixtures or on native range. The trial was run for two dry seasons (1994/95 and 1995/96) and one wet season (1995). Animals were weighed fortnightly and received routine veterinary care. The animals on the native pasture recovered on their own at the beginning of the wet season (this compensatory growth was due to the rapid improvement in the quantity and quality of pasture vegetation at the onset of the rains). However, this group was not as productive as those on improved pastures.

Agronomic evaluation

Pasture productivity

Yields from natural pasture and *Stylosanthes*-based fodder banks were compared at the end of the growing season, before grazing (Tarawali and Mohamed-Saleem 1994). Table 3 shows yields of about 4.3–7.9 t DM ha^{-1} for fodder banks containing 52–68% *Stylosanthes*. These data were generated from researcher-managed on-farm trials. The yields were measured from randomly placed 1 m × 1 m quadrats,

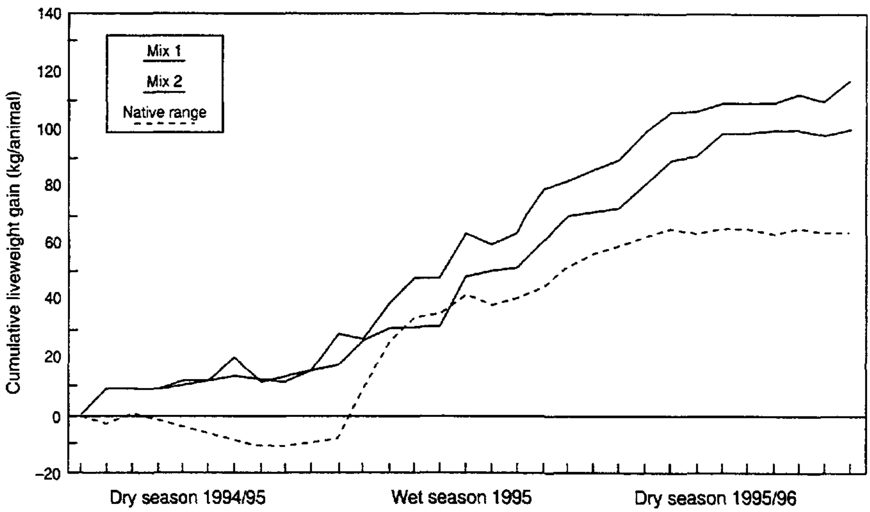

Figure 3. Effect of supplemental mixed-legume pastures on liveweight gains of Bunaji heifers. Source: Tarawali et al. (1996). Note: Mix 1 = *Centrosema pascuorum* + *Stylosanthes guianensis* + *Centrosema pubescens*; mix 2 = *Centrosema pascuorum* + *Stylosanthes guianensis* + *Centrosema macrocarpum*).

from which the herbage was cut and separated into legume, grasses, and forbs. The material was later dried at 60°C and then weighed to determine productivity. The information presented in Table 3 is just for *Stylosanthes* pastures, but the corresponding yield for natural pasture (control) generated in a similar way was 2.4–2.9 t DM ha^{-1}. The productivity for farmer-managed pastures with 30–60% *Stylosanthes* was about 4–5 t DM ha^{-1}.

Table 3. Average DM yield and proportion of *Stylosanthes* in selected fodder banks in International Livestock Centre for Africa's study areas.

Location	DM yield (t ha^{-1})	*Stylosanthes* component (%)
Abet	4.28	58
Ganawuri	7.90	60
Kachia	7.11	68
Kontagora	6.12	52
Kurmin Biri	6.10	60
Avg.	6.30	60

Source: Tarawali and Mohamed-Saleem (1994).
Note: Avg., average; DM, dry matter.

Table 4. Effect of different proportions of *Stylosanthes capitata* and *Stylosanthes hamata* on forage yields (total of 3 years), soil properties, and subsequent maize (fertilized with only P and K) production.

S. capitata–*S. hamata* ratio	Forage yield, 1990–92 (kg ha^{-1})	Maize yield, 1993 (kg ha^{-1})	Total soil N (g kg^{-1})	Organic C (g kg^{-1})
100 : 0	10 209	303 ± 70	0.15 ± 0.04	8.57 ± 1.2
75 : 25	14 822	587 ± 172	0.19 ± 0.01	9.85 ± 1.7
50 : 50	12 925	492 ± 114	0.22 ± 0.01	11.56 ± 0.5
25 : 75	11 959	509 ± 141	0.23 ± 0.18	10.48 ± 2.5
0 : 100	10 495	460 ± 190	0.20 ± 0.04	9.53 ± 2.2

Source: Tarawali and Peters (1997).

Results of an *S. hamata*–*S. capitata* compatibility trial (Tarawali and Peters 1997) showed that total forage-DM yields in the mixtures were higher than in the sole stands of either species (Table 4), with *S. capitata* increasing its contribution over time. This trial was initiated in 1990; *S. capitata* and *S. hamata* were sown at a seed rate of 10 kg ha^{-1} each in 2 m × 3 m plots. Four to six weeks after planting, the plants were thinned to 100 seedlings m^{-2} in various proportions (see Table 4). The five treatments were arranged in a randomized complete-block design, with four replicates. Plots were kept weed free and were fertilized with SSP at 150 kg ha^{-1} at planting and at 100 kg ha^{-1} in subsequent years (1991 and 1992). Forage parameters were studied for the first 3 years; in 1993, plots were cropped with maize to obtain information on the effect of various proportions of the two legumes on cereal production. The maize did not receive any N fertilizer, but basal dressings of P and K were each applied at 60 kg ha^{-1} as SSP and muriate of potash, respectively. Before maize planting, soil samples were taken for determination of total N and organic C.

Total soil-N concentrations were higher in plots following 3 years of *S. capitata*–*S. hamata* mixtures than in plots that had had sole stands of *S. capitata* (see Table 4). Organic C concentrations were higher in plots after the mixtures than in plots after either sole *S. capitata* or sole *S. hamata*. Maize yields were correspondingly higher following the mixtures than after either of the sole stands. The higher soil-N and organic C contents and maize yields in the plots following the mixtures suggest the complementarity of *S. capitata* and *S. hamata*. Thus, although not recommended for sole-legume pastures, *S. capitata* could be used in mixtures with other complementary legume species, such as *S. hamata*, *C. brasilianum*, and *C. pubescens*.

Crop production

In another trial (Tarawali 1991), maize yields at three levels of applied N (0, 60, or 120 kg ha^{-1}) were greater on plots that had had a leguminous cover crop than on plots that had been natural pasture. Without fertilizer-N additions, the average grain yields were 1 700 kg ha^{-1} in the leguminous area and 800 kg ha^{-1} for the natural pasture (Figure 4). The trial, which was initiated in 1986, was conducted at four locations in central Nigeria to evaluate the fertilizer response of maize grown after at least 4 years of uncropped natural fallow or 3 years of *Stylosanthes* pasture (fodder bank). The experiment was a split-plot design, with the *Stylosanthes* and non-*Stylosanthes* areas as the main plots and the levels of N as subplots. Basal dressings of P and K were each applied at 60 kg ha^{-1} in the form of SSP and muriate of potash, respectively. At the end of the growing season, in October, the crops were harvested, dried, and weighed to determine grain yield.

In the first year of cropping, maize grown on the natural pasture needed 45 kg N ha^{-1} to produce a yield equivalent to that of unfertilized maize grown on a good *Stylosanthes* pasture. In the second year, the yields were much lower, but

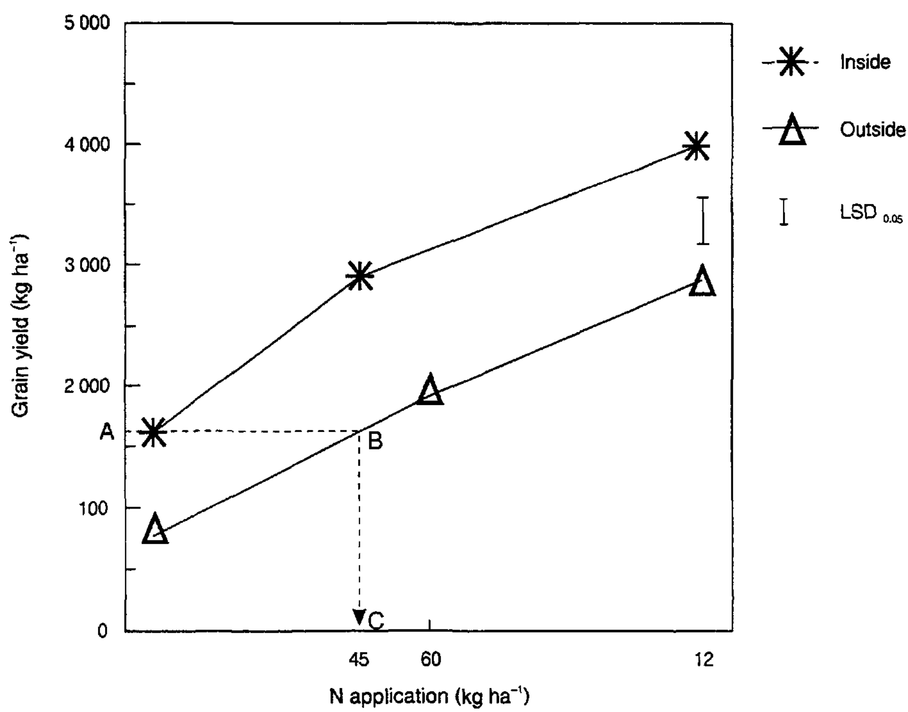

Figure 4. Effects of fertilizer-N on grain yield of maize inside and outside *Stylosanthes* plots.
Source: Tarawali (1991).

the proportional increase in yield attributable to forage legumes was similar to that in the first year. This suggests that the legumes still had some positive residual effect, but this was insufficient for the optimum growth of maize.

In the case of *acha* (*Digitaria exilis*) grown after *Stylosanthes,* no response was shown to the supplemental addition of fertilizer-N. A multilocation trial (Tarawali and Pamo 1992) compared the performance of *acha* grown in two main plots, previously under *Stylosanthes* or natural fallow, at various levels of N (0, 40, 80, and 120 kg ha^{-1}). P and K were each applied to all the plots at 60 kg ha^{-1}. The experiment was a split-plot design, and each treatment was replicated four times. At the end of the trial, grain yield was determined. The highest *acha*-grain yield (560 kg ha^{-1}) was obtained on the *Stylosanthes* pasture, with no N application (Figure 5). The highest yield on natural fallow required 40 kg N ha^{-1}. This trial shows that maximum *acha* yield can be obtained if the grain is planted after a *Stylosanthes* pasture and receives no N fertilizer.

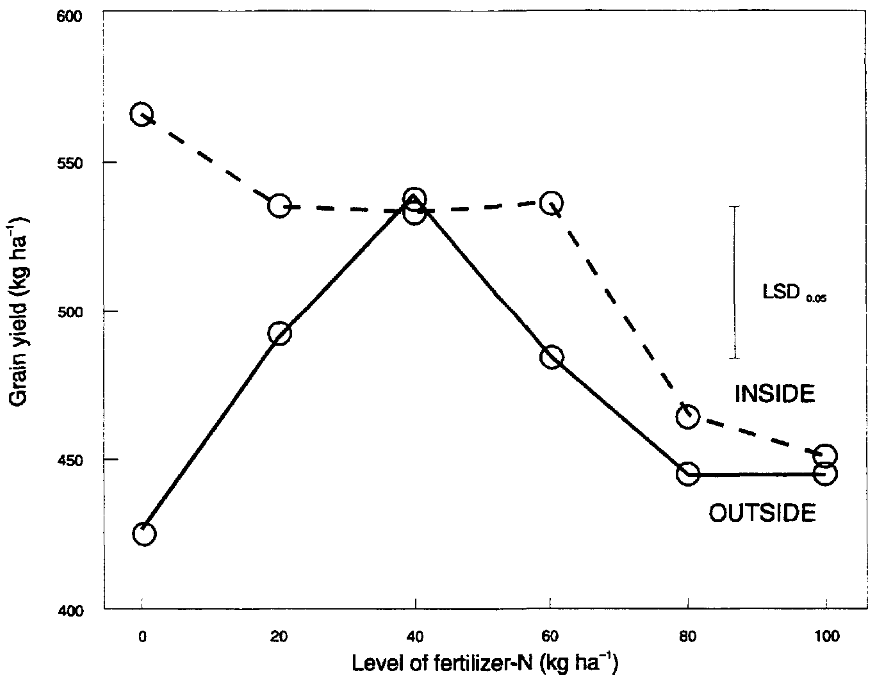

Figure 5. Response of *acha* inside and outside *Stylosanthes* plots to fertilizer-N. Source: Tarawali and Pamo (1992).

Table 5. Soil chemical and physical properties under *Stylosanthes* and natural fallow.

Property	*Stylosanthes* (3 years)	Natural fallow (>4 years)
N content (g kg^{-1})	1.14	0.87
CEC (cmol kg^{-1})	3.24	2.22
Organic C (g kg^{-1})	4.31	2.70
Bulk density (g cm^{-3})	1.51	1.66
Total porosity (%)	43.1	37.4
Macroporosity (%)	42.1	36.4
Microorganisms ($n \times 10^7$ g^{-1})	34	12

Source: Tarawali and Ikwuegbu (1993).
Note: CEC, cation exchange capacity.

The positive impact of *Stylosanthes* on crop production has also been demonstrated for other crops, such as millet, sorghum, and soybean (Tarawali and Mohamed-Saleem 1995).

The higher crop yields on the *Stylosanthes* pastures were due to the legume's improvement of the soil's physical and chemical properties. For instance, a series of measurements (Tarawali and Ikwuegbu 1993) showed that *Stylosanthes* decreased the soil's bulk density and increased its porosity (capacity to retain moisture), its CEC, and its organic C and N contents (Table 5). No standard errors are presented for these data because the analysis was conducted for a limited number of fodder banks.

Economic evaluation

The economic benefit of fodder banks was assessed by von Kaufmann and Mohamed-Saleem (1989), who compared the cost of producing a unit of CP from fodder banks (1.96 NGN kg^{-1} CP) with the market price of a given unit of cottonseed cake (2.27 NGN kg^{-1} CP) (in 1998, 75.2 Nigerian naira [NGN] = 1 United States dollar [USD]). It was shown that CP produced from fodder banks was cheaper than that from purchased cottonseed cake, an alternative form of dry-season feed supplementation (Table 6). Given the current high rate of inflation, coupled with the scarcity and high cost of cottonseed, the agropastoralists who established their fodder banks a few years ago should now be making some gain from their investments. Using a model to appraise the economic returns of fodder banks over 10 years, von Kaufmann and Mohamed-Saleem confirmed that fodder

Table 6. Costs of obtaining crude protein from a 4-ha fodder bank and from cottonseed cake, subhumid Nigeria, 1989.

	Quantity
Fodder bank (4 ha)	
DM produced (kg)	16 000
DM available (kg)	8 000
CP content (kg) [a]	720
Capital cost (NGN)	5 944
Recurrent cost (NGN kg^{-1} CP)	1.96
Cottonseed cake	
CP	720
Required DM at 30% CP (kg)	2 400
Capital cost (NGN)	0
Recurrent cost [b]	2.27

Source: von Kaufmann and Mohamed-Saleem (1989).
Note: CP, crude protein; DM, dry matter; NGN, Nigerian naira (in 1989, 7.3 NGN = 1 United States dollar [USD]; in 1998, 75.2 NGN = 1 USD).
[a] Assumes 9% crude protein content available in dry matter.
[b] Calculated as 680 NGN t^{-1} of cottonseed cake, at 30% CP.

Table 7. Economic returns on fodder banks in subhumid Nigeria over 10 years, 1989.

	Net present value [a] (NGN)	Internal rate of return (%)	10th-year herd value: Without fodder bank (NGN)	10th-year herd value: With fodder bank (NGN)	10th-year incremental net revenue (NGN)
IHP	1 414	22.5	49 907	90 833	4 950
IHP + reduced forced sales	7 538	34.1	49 907	90 833	7 138
IHP + increased crop yields	9 395	36.3	49 907	90 833	8 544

Source: von Kaufmann and Mohamed-Saleem (1989).
Note: IHP, improved herd productivity; NGN, Nigerian naira (in 1989, 7.3 NGN = 1 United States dollar [USD]; in 1998, 75.2 NGN = 1 USD).
[a] Calculated at 20% discount rate.

banks could be attractive investments (Table 7). For instance, their evaluation, which included capital and recurrent costs (such as those for fencing, seed, fertilizer, labour) of a 4-ha fodder bank and benefits (such as those from animal products and crop yield), showed an internal rate of return varying from 22.5 to 36.3% for fodder-bank-supplemented herds.

Adoption of *Stylosanthes* and farmers' perceptions

Agropastoralists in the Nigerian SHZ originally exploited *Stylosanthes* for cattle, but crop farmers later took advantage of the soil-improving properties of this cover crop for small ruminants and crop production (miniature fodder banks). Formal and informal surveys were conducted by a multidisciplinary team of scientists and extension workers to record farmers' reactions to the innovations and the associated benefits. Both farmers and agropastoralists acknowledged the beneficial effects of the fodder-bank intervention in terms of improved agricultural productivity (and hence increased income) as well as increased environmental protection. This was reflected in an increase in the number of fodder banks from 2 in 1980 to about 620 in 1991 (Figure 6). The documented adoption trend (Ajileye et al. 1994) was influenced mainly by the ILCA–ILRI projects and the Nigerian Livestock Department's promotion of *Stylosanthes* among agropastoralists and farmers, though there was evidence of farmer-to-farmer dissemination. The data came from records and were verified on field visits by extension staff. According to more recent reports, the technology has continued to expand in the farming systems of Nigeria and other West African countries (de Leeuw et al. 1994; ICTA 1995).

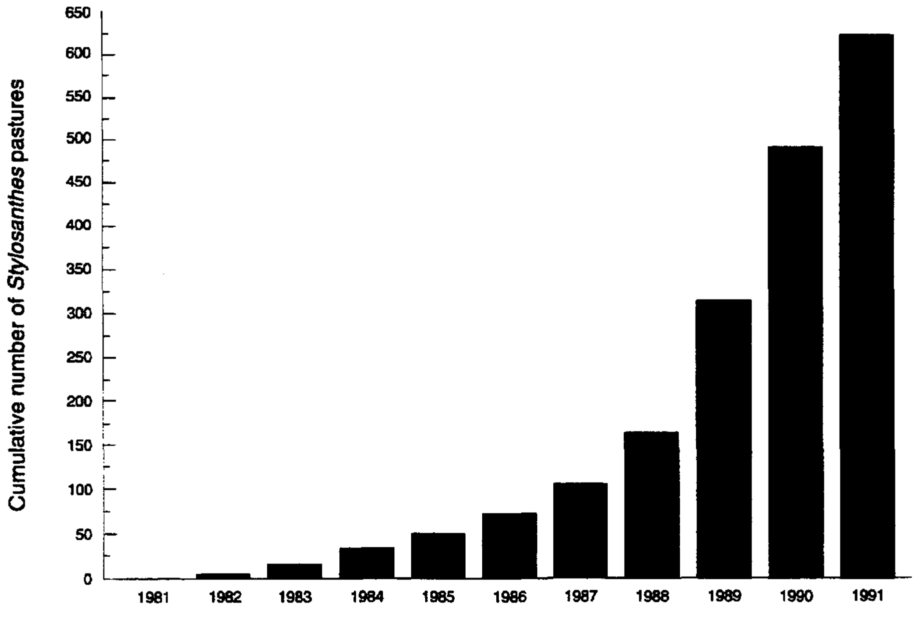

Figure 6. Cumulative number of *Stylosanthes* pastures in Nigeria from 1981 to 1991. Source: Adapted from Ajileye et al. (1994).

The subhumid zone of Cameroon

Climate and soils

In Cameroon, most of the earlier work on *Stylosanthes* was conducted on the Adamawa Plateau (Wakwa Animal Research Station, near Ngaoundéré), at an altitude of 900–1 500 m asl (Figure 7). The climate is characterized by a long-term mean annual rainfall of 1 706 mm and a growing period of 240 d. Most of the rain (91%) falls between April and October, with a peak during August and September.

The soil in the region is basaltic and slightly acidic (pH of 5.5) and has a clay texture, 4.9% organic matter (OM), 2.3% total N, 26 ppm P (Olsen), and low CEC. The vegetation is typically Guinea savanna, with tall grasses, such as *Andropogon*, *Hyparrhenia*, and *Pennisetum*, and a dense tree cover comprising *Isoberlinia doka*, *Lophira lauceolata*, *Daniellia oliveri*, *Parkia biglobosa*, *Anogeissus leiocarpus*, etc.

Socioeconomic conditions and cultural features

The potential users of *Stylosanthes* in northern Cameroon are agropastoralists who own livestock and practice some level of cropping (maize and sorghum, usually intercropped with cowpea). They are from the Fulani ethnic group. Unlike their counterparts in Nigeria, they have access to land, and each family owns up to 10 ha or more. They live in villages in which the houses are mostly constructed from mud, with grass roofing. Richer farmers use aluminium sheets. Agropastoralists try to overcome dry-season feed shortages by practicing transhumance, which imposes more trekking on the herders and the animals. During trekking, some of the animals die.

Farming systems and *Stylosanthes* management

As in the Nigerian SHZ, ruminant production on the Adamawa Plateau is constrained by the poor quality and quantity of the dry-season forage, and this situation has led to numerous problems. For instance, breeding, and hence calving, take place year-round. Many calves are born during the dry season, when forage is insufficient; cows are extremely weak and unable to produce enough milk to feed their calves. Not surprisingly, therefore, calf losses are high, and calves that do survive have health problems. In addition, animals that depend solely on natural vegetation for their nutrition suffer severe weight loss during the dry season (Lhoste 1967), with consequent reproductive failures (Voh et al. 1984). Nomadism and transhumance can to some extent compensate for this feed shortage by allowing pastoralists to exploit a wide range of natural herbage, but such a lifestyle removes them from basic social and technical-support services.

Figure 7. The subhumid zone of Cameroon.

To reduce the impact of the dry-season feed shortage on animal production, extension officers in Nigeria have been advocating the purchase of supplementary feeds, such as cottonseed cake, at least for animals at risk. However, these products are generally scarce and expensive. Planting forages (such as *Stylosanthes*) as an alternative was tested at the Wakwa station of the Institut de recherches zootechniques (IRZ, institute of animal research) in 1987, with a view to extending the concept to agropastoralists in the region.

The Wakwa station began testing several forage legumes as early as the 1950s (Rippstein 1985), and some, such as *S. guianensis*, *Desmodium* spp. and *C. pubescens*, have been found promising for the region (Yonkeu et al. 1994). However, scientists have never found an appropriate way to use these improved pasture species to suit the needs and capabilities of the traditional herders. Government efforts to improve rangeland and its management have been unsuccessful because range legislation cannot be enforced. The fodder-bank intervention, developed by scientists at ILCA in the SHZ of Nigeria, presents an alternative approach to introducing and managing improved forages (Otsyina et al. 1987). In an effort to test and possibly extend the concept, researchers established a fodder bank, using *S. guianensis* cv. CIAT 184, at the Wakwa station (Tarawali and Pamo 1992).

During the 1987 rainy season, a 4-ha paddock, fenced with metal and live posts (mainly *Ficus thonningii*), was cleared, plowed, and harrowed with a disc harrow. Seed of *S. guianensis* cv. CIAT 184 was first scarified in boiling water for 30 s and then sown (broadcast) at a rate of 10 kg ha^{-1}. This effort was not very successful in the first year, mainly because the pasture was dominated by grasses. Because of the scarcity of seed, a new fodder bank could not be established. Instead, the grasses in the 1987 paddock were hand-cleared, and the areas with poor regrowth were selectively reseeded. Contrary to Otsyina et al.'s (1987) recommendation, just after hand-weeding, N–P–K (20 : 10 : 10) fertilizer was applied to the pasture at the rate of 385 kg ha^{-1}.

Animal evaluation

Research on the response of livestock to *Stylosanthes* is very rare. However, Table 8 summarizes a feeding trial carried out in Cameroon using *Stylosanthes* hay or silage for Zebu heifers. In general, the heifers showed a preference for hay over silage (Rippstein 1985).

Table 8. Average consumption of *Stylosanthes* silage and hay by young female Zebu heifers.

	Silage		Hay	
Age (d)	kg DM head^{-1} d^{-1}	kg DM 100 kg^{-1} LW d^{-1}	kg DM head^{-1} d^{-1}	kg DM 100 kg^{-1} LW d^{-1}
0–20	2.8	1.1	4.7	1.6
20–40	3.1	1.2	5.1	1.8
40–57	2.5	1.0	4.3	1.5
Avg.	2.8	1.1	4.7	1.7

Source: Rippstein (1985).
Note: Avg., average; DM, dry matter; LW, liveweight.

Agronomic evaluation

Pasture productivity

The *S. guianensis* in Tarawali and Pamo's (1992) study had an average height of 1.41 ± 0.12 m. A total DM production of 5.5 t ha^{-1} from grass and *Stylosanthes* was recorded. The botanical composition indicated that *S. guianensis* constituted 93.4% of the pasture. The remaining 6.6% was made up of perennial grasses, such as *Brachiaria ruziziensis*, *Hyparrhenia rufa*, and *Hyparrhenia filipendula*. The performance of *S. guianensis* was very good, given the locality of the site and the poor terrain. According to guidelines developed by Otsyina et al. (1987) for classifying fodder banks (60–100% *Stylosanthes* = excellent; 23–34% *Stylosanthes* = poor), the fodder bank in Wakwa was in excellent condition (93.4% *Stylosanthes*).

The DM productivity of 5.5 t ha^{-1} is comparable to the average DM yield of *Stylosanthes* (4.0–5.0 t ha^{-1}) obtained in the Nigerian SHZ (Mohamed-Saleem and Suleiman 1986), where the fodder bank was developed. This suggests that, given the soils in the Adamawa region, 4 ha of improved pasture is sufficient for the dry-season supplementation of 15–20 stressed animals. On-farm trials in the SHZ of Nigeria have shown that agropastoral herds with access to *Stylosanthes* supplementation performed better than nonsupplemented herds (see Table 2). *Stylosanthes* can be expected to perform even better under Cameroonian conditions.

It is worth noting that annual burning of vegetation, whether accidental or intentional, is common on the Adamawa Plateau, especially at the end of the dry season. In this study, a fire that burned all the paddocks of dry grass around the site was stopped by the thick stand of green *S. guianensis* in the fodder bank. A good fodder bank therefore appears able to resist fire, at least early in the dry season.

Table 9. Effect of preceding cover crop on maize-grain yield, 1992/93.

Treatment (previous cover crop)	Maize-grain yield (t ha^{-1})	
	Without fertilizer	With fertilizer [a]
Natural fallow	1.22	2.45
Canavalia	1.48	2.88
Mucuna	1.67	2.69
Stylosanthes	2.30	3.68
Calopogonium	1.52	2.73

Source: Youri (this volume).
[a] N–P–K at 100 kg ha^{-1}.

Stylosanthes fallows

The principal constraints limiting cereal production (maize and sorghum) in northern Cameroon (Garoua; see Figure 7) are low levels of OM, deficiency of soil nutrients, *Striga* infestations, and high costs of inputs. Looking for ways to combat these constraints, the Institute of Agronomic Research (IAR) at Garoua focused on the use of cover crops (Youri, this volume).

In the 1992 growing season, four species of legumes were established: *Canavalia ensiformis*, *S. hamata*, *Mucuna pruriens*, and *Calopogonium mucunoides*. DM production was measured about 4 months after seeding: *S. hamata* had the highest yield (11.28 t ha^{-1}), followed by *Canavalia* (8.38 t ha^{-1}), *Calopogonium* (7.41 t ha^{-1}), and *Mucuna* (5.02 t ha^{-1}). The outstanding performance of *Stylosanthes* and the low yield of *Mucuna* in this study could be related to the fact that the former can thrive under low-P conditions, whereas the latter has a high P requirement (Sanginga, Okogun et al. 1996).

In the second year (1993), the leguminous plots and an adjacent natural fallow were planted with maize at two levels of fertilization (0 and 100 kg N–P–K ha^{-1}). The fallow preceded by *Stylosanthes* gave maize yields of 2.30 t ha^{-1} (0 kg N–P–K ha^{-1}) and 3.68 t ha^{-1} (100 kg N–P–K ha^{-1}). The natural fallow yielded the least: 1.22 t ha^{-1} in unfertilized plots and 2.45 t ha^{-1} in fertilized plots (Table 9).

In a separate experiment in 1991, three species of legumes (*C. ensiformis*, *S. hamata*, and *C. mucunoides*) were each intercropped with maize; a fourth treatment was a maize–maize intercrop. All the legumes were planted 3 weeks after the maize (one row of the legume and two rows of the cereal). In the second year (1992), each of the plots was split into two subplots: one to study the effect of the cover crops on weeds; the other, to evaluate the impact of the respective fallows

Table 10. Effect of preceding maize–legume intercrop on maize-grain yield, 1991/92.

Treatment (previous cover crop)	Maize-grain yield (t ha^{-1}) (%)	
	Without fertilizer	With fertilizer [a]
Maize	1.17 (100)	3.20 (100)
Canavalia ensiformis	2.14 (182)	4.44 (138)
Calopogonium mucunoides	2.17 (185)	4.00 (125)
Stylosanthes hamata	2.25 (192)	4.40 (137)

Source: Youri (this volume).
[a] N–P–K at 100 kg ha^{-1}.

Table 11. Effect of preceding cover crop on maize-grain yield, 1993.

Treatment (previous cover crop)	Maize-grain yield (t ha^{-1}) (%)	
	Without fertilizer	With fertilizer [a]
Natural fallow	1.59 (100)	4.08 (100)
Calopogonium	3.80 (238)	5.51 (135)
Stylosanthes	3.42 (215)	5.13 (125)

Source: Youri (this volume).
[a] N–P–K at 100 kg ha^{-1}.

on a succeeding maize crop. Again *Stylosanthes* gave the highest maize yields: 2.25 t ha^{-1} in unfertilized plots and 4.40 t ha^{-1} in fertilized plots (Table 10). Furthermore, *Stylosanthes* and *Calopogonium* provided excellent weed control.

In a trial in which maize was planted following a 1-year fallow of *Calopogonium*, *Stylosanthes*, or natural pasture, the legume-based plots yielded 2.21 t ha^{-1} (+138%) and 1.83 t ha^{-1} (+115%) more maize grain than the plots that had had a natural fallow (Table 11) (Youri, this volume).

Adoption of *Stylosanthes*

Stylosanthes guianensis appears to be well adapted to the Adamawa Plateau, and the fodder-bank package currently used by pastoralists in Nigeria stands a good chance of being adopted by small-scale farmers in Cameroon. The Cameroonian extension agency, in collaboration with a Gesellschaft für Technische Zusammenarbeit (GTZ, organization for technical cooperation) team at IRZ, encouraged pastoralists to establish *Stylosanthes* pastures for their animals. The idea took off in 1987, but it slowed down from 1988 on. Shortage of funds at IRZ meant that support services, such as the provision of seeds to extensionists, were no longer possible.

Stylosanthes was also introduced in the Bamenda region of Cameroon (Markon and Bambui; see Figure 7) in evaluation trials as early as 1974. Currently, Heifer Project International (HPI) is promoting the legume for dairy production. HPI is a charitable nongovernmental organization (NGO) committed to integrated agricultural development for resource-poor farmers (Nuwanyakpai, personal communication, 1997[2]).

In the researcher-managed trials involving *Stylosanthes* at IRA–Garoua, farmers showed interest in the use of the legume for *Striga* control and soil improvement, but this on-station–on-farm activity is still in its infancy. It is hoped that the program will involve more small-scale producers in the near future, especially if funds for a regional project involving Cameroon, Central African Republic, Zaire, and maybe Nigeria are approved by donors (Kounmenioc, personal communication[3]).

The subhumid zone of Côte d'Ivoire

Climate and soils

Bouaké in the central SHZ and Korhogo in the northern Guinea savanna are the centres for the adoption of *Stylosanthes* in Côte d'Ivoire (Figure 8). The average rainfall in the area is 1 000 mm. The soil is the ferruginous-tropical type (N'Guessan 1994); it is sandy, with a high proportion of gravel, and has a pH of about 6.0. Levels of P and N are <5% and 0.4–0.59%, respectively; the level of OM is 1.13% at Kohorgo and 1.55% at Bouaké. All these parameters vary considerably throughout the whole region.

The region is typified by broken savanna vegetation, with shrubs and trees, such as *Daniellia*, *Isoberlinia*, *Parkia*, *Lannea*, and *Pterocarpus*, and a number of grasses, such as *Andropogon*, *Hyparrehenia*, *Digitaria*, *Cymbopogon*, *Loudetia*, and *Pennisetum*.

Socioeconomic conditions and cultural features

The farmers, who mostly belong to the Baoulé and Senoufo tribes, live in villages and settlements, with about 10 persons per household. The Baoulés and the Senoufos are the landowners around Bouaké and Kohorgo. The economic activities in the Bouaké area are based on crops, whereas those in the Korhogo area are mainly based on crops and to a lesser degree on livestock managed by Fulani herders.

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[2]M. Nuwanyakpai, HPI, Cameroon, personal communication, 1997.

[3]J. Kounmenioc, IRZ, Cameroon, personal communication, 1997.

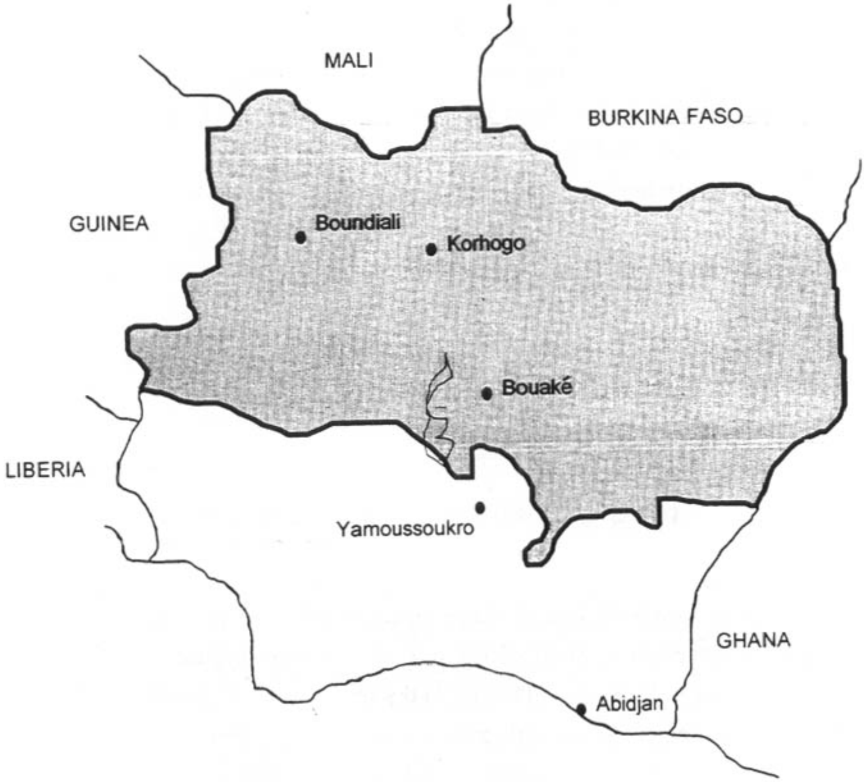

Figure 8. The subhumid zone of Côte d'Ivoire.

The male farmers, who are also the heads of the households, are 25- to 40-years old and have 1–5 children and one or several wives and associates within the compound. Children are sent to government schools, and in Bouaké fees are usually paid from farm income. Medical facilities are provided by the government, but individuals are expected to buy their own drugs. Some of the houses of the richer farmers and those participating in the peri-urban dairy project have aluminium roofing, but many other smallholders in the various communities use grass materials. The roads around the villages and farms consist of laterite, but they are better developed than other feeder roads in northern Côte d'Ivoire.

As in Nigeria and Cameroon, the low quantity and quality of the savanna vegetation, especially in the dry season, precipitated the introduction of improved pastures, such as those with *Stylosanthes*, which has a higher CP content as a result of its ability to fix soil N.

Farming systems and *Stylosanthes* management

The smallholders who currently cultivate *Stylosanthes* for dairy production in central Côte d'Ivoire are crop farmers who adopted livestock production after the introduction of the Eco-farms Project (see below). Although they keep other animals (such as chickens, goats, sheep, and pigs) on their farms, other tribes from the north (such as the Fulbe and Malinga, who have extensive farming systems) manage the Baoulé and Senoufo herds.

The peasants own both lowland and upland farms and practice mixed cropping, with up to 10 crop combinations on a single farm. Tobacco, soybean, rice, and especially cotton are grown as important cash crops The most common food crops are maize, yam, cassava, pepper, tomato, sweet potato, groundnut, and rice. Yam (usually grown in mounds and heavily mulched) and maize are usually grown as sole crops. Rice and vegetables are generally grown in lowland areas. Farm areas under crops vary from 1 to 5 ha. The high cost or unavailability of fertilizers has forced these farmers to rely entirely on green manures, animal manures, and fallow periods. Farmers who include cotton in their rotation have access to draft animals, fertilizers, and credit through the Compagnie ivoirien de développement du textiles (Ivorian textiles development company).

Stylosanthes was introduced and tested in the SHZ of Côte d'Ivoire (Bouaké and Korhogo) more than 35 years ago (Toutain et al. 1994) in an effort to improve the nutritional value of the low-quality natural range and to establish artificial pastures. Most of the experiments, which were mainly on station, focused on *S. guianensis* cv. Schofield and covered plant behaviour, management, and maintenance; sowing techniques; seed production; performance evaluation; and the importance of these species in livestock-production systems.

Low animal prices at that time and damage to *S. guianensis* cv. Schofield from anthracnose in 1980 retarded the introduction of this legume to smallholders. Screening of *Stylosanthes* varieties later identified disease-resistant ones, such as *S. hamata* cv. Verano (Toutain et al. 1994). Researchers recommended the use of this cultivar, in association with *Panicum maximum* (a perennial grass) cultivars C1 and T58, for future *Stylosanthes*-based pastures to discourage attack by fungal diseases (favoured by high *Stylosanthes* densities and humidity) and to take advantage of low-cost production techniques. In a new set of evaluation trials, the *S. guianensis* cultivars CIAT 184, L348, L359, and IRI 1022 were found to be high yielding and anthracnose tolerant (N'Guessan and Dosso 1995).

Eco-farms Project

The Eco-farms Project was jointly established by the Côte d'Ivoire government and Germany, through GTZ. The project sought to create a supply of milk around big cities to reduce the importation of dairy products, which had become very costly; intensify agricultural production; and create jobs for youth. The project got under way in 1987 through the extension support of the Société pour le développement des production des animaux (SODEPRA, society for the development of animal production) and GTZ; the general mandate of both agencies was to promote integrated animal production, with special emphasis on milk. SODEPRA, which ceased to function in the 1980s, was later replaced by the National Agency for the Support of Rural Development (NASRD). Côte d'Ivoire's Institut des savanes (savanna institute) supported the on-farm pilot studies with research and expertise.

Eight farmers around Bouaké were initially selected for this project. They focused on the production of milk for the city, and they were each given 10 crossbred cows, a shed, a borehole, 10 ha of *Stylosanthes*-based pastures, and a farmhouse, where the participant lived with his immediate family. In the past, installing such a structure cost 5–7 million CFA francs (XOF), but after the devaluation of the XOF, the same model was expected to cost around 10 million XOF (Eco-Farms Project 1995) (in 1986, 320 XOF = 1 United States dollar [USD]; in 1998, 610.65 XOF = 1 USD). Under this scenario, the farmer provided all the land required, and the facilities were provided to him on a loan-recovery basis.

To establish the improved pastures, the project workers prepared the land with a tractor and then broadcast *S. hamata* cv. Verano seed (5 kg ha^{-1}), in association with *P. maximum* cv. C1 or T58 seed (each at 5 kg ha^{-1}). N–P–K (10 : 18 : 18) was applied at the rate of 300 kg ha^{-1} to boost the performance of this grass–legume mixture in the initial year. The dairy animals were encouraged to graze the pastures year-round.

Animal evaluation

Interviews with about eight adopters and extension agents revealed that daily milk yields varied from 2.5 to 5.0 L per cow, but a systematic study jointly conducted by GTZ and NASRD in 1994/95 reported that, on average, the N'dama × Abondance crossbreds each produced 5.5 L d^{-1}, although some yielded up to 9 L in one milking. Table 12 shows the excellent potential of the crossbreds to be exploited for milk and beef production. For instance, one dairy cow produced about 1 500 L

Table 12. Some characteristics of the cattle used in the Eco-farms Project.

Parameter	Avg.
Weight at birth (kg)	26.3 ± 5.4 (M) 24.3 ± 3.6 (F)
Weight at 1 year (kg)	245 ± 28 (M) 226 ± 22 (F)
Weight at adulthood (kg)	397 ± 52 (M)
Rate of adult mortality (%)	3.3
Rate of calf mortality (%)	5.0
Age at first calving (months)	24.4 ± 3.2
Calving interval (d)	382 ± 14
Rate of fecundity (%)	87.6 ± 3.7
Duration of lactation (d)	382 ± 14
Milk yield per cow per lactation (L)	1 489 ± 355

Source: Eco-farms Project (1995).
Note: Avg., average; F, female; M, male.

of milk over 235 d of lactation. The weight of the calves at birth was 25 kg, although some were up to 30 kg. At 1 year, a bull weighed 230–300 kg, equivalent to the LW of an adult N'dama.

Economic evaluation

Some of the farmers collected up to 90 000 XOF month^{-1} from this enterprise (Kaligha, personal communication, 1997[4]), and such an income enabled them to pay school fees for their children, increase their herd sizes, and buy other farm inputs.

A systematic economic analysis conducted on six farms during 1994/95 demonstrated that milk accounted for 68.2% of the total income, followed by beef (20.6%) and crops (11.1%) (Table 13). The total revenue from each farm varied from 0.74 million to 1.78 million XOF, with a mean of 1.25 million XOF (Figure 9). This evaluation was based on variable inputs, such as seed, herbicides, fertilizers, labour, feeds, veterinary drugs, and fuel. The income included sales of milk, meat from both large and small ruminants, poultry, and crop produce.

The Eco-farms Project at Bouaké had the initial aim of ensuring that each farmer earned a revenue of 0.72 million XOF year^{-1}, which would be equivalent

[4]M. Kaligha, Agence nationale d'appui au developpement rural, Côte d'Ivoire, personal communication, 1997.

Table 13. Contribution of various products and enterprises to the total income of six Eco-farms, 1994/95.

	Farm income (× 10^6 XOF) (%)		
	Milk	Beef	Crops
F1	1.63 (71.9)	0.32 (14.3)	0.31 (13.8)
F3	1.15 (72.2)	0.29 (18.4)	0.15 (9.4)
F4	1.33 (70.6)	0.45 (23.8)	0.10 (5.6)
F6	1.08 (66.7)	0.43 (26.5)	0.11 (6.8)
F7	0.84 (70.7)	0.22 (18.2)	0.13 (11.1)
F8	0.48 (57.5)	0.18 (22.3)	0.17 (20.2)
Avg.	(68.2)	(20.6)	(11.1)

Source: Adapted from Eco-farms Project (1995).
Note: Avg., average; XOF, CFA franc; in 1998, 610.65 XOF = 1 United States dollar (USD).

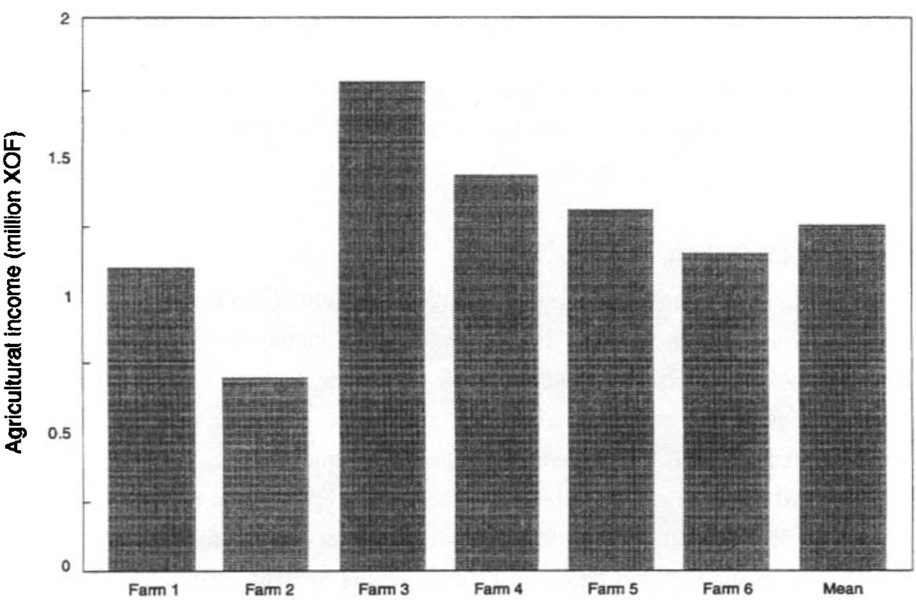

Figure 9. Agricultural income from six farms in the Eco-farms Project, Côte d'Ivoire. Source: Eco-farms Project (1995). *Note: In 1998, 610.65 CFA francs (XOF) = 1 United States dollar (USD).*

to the income of their counterparts in the towns. Three years after installation, each farmer was able to earn a total revenue of 1.50 million XOF $year^{-1}$. These interesting economic results — the regular and attractive revenue and the new perspectives of domestic dairy production, especially after devaluation — are some of the factors that prompted the further expansion of the Eco-farms Project around Bouaké.

Stylosanthes as improved fallow

In Bouaké, NGOs (for example, the Société de développement des forêts [society for forest development]) are promoting the use of cover crops, including *Stylosanthes* around Bouaké, mainly to reclaim land abandoned to aggressive weeds. In this system, the land is prepared with a tractor, and *S. guianensis* cv. CIAT 184 is sown in pure stands at the rate of 10 kg ha^{-1}; N–P–K (10 : 18 : 18) is applied at the rate of 300 kg ha^{-1} during the establishment year. The following year, the legume is plowed under, and the land is cropped with a cereal.

The assessment of crop performance following various periods of *Stylosanthes* fallow is still in its infancy, but previous on-station work in the SHZ of Côte d'Ivoire (N'Gguessan 1994) established the potential of using such fallows to boost crop yields and restore soil fertility. That study was conducted in Bouaké and Korhogo to assess the residual effects of *S. hamata* cv. Verano and *S. guianensis* cv. Cook, with or without fertilizer-N and fertilizer-P, on a subsequent maize crop. The legumes were grown from June 1982 to November 1983. Maize was planted the following wet season, which commenced in May 1984, after the legume biomass had been incorporated into the soil (relay cropping). For simplicity, only the results for the unfertilized *Stylosanthes* plots will be reported here.

Maize yields on plots preceded by *S. hamata* were 450 and 1 300 kg ha^{-1} in Korhogo and Bouaké, respectively; on plots preceded by *S. guianensis*, 1 000 and 1 400 kg ha^{-1} (Figure 10). Although these are preliminary results, they reflect the potential role of *Stylosanthes* in agricultural intensification.

Adoption of *Stylosanthes*

Stylosanthes was introduced in the SHZ of Côte d'Ivoire about 35 years ago, mainly in on-station evaluation trials. These initial materials were obtained from the Commonwealth Scientific and Industrial Research Organisation (Australia), the International Centre for Tropical Agriculture (Columbia), the Food and Agriculture Organization of the United Nations (Rome), and ILCA, now ILRI (Ethiopia). During those pioneer days, further extension of these leguminous pastures to farmers was inhibited because of the susceptibility of *S. guianensis* cv. Schofield to anthracnose in 1980.

Following intensive evaluations, some disease-resistant or -tolerant varieties were identified, notably *S. hamata* cv. Verano and *S. guianensis* cv. CIAT 184.

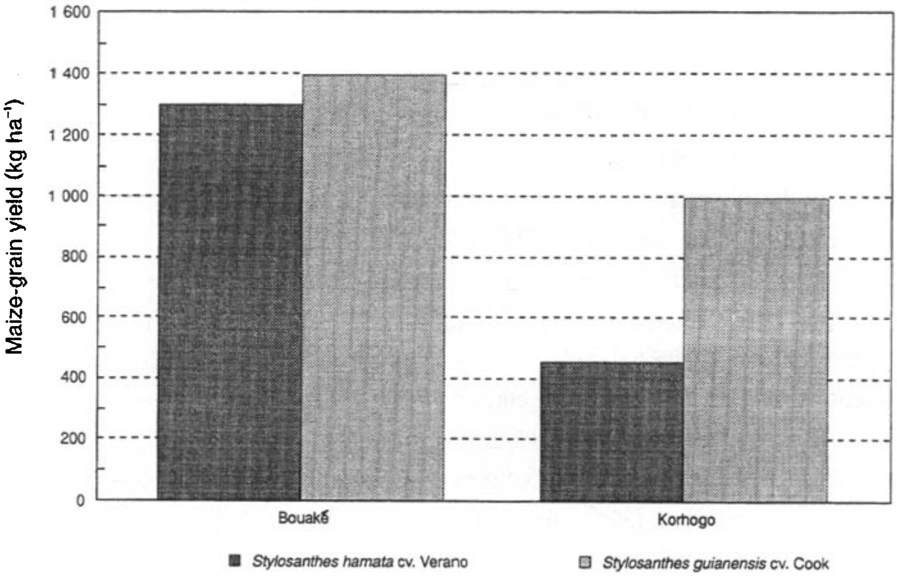

Figure 10. Grain yield of maize after unfertilized *Stylosanthes* at two locations. Source: N'Guessan (1994).

This successful evaluation program was supported at Badikaha (80 km from Korhogo) by a commercial seed-multiplication farm established to supply high-quality *Stylosanthes* materials to livestock owners, including adopters of Eco-farms in Côte d'Ivoire and other West African countries (Table 14). On this farm, *Stylosanthes* was sown on 183 ha, and a seed yield of about 100–300 kg ha^{-1} was reported for 1986.

Records and recent visits have shown that between 1987 and 1995 in Côte d'Ivoire, eight farmers each adopted 10 ha of *Stylosanthes*-based pastures around Bouaké to promote the dairy enterprise. It is expected that *Stylosanthes* pastures will be established between 1996 and 1998 for 30 farmers in central, 13 in south-east, and 13 in west Bouaké, making a total of 56 new adopters and 560 ha, although there have been 90 applicants (Eco-farms Project 1995; Mill, personal communication, 1997[5]). Funds for this new phase will be provided by the African Development Bank (ADB) and GTZ. The recent application of *Stylosanthes* in fallow management will also increase this acreage during the same period.

The West African Rice Development Association (WARDA) and its national partners are testing *S. guianensis* cv. CIAT 184 and *S. hamata* in rice-based

[5]E. Mill, GTZ, personal communication, 1997.

Table 14. Seed production at Badikaha seed farm, Côte d'Ivoire, 1986.

Species or cultivar	Area grown, 1986 (ha)	Expected yield (kg ha^{-1})	Estimated germination (%)	Seed price (XOF kg^{-1})
Panicum maximum				
T58	210			
C1	133			
1 A50	5			
2 A4	7	150	25–40	3 500
2 A5	19			
2 A6	12			
2 A22	4			
Brachiaria ruziziensis	80	500	70	1 500
Stylosanthes hamata	182	100–300	90	3 500
Stylosanthes guianensis				
CIAT 184	1	200	—	—
CIAT 136	0.25			
Aeschynomene histrix	8	300	80–90	3 500
Desmodium tortuosum	5	—	—	—

Source: M. Koffi Dongo, Badikaha Seed Farm.
Note: XOF, CFA franc; in 1986, 320 XOF = 1 United States dollar (USD); in 1998, 610.65 XOF = 1 USD.

systems in Côte d'Ivoire (four sites) and Burkina (two sites) and on lowlands (irrigated off-season crop in Vallée du Kon, Burkina) and flooded plains (Boundiali, Côte d'Ivoire). If successful, this has the potential to improve many hectares of land in the region (Becker, personal communication, 1997[6]).

The subhumid zone of southern Mali

Climate and soils

The SHZ in southern Mali is situated between latitudes 10 and 14°N and longitudes 4 and 8°W (Figure 11). The rainy season lasts from June to October and is followed by a dry period, which lasts from October to May. This dry period is divided into a cool spell, which is dominated by the harmattan, a cold wind from

[6]M. Becker, WARDA, personal communication, 1997.

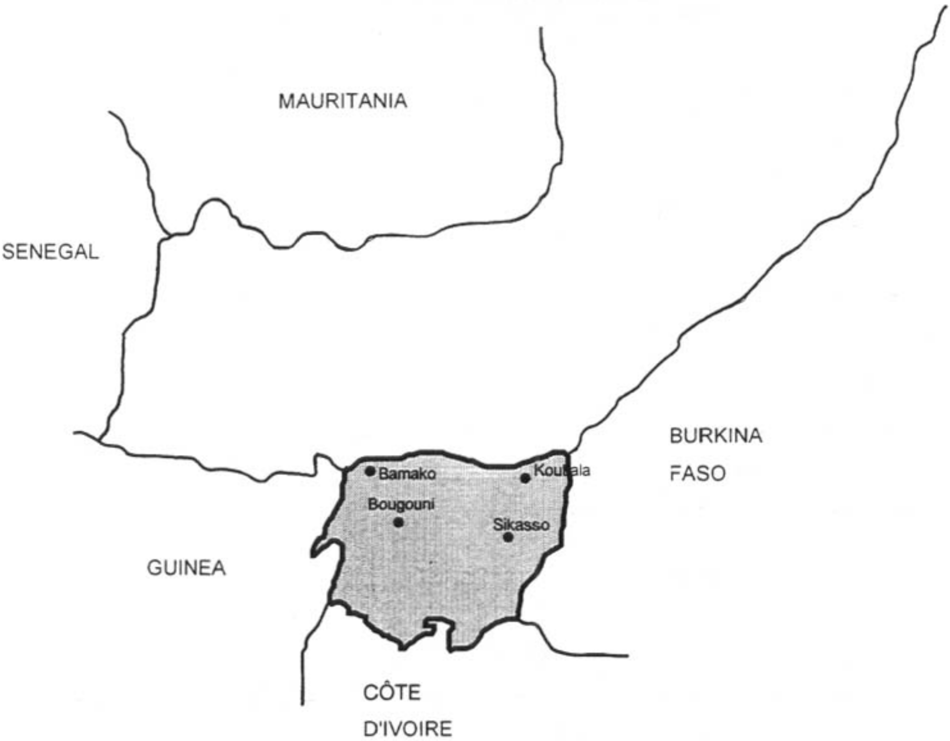

Figure 11. The subhumid zone of Mali.

the Sahara desert (December to February), and a hot spell (March to May). The average rainfall is 750 mm in the northern part (San), 980 mm around Koutiala, and up to 1 300 mm in the Sikasso area.

The soils are of the tropical-ferruginous type, with low levels of N and P and a low CEC. The typical toposequence comprises uplands, steep slopes, colluvial soil, banks, and lowlands.

The vegetation in the cultivated areas is the savanna type, with large trees, such as *P. biglobosa*, *Acacia albida*, *Adansonia digitata*, and *Butyrosprmum parkii*, all of which are useful to people. Other common vegetation includes *Pterocarpus*, *Combretum*, *Isoberlinia*, and *Deutarium*. The grasses are *Andropogon*, *Loudetia*, *Schoenefeldia*, *Hyparrhenia*, and *Pennisetum*.

Socioeconomic conditions and cultural features

The farmers in southern Mali live in village communities in Sahelian houses built of mud. The farmers are predominantly from the Minianka, Senoufo, and Bambara tribes. Population densities are high, and annual population growth rate is greater than 3%. The main economic activity is cotton production, which represents

20–30% of the cultivated land. Each household cultivates about 2–3 ha of cotton. The cotton is sold through cooperatives to the government for export and is Mali's main foreign-exchange earner. The enterprise is very well organized, and the farmers get very good prices for this crop. Over the years, this undoubtedly has improved the standard of living of the indigenous farmers, and they have developed a good knowledge of agricultural techniques. Average cotton yields are up to 1 100 kg ha^{-1}. About 70–80% of the farmers have at least a full team of oxen (plow, harrow) and a donkey-drawn cart; most of them own motorcycles, ox-drawn carts, and wheelbarrows, all of which make farm operations more efficient.

The smallholders tend to keep large herds, as this confers social prestige in the community. The farmers consider cattle herds a reliable option (compared with banks) for investing money generated from cotton. Southern Mali is not traditionally a cattle-husbandry zone, but the introduction of cotton, accompanied by animal traction, led to the growth of herds. Because of their Islamic background, the children attend Koranic schools, usually situated in bigger villages. Hospitals are provided in towns, and mobile clinics usually visit the villages.

The main problems affecting the communities are low soil fertility and land degradation caused by the expansion of cultivated lands, with few or no possibilities for fallow; roaming animals; lack of high-quality forage during the dry season; poor management of traction animals, labour, and equipment; disintegration of social unity within farmers' associations; and a tendency toward the break-up of extended families.

Farming systems and *Stylosanthes* management

The farmers in southern Mali depend on rain-fed agriculture. They produce cereals such as millet, sorghum, maize, and *fonio*, generally intercropped with cowpea. The main cash crops, in order of importance, are cotton, maize, rice, and groundnut. Cotton is usually grown in biennial and often triennial rotations with cereals. This farming practice is meant to benefit the food crops, for which no fertilizer inputs are usually provided; in contrast, the cotton usually receives N–P–K and cattle manure. Planting is done on ridges with adjacent furrows, which have the dual advantage of conserving water and retaining fertilizer. The grain yields are variable and tend to decline over the years. The farmers compensate for the low yields by increasing the area under cultivation; to prepare the land, they use animal traction and apply cattle manure.

The smallholders keep herds of 25–200 cattle, and these animals provide meat, milk, and traction. In addition, farmers also keep small ruminants (usually up to 20 or more), which usually satisfy the financial, social, and religious needs of the people. The herds depend on natural pasture during the wet season, then mainly on crop residues at the beginning of the dry season. These are supplemented with cottonseed cake (produced locally by the cotton industry) in the late dry season. Although produced locally, the cottonseed cake is reportedly still inadequate to support the growing cattle population in southern Mali. For instance, the cottonseed cake produced by the cotton mills in Koutiala and Koulikoro meets about 10–30% of the demand in southern Mali. Part of this cottonseed cake enters the commercial circuit and leaves the area for other regions in the country. Some farmers have been encouraged by extension workers to exploit *Stylosanthes* pastures for late dry-season supplementation of their cattle and small ruminants and to improve the nutritional status of their traction animals before commencement of land preparation. In the past, the use of improved pastures to feed animals was very rare in southern Mali.

The farmers usually establish *Stylosanthes* as sole crops, with guidance from farming-systems research scientists and extension agents. The land is mainly prepared by traction animals, and scarified seeds are broadcast at the rate of 10 kg ha^{-1}. Fertilizer (Phosphate naturel de Tilemsi™ [PNT]) is applied at the rate of 300 kg ha^{-1} at planting. Some farmers cut the legume and carry this fodder to the animals, whereas others use the improved pastures for grazing their animals.

Because of the legume's soil-improving characteristics, crops are usually introduced in *Stylosanthes* plots 3 years after establishment, to exploit the residual effect of the legume.

Land reclamation at the Dalabani seed-multiplication farm

The national seed-service farm was established at Dalabani (near Bougouni) by the Malian government to promote the production and distribution of high-quality seeds (cotton, rice soybean, cowpea, maize, sorghum, etc.) for crops grown by the cotton farmers in southern Mali. Continuous seed production commenced in 1975 but had to be stopped in 1992 because of the general decline in seed yield for all these crops. This was a result of soil degradation caused by lack of rest periods and failure to use amendments, such as cattle manure. Cover crops were then introduced, mainly to restore the fertility of the degraded soil on the farm. The usual seed-production activities of the farm were transferred to private-contract farmers, and the farm was planted with *Stylosanthes* spp. *Aeschynomene*, *Panicum*, etc. Fifty hectares of the land was specifically planted to *Stylosanthes*, and 22 ha of this was dedicated to seed-multiplication plots. The initial seed stock was purchased from the defunct Badikaha seed farm in northern Côte d'Ivoire, at a price of 4 000 XOF kg^{-1}.

Seeds harvested from the farm are usually sold to farmers and NGOs through the regional offices of the Compagnie malienne de développement des textiles (CMDT, Malian textiles development company). The yield varies from 200 to 300 kg ha^{-1}, and the *Stylosanthes* residue is fed to traction animals. The farm in Mali is able to produce *Stylosanthes* seeds for any organization in West Africa, provided the order is received in advance.

There is clear evidence (a high density of nitrophilous grasses) that the previously degraded soil has been rejuvenated, and the farm manager is now planning to go back to crop-seed production, in rotation with *Stylosanthes*-seed production. About 200 farmers visit the farm each year. These observers reckon that the idea of revitalizing the farm through cover crops is wise, and some of them promised to try it on their farms.

Animal evaluation

Research in Mali is currently focused on agronomic evaluation; however, farmers are evidently using *Stylosanthes* to promote dairy production and the performance of traction animals, and the legume seems to be having positive effects on both enterprises. In the CMDT zone around Koutiala, farmers allow work oxen to graze *Stylosanthes* before or after 2–3 h work.

Agronomic evaluation

In effect, it is the responsibility of the Institute of Rural Economy (IRE), and more specifically, the Division of Research for Rural Production Systems (DRRPS), to carry out the research and extension programs with a multidisciplinary team of scientists in three zones: the CMDT zone around Sikasso, Koutiala, and San; the CMDT zone at Bougouni; and Operation High Valley (OHV) zone, around Banamba, Koulikoro, Kati, Kangaba, and Bamako. All these extension bodies have been collaborating with other organizations, such as the Agro-ecological Project, the battle against erosion project (PLAE), and CMDT, to evaluate *Stylosanthes* in the farming systems of southern Mali. Some of these activities are summarized below.

In 1986, some herbaceous legumes, including *Stylosanthes*, were established in three villages (Tominian, Koutiala, and Fonsébougou); PNT was applied at three levels (0, 300, and 600 kg ha^{-1}). Some combinations of herbaceous legumes used were *B. ruziziensis* + *S. hamata* and *Cenchrus ciliaris* + *S. hamata*; pure *S. hamata* and natural vegetation were also in the trials.

Table 15. Effect of two types of fallows on the quantity and quality of fodder produced in the Operation High Valley zone.

Type of fallow	Biomass ($t\ ha^{-1}$)	Cellulose (%)	N (%)	P (%)
Stylosanthes hamata	6.3	41	0.8	0.05
Natural fallow	4.1	42	0.6	0.06
Level of significance (*P*)	0.05	NS	NS	NS
CV	34	18	34	19

Source: DRRPS (1990).
Note: CV, coefficient of variation; NS, not significant.

In the OHV zone, 11 villages have had improved *Stylosanthes* fallows since 1989. After 2 years, the improved fallow produced more DM (6.3 $t\ ha^{-1}$) than the natural fallow (4.1 $t\ ha^{-1}$), but the forage value was more or less the same, and the N content improved only slightly (Table 15) (DRRPS 1990).

Between 1987 and 1988, ILCA carried out feasibility studies on fodder banks at three sites: Madina (4 ha), Diassa (4 ha), and Sotuba (near Bamako; 6 ha) (ILCA 1989). The banks, which consisted of *Stylosanthes* fallows, were meant to secure supplementary feed for livestock during the dry season. At each site, the land was plowed, fertilized with SSP (120 $kg\ ha^{-1}$), and seeded with *S. hamata* (10 $kg\ ha^{-1}$). After 2 years of establishment, *Stylosanthes*-based pastures yielded up to 10 200 $kg\ ha^{-1}$ (71% stylo) at Sotuba, 5 500 $kg\ ha^{-1}$ (87% stylo) at Madina, and 6 129 $kg\ ha^{-1}$ (25% stylo) at Diassa (Table 16). The establishment of the fodder bank was preceded by several tests meant to identify species adaptable

Table 16. Characteristics of *Stylosanthes* fodder banks at three sites in the subhumid zone of Mali, 1988.

Parameter	Madina (sandy site)	Diassa (clay site)	Sotuba (sandy site)
Rainfall (mm)	1 069	1 069	1 088
Density (plants m^{-2})	1 492	820	1 570
Height (cm)	83	88	72
Biomass (kg DM ha^{-1})	5 540	6 129	10 200
Stylosanthes (%)	87	25	71
Grasses (%)	7	54	18
Broadleaf weeds (%)	6	21	11

Source: ILCA (1989).
Note: DM, dry matter.

Table 17. DM production of *Stylosanthes* in the peri-urban zone of Bamako.

	Rainfall (mm)		Biomass (kg DM ha^{-1})	
Village [a]	1990	1991	1990	1991
Falan	812	943	2 877	8 635
Sansankoroba	816	938	1 985	5 200
Bancoumana	774	888	2 580	6 200

Source: International Livestock Centre for Africa (unpublished).
Note: DM, dry matter.
[a] Data for Tienfala were not available.

to different sites in southern Mali. *Stylosanthes guianensis* was the most productive, followed by *Stylosanthes scabra* and then *S. hamata*. However, the first two species were susceptible to anthracnose and were therefore abandoned in favour of *S. hamata*.

In a peri-urban dairy program, jointly conducted by ILCA and IRE to improve milk production in Bamako, fodder banks consisting of *Stylosanthes* were established in four villages (Falan, Sanankoroba, Bancoumana, and Tienfala). The DM productivity was disappointing at all four sites in the first year, as a result of late seeding. However, in the second year, the yield was appreciable at all the locations (Table 17).

Crop production

DRRPS conducted on-farm trials on the effect of *Stylosanthes* and *Brachiaria* on soil fertility and the grain yield of subsequent cereals in the CMDT zone. The cover crops were planted either as sole crops or in combination in 1988. After 3 years, the plots were sown to sorghum. Soil analysis showed that after the fallow period, soil fertility had improved in the *Stylosanthes* plots, as was evident from better C–N ratios. For instance, the C–N ratio changed from a range of 22–25 to one of 8–12, signifying an improvement (Diarra and de Leeuw 1994). Grain yield of sorghum from soils preceded by the legume was also clearly better than that from non-*Stylosanthes* plots (Table 18) (DRRPS 1990).

Economic evaluation

A simple economic analysis of data from an SHZ site in Mali suggested that peasants' adoption of *Stylosanthes* generates a net income of 55 480 XOF ha^{-1} (Table 19). Fomba and Bosma (1994) concluded that the surplus cereal produced as a result of soil improvement does not guarantee the financial attractiveness of the

Table 18. Residual effect of established *Stylosanthes* on the yield of sorghum at Fonsénbougou, Mali.

Treatment	Grain yield (kg ha^{-1})
Stylosanthes + *Brachiaria*	995
Stylosanthes + *Brachiaria* (alternate rows)	979
Pure *Brachiaria*	848
Pure *Stylosanthes*	953
Natural fallow	518

Source: DRRPS (1990).

system and that extension schemes should focus on the optimal use of fodder by livestock in addition to crop yield. In Mali, as in Nigeria, the analysis indicated that fencing constitutes the highest expense (about 41%) in the package. Where the cotton industry is thriving, it may be more profitable to follow up an improved fallow with a cash crop, such as cotton, rather than with a food crop.

Similarly, an economic analysis based on linear programing confirmed that the adoption of *S. hamata* by farmers in southern Mali increased their incomes, provided a reliable market exists for animal products (Kébé 1994). In this evaluation the *Stylosanthes* system produced more animals (1029 tropical livestock nnits [TLUs] as opposed to 759 TLU) and more manure. The extra revenue generated from the sale of meat also provided the necessary capital to purchase inputs required for maize production. This analysis considered inputs such as land, labour, ox-plow, and cart; animal products and crops were considered the outputs.

Adoption of *Stylosanthes*

In southern Mali, the testing and diffusion of *Stylosanthes* owes much to the efforts of research and extension agents, in addition to those of DRRPS and CMDT, which actually have the national mandate for this. A summary of these efforts is given below to illustrate the potential for adoption of this legume.

Stylosanthes was introduced in 1974 to supply fodder and to reactivate degraded soils in Mali, mainly in the cotton-growing belt of the south. As already indicated, in 1986, *Stylosanthes* was tested in Tominian, Koutialia, and Fonsébougou. ILCA established three fodder banks at Madina, Diassa, and Sotuba between 1987 and 1988. In 1989, OHV introduced improved *Stylosanthes* in 11 villages, and in 1990, the peri-urban dairy team around Bamako established *Stylosanthes* in four villages (Falan, Sanankoroba, Bancoumana, and Tienfala).

Table 19. Partial budget analysis of a fodder plot in humid zones, with barbed-wire fencing and use of fodder after cutting.

	Amount (XOF)
Expenses	
Fencing	60 720
Seeds (12 kg)	18 000
PNT (600 kg)	18 000
Land preparation	10 000
Planting (1 d ha^{-1})	600
Weeding (2 d ha^{-1})	1 200
Cutting, transport, and storage	40 000
Total expenses	148 520
Income	
Fodder, over 3 years (11.2 t ha^{-1}; 20% losses)	168 000
Additional cereal production from fenced forage plot, as compared with unfenced plot	36 000
Gross margin	204 000
Net income	+55 480

Source: Fomba and Bosma (1994).
Note: PNT, Phosphate naturel de Tilemsi™; XOF, CFA franc; in 1998, 610.65 XOF = 1 United States dollar (USD). For the economic evaluation, the following prices were considered:
- *Stylosanthes* straw (= price of feed), 15 XOF kg^{-1};
- Cutting, transport, and storage, 5 XOF kg^{-1};
- Cereals, 60 XOF kg^{-1};
- Barbed-wire fencing, 360 XOF m^{-1}; local wood for posts and installation (wire strainers included), 100 XOF m^{-1} (total cost, 184 000 XOF ha^{-1});
- Equipment (writing off and including depreciation over 20 years; 11%), 20 240 XOF $year^{-1}$; total cost over 3 years, 60 720 XOF ha^{-1} (wire fencing, 188 400 XOF ha^{-1}); and
- Maintenance of fence, 10 000 XOF $year^{-1}$.

Promoting the technology, PLAE distributed 200 kg of *S. hamata* seed in 1991/92 to be used to establish sole pastures in 25 villages (Diarra and de Leeuw 1994). In the 1992/93 promotion, the same project distributed 1 000 kg of *Stylosanthes* seed in southern Mali.

Preextension *Stylosanthes* program

Faced with the constraints of maintaining soil productivity in southern Mali, DRRPS farming-systems scientists, in conjunction with CMDT extension agents, started testing *Stylosanthes* on farmers' fields in four villages (Kola, Karangana, Ségain, and Touroumadié) around Koutiala and Sikasso in 1989/90 (Fomba and Bosma 1994). The three principal objectives of this preextension phase were to evaluate the *Stylosanthes* system under farm conditions, determine the degree of adoption by farmers, and determine the support services required by the extension agents to successfully pass this message to farmers and fulfill their requirements, for instance, in the supply of seeds.

The introduction of *Stylosanthes* usually commences with a sensitization of farmers and the choice of voluntary farmers from each village. This is followed by a demonstration session on the establishment of *Stylosanthes* and live hedge enclosures to protect the legume; usually this session is organized by training agents. Subsequently, the sites are visited by other farmers from the village. The use of live fences is encouraged because wire fencing is very expensive. *Euphorbia balsamifera* and *Jatropha curcas* were used in this preextension program, as these species performed well in a previous program in the battle against erosion.

Stylosanthes seeds were unavailable in Mali to commence this extension program, but they were eventually acquired from NASRD (Côte d'Ivoire) at 4 000 XOF kg^{-1}. The same organization provided cuttings of *Euphorbia* free of charge.

After 3 years of activities, the preextension program ended with 49.3 ha covered. Of the original 310 participants, only 59 were still using the technology (Table 20). The dramatic drop in the number of participants could be related to the problems indicated by farmers in the Siwaa zone (see below).

During the evaluation, the farmers were asked to choose the three main problems they intended to combat using *Stylosanthes*. The problems the farmers cited generally depended on the particular situation of the village. For instance, restoration of soil fertility was perceived as an important issue in all the villages except Touroumadié, where land is always available (Table 21). Fodder production

Table 20. Trend in the adoption of *Stylosanthes* established in four villages in southern Mali, 1989–91.

	Number of farmers		Area occupied by final farmers (ha)	
Village	Initial	Final	Total	Avg. per farmer
Karangana	120	17	12.7	0.7
Kola	84	13	10.7	0.8
Ségain	58	11	15.5	1.4
Tourounmadié	18	18	10.4	0.5

Source: Fomba and Bosma (1994).
Note: Avg., average.

Table 21. Opinions of farmers on the order of importance of problems to be solved by using *Stylosanthes*.

		Importance (%)		
Village	Number of participants	Fertility	Erosion	Fodder
Karangana	32	47	0	53
Kola	23	30	56	14
Ségain	44	45	5	50
Touroumadié	22	9	45	45

Source: Fomba and Bosma (1994).

was also considered by all the villages to be important, except at Kola, where the farmers are busy combating soil erosion. At Touroumadié, because of the paddy fields, the problem of fodder should not be expected to be as acute as in any of the other villages, but the fact that the animals appreciate *Stylosanthes* explains the importance accorded to its production.

Transfer of *Stylosanthes* technology to farmers in the Siwaa zone by CMDT

The experience derived from the preextension exercise was very important for CMDT extension agents, who were already encouraging farmers in all the 25 CMDT sectors in the region to use *Stylosanthes*. The new program, which involved 45 farmers, was initiated in 1992 in the Siwaa zone, with the hope that the exercise would be extended in later years to other areas of southern Mali. The Siwaa zone covers two districts (Molobala and Koutiala) and six villages: four in Molobala and two in Koutiala. To stimulate *Stylosanthes*-seed production and to test the willingness of the farmers to pay for the seed, CMDT supplied it on the condition that the farmers would reimburse CMDT in the second year.

After 1 year, 49% of the farmers abandoned the program (Dembélé and de Vries 1993). Poor development of fodder during the first year and lack of follow-up by the trainers were two factors in the farmers' withdrawal from the scheme. Constraints that hindered the expansion of *Stylosanthes* in the Siwaa zone included lack of protection from roaming animals; ignorance of the types of species available; and lack of professional techniques for cutting, conservation, feeding, and seed collection.

Stylosanthes germination was good for 61% of the plots owned by the farmers who continued in the program but for only 27% of the plots owned by the farmers who withdrew. Also, management practices varied widely between the two groups. For instance, most of the farmers (72%) who opted out of the program planted the legume very late (October), whereas the majority of those (61%) who continued planted their *Stylosanthes* at the appropriate time (July). Fifty-nine percent of the farmers who abandoned their *Stylosanthes* plots paid no attention to fencing, but this was true of only 33% of those who continued. More live hedges were used by the latter (23%) than by the farmers who lost interest (9%).

Discussion

Main biophysical and socioeconomic constraints to adoption

Farmers in different countries have identified nine main problems that directly or indirectly influence their adoption of *Stylosanthes* (Table 22):

- Disease;
- Inadequate seed supply;
- Weed competition;
- Fencing;
- Land scarcity;
- Land tenure;
- Lack of capital;
- Labour requirements; and
- Fires.

Disease

The narrow genetic base for forage species in the Nigerian SHZ is a cause for concern, as it is limiting the uptake of the fodder-bank intervention in other agroecological zones and farming systems. Only three stylo cultivars (*S. hamata* cv. Verano, *S. guianensis* cv. Cook, and *S. guianensis* cv. Schofield) were initially identified for use in fodder banks. The situation has been made worse by the fact that two of these are susceptible to anthracnose. Reports that earlier introductions of *Stylosanthes* in Cameroon, Côte d'Ivoire, and Mali were susceptible to anthracnose scare off donors, policymakers, and potential adopters. Although *S. hamata* and *S. guianensis* cv. CIAT 184 are tolerant to anthracnose, new strains of the pathogen may develop and *S. guianensis* may lose its tolerance if it is improperly managed (especially in areas with high humidity), thus posing a serious threat to all *Stylosanthes*-based interventions.

Table 22. A comparison of *Stylosanthes*-adoption constraints and issues between countries: the main biophysical and socioeconomic constraints and key issues requiring policy intervention, promotional strategies, or further research.

Constraint–issue	Cameroon	Côte d'Ivoire	Mali	Nigeria
Disease	Anthracnose is a constraint to adoption, but the weak screening program needs to be strengthened	Anthracnose attack on *Stylosanthes* was a national disaster; intensive evaluations were developed to provide alternatives, such as *Stylosanthes–Panicum* mixtures, but more needs to be done on legume–legume mixtures	Anthracnose was reported; Mali needs to develop a sustainable cover-crop-evaluation program	Anthracnose was reported in *Stylosanthes*; intensive evaluation program was developed to find alternatives, but this needs to be expanded to include legume–legume mixtures
Inadequate seed supply	Shortage of seed has seriously affected uptake; Cameroon needs seed-production and seed-distribution enterprises	Closure of the national seed-production enterprise has created seed scarcity; Côte d'Ivoire needs more seed-multiplication and seed-distribution enterprises	Seed production and distribution are promoted by the government, but the high cost of this product warrants more seed-production efforts by all stakeholders	Low quantity and quality of seeds are a hindrance to adoption; more seed-multiplication and seed-distribution enterprises are required; research on cost-effective and sustainable seed-production techniques is also required
Weed competition	Competition from grasses is a problem; better management practices and legume–legume systems are advocated	Competition between *Stylosanthes* and associated *Panicum* and other weeds is reported; development of legume–legume systems could be a better alternative	Competition from grasses is not a serious problem, as *Stylosanthes* is established in cropped areas, where the species is well managed	Grass sometimes outcompetes desired *Stylosanthes* species in fodder banks; researchers need to identify more aggressive legumes or their mixtures

(continued)

Table 22 concluded.

Constraint–issue	Cameroon	Côte d'Ivoire	Mali	Nigeria
Fencing	Fencing is very expensive for fodder-bank adopters; cheap and suitable materials and establishment techniques need to be identified	Eco-farm Project recommends the use of *Gmelina* and barbed wire as fencing, but other suitable materials need to be identified to complement this system	Roaming animals have been the main deterrent to adoption; researchers need to identify suitable materials through evaluation trials	The need for expensive and labour-demanding fences to prevent roaming animals and uncontrolled grazing deters adoption; research should be encouraged to identify and establish both exotic and indigenous fencing material
Land scarcity	Farmers are reluctant to leave land in *Stylosanthes* fallow, owing to intensive cultivation; other systems, such as intercropping and sequential cropping, need to be developed	The land-scarcity problem is uncommon among the exploiters of *Stylosanthes*, as there is abundant land	High cropping intensity does not allow *Stylosanthes* to be incorporated as fallow crop in the same way as in Nigeria and Cameroon; other cropping practices should be identified	In intensively cultivated areas, farmers cannot leave land in *Stylosanthes* fallow for even 1 year; other cropping practices, such as intercropping or sequential cropping, need to be developed
Land tenure	Absence of secure land rights has affected diffusion of *Stylosanthes* among agropastoralists; favourable policies are required for adopters	Adopters of *Stylosanthes* in the Eco-farms Project have huge areas of land	Adopters of *Stylosanthes* are entitled to massive areas of land	Land-tenure issues are very serious constraints to adoption, especially by cattle owners; favourable land-use policies and more facilities for agropastoralists in grazing reserves are required

Lack of capital	Lack of loan schemes retards the adoption of *Stylosanthes*; low-interest loan schemes are required as incentives	Adoption of *Stylosanthes* is promoted by loans; farmers should be encouraged to target fodder banks to more lucrative enterprises	No loans are required for the promotion of fodder banks; the successful cotton industry provides capital for the required inputs	Incentives for fodder-bank adoption are provided through World Bank loan schemes; low-interest loan schemes are required; for sustainability, *Stylosanthes* should be targeted to more lucrative enterprises to generate sufficient income
Labour requirements	Labour is a serious bottleneck, and animal traction needs to be promoted	Côte d'Ivoire suffers a shortage of labour during the growing season, and animal traction is only well developed in the cotton belt; it needs to be better developed in other areas	There is shortage of labour, but ox-plows, carts, etc., are used by many farmers to alleviate this constraint; more research is required on the use of appropriate implements	Shortage of labour is acute, and animal traction is not widely used in central Nigeria; the technology needs to be introduced in these areas
Fires	Indiscriminate burning in rangelands is a very serious constraint to adoption of *Stylosanthes*; laws should be passed to deter this practice	Fires discourage farmers from adopting *Stylosanthes*; protective laws are required	Fires are not as serious in SHZ of Mali, where *Stylosanthes* is established in cropped areas as in Cameroon, Côte d'Ivoire, and Nigeria	Fires are a threat to further adoption of fodder banks; bush burning should be outlawed; fire breaks could also be constructed at the beginning of the dry season

Note: SHZ, subhumid zone.

Inadequate seed supply

The low quantity and poor quality of seed are major hindrances to the expansion of *Stylosanthes* in the SHZ of Nigeria. Seed production in the country is based on only one cultivar (Verano) because of the susceptibility of the other species to anthracnose. In Cameroon, a lack of seed prevents agropastoralists from establishing *Stylosanthes* for their herds. This is also a problem for extensionists who wanted to develop their own seed-multiplication plots for future use. In Côte d'Ivoire, seed production used to flourish but has ceased there, but Mali now has a successful national cover-crop seed-production program.

Weed competition

When *Stylosanthes* is established in association with grasses, such as *P. maximum,* but is not well managed, the legume will be suppressed, leading to a pasture that is dominated by grass and is lower in nutritional value. Also, aggressive and noxious weeds, notably *Imperata cylindrica* and *Sida acuta*, invade *Stylosanthes* pastures, sometimes completely displacing the desired legume.

Fencing

The *Stylosanthes* technology demands the use of fencing, which is very expensive (70% of the cost of a fodder bank in Nigeria), and local materials require additional labour, which some farmers cannot fit into their already busy schedule. This was a concern expressed by adopters in both Cameroon and Mali. *Stylosanthes* adopters suffer huge losses, in terms of both herbage productivity and subsequent crop yields, simply because they cannot afford appropriate fencing. This is not a concern expressed in Côte d'Ivoire, as the loan package there covers the cost of live fences of *Gmelina* and barbed wire.

Land scarcity

In intensively cultivated areas, farmers cannot leave land fallow for even 1 year, so they will find it difficult to include *Stylosanthes* fallows in their cropping systems unless they adopt other cropping practices, such as intercropping or sequential cropping. This concern is common in Cameroon, Côte d'Ivoire, and Nigeria but has not been expressed in Mali.

Land tenure

Where land rights are insecure, farmers are reluctant to make long-term commitments to land development. In many places in Nigeria, cattle owners do not have land rights; the land belongs to crop farmers, who have no interest in cattle production (although they do keep small ruminants) and are sometimes unwilling to give their unused fallow land to pastoralists for pasture development. This land-tenure constraint has affected the rate of adoption of fodder banks. The absence of secure land rights, the scarcity of land (as a result of intensive cultivation), and the open communal grazing system are some of the factors inhibiting diffusion of *Stylosanthes* to agropastoralists in Cameroon. However, land is not a restriction to fodder-bank adopters in either Côte d'Ivoire or Mali, as adopters in these countries own abundant land, sometimes up to 10 ha each.

Lack of capital

The diffusion of *Stylosanthes* technology to farmers through the Eco-farms Project came to a standstill because of a lack of capital. Also, the high interest rates and restrictions of the loan programs prevent farmers from exploiting these credit facilities. In Nigeria, when the World Bank withdrew its support for the loan scheme operating through the National Livestock Projects Department, the development of fodder banks in that country completely stopped. However, fodder banks are still promoted by other bodies, such as NGOs, and financially assisted extension programs, such as the Agricultural Development Projects. In Cameroon, the very weak initial use of fodder banks was partly due to lack of capital for research and extension. No loan scheme has been involved in the promotion of fodder banks in Mali, but the successful cotton industry provides capital for some farmers, thereby enabling them to buy the required inputs for the fodder banks.

Labour requirements

Each of the study countries was found to suffer an acute shortage of labour, as all available labour is required for subsistence cropping; Nigeria and Cameroon also suffer a shortage of agricultural mechanization, including animal traction. Additional labour is required to include *Stylosanthes* in the farming system, and this is scarcely available, especially to farmers with small families, or it is very expensive. In Côte d'Ivoire, farmers follow their traditional practice and concentrate on their crop fields during the growing season because of shortage of labour; they neglect the livestock enterprise, including the important task of managing legume-based pastures effectively.

Fires

Burning, especially during the dry season, is very common in most West African countries (especially Cameroon, Côte d'Ivoire, and Nigeria). Adopters are worried that *Stylosanthes* pastures reserved for the supplementation of cattle in the late dry season might be wiped out by fire at the most critical time; this makes the investment too risky.

Recommended policy interventions, promotional strategies, and further research

A critical point concerning the long-term sustainability of *Stylosanthes* is seed availability. Some countries, such as Côte d'Ivoire, import seed at a very high price, and others, such as Cameroon, do not have enough *Stylosanthes* seed to supply potential adopters. These constraints could be overcome if governments, private agencies, and farmers engaged in seed production enterprises, as is done in Mali and Nigeria, where *Stylosanthes* germplasm is available on the market in the same way as crop seed is. However, most of the seed farms are poorly managed in Nigeria. *Stylosanthes*-seed production is currently well handled by the national seed service in Mali; notwithstanding this, farmers should also be trained to produce and harvest their own seed. Appropriate advice on production and storage is needed by the farmers and these agencies. In Cameroon, national research and extension agencies, private companies, and even farmers should establish multiplication plots for *Stylosanthes* seed throughout the SHZ. Research to explore cost-effective and suitable techniques should be carried out concurrently.

The narrow genetic base of *Stylosanthes* species is also a problem, one that could be solved by implementing screening programs in a wide range of production domains and by identifying combinations of cover crops that complement each other. Over the years, ILCA has identified other promising species through its screening program. For instance, the best accessions in dry areas, such as Maiduguri (453 mm of rainfall), were *C. pascuorum*, *C. rotundifolia*, and *Lablab purpureus*. For high-rainfall areas, such as Jos and Makurdi (1 300 mm of rainfall), *S. scabra* and *C. brasilianum* were found to be the most successful. However, at Bauchi (780 mm rainfall), the best species was still *S. hamata* cv. Verano (Tarawali 1994). Similar screening programs are already under way in Cameroon and Côte d'Ivoire, and they are needed to complement the diffusion of fodder banks in Mali.

This evaluation was able to identify "best bets" such as *A. histrix*, which has very interesting features. This legume was found not only to produce high biomass in both dry and wet areas but also to suppress nematode and *Striga* infestation in crop fields (Weber et al. 1995).

The concept of legume–legume mixtures involving *Stylosanthes* and other cover crops should be developed, especially if year-round use of improved pastures is envisaged. Mixtures can also withstand drought, disease, fire, etc., better than sole cover crops. Better establishment techniques and cheap and better management practices are needed to guarantee a legume-dominant pasture. Probably the use of legume–legume mixtures, rather than sole legumes or legume–grass mixtures, should be explored through future research. Such studies have just started in Nigeria. They need to be initiated in Cameroon, Côte d'Ivoire, and Mali.

The persistent problem of anthracnose in the genus *Stylosanthes* could be overcome by setting up evaluation programs using other legumes for various agroecological zones and farming systems, in case there is a breakdown in the tolerance levels of *S. hamata* and *S. guianensis*. The country-wide evaluation undertaken by ILCA–ILRI and its national agricultural research system (NARS) partners in the Recherches en alimentation du bétail en Afrique occidentale et centrale (research on livestock nutrition in West and Central Africa) network is a step in the right direction. Recent reports indicate that this effort has slowed down in Mali, but the concept needs to be reactivated and even extended to new areas and countries.

Land tenure is a key policy issue in need of attention. The Nigerian government should create land-use policies favourable to the Fulani agropastoralists, whose main reason for not adopting *Stylosanthes* pasture is land-rights insecurity. The provision of grazing reserves for settling agropastoralists in Nigeria is a move in the right direction, but better facilities (schools, hospital, markets, boreholes, etc.) have to be provided to make these environments habitable and attractive. Such an approach is currently taken in Cameroon, where the government is settling agropastoralists on ranches.

Another approach employed by ILCA's farming-systems research team was to make *Stylosanthes* attractive to crop farmers who own land. Field days for demonstrating the benefits of legumes for crops and the use of *Stylosanthes* pastures for livestock were organized for both crop farmers and agropastoralists in central Nigeria. These demonstrations led the crop farmers to adopt the fodder-bank technology to improve the fertility of their continuously cultivated soils, as well as the quality of the feed they give their small ruminants (miniature fodder banks). The rationale is that once the crop farmers recognize *Stylosanthes* as a soil conditioner, they will be more likely to cooperate with agropastoralists who are seeking land to establish *Stylosanthes*.

Other factors seriously impeding the sustainability of *Stylosanthes* in West African farming systems are the shortage of labour and a lack of fencing materials to protect the legume against trespassing animals. To alleviate these constraints, the use of animal traction and carts in farm operations should be encouraged, to economize on manual labour, and there should be a complete integration of the crop and livestock sectors.

Adoption of animal traction seems to be weak in Cameroon and Nigeria. Feasibility studies on the introduction of animal traction in one of ILCA's case-study areas in central Nigeria stimulated a lot of interest from the local farmers, who used to hire carts and ox-plows from ILCA to carry out farm operations. The concept needs to be applied in other countries, and it requires further research on appropriate implements, weeding methods, feeding strategies, etc. In Côte d'Ivoire, complete integration of crop and livestock production should be recommended for all Eco-farms. The introduction of animal traction in these enterprises could reduce the labour constraint, encourage further integration, and increase total farm output. For instance, the soil-fertility improvements offered by *Stylosanthes* and manure from animals should be exploited for crop production. Conversely, residues from crops could be stored and fed to the animals during periods of feed scarcity.

Fencing *Stylosanthes* pastures or fallows represents 40–70% of the total cost of establishing a 4-ha leguminous pasture when imported metal posts and barbed wire are used. This is exorbitant. These costs could be avoided by using live fences, so research on the identification and establishment of suitable live fences should be pursued vigorously. The agroforestry divisions of national programs, such as CMDT, and the International Centre for Research in Agroforestry (ICRAF) should be able to recommend some promising species and better establishment methods. Alternatively, in countries where villagers are penalized by local custom and law if their animals damage crops, *Stylosanthes* could be protected, especially during the growing season, if farmers planted it within their crop fields. This innovation was demonstrated in southern Mali by a farmer who planted 2 ha of *Stylosanthes* in the middle of his cotton field; at the end of the growing season, he allowed his traction animals to graze the improved pasture. Another way of reducing the risk of damage to *Stylosanthes* by roaming village animals is to educate the community on the beneficial effects of the legume so that people give it the same respect and protection as they do other crops, which may also indirectly alleviate the problem of deliberate burning.

Using live fences — such as *Newbouldia*, *Ficus*, *Gmelina*, *Euphorbia*, citrus, and cashew — around farms is already in the culture of the farmers in all four countries. This suggests that the farmers may be willing to try fencing materials identified by researchers through the screening programs. Where animal traction is already well established (that is, in Côte d'Ivoire and Mali), fences are needed to prevent the animals from eating the *Stylosanthes* fields. Live fences should be promoted for this because they are cheaper than metal.

Indiscriminate burning of bush, especially during the dry season, should be banned through national legislation, and local strategies to implement controls should be developed. None of the four countries has so far adopted such a policy, which might deter the destruction of rangelands and make feed available for starving animals. Owners of *Stylosanthes* pastures should be encouraged to construct fire breaks at the onset of the dry season. This is a common practice in Côte d'Ivoire, Mali, and Nigeria for very large fodder banks (about 4 ha). Firebreaks are unnecessary in Cameroon for *Stylosanthes* plots used in intensively cultivated areas to promote dairy production.

Some of the *Stylosanthes* packages developed in certain countries are very capital intensive, and in most cases they are beyond the reach of small-scale farmers. Governments and development agencies could alleviate this problem by developing appropriate, low-interest loan schemes. A loan scheme sponsored by the Nigerian government and the World Bank promoted the diffusion of the *Stylosanthes* technology among the smallholders in the SHZ of Nigeria. Farmers in the Eco-farms project in Côte d'Ivoire now benefit from a funding scheme jointly provided by the Ivorian government, ADB, and GTZ. Such loan schemes are especially recommended for Cameroon and for all other West African countries where *Stylosanthes*-based technologies are capital intensive and peasants cannot afford the inputs.

Maximum benefits from *Stylosanthes*-based strategies to improve feed sources and soil can be realized in profitable enterprises, such as those with dairy herds or cash crops. Incidentally, research and extension activities for these enterprises are currently promoted in all four of these West African countries. In addition, the ILRI (formerly ILCA) has formed the Cattle, Meat and Milk Network to promote these enterprises, not only in West Africa but also on the continent as a whole.

Conclusions

Stylosanthes has the potential to improve feed sources, reclaim land, and control noxious weeds (especially *Striga*). These benefits are very important to both livestock and crop production in subhumid West Africa. Farmers can integrate the legume into their farming systems by growing *Stylosanthes* fallows or pastures in rotation or association with food or cash crops. Such a mixed-crop–livestock scenario could contribute to sustainable food production in West Africa. From this study, it can be seen that progress has been made in this direction, especially in the SHZs of Côte d'Ivoire, Mali, and Nigeria. Further testing and promotion seems warranted in Cameroon and SHZs of the region.

Information is available in both national and international research institutes to address the information gaps and assist in defining appropriate research and extension programs for farmers. For instance, ILRI–ILCA (de Leeuw et al. 1994; Tarawali et al. 1996) has undertaken extensive herbaceous-legume evaluations, including *Stylosanthes*-based mixtures, and animal evaluations. IITA and WARDA have information on the performance of cover crops (biomass, N accumulation, weed suppression, ecological adaptation, etc.) and soil management (Akobundu 1990; Tian et al. 1995; Sanginga, Ibewiro et al. 1996; Becker, personal communication, 1997[7]). ICRAF–Alley Farming Network for Tropical Africa (Atta-Krah 1987; Cobbina et al. 1990; Ladipo 1993; Kang et al. 1995) has many exotic and indigenous collections of trees that can be used as cheap fencing material. These institutes have several bases in West Africa. NGOs and NARS are also gaining experience that should be exchanged and acted on.

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[7]M. Becker, WARDA, personal communication, 1997.

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