Potential of Crop Rotation Using Forages in the Tropics

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The XIX International Grassland Congress took place in São Pedro, São Paulo, Brazil from February 11 through February 21, 2001.

Proceedings published by Fundacao de Estudos Agrarios Luiz de Queiroz

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Abstract

Soil fertility is a fundamental biophysical root cause of food insecurity sub-Saharan Africa. Low quality crop residues and grasses during the dry season also limit animal productivity. Forage legumes (herbaceous and tree legumes) have great potential to increase crop animal productivity. Technologies have been developed over the past 3 decades to fully integrate forage legumes into farming. Most of these technologies are still on shelves with low adoption by farmers. Rhe role of forage legumes in nutrient cycling is reviewed in this paper. The factor limiting adoption will also be discussed. Innovative dissemination pathways to increase adoption will be suggested.

Introduction

Recent studies in sub-Saharan Africa have shown that declining soil fertility is a major constraint to crop and livestock productivity (Stoorvogel et al., 1993). Traditionally especially in Africa crops and livestock have been functionally linked. There are ecological and socio economic interaction between livestock and crop production systems such as:

- animals provide manure to fertilize crops
- crops provide stover as feed during dry season
- animals provide draft power for land preparation
- livestock provide transport for inputs and outputs from the farm
- animals are assets which can be liquidated to provide capital for inputs.

Livestock production systems in the tropics

In order to understand the role of forages in crop rotation the livestock production systems have to be understood. In the tropics livestock is kept for milk, meat, manure, draught power, as a saving account and for other cultural practices. In traditional production systems most nutrient needs of livestock are met by natural forages and crop residues (Mohamed Saleem, 1998).

However increasing market forces are transforming the production systems based on shifting cultivation and extensive range grazing to more intensively managed intergrated systems. As livestock production becomes settled , it will increasingly incorporate crop production and pure cropping systems integrate animals as well (Mohamed Saleem, 1998). There is a need for detailed analysis of various livestock production systems and opportunities for integrating forages in the systems.

Pastoral systems

These systems have been developed over decades by communities living in arid and semi-arid areas. Pastoral systems involve nomadic or migrations in pursuit of better pastures.

Livestock production is the principal occupation of people. Open access grazing are used and there is little incentive to invest in forages or other practices to improve productivity of livestock. Hence the rangeland plays a major function of supporting livestock production.

Agro-pastoral systems

This system is a descendent of the pastoral systems. The livestock owners have settled for a variety of reasons such as disease, drought and large family size. The settlement is near people who cultivate land for crop production. Livestock production in the main activity and people continue to sell livestock products. As population is increases, cultivators and agro pastoralists put more land into cultivation and the quantity and quality of the remaining rangeland and productivity of herds decline. Therefore agro- pastoralists are more ready to adopt innovations to improve the productivity of farming systems and livestock production.

Mixed farming systems

This system was developed as a response to increase in population pressure and decrease in farm size. The intergration of livestock and crop production offers an avenue for intensifying landuse. The case for intergrating animal and crop systems is based on the premise that by-products from the two systems can be used on the same farm. The animals are for draught power, use roughage and low quality feeds and nutrient cycling through the soil, plants and animal manure contribute to overall higher outputs per animal and per hectare. Livestock also provide a means of acquiring cash and therefore support use of external inputs for crop production.

Commercial or market orientated smallholder livestock system

Demand for livestock products exceeds the supply in most parts of the tropics. In west Africa, local production at present meets only 60% of per capita dairy demand, and much of the deficit is by imports (Mohamed Saleem, 1998). These current deficits combined with the projected increases in demand presents a major market opportunity for peri-urban livestock production. According to Wintrock International (1992) meat producers need to rise to 11 million tonnes by 2025 and milk production to 43 million tonnes.

With privatization policies in countries like Zimbabwe, Kenya and others commercial dairy enterprises have emerged involving a complete package of breed, health, feed and other production innovations together with modern transport, marketing and processing facilities. In west Africa smallholder farmers supported by government are engaged in peri-urban fattening of purchased animals. In some peri-urban areas livestock producers have little or no access to land and depend on purchased feeds. There are tremendous opportunities for product exchange such as exchange of manure produced by animals for feed from surrounding farmers. In these production systems livestock feeding strategies vary from unrestricted grazing, restricted or seasonal grazing to zero stall feeding depending on the production system. As more land is cultivated grazing lands diminish. Hence integration of livestock and cropping sectors improves farm productivity, through manuring, animal traction and fodder cropping.

Use of forage legumes

Studies with forage legumes begun in the early years of this century in sub-Saharan Africa. In east Africa the first legumes were introduced into Uganda in 1906 for use primarily in soil conservation (Byenkya, 1988). In west Africa experiments were initiated on use of legumes to maintain soil fertility in 1922 (Vine, 1953). Systematic introduction, screening of legumes and grasses for their forage and soil regeneration was undertaken in the 1950s and 1960s in many countries including Ghana, Kenya, Malawi, Tanzania, Swaziland, Uganda, Zambia and Zimbabwe (Kategile, 1985 and Dzowela, 1988).

During the 1990s and 1980s pasture research continued and expanded with (IITA) and ILCA working at various sites in east, southern and west Africa. They introduced programs to collect, introduce and screen fodder species. Networks linking national and international institutes and scientists were formed to promote and coordinate pasture research activities (Dzowela, 1990).

It was an article of faith among animal scientists that improving the quantity and quality of feed through the introduction and cultivation fodder species was a prerequisite for the development of the livestock sector. Fodder cultivation was essential if the negative environmental impacts of nomadic livestock production were to be avoided through intensification, and if slash and burn agriculture was to be replaced by more productive, sedentary mixed farming systems.

The tropical species most cited are Stylosanthes species, Centrosema species, desmodium and sirato. Forages legumes have been studied in terms of establishment, fertilizer requirements nutritive value and chemical composition, defoliation management, grazing management and animal performance.

Legumes have been tested as components of grass-legume mixtures, reinforcement into native pasture, establishment of fodder banks and intercropped with crops or as sole pastures (Thomas and Sumberg, 1995). The potential of legume based technologies on sustainability of intensified farming systems time been recognized for a long time. Numerous trials have shown that leguminous can increase soil fertility reduce soil erosion, compaction suppress weeds and increase animal production.

These past research efforts however have often not resulted in large scale adoption of such technologies. Apart from few limited cases such as adoption of forages fodder using Stylosantheses in west Africa (Tarawali et al., 1999). The number of successful adoptions however is by far out, weighted by the number of reported failures.

Livestock production practices in Africa have evolved to ensure survival and maximum return from minimum effort. Emphasis is on survival and high animal numbers rather than productive potential (Thomas and Sumberg, 1995). However increasing demand for livestock producers and limited land resources, compels livestock products to be more market orientated.

The concept of crop a planted solely for use by livestock is generally contrary to the goals for smallscale farmers. Producers are risk averse in subsistence agriculture, so priority for use of resources such as labour is given to staple food crops. Hence legumes have to find niches and roles in the farming systems which answer critical constraints to crop production.

There is a large gap between potential benefits from legume based technologies, as generally reported by researchers and the contribution these technologies to farm household as seen by farmers. Approaches on transfer of forage based technologies for soil fertility improvement and methodologies to increase adoption rates will be discussed in this paper.

System niches for crop rotations with forages

Sub-Saharan Africa is dominated by alfisols altisols and oxisols with low activity clays (Deckers, 1993). Alfisols are widely distributed in the subhumid and semiarid tropics. They have low water retention and are susceptible to soil erosion and compaction. Alfisols acidify rapidly under continuous cultivation without proper nutrient management. Ultisols and oxisols cover considerable areas of subhumid and humid tropics. Their major chemical constraints are low nutrient reserves, multiple nutrient deficiencies, high P fixation and Al toxicity. Ultisols like alfisols have low water retention and susceptibility to erosion and compaction.

The main nutrient limiting crop production in African savannas is nitrogen and phosphorus in limited cases. Leguminous 'forages (trees and herbaceous spp) can potentially improve soils through numerous processes such as:

- biological N_2 fixation
- uptake of nutrients from depth beyond reach of animal crops
- increased water infiltration and storage
- reduce loss of nutrients through erosion and leaching
- improve soil physical properties. It is in the context of these processes that role of forages in crop rotations will be discussed.

Fodder banks using herbaceous legumes

Planted forage legumes (fodder banks) was considered by International Livestock Centre for Africa (ILCA) now called the International Livestock Research Institute (ILRI) as a more appropriate long term option for improving cattle productivity and soil fertility (Tarawali et al., 1999). It was against this background that technologies were developed for establishing stylos in natural range lands

(Otsyina et al., 1987) and an cropped areas (Mohamed Saleem, 1986) for improving forage quality and soil fertility.

In most of the studies conducted on fodder banks the benefits of the legume to subsequent crops was a function of the legume in the fallow. As N accrues in the soil grass invades the legume plots (Tarawali, 1991). The contribution of stylosantheses pasture with 25% grass infection was 40 to 50 kg N/ha to a maize crop. As grass density increased to 75% of total DM the N contribution declined to 30 kg N/ha (Tarawali, 1991). The N contribution of forage legumes to subsequent crops varies from 30 – 80 kg/ha. Legumes fallows also improved soil chemical, physical and biological properties.

Since maize was the most responsive crop it is suggested that this crop should be used as the first crop after stylosantheses or any other herbaceous legumes in crop rotations. In the second year of cropping crops such as sorghum or sunflower can be grown. Some of the constraints faced in fodder banks adoption by farmers were:

- fencing proved too expensive for farmers
- highly population land following is difficult
- competition between grasses and legumes
- diseases pests and
- land tenure .
- labour constraints
- lack of seed

The adoption trends in the subhumid zones of four west Africa countries (Cameroon, Cote d'Ivoire, Mali and Nigeria are shown in (Table 1) (Tarawali et al., 1999). Findings from the impact assessment study conducted by ILRI using data from 15 west Africa countries is that the lag period associated with diffusion of stylo based systems seems to be the order of 15 to 20 years. Hence the need for long term projects if impact has to be achieved.

Comparative advantages of woody versus herbaceous forage legumes

The yield response of crops following improved fallows normally depends on the biomass and N accumulation of the fallows (Szott et al., 1999). Given that biomass accumulation peaks at about one year in most herbaceous legumes, tree legumes can be more effective beyond one year duration as they are capable of larger biomass accumulation. Fallows or fodder banks of six months duration typically accumulate insufficient N to produce a crop yield response beyond one subsequent crop. Longer duration fallows of 2–3 years accumulate larger quantities of N and provide residual effects to two or three subsequent crops (Szott et al., 1999; Kwesiga and Coe, 1994). These experiments on improved fallows were done on non coppicing fallows such as Sesbania sesban and Tephrosia vogelli (Kwesiga and Coe, 1994). Experiments with three year fallows which included species which could coppice after fallow clearance hereby eliminating the need for fallow re-establishment were conducted at Msekera in eastern Zambia for five years. Maize yields of coppicing fallows of Leucaena leucocephala and Gliricidia sepium were above 3 t/ha over a five year period without addition of inorganic fertilizers (Fig 1).

However maize yields in sesbania fallows which is non coppicing started to decline after 3 years of cropping. The coppice growth had a high input of N to support high maize yields (Table 2). Leucaena and Gliricidia were the best species for coppicing fallows, which produced high quality biomass. This biomass is high in N, low in lignin and polyphenols and it can decompose and release N rapidly to synchronize with maize N demand and uptake.

We hypothesized that the coppicing gliricidia can utilize the residual soil water after maize harvest and recover soil nitrogen below the maize rooting depth during the long dry season from April to October. We monitored the soil water and nitrogen dynamics in all treatments for two seasons, 1997 to 1998, to test this hypothesis. This information will be used to simulate the long term trend of maize yield, water and nitrogen dynamics using the WaNuLCAS model. Theoretical simulations indicated that gliricidia coppicing could utilize enough residual soil water in an average rainfall of 980 mm/year to produce 2-4 t/ha of trees biomass and increased maize yield. At the end of the dry season, soil moisture profiles confirmed that the coppicing gliricidia treatment utilized about 40 mm more water, primarily from below 75cm depth, that in either the sesbania or continuous cropping treatments. This is probably an underestimation of the total deep uptake of residual water by the coppicing gliricidia since soil water content at 180 cm was still well below that of the other two treatments. Deeper access tubes are required to determine the actual depth of water extraction by the gliricidia roots. Based on the amount of biomass produced by gliricidia, we expect an additional water uptake of another 40 mm i.e. rooting depth would have to go beyond another metre deeper.

This trend in the soil water profile between the three treatments was maintained even after five months when a total of 767 mm of rains fell, indicating the maize crop in the gliricidia treatment used more than in the other two treatments. In addition, the high soil water content in both the sesbania and no fallow treatments indicate that nitrogen leaching can be a serious problem during this rainy period in both the sesbania and no fallow treatments. Indeed, measurements of inorganic profiles for all three treatments confirmed substantial differences in N levels below 75cm depth, with maximum concentrations in the no fallow treatment, followed by the sesbania and gliricidia treatments. These findings indicate that coppicing gliricidia provided a much more sustainable system than the sesbania fallow system because of its ability to utilize residual soil water and to prevent N leaching in such environments. Its resilience to rainfall fluctuations and sustainability will be explored using the WaNuLCAS model. In addition, we are evaluating the advantage of this system under farm conditions from an economic and labour perspectives.

The extra biomass produced during the end of the wet season and dry season can be cut and fed to livestock. These coppicing fallows provide an excellent opportunity of intergrating crop production with livestock production systems. The gliricidia fallows loose leaves as litter during the dry season. When a gliricidia fallow is about 18 months old, the fallows can be cut prior to the dry season. The high quality green biomass can be used as fodder (Fig 2). The fallow will resprout and have coppice growth which it will retain as green leaves during the dry season. The coppice biomass which is of higher quality than litter can be cut and applied to a maize at the beginning of the wet season. The effect to this management technique on fallow residual effects on maize is still under investigation at Msekera Research Station in eastern Zambia.

Cut and carry fodder banks

In countries like Kenya and Zimbabwe where peri-urban dairy production systems have emerged, cut and carry fodder banks using leguminous trees are important feed resources. Trees such leucaena, gliricidia calliandra alone or in combination with napier grass have been used to reduce the dependency on bought in concentrates which are expensive for smallholder farmers. The issue of sustainable of use of land under a fodder bank for cropping is still not very well understood. The cut and carry system is a nutrient mining system without any nutrient applied to the system except N fixed by the legumes. The effects different fodder trees in a cut and carry system for 5 years is shown in (Table 3). In plots where maize was cropped without any application inorganic sources of N, P and K maize yields where very low.

However application of 80 kg N/ha together with 40 kg P/ha significantly increased maize yields compared to plots where only 50 kg N/ha was applied (Table 3). This was shown with highly productive species such as leucaena, gliricidia and calliandra. There is also a possibility of soil acidification when a piece of land is under nodulated legumes for a long period (Noble et al 1999). Changes of 1 pH unit to a depth of 60 –80cm have been measured over a 20–25 year period under grazed leucaena pastures in Australia. The mechanisms involved with associated decrease in soil pH are:

- generation of protons from nitrification and subsequent loss of NO_3 (Bolan et al., 1991)
- release of protons from organic acids (Helyar and Poter, 1989)
- increase CEC with corresponding increase in exchangeable acidity (William and Donald, 1957)

The rate of acidification is greatest from high yielding, pure stands which are cut and removed from the site, where the soils are lightly textured and low buffering capacity and where pH is neutral to slightly acid. Such soil conditions are quite extensive in southern and west Africa. Long term research is needed in this area. Selection of provenances or species with low ash alkalinity and hence lower potential for a soil acidification may be possible.

Increasing adoption forage legumes on farm

In sub-Sahara Africa native pastures and crop residues continue to be the major source of nutrients for livestock production (Thomas and Sumberg, 1995). The capacity of forage legumes to improve soil fertility and pasture and animal production in view of scientists is beyond dispute. In some cases farmers have an appreciation of the legumes. Research over the past 30 years have identified legumes which are adapted for different environments. Unlike in Australia adoption of legumes in Africa has been very low. Some of the reasons cited for low adoption rate by previous authors are:

- ecological conditions
- traditional livestock production goals
- labour and capital investments
- land tenure problems
- weak extension systems
- inadequate diagnosis and analysis

The challenge for future research is to determine what needs to be done so that there is high adoption of forage legumes on farm. The paper will conclude with few innovative strategies to increase the adoption rate of forage legumes by farmers.

Forage researchers have usually set out to address a problem without the input farmers. Recent research have shown farmer participation in problem diagnosis, technology design and testing and evaluation increased adoption of improved fallows in Zambia (Kwesiga et al., 1999). By working together with farmers mutual trust and genuine partnership developed between researchers, farmers and extensive agencies. This confidence helped farmers to modify technologies to suit their circumstances and increased level of experimentation by farmers hence the high rate of adoption of improved fallows.

National extension systems are very weak in terms of resources for wider adoption. Going into partnership with reputable NGOs have shown to increase adoption.

The experiences in eastern Zambia have shown working with World Vision International, Plan International and grass roots local NGOs have increased the number of farmers adopting fallows over a short period of time (Fig 4). In addition different dissemination pathways have to explored for wider adoption and impact. Our experiences in Zambia working with improved fallows using different dissemination pathways such as:

- farmer exchange visits
- farmer trainers
- traditional chiefs and leaders
- development facilitators and
- national extension systems could easily scale up the adoption of improved fallows.

ICRAF's main strategies for scaling-up improved fallow innovations in Eastern Zambia

Working with government extension service

Government structures are often rigid, hierarchical and autocratic. Power and control rests in the top most level where programmes are designed and resources allocated. Governments also have a natural tendency for centralisation, bureaucracy and control. In spite of these draw backs, working with government to scale up may be more beneficial to the poor because governments:

- remain largely responsible for social services including health, education and agricultural extension on which the poor people rely;
- remain the ultimate arbiter and determinant of wider political changes on which sustainable development depends;

- only governments are seen as being the provider especially in Africa. Any attempts to privatise the above services is bound to result in further neglect of the poor.

Firstly, when the decision to work with government is taken the constraints and difficulties of the government system have to be recognised and accepted beforehand. Typically, resources are often in short supply, motivation is often lacking because salaries are low and conditions of service poor. Inevitably, if progress has to be achieved, it will be slow. Thus, agencies that undertake to work in partnership with governments must be committed for a long time.

ICRAF's work in Southern Africa still relies on government support and infrastructure. ICRAF has a memorandum of understanding (MOU) with the government of Zambia, to conduct agroforestry research and development work in her territory. In return for this commitment, ICRAF gets land for experimentation, seconded scientists, access to field sites without interference and an enabling environment to work with the rural poor. The improved fallow technologies were developed in partnership with government research agencies and extension services.

Secondly, personalities and relationships between individuals are a vital element in successful government–NGO partnerships. If these relationships do not exist, no amount of money or advice will make a difference. In Eastern Zambia, ICRAF still enjoys very good relationships with the political establishment; from the office of the provincial minister to chiefs and village headmen who allocate land and influence local policies. Through our good relationships with the provincial and district agriculture offices, ICRAF has been able to access the district farm institutes to demonstrate technologies and get feedback from farmers at the on-set of the programme. The camp extension officers were attached to the project to learn and be trained in agroforestry technologies as well as to select farmers with whom to conduct initial on-farm trials. This pathway is still one of our main strategies for scaling-up. Furthermore, ICRAF has access to the government media to disseminate technologies. We hope eventually to impact on government policy and practice when the conditions for influence become favourable.

Networking with NGOs: ICRAF-World Vision partnership in Eastern Zambia

World Vision International (WVI) in Zambia has similar objectives as ICRAF, that is, to address food security by increasing farmer productivity (per hectare crop yield). Whereas ICRAF had developed the technology, it lacked the capacity and mandate for wider dissemination. ICRAF's capacity to mobilise at the grassroots level could only reach very few farmers carrying out on-farm research. At the same time, its traditional partners, mainly government extension services, had limited understanding of natural resource management strategies since they were largely commodity based. They were also constrained by limited budgets that curtailed their day to day functioning including training.

Therefore, in order for ICRAF to move forward in a manner that would benefit smallholder farmers, she needed partners with the willingness to understand her technologies as well as the capacity and credibility to operate at grassroots level. WVI has a grassroots network of staff and volunteers trained to facilitate extension.

It also has networks with churches, women's organisations and other community groups. However, it also had a constituency of grassroots farmers and communities that expected handouts from it because it is a Christian organisation. This was a worrying trend. To ICRAF's delight though, World Vision was aware of the potential of agroforestry interventions and had at a small scale already tried out using improved fallows as an option for sustainable soil organic matter build up. They had introduced the technology to 5 communities and by 1996, 500 farmers were already testifying to the benefits of improved fallows.

With both parties (WVI and ICRAF) acknowledging that they needed each other, it was easy to talk and find common ground. They jointly designed a 5-year project geared at introducing improved fallow technology to 12,000 small-scale farmers in the Eastern Province of Zambia. For its part, ICRAF agreed to provide training in nursery development and management, supply initial seed, train trainers and lead farmers, supply agroforestry training manuals and information (e.g. Kwesiga and Beniest, 1998) enable farmers opting to produce agroforestry seed, provide laboratory support and soil analysis, participate in monitoring and evaluation, and in general, to be on hand to answer technical questions from WVI staff.

The project was designed to integrate components which included introducing agroforestry to communities that had not been reached by ICRAF and government extension agencies, crop diversification, soil moisture conservation, improved farmer access to agricultural extension and markets. The programme received funding from USAID to the tune of US$ 3.94 million for 5 years from 1998 to 2002. Since the fundamental strategy was to expand the organisational capacity, most of the funds have gone into hiring new staff to increase WVI capacity to work with more communities and farmers. This project is now being implemented by WVI, ICRAF and Ministry of Agriculture in Zambia with the participation of small-scale farmer communities. By the 1999/2000 planting season, the project was working with over 3,000 farmers. The growth in number of farmers adopting and planting improved fallows is expected to be exponential once the main groundwork has been laid.

Building grassroots movements to replicate successful projects

ICRAF facilitates exchange programs for introduction of new technologies between farming communities that have experience in agroforestry. The main objectives are empowerment of farmers as trainers, knowledge transfer from farmer to farmer, farmer assessment of technology performance and farmer-to-farmer backstopping of activities. The more intensive farmer-to-farmer capacity building programs usually last from three to five days in host villages.

Planning and organisation of programs including content is largely carried out by host farmers. ICRAF provides some logistic support like transporting farmers, while the host farmers organise accommodation, meals and entertainment in the village for the trainees.

So far, ICRAF has facilitated several exchanges from or into Eastern Zambia, including:

- From Kasungu in Malawi to Chipata, Eastern Province of Zambia (November 1997). Chipata represents the epicentre of improved fallow technology development where farmer testing and adoption in the sub-region is most advanced, hence its choice as the site to host the first visit. The visitors who comprised 18 farmers (9 men and 9 women) were trained by their fellow farmers in Zambia who had adopted improved fallows of *Sesbania sesban, Tephrosia vogelii, Cajanus Cajan* and *Gliricidia sepium.* Upon return to Malawi, the 18 Kasungu farmers organised themselves into an agroforestry interest group with the result that 122 farmers planted *Sesbania sesban* and/or *Tephrosia vogelii* for soil fertility replenishment in the 1997/98 season.
- A reciprocal exchange of 18 farmers from Eastern Zambia to Kasungu (October 1998) focused on farmer backstopping, monitoring and evaluation.
- Another exchange visit was organized for farmers from Angonia District in the Tete Province of Mozambique to the Eastern Province of Zambia.

- Other farmer-to-farmer capacity building programs have been facilitated between farmers from CARE and WVI project areas in the Southern Province and the Eastern Province of Zambia.

A visit by ICRAF to Kasungu in January 1999 showed that farmers and government extension staff had recorded names of 480 farmers who had established improved fallows, a four time increase from the previous season's users. Based on seed requests in November 1999, an estimated additional 500 extra farmers planted improved fallows during the 1999/2000 season.

The spread of agroforestry across the border from Eastern Province of Zambia was not restricted to Kasungu, but drew attention from farmers over 300 km away-Nyanyala village in Malawi's Southern Region. Farming systems in Southern Malawi are comparable to the ones in Kasungu, providing opportunities for facilitating other exchange visits. Two such visits facilitated by ICRAF have already taken place.

We have found that one participant of such farmer-to-farmer capacity building reaches on average 6 to 10 fellow farmers at home, who again will plant agroforestry trees on their land. This, together with the low costs involved, makes the farmer-to-farmer exchange pathway a very attractive one for achieving wider impact.

The advantage of the farmer-to-farmer training linkages between Eastern Province of Zambia, Central & Southern Region of Malawi and the bordering areas of Mozambique is of interest. We call this area the "Chichewa Triangle", as language and culture are the key bondage for providing conditions of homophile (Rogers, 1995) and hence successful dissemination.

ICRAF is targeting the dissemination of improved fallows within this area first, which hopefully will then allow the emergence of new opportunities for further geographic diffusion by building bridges to other neighbouring languages and cultures in the region. With regard to the geographic diffusion of the improved fallow technology within the "Chichewa Triangle", potential adoption areas need to be defined, based on bio-physical and socio-economic limitations of the improved fallow technology. Organisational aspects and costs of the farmer-to-farmer training will further guide decisions on matching "expert" and "novice" communities (Böhringer, 1999) with targeted areas.

Influencing policy reform: Linking with grassroots organisations

In addition to the dissemination efforts highlighted above, the programme has organised workshops for different levels of policy makers to promote the adoption of agroforestry. The policy makers range from village headmen in traditional authorities to paramount chiefs, elected officials, senior civil servants and the private sector. These workshops have been very useful and have helped to produce strong recommendations (by-laws) that protect and promote cultivation of trees on farm. The large number of stakeholders in natural resource management issues and the existence of groups with conflicting interests necessitate the involvement of various levels of policy makers in these processes.

If not addressed, these conflicts may hinder technology adoption. For example, in eastern Zambia institutional arrangements authorise free range grazing of livestock after the harvest of crops. For those land users who may want to establish nurseries and plant improved fallows and other trees in their farms, this arrangement poses a serious threat to the survival and sustainability of the desired agroforestry interventions. In 1998, ICRAF in Zambia facilitated a workshop under the auspices of the local traditional chiefs to identify institutional arrangement that hindered or accelerated adoption of agroforestry technologies and to seek ways of alleviating those constraints. The workshop provided an opportunity for institutional arrangements to be established to facilitate wide adoption of agroforestry. These included:

- endorsing the penalties on those whose livestock damaged agroforestry trees and crops because they did not herd their animals during the cropping season
- determining a period when bush fires can be set–early burning after harvest
- prolonging the re-assurance of tenure on leasehold land if the land user planted trees
- bylaws empowering the local authority to prevent crop cultivation on hill sides if soil conservation measures were not adhered to.
- revisions of the chiefs act by the government to reinstate some of the powers of the chiefs and other traditional authorities.

Factors contributing to the current achievements

Development is a process whereby people learn to participate constructively in the solving of their own problems. The driving force is people's enthusiasm for change. People who work with development programs must motivate farmers through results rather than by promises. Our current achievements so far can be attributed to:

- Correct diagnosis of farmers' problems from the onset of the programme;
- Involvement of farmers and extension staff in the research process from the inception of the programme. The scientists, like the camp extension staff, spent much time interacting with farmers and could respond quickly to the needs of farmers;
- Starting small and using local knowledge in the design of solutions;
- Demonstrating easily recognizable results;
- The strategy of testing a wide range of management options with farmers (e.g., offering different species with intercropping and pure stand options) and then allowing them the freedom to modify, innovate, and improve the prototypes;
- The technology accommodated men and women alike, as half of the participating farmers are female. It also appears to be attractive to a range of different types of farmers, e.g., high income and low income, ox-and hoe-cultivators.
- Working with partners at all levels: government research and extension services, local farmer groups and big NGOs like World Vision who shared a similar vision with ICRAF;
- The funding of the research programme has been adequate and for a reasonable length of time;
- Ex-ante economic analysis helped identify key features of the technology that make it financially attractive, e.g. bare-root seedlings and the superiority of a two-year fallow over one-and three-year fallows;
- Development of an adaptive research and dissemination network for testing and extending the technology in new areas.

Conclusion

Considerable resources have been invested in forage legume research over past 40 years. Many technologies have been developed which are sit in the shelf. These need to be adopted to reduce poverty and increase farmer's income. There is still need for maintenance research so that effort spent previous research is not lost. More importantly researchers should work with farmers in a participatory mode in order to increase adoption. Otherwise scientists we will continue to produce technological bullets in an institutional vacuum.

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Table 1 - Summary of adoption of Stylo for four West African countries.

Country	Maximum number of adoption
Cameroun	2000
C ote d' ivoire	112
Mali	1421
Nigeria	4166

Source Tarawali etal. 1999

Table 2 - Coppice biomass (t ha^{-1}) and N(kg/ha) input of 3 year fallow species from 1996-2000

	1997	1998	1999	2000	1997	1998	1999	2000
	Coppice biomass (t/ha)				Nitrogen input (kg/ha)			
S.siamea	1.87	3.35	3.27	4.97	23.19	47.12	54.57	71.46
L. leucocephala	1.39	2.30	2.88	2.90	47.82	77.74	78.77	92.52
G. sepium	1.32	2.07	2.46	3.27	43.87	77.69	71.21	108.59
F. mycrophylla	0.82	1.30	2.35	1.68	20.50	30.68	57.17	40.92
C.calothyrsus	0.12	0.57	0.29	0.40	2.57	6.67	9.10	8.51

Table 3 - Residual effect of Fodder with MPT trees on maize grain yield (t ha^{-1})

Fertiliser rate Kg ha^{-1}	Gliricidia sepium	Leucaena leucocephala	Calliandria calothyrsus	Cajanus cajan	Acacia angustissima	Flemingia macrophylla
0N0P0K	1.70	1.40	0.83	2.73	2.17	2.20
50N	2.10	3.33	1.43	2.83	3.17	2.40
50N 40P	2.70	3.93	3.33	2.60	4.03	3.33
50N 60K	2.60	2.93	3.43	2.87	3.87	2.57
80N 40P 60K	3.30	3.37	3.37	2.80	3.10	2.77
S.E.D.	0.31	0.33	0.27	0.36	0.34	0.21
LSD (0.05)	0.72	0.77	0.63	0.83	0.77	0.48

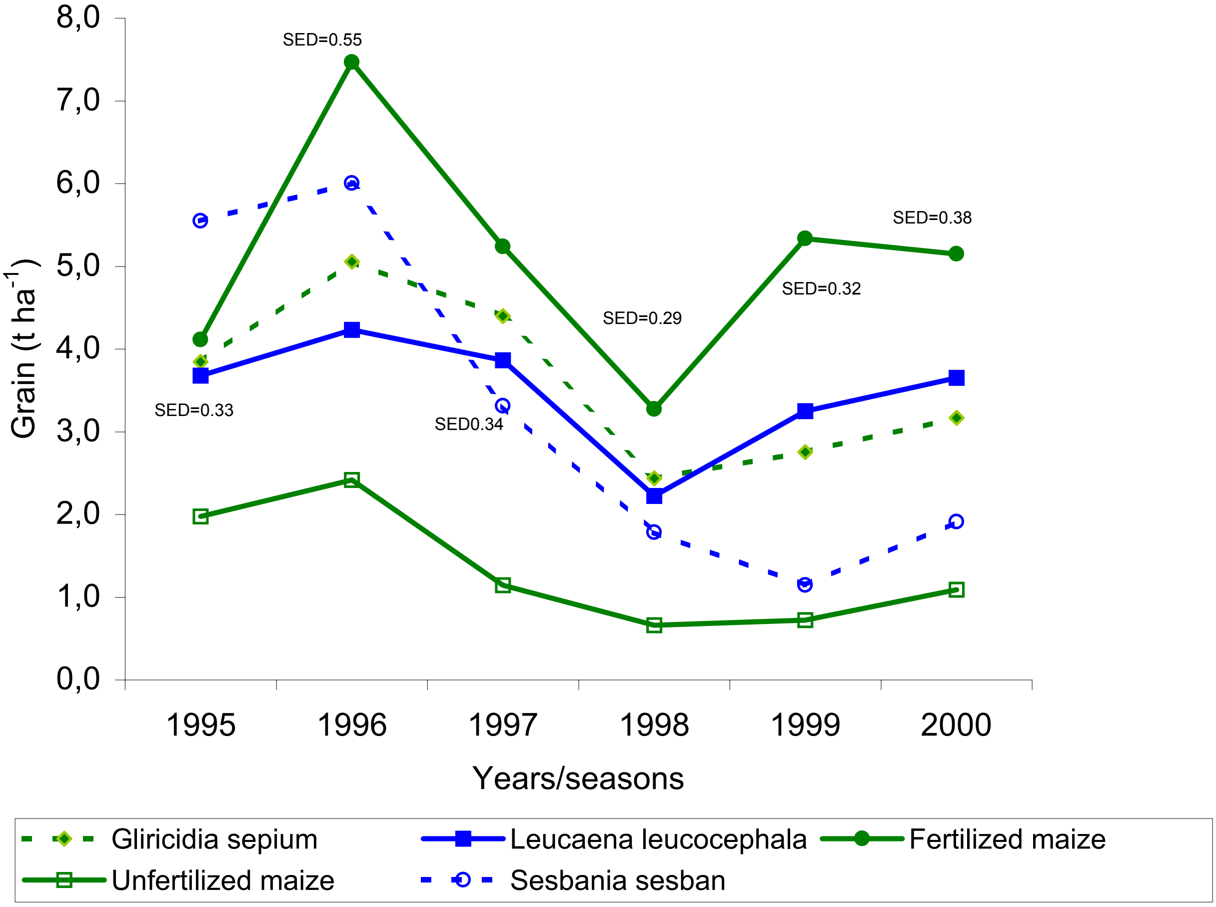

Figure 1 - Maize grain yield after 3 year fallows for six season (1995-2000).

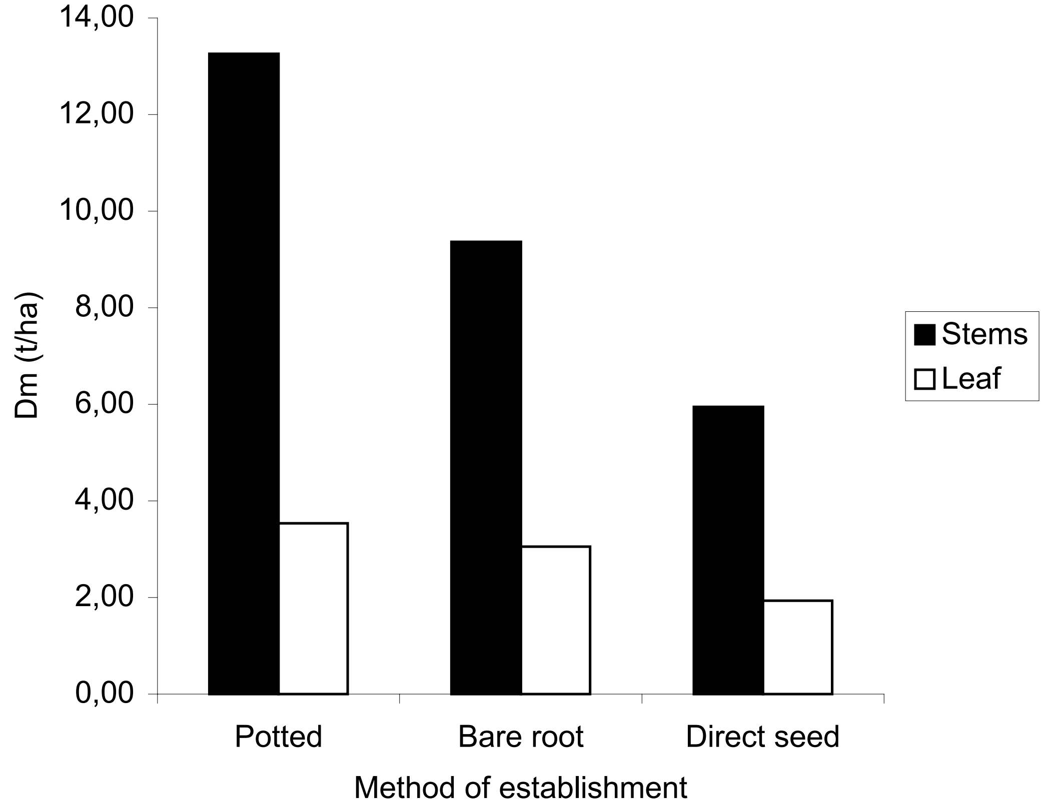

Figure 2 **- Gliricida trial biomass (t ha^{-1}) as affected by establishment method.**

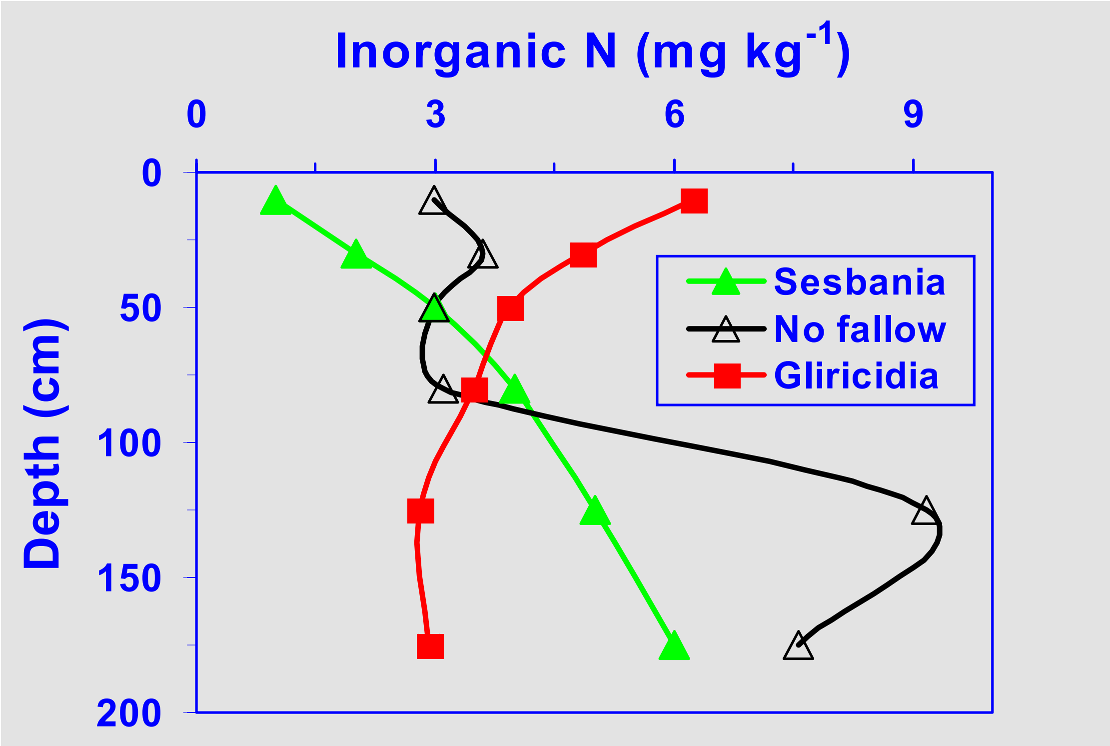

Figure 3 **- Inorganic soil N during the dry season three years after fallows.**
(Chipata, Zambia)

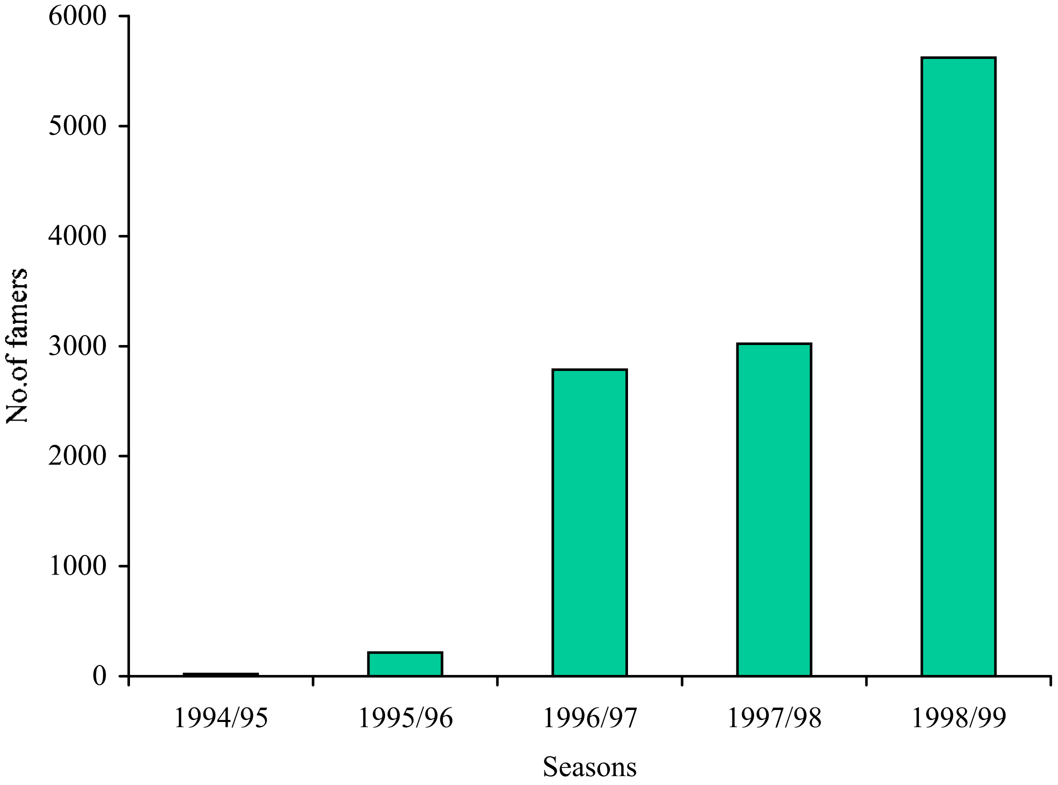

Figure 4 - Cumulative number of farmers testing or adopting improved fallows in Eastern province of Zambia.