The use of improved forages for sustainable land use

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Summary

Tropical grasses and legumes are proving to have multiple end uses and when well managed contribute to more sustainable land use. In addition to use as pasture plants they are being used as fodder banks for grazing or 'cut and carry', for cover crops, as erosion barriers, for fallow improvement and as agro-industrial crops.

Selection of forages in CIAT initially had a narrow focus, namely, for pasture improvement for the acid infertile soils of the Llanos of Colombia. However, selection under conditions of low soil fertility and high disease and insect incidence resulted in liberation of species that have since proved to have wide adaptation to many other agro-ecosystems.

Further, the use of these legumes and grasses in prototype production systems has shown that they are beneficial in terms of improved soil physical, chemical and biological characteristics and can contribute to sustainable pasture and integrated crop-livestock systems in different agro-ecoregions.

A range of grasses and legumes from these selections have been released by different countries. There has been widespread adoption of the grasses for use in improved pastures but poor adoption of the legumes. The reason for the poor adoption of legumes is that (i) many have not been persistent under grazing (ii) there is little recognition by farmers of the long term benefit and (iii) many land holders have focused on profits arising from increased land values rather than increased productivity *per se*. It is now recognized that successful introduction of legumes for pastures will depend on choice of appropriate production 'niches', in particular, in more intensive livestock and crop-livestock systems and on development of legume technology in partnership with farmers.

New opportunities have been recognized for the use of grasses and legumes in non-livestock systems. There has been widespread adoption as covers for high value tree crops even though there has been little extension effort in this area. Legumes have been successfully adopted for feed meal production and could be more widely used in improvement of fallow lands.

There is a need for development of indicators at the farm level for use in the economic assessment of the long-term value of new 'forage' technology for the community as well as the more immediate benefits to the individual. Further input in sociological studies and development of seed systems for production of cheaper seed is required.

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The forage germplasm resource

Forages comprise a wide array of species, mostly from the Gramineae and Leguminosae families. For example in the CIAT genebank, which has a mandate to maintain and develop germplasm for the subhumid and humid tropics, there are some 150 genera and 750 species among the 21,000 accessions, though 26 genera account for 82% of the collection. While all these have been collected and conserved with a view to potential use, they only represent a small proportion of the total diversity of tropical plants used as forages. Nevertheless, as in the temperate zone, a much smaller number of genera and species is generally recognized as having commercial potential. However, in contrast to the temperate zone, most of the forages which are recognized commercially in the tropics are selected wild species rather than bred lines. This even applies to species such as the grass *Brachiaria decumbens*, a single genotype, which is planted over some 40 million ha in South America.

Most tropical genera, with potential for commercial use, have been recognized for many years. Nevertheless, potentially useful species are still being recognized in these genera and in new genera which only a few years ago were not considered of major importance for forage. One of the better known novel species is the wild peanut, *Arachis pintoi*, which though released in 5 countries is still not widely used. Another new species which we consider to have commercial potential is the shrub legume, *Cratylia argentea.* Both originate from the Cerrados of Brazil.

Many of these new or novel species have been recognized by extensionists, farmers and others for many years but this information is not widely known. One of our responsibilities in CIAT is to gather, process and make such information more widely available. Thus we are interested to learn of potential new forage germplasm from persons like yourselves who are involved in development. We are restricted in how quickly we can acquire and evaluate the material ourselves because of the time delay in following quarantine procedures and for seed increase, but we can feed such information into databases that are widely accessible. In addition to maintaining a priority set of tropical forages and legumes within CIAT, we are developing a coordinated network with other International Agricultural Research Centers (IARC) to facilitate the international flow of forage germplasm and information about forages.

A new phase of research that has begun is to develop geographic information systems (GIS) that can predict the occurrence and potential distribution of key forage species. This has commenced for the legume *Stylosanthes* and we plan to undertake it also for the genus *Arachis.*

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Multi-purpose use of forages

Forage by definition is vegetative material that is used as feed by herbivores. However, we now recognize that many forage plants have the potential for multi-purpose use. Many legumes can be used as soil covers and for improvement of fallow land. Both grasses and legumes can be used as barriers in control of erosion and for rehabilitation of degraded mining land. Tropical legumes are also used for feed meal production for cattle, pigs and poultry.

An important lesson we have leamt over the years is to make materials widely available and to interact with farmers and others in the development of their end use. As a species becomes widely distributed and used, alternative uses become apparent. Shrub legumes are given wide publicity as multi-purpose species but the same case can be made for many herbaceous legumes.

Stylosanthes guianensis CIAT 184 was collected in the hillsides near Cali by Dr Rainer Schultze-Kraft of CIAT in 1973, first evaluated in the savannas of Colombia, where it succumbed to anthracnose disease and then in the forest margins at Pucallpa, Peru, where it was shown to have very good adaptation. It was promoted in Peru and released as a pasture plant in 1985 but did not have good persistence under grazing. It is now recognized as having potential as a legume for use as a cover in oil-palm plantations and to improve the natural fallow in a prototype agroforestry system being evaluated for the region. It was taken to China in 1984 by personnel who came to CIAT for training. It proved highly adaptable and more vigorous and anthracnose tolerant than cultivars of *Stylosanthes* that had been selected and distributed from Australia. It is primarily used as a cover crop in orchards and as a rotation crop to break the disease cycle in melon crops from where it is harvested and dried for use as a component for feed meal. Some 30,000 ha are planted each year. It's success also depended on the development of a local seed industry that produces 50 tonnes of seed per year at a cost of USD 3-5/kg.

Centrosema acutifolium CIAT 5277 was released as a pasture plant for the Llanos of Colombia in 1987. It was not widely adopted because of poor persistence due to lack of seed production under grazing. It has been identified by a local company in Pucallpa, Peru, that is developing perennial crop systems for smallholder farmers, as the most appropriate cover under the tree crops, 'hearts of palm' and 'comu-comu' (a fruit high in ascorbic acid). Local seed production has been developed by persons who received training in CIAT.

Centrosema macrocarpum, identified in CIAT as a potential pasture plant but not officially released by the national agricultural research systems (NARS), is being widely used in research and development projects in South America and Africa as a cover plant and for fallow improvement.

Arachis pintoi CIAT 17434 was first evaluated in the Llanos in 1979 where it proved to be persistent when grown in association with vigorous *Brachiaria* species and grazed at 4 animals/ha. The first *A. pintoi-Brachiaria* pasture still persists after 14 years of heavy grazing. It was released in Colombia in 1992 as Maní Forrajero Perenne.

However, it also found early use as a cover crop in oil palm and coffee plantations where farmers were prepared to pay the high price demanded by seed producers. In Central America it is being used as a cover crop in banana, coffee, palm, pepper and citrus plantations and for erosion control on steep exposed banks. In Colombia, research at the Centro Nacional de Investigación de Café (CENICAFE) has shown that use of *A. pintoi* as a cover crop reduces the need for weeding after the first year, reduces soil erosion and the N fertilizer input for the associated coffee (Cruz et al. 1994). The commercial banana industry in Central America is particularly attracted to the use of *A. pintoi* as a cover because it reduces the need for chemical weed control and results in increased soil microflora. In a recent meeting of the RIEPT-MCAC (Red Internacional para Evaluación de Pastos Tropicales-México, Centro América y el Caribe) in Central America, 13 of 28 technical contributions on research and development related to *Arachis* were concerned with it's use for cover and soil improvement rather than as a feed.

Adoption of forages for sustainable land use

In the 1990's, there has been an emphasis worldwide on developing agricultural practices that will lead to more sustainable land use rather than a single focus on increased productivity. Higher productivity is still be needed to ensure an improvement in living standards in rural and urban areas in the developing countries but with the emphasis on increased efficiency of production with a reduction in damage to the environment. Forages are now seen as components in a production system that can contribute to more sustainable land use practices.

Pastures

The large expansion in livestock production in South America in the past decades has been through expansion of the area used for cattle; more recently into marginal areas that have been less suitable for other agricultural uses (Janssen et al. 1990). Government policies have favored expansion rather than intensification of land use; in particular, the ability to capitalize on a market for land in marginal areas together with rising land prices have driven livestock development. This has not been a favorable economic environment for investing in technology that will give increased productivity per unit area of land; e.g. the high productivity that could be obtained with grass-legume associations. It is estimated that 90% of the grazing land in tropical Latin America remains in native pasture and even 60% of the 180 millon ha of grazing land in the most developed country, Brazil (Rivas 1995a).

However, improved grasses have been widely adopted. It has been suggested that this likewise is due to increased value of land sown to these grasses (see Thomas et al. these proceedings). Benefits of these improved grasses in the lowland savannas has been increased animal and crop productivity and soil improvement. The improvement in soil parameters such as soil carbon and infiltration is largely associated with the introduction of grasses while legumes have been shown to give an additional benefit of higher soil N, increased soil fauna, increased turnover of P and increased animal productivity. Nevertheless, soil degradation can also occur with improved grasses. This may be in part due to depletion of soil nutrients, in particular N, but, in general, experience and limited research results show that this is largely due to overgrazing; overgrazing in the sense that, under severe defoliation, the grasses develop reduced root systems and are less vigorous, exposing the soil and leading to erosion on steeper slopes. *It is false to believe that some resilient grass or grass-legume association will substitute for poor management.*

Insert Table 1

Higher productivity and thus increased turnover of cattle must also be an attractive feature to farmers in addition to increased land value (Table 1). It can also be seen from Table 1 that while there is a 16-fold increase in productivity over native pastures with the introdu..on of improved grasses, there is only a 2-fold increase over improved grasses with the introduction of a legume to these improved grasses. Under good management improved grasses have given consistent high production over 18 years at the Carimagua research station. In the livestock industry improved grasses are considered to have a useful life of 15 years (Rivas 1995a).

The grass, *Andropogon gayanus* CIAT 621, was rapidly and widely adopted after its release in 1980 in Colombia and in Brazil. In Colombia, while it was released because of good adaptation to the infertile soils of the Llanos, it became most widely adopted on the more fertile soils of the North Coast area where it proved to be more productive in the dry season than available grasses (Estrada 1985). In Brazil, where it increased to occupy some 1.52 million ha over 10 years, reasons for adoption were i) drought resistance, ii) adaptation to acid soils, iii) resistance to spittlebug, iv) rapid regrowth after rain and v) good tolerance to fire in addition to acceptable animal productivity (Sáez and Andrade 1990).

Brachiaria humidicola CIAT 679, which was introduced in Colombia in 1985 but not officially released until 1992, was well accepted by farmers because of its resistance to the insect pest, 'spittlebug', persistence and ability to compete with weeds (Cadavid 1995). It comprised 32% of the area sown to improved grasses in the Altillanura Oriental (Llanos) in 1989 and 40% in 1992.

Though there is considerable information showing that legume-grass pastures have a more beneficial effect on improvement of soil properties and animal productivity than pure grass pastures, there has been poor adoption for use in pastures (Rivas 1995a). The main reason for poor adoption of legumes to-date has been poor persistence due to susceptibility to defoliation or the inability to set seed and re-establish in association with vigorous grasses. Other reasons are the higher cost and management input required for grass-legume associations than for pure grass pastures. Another reason is that in extensive situations, where most of the research was carried out, there are likely to be more profitable alternatives to investment in grass-legume technology than in more intensive mixed-farming situations where land prices are high and have stabilized (Thomas et al. these proceedings).

Arachis-Brachiaria associations now offer a sustainable and persistent grass-legume alternative for intensive livestock industries in the humid tropics (Lascano 1994; Hernández et al 1995). *Arachis* has proved its potential over other pasture legumes for the humid tropics because of its persistence under heavy and continuous defoliation. The proportion of *Arachis* in a pasture increases with grazing pressure; lenient defoliation during establishment leading to failure of the legume.

Cover crops

Herbaceous legumes are being widely used as cover crops in tree plantations. This practice was developed and widely used in plantations in Asia where legumes from South America, *Centrosema* and *Stylosanthes* were used together with legumes that occurred in the region, *Calapogonium, Desmodium* and *Pueraria*. The practice is now becoming more widespread in South America and a new range of legumes is available. These are largely a by-product of screening of legumes for pasture use. However, attention is now being turned to screening legumes for different end uses, including green manure and cover crops.

One of the problems of using covers in areas with a marked dry season is competition with the main crop for soil moisture. A collaborative CIAT-BMZ-GTZ project working on soil conservation practices for cassava has identified an accession of *Chamaecrista rotundifolia*, CIAT 8990, as less competitive than other cover legumes (CIAT 1995).

Industry and farmers in Central America have already adopted one of new pre-release accessions of *A. pintoi*, CIAT 18744, as cover legume for tree crops in preference to the released cultivar CIAT 17434. At least one-third of the sales of *A. pintoi* CIAT 17434 in Colombia (Rivas 1995b) and Central America are for cover crop use.

Barriers

Both grasses and legumes have been adopted widely to stabilize contour rows and furrows for control of soil erosion. In the Sikka province of Flores, Indonesia, some 40,000 of small farm holdings were stabilized with *Leucaena* with beneficial results on crop yields and water retention (Piggin and Parera 1985). This high rate of adoption was achieved by the use of incentives. Farmers did not receive assistance by way of an improved 'package' for maize production until they had planted *Leucaena* on the contour. However, they also received assistance by way of training and technical input in developing the *Leucaena* rows.

In Cauca Department, Colombia, farmers selected edible forage grasses such as elephant grass *(Pennisetum purpureum)*, imperial grass *(Axonopus scoparius)* and Guatemala grass (*Tripsacum andersonii*) over vetiver grass (*Vetiveria zizanioides*) because of greater utility (Ashby et al.   ) The BMZ-GTZ investigation, carried out on-farm in the same region, identified dwarf elephant grass cv. Mott as another alternative for use in barriers (CIAT 1995). Though the use of barriers has been successfully demonstrated and adopted by some farmers, use is still not widespread in the area. The reasons are not clear but the agricultural system in Cauca is much more diverse than in Sikka and farmers rely less on food crops for subsistence.

Legumes for fallow improvement

Fallow forms a large part of the total land area in many smallholder farming systems and is unproductive except from the aspect of regeneration of organic matter and available nutrients. A fallow used for alternative purposes, such as timber or fodder or a shortened fallow, could increase overall productivity. Though we have only recently focussed attention on use of legumes to improve fallows, there is good evidence of the value of introduction of legumes in fallow improvement.

Though *A. pintoi* has been released officially in 5 countries, it is still in an incipient stage of adoption for pastures. A survey of 50 persons in Colombia who had purchased seed revealed that 70% were satisfied and would introduce more *Arachis* to their farms. The main problems experienced were associated with establishment such as weed control, slow establishment and poor growth under dry conditions (Rivas 1995b). There appears to be more widespread adoption in Central America though there have not been any surveys made.

Nestlé is currently funding a project in Caquetá, Colombia, to investigate the feasibility of *Arachis*-based pastures to increase milk production on dual-purpose cattle farms. All research is being carried out on-farm and we are learning many lessons about the development of improved grass-legume pastures as forage components in a production system. Firstly, farmers do not have ready access to machinery, and establishment using herbicide application is being developed. Secondly, farmers have not been aware that heavy grazing during establishment favors the establishment of *Arachis;* they have had the practice of shutting up new sowings of grasses until they set seed. Thirdly, it is becoming obvious that the potential of the new legume technology for increasing milk production will only be realized with well managed cows of higher genetic potential for milk production. Notwithstanding the problems encountered, the project, which has only been operational for one year, has had a significant impact in the area. Caquetá has now become the largest market for sales of *Arachis* seed to farmers, independent of seed inputs associated with the project.

In general, the forage technologies we are developing appear to be more suited to intensive crop-pasture than extensive situations. For example, we have not developed cheap establishment techniques as has been done in Australia, where almost 1 million ha *Stylosanthes* has been introduced into native pastures largely by oversowing.

A final point on the contribution of improved pastures and fodder towards more sustainable land use is that they may be introduced in one portion of the landscape to reduce pressure on other parts. In Costa Rica, a forestry project aimed at re-afforestation of steep eroded upper slopes had to be modified as cattle were grazing the area being replanted during the dry season (S. MacLennan, private communication). The modification was to intensify production of forage for dry season feeding on lower slopes in order to reduce grazing pressure on upper slopes. This project is still in progress and will be used as a site in the Tropileche Project (CIAT, 1995b).

Fodder crops and fodder banks

We have had limited experience with these because until recently most of our research was concentrated on grazed pastures in humid areas. We are conscious of their usefulness in providing supplementary feed during the dry season for intensive and semi-intensive systems such as dual-purpose cattle production. We will be investigating the use of them in the Tropileche project.

Some smallholder dairy farmers, e.g. in Costa Rica, have found protein fodder banks easier to establish and manage than grass-legume pastures. They have been encouraged by the increase in milk production when cattle have been given access to them for a few hours each day. Shrub legumes such as *Leucaena, Erythrina* and *Gliricidia* and forage *Arachis* have been used as fodder banks for milking cows.

In the Amarasi province of Timor, Indonesia, *Leucaena* was introduced on a large scale to replace forests destroyed by shifting cultivation. It became naturalized and resulted in the development of a fallow system for crops and tethered or stall fed livestock that was very productive and increased the overall welfare of the farmers in the department (Piggin and Parera 1985). Likewise, the legume, *Mucuna,* became naturalized in parts of Central America and stabilized the small holder cropping system in the area (Buckles et al. 1992). We have observed a potential for *Centrosema pubescens* or *C. macrocarpum* to achieve the same role in West Africa.

In CIAT, we have demonstrated a potential role for *Centrosema macrocarpum* and *Stylosanthes guianensis* in fallow land in Cauca (CIAT 1995) as have ICRAF (International Center for Research in Agroforestry) in Yurimaguas in Peru. There is also a possibility that perennial *Arachis* species might play a similar role once a management system is devised to control competition from *Arachis* in companion crops.

Legumes and grasses as agro-industrial crops

Stylosanthes guianensis CIAT 184 is well established as an important component in feed meal production in China. The return from the use of land for stylo feed meal production is greater than it's use for grass-legume pastures used for beef production. *Leucaena* was used in a similar fashion in the Philippines until productivity was destroyed by the psyllid insect. In Cauca, Colombia, the previously mentioned BMZ-GTZ project facilitated the development of a small holder industry led by women for production of citronella oil from the grass, *Cymbopogon nardus*, which is grown in barriers.

Environmental impact of improved forages

There is a need to assess the impact of new technology to society as a whole as well as to the individual. It is relatively simple to demonstrate a beneficial physical effect such as reduced erosion, increase N availability and more stable pasture associations, which will have an immediate impact for the individual, but more difficult to place a value on these for society as a whole. This is the reason why there is a major emphasis at present on the development of indicators for sustainability which might be used to derive an economic value on environmental impact. This is an area in which will collaborate with other Programs in CIAT and other institutions. In the Tropileche Project, we have planned to develop indicators at the farm level and investigate methods for apportioning benefits to the individual and to society.

One area where we are conscious is that of the impact of introduced species on the natural environment, including that of the natural biodiversity of a region. Agricultural development has resulted in the replacement of large areas of native vegetation rich in genetic diversity with vegetation of very limited genetic diversity. The classic example is the presence of some 40 million hectares in tropical America of one genotype of *Brachiaria decumbens.* We advise caution against use of species which may become widespread weeds and aim to make a number or a mixture of genotypes available for each production system.

Limitations to adoption

The main limitations to adoption have been inappropriate technology and the lack of a cheap and reliable source of seed.

Inappropriate technology may be due to a combination of technical, economic and social reasons. We consider that the most effective way to ensure that technology is appropriate is to develop it in conjunction with farmer participation. Hence though we are a germplasm development program, the task is not completed until a new line or accession has been demonstrated as having a role as a component in a production system. One difficulty is that participatory methods have not been well developed for intermediate components such as forage and whose effects, particularly environmental ones, are only evident in the longer term.

The provision of a reliable source of cheap seed remains a challenge, particularly for legumes. There is a well established seed industry in Brazil that could supply the grass seed needs for tropical America. However, because of lack of control and appropriate regulation in various countries, the price and reliability of seed supplies is very variable. An efficient legume seed industry has been developed in Bolivia which has had large social benefits for the small farmers who produce the seed. With minimal inputs this fledgling industry could be expanded to meet the needs of legume seed production. The most difficult aspect will be to circumvent grasping attitude of officials and entrepreneurs in the various countries where seed needs to be marketed.

Unfortunately, sociology and seed production are two areas where we now lack capacity and where we seek additional input from others.

Conclusion

Improved forages can make a major contribution to improving sustainable land use practices. The widespread adoption and potential use of forages for different end uses selected at CIAT is due to their adaptation to a wide array of ecoregions and production systems. This is a result of strong selection pressure for adaptation to infertile soils and diseases and pests.

Following this initial selection of forages, there is a need to target areas where there is potential for adoption and involve farmers and sociologists in the development of these selections as potential forage components, be it for pasture, cover crop or agro-industrial use. Seed supplies need to be developed concurrently with the diffusion of technology. In terms of both contribution to the individual and to society there is a need to consider the whole production system and not only the forage or livestock component.

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Table 1. Mean liveweight gain of cattle over 4 years on different pastures at Carimagua, Llanos of Colombia

Pasture	Stocking rate	Liveweight gain	
		per head	per hectare
	(hd/ha)	(kg/hd)	(kg/ha)
Native savanna	0.2	60	12
Brachiaria decumbens	1.7	120	200
B. decumbens/Pueraria	1.7	170	290
B. humidicola/Arachis	2.4	183	440

Source: Lascano and Estrada 1989; Lascano 1994.

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