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The role of forages in reducing poverty and degradation of natural resources in tropical production systems

In the tropics forages are a key to revitalisation of low input mixed farming systems. The use of improved forages in highly productive pastures dramatically reduces the land area needed for animal production, increasing land use efficiency. In high-yielding cut-and-carry systems based on high quality grasses and legumes (herbaceous, tree and shrub) year-round animal productivity is enhanced, manure quality improved and labour requirements reduced. Leguminous forages used as cover crops in plantations, as green manures and improved fallows have reduced the cost of weeding in terms of cash and environmental damage, and lessened the need for nitrogen fertiliser inputs. Moreover, the introduction of improved legumes and grasses offers the possibility of reclaiming severely degraded lands. The appropriate use of multipurpose forages leads to improved human nutrition through more beef and milk and increased income and cash flow through better utilisation of available natural resources. The multiple functions of forages increases the capacity or resources for production and allows intensification of production systems, enabling resource-poor farmers to break the vicious cycle of poverty and resource degradation. These concepts are explored in this paper through use of case studies which have involved farmers in the research and development process.

1. Introduction

The objective of agricultural research and development is develop sustainable production systems. This goal can only be attained when environmental protection is balanced with social and economic sustainability, a paradigm agreed to by 172 governments at the UN conference ‘Environment and Development’ in Rio de Janeiro (Burger 1998). All parties must reach an agreement on trade-offs between enviromental protection, productivity and improvement of social welfare. Recent research has highlighted the concept of linking degradation of natural resources with the impoverishment of small-scale farmers and rural communities (Carls & Reiche, 1998, Lopez-Pereira 1997, Kaimowitz 1997, Vosti and Reardon 1997). Land and water degradation decrease crop yields and increase food costs leading to poverty (Vosti and Reardon 1997), which in turn can further increase the pressure on natural resources. Achieving food and income security is a pre-requisite to poor farmers making decisions beyond immediate survival and investing in the sustainable use of natural resources. Intensification of production with a NRM focus is likely to be the only way to reverse degradation, alleviate poverty and improve food and income security of resource-poor farmers.

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1.1 Opportunities for intensification of smallholder production systems

Opportunities for intensification in smallholder farming systems are limited because of the inability of farmers to pay for external inputs. Forages, in particular legumes, integrated with crop, trees and livestock can produce synergistic effects and minimize external inputs (McIntire et al. 1992, Humphreys 1993, Thomas et al. 1995, McCown et al. 1992, Smith et al. 1997, Schultze-Kraft and Peters 1997, Sanchez 1999). The versatility of forages allows them to be used in the complex production systems of the tropics and subtropics (Schultze-Kraft and Peters 1997). Nevertheless, the role of forages in reducing poverty and resource degradation is itself complex. Forages can have both direct and indirect effects in increasing resource and land use efficiency (Humphreys 1993). Most forages are multi-purpose plants. Direct effects on crop production include weed suppression, pest and disease reduction (when used in rotation), while indirect effects include their use as green manures, improved fallows, cover crops and live barriers.Production costs are decreased due to the reduced need for external inputs as fertilizers and pesticides and there are environmental benefits from less contamination of crops and water with pesticide residues, conservation of fossil energy as well as soil improvement through N fixation. Higher feed quality also results in improved manure and compost. Increased productivity can result in improved cash income and the ability to pay for household needs and education or income derived from livestock as a market-oriented activity can improve cashflow and purchasing power for inputs and thus act as an 'engine for sustainable intensification' (Delgado et al. 1999).

The increased land-use efficiency resulting from intensification can lead to protection of areas unsuitable for agricultural production where policies favor maximizing return from labor and land rather than clearing new land for agriculture (Schultze-Kraft and Peters 1997, De Haan, ND, White et.al. 1999). Increased feed production on agricultural land marginal for cropping and recuperation of degraded land also contribute to increased land use efficiency (Schultze-Kraft and Peters 97, Delgado et al. 1999, Naidu and Harwood 1997, De Haan et al., ND).

1.2 Effect of improved forages on livestock production in enhancing income , equity maintenance of ecosystem health

The most important contribution of improved forages is their direct effect on livestock production. Traditionally, livestock have been a component in farming systems and important source of income for the poor in developing countries. Animal production may produce higher returns than crop production (Delgado et al 1999). It is a commodity with a high value added output, though accessibility is often limited by capital for purchase of livestock while potential use may be limited by cultural and religious preferences (Delgado et al. 1999). In contrast to most other commodities, ruminant livestock are a mobile resource allowing market assess even from remote areas and deferment of sale depending on need for cash and the market opportunity. Flexibility of transport and marketing is increased through processing. The importance of livestock in poverty alleviation is illustrated in a study by Escolán et al. (1998) in Honduras, where the possession of livestock was the single most important factor in differentiating between the poverty levels. Livestock provide a stable cash reserve, independent of inflation and are an important source of traction. Recent experience from Central America shows that diversified farming systems that include livestock minimise risks of natural; the effects of hurricane 'Mitch' caused almost complete loss of crops, whereas livestock losses and and income derived from livestock were comparatively low. Livestock activities can have a positive effect on improving equity distribution of household income between men and women. In many cases the rural poor, especially women, get a larger share of their income from livestock than the relatively wealthy (Delgado et al.1999). According to Delgado et al (1999) we can expect a livestock revolution with one of the largest structural shifts in history of agriculture. How it will be handled will have effects for food security, welfare of the rural and urban poor and environmental sustainability. The increased need for animal feed to meet this increased demand for livestock will have to be satisfied by higher efficiency of land use through intensification. For this reason of the need for intensification, we focus this presentation on the mixed farming systems used by smallholders in the tropics and subtropics. For this intensification it is necessary that the true environmental costs of purchased feed (often transported over continents), fertilizer and use of pesticides are appropriately charged and scarcity of resources are reflected in cost-benefit analyses. Policies in such a direction are likely to counteract the industrialization of livestock production in developing countries which could harm the welfare of the poor Delgado et al. (1999). Improved forages are of particular importance in such a concept, being a renewable resource and make a positive environmental contribution. There is a further enviromental benefit through reduction of global warming through carbon sequestration (Fisher et al. 1995). If these considerations are accepted, the impact and adoption of forage technologies is likely to increase greatly in the future.

1.3 The unattained potential of forages

Despite the tremendous potential of forages, in particular legumes, the adoption of forage legumes has been slow (Thomas and Sumberg 1995, t'Mannetje 1997, Schultze-Kraft and Peters 1997, Miles and Lascano 1997, Elbasha et al. 1999). Together with unfavorable policies, the limited and slow adoption can be attributed to the lack of participation of farmers in research and development and lack of coordination on feed improvement, soil fertility maintenance and community participation (Thomas and Sumberg 1995, Schultze-Kraft and Peters 1997). Therefore, this paper will not address only the potential and actual impacts of forages but also novel technologies to improve adoption of forages into smallholder mixed farming systems.

2. Some examples of forage adoption in improving productivity and farmer welfare

1. Seed production by small farmers in Bolivia through SEFO-SAM

An essential component in the adoption of improved grasses and legumes by farmers is the supply of seed to farmers at a reasonable price (Ferguson and Sauma 1993). Smallfarmers can play a role in the production of seed and at the same time improve their welfare from the sale of seed provided that a suitable mechanism is established to facilitate the process (Sauma et. al. 1994). In Bolivia, this mechanism was the establishment of SEFO-SAM (Empresa de Semillas Forrajeras, Sociedad Anónima Mixta) in 1972 as a private cooperative with COTESU, an aid agency, UMSS (Universidad Mayor de San Simón) and producers as partners.
A seed industry framework with certification and controls was being set in the country up for crops, however, the challenge was much greater in the area of forages because of the many agroecosystems and variable demand for forage seed. The objectives of SEFO-SAM were to i) to provide a national system for production of seed, ii) a wide range of forages adapted to all the agroecosytems, iii) seed of high quality meeting international standards with stable prices, and iv) involve small and medium producers in seed production.
SEFO's role has been i) to ensure a market for the seeds produced, even involving itself in selection and evaluation of new species with UMSS and other agencies, ii) to share (and subsequently recuperate) investment costs with farmers where this was necessary, iii) to provide technical support and iv) in cleaning, storing and marketing the seed. Five regions are involved in seed production, Cochabamba and San Jan de Oro (alfalfa), Moromoro (oats and other cereals), Santa Cruz (tropical grasses) and Yacapani (tropical legumes). Seed conditioning, storage and quality assessment are centralized in Cochabamba which is cool (2550 masl) and has a dry climate (470 mm/annum). COTESU contributed $1.5 m to SEFO-SAM between 1975 and 1998. Since then it has been self-financing.
SEFO-SAM now produces seed of 38 forage varieties, and has sold more than 6,000 tons of seed, sufficient for some 250,000 ha of cultivated forages for milk and beef production. There are more than 1000 small producer families associated with the seed production and many of these are now shareholders in SEFO-SAM. An important element that has contributed to the success of the whole project is the high level of trust that SEFO-SAM has established in its dealings with farmers.
There have been large economic and social benefits to individual families and communities. Net income (except for labor costs) from seed production varies with zone and farm size. In the Andean zone farmers producing cereal seed obtain $100-150/ha and may produce seed on 3 to 4 ha. Those producing alfalfa seed obtain a net income of $600-800 from 1 ha of irrigated land. Tropical legume seed is produced largely by colonist farmers who previously had little or no cash income. Seed production of kudzu results in a net income of $800-1000/ha and of *Arachis pintoi* $5,000-8,000/ha. However, they usually only can grow up to 0.2 ha of *A. pintoi* because of the high amount of labor needed for harvesting this seed which is produced underground (G. Sauma, unpublished data). The benefit of this increased cash income is very evident among the families involved. Simple palm houses (pahuichis) have been replaced by brick houses and families have purchased household appliances and motor bikes.
SEFO-SAM has also involved itself in improving resources and community welfare in those areas where it is active through improvement of irrigation systems, roads, and construction of schools and sports areas. The

network it has established is proving to be a useful mechanism for the participatory development of other agricultural technologies.
Though SEFO-SAM remains a relatively small organization with a total of 14 support and professional personnel, it has been active in training and interaction with national and international organizations in evaluation of new forage varieties. Difficulties have been experienced during periods of national economic recession but these have been surpassed and SEFO-Sam is now investing its own funds to ensure stability. The needs of forage seed in Bolivia have been satisfied and expansion now depends on the ability to export seed. This new phase has been assisted by the high reputation SEFO-SAM has for producing high quality seed. Some 220 tons of seed has been exported to countries in South and Central America and Asia in the last 5 years.

2.2 Mucuna in Central America and West Africa

Mucuna is insofar a particularly interesting case as it is not a forage as such but rather an exemplary multipurpose legume that actually is playing a range of roles, particularly at the level of resource-poor smallholders. The genus *Mucuna* is of Southeast Asian origin and most of the species that are used for agricultural purposes are now considered to be *Mucuna pruriens* cv. group Utilis (Wulijarni-Soetjipto and Maligalig, 1997). Mucuna is an annual, fast growing and vigorous climber best adapted to the humid and wet-subhumid tropics. Besides its use as discussed in this section, it is also a medicinal plant (contains L-dopa), and the seed ("beans") can be used for human consumption (Osei-Bonsu et al., 1996).
Mucuna ("velvet bean") was very important in the southern USA during the first decades of this century, when it was used in maize and cotton rotations (intercropping) with two objectives: to improve soil fertility for the next crop and, after crop harvest, to provide forage to grazing livestock or to harvest the beans for livestock feed. The importance of the crop declined when mineral fertilizer prices fell and, simultaneously, its replacement by soybean, a higher value crop, began (Buckles, 1995).
From USA Mucuna was introduced to Central America where it is now widely used, by >10.000 hillside farmers in Atlantic Honduras, and several thousands in Guatemala and Southern Mexico, in the so-called "abonera" ("fertilized field") system: a relay cropping system with maize and mucuna in which the legume plays an important role in (i) soil fertility and soil structure improvement, (ii) soil protection against erosion, and (iii) weed control (Buckles et al., 1998).

The high adoption rate of the "abonera" system is, among others, due to the resulting increase of land-use intensity in comparison with the traditional bush-fallow system (50% LUI vs. 33%), and the subsequent higher profitability of maize cropping with respective benefits for resource-poor hillside smallholders. The use of mucuna as forage for livestock, however, is still unexplored in Central America (Buckles et al., 1998).
Mucuna in the humid tropics of Central America is an interesting, rather uncommon example of success of a legume that is only used for soil improvement. The speculation seems to be justified that mucuna may also play an important role as a forage once (i) this potential has been recognized, (ii) production system diversification becomes more attractive, and (iii) adapted livestock keeping technologies – which beside the annual mucuna should involve other high quality forages – can be offered to hitherto crop-only hillside farmers.
Mucuna became important also in West Africa, mainly in the humid (derived savanna) zone of the Republic of Benin. In contrast with Central America, where the technology dissemination process was a spontaneous from-farm-to-farm spreading, in West Africa it was mainly due to the promotion by Sasakawa Global 2000", an NGO (Vissoh et al., 1998). The main use of mucuna is as short-fallow crop for soil fertility restoration and weed control, mainly *Imperata cylindrica*. However, mucuna foliage and pods are also increasingly used as livestock forage. In northeastern Benin, mucuna is more than any other legume used as forage (Carsky et al., 1998). At present, there are >10.000 farmers in Benin who use mucuna on a total area of approx. 1000 ha (Elbasha et al., 1999). These figures, along with promising results from economic analyses (Vissoh et al., 1998), indicate the impact and potential of mucuna as a multipurpose legume for resource-poor smallholders.
Future opportunities to further utilise the potential of Mucuna include the collection and selection of germplasm with higher feed quality for ruminant and non-ruminant nutrition and to enhance medical utilisation.

2.3 Contribution of the forage peanut *(Arachis pintoi)* to increase income of livestock farmers through improved milk yield

The Andean piedmont of the Amazon basin in the Caquetá Department of Colombia (0^0 and 2^0 N latitude and 71^0 and 76^0 W longitude) with acid soils and high rainfall (3,200 mm/year) is an integral part of the American tropical rainforest. It covers 1.8 million hectares of Andean piedmont of which 1.4 million hectares is below 1000 masl and used for cattle production. Most of the land is held by smallholders with less than 50 ha of land who maintain their cattle for meat and milk and production (Ramirez and Sere, 1990). As a result of degradation of naturalized or sown Brachiaria pastures, milk yields of cows are low and income of livestock farmers is reduced (Michelsen, 1990).

Over the period 1987-98, CIAT's forage researchers collaborated with local institutions present in the region in selecting grasses and legumes adapted to acid soils and with the potential for reclaiming degraded pastures. The most successful legume was *Arachis pintoi* which grew well in association several *Brachiaria* species. This was not surprising given the high quality (Lascano and Thomas, 1988), compatibility with aggressive grasses (Grof, 1985) and persistence under grazing (Lascano, 1994) exhibited by *A. pintoi* in acid soils with moderate fertility under humid savanna conditions.

Limited on-farm evaluation of *Arachis* -based pastures had indicated that is was persistent under farmer's management. However, it was evident that livestock producers in the region were not adopting the *Arachis* technology mainly because of lack of promotion, little knowledge on benefits and high cost of the seed. Thus CIAT, in cooperation with other public (CORPOICA, U de la AMAZONIA) and private (NESTLÉ) institutions, initiated an on-farm Research and Development Program to demonstrate that milk production and income of farmers could be increased through reclamation of degraded pastures with *Arachis* in the piedmont region of Caquetá.

Results indicated that milk yield increased on the average by 0.5 liters/cow /day due to the introduction of *Arachis* in degraded pastures. Ex-ante economical results showed that with this level of milk yield increment, the *Arachis* technology had a higher profitability (21.8 %) for farmers when compared with the traditional grass alone technology (12.0 %). The analyses also showed that the investment would have a greater economic benefit on increasing the reproductive rate of cows than on increases in stocking rate or milk yield. This information, together with the reliable market for milk contributed to a desire by both participating and non-participating farmers in the project to consider investing on the *Arachis* technology for the reclamation of degraded pastures. Over 3000 ha of *Arachis* -based pastures had been established by 100 farmers by the end of the 4-year project, indicating that a process of adoption of a legume technology is under way. This positive sign of adoption of a robust forage legume technology has positive implications on income generation of livestock farmers and on natural resource management in livestock farms of the amazon region.

2.3 Impact of *Stylosanthes guianensis* in China

The expansion of the use of *Stylosanthes guianensis* in South China is an impressive study of legume adoption benefiting poor farmers. The success of *S. guianensis* in China was based initially on the Australian-selected cultivar cv. Graham and CIAT 184 cv Pucallpa (Peru) that has been renamed cv Reyan II Zhuhuacao in China. Introduced in 1982, by 1993 *S. guianensis* CIAT 184 was grown annually on 3000-5200 ha in Guangdong and Hainan provinces (Devendra and Sere 1993, Liu and Kerridge 1997), with an additional 24000 ha of *S. guianensis* cv. Graham. More recent figures are not available but based on average annual planting of 21500 ha between 1989 and 1993 and a conservative estimate of persistence of 3-4 years (Devendra and Sere 1993) it can be extrapolated that the area grown to *S. guianensis* is increasing by 15-20 % every 5 years. By 1993 figures in Guangdong province alone *S. guianensis* is said to be used by over 100,000 families for feeding to ducks, pigs and for production of leaf meal.

Of particular interest is the so far unique utilization of *S. guianensis* as leaf meal for incorporation in compound feeds for pig and poultry compound feeds. The legume is grown for forage meal production as a rotation crop in vegetable areas (to reduce disease incidence), on land of limited cropping potential or as intercrop in fruit orchards. This minimizes competition for valuable land for crop production and makes maximum use of the ample labor supply. As the major cost is in drying of the meal, smallfarmer involvement is usually associated with semi-government companies that manage the drying and sale of the product. Farm yields average 15 t/ha and the meal is sold for US $ 140/ton (Liu and Kerridge 1997). Because of this high return, growing *S. guianensis* for meal production has spread rapidly in Hainan and Guandong provinces. It is estimated that more than 6000 ha are grown annually. The use of *S. guianensis* for leaf meal has offered poor farmers not only a feed resource for non-ruminants but it is also an opportunity to raise income through the sale of the leaf meal.

The success of *S. guianensis* as leaf meal indicates the yet largely unexplored potential of agro-industrial use of forages, offering further means of increasing income and poverty alleviation of the rural poor.

2.4 Impact of forage legumes in Africa

Like for *Mucuna* (see above) in Central America there is considerable success of forage legumes in West Africa, with potential for extended adoption (Elbasha et al. 1999). And like in the case of *Mucuna* there is a considerable time lag between technology development and adoption by farmers. Alone for the fodder bank technology based on forage legumes Elbasha et al. (199) estimate that by 1997 there are 27.000 farmers growing 19.000 ha of forage legumes in 15 countries. Up to 1997 the internal rate of return of research costs was 38.5%, based on modest estimates of impact on meat-and-milk production (ex-post analysis) and on grain production (economic surplus model). Of concern is the considerable time lag of about 15 years between introduction of the technology and wide-scale adoption by farmers.
Elbasha et al. (1999) see a shift to greater importance of crop residues in the future to raise livestock production. Though this assessment is likely to be true, this not necessarily will imply a lower demand of forage species as postulated by these authors as forages play an important role particularly on marginal agricultural land not suitable for crop production (see comments in the introduction). Through fertility improvement and soil restoration in fallow systems forages could be the basis for sustainable crop production; moreover, if undersown into crops, they may have a positive effect on crop residue quality (REFERENCE: POWELL?). Therefore it is assumed that the potential adoption and impact of forages, in particular legumes may be much greater than anticipated by Elbasha et al (1999).

Other examples of adoption of forages include the adoption of *Tithonia diversifolia* for soil restoration in Western Kenya by about 4000 farmers (Mureithi et al 1998, Rao et al 1998)) and use Agroforestry systems based on *Sesbania, Tephrosia, Gliricidia* and *Cajanus cajan* by 100000 farmers In Southern Africa (**IZAC, Sanchez 1999** -CONFIRM). The potential benefits the smallholder dairy sector in Kenya for adopting *Calliandra calothyrsus* as a substitute for dairy meal amount to about USD 102 million per year (Franzel et al. 1998).

3. Some *Ex-Ante* examples

3.1 The potential impact of legumes in smallholder farms: *The case of Arachis pintoi* and *Cratylia argentea* in the hillsides of Costa Rica

In the seasonally sub-humid hillsides of the Central Pacific region of Costa Rica, milk is primarily produced by smallholders. It is estimated that 60% of farms in the region are small (i.e., <20 ha), 31% are medium size (20 to 100 ha), and 9% of farms are large [> 100 ha (Censo Agropecuario, 1987)]. Milk is produced in grazing systems using native pastures during the rainy season. However, during the 5-to-6 month dry season, milk production is drastically reduced due to a shortage of feed. Producers overcome this limitation by supplementing milking cows with hay, crop residues, and costly feed concentrates and by-products such as chicken manure (Holmann and Estrada, 1997). One of the objectives of CIAT is the development of new on-farm feeding alternatives based on improved grasses and legumes. To achieve this, new germplasm is tested and validated with the participation of producers in different benchmark sites for further evaluation and to estimate the potential impact of these new technologies and the possible constraints to adoption.
In collaboration with the Ministry of Agriculture and Livestock (MAG) of Costa Rica, the Escuela Centroamericano de Ganaderiá, the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) and the Univeristy of Costa Rica (UCR), CIAT introduced the legume *Arachis pintoi* in association with *Brachiaria* spp. grasses for wet season feeding and the shrub legume *Cratylia argentea* in combination with sugarcane for dry season feeding of milking cows on smallholder farms in the Central Pacific region of Costa Rica.
Tropical grasses during the rainy season have adequate amounts of energy but the protein content is usually low, especially in unfertilized pastures. Legumes, on the other hand, are tropical forages with a high protein content. Thus, providing a diet of tropical grasses in association with legumes lead to increases in milk yield. Milking cows receiving supplementation with concentrate feeds which grazed the grass-legume mix with *Arachis pintoi* produced 9% and 11.4% more milk than those cows which only grazed *B. decumbens* (Romero and Gonzalez,

1998). These results suggest that milking cows under grazing conditions showed a response in milk yield to legume supplementation above concentrate feeding.

During the dry season milk yield is significantly reduced due to lower quantity and quality of forage on offer. Producers overcome this constraint by feeding agro-industrial by-products. Among them, the cheapest feed source available in the dry hillsides of Costa Rica is chicken manure. However, its availability is limited and its cost in real terms is increasing. Thus, finding a forage alternative for dry season feeding which can be established on dual-purpose farms to substitute the use of chicken manure or feed concentrates has been relevant.

Table 1 shows average daily milk yield during a six-week trial on a smallholder farm to replace the use of chicken manure by supplementing *Cratylia argentea* with sugarcane (Lobo and Acuña, 1998). As observed, milk yield/cow was maintained in spite of the fact that chicken manure was totally eliminated. However, since feeding cost per cow was reduced as a result of the substitution, the benefit/cost ratio was increased from 1.57 to 2.14. Thus, the producer was better off because his cash flow was improved.

Table 1. Milk yield and benefit/cost ratio from purpose cows receiving sugarcane, *Cratylia argentea*, and diminishing amounts of chicken manure in Esparza, Costa Rica.

	Weeks 1 & 2	Weeks 3 & 4	Weeks 5 & 6
	(3 kg/cow chicken manure)	(1.5 kg/cow chicken manure)	(no chicken manure)
Milk yield/cow/day	3.48	3.35	3.41
Feed cost/cow/day	0.60	0.51	0.43
Milk income/cow/day	0.94	0.90	0.92
Benefit/cost ratio	1.57	1.76	2.14

Given the research results obtained from on-farm data presented above, an ex-ante analysis was performed to estimate the potential impact of these legume-based forage technologies using ase studies, involving farmers participating in the CIAT-led Tropileche Consortia convened by ILRI. Through utilisation of improved grasses (*Brachiaria* spp.), inclusion of *A. pintoi* for wet season grazing and *Cratylia argentea* for dry season supplementation the production cost per kg milk were reduced up to 30% and up to 36.5% of land currently allocated to livestock production was freed for alternative uses.

4. Future prospects with likely high impact and new approaches to improve impact of research

4.1 *Desmodium ovalifolium* - a persistent multi-purpose legume option for the humid tropics

The multi-purpose legume *Desmodium heterocarpon* (L.) DC. subsp. *ovalifolium* (Prain.) Ohashi (Ohashi, 1991) was introduced to South America in the mid 70's (Schmidt & Schultze-Kraft, 1997). During the 80's the legume was evaluated through the International Tropical Pastures Evaluation Network (RIEPT; its Spanish acronym) in South America for utilsation in pastures (Franco *et al.* 1990, 1992a, 1992b.) Although a commercial variety (cv. Itabela) was released in Brazil (CEPLAC-CEPEC, 1990), adoption has been low because reports from some experimental sites indicated low palatability to grazing cattle, due to high contents of anti-nutritional compounds (tannins) (Carulla, 1994; Lascano *et al.*, 1995). Nevertheless *D. ovalifolium*, which is well-adapted to the acid, low-fertility soils of the humid tropics (Grof, 1982), has been adopted by farmers mainly in oil palm plantation areas like in the southern parts of Zulia, Venezuela (10.000 ha) and the Magdalena Medio area in Colombia (1600 ha), not only as a cover crop but also as a forage legume in mixtures with grasses (Schultze-Kraft & Schmidt, 1998). In the tropical forest margin area of Caquetá, Amazon basin of Colombia, around 600 ha of pastures containing *D. ovalifolium* can be found, mostly managed by smallholders. Inadequate management strategies and sometimes intermediate to low palatability of the forage legume were identified as major constraints for a wider adoption. In a recent, BMZ-funded research co-operation between the University of Hohenheim and the International Center for Tropical Agriculture (CIAT) (Schmidt *et al.*, 1997), broadly adapted *D. ovalifolium* genotypes with higher nutritional value were identified.

As smallholders in the mentioned areas are increasingly diversifying their farming systems including tree-livestock integration and intensification around tree cropping (rubber, fruits) in former grazing land, they are especially expected to benefit to the full extent from a multi-purpose legume with characteristics like *D. ovalifolium*. The plant species has no major pests or disease problems in the humid tropics. Its great tolerance to shade (Wong, 1991), the non-climbing, aggressive and stoloniferous growth habit, the subsequent suppression of weeds (Bradshaw & Lanini, 1995), the ability to fix nitrogen (90 kg/ha/a; CIAT, 1981), and the formation of persistent mixtures with aggressive grasses (e.g. *Brachiaria* spp.) makes the legume an attractive, labour and input reducing option for resource poor farmers in mixed smallholder farming systems. Since only small quantities of seed are required (700 g/ha pasture; 3 kg/ha under tree crops) with seed prices ranging from 12-15 US$/kg, establishment costs in plantations and pastures are low. Furthermore, the legume enables smallholders to increase their market-derived income through improved crop production with reduced inputs, enhanced livestock production due to complementary cover-crop grazing opportunities, and additional income from seed production. Around Pto. Wilches, Santander, Colombia, each year a total of 10 t of seed are harvested by smallholders, which are then sold to plantations or for pasture purposes suggesting a wider utilisation of *D. ovalifolium* in Colombia and Venezuela (Henry Mateus, CORPOICA-Barrancabermeja, pers. com, 1998).

4.2 Forages and the rural poor in Southeast Asia

Approximately 70% of the workforce in Southeast Asia is involved in smallholder agriculture – the sector which also has the greatest problems with chronic poverty. Livestock are an integral part of most upland farming systems in Southeast Asia and are often used by farmers as a ‘stepping stone’ out of this process of increasing poverty, being a means to obtain cash depending on markets opportunities, utilise feed resources which cannot be utilised for any other purpose and offering manure and draft power for crop production.

Traditionally, farmers have used freely available local feed resources for their livestock, such as residues from crop fields and communal grasslands, forests and roadsides. With increasing human and animal populations, the communal resources are becoming scarcer, and, degraded by over-use. This is stimulating an increasing demand for planted forages in upland areas to sustain livestock production.

Research and development on forages for smallholder farmers has been active in Southeast Asia for at least 40 years. The conventional approach to developing forage technologies in the past was prescriptive. Research services provided technology packages to an extension service, which then delivered them to ‘model’ farmers with an expectation that the technology would spread to other farmers. Most of this process was controlled or driven by researchers with little or no input from farmers. Model farmers often received preferential treatment by way of incentives and frequently accepted forage technologies because of the associated incentive. There has been little substantial adoption from this approach.

The Forages for Smallholders Project (FSP; an AusAID funded project) is using a participatory approach to developing forage technologies with smallholder farmers that has been synthesised from similar approaches developed by other organisations, in particular CIAT. The approach takes advantage of local knowledge and the interest of farmers to experiment and solve their own livestock feeding problems. It uses many of the principles of Participatory Rural Appraisal, but extends the active participation of farmers well beyond the initial stage of appraisal to forage technology development and evaluation on farms (see Figure 2). The approach begins with in-depth participatory diagnosis by both men and women in the farming community. A problem tree analysis helps them to define, group and prioritise their main problems. Possible solutions to these problems are then discussed and plans made about how to test and evaluate the alternatives. The evaluation process is monitored and assessed and necessary changes made to any technology that is being developed or adapted. The core principle of the process is active, decision-making involvement of farmers at all stages of forage technology development with technical input and facilitation by government staff. It encourages innovation and adaptation of the technologies originally offered.

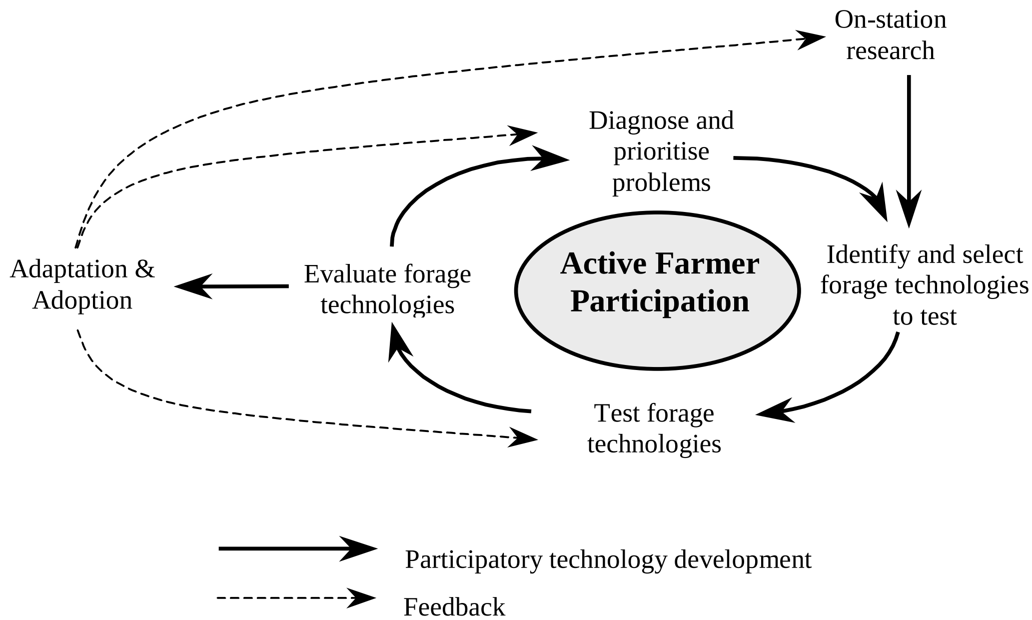

Figure 2: The participatory approach to forage technology development

The advantages of this approach are becoming apparent from on-farm work at more than 20 upland sites in 5 countries throughout Southeast Asia, with a small suite of robust, broadly adapted forage species (Stür et al, 1998). The main benefit that is emerging is more-rapid experimentation, adaptation and adoption. An example comes from two years on-farm work at 2 sites in northern Laos (Table 1). The number of farmers experimenting with forages doubled each year. After the first year 41 farmers (49% of the total) stopped experimenting with forages but after the second year only 19% stopped planting forages, mainly because after the second year, almost 60% of the new farmers planting forages were farmers who asked to join the process after seeing their neighbours' plots.

Table 2. Number of farmers experimenting with forage technologies in two provinces in northern Laos

Year/site	Xiengkhouang	Luangphabang	TOTAL
1997	17	66	83
1998	88	81	169
1999	223	172	395

These farmers are still only experimenting with forages in small plots, but experience from other more-advanced sites has shown us that once farmers are familiar with the species and the benefits they can provide (which generally takes two years), expansion from experimental plots to significant areas can be rapid. At one site in East Kalimantan, Indonesia, an initial group of 5 farmers moved from evaluating many forages in small plots to expanding the areas of 2-3 of these on their own farms (up to 1 hectare) and then to 120 other farmers in their village, all within 4 years. There is now an equal number of farmers outside the project area planting forages from farmer-to-farmer exchanges. The challenge now is to develop and implement methods for scaling-up the level of impact, within a participatory framework.

Conclusions and Outlook

In the opinion of the authors, in view of limited capital resources for smallholders, the intensification of mixed farming systems production need to focus on higher productivity of land and labor. That is supported by a study of Fujisaka and White (1998) of the forest margins margins that decreasing farm size is linked to intensification and diversification. We believe that for the resource poor farmers sustainable intensification of both crop and livestock production, will largely depend on the use of improved forages. This is especially true considering and charging the true environmental costs of purchased inputs – if they are available for the small farmer. To alleviate poverty, there need to be a focus on value-added products to raise farm income. Research – and development need to emphasize market opportunities and the implied potential impact to alleviate poverty and enhance food security. A strategy not recognizing this will have to be to the detriment of small farmers with the resulting social and political problems. Forages are a particularly versatile resources to achieve such an intensification in an environmentally sustainable manner.

The true potential of forages has by far not been exploited. There is continued need for search for appropriate germplasm, in particular adapted to the demands of farmers, as shown in the case studies for *Mucuna*, *Desmodium* and *Arachis.* To enhance the development and adoption of appropiate germplasm, novel techniques involving more strongly the ultimate client, the smallholder farmer need to be employed; strategies for seed production involving farmers are key for the adoption of forages. The case studies of SEFO in Bolivia and the FSP in South-East Asia strongly support the success of such participatory approaches. It will also be important that institutions at different levels – local, national and international – will work closely together (with farmers) to maximize efficiency of scarce resources (Schmidt, Schultze-Kraft and Peters, unpublished).

Largely untapped is the potential of forages for agro-industrial uses, the use of *Stylosanthes* leaf meal in China and the potential of Mucuna for medicinal uses only being examples. Such uses offer tremendous opportunities to raise the income and thus alleviating poverty for smallholders. Further research in this direction is uregently needed.

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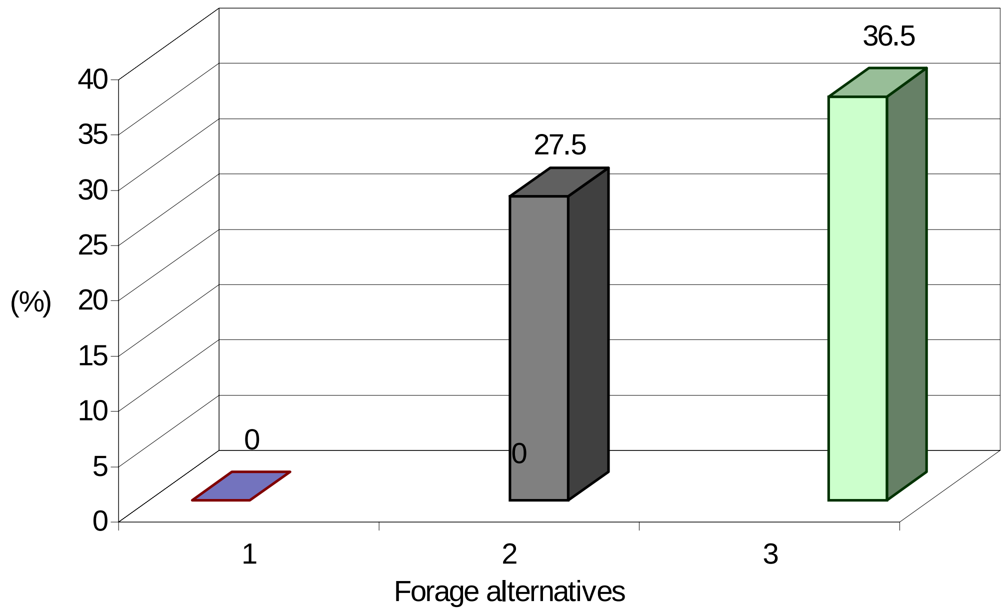

Figure 1. Percentage of pasture area that could be allocated to other uses as a result of adopting improved forage options, assuming constant herd size, Costa Rica. (1 = Cratylia argentea + sugarcane; 2 + Brachiaria spp. + C. argentea + sugarcane; 3 = Brachiaria spp. + Arachis pintoi + C.argentea + sugarcane)