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THE ROLE OF FORAGES IN REDUCING POVERTY AND DEGRADATION OF NATURAL RESOURCES IN TROPICAL PRODUCTION SYSTEMS

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Abstract

The paper reviews the role of forage crops in improving the productivity of smallholder farming systems and breaking the cycle of poverty and resource degradation. It reviews the contributions of forage crops to increasing farm incomes, intensifying farm production, and contributing to better human nutrition. Several case studies are presented, including mucuna *in Central America and West Africa, the forage peanut in Colombia, a forage legume in China, forage crops in Costa Rica and the production of forage crop seed in Bolivia. The paper also describes a strategy for farmer participatory research for identifying suitable forage crops in Southeast Asia.*

Research findings

- *Improved forages in pastures help increase land use efficiency.*
- *High-yielding cut-and-carry systems enhance year-round animal productivity and reduce labour requirements.*
- *Leguminous forages used as cover crops can reduce weeding costs and lower the need for chemical fertiliser.*
- *The introduction of improved legumes and grasses can help reclaim severely degraded lands.*

Policy implications

- *Research needs to emphasise market opportunities for rural poverty reduction, and livestock production can play an important role.*
- *Forages are a versatile resource and more research is needed to identify appropriate species for different farming systems.*
- *Participatory approaches are essential for developing forage crop options for smallholders.*

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Acronyms

CIAT	Centro Internacional de Agricultura Tropical (CIAT)
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza
CORPOICA	Corporación Colombiana de Investigación Agropecuaria
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
LUI	Land-use intensity
MAG	Ministry of Agriculture and Livestock
NRM	Natural Resource Management
UCR	University of Costa Rica

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1 INTRODUCTION

The objective of agricultural research and development is to 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 environmental 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 and Reiche, 1998; Kaimowitz, 1997; Vosti and Reardon, 1997). Land and water degradation decreases crop yields and increases 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 prerequisite for poor farmers making decisions beyond immediate survival and investing in the sustainable use of natural resources. Intensification of production with a natural resource management (NRM) focus is likely to be the only way to reverse degradation, alleviate poverty and improve food and income security of resource-poor farmers.

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 crops, trees and livestock can produce synergistic effects and minimise external inputs (McIntire et al,; 1992; Humphreys, 1994; Thomas et al., 1995; Schultze-Kraft and Peters, 1997). The versatility of forages allows them to be used in different ways 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, 1994). Most forages, in particular legumes, 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 such as fertilisers 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 nitrogen 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 favour maximising returns from labour and land rather than clearing new land for agriculture (Schultze-Kraft and Peters, 1997; Cees De Haan et al., 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, 1997; Delgado et al., 1999; Cees De Haan et al., ND).

Effect of improved forages on livestock production in enhancing income, equity and 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 an important source of income for the poor in developing countries. Animal production may produce higher returns than crop production. 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 access even from remote areas and deferment of sale depending on need for cash and market opportunity. Flexibility of transport and marketing is increased through processing of livestock products. 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 disasters; the effects of hurricane 'Mitch' caused almost complete loss of crops, whereas livestock losses and losses of income derived from livestock were comparatively low. Livestock activities can have a positive effect by making the distribution of household income between men and women more equitable. 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 the history of agriculture. How it will be handled will have implications 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. Because of the need for intensification, we focus this paper on the mixed farming systems used by smallholders in the tropics and subtropics. In evaluating different paths to intensification it is necessary that the true environmental costs of purchased feed (often transported over continents), fertiliser and use of pesticides are appropriately charged and scarcity of resources are reflected in cost-benefit analyses. Policies favouring mining of natural resources are likely to have an adverse effect on the intensification of livestock production in developing countries, which in turn could lead to reduced benefits for the poor (Delgado et al., 1999). Improved forages can make a significant contribution to conserving natural resources. If these considerations are taken into account, the impact and adoption of forage technologies is likely to increase greatly in the future.

The unattained potential of forages

Despite the tremendous potential of forages, in particular legumes, the adoption of improved forage technologies, especially those based on forage legumes, has been slow (Thomas and Sumberg, 1995; t'Mannetje, 1997, Schultze-Kraft and Peters, 1997; Elbasha et al., 1999). Together with unfavourable 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 ways to improve adoption of forages into smallholder mixed farming systems. Because of their potential as a basis of sustainable systems we emphasise opportunities and challenges of forage legume options. We present some successful case studies and aim to draw lessons from these, trying to identify potential pathways for more sustainable systems based on forage technologies. The emphasis is less on delivering ready made technology packages than pointing towards general directions of research and development which need to be adapted to particular social, economic and environmental conditions.

2 SOME EXAMPLES OF FORAGE ADOPTION IN IMPROVING PRODUCTIVITY AND FARMER WELFARE

Mucuna in Central America and West Africa

Mucuna is a particularly interesting case insofar as it is not forage as such but rather an exemplary multipurpose legume that actually plays a range of roles, particularly at the level of resource-poor smallholders. The genus *Mucuna* is of south-east Asian origin and most of the species 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. Beside 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). However, for utilisation on a larger scale, studies on the variations in L-dopa content as a result of genetic diversity and environmental effects are necessary. While for medicinal purposes a high content is desirable, for general human – and animal – consumption L-dopa is an undesirable component due to its toxic effects.

Mucuna ('velvet bean') was very important in the southern USA during the first decades of the twentieth 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 supply livestock feed by harvesting the beans. The importance of the crop declined when mineral fertiliser prices fell and it was simultaneously replaced by soybean, a higher value crop (Buckles et al., 1998).

From the 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' ('fertilised 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 success of the legume lies in its capacity for self-regeneration. In turn, farmers have had to learn to keep it suppressed during the early stage of maize growth to minimise competition with the crop.

The high adoption rate of the 'abonera' system is due, among other factors, to the resulting increase of land-use intensity (LUI) 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 not fully explored in Central America

(Buckles et al., 1998). Nevertheless some farmers plant it with maize and then use it as animal feed together with the maize stover, in the dry season.

Mucuna in the humid tropics of Central America is an interesting, rather uncommon example of success of a legume that is mostly used for soil improvement. Speculation that mucuna may also play an important role as a forage seems to be justified once (i) this potential has been recognised in the region, (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 was disseminated spontaneously from farm to farm, in West Africa it was mainly due to the promotion by 'Sasakawa Global 2000', a non-governmental organisation (Vissoh et al., 1998). The main use of mucuna is as a 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 approximately 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 utilise the potential of mucuna further include the collection and selection of germplasm with higher feed quality for ruminant and non-ruminant nutrition and enhancing medicinal utilisation.

Contribution of the forage peanut (*Arachis pintoi*) to increase income of livestock farmers through improved milk yield in Caquetá, Colombia

The Andean piedmont of the Amazon basin in the Caquetá Department of Colombia (between 0^0 and 2^0 N latitude and 71^0 and 76^0 W longitude) with acid soils and high rainfall (3200 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 metres above sea level 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 production (Ramirez and Sere, 1990). As a result of degradation of naturalised or sown *Brachiaria* pastures, milk yields are low and the income of livestock farmers is reduced (Michelsen, 1990).

Over the period 1987–98, forage researchers from the Centro Internacional de Agricultura Tropical (CIAT) collaborated with local institutions present in the region to select 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 with 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. *Arachis pintoi*, a close relative to the common peanut (*Arachis hypogea*), originating mainly from Brazil, is valued by farmers mainly as a herbaceous pasture and cover legume. Its high persistence is a combination of the ability to form rhizomes combined with underground seed production; though it can be propagated vegetatively, the main limitation of *Arachis* is the high cost of establishment due to its large seed size and – as is true for most pasture intensifications – higher management requirements in contrast to pure grass pastures.

Limited on-farm evaluation of *Arachis*-based pastures had indicated that it was persistent under farmers' 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 of its benefits and the high cost of the seed. Thus CIAT, in cooperation with other public (Corporación Colombiana de Investigación Agropecuaria – CORPOICA, U de la Amazonia) and private (Nestlé) institutions, initiated an on-farm research and development programme to demonstrate that milk production and the 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 average by 0.5 litres/cow /day due to the introduction of *Arachis* in degraded pastures. Ex-ante economic analysis showed that at this level of milk yield increment, the *Arachis* technology gave a higher profit margin (21.8 %) than traditional grass-only technology (12.0 %) (Rivas and Holmann, 2000). The analysis also showed that the returns were greater in terms of increasing the reproductive rate of cows than in terms of boosting stocking rate or milk yield. This information, together with the reliable market for milk contributed to a desire by farmers, whether participating in the project or not, to consider investing in 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 four-year project, indicating that a process of adopting a legume technology is under way. This positive sign of adoption of a robust forage legume technology has positive implications for income generation of livestock farmers and for natural resource management in livestock farms of the Amazon region. Further adoption of *Arachis* in the Amazon and other regions of Latin America is likely to be closely related to current intensification processes.

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. *Stylosanthes guianensis* is a perennial herbaceous forage legume of South American origin, of medium to good forage quality. Its main limitation is its lack of persistence under grazing or frequent cutting and the susceptibility of many accessions to anthracnose. The success of *S. guianensis* in China was based initially on the Australian-selected cultivar cv. Graham and CIAT 184 cv. Pucallpa (Peru) which 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 24,000 ha of *S. guianensis* cv. Graham. More recent figures are not available but, based on average annual planting of 21,500 ha between 1989 and 1993 and a conservative estimate of persistence of three to four years (Devendra and Sere, 1993), it can be extrapolated that the area grown to *S. guianensis* is increasing by 15–20% every five 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. In these systems *Stylosanthes guianensis* is largely used as a cut and carry feed.

Of particular interest is the so far unique utilisation of *S. guianensis* as leaf meal for incorporation in 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 an intercrop in fruit orchards. This minimises competition for valuable land for crop production and makes maximum use of the ample labour supply. As the major cost lies in drying the meal, small farmer involvement is usually associated with semi-government companies which 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 also an opportunity to raise income by selling the meal.

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

The case of *Arachis pintoi* and *Cratylia argentea* in the hillsides of Costa Rica

In the seasonally dry 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% medium (20 to 100 ha), and 9% large (> 100 ha (Censo Agropecuario, 1984)). Milk is produced in grazing systems using native pastures during the rainy season. However, during the five- to six-month dry season, milk production is drastically reduced due to a shortage of feed. Producers overcome this limitation by giving supplements to milking cows of hay, crop residues, costly feed concentrates and by-products such as chicken manure (Holmann and Estrada, 1997). One of the objectives is the development of new on-farm feeding alternatives based on improved grasses and legumes. New varieties are tested and validated with the participation of producers in different benchmark sites to estimate the potential impact and the possible constraints to adoption.

In collaboration with the Ministry of Agriculture and Livestock (MAG) of Costa Rica, the Escuela Centroamericano de Ganadería, the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) and the University of Costa Rica (UCR), CIAT (in partnership with the Tropileche Consortia convened by the International Livestock Research Institute (ILRI)) 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 unfertilised 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 leads 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 showed that cows under grazing conditions gave a response in milk yield to legume supplementation above concentrate feeding alone.

During the dry season milk yield is significantly reduced due to the lower quantity and quality of forage on offer. Producers overcome this constraint by feeding agro-industrial by-products. The cheapest of these 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 for chicken manure or feed concentrates is quite relevant.

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

	Weeks 1 & 2 (3 kg/cow chicken manure)	**Weeks 3 & 4** (1.5 kg/cow chicken manure)	**Weeks 5 & 6** (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

Table 1 shows average daily milk yield during a six-week trial on a smallholder farm where chicken manure was replaced by supplementing *Cratylia argentea* with sugarcane (Lobo and Acuña, 1998). *Cratylia* was given ad libitum. (Data from another trial suggest that cattle consume about 2.9 to 3% of their body weight of fresh *Cratylia* in these circumstances (Holmann, personal communication)). As observed, milk yield per cow was maintained despite the fact that chicken manure was totally eliminated. However, since the 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.

An ex-ante analysis was performed to estimate the potential impact of these legume-based forage technologies. Through utilisation of improved grasses (*Brachiaria* spp.), inclusion of *A. pintoi* for wet-season grazing and *Cratylia argentea* for dry-season supplementation the production costs per kg milk were reduced by 30% and it was estimated that 37% of land currently allocated to livestock production could be freed for alternative uses (Holmann, 2000). An alternative use is to reforest the steeper slopes with commercial timber trees.

Other opportunities

Opportunities for forage legumes in West Africa

As with mucuna in Central America (see above), forage legumes have had considerable success in West Africa, with potential for extended adoption (Elbasha et al., 1999). Again as in the case of mucuna there is a considerable time lag between technology development and adoption by farmers. For the fodder bank technology based on forage legumes Elbasha et al. (1999) estimated that by 1997 there were 27,000 farmers growing 19,000 ha of forage legumes in 15 countries. The considerable time lag of about 15 years between introduction of the technology and wide-scale adoption by farmers is a matter for concern.

Elbasha et al. (1999) foresee a shift to greater importance of crop residues to increase livestock production. Although this assessment is likely to be true, it will not necessarily imply a lower demand for 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) and could be the basis for sustainable crop production through their role in soil fertility improvement and nutrient cycling. Moreover, if under-sown into crops, they may have a positive effect on crop residue quality. 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), especially if species even better adapted to the productions systems and demand of farmers are developed. Currently, the International Institute of Tropical Agriculture (IITA) and ILRI are developing participatory approaches for legume development and targeting options to particular niches (N. de Haan, personal comment).

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

The multi-purpose legume *Desmodium heterocarpon* (L.) DC. subsp. *ovalifolium* (Prain.) Ohashi was introduced to South America in the mid '70s. Although a commercial variety (cv. Itabela) was released in Brazil, adoption has been low because its high tannin content makes it quite unpalatable to grazing cattle (Lascano et al., 1995). Nevertheless *D. ovalifolium*, which is well-adapted to the acid, low-fertility soils of the humid tropics, has been adopted by farmers in oil palm plantation areas such as the southern parts of Zulia, Venezuela (10,000 ha) and the Magdalena Medio area of Colombia (1600 ha), not only as a cover crop but also as a forage legume in mixtures with grasses. In the tropical forest margin area of Caquetá, in the 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 to wider adoption. A recent research project funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) and carried out by the University of Hohenheim and CIAT (Schmidt et al., 1999) identified broadly adapted *D. ovalifolium* genotypes with higher nutritional value.

As smallholders in the areas mentioned are increasingly diversifying their farming systems (including tree-livestock integration and the introduction of new tree crops such as rubber and fruits on former grazing land), they could benefit from the improved material. The species has no major pest or disease problems in the humid tropics. Its great tolerance of shade, non-climbing, aggressive and stoloniferous growth habit, subsequent suppression of weeds, ability to fix nitrogen (90 kg/ha/annum), and 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 US$12–15 per kg, establishment costs in plantations and pastures are low. Additional income from seed production, as found around Pto. Wilches, Santander, Colombia, where each year a total of 10 tons of seed are harvested by smallholders for sale to plantations or for pasture purposes, suggests an increasing utilisation of *D. ovalifolium* in Colombia and Venezuela (Henry Mateus, CORPOICA-Barrancabermeja, personal communication, 1998). Currently CIAT is selecting specific accessions of *D. ovalifolium* to be used as cover crops in plantations. Testing is done on commercial plantations and further development with farmers and diffusion are underway.

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 at a reasonable price (Ferguson and Sauma, 1993). Small farmers 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 up in the country for crops; however, the challenge was much greater in the area of forages because of the many agro-ecosystems and variable demand for forage seed. The objectives of SEFO-SAM were to provide i) a national system for production of seed, ii) a wide range of forages adapted to all the agro-ecosystems, iii) high-quality seed of international standard at stable prices, and iv) to 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 recoup) investment costs with farmers where this was necessary, iii) to provide technical support and iv) to clean, store and market the seed. Five regions are involved in seed production: Cochabamba and San Juan de Oro (alfalfa), Moromoro (oats and other cereals), Santa Cruz (tropical grasses) and Yacapani (tropical legumes). Seed conditioning, storage and quality assessment are centralised in Cochabamba which is cool (2550 metres above sea level) and has a dry climate (470 mm/annum). COTESU contributed $1.5m to SEFO-SAM between 1975 and 1988. 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 contributing 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 labour 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 three to four ha. Those producing alfalfa seed obtain a net income of $600–800 from one 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, the farmers can usually grow only up to 0.2 ha of *A. pintoi* because of the high labour requirement for harvesting this seed which is produced underground (G. Sauma, unpublished data).

The incentive for families to become involved in seed production is the immediate payment in cash which is used for medical expenses, to send children to the best schools, and purchase bicycles, motor bikes, and household appliances. In the case of cereals, farmers are paid three to four times the value of commercial grain. The benefit of increased cash income is also evident in families replacing simple palm houses (pahuichis) with brick houses; 90% of families now have brick houses. Women participate in all activities, in particular seed harvesting. It is difficult to make direct comparisons of seed production with traditional cropping, say of rice and maize. A family producing only kudzu can gain $1000/ha in cash whereas a family producing rice gains only $30/ha in cash but produces sufficient rice for its own consumption. Seed producers produce a higher cash income than milk producers who are unable to save money as do the seed producers.

In the areas where it is active SEFO-SAM has also become involved in the improvement of irrigation systems and roads and the construction of schools and sports facilities. A survey showed that 80% of families in seed-producing communities have increased their well being. The network SEFO-SAM has established is proving to be a useful mechanism for the participatory development of other agricultural technologies.

Although SEFO-SAM remains a relatively small organisation with a total of 14 support and professional personnel, it has been active in training and interaction with national and international organisations in evaluation of new forage varieties. Difficulties have been experienced during periods of national economic recession but these have been overcome and SEFO-SAM is now investing its own funds to ensure stability. The need for forage seed in Bolivia has been satisfied and expansion now depends on the ability to export seed. This new phase has been assisted by SEFO-SAM's reputation for producing high-quality seed, some 220 tons of which have been exported to countries in South and Central America and Asia in the last five years, either direct to farmers or to research and development institutions. Although long-term figures are not available, there is a trend towards the sale of tropical legumes as the main economic resource in the enterprise. The welfare of more families will be improved as SEFO-SAM increases international sales.

3 FUTURE PROSPECTS WITH LIKELY HIGH IMPACT AND NEW APPROACHES TO IMPROVE IMPACT OF RESEARCH

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 and are often used by these farmers as a stepping stone out of the cycle of increasing poverty. In particular, livestock

- are a vital source of livelihood security, providing a ready source of cash in times of greatest need (e.g. buying rice if natural disasters strike or to cover medical expenses)
- can be sold at any time on a market which has

constant demand and relatively stable prices

- mostly utilise feed resources which cannot be used for any other purpose and
- provide an essential source of manure and draught power to sustain crop production

Historically, farmers have used freely available local plant resources for feeding their livestock, in particular residues from crop fields and native forages in communal grasslands, forests and roadsides. With increasing human and animal populations, these 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 going on in Southeast Asia for at least 40 years. During this time, the approach to developing forage technologies was highly prescriptive, with research institutions providing technology packages to extension services, which then delivered them to ‘model’ farmers with an expectation that the technologies would spread naturally to other farmers. Most of this process was controlled or driven by researchers with little or no input from farmers. Consequently, the technologies were either targeted at commercial farming systems or had little relevance to the needs and opportunities of smallholders. 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.

To help overcome these problems, in 1995 the Forages for Smallholders Project (FSP; funded by the Australian Agency for International Development (AusAID) and managed by CIAT and the Commonwealth Scientific and Industrial Research Organisation (CSIRO)) introduced a participatory approach to developing forage technologies with smallholder farmers in upland areas of Southeast Asia (for details see Horne et al., 2000 and Stür et al., in press). The approach takes advantage of indigenous knowledge and the capacity 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 1). The approach begins with in-depth participatory diagnosis by a broad cross section of the farming community, including both men and women and farmers from the different wealth groups. This helps them to define, group and prioritise their main problems. Opportunities for solving 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.*

Before using this approach, the FSP first had to identify a small range of robust, broadly adapted forage varieties to offer farmers. Researchers introduced more than 500 potentially promising forage accessions and evaluated these in nurseries to eliminate those that were poorly adapted to acid, infertile soils, had disease or pest problems, had weed potential or were not easy to propagate. The varieties selected from these evaluations, along with varieties already identified by national research organisations, were evaluated in regional trials by researchers and in on-farm trials by farmers throughout Southeast Asia and southern China (Stür et al., 2000). From the technical evaluations and farmer feedback, a small range of robust, broadly adapted forage varieties was identified that could be offered farmers.

Figure 1 The participatory approach to forage technology development

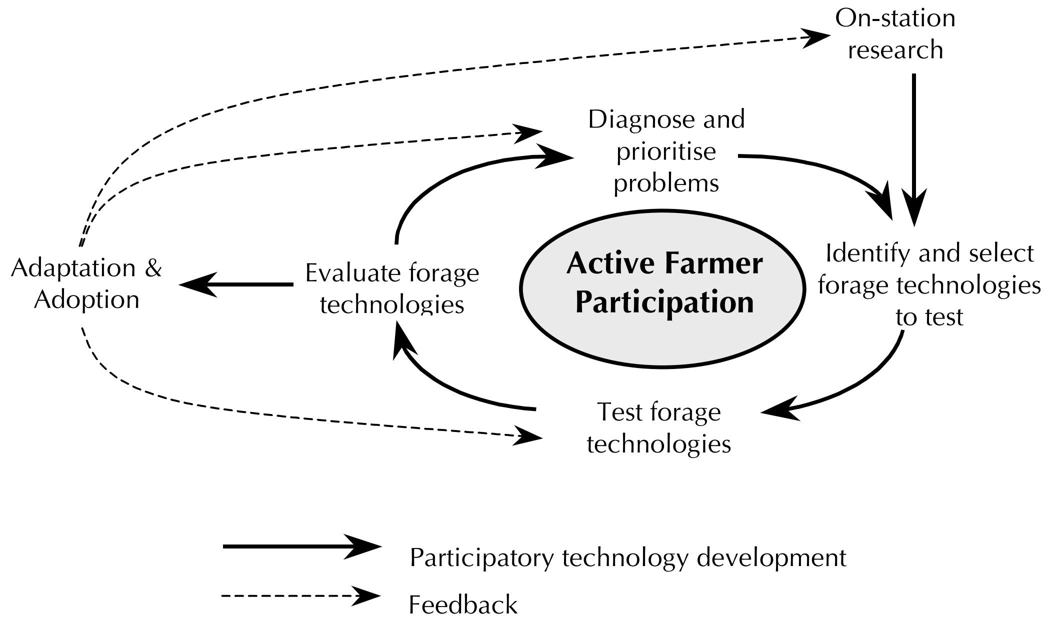

Table 2 Forage varieties offered to smallholder farmers in Southeast Asia[a]

		Climate			Soil fertility and acidity			Ways of growing forages							
Species	**Varieties**	**Wet tropics with no or short dry season**	**Wet/dry tropics with long dry season**	**Cooler tropics (e.g. high elevation)**	**Fertile (neutral to moderately acid soils)**	**Moderately fertile (neutral to moderately acid soils)**	**Infertile (extremely acid soils)**	**Cut & carry plots or rows**	**Grazed plots**	**Living fences**	**Contour hedgerows**	**Improved fallows**	**Cover crops in annual crops**	**Cover crops under trees**	**Ground covers for erosion control**
(a) Grasses															
Andropogon gayanus	'Gamba'	•	• •		•	•	•	• •	•		•				
Brachiaria brizantha	'Marandu', 'Karanga', 'Serengeti'	•	• •	• •	•	• •	•	• •	•		•				
Brachiaria decumbens	'Basilisk'		•	• •	• •	•	• •	•	•	• •					•
Brachiaria humidicola	'Tully', 'Yanero'	• •	•	•	•	•	• •	•	• •						• •
Brachiaria ruziziensis	'Ruzi'	• •		•	• •	•		•	• •						•
Panicum maximum	'Si Muang'	• •	•	•	• •	•		• •	•		•				
Paspalum atratum	'Terenos'	• •		•	•	• •	•	• •	• •		• •				
Pennisetum purpureum and Pennisetum hybrids	'Napier', 'Mott" King'	• •		•	• •	•		• •			•				
Setaria sphacelata	'lampung', 'Solander'	• •	•	• •	• •	•		• •	•		• •				
(b) Legumes															
Arachis pintoi	'Itacambira', 'Amarillo'	• •		•	• •	• •			•					• •	• •
Calliandra calothyrsus	'Besakih'	•		• •	•	• •		• •		•	•				
Centrosema macrocarpum	'Ucayali'	• •	•		• •	•		•				• •	• •	•	•
Centrosema pubescens	'Barinas'	• •	•	•	• •	•		•				• •	• •	•	•
Desmanthus virgatus	'Chaland'	• •		• •	• •	•		• •			•				
Desmodium cinerea	'las Delicias'	•	•		•	•		• •			• •				
Gliricidia sepium	'Retalhuleu', 'Belen Rivas'	• •	• •		•	• •		• •		• •	•				
Leucaena leucocephala	'K636', 'K584'	• •	• •	•	• •	•		• •	•	•	•				
Stylosanthes guianensis	'Stylo 184'	• •	• •	•	• •	• •	• •	• •	•		•	• •	• •	•	

[a] *Source*: adapted from Horne and Stür (1999).
• • = highy suitable, • = possible, no mark = not suitable.

These are summarised in Table 2 and further described in Horne and Stür (1999).

These forage varieties were offered to smallholder farmers, using the approach outlined in Figure 1, at 16 'upland' sites in five countries (Indonesia, Laos, Philippines, Thailand and Vietnam) (Table 3).

The main benefit to emerge from combining these promising forage varieties with a participatory approach to integrating them onto smallholder farms is more rapid experimentation, adaptation and adoption. An example comes from early on-farm work at the two shifting cultivation sites of the FSP. In the northern mountainous regions of Laos, which are typified by steep topography, unreliable rainfall, remoteness and very limited fertile land, the most fundamental causes of poverty perceived by farmers result from externalities which affect livestock and rice production. Rice shortages of five to six months a year are common and people rely heavily on livestock as a mechanism for coping with these shortages. Livestock disease is commonly ranked in the top three main causes of poverty (especially among the poorest people in the community who can only afford to keep small animals) and acquiring livestock is often the primary solution that farmers choose for solving poverty. The FSP started working with farmers in these areas in 1997. The number of farmers experimenting with forages doubled each year, despite a high dropout rate (49%) after the first year (Table 4). This was mainly because growing forages was a completely new concept for all farmers. They invariably chose to first plant intensively-managed plots for cut-and-carry feed near their houses, which did not provide high benefits in the first year. Almost 60% of the farmers planting forages for the first time in 1998 and 1999 asked to join the process after seeing their neighbours' plots. This level of farmer involvement and enthusiasm had not been previously experienced by the Lao researchers.

These farmers were only experimenting with forages in small plots (<500m^2), 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 at least two years), expansion from experimental plots to significant areas can be rapid. At three sites in East Kalimantan, Indonesia, the total area of introduced forages ranges from 1000–2000 m^2 (Table 5). These areas are still relatively small compared with livestock farmers in other parts of the world. Some farmers may continue to increase their areas, but most are unlikely to do so since they have limited land resources. The introduced forages are used as a supplement to naturally occurring feed resources, rather than to replace them. Most farmers used the introduced forages:

- as an emergency source of feed for days when labour for cutting feed or tending animals was in short supply (e.g. rainy days, planting and harvest time, times of sickness);
- for periods when feed was difficult to find (especially in the dry season);
- for sick or pregnant animals;
- as an additional feed at night (Stür et al., in press).

The participatory approach used to develop forages to this stage (Figure 1) is a participatory 'research' tool. In many cases successful implementation has depended on dedicated, dominant, charismatic individual development workers using good facilitation skills and close personal contact with farmers. When forage technology development on-farm moves beyond this research phase (evaluation and adaptation of technologies) into expansion, these methods are no longer adequate. Individual development workers can no longer cope with the numbers of farmers or their geographic spread. The challenge now is to develop and implement methods for expanding the level of impact, within a participatory framework. This is one major goal of a new AusAID-funded CIAT-managed project in Laos (the Forages and Livestock Systems Project).

4 CONCLUSIONS AND OUTLOOK

In the opinion of the authors, in view of limited capital resources for smallholders, the intensification of mixed farming systems production needs to focus on higher productivity of land and labour. This is supported by a study of Fujisaka and White (1998) of the forest margins, according to which decreasing farm size is linked to intensification and diversification. We believe that for resource-poor farmers sustainable intensification of both crop and livestock production will largely depend on the use of improved forages. This is especially true when the true environmental costs of purchased inputs are considered, that is, if they are even available to the small farmer. To alleviate poverty, there needs to be a focus on value-added products to raise farm income. Livestock and livestock products provide a source of cash income, without which poverty will not be alleviated. Research – and development – needs to emphasise market opportunities and the implied potential impact to alleviate poverty and enhance food

Table 3 Number of farmers evaluating forages in different farming systems in 1999[a]

Farming system	Number of sites	Total number of farmers
Shifting cultivation	2	395
Grasslands	3	250
Extensive upland	3	281
Moderately intensive upland	5	520
Intensive upland	3	332

[a] Adapted from Stür et al., (in press)

Table 4 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

security. Participatory approaches are mandatory to develop options addressing the needs of smallholder farmers and to enhance uptake of technology. The potential of forages for agro-industrial uses, e.g. the use of *Stylosanthes* leaf meal in China and the potential of mucuna for medicinal uses, is largely untapped. Such uses offer large opportunities to raise the income of smallholders. A strategy which does not recognise the need to develop market opportunities to increase cash income will be to the detriment of small farmers and will perpetuate social and political problems. Forages are a particularly versatile resource to achieve intensification in an environmentally sustainable manner.

The true potential of forages has not been exploited by far. There is a continued need to search for appropriate germplasm particularly adapted to the demands of farmers, as shown in the case studies for *Mucuna*, *Desmodium* and *Arachis*. There is an even greater need to adopt novel techniques for evaluation, adaptation and dissemination, which involve the ultimate client, the smallholder farmer. Strategies for multiplication and seed production involving farmers are also a key to the wider adoption of forages. The successes demonstrated in the case studies of SEFO in Bolivia and the FSP in South-east Asia strongly support the use of participatory approaches. It is also important that institutions at different levels – local, national and international – work closely together (with farmers) to maximise the efficiency of scarce resources (Schmidt, Schultze-Kraft and Peters, unpublished).

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Table 5 Adoption of forage technologies at three FSP sites in Indonesia in 1999

	Kuala Kapuas, Central Kalimantan (n = 240)[a]	Sepaku, East Kalimantan (n = 84)	Makroman, East Kalimantan (n=51)
Predominant farming system	Extensive upland	Grassland	Moderately intensive upland
Introduced forage area planted			
- mean area per farmer (m2)	1650	2000	1000
- percentage of total area grown			
grasses (%)	100	94	75
tree legumes (%)	0	1	15
herbaceous legumes (%)	0	5	10
Total number of forage varieties grown by farmers[b]	9	18	16
Forage varieties most frequently grown by farmers (Rank 1-3, based on area)			
- Brachiaria brizantha 'Marandu'	-	-	3
- Brachiaria decumbens 'Basilisk'	-	2	-
- Brachiaria humidicola 'Tully'	1	3	-
- Brachiaria humidicola 'Yanero'	2	-	-
- Paspalum atratum 'Terenos'	-	-	1
- Paspalum guenoarum 'Bela Vista'	-	-	-
- Pennisetum purpureum 'Napier'	3	-	-
- Pennisetum hybrid 'King'	-	1	-
- Setaria sphacelata 'Lampung'	-	-	2

[a] Survey sample size
[b] Varieties are included in count if area is at least 100m^2
Source: (adapted from Stür et al., in press)

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