PERSPECTIVES OF GRASS-LEGUME PASTURES FOR SUSTAINABLE ANIMAL PRODUCTION IN THE TROPICS

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Global trends in beef and milk production and consumption

Food products of animal origin have played a key role as source of dietary protein for human consumption throughout the world since the beginning of history. The population of the developed countries currently consume about 3 to 4 times as much meat and 5 to 6 times as much milk products per capita as in developing countries of Asia and Africa. However, an ongoing revolution in global agriculture is causing profound impacts on human health, livelihoods, and the environment. Population growth, urbanization, and income growth in developing countries are fueling a massive increase in demand for food of animal origin. While per capita meat consumption experienced only a 5.4% growth in the developed countries between 1983 and 1993, it increased by 40% in the developing countries during the same period (Delgado et al., 1998).

Emerging trends and global food projections for the year 2020 indicate that, given current policies: a) price of beef and milk will decrease by 4% and 9%, respectively; b) worldwide demand for meat is expected to rise by 11.7% in the developed world and by 91.3% in the developing world, with China alone accounting for more than 40% of this increase; c) demand for milk will rise 9.7% in the developed world and by 84.3% in the developing world; d) developing countries will increase beef production by 87.1% and developed countries by 13.7%; e) milk production will increase by 85.6% in developing countries and by 12.9% in the developed countries (Rosegrant et al., 2001).

Global food projections also show that by the year 2020, meat consumption in developing countries will outgrow production by 12 million metric tons, while the developed countries will have a net production of 11 million tons for export (Delgado et al., 1998).

Traditionally, livestock has been one of the most important activities in farming systems in the tropics and subtropics and one of the main sources of income and protein for the poor in developing countries (Humphreys, 1997; Peters et al., 2001). A study conducted in Honduras showed that livestock was the single most important factor in differentiating between poverty levels. Livestock provide a stable cash reserve independent of inflation and are an important source of traction (Escolán et al., 1998) and a means of transportation.

According Delgado et al. (1999) a Livestock Revolution is taking place and it will result in one of the largest structural shifts in the history of agriculture. By the year 2020 developing countries will consume 100 million metric tons more meat and 223 million metric tons more milk than in 1993. The way this revolution is handled will have implications for food security, welfare of the rural and urban poor and environmental sustainability.

Around 40% of the global land surface, excluding Greenland and the Antarctic, is covered with pastures (Sbrissia & Silva, 2001). In tropical countries beef and dairy cattle production systems are based mostly on pasture production as the main source of animal feed. In countries such as New Zealand over 90% of the nutrients required by ruminants are

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obtained directly through grazing (Hodgson, 1990), a situation similar to that of Brazil, and particularly the Legal Brazilian Amazon (Andrade, 2004).

Among the tropical countries, the favorable environmental conditions have led to a strong growth of beef and dairy cattle production systems in most of the Brazilian territory. Between 1990 and 2002 the Brazilian cattle herd grew 26%, from 147,1 million to 185,4 million heads. During the same period the cattle herd in the Legal Brazilian Amazon rose 118,6%, from 26,3 million to 57,4 million heads (IBGE, 2003). Keeping the emerging trends in the last five years and the same technology level in the production systems, it is projected that the deforested areas in the Legal Brazilian Amazon will rise from 12.4% in 2003 to 21.5% of the total area of the region in 2020. The cattle herd will rise from 57 million heads in 2002 to 175 million heads (60% of the Brazilian cattle herd) in 2020, occupying an area of 146 million hectares of pastures (Valentim & Gomes, 2003).

In the last decade a joint effort between the Brazilian Government and the private sector has resulted that, as of 2003, 85% of the country's cattle herd was in areas that had been certified as free of Foot and Mouth Disease (FMD) with vaccination. This, together with recent problems outside Brazil with Mad Cow Disease (BSE) and strong changes in exchange rates leading to the devaluation of the national currency, the real, against the dollar, resulted in strong incentives for the country's meat exports. Since 1995 beef exports rose from $500 million dollars to $1.5 billion dollars in 2003. The volume of exports increased from 232 thousand tons in 1997 to over 1.3 million metric tons of carcass weight, ranking Brazil as the world's largest beef exporter in 2003 (CNA, 2004; Kaimowitz at al., 2004).

The increasing share of Brazilian beef and dairy products in the world market is giving rise to concerns in the national and international community regarding the potential negative impacts of increased deforestation for the expansion of cattle productions systems in the Legal Brazilian Amazon. The international environmental concerns may be genuine, but they can also represent a strategy to create new forms of barriers with the intent of restricting the continuing growth of the Brazilian cattle herd and also the increasing share of Brazilian beef and dairy products in the world market.

There is an urgent need for farmers and researchers in the tropics to focus on development of cattle production systems with higher productivity of land and labor in the areas already deforested, as a strategy to reconcile sustainable economic growth, improvement of income and welfare of the population, and environmental conservation. The establishment and maintenance of persistent grass-legume pastures is one of the options to increase productivity, profitability and also to ensure long-term sustainability of cattle production systems in the tropics.

Potential of legumes for increasing profitability and promoting sustainability of cattle production systems in the tropics

Farmers in tropical countries are under increasing pressure to stop expansion of livestock activities into new areas of native ecosystems, especially tropical forests, and to improve land use efficiency in the areas already under production. Opportunities for intensification of cattle production systems in the tropics, especially for smallholders, are limited because of the inability of farmers to pay for external inputs.

Nitrogen is considered the most limiting nutrient in many agricultural ecosystems (Wedin, 1996; Humphreys, 1997). The main reason for this is that, even though the nitrogen (N) pool is the largest, it is available to plants only through highly endergonic biological processes mediated by free-living or plant-associated bacteria that require between 25 to 30 moles of ATP per mole of N_2 fixed (Marschner, 1995).

The integration of legumes (herbaceous and trees species) can produce synergistic effects and minimize external inputs, particularly nitrogen fertilizers, in agricultural ecosystems (Thomas et al., 1995; Peters et al., 2001). Recent studies in Brazil reported annual biological nitrogen fixation ranging from 88 to 180 kg/ha by three cultivars of *Stylosanthes* spp. (Miranda et al., 1999) and from 26 to 99 kg/ha by seven accessions of *Arachis* spp. (Miranda, 2002).

Of equal importance is the significance of legumes in mitigating global warming as a result of increased net primary productivity (NPP), improved diet quality and reduction of methane emissions from cattle. Biological N fixation may be regarded as one engine of increased NPP directed to increasing carbon sequestration. Legumes also are important in the maintenance of the nutritive value of forage, both where they are ingested directly or where they contribute N to minimize the expected reduction in leaf:stem ratio and the protein dilution in the associated grasses as CO_2 level increases. Individual animal production benefits by reducing methane emissions and increasing the ratio of product:methane emission (Humphreys, 1997).

Forage legumes are multipurpose plants and, therefore, can increase resource and land use efficiency in cattle production systems by: 1) increasing forage yield and quality, particularly during the dry season; 2) improving weed suppression, pest and disease reduction as a result of increased ground cover and ecosystem diversification; 3) adding N to the system through symbiotic nitrogen fixation; and, 4) improving nutrient cycling. As a result, production costs are decreased and profitability is increased due to the reduced need for external inputs such as fertilizers and pesticides, and there are benefits from less environmental contamination (Humphreys, 1994; Delgado et al., 1999; Peters et al., 2001).

Results of on-station and on-farm research, obtained in dry regions of Central America, demonstrate the large impacts of legume-based feeding systems on milk production and income of farmers who operate dual-purpose cattle systems. For example, grass-legume pastures consisting of *B. decumbens* and *Arachis pintoi*, when compared with grass-only pastures of *B. decumbens* or *B. decumbens* + *Hyparrhenia rufa,* showed average increase of: a) 33% in forage availability; b) 30% in crude protein; c) 2.2% in digestibility in comparison with *B. decumbens* and 9.6% in comparison with *B. decumbens* + *H. rufa* pastures; d) 6.4% in milk production. In another study, milk yields of lactating cows grazing grass-only pastures of *B. decumbens*, were compared with those of cows grazing pastures of the same grass planted with strips of *Cratylia argentea*, or grass-only pastures supplemented with the legume in a cut and carry system. During the dry season, cows grazing grass-legume pastures increased milk production by 23% in comparison with those grazing grass-only pastures, and by 12% in comparison with those grazing the grass-only pastures and receiving supplementation with the legume in a cut and carry system (Lascano et al., 2002).

In Minas Gerais, Brazil, milk production of cows grazing *B. decumbens-S. guianensis* cv. Mineirão pastures increased by 15.6% when compared with those grazing grass-only pastures (Barcellos & Vilela, 1999). Studies of Vilela et al. (1999), in the Cerrados of the same state, showed a 56% increase in live weight gain of Nelore heifers when degraded pastures of *B. decumbens* and *B. ruziziensis* were reclaimed using *S. guianensis* cv. Mineirão. In the Cerrados of Mato Grosso do Sul, Brazil, grass-legume pastures consisting of *B. decumbens* associated with *S. capitata* + *S. macrocephala* cv. Campo Grande resulted in 7%, 18% and 20% increase in animal live weight gain per hectare, when grazed under stocking rates of 0.6, 1.0 and 1.4 animal units/ha, respectively, in comparison with grass-only pastures (Valle et al., 2001).

Reasons for lack of wide adoption of grass-legume pastures by farmers

Despite the great potential of forage legumes to improve productivity and profitability of livestock production systems, the adoption of technologies developed during the past 40 years have been limited and slow. Important reasons for lack of wide adoption of grass-legume pastures in cattle production systems in the tropics are: 1) unsuccessful experiences among farmers and researchers resulting in lack of credibility of this alternative; 2) lack of commercial cultivars adapted to different environmental conditions; 3) low availability and high cost of commercial seeds in the market; 4) lack of knowledge among farmers regarding the adequate management of grass-legume pastures; 5) lack of persistence of legumes in the associations with grasses; 6) the lack of farmers participation in research and development; 7) lack of coordination on feed improvement; 8) soil fertility maintenance; and, 9) unfavorable policies (Barcellos & Vilela, 1994; Spain, 1995; Thomas & Sumberg, 1995; Fisher et al., 1996; Mannetje, 1997; Schultze-Kraft & Peters, 1997; Elbasha et al., 1999; Hoveland, 1999; Barcellos et al., 2001; Pereira, 2002).

Even though traditional and modern farming systems in the tropics almost invariably have included legumes for centuries, this has not been the case in cattle production systems. In Brazil, for example, one of the centers of origin of several genera of legumes with forage potential, such as *Aeschynomene*, *Arachis, Centrosema*, *Desmodium*, and *Stylosanthes,* farmers historically have failed to recognize the contribution of native legumes as important sources of feed for livestock production. Even nowadays, it is quite common to see native legume species or exotic species that encroach in cultivated grass pastures, and are widely recognized in the scientific literature as good feed sources for livestock, to be considered by farmers as weeds, being mechanically or chemically eliminated from their pastures.

Possible explanations for this behavior of farmers in the tropics are: 1) legumes are usually a minor component of native grassland ecosystems and frequently occupy a lower strata in the pastures, as is the case, for example, with wild *Arachis* in the native ecosystems of Brazil which, in many cases, developed under the partial shade provided by native grasses; 2) farmers, traditionally, pay less attention to what animals actually graze and much more attention to the predominant botanical component and manage pastures to favor grass species, both in native and cultivated pasture ecosystems, as is the case, for example, with the occurrence of native *Stylosanthes* in cultivated pastures in Minas Gerais.

Poor persistence of legumes in mixed pastures is a worldwide problem, and one of the main causes of the low adoption of this technology. Scientists from Australia, New Zealand and the United States selected the following priority areas for future collaborative research in forage legume persistence: 1) forage legume germplasm development; 2) legume plant population dynamics (demography); 3) soil nutrient stress in legumes; 4) basic adaptative mechanisms by legumes to stressful environments; 5) disease, insect, and other pest biology, resistance and control in legumes; and 6) dynamics of the plant-animal interface during grazing (Marten et al., 1989).

Until recently, most releases of new grass and legume cultivars in the market were done with limited or no validation under real on-farm economic, social and environmental conditions. This is especially true regarding long-term on-farm validation of grass-legume recommendations under grazing. Much of the research for development and recommendation of new cultivars of grasses, legumes and grass-legumes associations in the tropics has been done in experimental stations, with good control of some environmental conditions (soil fertility, for example) and adequate management practices during establishment and evaluation of the experiments. These conditions are far distant from the economic, social and cultural realities of the majority of farmers in this region. Once grass-legume technologies are recommended they frequently fail to succeed under real farm conditions over long periods, leading to staggering rates of failure and of discredit of this alternative. Even today, the constant budget restrictions of public research institutions and the high costs of validating these technologies at farm level are the main causes of failures, lack of wide adoption and persistence of grass-legume pastures in cattle production systems in the tropics.

Also, most research conducted with forage plants in the tropics were based on parameters and variables that do not allow an appropriate understanding of the soil, plant and animal processes and interactions that take place in a dynamic pasture ecosystem under grazing (Silva & Pedreira, 1997). Adoption of incorrect management decisions are an important factor in the process of degradation of pastures established with cultivated grasses, and are certainly among the key factors affecting persistence and successful adoption of grass-legume pasture technologies by farmers in the tropics.

Research and development of forages for small farmers has been going on in Southeast Asia for at least 40 years. The predominant approach in developing technologies was highly prescriptive, with research institutions providing technology packages to extension services, which established them in what they believed to be "model farms" and expected that these technologies would spread naturally to other farmers. Most of this process was controlled or driven by researchers, with little or no input from farmers. There has been little substantial adoption from this approach (Peters et al., 2001).

Since 1970, a sustained decline in farmer's terms of trade and rapid changes in profitability of livestock and cropping enterprises have directly or indirectly influenced the persistence of many temperate and tropical legumes in Australia. Reduced phosphorus fertilizer use, overgrazing, expansion of crop areas, and the introduction of new cropping technologies are implicated in the decline of legumes. Land degradation problems (soil acidification, salinization, waterlogging, and compaction), and occurrence of new diseases and pests or increased prevalence of those previously known have also contributed to substantially reduce legume persistence (Gramshaw et al., 1989).

Success stories of wide adoption of grass-legumes pastures in the tropics

The successful utilization of grass-legume pastures is a reality in several temperate countries. In New Zealand, for example, white clover (*Trifolium repens*) is a very important component of the animal production systems, with the majority of the farms presenting 15 to 20% of this legume in the botanical composition of their pastures (Caradus, 1996). The South of Australia is another region were most pastures (88%) are based in grass-legume associations (Gramshaw et al., 1989). White clover is the temperate legume most studied and planted in mixed pastures around the world. Estimates are that pastures with this legume cover areas of 9 million hectares in New Zealand, 6 million hectares in Australia, and 5 million hectares in the United States (Gramshaw et al., 1989; Marten et al., 1989).

However, the general situation in the tropics is quite different, and the successful use of grass-legume pastures is an exception, with only a few cases reported in the literature, most of which were achieved in the last two decades. In Queensland, tropical Australia, Gramshaw et al. (1989) estimates that only 30% of the cultivated pastures consist of grass-legume associations. In the Cerrados region of Brazil, actually the principal cattle production region of the Country, the estimates are that only 2% of the pastures are based in grass-legume associations, mainly involving *Calopogonium mucunoides* and *Stylosanthes* spp. (Macedo, 1995; Zimmer & Euclides Filho, 1997).

Despite this scenario, there are some recent stories of success of wide adoption of grass-legume pastures in the tropics, which suggest that the perspectives of the technology are very promissory for sustainable animal production in the tropics in the future.

Since 1987, an ongoing joint effort of the International Center for Tropical Agriculture (CIAT), with local public (Corporación Colombiana de Investigación Agropecuaria - CORPOICA, Universidad de la Amazonia) and private institutions, with participation of farmers of Colombia have led to the successful establishment of more than 3,000 ha of grass-legume pastures based on *Arachis pintoi* by 100 farmers in their dairy cattle production systems (Peters et al., 2001). Results obtained by Rivas & Holmann (2000) indicated that daily milk yield increased on average 0.5 liters/cow due to the introduction of the legume in degraded pastures. The use of grass-legume pastures resulted in a higher profit margin (21.8%) than traditional grass-only pastures (12.0%).

In 1995 the Forages for Smallholders Project, managed by CIAT and the Commonwealth Scientific and Industrial Research Organization (CSIRO), introduced participatory research and development approaches to developing forage technologies with smallholder farmers in upland areas of Southeast Asia. As result of this effort, by 1999, small farmers in East Kalimantan, Indonesia, had 10% of the total area grown with herbaceous legumes and 15% grown with tree legumes in moderately intensive upland farming systems (Peters et al., 2001).

The cultivar Campo Grande, released in 2000 by Embrapa Beef Cattle, is a mixture of *Stylosanthes capitata* and *Stylosanthes macrocephala* lines. The cultivar is a seed mixture containing, on a weight basis, 80% *S. capitata* and 20% *S. macrocephala* (Embrapa, 2000). According Yassu & Campos (2004), Embrapa Beef Cattle estimates that there are over 120,000 ha of grass-legume pastures established with cv. Campo Grande in Brazil, mainly in the Cerrados region.

The case of *Pueraria phaseoloides* in Acre, Brazil

In 1976 the Program for Reclamation, Improvement and Management of Pastures in the Brazilian Amazon (PROPASTO) established on-farm experiments in the State of Acre. These experiments consisted of introducing and evaluating the adaptation and forage productivity and quality of grass and grass-legume stands, both under cut or grazing (Valentim & Costa, 1982a; 1982b). Similar experiments were established in all states in the region. Since then, research has recommended new species of grasses, legumes and grass-legume associations for establishment of improved pastures in the environmental conditions of the Brazilian Amazon (Valentim & Costa, 1982a; 1982b; Dias Filho & Serrão, 1986; Serrão & Toledo, 1990; Costa et al., 1997; Dias Filho, 2003).

The grass cultivars recommended were an instant success among farmers, with *Brachiaria brizantha* cv. Marandu becoming the predominant species planted by farmers, occupying more than 80% of the total pasture area established in Acre until 1998 (Valentim et al., 2000). However, the legumes recommended had limited adoption and most failed to persist in the pastures after a few years under grazing, mainly due to the incidence of diseases and poor management, among other factors.

The exception occurred in Acre where, after more than 20 years after farmers began to establish the legume *Pueraria phaseoloides* (Tropical kudzu) in association with grasses, over 30% (420,000 hectares) of the pastures consists of grass-Tropical kudzu associations, many of which have persisted for more than 20 years under grazing (Valentim & Carneiro, 1999). According Witcover et al. (1996) 23% of the small farmers in the Pedro Peixoto Settlement Project in the State of Acre reported the use of Tropical kudzu in their cattle production systems.

There are several reasons to explain the wide adoption of grass-Tropical kudzu pastures in Acre. First, since the early 1980's Embrapa Acre established grass-Tropical kudzu pastures in strategically selected areas owned by farmers that were seen as leaders and innovators among their peers. Second, Tropical kudzu presented excellent adaptation and high seed production in the different environmental conditions of the State. It soon became a cash crop for small farmers that started to use it also as an improved fallow in the process of reclamation of degraded land that was later cultivated with annual crops such as rice, corn and beans (Valentim & Carneiro, 2001). This resulted in high availability of low cost legume seeds in the market, making Acre a seed exporter for other regions of Brazil.

Later in the 1980's, farmers began to be pressured by governmental and non-governmental organizations to reduce deforestation for establishment of new pastures and to reclaim degraded pasture areas. With the great distances from markets, poor roads and low profitability of extensive beef cattle production systems, the use of modern inputs such as fertilizers were not economically viable. At this point Embrapa Acre presented farmers once again with successful on-farm experiences with establishing and managing grass-Tropical kudzu pastures that, at that time, were 7 to 10 years old. After the first couple of talks and field days conducted by researchers and extension agents, the owners of the demonstration farms became the true agents in the process of technology transfer. In 1989, under the pressures of the moment, there was a rush of farmers to establish grass-Tropical kudzu pastures and prices of the legume seeds increased from US$ 4.00 to US$ 11.00 per kilogram from July (harvest period) to November (the end of the planting season) (Valentim, 1989; 1990).

Valentim et al. (1984) recommended a seed rate of 1.0 kg/ha of Tropical kudzu seeds in mixture with the grass seeds. However, in the next fifteen years it became a common rule for farmers in Acre to use a seed rate of 1.0 kg of Tropical kudzu seeds for each 2.42 ha (one alqueire). It is estimated that, actually, Tropical kudzu is present in over 50% of the total pasture area in Acre, in percentages ranging from less then 10%, in pastures under more intensive grazing, to over 90%, in areas where death of *B. brizantha* cv. Marandu is occurring, due to the lack of adaptation of this grass species to low permeability soils (Valentim et al., 2000; 2002).

In Marandu-Tropical kudzu pastures where the grass started to die, the legume acted as a buffer and saved farmers from complete bankruptcy. Tropical kudzu prevented weeds from completely taking over the pastures, supplied good quality forage for the animals and increased the nitrogen status of the soil. This allowed the farmers time to gradually re-establish the pastures using manual control of weeds, such as *Paspalum virgatum*, followed by planting vegetatively stoloniferous species like African stargrass (*Cynodon nlemfuensis*), Tangola grass (*Brachiaria mutica* x *Brachiaria arrecta*), *B. humidicola* and *Arachis pintoi* cv. Belmonte (Valentim et al., 2004).

The case of forage peanut in Acre, Brazil

Since 1998, with the increasing area affected by the death of Marandu grass, farmers of Acre began to search for alternatives to maintain productivity and profitability of their cattle production systems. However, the traditional strategy of converting forest areas into pastures has been severely restricted by strong enforcement of the environmental legislation by state and federal agencies and by implementation of state policies favoring sustainable forest management. This forced farmers to search for alternative technologies to reclaim degraded pastures and to intensify their production systems using adapted species of grasses and legumes, solar energy and electric fences to manage pastures under rotational stocking, and breeding Nelore (*Bos indicus*) with European breeds (*Bos taurus*) (Valentim & Andrade, 2003a; 2003b).

It was soon observed that Tropical kudzu did not have good compatibility with some of the new grass species being established by farmers, such as African stargrass. Also, in grass-Tropical kudzu associations that had been successfully managed under continuous stocking for over 20 years, persistence of the legume was severely affected when these pastures began to be managed under rotational stocking with stocking rates above 1.5 animal units per hectare. This has confirmed the evidence in the literature about the sensitivity of twining legumes such as *P. phaseoloides* to rotational stocking and to high grazing pressures (Skerman, 1977; Roberts, 1982; Lascano, 2000; Andrade, 2004).

In the beginning of 2000, farmers that traditionally collaborated with Embrapa Acre for on-farm validation of technologies demanded new alternatives of legumes adapted for use in more intensive cattle production systems, which included pasture management under rotational stocking. At that time, as a result of research initiated in 1990 with *Arachis pintoi* (forage peanut), cultivar Belmonte, released in 1999 in Bahia, Brazil (Pereira, 2002), was in pre-recommendation phase for the environmental conditions of Acre. In March 2000, one farmer started to establish *A. pintoi* cv. Belmonte in association with African stargrass in the process of reclaiming degraded pastures in low permeability soils where Marandu grass had died. Both the legume and the grass were manually planted using vegetative material (stolons). The initial success of this experience soon couth the attention of other farmers that were facing similar problems. In April 2001, approximately 20 farmers had established this legume in association with African stargrass, Marandu grass (both in well drained and low permeability soils), *B. decumbens* cv. Basilisk and *B. humidicola*. In December 2001, *A. pintoi* cv. Belmonte was officially recommended by Embrapa Acre for diversification of pasture ecosystems and also as a cover crop for soil protection in Acre (Valentim et al., 2001).

The news of the success of using this legume in the reclamation of degraded pastures, and in the improvement of other grass pastures still productive, rapidly spread among farmers in Acre. By March 2004, close to 1,000 small, medium and big farmers of Acre had already introduced forage peanut in their pastures, some in almost 100% of their farms, with areas of up to 2,000 hectares. It is estimated that forage peanut has been planted in association with grasses in approximately 65,000 hectares of pastures in Acre. In some farms, these pastures have been successfully managed with 2.5 animal units/ha, with Nelore x Angus crossbreed steers ready for slaughter (255 kg of carcass weight) with 24 months and primiparous calving with 22-24 months of age (Valentim & Andrade, 2003a; 2003b).

Recent news on national television networks, newspapers and rural magazines reporting the successful use of forage peanut in grass-legumes pastures in the Western Amazon (Acre), and in the South (Rio Grande do Sul) and Northeast (Bahia) regions of Brazil, have led to a strong demand for information and propagative material of this legume by farmers from most parts of the country. In Acre, it was noted that many initially reluctant farmers became interested in planting this legume soon after the news on TV.

The perspectives of the use of grass-forage peanut pastures in tropical regions are very encouraging, especially in the humid climates. There is no doubt that forage peanut is the tropical herbaceous legume with the highest number of favorable attributes related to persistence under grazing. Some of these attributes are: 1) prostate and stoloniferous growth habit, with many growth points protected from grazing; 2) prolonged plant life span (half life of 25 months); 3) high production of buried seeds, which germinate vigorously in the beginning of the rainy season; 4) good shade tolerance (Grof, 1985; Jones, 1993; Fisher & Cruz, 1995; Thomas, 1995; Vaz et al., 2002). In the coastal region of Bahia, Brazil, there are reports of *B. humidicola*-forage peanut pastures more than 10 years old (Pereira, 2002). In Acre, there are mixed pastures of Massai grass (*Panicum maximum* x *P. infestum* cv. Massai) and forage peanut still productive 9 years after planting, and African stargrass-forage peanut pastures established in 2000 presenting no evidence of legume decline.

Actually in Brazil, the research with forage legumes is concentrated mainly with *Arachis pintoi* and with the genera *Stylosanthes* (Barcellos et al., 2001). These legumes are native from the Brazilian flora and the new cultivars recently released have played an important role in the renovation of the interest among researchers and farmers in the utilization of grass-legume pastures in the Country.

Innovative strategies to ensure wide adoption of grass-legume pastures in the tropics

As stated previously, the restricted adoption and high rates of failure in the use of grass-legume pastures in livestock production systems in the tropics have been caused by several technical, social, economic and environmental factors. Among these, the utilization of inappropriate strategies in the processes of research and development and technology transfer have played an important role in the lack of credibility of grass-legume technologies among researchers and farmers in the region.

According Valls & Simpson (1995) the collaborative research for collection, evaluation, improvement and the adequate use of germplasm of the genus *Arachis* show how science can help overcome knowledge gaps that are critical for the sustainable use of the natural resources. National and international cooperation was the basis for the great research achievements with *Arachis* both as forage and as a cover crop.

The true potential of forage legumes, both in pure stands and in grass-legume pastures in the tropics has not been adequately exploited thus far. Peters et al. (2001) suggest that, in order to promote wider adoption of legumes in livestock production systems, there is a continued need to: 1) search for appropriate germplasm, particularly adapted to the demands of farmers; 2) adopt novel techniques for evaluation, adaptation and dissemination, which involve participation of farmers; and, 3) adopt strategies for seed production that involves farmers.

In the last decade, research with legumes in the tropics has focused in the selection of species for utilization in extensive and semi-intensive livestock production systems. There is a need to increase the basic knowledge regarding plant physiology, management, mechanisms of persistence and productivity of legume-based pastures, in order to provide adequate information support systems for farmers (Barcellos et al., 2001). The final stages of evaluation and validation of new genotypes are particularly important. It has been recommended: a) to enlarge the teams working with forage legumes, a factor that has limited a more comprehensive study of the promising materials with respect to the basic knowledge and in advanced stages of research (Barcellos & Vilela, 1994); b) to develop less rigid and lower cost methodologies for the final stages of evaluation, increasing the number of accessions evaluated (Pereira, 2002); c) to associate the development of new cultivars to the production systems and to increase the partnerships with the private sector and with institutions that provide technical assistance to farmers; and, d) to improve the processes of technology transfer, by using modern means of communication and appropriate language to the target public (Barcellos et al., 2001).

Support of research in the persistence of forage legumes is not only prudent, but also essential for truly sustainable agriculture. Increased legume persistence will lead to more effective management of agricultural production systems and reduce risks associated with the ever-changing economic and environmental stresses (Marten et al., 1989). It is equally important that institutions at different levels – local, national and international – work closely together with farmers to maximize the efficiency of scarce resources (Valls & Simpson, 1995). Support for increased collaborative interdisciplinary research among and within countries is essential to ensure improvement of legume persistence that will contribute to improve economic and social well-being.

The development of grazing management strategies to grass-legume pastures is an important step to ensure wide adoption of the technology; however, is not a simple task. Even in temperate countries, with a longer history of research in grass-legume pastures, there is a high degree of uncertainty about grazing management strategies to control species balance in mixed pastures (Hodgson & Silva, 2000). Some factors that complicate the definition of grazing management strategies for grass-legume pastures are: a) competition for resources among species; b) differences related to reactions to grazing; c) differences related to animal preference; and, d) differences in reaction to climate variations (Spain, 1995; Lascano, 2000). In tropical regions, an additional difficulty in understanding and managing grass-legume pastures is the great diversity of forage species and morphological types, allowing a very high number of binary associations. These factors suggest the need to develop specific grazing management strategies for each grass-legume association (Cruz & Sinoquet, 1994; Thomas, 1995; Fisher et al., 1996).

In Brazil, there has been a growing interest in developing grazing management strategies based on descriptors of pasture condition. Research results have shown that the concepts developed in temperate countries, with a few adaptations, can also be used to define grazing management strategies for pastures in the tropics (Hodgson & Silva, 2002). In Acre, the concept of sward state proposed by Hodgson (1985) was successfully applied by Andrade (2004) in developing grazing management strategies for grass-forage peanut pastures (Table 1).

Table 1. Sward targets for rotational stocking management of mixed pastures with forage peanut in Acre (Andrade, 2004).

Season	Sward height (cm)			
	Massai grass-forage peanut		Marandu grass-forage peanut	
	Pre-grazing	Post-grazing	Pre-grazing	Post-grazing
Rainy (October-May)	65 – 70	35 – 40	45 – 50	25 – 30
Dry (June-September)	50 – 55	30 – 35	30 – 35	20 – 25

In selecting grasses and legumes to establish mixed pasture ecosystems, besides observing the complementarity between the grass and the legume regarding their environmental requirements, researchers should also take into consideration the type of product (meat or milk), the technology level used and target productivity established to ensure profitability and sustainability of the cattle production systems. Gramshaw et al. (1989) advises that the restricted range of commercial species available for some environments should cause concern in view of previous experiences with unforeseen diseases.

It is still common for farmers in the tropics to convert native ecosystems into cultivated pastures without any previous knowledge of environmental conditions, particularly soil chemical and physical properties. Also farmer's decisions regarding which forage species to plant are usually made without support of reliable technical information. This emphasizes the urgent need to sharply improve the scientific knowledge regarding environmental potentials and restrictions for sustainable livestock production in the tropics. It is also essential that the technical information is accessible to local stakeholders, particularly, policy makers, extension agents and farmers for successful establishment and persistence of grass-legume pastures in the tropics.

The wide adoption of grass-legume pastures with *P. phaseoloides* and *A. pintoi* in Acre, *S. guianensis* cv. Mineirão and *S. capitata* + *S. macrocephala* cv. Campo Grande in the Cerrados of Brazil, indicates that the key steps in achieving success in these processes were: 1) interdisciplinary and multi-institutional collaborative research among national and international institutions; 2) the building of strong and reliable relationships between researchers and stakeholders, particularly farmers and policy makers, involved in livestock production; 3) the use of participatory approaches in research and development of forage technologies; 4) the use of innovative farmers that have successfully adopted grass-legume technologies as trainers for extension agents and farmers, also using their farms as demonstration sites; 5) better integration with the beef and dairy production chains contributed to increase efficiency of research and development and to overcome constant budget restrictions of public research institutions and also to ensure that grass-legume technologies succeed over long periods under real farm conditions.

Conclusions

Grass-legume technologies are essential for adequate policy action to ensure that the ongoing Livestock Revolution in the tropics can reconcile economic growth, poverty alleviation and environmental conservation.

The establishment and maintenance of persistent grass-legume pastures is a key option to increase productivity and profitability of cattle production systems in the tropics. Based on current available technologies, ongoing research and success histories of wide adoption of grass-legume pastures at farm level, there are good perspectives that these technologies will play a key role in ensuring sustainability of cattle production systems in the tropics in the future.

Innovative research and technology transfer strategies are essential to promote successful histories and wider adoption of grass-legume pastures by farmers in the tropics. Innovative farmers that have successfully adopted grass-legume technologies can be used as effective trainers for extension agents and farmers, also using their farms as demonstration sites. Participatory approaches and better integration with the beef and dairy production chains are key strategies to increase efficiency of research and development and to overcome constant budget restrictions of public research institutions and also to ensure that grass-legume technologies succeed over long periods under real farm conditions.

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