AGROFORESTRY SYSTEMS IN THE HUMID FOREST MARGINS OF TROPICAL AMERICA FROM A LIVESTOCK PERSPECTIVE[1]

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ABSTRACT

Livestock is an important component of production systems in different agroecologies of tropical America. However, cattle production in the humid forest is not sustainable and has been associated with environmental degradation, since the area in pastures was under natural forest. Therefore, there is a need for ecologically sustainable and economically attractive technologies to prevent further deforestation and to reclaim large areas of degraded pastures in the forest margins of the region. An alternative is the integration of trees, pastures and livestock. In this paper, entry points for agroforestry systems in forest margins of tropical America are identified, some examples of existing and proposed livestock-based agroforestry systems are presented, and opportunities and some actions needed for the development and adoption of sustainable agroforestry systems are discussed. It is suggested that pastures based on mixtures of grasses and legumes adapted to major environmental constraints, and capable of persisting under heavy grazing, will contribute to reverse degradative processes in forest margins. This improved pasture technology could be the basis for the development of sustainable livestock-based agroforestry systems. The role of the forestry component in pasture-livestock systems is less clear due to the lack of quantitative information on the interactions of trees with animals in grazed pastures.

INTRODUCTION

Cattle raising is an important component of production systems in all major agroecosystems (savannas, hillsides, and forest margins) of tropical America. However, cattle production in the humid forest is controversial due to environmental degradation caused by deforestation to establish pastures. Large scale clearing for pasture establishment arose mainly by the opportunity for beef export in Central America and southern Mexico (Myers, 1981) and by economic subsidies in the eastern Amazon of Brazil (Hecht, 1985; Serrao and Toledo, 1990). These policies have been revised, but deforestation is still occurring at a fast rate in the Atlantic coastal plains in Central America and the Amazon basin colonized by landless-poor people (Leonard, 1987; Hecht, 1993). It is estimated that the area deforested in the Amazon basin may already exceed 60 million ha (Anderson, 1990), of which 50% is estimated to be under pastures carrying 23 million head of cattle (CIAT, unpublished results). It is this forest margin area that attention is focused on, in order to reduce pressure on primary forest.

Large and small producers in forest margins of the region view cattle not only as a secure source of income, but also as a means of extending the economic life of cleared areas (Hecht, 1993). Therefore, there is an urgent need to research and promote technologies for livestock-based systems that are environmentally sound. One solution suggested by many researchers and developers to reclaim deforested land is the integration of trees, pastures and livestock. The argument is that trees could provide tangible benefits (i.e. living fences, forage, fuelwood, timber, fruits) to the farmer and also contribute to soil enhancement through nutrient cycling (Vergara, 1987; Nair, 1987; Gutteridge and

Shelton, 1993).

In this paper we describe predominant production systems in cleared forest areas of tropical America and present some examples of existing livestock-based agroforestry systems. We also highlight results from an improved grass-legume pasture technology, and outline some actions needed for development and adoption of sustainable agroforestry systems in forest margins of the region.

ENTRY POINTS FOR AGROFORESTRY SYSTEMS IN FOREST MARGINS OF THE REGION

Two contrasting livestock-based systems are commonly found in the humid forest of tropical America, namely medium to large livestock operations and smallholder mixed farms. Each system has unique characteristics and consequently offers different opportunities to establish improved agroforestry practices.

Livestock systems

Large and medium scale livestock operations in the humid forest of tropical America have been mainly formed by mechanized clearing of the forest followed by the establishment of pastures for extensive beef production in less dense populated areas or more intensive milk and beef production (i.e. dual purpose cattle systems) in areas with more population and market opportunities (Serrao and Dias Filho, 1991; Toledo and Torres, 1990).

These systems are not sustainable due to several reasons:(1) lack of adaptation of introduced grasses, e.g. star grass, guinea grass, to low soil fertility, (2) biotic pressures on introduced grasses, e.g. spittlebug on *Brachiaria decumbens,* *B. humidicola*, and (3) improper management such as the lack of fertilization and overgrazing (Toledo, 1985; Pezo et al., 1992). Thus, there is a need to reclaim large areas of degraded pastures through technologies that are ecologically sustainable and economically attractive to farmers.

Smallholder mixed systems

In smallholder colonist systems, clearing and burning of primary and secondary forest is followed by a sequence of annual crops e.g. corn, beans, cassava and the establishment of grass-based pastures. Within the farming system cattle raising represents a form of income and savings with low opportunity cost in labor (Loker, 1989; Kass et al., 1992). When pastures degrade due to reduced soil fertility and weed invasion, smallholders that are not constrained by land, allow degraded areas to fallow. Thus, practices that shorten fallow periods could be attractive to these small farmers and also contribute to reduced pressure on the primary forest. However, there are small farmers that can not fallow degraded areas due to limited land, particularly in Central America. Under these circumstances some agroforestry options are: alley cropping (Kass et al., 1993a), and integration of leguminous trees in grazed pastures or cut and carry systems (Pezo et al., 1990).

AGROFORESTRY SYSTEMS IN THE REGION

In this section we briefly refer to livestock-based agroforestry systems practiced by some large and small farmers in the humid forest areas of tropical America. In addition, we refer to agroforestry systems being researched and to systems that have been proposed to shorten fallow periods.

Examples of livestock-based agroforestry systems

There are two well documented examples of commercial livestock-based agroforestry systems in the humid forest of Central America. In Turrialba, Costa Rica a system with *Pinus caribaea* for pulp with *Panicum maxium* as dominant understorey was described by Somarriba and Lega (1991). Grazing of the understorey began when the plantation was 2.5 years and ended when the trees were 8.5 years, due to shading of the grass. The maximum stocking rate estimated for the system was 0.87 AU/ha with a liveweight gain of 450 g/head/day. The use of livestock in the system allowed extra income to the farmer and reduced cost of weeding and risk of fire. Another example of a livestock-based agroforestry in Turrialba, Costa Rica involves the association of the grass *Axonopus compressus* with naturally generated trees of *Psidium guayaba* (average of 264 trees/ha). The trees provide fuelwood (4.3 m^3/ha) and fruits for livestock (11 kg/hd/day), which also help to distribute the seed of the fruit in the pasture (Somarriba 1985 a, b c).

Legume trees such as *Gliricidia sepium* and *Erythrina* spp. are also used by farmers in the humid forest of Central America as live fences or for shade in coffee plantations (Budowski, 1987). However, their use for feeding livestock is limited probably due to lack of dry season stress and high labor input needed in cut/carry systems.

In the forest margins of the eastern Brazilian Amazon, there are examples of agroforestry systems, which have been described by Veiga and Serrao (1990). In these systems innovative farmers have planted trees, e.g. rubber, coconut palm, pine, mangos, and Brazil nut in degraded pasture areas using different spacing arrangements and grasses planted between rows for grazing. Success has been variable depending on species of tree used and management applied. For example, stable and productive systems were observed with pine and Brazil nut. In contrast, systems with "Urucu" (*Bixa orellana*) and coconut palm were considered to be less successful. Major limitations of the silvopastoral systems evaluated were damage of young trees by livestock and lack of persistence of the understorey pastures due to shading, overgrazing, lack of maintenance fertilization and weed invasion (Veiga and Serrao, 1990).

There are other examples of agroforestry systems used by smallholders in the Amazon basin. A system based on cashew nut is practiced in a farm community near Paragominas, Brazil (J. M. Spain, personal communication). After clearing and burning primary forest, seedlings of cashew nut (*Anacordium occidentalis*) are planted with an annual crop. At the end of the crop sequence, cashew nuts are 2-3 m tall and spaces between trees are planted with a grass, such as *B. decumbens*. Cattle consume the cashew apple and leave the nut untouched, which are gathered from the soil and the tree. The grass between rows of cashew trees in young plantations was vigorous and farmers indicated that it was more productive than in open pastures, until shaded-out.

Another form of agroforestry practiced by some smallholders in tropical America, is through protection of valuable trees. In certain regions of the humid forest of Central America, farmers have come to appreciate the natural regeneration of *Cordia alliadora* in pastures, due to the high commercial value for its timber and straight trunk which allows light penetration for pasture growth (Budowski, 1993). In Rio Branco, Acre, Brazil, some farmers protect the Brazil nut when clearing areas to establish crops and pastures (Toledo and Torres, 1990). Also farmers in central and northern Brazil use the Babassu palm (*Orbignya martiana*), which dominates cleared sites and serves as a source fuel for burning to increase soil fertility, while allowing cropping or grazing between the trees (May et al., 1989).

Research on livestock-based agroforestry systems

In the humid tropics of Latin America two groups have been prominent in livestock-based agroforestry research: CATIE in Turrialba, Costa Rica, and CPATU/EMBRAPA in Belém, Brazil. Researchers at CATIE have evaluated nitrogen-fixing trees, such as *Erythrina* spp. and *Gliricidia sepium* to recover degraded pastures (Romero et al., 1991) and to recycle nutrients (Libreros, 1990; Cooperband, 1992). Results have shown that biomass production and protein content of the wide spread African star grass were higher when grown under *E. poeppigiana* than when grown alone (Pezo et al., 1990). Pastures under *E. poeppigiana* also reduced the invasion of weeds.

The group at CATIE also evaluated biomass production of different legumes and grasses grown in association with tress (Bazill, 1987, Bustamante, 1991), antinutritional factors in fodder from legume trees (Valerio, 1990; Payne, 1993) and the value of this fodder as protein supplement for ruminants. For example, supplementation of *E. poeppigiana* resulted in linear increases in the milk yield of goats (Esnaola and Rios, 1986) and cows (Tobón, 1988) on grass basal diets. The work on feeding value of leguminous trees has been reviewed by Pezo et al., (1990), Romero et al., (1993) and Camero et al., (1993).

In Brazil, the group in CPATU is well known for its work on pasture research, plant sucession in abandoned pastures and testing of agroforestry systems for regeneration of degraded pastures. For example, researchers working in CPATU have been evaluating in the Paragominas area, different tree species (i.e. *Schyzolobium amazonicum, Bagassa guianensis, Eucalyptus tereticornis*) in association with grasses, such as *B. brizantha* cv. Marandú, *B. humidicola*, and Coloniao. Results after 4 years (summarized by Veiga and Serrao 1990) showed that biomass yield under trees was more affected by the species of grass used than by the tree species. The grass *B. brizantha* cv. Marandú produced 2-2.5 more dry matter than Coloniao, regardless of the tree species in the association. Work at CPATU has also shown that seedlings of certain tree species of economic value such as cashew nut (*A. occidentalis*), urucu (*Bixa orellona*) and mahogony (*Switenia macrophylla*) can be established sucessfully in degraded pastures (Serrao et al., 1993). In addition, it has been shown that 70% of the cost of establishing trees in degraded pastures can be recovered by annual crops for three years.

Agroforestry research aimed at recuperating degraded pastures in the humid forest has also been carried-out in the Amazon of Peru. Reátegui and Del Castillo (1990), successfully established pastures of *B. decumbens* in association with *Cedrelinga catenaeformis, a* native tree legume, using cassava as a pioneer crop. In the Amazon piedmont of Colombia, Florencia, Caquetá, where large areas of forest have been converted into pastures, a group of researchers of CORPOICA is currently multiplying and evaluating legume-shrubs and trees, such as *Codariocalyx gyroides, Cratylia argentea, Gliricidia sepium, Clitoria fairchildiana, and Erythrina fusca* for the reclamation of degraded areas.

Of interest also is the "coca" agroforestry research and development project carried-out (1985-1990) in smallholder farms in the lower forest of northeast Ecuador. The production system of colonists in the region is characterized by an area of robusta coffee producing 84% of income, cattle on pastures producing 11% of income and shifting cultivation of annual crops for home consumption on farms of 50 ha (Ramírez et al., 1992). The project´s aim was to: (1) increase or incorporate trees of commercial value in coffee and pasture areas, (2) improve management of coffee plantations, and (3) introduce a legume (*Desmodium ovalifolium*) as cover crop in coffee and in pastures in association with grasses (Peck and Bishop, 1992).

Farmers in the project accepted the concept of natural regeneration or introduction of trees with commercial value in coffee and pastures. However, they were less enthusiastic about the use of *D. ovalifolium* as a cover in coffee or in association with grasses in pastures, mainly due to its aggressiveness and lack of palatability to cattle (Ramírez et al., 1992). Given that expansion of pastures for livestock was a high priority of farmers, it was recommended that future research emphasized development of high quality, productive, and persistent grass-legume pastures.

Research on fallow improvement

A common feature of traditional fallow systems practiced by indigenous communities in Central America and the Amazon basin is that trees with certain value are left standing when the forest is cleared for the cropping phase (Peck, 1983; Kass et al., 1993b). As a result, the subsequent fallow is shorter due to increased biomass. Researchers have tried to mimic traditional fallow systems by introducing single tree species, usually nitrogen-fixing leguminous species. For example, the associations of *Inga edulis* with *D. ovalifolium* was found to be effective in reducing fallow periods in Yurimaguas, Peru (Szott et al., 1991). This same association was evaluated earlier in a humid forest site of Ecuador to enrich fallow in a system involving sheep (Bishop, 1983). The Inga trees provided excellent fuelwood and charcoal in less than 6 years and *D. ovalifolium* provided forage for grazing sheep.

An agroforestry model to reduce fallow periods for mixed farmings systems in forest margins of tropical was proposed by Loker (1989) after studying traditional slash and burn systems in Peru. The system defined as 1 year crop, 6 year pasture + trees and 2 year fallow has a number of advantages in mixed smallholder farms: (1) sustained crop and livestock yield without application of purchased inputs and (2) reduce fallow period, which in turn could take pressure away from the primary forest. In addition, the system could be attractive to farmers, since it attempts to maximize return to labor while minimizing capital inputs. The key to viability of the model proposed by Loker (1989) is the natural regeneration of trees and the use of productive grass-legume pastures.

In general, the experience of some innovative farmers and results from research on agroforestry in the region has shown that natural regeneration or introduction of trees in pastures is feasible and that legume trees are an alternative to reduce fallow periods. In addition, research in the region has shown that trees in pastures contribute to nutrient cycling and to increased growth and protein content of certain grasses grown in the understorey. However, research carried-out has failed to show benefits of the tree component in animal production from grazed pastures.

OPPORTUNITIES TO PROMOTE LIVESTOCK-BASED AGROFORESTY SYSTEMS IN THE REGION

We acknowledge that technical solutions alone will not be sufficient to stop deforestation in the humid forest of tropical America. However, a discussion of non-technical issues (i.e. policies) are beyond the scope of this paper and have been covered in a recent publication by Hecht (1993). In the discussion that follows we briefly refer to an improved grass-legume technology which has potential not only for reclaiming degraded areas, but also for preventing degradation in already deforested areas in tropical America.

Improved grass-legume technology

Pasture degradation in tropical forest margins begins with a decline in soil nutrients, followed by loss of plant vigor, weed invasion and soil compaction (Serrao and Toledo, 1990). This process is particularly severe in pastures established with grasses poorly adapted to acid-infertile soils or the biotic environment. As a consequence, the TFP (Tropical Forages Program) of CIAT (Centro Internacional de Agricultura Tropical) and National Research Institutions of the region gave high priority to the development of a pasture technology which integrated acid-tolerant grasses with legumes to increase livestock production while preserving or enhancing soil fertility (Toledo, 1985).

This effort has resulted in the selection of grass and legume species which allow high animal performance and pasture stability over-time. For example, in Yurimaguas, Perú, grass-legume pastures (*Andropogon gayanus, Stylosanthes guianensis, Centrosema pubescens*) yielded annual liveweight gains of 400-500 kg/ha over a 10 year period (Lara et al., 1991). In the humid forest of Costa Rica (Guápiles), the association of *Brachiaria brizantha* cv. Diamantes (a grass resistant to spittlebug) with *Arachis pintoi* (forage peanut) has produced an average of 900 kg of LWG/ha/year over a three year period, which represents 30% more than obtained in the grass alone pasture (Hernández et al., submitted for publication). In another humid forest region of Costa Rica (Turrialba), the association of star grass with *A. pintoi* resulted in 1 liter/day more of milk when compared to grass alone (Heurck, 1990). These differences in liveweight gain and milk yield due to the legume are expected to be greater as pure grass pastures become nitrogen deficient and are invaded by weeds.

The *A. pintoi*-grass associations tested in humid forest and savanna environments are outstanding in that the amount of legume increases with increasing grazing pressure and the association resists weed invasion (Ibrahim et al., 1993; Lascano, 1994). Grass-legume pastures grown in acid infertile soils were also shown to increase soil nitrogen in the savanna (Rao et al., 1994) and soil macrofauna biomass in the humid forest (Lavelle and Pashanasi, 1989). A recent discovery is that grass-legume pasture such *B. humidicola*/*A. pintoi* grown in heavy textured soils in savanna with high rainfall, act as a carbon sink by accumulating 30% more organic carbon at depth in the soil as compared to native grasses, (Fisher et al., submitted for publication).

Therefore, these grass-legume pastures have great potential to increase livestock production, while contributing to reverse degradative process in acid-infertile soils of forest margins and to carbon sequestration, which could have important environmental implications.

Integration of improved pastures and trees in livestock-based systems

Introduction of improved grass-legume pastures after slash and burn of secondary vegetation is an alternative that has been sucessful in smallholder farms in forest margins of

Pucallpa, Peru (Loker, 1988). However, recovery of native vegetation after abandonment of degraded pastures will depend on the intensity with which sites were utilized (Uhl et al., 1988). In severely degraded areas, where natural regeneration of forest vegetation is unlikely to occur, pasture establishment can be an expensive operation involving mechanization, application of fertilizers and weed control. One possibility to reduce cost is through the establishment of the improved grass-legume pastures in association with annual crops, using acid-soil tolerant, new lines of rice developed by CIAT and used sucessfully in savannas of tropical America (Zeigler et al., 1994) and corn lines being developed by CYMMYT. Pasture renovation in better soils of the humid forest of Central America could also be accomplished through the association of improved grasses with maize or soybeans (Duarte, 1991; Pérez et al., 1993). Alternatively, severely degraded areas could be renovated with acid-tolerant fast growing herbaceous legumes (i.e. *S. guianensis* cv. Pucallpa, *C. macrocarpum*, *Vigna ungiculata*) in a green manuring system.

Planting trees in pastures is another alternative to reclaim degraded areas, eventhough some have expressed doubts on the willingness of farmers to engage in this activity, at least in the Amazon basin (Neptad et al., 1990). It is more likely to expect farmers to integrate trees in current production system by protecting valuable tree species (i.e. timber, fuelwood, fruit) and/or by planting legume tree species as living fences or as a source of fodder, particularly in areas with well defined dry season.

ACTIONS NEEDED TO PROMOTE ADOPTION OF AGROFORESTRY PRACTICES

Most of the literature available in the region on systems that integrate trees, pastures and livestock is highly descriptive and inadequate to promote farmer adoption of new practices. Thus, there is a need to carry-out participatory research. The on-farm research approach used in the "coca" agroforestry project in Ecuador is in the right direction, and should be used as a model when designing new projects. However, on-farm research and development in agroforestry should be linked to seed supply systems for effective delivery to farmers of components being developed (i.e. tree, grass and legume species).

Finally, we acknowledge that livestock-based agroforestry systems are complex and of long-term nature, and thus, possess serious difficulties in research. This complexity calls for an interdisciplinary approach to quantify processes and outputs in existing and new livestock-based agroforestry systems in the region.

RESEARCH PRIORITIES

After reviewing the literature on livestock-based agroforestry systems in the region, there are some areas that we feel merit immediate attention by researchers:

- Evaluation of indigenous and introduced tree species for performance in contrasting environments.

- Evaluation of acid-tolerant grass and legume germplasm for adaptation to soil, climate, pest and disease, and for ability to compete with weeds under different shade regimes.

- Methods of establishment of grass-legume pastures, in combination with trees and annual crops in deforested sites representing different stages of land degradation.

- Studies on animal production in grass and grass-legume pastures with and without trees.

- Studies on soil physical, chemical and biological changes in grass and grass-legume pastures with and without trees.

- Biological and economical assessment of performance of existing and new livestock-based agroforestry systems.

CONCLUSIONS

In this paper we have suggested the potential benefits of new productive and persistent grass-legume pastures as a component of sustainable livestock-based agroforestry systems designed to reclaim degraded areas and prevent land degradation in forest margins of tropical America. However, we are not certain of the value of the forestry component since there is a lack of hard data on animal production amenable to analysis.

The improved grass-legume technology that is available and being adopted by farmers, coupled with appropriate policies could contribute to gradual conversion of what are now unstable and extractive production systems to stable and productive mixed systems. To accomplish this, there is a need to evaluate this pasture technology in areas of active colonization, with and without a forestry component and using participatory research methods. If we fail to do so, our research and development efforts will not gain credibility among the farmer, government and donor community.

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