Does Intensification of Pasture Technologies Affect Forest Cover in Tropical Latin America? : Inverting the Question

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Cattle in tropical Latin America[1] have many talents: for the rural farmer they provide a means to status and stable cash income. Yet for the environmentalist, they are a chewing and belching nemesis of the forest and atmosphere. These two views provide a spirited debate between the sometimes-conflicting goals of economic development and environmental preservation. At the crux of the conflict lie questions regarding how advances in pastures/cattle technology influences deforestation.

The relationship between pastures and forest cover contains the combined issues of land degradation, technology feasibility, adoption, and farmer incentives to preserve forests. Given that the value of forested land in tropical Latin America (and elsewhere) is low, continued deforestation and extensive cattle production appear to be rational private choices. The forest margin regions of the Amazon provide an example of such land use. In the case of older forest margins, which are more developed regions such as in Central America and increasingly in South America, farmers intensify production in order to prevent degradation of pastures and avoid the higher cost option of expanding onto neighbouring lands. Hence, the initial question posed by our research, whether intensification causes increased or decreased deforestation has resulted in an unfortunate alternative hypothesis: *forest scarcity is a pre-requisite for technology intensification.*

This hypothesis is similar to that attributed to Boserup (1965). Paraphrasing her argument, intensification rarely takes place while possibilities for expansion still exist. Both approaches lead to a similar conclusion, yet it is the mechanism that differs. The basis of her argument concentrates upon the relation between demographics and technological change, while our hypothesis concerns the private financial benefits between the intensive and extensive land use options.

Generally speaking, two opposing influences affect land prices: the level of development (i.e. market access) and the amount of remaining forest cover. In areas where land values are low, markets are immature and forest is relatively abundant. Whereas high land prices are a result of more developed markets and associated scarce forest cover. If land is prohibitively expensive, production increases will be attained by an intensification of the current land holdings. Thus a related hypothesis results, which relates intensive technology and forest cover. *Intensification technologies can lead to maintenance of forest cover only if they are a less expensive option than extensive growth*.

The implications of failing to reject these hypotheses then necessitate a shifting of research priorities from examining the positive or negative impacts of intensification on deforestation to ones of how to guide research efforts so that deforestation and extensive land use become a less attractive option for farmers. Together, both technical research to increase land use productivity, and policy research to test ways to increase incentives for forest preservation, become a pressing global need.

This paper presents data of the research and extension consortium *Tropileche* to support these hypotheses. Since longitudinal data linking pasture and forest cover are scarce, the following is a synthesis of empirical results from three research sites (Costa Rica, Perú and Colombia). These sites provide a stage on which to compare the introduction and effects of an intensive technology option: improved feeding systems for small-scale farmer milk and beef production. Nevertheless, the causal links between pasture technology intensification and deforestation are difficult to distinguish. This paper takes a step toward identifying the prospects of intensive pasture technology being able to affect deforestation.

The paper is ordered as follows: the first section is an overview of literature regarding the link between cattle and deforestation and situates improved pasture technology within the realm of intensive livestock technology options. In the second section, the discussion is focussed on if and how intensification of pasture technologies affects deforestation. Section three presents the hypotheses and analysis framework. In the fourth section, the three study sites are introduced along with the pasture technology options. Section five contains the empirical results of technology adoption and link between pasture technology and forest cover. The sixth section presents policy option and concludes.

Cattle, Pastures, Technology and Deforestation

It is difficult to distil the specific role of pastures and cattle within the larger issue of tropical deforestation. Even though deforestation can be directly linked with the growth of livestock, other complementary driving forces of deforestation are important to acknowledge. The relative importance of these forces can differ according to farm size and geographic location. To clarify the role of cattle in deforestation debate, the following section first places the issue of pasture and cattle in the larger context of deforestation, and second, specifies how improved pastures relate to the more general subject of intensive livestock technology.

Cattle within the Deforestation Debate

Since the early 1980s, a correlation between increasing pasture land and decreasing forest cover has been used in arguments to state that cattle production is a dominant driving force of deforestation (Myers, 1981; Shane, 1986). Even though pasture is often a final stage of a land use transition beginning from primary forest, many other factors are considered to be driving forces of deforestation. These forces can be divided into three general theories: 1) an expansion of human population, 2) the extraction and exploitation of natural resources, and 3) the role of government policies and structural factors (Hecht, 1993; Pichón, 1997). While these driving forces of deforestation do not necessarily lead to the expansion of pastures, they are often a necessary first step for it to occur. A large number of studies provide a wealth explanations of why pastures replace forests. Explanations can be divided into three principle themes. (adapted fromGodoy and Brokaw, 1994; Kaimowitz, 1996; Faminow and Vosti, 1998)

Governmental Policies Favouring Pasture Establishment

- Land tenure polices that require a demonstrative use of the land (often via pastures) in order to establish and retain property rights. (Mahar, 1989; Jones, 1990; Southgate et al. 1991; Binswanger, 1991)
- Government provision of input and producer-prices subsidies, financial credit and tax breaks for livestock. (Mahar, 1989; Binswanger, 1991; Schneider, 1995; Barbier and Burgess, 1996)
- Policies that depress timber values and make forest management less profitable. (Kishor and Constantino, 1994; de Almeida and Uhl, 1995)
- Reduced violence lowering the risk of ranching in isolated areas. (Maldidier, 1993)
- Development projects that provide alternatives to coca production, often promote livestock. (White et al. 1999)

Private Benefits of Livestock and Pastures

- Favourable international markets (Myers, 1981; Nations and Komer, 1982) and/or national markets (Schneider, 1995; Faminow, 1996) for cattle products.
- Attractive characteristics of cattle systems such as: low labour needs, management requirements, prestige value, transportability, limited use of purchased inputs, biological and financial flexibility, inflation hedge, and risk diversification. (Hecht, 1993)

Limits of Technology and the Environment

- The lack of other viable income sources because of declining agricultural yields. (Mahar, 1989; Seré and Jarvis, 1992) (Hecht, 1993; Thiele, 1993)
- Slow technological change in livestock management, which favours extensive production systems. (Serrão and Toledo, 1992)
- Degradation of pastures lead to their abandonment and further intrusion into the forest. (Toledo et al. 1989; Serrão and Toledo, 1992; Seré and Jarvis, 1992; Schelhas, 1996)

Given that tropical Latin America is a heterogeneous region, the above explanations should be viewed as a general presentation. Moreover, since the 1980s, governmental policies along with economic and environmental conditions have changed in the last two decades.

Improved Pastures within Intensive Livestock Technologies

In this paper we concentrate our analysis upon one facet of cattle production: improving pastures in milk and beef (dual-purpose) production systems. While there exist livestock management options such as specialising in dairy or beef, they are often larger-scale operations (Mattos and Uhl, 1994; Nicholson et al. 1995). Why focus the analysis upon improved pastures and for only small-scale farmers? There are two principle reasons, first small-scale farmers have a considerable effect upon forest margins, and second unlike other intensive technologies, improved pastures can be employed by small-scale farmers as well as the larger-scale producers.

First to illustrate the relative importance of small-scale farms and cattle, within many of the Central American countries farmers with less than 60 ha own approximately 40% of the cattle (see (Kaimowitz, 1996)for details). In Perú it is estimated that nearly 46% of all farms in the Amazon have cattle and 95% of them have less than 100 head (Instituto Nacional de Estadística, 1986). The impact of small-scale farms is analogous in the Brazilian Amazon, where according to Fearnside (1993), even though small-scale farmers hold 10% of the land they account for 30% of all deforestation activity.

Second, while there exist other technologies that can increase cattle production, such alternatives are not as divisible nor scale-neutral as improved pasture technologies. For example, many management options (use of feed supplements, rotating pastures, artificial insemination or establishing complex agro-silvo–pastoral systems) do not address the more urgent needs of the labour and capital scarce small-scale farmers, especially those who are on the frontier and have little access to these technologies.

How Can Pasture Technology Affect Deforestation?

The relationship between improved pasture technology and deforestation has been regarded as a quandary for years. For example in the early 1980s, the CIAT Tropical Pasture Program came under pressure to expand research efforts into the forest margins. Yet there existed a major dilemma. If new germplasm and management strategies were highly productive and sustainable, would they contribute to accelerated forest clearing? Or if nothing were done, would current management, which leads to rapid degradation and low productivity, accelerate clearing even more? (Spain and Ayarza, 1992) Almost a decade later, the issue was no closer to being resolved (Seré and Jarvis, 1992).

Two opposing schools of thought are found in the literature: improved pasture technologies either increase deforestation, or decrease deforestation. Little empirical evidence is used to support whichever argument. In this paper, in addition to providing empirical results, we add a third perspective: pasture technologies can also have no effect upon forest cover.

Technology Decreases the Push Forces into the Forest

Those who argue that intensive pasture technologies decrease deforestation, suggest that technological limitations in a tropical environment lead to severe productivity declines and thus force farmers to either fallow or abandon their cultivated land and clear more forest for pasture. The contention is that by developing new low-cost technologies, productivity can be maintained, thereby reducing deforestation.

Both small-scale and larger-scale farms can be affected by pasture technological improvements. Facing declining production levels especially with agricultural crops, small-scale pioneer settlers often sell their land to ranchers and migrate deeper into the forest (Jones, 1990; Thiele, 1993; Rudel, 1995; Nicholson et al. 1995). The assertion is that low-cost pasture technology permits small-scale farmers to raise cattle within their farming system, earn profits and reduce the incessant need to migrate into the forest. Larger-scale, established cattle systems also face a number of detrimental environmental factors. Pastures commonly suffer from a rapid decline in carrying capacity. Due to decreasing soil fertility, prolonged dry seasons, soil compaction, insect pests and weed invasions (Serrão et al. 1979; Nepstad et al. 1991). For example in Brazil, pastures established immediately after cutting the forest, permit a stocking rate of 2.0 head ha^{-1} for approximately four years. However in another three to six years, weed encroachment and declining soil fertility permit a stocking rate of only 0.3 head ha^{-1} (Serrão and Homma, 1993; Mattos and Uhl, 1994).

The implications of a declining carrying capacity are geographically widespread and increasing. For example by the late 1970s within previously forested regions of Brazil, approximately one-fifth of pastures (2.5 million hectares) were degraded or in an advanced stage of decline (Serrão et al. 1979). By 1990, at least half of all pastures (approximately 10 million hectares) had become degraded (Serrão and Homma, 1993). In many countries of Central America, varying degrees of degradation has also been documented (see Kaimowitz, 1996). It is the contention of the degradation-technology school of thought that new low-cost forages and management techniques will reduce pressure upon forest cover by making degraded and abandoned land once again productive.

Targeting pasture technology research outside forested areas was also hypothesized as being able to reduce pressure on forest cover. Smith et al. (1994) claimed that in South America '…[t]he savannah could provide an outlet for the economic objectives of national governments, and for venture capital, while relieving pressure for exploiting the forest margins.'

Technology Increases the Pull Forces into the Forest

The other school of thought, claiming that improved pasture technology increases deforestation, uses an economic rationale. The line of reasoning has two related components: intra- and extra- farm. The intra-farm argument follows something like this: improved pastures lead to higher productivity and therefore more profitable cattle systems. By being economically attractive, farmers then have increased incentives to convert their remaining forest to pasture.

The economic argument also works on an extra-farm level. By being a profitable and therefore an attractive investment opportunity, outside capital and people would flow into the frontier regions in order to establish more cattle ranches. Hence, forests would fall faster, leaving cattle to munch the tastier forages. Such a migration-effect logic also follows for any profit-increasing agricultural technology applicable to forest lands (Tomich et al. 1998).

No Effect: Technology is a Secondary Issue or Infeasible

With the existence of many factors that explain how and why pastures replace forest lands, the impact of technology intensification is perhaps minor. A windfall economic benefit from land speculation is surmised to be a primary factor (Kaimowitz, 1996). Yet in South America, the contributing role of land speculation to the spread of cattle ranching is under suspicion (Faminow and Vosti, 1998). The empirical evidence that supports the widely-held belief comes from one data set (Mahar, 1979). Subsequent data and analysis reveal that the real prices of farmland and pastures in the Amazonia were stagnant relative to the rest of Brazil. Thus, Faminow and Vosti conclude that the notion of large speculative earnings being consistent and widespread in the Amazon, is unfounded.

Another explanation exists decrying the secondary role of technology. (Nicholson et al. 1995) state that 'intensification of cattle systems is unlikely to alter dramatically the deforestation rate in Central America because consumer demand for livestock products is not the principle factor motivating most migration to forest areas.' While the logic of how consumer demand leads to intensification is not articulated, their argument reflects doubts regarding the potential of technology to decrease deforestation.

Furthermore, pasture technologies simply may be inaccessible or too expensive to implement for many farmers who live near forests. Besides some intensive management systems displaying agronomic and financial benefits are not always widely adopted. For the Western Amazon, Faminow et al. (1998) submit that other barriers to adoption include high price risks of the cattle products.

Framework and Hypotheses

Despite a recognition that the effects of pasture technology upon forest cover were not well known, the topic remains a relatively new research issue. A pair of factors contributes to the dearth of empirical research. First, before the early 1990s, much tropical pasture research contained vestiges of a Green Revolution motivation. The primary aim was to achieve sustainable productivity increases in the face of degrading tropical soils and weed/pest invasions. Second and closely related, data that link technology interventions of improved pastures with surrounding forest cover are scarce. Thus in order to increase the generality of the results with limited data resources, the analysis requires an alternative approach.

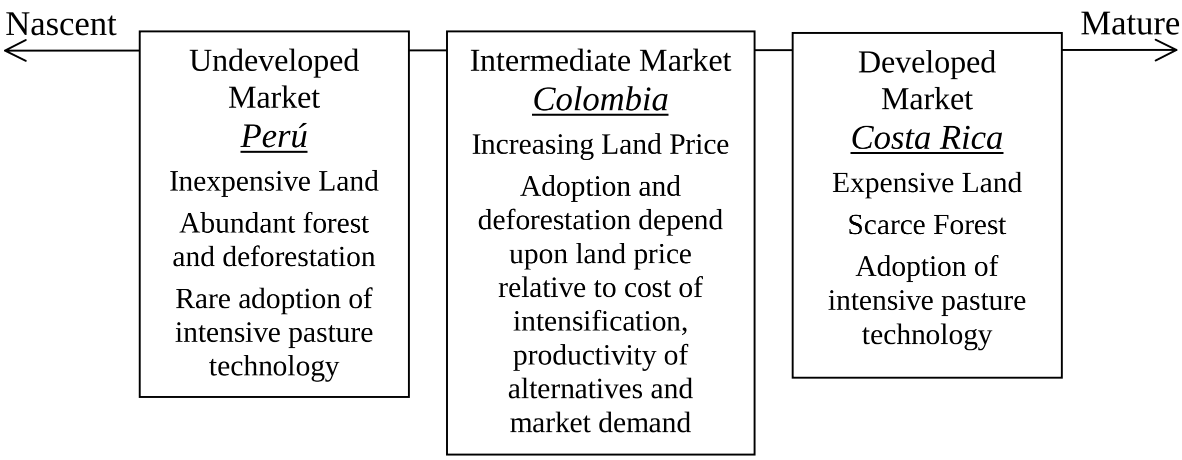
The following analysis synthesizes research results from different sites by means of their land use history. The framework permits a linking of evidence to test the general hypothesis: *forest scarcity is a pre-requisite for technology intensification*. At the centre of the argument is the farmer decision of land use. More specifically, a farmer has a choice between intensive (improved pastures) or extensive (forest clearing) land use options. The relation between intensive and extensive options leads to a second hypothesis: *intensification technologies can lead to a maintenance or expansion of forest cover only if they are a less expensive option than extensive growth*. The association between improved pasture technology and forest cover contains the combined issues of technology feasibility, adoption, and farmer incentives to preserve forests.

The literature presents a variety of studies of land use dynamics. They range from a focus upon a relationship between population density and land management intensity (Boserup, 1981; Serrão and Toledo, 1992), to ones that examine agricultural production changes and market access at the frontier (Henkel, 1971; Maxwell, 1980; Richards, 1997). The below land use continuum combines aspects of the above approaches to examine a dynamic trend demonstrated by *Tropileche* research sites.

Each of the study sites feature an array of local and national influences that affect land use decisions. They are divided into two general categories: bio-physical and socio-political-economic (Table 1). The first category, bio-physical, refers to agro-ecological conditions such as soil, slope and on-farm forest cover. The second general category, socio-political-economic, contains such factors as farm characteristics, markets, and policies (e.g. subsidized credit, extension-technical assistance, protective tariffs and land tenure).

Out of the set of influencing factors presented for each of the study sites, we distinguish one measure, land price, which captures the effect of two opposing forces: the level of development (i.e. market access) and the amount of forest cover. In areas where land prices are low, markets are immature and forest is relatively abundant. Whereas where land prices are high, markets are more developed and forest cover is scarce. Land price also serves as an *ex-ante* indicator for the feasibility of pasture technology adoption. On one side of the continuum lie nascent regions where intensive pasture technologies are not adopted (Figure 1). In these areas, adoption of intensive technologies, first step required to affecting forest cover, is not an attractive option. On the other side of the continuum, lie regions where improved pasture technologies are an attractive option and appear to be adopted yet the effect on forest cover is small since little forest remains. Nevertheless, there may be opportunity for reforesting land areas. An intermediate position along the continuum is where adoption is feasible and may reduce pressure on forest cover.

Figure 1. A Land Use Continuum with respect to Markets, Land Prices, Forest Cover and Technology Adoption



The Study Sites and Improved Pasture Options

In 1996 and 1997, data were obtained from characterization surveys by the *Tropileche* research consortium. Farms in these sites were chosen to validate new and promising forage germplasm and are representative of those producing milk in terms of farm size, input use, productivity, income and constraints (For details of the consortium see Holmann, 1998)

Costa Rica

The study site, Esparza, is located in the Central Pacific region of Costa Rica. Since settlers arrived here more than 500 years ago, the site is no longer considered a forest margin. Average farm size is 29 ha with 5% under perennial crops, 11% in seasonal agriculture, 75% under pasture, and 9% under forest (Centro Científico Tropical, 1994). The mean herd size is 43 head with an average stocking rate of 0.9 AU ha^{-1} (Fujisaka et al. 1997). Pastures are in different stages of degradation (i.e., severe on steep slopes and slight in the lowlands). Land values are high, averaging \$2,500 ha^{-1}, due to a long history of public-funded infrastructure investment (e.g. paved roads, electrification, health and education system) and close access to markets.

Colombia

A more recent forest margins site, Florencia Caquetá, is in the piedmont of the Colombian Amazon watershed. Settlers arrived in the 1900s and cleared most of the forest cover. Currently, the main agricultural activity is beef and milk production (87% are dual-purpose) for which Caquetá comprises 7% of the national herd, or approximately 1.1 million head. The stocking rate on native pastures is approximately 1.1 AU ha^{-1}. Farms are typically 150 ha in size and commercial land prices are moderate, ranging from \$400 to \$600 ha^{-1}, depending on farm location and soil quality. Approximately 10% of the typical farm is in forest and 58% in pasture (Rivas and Holmann, 1998).

Perú

The nascent forest margin study site, Pucallpa, is located in the eastern part of Perú within the Amazon basin. Settlement of the area began in the 1940s after construction of a linking road between Pucallpa on the Ucayali river, a major Amazon tributary, and the capital city of Lima. Unlike the two above sites, land uses in Pucallpa region are more heterogeneous in a manner where the current cropping/ranching activity is related to the number of years since the forest was originally cleared. Within the Pucallpa research site, the amount of remaining on-farm forest is inversely related to the time since settlement. In the more recent, 59% of the farm is forested, whereas in more mature regions forest coverage decreases to 40%. Ranchers have an average of 19% of their land with forest. Land area dedicated to pastures generally increases according to the age of the settlement. The recent settlers have about 10% in pasture whereas the more established have 19%. Cattle ranches have 66% of their land in pasture (Smith et al. 1999). The stocking rates on traditional pastures is approximately 0.6 AU ha^{-1} (Fujisaka and White, 1998). Land values are relatively low ranging from US$100 - 200 ha^{-1} depending upon the quality of road access.

Improved Pasture Technology Options: Legumes and New Brachiarias

The three technological options of the *Tropileche* consortium presented in this analysis include the establishment of a new grass variety (i.e. *Brachiaria*), a grass and legume association (i.e. *Brachiaria* with *Arachis*), and a cut-and-carry system with *Cratylia*, a leguminous bush that serves as a protein bank during dry months. Capital for establishment and annual labour requirements range from a low of $250 ha^{-1} and 7 man-days ha^{-1} yr^{-1} for *Brachiaria* alone, $300 ha^{-1} and 7 man-days ha^{-1} yr^{-1} in association with *Arachis*, to $400 ha^{-1} and 19 man-days ha^{-1} yr^{-1} for the *Cratylia* option. Pasture maintenance requires reseeding approximately every four years at a 25% of the establishment cost. To varying degrees in all sites, the improved forages produce an increase in both stocking rates and milk production. The performance by improved over native pasture ranges from a minimal increase (0.2 AU ha^{-1}, 0.3 kg $head^{-1}$ day^{-1}) in Perú from the *Brachiaria* option, to a large increase by the Cratylia (1.6 AU ha^{-1}, 2.0 kg $head^{-1}$ day^{-1}) in Costa Rica. Management strategies greatly affect results; Table 2 provides detail per option and site (Rivas and Holmann, 1998;

Holmann and Estrada, 1998; Holmann, 1998).

Empirical Results

The link between improved pasture technologies and forest cover is dependent upon farmer decisions regarding land use. Nevertheless, does improved pasture technology decrease pressure upon the surrounding forest by providing financial incentives to invest in an intensive rather than extensive manner? We address this question by examining the issues of technology adoption, the effect of land prices, and the link between technology and forest cover.

Technology Adoption

Each of the three sites presents a different adoption tale. In Costa Rica, the six-month dry season with resulting low forage output, is a common constraint that influences farmer decisions. To feed dual-purpose cows during those dry months, producers have adopted all three options, the grass, the grass-legume association and cut-and-carry systems. Overall, 15% of pastures are improved, ranging from 45% within small-scale farms to 5% in large farms (Fujisaka et al. 1997). This potentially counterintuitive result emanates from the fact that small-scale farms require more intensive land use strategies. Despite establishment costs, they more readily adopt the new technologies to increase stocking rates.

In Colombia during the last 10 years, cattle producers have had strong incentives to adopt new pasture technologies which are resistant to spittlebug (*Mahanarva spp.* and *Zulia colombiana*) as this pest reduces pasture biomass production by 30-35% (Daniel Peck, Colombia, 1999, personal communication). Use of the susceptible *Brachiaria decumbens* is giving way to the more resistant *B. humidicola* and *B. brizanthia*, which appear on 38% and 25% of the farms respectively. About 9% of farms have adopted the leguminous *Arachis Pintoi.* Although over 80% of the producers were satisfied with the performance of *Arachis* scarce capital resources limit further establishment (Rivas and Holmann, 1998).

The forest margins of Perú provide another distinct result. During the 1970s, *Brachiaria decumbens* was promoted as a means to improve pasture performance. Since native grasses such as *Torourco* species degrade relatively quickly, *Brachiaria decumbens* with its greater vitality has had high rates of adoption. From 1982 to 1996, Brachiaria use as a increased from 15.5% to 40% of total pasture cover (Riesco et al. 1986; Fujisaka, 1997). Yet, continued pasture technology improvement proves to be more difficult, especially in systems associated with legumes. Efforts to promote these leguminous forages face financial challenges as presented below.

Benefits and Costs of Pasture Investment

The feasibility of adopting improved pastures can best be examined by contrasting their financial performance with the option of purchasing more land or clearing remaining forest, and expanding pasture area. Financial benefits and costs refer to the private landholder. While there may be societal benefits and costs, they are likely to be much less important to issues of adoption and the technology-forest cover link, and hence are not addressed in this paper. For more information regarding societal benefits see (Nations, 1992; Toledo, 1992). Below is a financial benefit and costs analysis of the improved pasture options and their comparison with the extensive alternative.

Labour inputs are assumed to be the same across all countries because labour productivity is likely to be similar. For small-scale farmers although improved pastures require increased labour inputs for their maintenance, the large initial establishment cost is the most severe limitation to adoption. Thus it is illustrative to compare the costs of pasture options. To make the intensive and extensive options comparable, we examine their production levels, which include the stocking rates and milk production.

Benefits from improved pasture investments are realized over time. Thus in order to determine the financial performance of improved pastures, cash flows of both benefits (increased milk and beef production) and costs (establishment and maintenance) need to be summed and compared accordingly. A useful measure by which to examine an investment over a time frame is the internal rate of return or IRR. By definition, the IRR is the interest rate received for an investment consisting of payments and income that occur at regular periods.

For the three sites, a 12-year time frame was employed to compare the IRR performance of the improved pasture options (Table 2). In Costa Rica, the IRR ranged from 10.1% for the *Brachiaria-Arachis* association to 12.3% for Cratylia. For Colombia, the IRR of an improved legume-based pasture (*Brachiaria decumbens* and *Arachis pintoi*) pasture is approximately 19%, whereas the IRR for *Brachiaria decumbens* option is 12%. In Pucallpa, the *Brachiaria decumbens* and *Arachis pintoi* association has an IRR of 9.8%. Even though the local real interest rate exceeds the IRR performance of the improved pastures in all sites, farmers adopt the technologies by self-financing the establishment costs.

Direct comparison between the improved pasture and the extensive alternative requires examination the establishment costs. Included within the improved pasture cost estimates are those of pasture establishment; the extensive option also includes fencing costs. At the Costa Rica site, the total capital investment per hectare for the extensive option is about US$2,600. In comparison, the investment required to adopt the *Cratylia* option is approximately US$ 400 ha^{-1}, which permits a 89% of stocking capacity and 92% of the milk production as doubling the pasture area. For Colombia, the total investment cost of native pasture land is $830 ha^{-1}, whereas an additional investment of $780 is required to establish and stock an improved pastures with *Brachiaria/Arachis*. The legume association produces 83% of the cattle and 75% of the milk that the extensive option provides. In Pucallpa, an additional native pastures cost approximately $450 ha^{-1} whereas the additional investment to establish an improved forage alternative is about $250. This latter alternative holds 93% of the stock and produces 56% of the extensive option.

Land Price: An Ex-Ante Indicator of Adoption Potential

The above *Tropileche* experiences lead to the question: what determines adoption of a specific intensive pasture technology option? Despite a list of potential influencing factors, commercial land price appears to be the single most important force that drives the decision to invest in improved forage technologies. As land price rises, the possibility of increasing farm size becomes more difficult since capital is the most scarce resource. Thus, high land prices induce farmers to adopt improved forage alternatives in order to enlarge herds with less cost. Land costs range from a high in Costa Rica of \$2,400 ha^{-1} to a low of \$150 ha^{-1} in Perú, with Colombia at \$450 ha^{-1}. Generalizing, the cost of the commonly adopted technology increases as land price increases.

Evidence from the sites suggest that higher land prices result from market maturity as defined by demand (quantity and quality of milk) and ease of transportation (short distance and good roads). The value of market access is capitalized into the price of land. Each of the sites represent a different level of market involvement and associated land price, following that of the land use continuum (Figure 1). For example the Costa Rica site, fluid milk is supplied to a central processing facility and thereby captures a high value. In Florencia Colombia, the milk produced is used to satisfy industrial demand. A satellite processing facility condenses the liquid for subsequent processing at a central metropolitan facility, in order to lower transport cost. On the other hand in Pucallpa, efforts to attract investment to construct a milk processing facility have been unsuccessful. To illustrate, a Nestlé supply requirement (200,000 litres of milk day^{-1}) prevents establishment of a processing facility in the region. Other considerations include poor quality of the surrounding roads and long distance to adequate market(s).

The Link between Improved Pasture Technology and Forest Cover

To examine the impact of improved pastures upon forest cover, we employ two methods, one, a cross-sectional analysis of the threes sites using a land use history framework, and two, a time series comparison of one site, Florencia.

With respect to the land use continuum, Pucallpa lies on the nascent side. (Figure 1) Improved pasture technologies are not a viable option for most farmers. It is much less expensive to purchase more land than to intensify current land holdings. Since the necessary first step of a two step process, technology adoption, is not feasible, there is no or little impact of improved pastures upon forest cover. Thus Pucallpa area remains in a trap: little demand for milk products because of insufficient supply and low supply because of insufficient demand. In light of the frustrated attempts to promote new pasture technologies in the region, *Tropileche* is in the process of redirecting research efforts. These results match those found in western Brazil. Despite 25 years of research and promotion, improved pasture technologies and livestock management systems have not been adopted by most small-scale farmers. (Faminow et al. 1998)

Brachiaria in Pucallpa demonstrates that, technology adoption is not necessarily intensification. Before it was an intensivie technology introduced on ranches, but it is now easily propagated and grows vigorously. In addition, there is a perverse result regarding *Brachiaria* adoption and forest cover link. The current situation of low stocking rates in the region, compounded by political instability during the late 1980s, has led to a biomass supply that exceeds cattle demand (Fujisaka and White, 1998). In some cases, *Brachiaria* has become a weed and flammable fuel that often permits fire to spread into the surrounding forest.

On the mature side of the land use continuum appears Costa Rica. The first step, adoption of improved pastures, is financially feasible. Yet the ability of technology to affect forest cover is tenuous. Current deforestation in this region is not an issue, as it occurred decades ago. Rather reforestation of marginal agricultural and pasture lands seems to be a thrust of the government and development community. It would be erroneous to attribute intensive pasture technologies as being the primary impetus for reforestation efforts, especially with the possible existence of other influences such as policy. Perhaps as we argue below, government policy initiatives are required to either protect forest cover or reforest.

Lying between sites of Perú and the Costa Rica, is the intermediate example of Colombia. A time series result suggests that improved pasture technology does reduce pressure upon forests. A 1986 survey found that on average, 7% of farm area was forested and 26% was under improved pastures (Ramirez and Seré 1990). In 1997, improved pasture area increased to 58% and, albeit not statistically different from zero, forest area increased to 10% (Rivas and Holmann, 1998). Presently, the increased biomass production appears to have exceeded the ability of herds to consume it. Thus there is little financial incentive for farmers to expand into the surrounding forest.

These Colombian results have two caveats. First, whether or not this land use outcome is temporary or permanent is unknown. Factors such as an abundance of feed supply coupled with a limited ability to increase herd size (with the binding constraints of capital and biological herd growth) may lead to a mere short-term pressure reduction upon forest cover. Hence, this pasture-forest relation may not be an equilibrium state. As years go by, the constraining factors affecting the land use decisions of farmers are likely to change.

Second, the above results were reported in percentage terms. Over the eleven year span, farm sizes grew from an average 131 to 158 ha. In absolute terms, improved pasture coverage increased from 33 to 91 ha while average forest cover increased from 9 to 16 ha. While the increase in farm size appears to be the result of consolidation with neighbouring ranches, there may have been some encroachment into forests. Thus, the overall result upon forest cover at a regional level may not be as clear.

Conclusions

A synthesis of research evidence regarding the effect of improved pasture technology upon forest cover has resulted in an alternative hypothesis. *Forest scarcity is a pre-requisite for technology intensification*. A land use continuum provides a context for the shift in causality. On one side of the continuum representing nascent regions with low land values, both continued deforestation and extensive cattle production appear to be rational private choices. The Peruvian Amazon is an example of such land use. As land use becomes more mature, with less forest and better developed markets, land prices rise. In Colombia and to a greater extent in Costa Rica, farmers intensify production in order to avoid degradation of pastures and the higher cost option of expanding onto neighbouring lands. Hence, the price of land captures the influences of a range of bio-physical and socio-political-economic factors, thus producing a simple decision rule that mirrors the second hypothesis. *If it is cheaper to intensify production than to cut surrounding forest or purchase more land, then improved pastures are an attractive and adoptable technology.*

The most apparent technology-forest cover link, in Colombia, is likely to be ephemeral. Policy interventions will likely be needed in order to achieve long-term success in controlling deforestation. In tropical Latin America where land degradation can spur further deforestation, technological advances that make land productive again are a critical component of a policy response. Yet minimizing deforestation and land degradation are but two environmental objectives. A concurrent issue is the human welfare of the people living at the forest margin. Technical advances such as improved pastures will achieve these multifaceted objectives of human welfare and environmental quality as long as they are properly targeted and coupled with policies that will restrict deforestation or make it an unattractive financial alternative. To achieve these goals, some policy options are presented below. (Also see Ledec, 1992; Nicholson et al. 1995; Kaimowitz, 1996).

Protected Areas. National parks and reserves can be an effective policy option to maintain forest cover. Yet issues regarding property rights, governance, land encroachment, etc. can be especially challenging. One fact of interest- the U.S. national park system was maintained and patrolled by the armed forces during the first 40 years of their existence. This statement is not to espouse military involvement but is rather used to illustrate the magnitude of effort that may be required to enforce the policy.

Extractive reserves make land with standing forest more valuable. The promotion and development of non-traditional forest products is such an initiative that can provide private incentives to use forests. (Kishor and Constantino, 1994; Rice et al. 1997)

Targeted Agricultural Research. One challenge of many universities, national and international research centres is to continue developing new agricultural and livestock technologies. Closely associated is the need to target the research domain. Credit, tax and land reform policies are incentives to rehabilitate degraded lands for either improved pastures, agricultural use or reforestation.

Public Conservation Payments. These may come in many forms with similar goals such as reforestation campaigns and carbon sequestration payments. Particularly tricky can be the longer-term effect of these policy interventions. Reforestation may not result because of an inappropriate incentive structure. For instance, typically reforestation is concerned with the number of trees planted not with those that actually grow. Even more challenging is the establishment of a functioning carbon sequestration payments system. In theory, private landholders receive monetary compensation for the public services they provide. Market mechanisms, monitoring and accountability are current themes under development. (Swisher and Masters, 1992)

Private Market Cattle Product Certification. Could milk processors mandate intensive ranching practices such as use of silvo-pastoral agroforestry systems or intensive pasture management? Enforcement could be performed by the private sector if incentive-compatible structure were in place. While marketing benefits accrued from producing a 'green' product may be sufficient to cover costs, the media/public may need to monitor the private sector.

While unpleasing to some, the future of forest margin regions will continue to have cattle because of producers and consumers demands. In many frontier regions, farmers are searching for land use alternatives. Example of desperation are the Pucallpa farmers who establish pastures without having cattle. The mere hope of having cattle is enough to force the land use decision. Moreover, consumer demand increases for animal products are expected to be especially large. For all developing countries, the expansion of the livestock industry with annual growth rates from 1982 to 1993 (7.4% for poultry, 6.1% for pork, 5.3% for all meat and 3.1% for milk) is so great that an IFPRI/FAO/ILRI (1998) study calls it 'The Next Food Revolution.' Whether the necessary increases in agricultural and animal production will be extensive or more intensive/commercial, is open to debate (May and Segura Bonilla, 1997).

Thus, the implication for research then shifts from examining the positive or negative impacts of intensification on deforestation to one improving the feasibility of adopting intensive technologies. The goals of future research are then to provide alternative land uses whereby deforestation and extensive land use will no be longer the farmers' most attractive option. To address the issue, two concurrent efforts must take place: technical research, to increase productivity and prevent land degradation coupled with policy analysis and implementation to increase incentives for forest preservation while addressing farmer objectives.

[1] Central and South America, except the Southern Cone (Argentina, Uruguay and Chile).

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Table 1. Summary of Influencing Factors of the Improved Pasture Technologies - Forest Cover Link

Influencing Variable	*Costa Rica*	*Colombia*	*Perú*
Bio-physical			
Soil Productivity	Good	Poor	Poor
Farm in forest (%)	9	10	32
Pasture Degradation			
Via Erosion	High	Low	Low
Other Means		Spittlebug	
Socio-political-economic			
Farm Characteristics			
Size (ha)	90	150	30-50
Land Price (US$)	2,400	450	100-200
Off-Farm Work Potential			
Permanent	High	Low	Low
Seasonal	High	Low	Moderate
Market Conditions	Good	Fair	Poor
Milk price	0.28 (cooled)	0.23	0.22
Market demand	High	High	Low
Transport Cost (% milk price)	7	10	8
Ave. Distance to Processing	60 km	80	---
Milk processing facility	high value	industrial grade	none
Public Policies			
Milk Tariffs	104	30?	0
Credit (real interest rate)	14	23	34 if possible
Extension Service	Good	Limited	Limited
Land tenure problem	No	No	No
Years since Initial settlement	200+	40-80	1-50

Table 2: Costs (Labor and Capital) and Benefits of Pasture Options

Country and Pasture Technology	*Labor Input* (man-days ha^{-1} yr^{-1})	*Labor Costs* (\$ ha^{-1} yr^{-1})	*Capital Input* (\$ ha^{-1})	*Stocking Rate* (AU ha^{-1})	*Milk Production* (kg $head^{-1}$ day^{-1})	*IRR* [a] (% yr^{-1})
Costa Rica						
Native	3	30	-	0.9	4	-
Brachiaria	7	70	270	1.3	5	9.4
Brachiaria / Arachis	7	70	300	1.5	5.8	10.1
Cratylia	19[b]	190	395	2.5	6.0	12.3
Colombia						
Native	3	39	-	0.9	2.4	-
Brachiaria	7	91	270	1.2	3.0	12
Brachiaria / Arachis	7	91	300	1.5	3.6	19.3
Perú						
Native	3	12	-	0.7	2.5	-
Brachiaria	7	28	50-250	0.9	2.8	0-12
Brachiaria / Arachis	7	28	280	1.3	3.3	9.8

[a] Lactating herd is 60% in Costa Rica, 58% in Colombia, and 41% in Perú.

[b] Labor input only during the dry season