Grasslands, cattle and land use in the neotropics and subtropics

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September 23, 1996

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Abstract

The paper reviews trends in land use change in the tropics and subtropics of Latin America and the Caribbean, and their relation to the evolution of the cattle industry in the region. It is posited that horizontal expansion is nearly finished, and that cattle sector, and the grasslands that support it, are ibeginning to intensify. Nevertheless a number of paradoxes subsist and are discussed. Most notable among these are the interactions among land speculation, a characteristic aspect of much of the extensive cattle industry throughout history, with policies and technologies. An overview of grassland-based cattle systems is given and their social, economic and environmental are discussed, showing some of the tradeoffs between intensification, equity and environmental impact. In this context, the desirability of integrating the crop and cattle enterprises is pointed out, and some of the barely incipient trends are identified. The potential benefits brought about by public sector funded research on tropical pastures has been simulated and is summarized, iimplying that this area of investment has been systematically underfunded. Lastly, the overriding importance of policy changes, and their close interactions with technology developments are analyzed based on simulations ran for the region, and it is concluded that grassland and animal scientists should become more involved in policy debates regarding development of the sector and its environmental implications.

Keywords: Tropical Latin America, cattle, grasslands, trends, development, policy, production, consumption

Introduction

Latin America and the Caribbean (LAC) is a highly diverse region, both between and within countries. Nevertheless, during the 1990's national economic and development policies have rapidly changed, and the macroeconomic context for agricultural development is more uniform across the subcontinent than in the past. In this scenario of changing policies, past diagnoses and remedies have become rapidly outdated (Jarvis, 1986; Smith et al.,1996a).

Cattle, sheep and goats are bred and fattened almost exclusively on forages, and most of them are grazed year-round. Historically, traditional systems such as extensive cow-calf operations and other low input/low output grazing systems based largely on native grasslands, have had internal rates of return (IRR) of 3-6% without considering appreciation of land values (Vera and Sere, 1985; Jarvis 1986); nevertheless, the expectation of land appreciation has been one of the driving forces behind horizontal expansion of the industry in the agricultural frontier of South America (e.g. Smith et al., 1996b). These extensive systems which will soon become nearly extinct, have been highly sustainable (Eden, 1990), and graziers in the frontier areas have shown relatively little sensitivity to changes in beef prices (Kaimowitz, 1994). This phenomenon is explained by a complex of factors, including the fact that historically, these systems have experienced unfavourable input/output price ratios, leading to a cost structure that includes very few purchased inputs. Nevertheless, with a few exceptions along parts of the Amazonian rainforest of Brazil and Bolivia, the horizontal expansion is nearly finished.

The opening up of the national economies to international markets that has taken place in the late 80's and early 90's, has brought about major changes in land use, most of which are yet not adequately documented. The cereals and oilseeds sectors

were the first to experience revolutionary changes (see for example, Barkin et al., 1991). These in turn appear to have influenced the spatial distribution of the swine and poultry industry which are so dependent on cereals and oilmeals. The phenomenon is most notable in the large area of tropical grasslands, or *Cerrados*, of Brazil, and in the mid 90's there is circumstantial evidence that it is beginning to influence also the beef and milk industries via the use of oilmeals and grains in the finishing phase of young steers.

Population, consumption and production

LAC is very different from other developing regions in Africa and Asia. Its population is relatively low (Table 1) and, more importantly, it is largely urban. Current trends predict that by year 2005, 85% of it will be urban, a percentage larger than that of Europe. That figure has already being achieved in some countries and subregions within countries, most notably in parts of the core Cerrados and in South America southern cone. Another distinguishing trait of the region's endowment of resources, is large land availability per capita (Table 1), though its distribution is largely skewed. The region's cattle herd is very large relative to the human population (Table 1). Five countries (Argentina, Brazil, Colombia, Mexico and Venezuela) account for 86% of the total cattle herd, over 80% of the beef and milk production of the subcontinent, and 78% of the pasture lands. Associated with land and cattle availability, the ratio of area occupied by grasslands and cattle, relative to that of crops, is higher than the world's average (Table 1) and is several times higher than that of the rest of the developing nations. In this context, it should be noted that the largest world reserves of arable land are located in Africa and South America, where only 21% and 15% respectively of the potential agricultural land was being used in the early 80s (Dudal, 1982).

There is a close correspondence between the pattern of land use described above and dietary habits that dates back to the time of the Spanish conquest. During the

last two decades, meat consumption in LAC has ranged between 35 and 40 kg/capita.year, 50% of it being beef. In TLAC, beef consumption per capita in 1995 was 16 kg (FAO, 1996); this compares with about 5 kg in Africa and 2 kg in the Far East. Milk consumption in TLAC over the period 1986/93 averaged 96 kg/capita.year, which is above the world's average, and is three times higher than that of the rest of the developing world. Per capita protein consumption in LAC ranges between 65 and 70 g/capita.year, which is similar to the world's average, but 40-45% of it is of animal origin. This is twice as much as that of Africa, and the Middle and Far East.

Studies conducted in both rural and urban populations of a number of TLAC countries (Rubinstein and Nores, 1980; Sanint et al., 1985) have shown that income elasticies for beef and milk are very high (Table 2), particularly among the two lowest quartiles of the population (~~approximately~~ 40% of the region's population), and that beef and milk account for 25-33% of the total food expenditure of that segment of the population. These high income elasticies constitute an exception among agricultural products, shared only by vegetables, fruits, vegetable oils and fish and seafood (de la Vega, 1996). Thus, it should not be surprising that the growth rate of demand tends to be higher than that of the supply (Table 2), particularly in view that many governments have historically considered beef and milk as wage goods (Jarvis, 1986), thus keeping prices to the consumer under tight control.

Paradoxes of Development

The coexistence of high demand and dietary preference for beef and milk, with government reign over prices, and with high expectations for land appreciation in the frontier areas has historically explained the extensiveness of much of the cattle industry in LAC, a situation that has begun to change since the mid 80's.

Large portions of the estimated 590 million hectares of grasslands in LAC (Table 1) are contiguous, such as the majority of the 250 million ha of neotropical savannas (Bolivia, Brazil, Colombia, Venezuela), the approximately 75 million ha of tropical forests converted to pastures (Kaimowitz, 1994) in South and Central America, and the 84 million ha of temperate Pampas and subtropical native grasslands (Solbrig and Vera, 1996). On the other hand, derived grasslands in the low-mid altitude hillsides of Central America and the Andean foothills and valleys are highly fragmented.

Native grasslands throughout LAC are under threat. Since the late 80's there has been a pronounced process of "agriculturization" of the Pampas, subtropical grasslands and parts of the neotropical savannas, driven largely by the expansion of soybeans that in 1995 were cropped in over 20 million ha, and other crops also. Cattle from the Pampas, Andean valleys and foothills, and other areas have increasingly been displaced to more marginal areas (Figure 1) which explains the sustained low apparent productivity of cattle in TLAC.

Consistent with the above view, and largely driven by policies, is the large expansion of pastures and cattle in the Amazon rainforest and tropical forest areas along the Caribbean coast of Central America and Mexico. Numerous authors have satanized the cattle industry in those areas, but current analyses have consistently identified misguided government policies as the main culprit for deforestation in a variety of countries (Sherbourne et al., 1991; Jones and Painter, 1995; Kaimowitz, 1994; Skole et al., 1994). Similarly, it has been recognized that "...pastures returning to forests are the dominant features in the culturally modified areas" and that "..the succesional process that cattle ranchers decry as pasture degradation, ecologists welcome as return to the forest" (Moran et al., 1994). Many institutions and scientists in the region also hypothesize that the sustainable intensification of crop and cattle production in the neotropical savannas would constitute an

alternative to the continued advance of the agriculture frontier in the Amazon, at least in the medium term.

At the same time that these shifts in land use patterns are ongoing in the frontier, the reverse process is occurring in some traditional agricultural areas. In the mid 90s sown grasslands and intensively grazed beef and milk cattle are beginning to replace traditional crops such as coffee and maize-beans associations in many hillsides areas, cotton in flat lands, and maize plantations in highland plateaus of Mexico and some Central America countries (Vera, pers. obs.; Estrada, pers. comm.; Bellows et al, 1996). These changes are closely associated with changes in the international prices of those commodities (e.g. coffee, but also due to the spread of pests; cotton, maize) and removal of trade barriers (importation of cheap maize from the US). During the 80s, the price of cotton decreased 1.4%.year^{-1}, sugar 8%.year^{-1}, and coffee 5.3%.year^{-1} (de la Vega, 1996). During the early 90s there has been some recuperation of these prices, but the cumulative effect is still negative, thus explaining the recent increase of cattle production in some of those regions.

Recent studies have shown the complex interactions between land appreciation, policies, agricultural technology, intensification of the cattle industry and issues of natural resource management. Smith et al.(1996b) have shown the rationale for the existence of extensive production systems on native savannas of Colombia when land prices are stagnant at low levels; under these circumstances, resource degradation is unlikely. As infrastructure improves, land prices may increase rapidly and capital gains dominate profitability; thus, only technologies that will lead to spectacular increases in productivity can induce intensification (e.g., the 10-20 fold increase in beef production per ha on grass-only pastures relative to native rangeland in Colombia). Once land prices plateau at high levels, as in established ranching and farming areas of the Brazilian savannas today, farmers may be more open to technological advances even if the production gains are not dramatic (e.g.,

grass-legume versus grass-only pastures). The tradeoff may well be that natural resources such as native grasslands, gallery forests, and water sources may be threatened with extinction in this phase. Their protection will need new policies which internalize the environmental services of these resources.

Cattle production systems: pros and cons

As indicated above, TLAC is a highly diverse region. The same applies to extant grassland-based cattle production systems in the neotropics. The main characteristics of these systems are summarized in Table 3. As suggested there, beef and milk production have tended to favor the replacement of neotropical savannas by sown pastures based exclusively on introduced grasses of African origin. Various current estimates imply that 20-25% of the neotropical savannas have been sown to these grasses (largely *Brachiaria spp.*) and that up to 10% of the area has been converted to intensive annual and perennial crops.

In general, there is as yet, limited purposeful within-farm integration between the cattle and the crop enterprises, though there are some encouraging signs of it in the "core" area of the Brazilian Cerrados, a trend-setting region for the rest of the South American tropics. Recent developments of new crop (rice, soybeans, maize) cultivars well adapted to acid soils may accelerate the development of purposefully integrated crop-cattle systems, but their feasibility will continued to be governed by international prices. As long as many northern countries continue to subsidize cereal grains, the competitive ability of tropical areas will be hampered.

Low intensity, low yielding dual purpose systems (Table 3) in which *Bos indicus x B. taurus* crossbred cows are milked once a day provide 40% of the milk produced in TLAC, and represent 75-80% of the milked cows (Rivas, 1994). The economic advantages of these systems have been well documented (Sere and Vaccaro, 1984). In essence they employ resources with low opportunity cost (e.g., family

labor), economic risks are very low, they provide extreme flexibility in terms of cattle management and feeding, 80% of the capital is represented by land and cattle, and they are most frequently operated by small and medium farmers. Nevertheless, in the mid 90s there are signs of rapid intensification of these systems as well, with implications in terms of capital requirements, more diversified feeding systems of higher quality, somewhat less dependence on directly grazed forage (particularly during the dry season), use of conserved forages, and the adoption of improved animal genotypes. In fact, there is ample evidence that dual purpose systems rapidly intensify in response to improvements in transport and marketing infrastructure, and new technological options such as improved pastures (Ramírez and Seré, 1990; Michelsen, 1990).

Important social and environmental impacts of some of these systems are listed in Table 4. Some of the impacts are well documented in the literature, but many of them have received scant attention as yet. Frequently, there are tradeoffs between intensity and efficiency of these systems, and social and environmental impacts. For example, cow-calf operations are highly compatible with the maintenance of low quality but abundant and diverse neotropical savannas; in turn, these systems do not generate labor opportunities and constitute low output systems. Dual purpose systems, although relatively extensive also in terms of land use, maximize use of family labor but in frontier areas there is evidence of deforestation of gallery forests in the savannas and of rainforest degradation (Franz and Pimenta da Aguiar, 1994).

More intense and efficient grass-based beef and milk production systems have led to replacing native rangelands with large areas of monospecific introduced pastures. Current estimates (H. Zimmer, pers. com.; Macedo, 1994) suggest that there may be 50 million ha of pastures sown with only 3-4 genotypes of *Brachiaria spp.* across tropical South and Central America. Some authors have expressed concern about the danger of colonization ("Africanization") of the neotropical savannas by

some of these species (Inchausti, 1995.) but the phenomenon, if real, appears to be associated with small niches (Klink, 1994). A much larger risk is that due to the spread of potentially devastating pests, as the well known case of *spittle bug* (*Anaelomia sp., Zulia sp.*) on *Brachiaria decumbens* has shown (Lapointe and Miles, 1992). There is some evidence that where this risk is high, farmers attempt to buffer future risks by undergrazing and deferring pastures, an strategy that on the long term favors the build up of the pest and lowers efficiency of pasture use.

The temporal and spatial integration of grass-legume pastures with annual and other crops is generally deemed as highly desirable (see for example Vera et al., 1992). Indeed, in the temperate Pampas of Argentina, the wheat-alfalfa system was highly successful for over 50 years, until it begun to be replaced by the more profitable wheat-soybeans rotation and other crop-only systems(Solbrig and Vera, 1996). Despite the existence of appropriate components and technologies for implementation of neotropical ley farming systems, there has been limited adoption of those systems. Alternatives such as the periodic rehabilitation of grass-only pastures with fertilized annual crops (Vera et al., 1994) such as maize, sorghum, upland rice millets or soybeans appear to be more acceptable in areas of the Brazilian Cerrados (H. Zimmer, pers. comm.). It is also hypothesized that forage legumes may enter these systems, but initially mainly as cover crops in zero tillage systems, and as green manure in minimum tillage crop-based systems. Similarly, it is hypothesized that grass-legume pastures and "protein" or legume banks may constitute a suitable step in the gradual intensification of dual purpose systems located in regions with reliable milk markets (Vera et al., in preparation).

The most controversial issue is the intensification of pasture-based beef and milk systems in the rainforest areas. Brazilian researchers have convincingly argued in the last few years that this process is not only technically and economically feasible, but that it is more sustainable than the use of extensive pastures and that is being increasingly adopted in some of the oldest settlement areas such as in

southern Para State (Serrao and Homma, 1993; see specially Mattos and Uhl, 1994). In another development, pasture technology developed by CIAT for the savannas has been adapted by ICRAF for the Peruvian rainforest, essentially by combining tropical legumes with annual and plantation crops such as peachpalm and other agrosilvopastoral systems; some of these systems have withstanded the test of time under experimental conditions. Similarly, the upland rice-pasture system developed for the neotropical savannas (Vera et al., 1992), has been successfully tested in the Peruvian and Brazilian rainforest (Vera, pers. obs.; Furley, 1994). Conventionally established grass-legume pastures grazed by milking cows and receiving no chemical inputs, have persisted 8-10 years in farmers' fields provided they received adequate grazing management (Reategui et al., 1995). As a matter of fact, Torres Zorrilla (1994) has documented the very low environmental impact of the intensification of tropical milk production in Costa Rica, and has argued that it has been associated with decreased deforestation. Working in the Ecuadorian rainforest, Ramírez et al. (1992) concluded that the on farm introduction of a tropical legume, *Desmodium ovalifolium*, as cover crop in coffee plantations, together with improved agroforestry practices and the use of grass-legume pastures is profitable, and provides improved cash flow and system productivity. Nevertheless, they also recognized that the design and implementation of appropriate policies constitute essential prerequisites for successful adoption of these technologies and for internalization of social costs associated with changing land uses.

As Mattos and Uhl (1994) argue *"..the debate is no longer whether or not cattle belong in the Amazon. Ranching is in the Amazon to stay".* The real issue is how to make cattle rearing in the rainforest areas more resource-friendly, and this most likely implies more intensive, knowledge-based, grazing and feeding management, and the setting up of an appropriate policy context (Nores and Vera, 1993; Nicholson et al., 1995).

In the last analysis, this same argument is applicable to all of the most productive, efficient, and resource-conserving systems listed in Table 4 (Vera, 1996).

Pasture research in TLAC: is it enough?

Research on tropical and subtropical pastures in LAC has traditionally been conducted by the public sector, although with large differences between countries in the amount and quality of resources allocated to it. Given the importance of the grassland-based system of beef and milk production, it is timely to ask whether resources assigned to researching these systems and its components have been sufficient. A partial equilibrium model was applied by Rivas (1996) to assess the returns to research on 24 different pasture technologies for the savannas, forest margins and mid-altitude hillsides in the tropics of South America. Assumptions regarding probability of success in the development of each of the technologies, time horizon for adoption, the size of the impact area (3% of the savanna grasslands, 18% of the pastures in the rainforest, and 32% of the hillsides grasslands), and technical coefficients were highly conservative. Long term growth rates of demand and supply , and price elasticies were used (Table 2). Over a period of 35 years (1994-2029), the net present value (NPV) of the derived benefits amounted to US$ 4 billions, or an internal rate of return (IRR) of 55%. It was further shown that pasture technologies directed at the savannas and deforested forest margins ecosystems accounted for the bulk of the benefits. In terms of the social distribution of the projected benefits, it was estimated that 87% of them would accrue to consumers, and that roughly one-half of these benefits would be received by the two lowest quintiles of the population (consumers and small farmers). Lastly, linkages with other sectors of the economy were large, and every dollar of income in the cattle sector generated 0.55 dollars in other sectors. Nevertheless, the environmental impact of these technologies could not be accommodated in the analysis.

This, and similar analyses made earlier on (Jarvis, 1986), suggest that research on tropical grasses and legumes has been systematically underfunded in LAC, an statement that is further supported by examinining the human and financial resources deployed in the region (RIEPT, 1987).

Conclusions: pasture research in the larger context

There is no doubt that the pasture-based cattle industry of TLAC will continue to be of major significance in terms of land use and economic activity well into the next century. This scenario, and the economic analyses summarized above, would argue for continued allocation of public and private funds to technology generation. Nevertheless, there are at least two dimensions of the problem that have received limited attention thus far.

Firstly, current trends in LAC favor a decrease in the size and funding of the public sector. Many of the formerly public sector funded activities are being increasingly privatized, including agricultural research. It is generally agreed that some of the benefits of agricultural research can easily be appropriated by the private sector (e.g., improved cultivars), but the issue of funding research on the environmental consequences of new policies and technologies, and the simulation of alternative development paths for the farming sector is not easily privatized nor has it being the subject of debate in the LAC societies.

Secondly, limited simulation of alternative land uses in which pastures and cattle continue to assume major roles, shows the highly synergistic effects of appropriate policy scenarios and technologies (Smith, Winograd, Gallopin and Pachico, in prep). These simulations suggest that a combination of policies and technologies can control the expansion of the agricultural frontier in tropical America, and can achieve environmental protection without sacrificing agricultural production. It is highly suggestive that simulated results indicate that the impact of policy is four

times larger than that of technology in both the Amazon and the Cerrados. Furthermore, "results reveal that incorporation of environmental concerns in technology development strategies has minimal impact on frontier expansion if policies remain unfavorable, particularly in the Amazon" (Smith et al., in prep.).

The unavoidable conclusion is that, as Nores and Vera (1993) suggested in the previous IGC, science and grassland scientists have to more actively contribute to the societal debate so that policy adjustments are made based on scientific facts.

References

Arango-Nieto, L., A. Charry and R. R. Vera, eds. (1989). Panorama de la ganadería de doble propósito en la América Tropical. ICA-CIAT, A. A. 151123 Eldorado, Bogotá, Colombia, 313 pp.

Barkin, D., R. L. Batt and B. R. DeWalt. 1991. The substitution among grains in Latin America. In M. J. Twomey and A. Helwege, eds., Modernization and Stagnation in Latin American Agriculture into the 1990s. New York, NY: Greenwood Press, pp. 13-54.

Bellows, B. C., P. E. Hildebrand and D. H. Hubbell. 1996. Sustainability of bean production systems on steep lands in Costa Rica. Agric. Systems 50: 391-400.

Castañeda, H. 1991. Caracterización y experimentación en sistemas mixtos de producción en San Gil (Colombia). Turrialba 41:22-30.

de Gracia, M. 1991. Sistemas de producción bovina de doble propósito en Panamá. Turrialba 41:108-120.

de la Vega, M. F. 1996. El comercio exterior de México con Centroamérica y sus potencialidades. Comercio Exterior (Marzo, 1996): 221-231.

Dudal, R. 1982. Land degradation in world perspective. J. Soil Water Conserv. 37:245-249.

Eden, M. J. 1990. Ecology and Land Management in Amazonia. London: Belhaven Press. 269 p.

Fisher, M. J. , I. M. Rao, R. J. Thomas, M. A. Ayarza, C. E. Lascano, J. I. Sanz and R.R. Vera. 1994. Carbon storage deep in the soil by introduced pastures in the South American savannas . Nature 371 (15 September 1994):236-238.

Franz, P. R. F. and J. L. Pimenta da Aguiar. 1994. Characteriizãção da agropecuaria do Estado de Mato Grasso - Sondagem. Projecto Novas Fronteiras do Cooperativismo- PNFC, Ministerio da Agricultura, Brasilia, Brazil,

Fujisaka, S., Bell, W., Thomas, N.,Hurtado, L. and Crawford, E. 1995. Slash-and-burn agriculture, conversion to pasture, and deforestation in two brazilian Amazon colonies. Agriculture, Ecosystem and Environment (in press).

Furley, P. A., ed. 1994. The Rainforest Frontier: Settlement and Change in Brazilian Roraima. London: Routledge.

Gutierrez, W., and E. Hernández. 1991. Sistemas de producción bovina de los pequeños productores de Pucallpa, Perú. Turrialba 41:40-46.

Inchausti, P. 1995. Competition between perennial grasses in a neotropical savanna - the effects of fire and of hydric nutritional stress. Journal of Ecology 83:231-243.

Jarvis, L. S. 1986. Livestock Development in Latin America. Washington D. C.: The World Bank, 214 p.

Jones, J. C. and M. Painter. 1995. Environmental destruction, ethnic discrimination and international aid in Bolivia. In The Social Causes of Environmental Destruction in Latin America, M. Painter, ed. Ann Arbor, Michigan: U. of Michigan Press, pp. 169-216.

Kaimowitz, D. 1994. The end of the hamburger connection? Livestock and deforestation in Central America in the 1980s and 1990s. In: Reforma de las políticas de gobierno relacionados con la conservación y el manejo de los recursos forestales en América Latina", World Bank, CIFOR, USAID, IICA; Washington, D.C.: Development Strategy for Fragile Lands.

Klink, C. A. 1994. Effects of clipping on size and tillering of native and African grasses of the Brazilian savannas (the cerrado). Oikos 40:365-376.

Lapointe, S. L. and J. W. Miles. 1992. Germaplasm case study: Brachiaria species. In Pastures for the Tropical Lowlands: CIAT's Contribution. CIAT, Cali, Colombia, pp. 43-56.

Lhoste, P., B. Rey and N. Cervantes. 1985. Elevage, système de culture et utilisation de l'espace dans le système éjidal au Mexique- Etat de Colima. Cahiers de la Recherche-Dévelopment 7:65-74.

Loker, W., R. R. Vera and K. Reátegui. 1996. Pasture performance and sustainability in the Peruvian Amazon: results of long-term on-farm research. Submitted to Agricultural Systems.

Macedo, J. 1994. State of the art of research on management of acid soils in the Brazilian Cerrados. Paper prepared for the CGIAR Soil, Water, and Nutrient Initiative, Schortzau Conference, Germany, 9 p.

Mattos, M. M. and C. Uhl. 1994. Economic and ecological perspectives on ranching in the Eastern Amazon. World Development 22: 145-158.

Michelsen, H. 1990. Análisis del desarrollo de la producción de leche en la zona tropical húmeda: el caso de Caquetá, Colombia. Documento de Trabajo No. 60, CIAT, Cali, Colombia, 68 p.

Morán, E. F., E. Brondizio, P. Mausel and Y. Wu. 1994. Integrating amazonian vegetation, land-use, and satellite data. Bioscience 44: 329-338.

Nicholson, C. F., R. W. Blake and D. R. Lee. 1995. Livestock, deforestation, and policy making: intensification of cattle production systems in Central America revisited. J. Dairy Sci. 78: 719-734.

Nores, G. A. and R. R. Vera. 1993. Science and information for our grasslands. Proc. Inter. Grassland Congr. 17: 33-38.

Ramírez, A. and C. Seré. 1990. Brachiaria decumbens en el Caquetá, Colombia: adopción y uso en ganaderías doble propósito. Documento de Trabajo No. 67, CIAT, Cali, Colombia, 118p.

Ramírez, A., C. Seré and J. Uquilas. 1992. Impacto Socioeconómico de Sistemas Agroforestales en la Región Amazónica del Ecuador. Proyecto colaborativo: Ministerio de Agricultura y Ganadería del Ecuador-Fundación para el Desarrollo Agropecuario-Centro Internacional de Agricultura Tropical (MAG-FUNDAGRO-CIAT), Quito, Ecuador. 137p.

Reátegui, K., R. R. Vera, W. L. Loker and D. M. Vásquez. 1995. On-farm grass-legume pasture performance in the Peruvian rainforest. Experimental Agriculture 31(2):227-239.

RIEPT (Red Internacional de Evaluación de Pastos Tropicales). 1987. La investigación en pastos dentro del contexto científico y socioeconómico de los países. V Reunión del Comité Asesor de la RIEPT, Davis, Chiriquí, Panamá. Cali: CIAT, Documento de Trabajo, 622 p.

Rivas, L. 1994. Perspectivas técnicas y productivas de la ganadería en América Latina. In Seminario sobre La Ganadería, una Industria Rentable hacia el Siglo XXI. CICADEP-Banco Ganadero, Río Negro, Antioquia, Colombia, 35 p.

Rivas, L. 1996. Los modelos económicos de nivel agregado como instrumentos de apoyo a la investigación agropecuaria. Taller sobre Metodologías para Investigación en Fincas con Sistemas de Producción Animal de Doble Propósito, CIAT, Cali, Colombia, July 8-12, 1996

Rubinstein, E. and G. A. Nores. 1980. Gasto en carne de res y productos lácteos por estrato de ingreso en doce ciudades de América Latina. Working Paper, CIAT, Cali, Colombia.

Sanint, L. R., L. Rivas, M. C. Duque and C. Seré. 1985. Análisis de los patrones de consumo de alimentos en Colombia a partir de la encuesta de hogares DANE/DRI de 1981. Rev. Planeación y Desarrollo 17: 37-68.

Sere, C., and L. Vaccaro. 1984. Milk production from dual-purpose systems in tropical Latín America. In A. J.Smith, ed., Milk Production in Developing Countries. Centre for Tropical Veterinary Medicine, U. of Edinburgh, pp. 459-475.

Serrão, E. A. S. and A. K. O. Homma. 1993. Country profiles: Brazil. In Sustainable Agriculture and the Environment in the Humid Tropics. Washington, D. C.L National Academy Press, p. 263-351.

Sherbourne, J., C. Halbrendt and C. M. Gempesaw. 1991. The impact of government policy upon productivity changes: the case of farms in the Amazon region of Brazil. Investigación Agraria - Economía (Madrid) 6: 207-221.

Skole, D. L., W H. Chomentowski, W. A. Salas and A. D. Nobre. 1994. Physical and human dimensions of deforestation in Amazonia. Bioscience 44: 314-322.

Smith, J., M. Winograd, G. Gallopin and D. Pachico. 1996a. Dynamics of the agricultural frontier in the Amazon and Savannas of Brazil: simulating the impact of policy and technology. (submitted for publication).

Smith, J., J. V. Cadavid, A. Rincón and R. R. Vera. 1996b. Land speculation and intensification at the frontier: a seeming paradox in the Colombian savanna. Agricultural Systems (in press).

Solbrig, O. T. and R. R. Vera. 1996. Impacto de la globalización en las llanuras del cono sur. In O. T. Solbrig, ed., III Foro del Ajusco, Globalización Económica y Desarrollo Sostenible en América Latina y el Caribe; Mesa: Impactos, Indicadores y Alternativas. UNEP and Colégio de México, 4-6 September 1996. México.

Torres Zorrilla, J. A. 1994. Agricultural modernization and resources deterioration in Latin America. San José, Costa Rica: IICA Program Papers Series no. 45.

Vera, R. R. and C. Seré. 1985. Livestock production systems in tropical South America: a comparative analysis of Brazil, Colombia and Venezuela. In Sistemas de Producción Pecuaria Extensiva: Brasil, Colombia, Venezuela - Proyecto ETES. R.R. Vera and C. Seré, eds., CIAT, Cali, Colombia.

Vera, R. R., R. Thomas, L. Sanint and J. I. Sanz. 1992. Development of sustainable ley-farming systems for the acid-aoil savannas of Tropical America. Anais da Academia Brasileira de Ciencias **64** (supl. 1):105-125

Vera, R.R., J. I. Sanz, P. Hoyos, D. L. Molina, M. Rivera and M. A C. Moya. 1994. Pasture establishment and recuperation with undersown rice on the acid soil savannas of South America. In Huisman, E. A., J. W. M. Osse, D. van der Heide, S. Tamminga, B. J. Tolkamp, W. G. P. Schouten, C. E. Hollingworth and G. L. van Winkel (editors), *Biological Basis of Sustainable Animal Production*, Proceedings of the Zodiac symposium, Wageningen, The Netherlands, April 13-15, 1993. EAAP publication No. 67, 1994, Wageningen Press, Wageningen, The Netherlands, pp. 89-95.

Vera, R. R., K. Reátegui and W. M. Loker. 1995. Milk and pastures in the frontier: the case of the Peruvian forest margins. (Submitted to Experimental Agriculture).

Vera, R. R. 1996. Strategies for sustainable agriculture in acid savannas of Latin America. Invited plenary paper, Workshop on Long-Term Research on Soil, Water and Nutrient Management, Ohio State University and USAID, Columbus, Ohio, 26-26 July 1996.

Ullrich C., R. R. Vera, and J. H. Weniger (1994) Milk production by dual purpose cows on grass-alone and grass-legume pastures. Pasturas Tropicales 16(3):27-30.

Table 1. People, land and cattle resources in Latin America and the Caribbean

	LAC	WORLD	LAC, %
Human pop., 1995, millions:			
total	482	5716	8.4
rural	124 (26%)	3131 (55%)	4.0
Consumption of animal proteins, % of total protein consumed (1992)	43.3	34.8	124
Per capita consumption, 1992 (kg/year):			
beef	21	10	210
milk	93	75	124
Total area, million ha	2054	13098	15.7
Cattle, 1995:			
million heads	337.9	1306.5	25.9
head/person	0.70	0.23	
Annual & permanent crops, 1993, millions ha	140.9	1447.5	9.7
Grasslands, 1993, million ha	590	3361.7	17.6
Beef production, 1995, millions metric tons			
LAC	11.2	53.2	21.1
Tropical LAC [1]	8.1		15.2
Milk production, 1995, millions metric tons			
LAC	48.9	456.7	10.5
Tropical LAC [1]	38.3		8.2
Ratio of cattle area:crop area	4	2.3	

	1970	1995	2025
Urbanization, %	57	74	85

Source: Own calculations based on FAO, World Bank and CEPAL databases

[1] Excluding Argentina, Chile and Uruguay

Table 2. Typical values for the supply and demand of beef and milk in tropical Latin America and the Caribbean.

	Beef	Milk
Historical growth rates of:		
demand, %.year^{-1}	2.2	2.2
supply, %.year^{-1}	1.8	1.9
Growth rates in 1990-1995 of:		
supply, %.year^{-1}	2.9	3.2
cattle stock, 5.year^{-1}	0.6	
pasture area, %.year^{-1}	0.2	
Income elasticity	0.6 - 0.8	0.7 - 0.9

Source: Rivas, 1996; Rivas, 1994; de la Vega, 1996, Hollman (pers. comm.)

Table 3. Diversity in important beef and milk production systems of the neotropics and subtropics

Type of operation	Based on: Native grasslands	Based on: Sown pastures	Purposeful integration with crops	Purchased inputs	Market orientation	Mgmt. input	Examples found in	References
Cow-calf	+++	+	0	+	commercial	+	Outlying neotropical savannas (Llanos, Cerrados) Poorly drained Pampa (Argentina) Marginal soils (Uruguay, S. Brasil, many others)	Vera & Seré (1985) Solbrig & Vera (1996)
Semi-intensive beef fattening	0	+++	+ [1]	++	commercial	++	Neotropical savannas (Llanos, Cerrados, many others)	Smith et al. (1996b) Vera & Seré (1985)
Intensive beef fattening	+	+++	+++ [4]	++	commercial	++	Pampa (Argentina)	Solbrig & Vera (1996)
	0	+++	++ [2]	+++	commercial	+++	High altitude tropics (Colombia, Ecuador, C. Rica) Pampas (Argentina, Uruguay) Irrigation areas (Mexico, Peru, Chile, others)	Solbrig & Vera (1996) Lhoste et al. (1985)
Systematic tropical dual purpose	+	++	+ [3]	++	commercial	++	N. Coast of Colombia Venezuelan Savannas Andean foothills Colombia, Venezuela, Ecuador Amazon rainforest Caquetá, Colombia Most of lowland/mid-altitude C. A.	Arango-Nieto et al. (1989) Seré & Vaccaro (1984) Castañeda (1991) Ullrich et al. (1994) De Gracia (1991)
Opportunistic tropical dual purpose	+	+	0	+	family + opp. sales	+	Amazon rainforest: Peru, Ecuador, Bolivia, Acre/Rondonia (Brazil), etc Outlying hillsides areas of Andes and Central America	Vera et al. (unpubl) Gutierrez & Hernández (1991) Fujisaka et al. (1995) Loker et al. (1996)
Incipient tropical ley-farming systems	0	+++	+++	+++	commercial	+++	Core area of the Brazilian Cerrados	Vera (pers. observations)
Incipient & potential systems: "organic" beef (also mutton, lamb); other brands of origin	++	++	0/+ ?	+	commercial	+++	Pampas (Argentina, Uruguay) (also Patagonia ,Argentina)	Solbrig & Vera (1996)

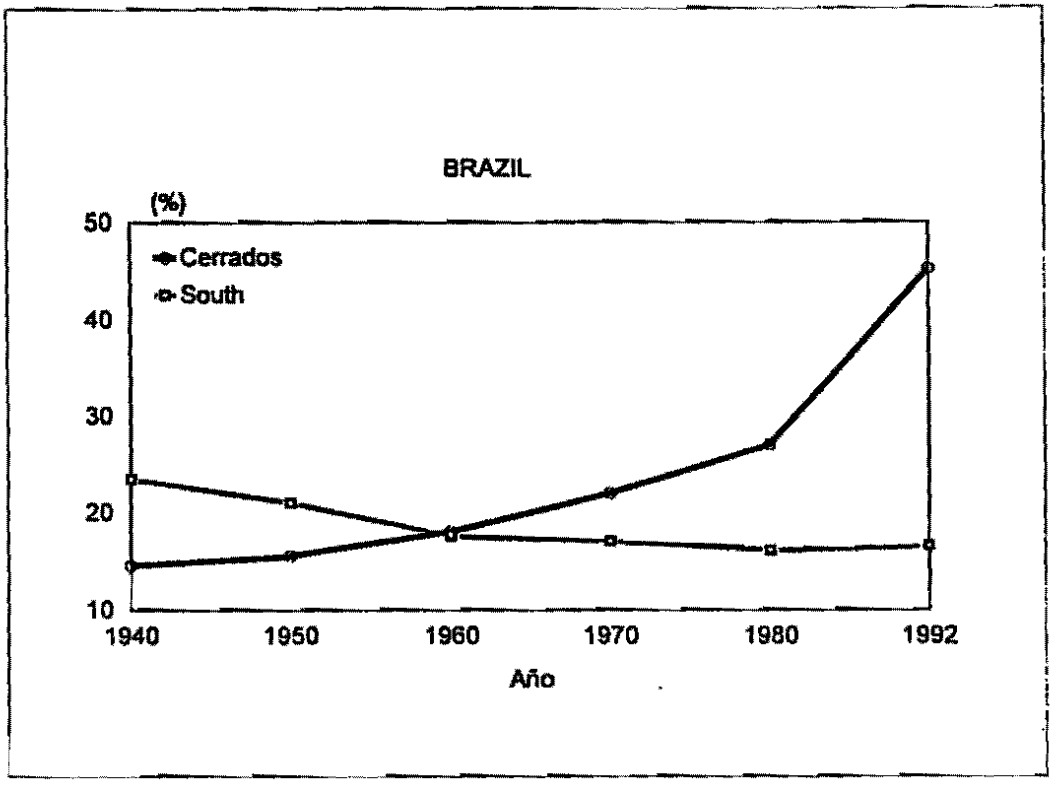
1 Unplanned grazing of stubbles, other residues
2 Includes sorghum, maize, other silages
3 Unplanned grazing of stubbles, cut and carry forages, browsing of fodder trees.
4 Includes the traditional wheat-alfalfa rotation of the Pampas, now seriously threatened.

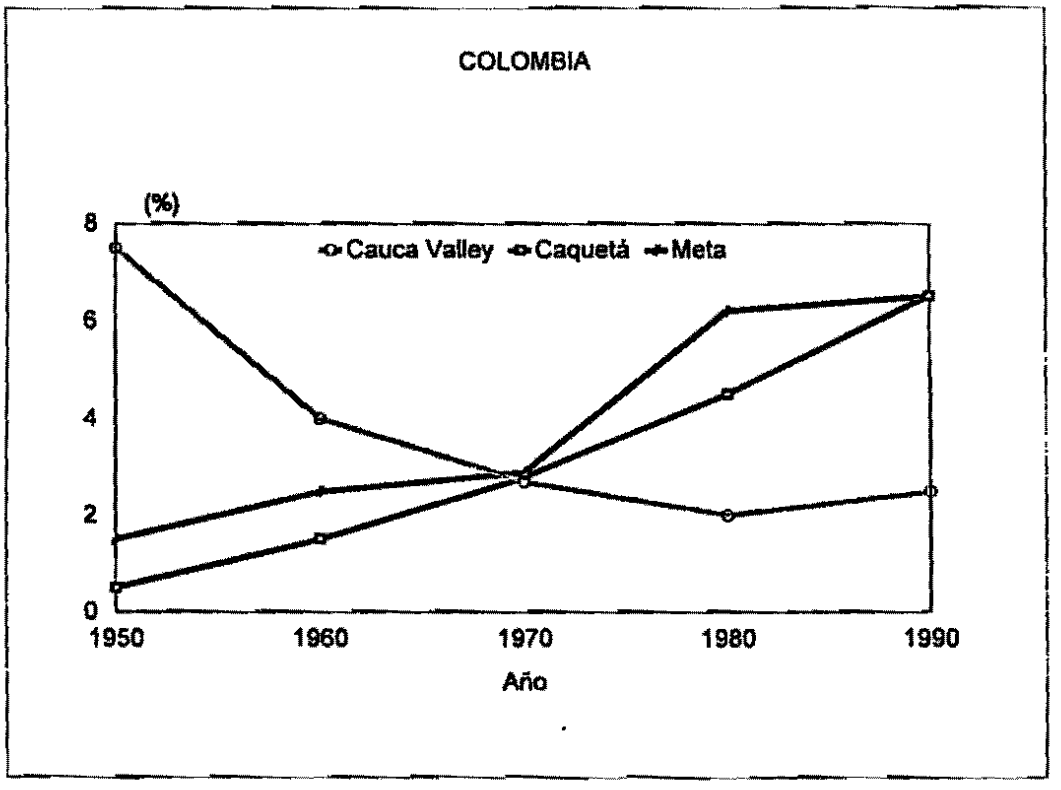
Table 4. Social, economic and environmental impacts of beef and milk systems of the humid neotropics and subtropics

System	Impacts	
Cow-calf + growing	Income maximization, but low input/low output Effective use of marginal lands Slow range degradation	Land appreciation (Low) soil nutrient extraction Very low labor use
Semi-intensive beef fattening on pastures	Income maximization Favors subdivision of large ranches Native grasslands replaced by monospecific pastures Produces inexpensive beef for urban populations	Low labor use May lead to soil compaction Well suited for tropical ley farming systems
Dual purpose systems	Maximizes use of family labor Regular income flow Risk minimization Makes small farms viable	Soil nutrient extraction Can lead to deforestation and land degradation Increases equity and nutrition
Intensive pasture-based milk	Income maximization Increases employment in agro industries Cheap milk for urban populations	Can pollute water streams & compact soils Economies of scale can lead to vertical integration
Tropical ley-farming systems	Maximizes efficiency of use of resources No known negative environmental impacts Increases landscape diversity	Relatively capital-intensive and very information-intensive Economies of scale ? Integration with rangelands ?
Specialty beef, lamb sheep cheese, etc	Very management- and information-intensive High value added; large linkages May benefit conservation/mgmt. native grasslands	Small market niches (?)

Note: in addition to the above, deep-rooted tropical grasses were shown by Fisher et al. (1994) to sequester very large amounts of carbon up to depths of 1 m.

Figure 1. Spatial and temporal distribution of cattle in Brazil and Colombia: data shows increasing proportions with time of the national cattle herd in the Cerrados, in comparison to South Brazil, and in the savannas (Meta) and rainforest (Caqueta) of Colombia relative to an interandean valley (Valle).


BRAZIL
(%)
50
40
30
20
10
Cerrados
South
1940
1950
1960
1970
1980
1992
Año


COLOMBIA
(%)
8
6
4
2
0
Cauca Valley
Caquetá
Meta
1950
1960
1970
1980
1990
Año