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PASTURE-CROP TECHNOLOGIES FOR ACID SOIL SAVANNAS AND RAIN FORESTS OF TROPICAL AMERICA

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Introduction

Rural development implies the efficient increase of agricultural productivity for domestic markets, export, or a combination of both Efficiency in rural development should be measured in terms of increases in real income and rising rural standards of living However, these increases should not come at the expense of the degradation of natural resources

Achieving rural development depends on **national policies** to create the framework in which the agricultural sector operates (favorable input/output price ratios availability of credit, economic stability and security) It also depends on **infrastructure** and development, particularly at early stages in the process when government must provide social infrastructure and farmers needs Raising farm productivity during initial stages of agricultural development often demands low-input technologies that make efficient use of available resources At the same time, technological innovations should contribute to the conservation of natural resources

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These innovations should be capable of responding to improved management practices and the increased use of purchased inputs that come with the development process and agricultural intensification

Development schemes, based on appropriate domestic policies and infrastructure development, have failed in the past due to the lack of suitable technology Farmers have been encouraged to apply imported technologies successfully utilized under distinct socioeconomic and natural-resource conditions, but these technologies have proved inappropriate for local needs and conditions This has led to rejection of the proposed technology, ineffective use of development funds, and failure to achieve enduring rural development

In this work, some pasture-crop technologies appropriate for the acid, infertile soils of the Latin American tropics are presented and discussed These have the potential to provide a proper technological basis for sustained rural development of these regions

Background

Tropical America has large regions with underutilized lands The tropical savannas (153 million ha) and humid tropics (513 million ha) are important land resources for the development of the continent (Cochrane et al 1984) These regions are characterized by year-round growing seasons gentle topography, good soil physical conditions and abundant water The main constraint on their development has been the negative chemical characteristics of these heavily weathered soils (Oxisols and Ultisols), including low pH, high aluminum saturation, and low base status The cattle industry in tropical America is far more important relative to other areas of the developing world (East Asia and Africa) There are approximately 250 million head of cattle in the American tropics, roughly 20/ of the world s total cattle inventory (CIAT, 1988b)

Human population migration is also a notable feature of tropical America Urbanization is a growing trend in the region As shown in Table 1, urbanization in South America and Mexico increased from about 45/ in 1960 to more than 65/ in 1985 The urban population in Central America increased from about 40/ to 60/ in the same period (FAO, 1970-1986) Roughly 20/ of the region s population has moved to cities in the last 25 years

Table 1 Urbanization in tropical America (1960-1985)

Country	Urban population (/)	
	1960	1985
Tropical South America	47 8	66 9
Bolivia	39 0	56 4
Brazil	48 2	74 8
Colombia	48 5	68 2
Ecuador	42 5	67 1
Paraguay	44 0	53 5
Peru	47 6	61 0
Venezuela	64 9	87 6
Central America	39 5	58 9
Mexico	45 0	67 1

SOURCE FAO (1970-1986)

At the same time, a significant portion of the rural population has moved from impoverished and crowded areas of the countryside to marginal frontier areas Patterns of migration and colonization vary among countries and ecosystems The savannas are initially occupied by well-to-do ranchers, spontaneous colonization of this ecosystem by the poor is extremely difficult due to the poverty of the soils and original vegetation However, intensification of land use resulting from the utilization of improved pasture-crop technologies permits subdivision of land and may result in future economic growth and social benefits The humid tropics, after infrastructure is installed to integrate territories or to open access to timber and oil exploitation, are more attractive to settlers because of higher soil fertility realized through clearing and burning of the original forest biomass Logging, shifting cultivation, and cattle are the main production systems in these areas

Population growth rates in the humid tropics are considerably higher than national averages due to colonization Areas of active colonization such as Rondonia in Brazil and Ucayali in Peru have population growth rates about three times those of the respective national averages (Table 2)

Population growth and redistribution in tropical American countries have resulted in changes in land distribution and agricultural production systems Higher demand for food among expanding urban populations and overall population growth have pushed up prices of higher fertility land closer to urban markets Intensification of land use and expansion of crop production are pushing cattle operations onto marginal and frontier areas where land has a lower opportunity cost

Table 2 Effect of colonization on population growth in the humid tropics

Country or region	Population growth rate (1960-1985) /	1985 (1000)
Brazil	2 7	
Pará	4 2	4318 4
Acre	3 4	366 4
Rondônia	8 6	908 9
Colombia	2 5	
Caquetá	4 1	287 1
Putumayo	3 1	119 8
Peru	2 7	
San Martin	3 5	381 9
Ucayali	7 9	270 0

SOURCES For Brazil, FIBG (1970-1986) for Colombia DANE (1967, 1978, 1986), for Peru, Oficina Nacional de Estadísticas y Censo (1961-1972) and OEA (1964-1974)

For example in 1950, cattle population in the developed southern Brazilian states of Rio Grande do Sul and Santa Catarina comprised 21 4/ of the national herd In 1985, this figure was reduced to 12 7/ At the same time cattle in the Cerrados states of Goiás and Mato Grosso (areas of predominantly acid infertile soils) increased from 15 3/ of the national herd in 1950 to nearly one-third of the Brazilian cattle population in 1985 (Table 3) Similarly, in Colombia, the fertile Cauca Valley had 7 5/ of the Colombian herd in 1950 In 1985, its proportion was reduced to only 2 2/ In the savanna region of Meta, percentage of the national herd increased from an insignificant 0 6/ to 6 1/ over the same period And in Caquetá, in the Colombian humid tropics, cattle population increased from 1 4/ to 5 5/ of the national herd over the last thirty-five years

Table 3 Regional shift of the cattle industry as a contribution to nationals herds in Brazil and Colombia

Country or region	1950	1985
	(/)	
Brazil		
South (Rio Grande do Sul and Santa Catarina)	21 4	12 7
Cerrados (Goiás and Mato Grosso)	15 3	31 0
Colombia		
Valle (Valle del Cauca)	7 4	2 2
Amazon (Caquetá)	1 4	5 7
Llanos (Meta)	0 6	6 1

SOURCES FIBG, 1970-1986 for Brazil DANE, 1976, CVC, 1977-1986, and CEGA, 1987 for Colombia

Marginal and frontier areas with acid and infertile soils are being increasingly incorporated into the national agricultural economies of the region Lower productivity of cattle and cropping operations on these lands as well as the lack of sustainable production systems in these fragile environments are major concerns of the societies involved

Beef, milk, rice, maize, and, increasingly, sorghum (for animal feed) are major crops in tropical America The demand for beef and milk has been outpacing growth in production of these commodities in tropical America While production grew 2 2/ for beef and 3 7/ for dairy products between 1970 and 1981, demand for these products grew 5 3/ for beef and 5 0/ for dairy products (CIAT, 1984) The importance of rice in Latin American diets is a relatively recent phenomenon, and its rate of production and consumption has grown dramatically over the last 50 years In the 1920s, Latin America produced about 1 07 million metric tons of rice, and average consumption per capita was about 14 2 kg per year During the 1984-86 period, production was 17 2 million metric tons per year, and average annual per capita consumption was 45 4 kg It has been estimated that low-income urban consumers in Latin America spend between 12/ and 26/ of food expenditures on beef, 7/-18/ on milk (Rubinstein and Nores, 1980) and an average of 11/ on rice (IBE, 1988)

Income growth and urbanization are also increasing demand for animal feed grains such as maize, sorghum, and recently dried cassava for poultry and swine production The average growth rate of per capita maize consumption between 1970 and 1982 was 1 8/ per year in tropical America Net imports of maize per capita grew from 3 1 g during 1961-65 to 25 kg during 1980-82 (CIMMYT, 1987)

The agricultural sector in Latin America is highly dynamic, but much can still be done to increase productivity and modernize agriculture on prime lands However due to internal policies in these developing countries agricultural development of marginal and current frontier lands is expanding, particularly in the Cerrados of Brazil and the Llanos of Venezuela, where an extensive transportation infrastructure has been created

In the Colombian Llanos, despite limited infrastructure, intensification of land use and subdivision of farms are rapidly occurring Colonization of humid tropical areas is also proceeding rapidly, triggered by socioeconomic conditions in areas of outmigration and the development of infrastructure in this region Unfortunately, this phenomenon is bringing about resource degradation due mainly to the lack of knowledge about this ecosystem and lack of technology for its efficient use

The design of new technologies to facilitate the development of these areas of acid, infertile soils through economical and ecologically sound pasture-crop production systems is the goal of CIAT s Tropical Pastures Program

Technological Options

The success or failure of any technological innovation in agriculture depends on the fit between the proposed technology and specific conditions at the farm and regional level

The production components Crops, pastures, livestock, and/or trees must efficiently convert solar energy, water, and soil resources into valuable products These are the genetic bases used in the production system to obtain agricultural yield and income

Management Management includes the varying combinations of labor, fertilizer, and other inputs, together with the knowledge necessary to organize these elements into effective agricultural production systems Management also includes post-harvest utilization, processing, and marketing Management skills are strongly dependent on tradition, experience, and education as well as available production components, natural resources, and the farmer s access to capital, credit, machinery, and other inputs

<u>The market</u> The farmer s main goal is profit Farmers strive to manage available resources (labor, land capital, and technology) to optimize production and reduce risk Strong, reliable markets with favorable input/output price ratios are essential for the success of a technology

Technically sound production components and management can fail because of market deficiencies Some products have larger and more well-developed markets than others For products such as rice, beef, and milk, marketing constraints are largely limited to the development of infrastructure (to provide access) and favorable prices The success of other crops that are perishable or novel and thus have limited demands (such as fresh cassava and native tropical fruits) is largely contingent on the existence and development of markets

New, low-input pastures for acid, infertile soils

Through extensive germplasm collection of wild grasses and legumes native to the acid, infertile soils of tropical Latin America, Africa, and Asia, the germplasm collection of CIAT s Tropical Pastures Program was increased from about 4,000 accessions in 1978 to more than 23,000 accessions in 1988

Decentralized screening of these materials for adaptation to soil, climate and biotic pressures of the main humid and subhumid ecosystems of tropical American lowlands has produced a new generation of forage grasses and legumes for these regions This is a continental effort conducted by CIAT in cooperation with national research institutions (NARIs) at four major screening sites representing two major savanna ecosystems the Llanos (Carimagua, Colombia, in cooperation with ICA) and Cerrados (Planaltina, Brazil, in cooperation with EMBRAPA) as well as the humid tropics of the Amazon basin (Pucallpa Peru in cooperation with INIAA and IVITA) and the more intensive cattle production systems of Central America (Costa Rica in cooperation with MAG and CATIE) Selections made at these four sites are further tested by NARIs throughout the continent at more than 200 sites, where final selections are made for evaluation under grazing, validation on-farm, and for eventual commercial release

The new generation of materials is resistant to prevalent pests and diseases and requires lower levels of purchased inputs than traditional pasture species Figure 1 shows that an adapted grass, Andropogon gayanus CIAT 621, was successfully established on soils with low phosphorous availability The same species responds to increased levels of P and liming The non-adapted grass, Panicum maximum cv Makueni (an imported cultivar), barely survives without liming and only reaches the productivity levels of the adapted species at much higher levels of lime and P application Effective savings of P and lime are achieved through the use of species adapted to acid, infertile soils

Combining adapted grasses with nitrogen-fixing forage legumes reduces the need for the application of expensive nitrogenous fertilizers in pasture establishment and maintenance Low-input pasture technology based on adapted grass-legume cultivars is achieving striking levels of productivity in the savanna ecosystem Figure 2 shows the

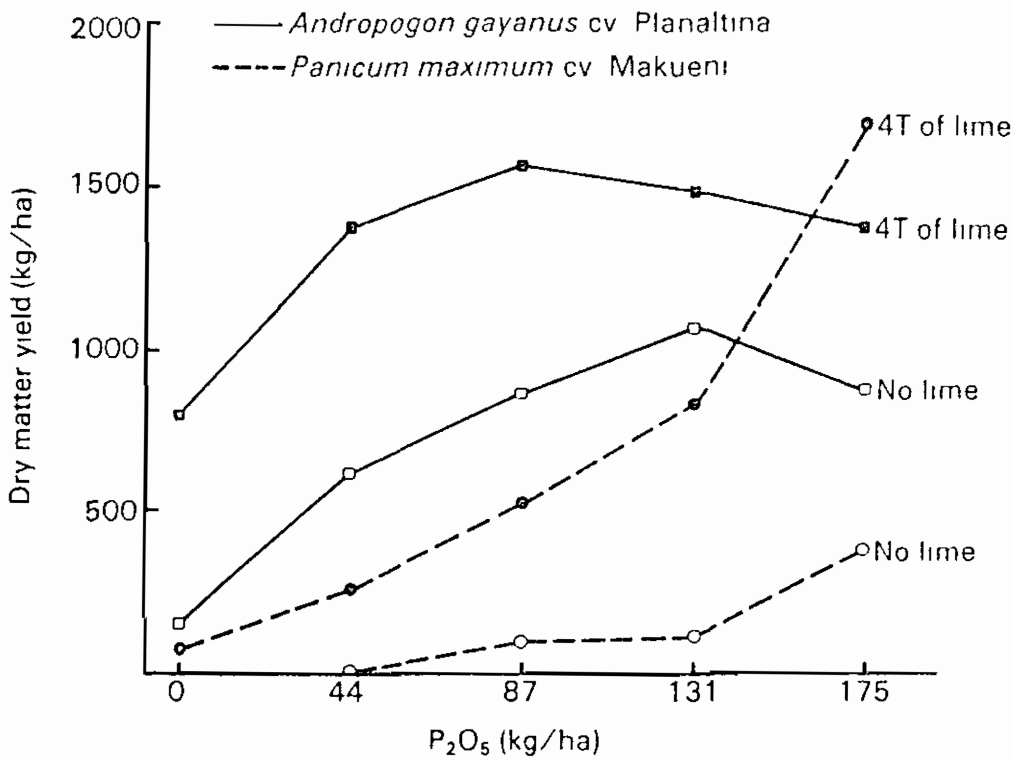


FIGURE 1 Establishment of two grasses under residual effect (10 years) of P fertilization and liming in the Brazilian Cerrados Taken from Toledo (1985)

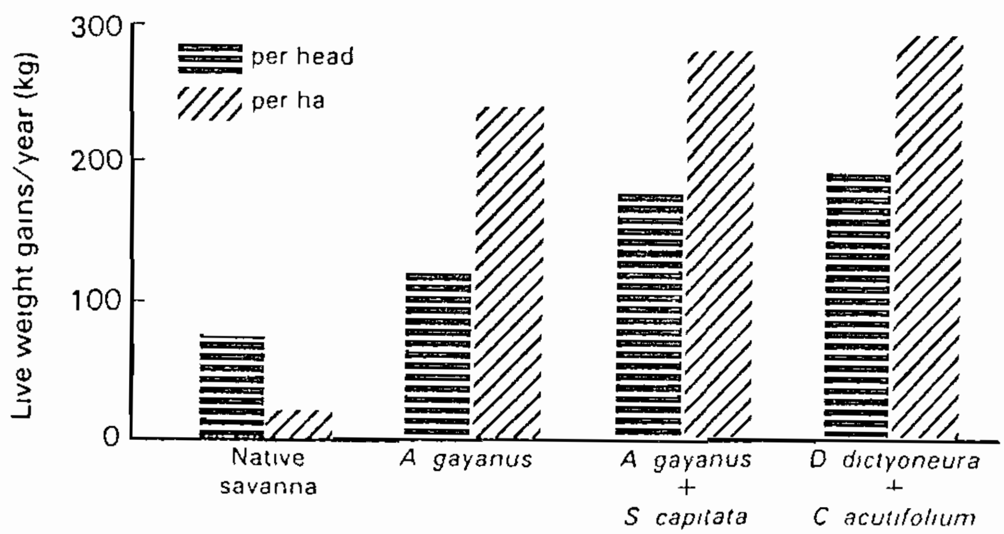


FIGURE 2 Productivity of best managed native savanna and new pastures in the Oxisols of the Colombian Llanos (CIAT 1988c)

magnitude of productivity increases of *A gayanus* alone and in association with the commercially released legumes *Stylosanthes capitata* cv Capica and the association of the newly released grass and legume cutivars *Brachiaria dictyoneura* cv Llanero and *Centrosema acutifolium* cv Vichada The productivity of the grass-legume associations is twice that of native savanna grassland in terms of liveweight gains per head of cattle and 15-fold in terms of liveweight gains per hectare

In the last three years, farmers in the Colombian Llanos have established more than 6000 hectares of new grass-legume associations using these pastures as a strategic supplement to the native grassland (CIAT, 1989) The main factor limiting further adoption in Colombia has been legume seed availability In the Cerrados of Brazil, with an aggressive commercial seed sector, an estimated 500,000 hectares have been planted in *A gayanus* due to its tolerance to insect pests and better dry-season performance compared with *B decumbens*

For the humid tropics, new grass-legume pastures that effectively capture and recycle limited soil nutrients are emerging for the reclamation of degraded lands and the intensification of production on already cleared forest areas

Moderate to high levels of animal liveweight gains can be expected from this emerging adapted germplasm-based pasture technology Table 4 shows experimental results of research underway in different areas in the region, indicating that with selected germplasm, it is possible to obtain average daily animal gains above 400 g and annual animal gains per hectare superior to 500 kg, especially when legumes are present in satisfactory quantities in the pasture

Legume contribution to pastures in the humid tropics is reflected not only in additional liveweight gains but also in increased carrying capacity and stability of the sward Legumes contribute directly and indirectly to higher levels of protein in the diet, especially in the dry season when grass availability is reduced

Table 4 Liveweight gains from grass-legume pastures

Pasture	No of years	Stocking rate	Weight gain	
			Daily per animal (g)	Yearly per ha (kg)
Paspalum notatum (Tienza)[a]	-	-	-	200
Andropogon gayanus[c]	2	2 1	0 443	340
Brachiaria humidicola[c]	2	2 5	0 380	351
A gayanus + S guianensis[d]	5	4 4	0 412	660
A gayanus + C macrocarpum[b]	2	3 5	0 510	650
B decumbens + D ovalifolium[d]	5	5 5	0 447	897
B dictyoneura + D ovalifolium[b]	4	5 0	0 440	803

a Cauca, Colombia (Escobar et al , 1971)

b Quilichao, Colombia (CIAT, 1988c)

c Paragominas, Brazil (EMBRAPA, 1988)

d Yurimaguas, Peru (Dextre et al , 1987)

Long-term grazing trials data comparing grass versus grass-legume pasture performance are needed to assess the contribution of legumes to productivity of pastures in the humid tropics Research on the new pasture options has not yet reached this stage However, we can extrapolate results from wet-season performance in the savanna ecosystem to estimate productivity in more humid ecosystems Data from a ten-year-old grazing trial at Carimagua in the Colombian Llanos, comparing the association _B decumbens_ + _Pueraria phaseoloides_ with _B decumbens_ alone at a stocking rate of two animal units per hectare indicates that the inclusion of the legume raises productivity by only 5/ during the initial four years (Figure 3) Thereafter, the legume contribution to relative productivity becomes exponential This suggests the importance of legumes for pasture stability and sustainability under continuously wet environments The length of the dry season in the humid tropics varies from zero to three months per year Thus, the legume contribution is bound to be larger even in the first years through its direct contribution to animal production during the dry period

Acid-poor soil-adapted crops

Low-cost establishment as well as increased productivity are decisive for the adoption of these new, low-input pasture technologies in both the savannas and the humid tropics One possible route for lowering the costs of pasture establishment is the use of pioneer crops to pay for land preparation and the application of soil amendments in the establishment process This will require crop cultivars adapted to acid, infertile soils Adapted cultivars may also open the possibility for ley farming systems in these regions, using residual fertility and improvements in soil structure provided by the grazing phase of the crop-pasture system CIAT, CIMMYT and INTSORMIL (International Sorghum and Millet Program) are working on the development of acid soil-adapted lines of rice maize, and sorghum

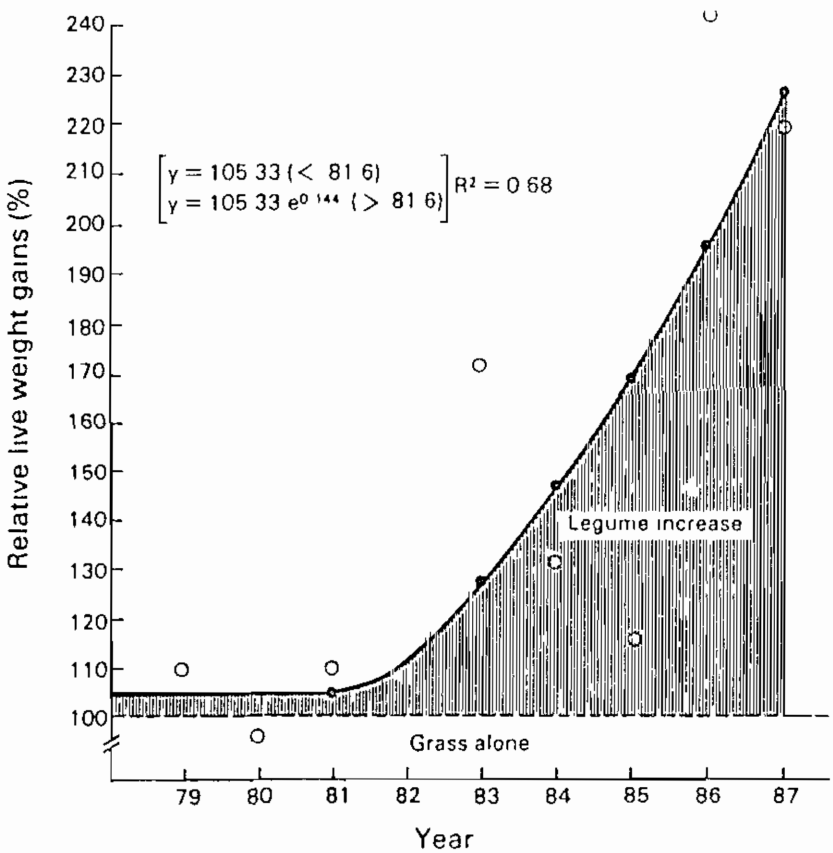


FIGURE 3 Relative yield of *B decumbens* + *P phaseoloides* pastures to *B decumbens* alone during rainy periods in the Colombian Llanos

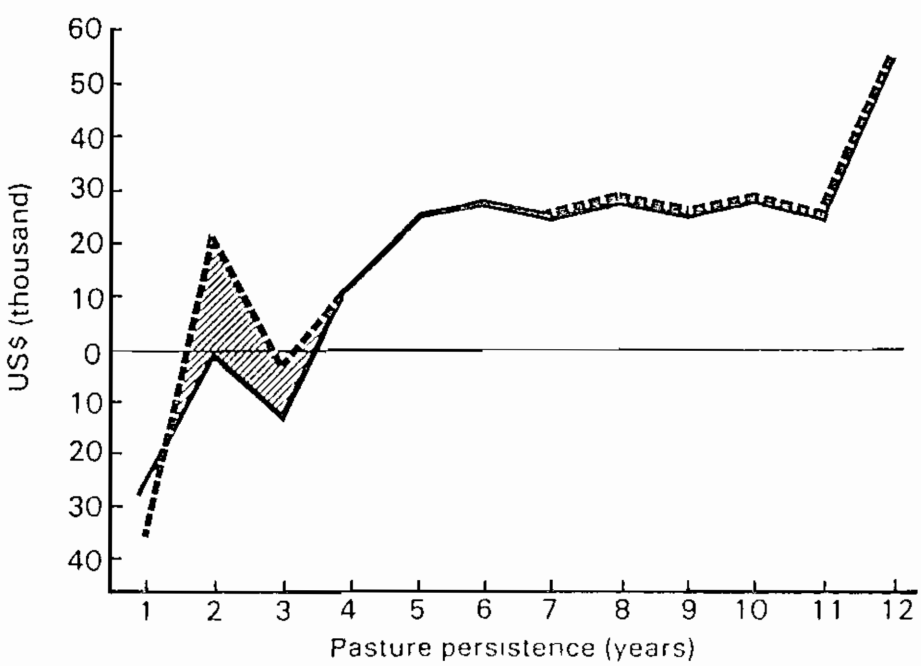


FIGURE 4 Marginal cash flow in the establishment of improved pastures with ( ) and without (——) sorghum as companion crop in the Colombian Llanos (Sere and Estrada 1987)

Upland rice The main constraints for developing high-yielding upland rice for the acid soils of the savannas is tolerance to rice blast and grain quality for the consumer Several selected lines for upland conditions, resulting from crosses of IITA (International Institute of Tropical Agriculture), IRRI (International Rice Research Institute), and EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária) materials, were planted in 1988 under three different conditions in the Colombian Llanos The chemical correction of the soil included the application of 250 kg of dolomitic lime, 60 kg of P_2O_5 , and 40 kg of K_2O Pesticides and herbicides were not applied (CIAT, 1988a) Table 5 shows the yields of the best lines compared with the best local controls The new, adapted upland rice lines outyielded the checks in all contrasting locations

Table 5 Grain yields (kg/ha) of rice lines under three contrasting savanna environments of the Colombian Llanos

Pedigree	San Martin	Puerto Gaitán	Yopal
CT 6947-7-1-2-M	-	1172	3138
CT 6515-18-1-3-1-2-M	3256	806	2794
CT 6261-5-7-2P-5-M	-	1396	2594
CT 6196-33-11-1-3-M	-	1320	2463
CT 6196-33-2-9-4-M	1117	1025	2400
Checks			
IAC-165	0	1064	2762
TOX-1011-4-1	0	834	1869
Oryzica 2	0	0	2275

SOURCE CIAT, 1988a

Maize for acid soils Recent efforts of CIMMYT to develop germplasm for stress' environments in Latin America included the conformation of acid-soil tolerant populations (two yellow, two white) to be improved through recurrent selection Some of the data on the performance of 613 yellow families in several acid-soil sites is presented in Table 6 Experimental sites were limed to reduce aluminum saturation to about 60%, and 120 kg of N + 80 kg of P_2O_5 were applied as fertilizers The 56 selected families significantly outyielded the rejected ones by 1 metric ton per hectare These results are very encouraging given the importance of maize as a subsistence and cash crop in the farming systems of the savannas and humid tropics

Table 6 Yield (kg/ha) of selected and rejected maize families for adaptation to acid-soil sites

Site	Maize yield Selected (56)	Maize yield Rejected (557)	Significance of differences
Carimagua, Colombia	3980	2080	***
Yurimaguas, Peru	3510	1650	***
Mindanao, Philippines	1800	860	***

*** P < 001

SOURCE Haag and Pandey, 1988

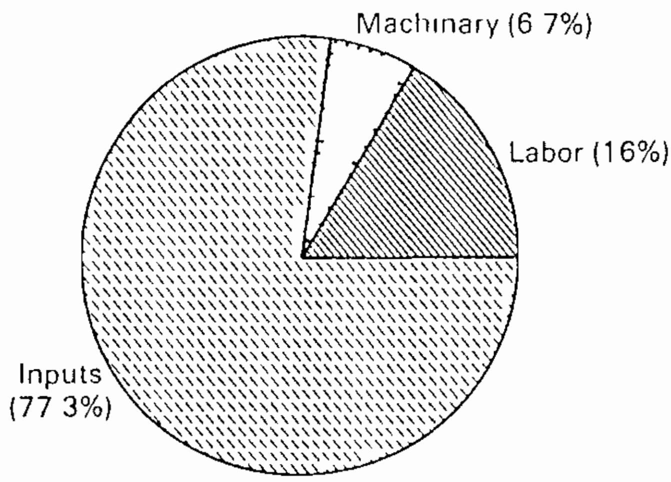
Sorghum in the acid savannas The Oxisols of the Llanos have an average of 88% aluminum saturation The new, adapted lines of sorghum being developed by INTSORMIL perform well up to 60% Al saturation Yields of 2 t/ha are obtained in the Llanos with the application of lime to reduce Al saturation to 60% along with 49 kg of N 17 kg of P, and 40 kg of K per ha Yields of 3 t/ha were obtained in

(Figure 4) Marginal profitability of pastures established in association with sorghum increases from 34% to 52% per year for sorghum yields ranging from 1 3 to 2 5 t/ha

Under the subsidized conditions of the Brazilian Cerrados, 1 5 t/ha of lime and fertilizers (P and K) are applied for the on-farm trials to establish legume protein banks Leucaena leucocephala and S guianensis in association with a maize crop to reduce costs Figure 5 shows the cost structure of establishing these Leucaena-Stylo protein banks The total cost per hectare is high (US$426/ha at the official exchange rate) and inputs represent the largest share (77 3%) The maize sale reduced the total cost by 48% The high levels of inputs are required in this case because Leucaena is not an acid-soil-tolerant forage tree

The high recycling capacity of grass-legume pastures can, over time, maintain nutrients in the topsoil profile Figure 6 shows the relative increase of K, Mg, and Ca in the upper 20 cm of an Oxisol in the Colombian Llanos after four years under an A gayanus + P phaseoloides pasture with maintenance fertilization every second year (CIAT, 1984a) While Ca and Mg more than double their concentration in the topsoil, K remains constant This concentration of nutrients in the topsoil, together with increased inorganic matter and improved soil structure resulting from grass-legume pastures, provides an improved environment for crop production in these tropical savanna Oxisols

Although chemical and physical soil conditions strongly influence the success or failure of crops and pastures soil microbes are also an important component of soil-plant interactions, particularly in these low-input species Apart from the well-known benefits of legume-rhizobium symbiosis, other microbial processes such as micorrhizae -which contribute to the uptake of phosphorous--are also important



Total cost = US$426
Maize sale = US$203 (48%)
Net cost = US$223

FIGURE 5 **Cost structure of the establishment of *Leucaena leucocephala* + *Stylosanthes guianensis* protein banks including corn as cash crop in the Brazilian Cerrados (Saez personal communication 1989)**

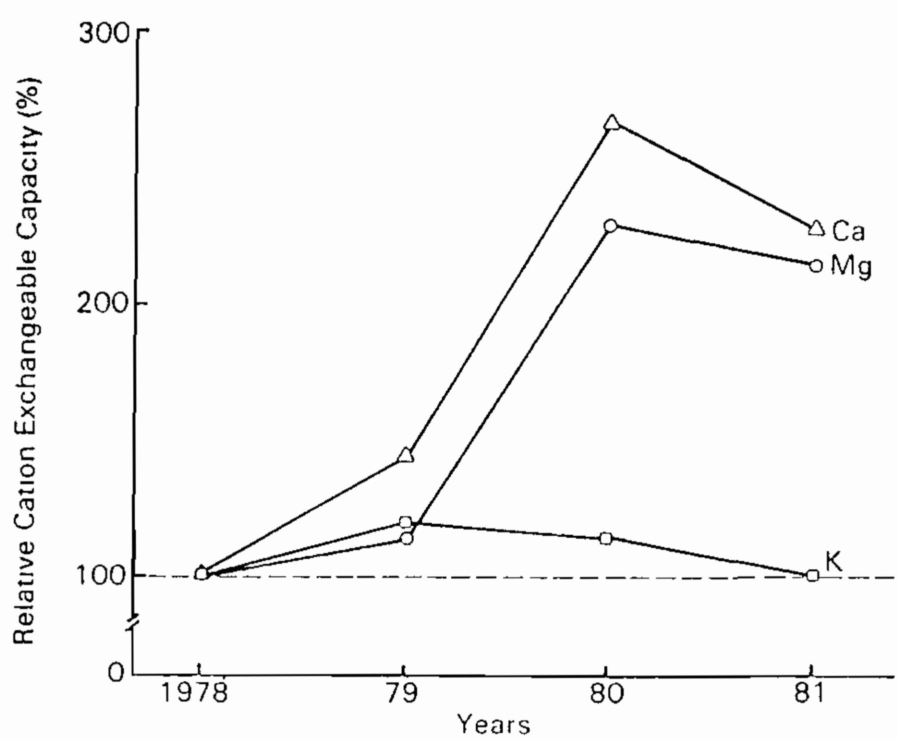


FIGURE 6 Relative increases of Ca Mg and K under an *A gayanus* + *P phaseoloides* pasture at Carimagua Colombia (CIAT 1984a)

Dodd et al (n d a , n d b , and n d c), for example, showed the role of sorghum and _P phaseoloides_ in raising the population of micorrhizal fungi infecting subsequent crops and pastures established in Oxisols of the Colombian Llanos

The new generation of acid-soil-tolerant crops and pastures (especially rice and sorghum) is expected to contribute greatly to the intensification of land use in these savannas traditionally utilized extensively The reduction of pasture establishment costs by using crops and the subsequent benefit from improved soil conditions after grass-legume pastures for crop production is extremely important for the development of highly productive and sustainable pasture-crop production systems in the Oxisols and Ultisols of the tropical savannas of Latin America

Crops and pastures in the humid tropics

Pioneer settlers in the humid tropics plant crops such as rice, maize, cassava, and cowpeas in systems of shifting cultivation after clearing and burning the forest to temporarily increase soil fertility The limited surplus generated from cropping activities using this ephemeral soil fertility and family labor, often augmented by on farm employment, is frequently invested in livestock Livestock, especially cattle, represent a secure investment that maintains its value in inflationary economies and provide a ready source of cash when marketed Cattle are gradually integrated into mixed crop-livestock systems through the inclusion of pastures in rotation with annual crops and long, bush fallow agricultural cycles Land degradation due to declining fertility is the major economic and environmental problem for the development of efficient and sustainable production systems in the humid tropics

Establishing the new grass-legume pastures in these degraded lands requires investments of varying proportions of time, labor, and capital Farmers have developed production systems that combine crops, pastures, and bush fallows Two contrasting examples from the humid tropics are the production systems of Pucallpa, Peru, and Caquetá, Colombia In Pucallpa, farms average about 59 ha with 41% of the area in pastures, 11% in crops, 17% in secondary forest, and 31% in primary forest Cattle average 30 head per farmer, with production of beef and milk (Riesco, 1982) In Caquetá, Colombia, dual purpose farms average 130 ha with 73% of the area in pastures, only 3% in annual crops 17% in secondary forest, and 7% in primary forest Production is dual-purpose (beef and milk) and farmers own an average of 121 cattle (Ramirez and Seré, n d)

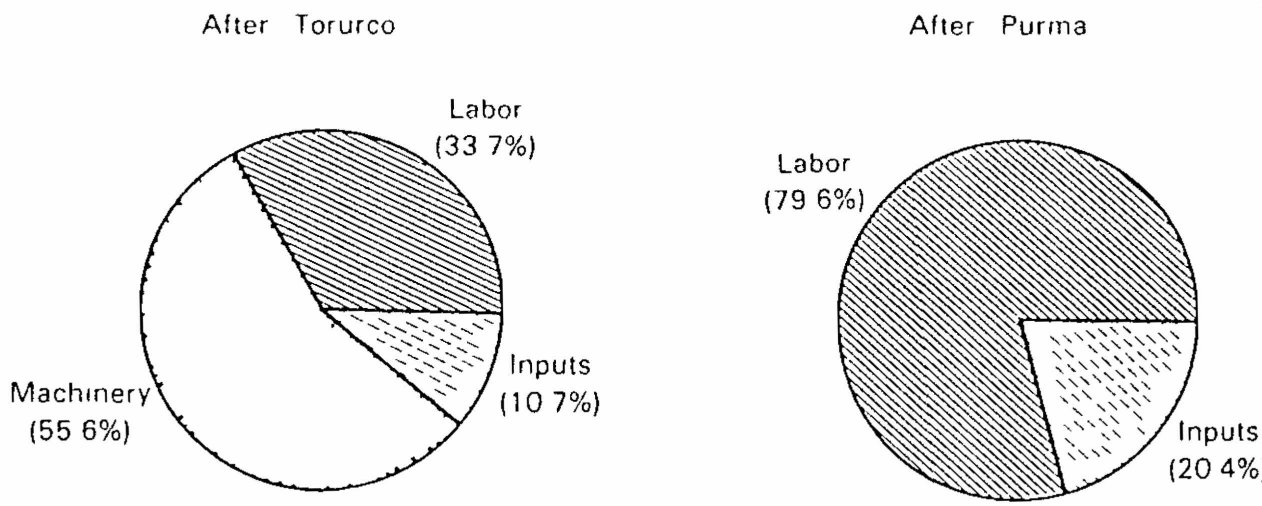
The quality of pasture and its management is often not uniform on these farms Areas vary in age after establishment as well as in intensity of use and weed control Older pastures, closer to the house and corral are normally managed with higher grazing frequency and pressure and with continuous hand or chemical weeding These more accessible areas are often degraded into a disclimax native grass community (known locally and referred to here as torurco) made up of palatable native grasses such as <u>Axonopus compressus</u> and <u>Paspalum conjugatum</u> with some legumes (<u>Desmodium triflorum</u>, <u>D ascendens</u>, <u>D incanum</u>, <u>Aeschynomene americana</u>, and <u>Calopogonium mucunoides</u> in small proportions These torurco pastures are fairly stable at low productivity levels (<0 8 AU/ha) However, because of overgrazing they can be further degraded into less palatable species such as <u>Homlepsis aturensis</u>, <u>Cyperus</u> spp , and <u>Pteridium</u> spp (Toledo, 1984)

Soil conditions in these degraded torurco grasslands are extremely poor High levels of compaction and low levels of nutrients are common, and seed reserves from the original forest have normally been exhausted Under these conditions, if grazing is discontinued the regeneration of the forest biomass is extremely slow (Uhl et al 1988) It may take 15 years to reach the level of biomass displayed by a secondary forest after five years of fallow following two-year crop cycles

The other part of the pasture area of these farms is more extensively managed, with a lower stocking rate and a minimum of weeding These areas are normally farther away from the central infrastructure of the farm and are less accessible to cattle They are typically managed in a shifting crop-pasture-fallow system Crops such as rice and maize are planted every 8-12 years after clearing and burning the secondary forest regrowth (known locally and referred to here as purma) Pastures are planted along with, or shortly following, crops and are grazed for three to five years at a low stocking rate with limited weedings Eventually, these areas are dominated by weeds and shrubs, grazing is interrupted and the area is allowed to go fallow for 8-12 years, after which the vegetation is burned and the cropping cycle begins again The success and sustainability of these crop-pasture-purma systems depends heavily on maintaining an adequate fallow period

Reclamation of these contrasting degraded lands is also required for the different approaches On one hand, in areas of native grassland (torurco), higher levels of inputs will be required (machinery, fertilizers, seeds, weed control) After purma, minimum purchased inputs (seeds) and labor are needed Figure 7 shows the cost structure of these two reclamation options, using maize as the cash crop in Pucallpa, Peru

The total cost of reclaiming degraded areas in



	After Torurco US$		After Purma US$	
Total cost	= 338		125	
Maize sale	= 93	(28%)	100	(80%)
Net cost	= 245		25	

FIGURE 7 Cost structure of pasture reclamation after ' torurco (degraded grassland) and after purma ' (secondary forest) including maize as a cash crop in Pucallpa Peru

torurco is more than twice that of reclaiming purmas and it requires machinery and higher levels of purchased inputs often not available to farmers. The net cost of mechanized reclamation of degraded torurco is almost ten times higher than that of traditional reclamation after purma. However, if capital is available to buy more cattle for the intensification of the pasture component of the production system, the time required for the natural purma system to work may be excessive.

One option is to use the new grass-legume pastures to improve the traditional purma system. Higher recycling capacity and productivity of the improved pasture technology will allow farmers to make better use of the disturbed lands. This pasture will maintain higher stocking rates for longer periods of time without losses in soil fertility.

At the initial stages of development of a region, an improved crop-pasture-fallow system will probably be the most adoptable option. Figure 8 illustrates this option. Land clearing and burning of the primary forest occur after Time zero. Crops and the grass-legume pastures are established at Time 1. After the crops are harvested the N_2-fixing pastures can be grazed for four years with 2 AU/ha. Simultaneously, selected commercially valuable trees (such as *Guazuma crinita*, *G. ulmifolia*, *Jacaranda copaia*) are allowed to resprout and are protected from weeding (Time 2). During the fifth and sixth years, carrying capacity of the pasture is reduced to 1 AU/ha to compensate for yield reductions expected under a more shady environment (Time 3). After six years of grazing, the land is taken out of production and left fallow for two years, possibly with oversowing of *P. phaseoloides* or another rapidly growing high-N_2-fixing legume to facilitate recovery (Time 4). At the end of the fallow period any commercially valuable tree species are harvested before the plot is burned and the

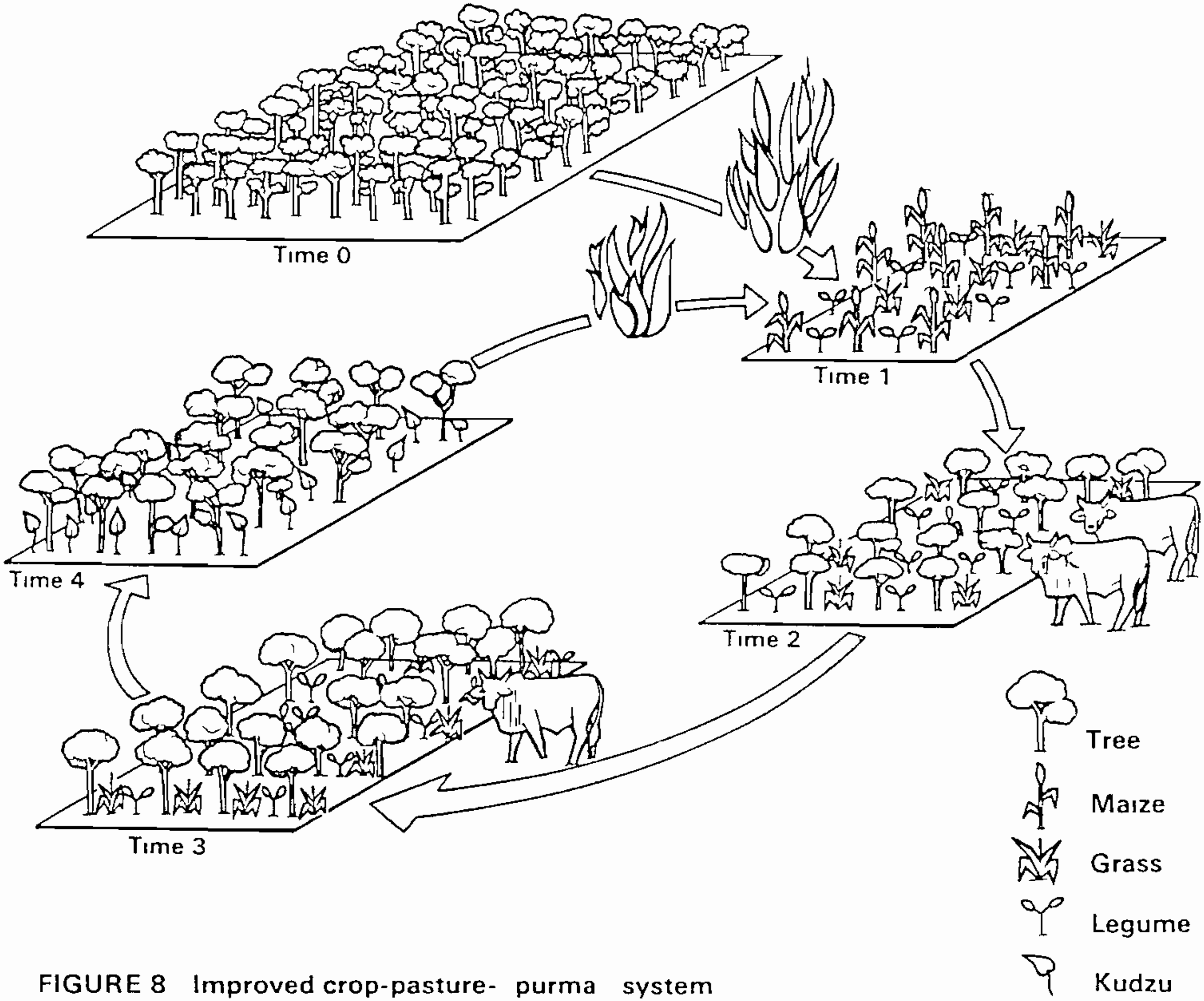


FIGURE 8 Improved crop-pasture- purma system

cycle begins again with the planting of crops and pastures This system relies on the N_2 fixing and nutrient cycling of the new pastures, which will easily allow farmers to intensify management and realize 20%-25% increases in productivity while avoiding soil degradation The system requires minimal change on the part of the farmer The only technological innovation is the use of improved species The system allows a 50-ha farm to maintain 55-60 head of cattle and produce annual crops on 5 ha of land every year

In areas of longer term colonization in the humid tropics, a mix of torurco and purma areas exists Farmers have low productivity areas close to the farm infrastructure where they most need high productivity They face the dilemma of moving the center of management closer to the more productive purmas or reclaiming the close-in torurco areas Both alternatives are expensive

An economic analysis was performed on three alternative methods of reclaiming torurco areas using a ten-year period as the base line for evaluating economic returns The assumption is that the three alternatives result in pastures with the same productivity and persistence at the tenth year

The mechanized reclamation alternative The torurco is grazed for ten years at low stocking rates (0 65 AU/ha), assuming liveweight gains of 275 grams/head/day, yielding an estimated net yearly income of US$32 70/ha The area is then mechanized and fertilized to upgrade soil conditions, and grass-legume pastures are established along with maize as a cash crop The cost of pasture establishment is US$244/ha as shown in Figure 7

The legume cocktail option The torurco is grazed for seven years with the same management and returns specified above The area is then reclaimed using a combination of aggressive legume germplasm but without mechanization Soil chemical and physical properties are improved through sowing legumes such as *Centrosema macrocarpum* or *P phaseoloides* in combination with a fast-growing legume such as *S guianensis* The legumes are planted after heavy grazing herbicide (Roundup, 1 5 l/ha) is used to control weeds, and band application of 70 kg of triple superphosphate is made in strips over 50% of the area

The manual sowing of the legume cocktail is done using a digging stick to superficially open the soil in the treated strips Total labor requirement is 7 man days/ha Table 7 shows the cost structure of this reclamation option

Table 7 Cost of non-mechanized establishment of a legume cocktail in torurco grassland

Inputs and labor (US$)	Cost
Herbicides (1 5 L of Roundup/ha)	25 50
Fertilizer (70 kg of SPT/ha)	2 25
Seeds (3 kg/ha)	9 00
Total cost of inputs	36 75
7 men-days/ha	12 25
Total cost/ha	49 00

After three years with no grazing enough aerial and root biomass has accumulated to restore soil structure and fertility The area is then cleared and burned and grass-legume pastures are established along with a maize companion crop with the same US$25/ha cost estimated for establishment of pasture after purma (Figure 7) This option requires less labor in clearing but may require more labor in weed control during the establishment phase

This option uses the adaptation of legumes to low-fertility soils, their deep, profuse rooting systems and their capacity to fix nitrogen to accelerate the natural build-up of soil fertility This replaces 10-15 years of natural fallow with three years of managed legume-cocktail fallow

Torurco fallow option The third alternative evaluated is to eliminate grazing for the entire ten year period, allowing secondary regrowth to slowly accumulate and to use the traditional purma technology to reclaim the area (costs are US$25/ha see Figure 7) In this alternative, the farmer must take the area out of production for ten years during the extended fallow period

Table 8 shows the net cash flow of the three alternatives The alternative with highest net present value (NPV) (i = 10%/year) is the non-mechanized managed legume-cocktail fallow with an NPV of US$124 20, followed by the mechanized option with an NPV of US$106 50 The option of taking the land out of production for ten years has a negative NPV, which explains why farmers do not use this option This analysis shows the importance of investigating non-mechanized, low-cost reclamation techniques similar to option 2 presented here Pasture reclamation using mechanization fertilization and pioneer crops may be feasible for larger areas where access to machinery and capital exists

Table 8 Economic net fluxes of three torurco grassland reclamation alternatives

Year	Three establishment alternatives		
	Mechanized	Legume cocktail (US$)	After fallow
1	32 70	32 70	0
2	32 70	32 70	0
3	32 70	32 70	0
4	32 70	32 70	0
5	32 70	32 70	0
6	32 70	32 70	0
7	32 70	-16 30[b]	0
8	32 70	0	0
9	32 70	0	0
	-212 30[a]	-25 50[c]	25 50[c]
NPV (i = 10%/year)	106 50	124 20	9 80

a (245 00 + 32 70) = Mechanized net cost of establishment + annual revenue

b (- 49 00 + 32 70) = Cocktail net cost of establishment + annual revenue

c (- 25 50) = Net cost of establishment after purma

In Pucallpa, Peru, CIAT is studying several alternative crops for the reclamation of torurco grasslands including rice, maize, and cowpeas Figure 9 shows the effects of fertilizers and land preparation on rice yields There is a clear interaction between fertilizer response and disk harrowing, with fertilizer response increasing after disk harrowing was applied The same pattern is illustrated in Figure 10 for cowpeas However, maize yields were highest with zero tillage reducing fertilizer response with disk harrowing (Figure 11) The response of rice and cowpeas to tillage suggests that soil compaction in degraded torurco grasslands is a major constraint for the development of their root systems

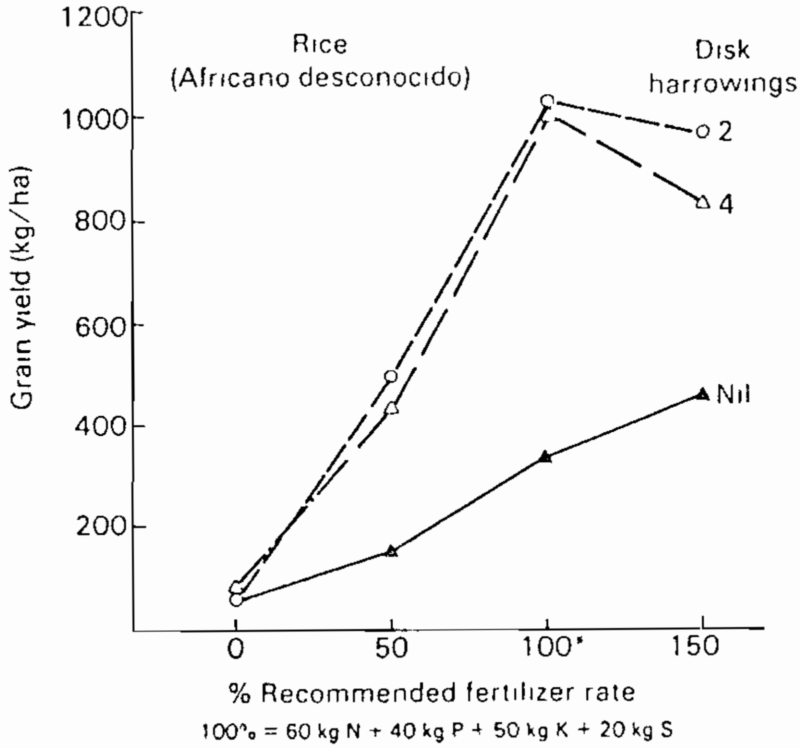


FIGURE 9 Rice yield under different fertilization rates and levels of disk harrowing (number of passes) after torurco at Pucallpa Peru (CIAT 1989)

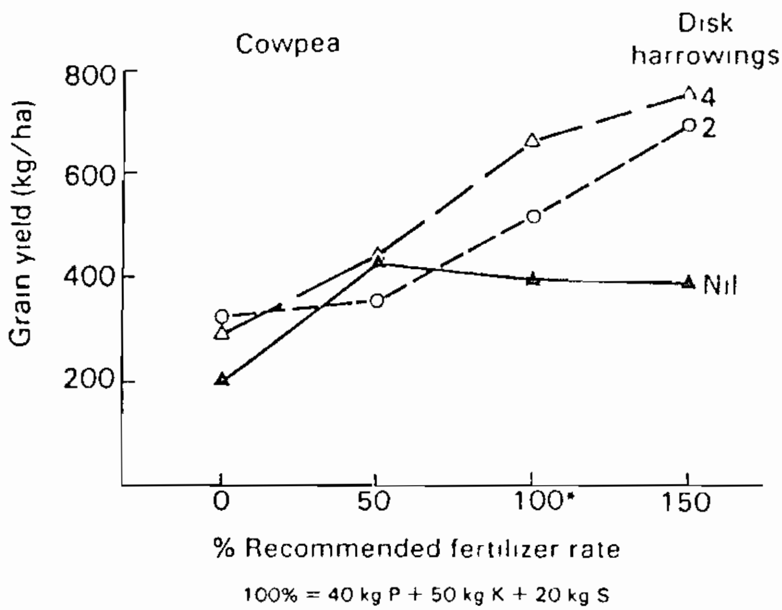


FIGURE 10 Cowpea yield under different fertilization rates and levels of disk harrowing (number of passes) after torurco at Pucallpa Peru (CIAT 1989)

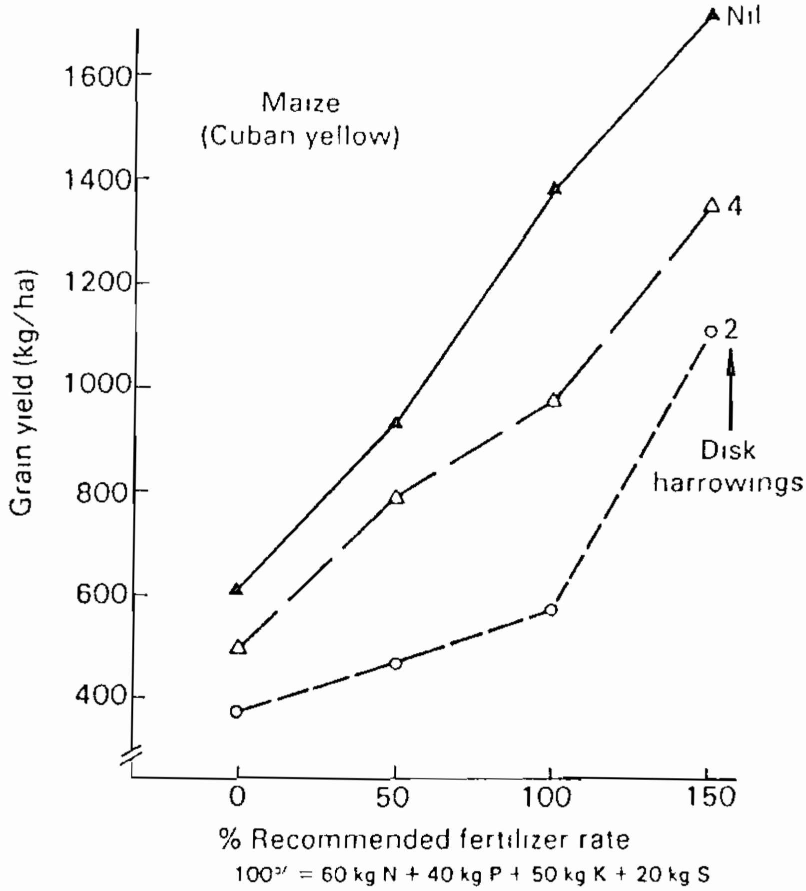


FIGURE 11 Maize yield under different fertilization rates and levels of disk harrowing (number of passes) after torurco at Pucallpa Peru (CIAT 1989)

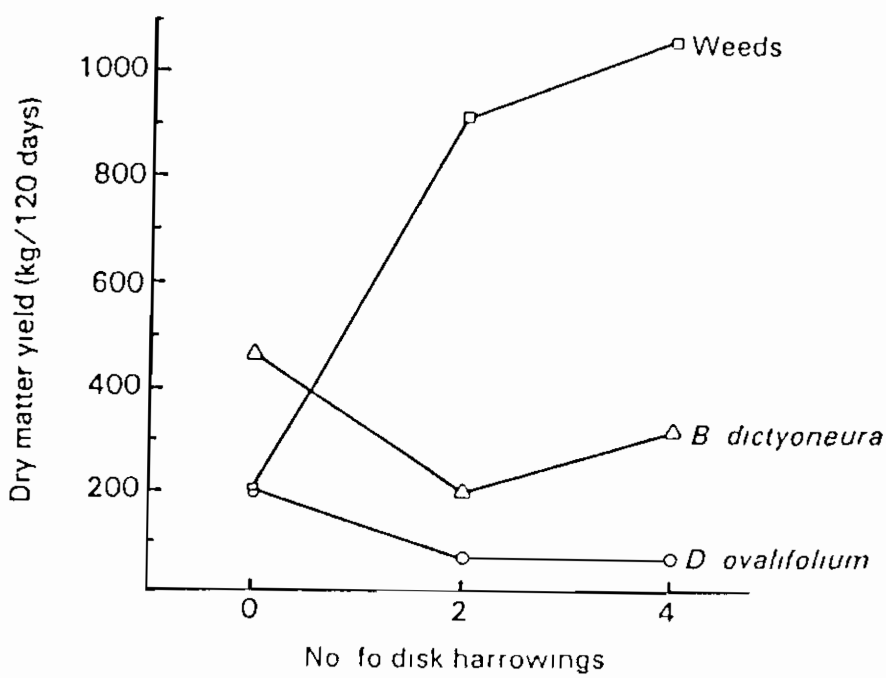


FIGURE 12 Weed invasion and yield of *B dictyoneura* and *D ovalifolium* as affected by tillage levels after torurco at Pucallpa Peru (CIAT 1989)

The maize response suggests that compaction is not a constraint for its more vigorous root system However, the reduction in response to fertilizer with tillage indicates that weed invasion associated with tillage is a major competition constraint for maize productivity Figure 17 shows the dramatic increase of weeds in tillage treatments due to the activation of seed reserves in the soil and soil mineralization

Dry matter yields of the grass and legume planted simultaneously with the three crops were reduced by weed competition due to harrowing This fact shows the importance of weed invasion after land preparation and the potential of maize as a cash crop in non-mechanized pasture reclamation

Research and Development Needs

Further research efforts are required to overcome major constraints for the development of economically sound and sustainable production systems in savanna and humid tropical ecosystems where cattle and crop production are currently expanding These land resources of varying fragility will be increasingly used in the near future by the societies of Latin America Agricultural expansion into the savannas is of minor degradation risk However, degradation of the soil and loss of biomass in the rain forest areas are a major research and development concern

A two-pronged research strategy needs to be followed First, technology should be developed for the intensification of land use in the tropical savannas This will allow reduction in farm size and make it feasible for land-hungry colonists to settle this less fragile ecosystem, thus reducing pressure on the humid tropical forest areas Second, the pasture-crop-tree technologies that are highly productive and sustainable should be developed to replace degrading production systems found in areas of the humid tropics already cleared This strategy is particularly important for countries with no savanna resources

The intensification of land use in these two ecosystems is the only way to prevent ever greater rates of deforestation in tropical America in the medium-term by societies interested in increasing their arable land base Intensification of production on already disturbed sites should be combined with immediate and concerted efforts to preserve sufficiently large and representative areas of these ecosystems to reduce the threat of species extinctions and loss of biodiversity Proposed research strategies suggest the following priorities

<u>At the genetic level</u> Further develop highly adapted, productive cultivars of crops, pastures, and trees as potential components of mixed agro-silvo-pastoral systems

<u>At the technological level</u> Study soil-plant-animal-management interactions in different relevant integrated production systems under a range of natural conditions to develop management principles

<u>At the farm level</u> Study farmers socioeconomic constraints and natural-resource availability to develop management techniques that optimize profitability and sustainability of production systems These management techniques should use new genetic materials, develop handling and processing technologies to reduce losses, and broaden the market of agricultural products This is particularly important in native and tree crops with high potential value but limited markets such as cassava, plantains, tropical fruits (cupuazu, guarana, camu-camu, etc), and native industrial products (timber resins, fibers, etc)

At the microregional level Study and characterize the area s natural resources to better organize use of land resources, including the protection and reforestation of more fragile areas

Develop a microregional communication and marketing infrastructure to activate the rural economy by facilitating productivity and trade of farm products with high economic potential

At the regional/national level Define areas of protection and areas to be developed based on sound conservation and economic criteria

Develop and implement appropriate policies to facilitate regional and national development

At the international level Strengthen national institutional capacity for natural resource appraisal as well as agricultural research and development, enhancing their work through better access to information, equipment and training

Invest in pasture crop rural development cases in contrasting microregions to learn first-hand the complexities of these systems and appropriate development approaches to increase rural productivity, incomes, and sustainability

Final Remarks

Rural development implies modification of natural environments as well as the proper use and conservation of natural resources However, farmers in their struggle to leave poverty behind are not worried about regional or global concerns such as conservation of natural resources (erosion, deforestation watershed management global warming) They are not aware of the sustainability issue since their main concern is their income To correct present development and conservation problems, a combination of appropriate policies and technologies must be in place The development of suitable technologies depends on the use of sound genetic materials, knowledge about integration and management in relevant farming systems, and the availability of markets for farm products

Research on integrated tree livestock-cropping systems based on high inputs, products with limited markets and requirements of sophisticated management no doubt will yield interesting papers and information about what can be done 'if' These will be nice demonstrations but irrelevant to the possibilities of rural development

Research and development institutions should work closely together to solve the most pressing technology constraints at the regional level and to increase the productivity of the most important components of existing farming systems Often, there are only two or three such components in a region and we must choose our research targets carefully Defining a well-focused target for regional research and development requires coordination for the best use of available genetic, informational and financial resources The effort should aim to facilitate the adoption of new technologies to increase regional productivity, farmers incomes, and rural well being Raising incomes will expand local markets for a variety of goods and services In this way, regional development, modernization, and agricultural intensification can proceed together

CONTROL DIARIO DE CONTADORES

Código Máquina 5034

Fecha	Inicial	Final	Total

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