Tropical Pastures Program

Background documents to the external program review's visit to the eastern plains of colombia.

1989

CIAT Centro Internacional de Agricultura Tropical

CONTENTS

THE ROLE OF CARIMAGUA

Carimagua is the main research station for the Tropical Pastures Program of CIAT. It was founded by the Instituto Colombiano Agropecuario (ICA) in 1969 as an investment in the future by the Colombian government leading to the development of the vast savanna resources of the Eastern plains (Llanos) of the country.

The Tropical Pastures Program and the Cassava Program have worked at Carimagua since the late 70's, while in the current year the Rice Program has initiated research activities in association with the Tropical Pastures Program.

ICA's main research activities have been in soil characterization and management, in the characterization of the native grasslands, and in the utilization of improved pastures in cow-calf production systems. They have also worked on oil palm, mango, cashew and annual crop production. During the last years ICA's work has been focussed on utilization of improved pastures as well as in cattle management, reproduction, and breeding.

Research of the Tropical Pastures Program of CIAT during the 80's focussed on the selection and development of new germoplasm (grasses and legumes) adapted to poor acid soils (Oxisols), represented by Carimagua, as well as for resistance to prevailing pests and diseases. The best germoplasm selections have been studied for their compatibility in grass legume associations under grazing. Their potential for animal production has also been assessed, and together with ICA, the Tropical Pastures Program is now exposing the promising new pastures to farmers' conditions throughout the Llanos.

Two grasses and two legumes have so far been released comercially by ICA and are being adopted widely. They are the grasses *Andropogon gayanus* cv Carimagua (CIAT 621) and *Brachiaria dictyonuera* cv Llanero (CIAT 6133) and the legumes *Stylosanthes capitata* cv Capica (CIAT 10260) and *Centrosema acutifolium* cv Vichada (CIAT 5277).

In addition to the materials already released for the Llanos ecosystem, the Tropical Pastures Program has several new generations of germplasm in the pipeline. Among the promising materials are new accessions of the legumes *Arachis pintoi*, *Centrosema brasilianum*, *Desmodium ovalifolium*, *Centrosema macrocarpum*, and *Flemingia macrophila* and the grasses *Brachiaria brizantha* and *Panicum maximum*.

The Tropical Pastures Program is sure that these new adapted materials have great potential to make an impact in the regio~ by increasing both animal productivity and the sustainability of production systems based on them. However, the new technology brings with it two main challenges for ICA and for CIAT:

1. The need to assemble the new germplasm selection in pastures at farm level.

2. The need to demonstrate and document the commercial feasibility of animal production in sustainable grass-legume pastures with minimum inputs.

The Tropical Pastures Program recognizes that these new systems will require better management in order to exploit their full potential in intensive production systems.

A very important task for the Tropical Pastures Program during the coming years will be to develop knowledge and understanding of the way these pasture function in terms of how the soil-plant-animal complex interacts with management, with special emphasis on nutrient cycling. Similary, knowledge and understanding of the interactions between crops and pastures will be needed to develop systems of ley farming in savannas.

The Carimagua and the Llanos visits have been organized to give a brief overview of the work of the Tropical Pastures Program in this ecosystem and its relevance to the general mandate of the program.

SOIL-PLANT-ANIMAL MANAGEMENT RELATIONSHIPS AND NUTRIENT CYCLING

The use of improved grass-legume pastures to increase animal productivity in tropical savannas offers new challenges for the Tropical Pastures Program. In addition to providing new adapted germplasm, the Tropical Pastures Program must also develop the components of pasture management technology that make it possible to sustain production in the longer term. A team effort within the Program will be focussed specifically towards incorporating studies of the soil-plant-animal interaction into the process of evaluating new germplasm. Studies of the plant-animal interface are seeking to understand how different practices of animal management influence plant persistence and productivity. Studies of nutrient cycling will concentrate on evaluation of gains and losses of nitrogen in improved grass-legume pastures and how the interactions between soil, soil, plant and management influence the dynamics of phosphorus and other key nutrients in grazed systems.

The present conditions provide a unique opportunity to conduct strategic research on aspects mentioned above. The Tropical Pastures Program has the adapted germplasm, the skills and the resources. The expected output of this effort will be (1) to increase the knowledge and understanding of the processes that are responsible for tolerance to acid soils in adapted grasses and legumes and to seek way of utilizing applied inputs most effectively; (2) to provide to the RIEPT simple methodologies to evaluate these processes; (3) to devise better management recommendations for improved pasture at the farm level.

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PASTURE ADOPTION SURVEY OF THE EASTERN PLAINS OF COLOMBIA (PRELIMINARY INFORMATION)

In order to estimate the degree of adoption of improved pastures and the factors determining adoption, a sample survey of producers of the two main counties (Puerto Gaitán and Puerto López) of the well-drained savannas of the Eastern Plains of Colombia was undertaken. This project is being undertaken jointly by CEGA (Corporación de Estudios Ganaderos y Agrícolas) and the Tropical Pastures Program of CIAT.

A sample of 86 farms out of 728 farms listed a producing cattle according to ICA records and of more than 40 hectares were randly chosen and interviewed conducted.

The information requested covered the topics of resource endowment of the farms, land use, evolution of areas of pastures, management practices related to these pastures and planting intentions. An additional set of questions specifically addressed the issue of the adoption of Stylosanthes capitata cv Capica, the first legume released by ICA for that region in 1983.

Enclosed is a selected set of tables and graphs covering the most interesting topics.

LAND IN PASTURES, EASTERN PLAINS OF COLOMBIA, 1989*

Pasture	Estimated area (hectares)	Percentage of error**
Total area	990,029	19.2
Native pastures	871,664	21.7
Improved pastures	90,755	20.4
Legume grass associations	7,009	40.0

* Extrapolated from survey of 86 farms in the Municipios of Puerto López and Puerto Gaitán

** Error probability = 20%

PASTURES IMPROVEMENTS BY SPECIES.
EASTERN PLAINS OF COLOMBIA, 1989*

Species	Estimated area (hectares)	Percentage of error**
A. gayanus	3014	44.1
B. decumbens	47853	28.1
B. humidicola	27232	23.8
B. dictyoneura	1363	66.4
B. brizantha	135	83.8
A. gayanus + S. capitata	2482	79.1
A. gayanus + C. acutifolium	339	120.1
B. decumbens + S. capitata	1490	66.1

* Extrapolated from survey of 86 farms in the Municipios of Puerto López and Puerto Gaitán

** Error probability = 20%

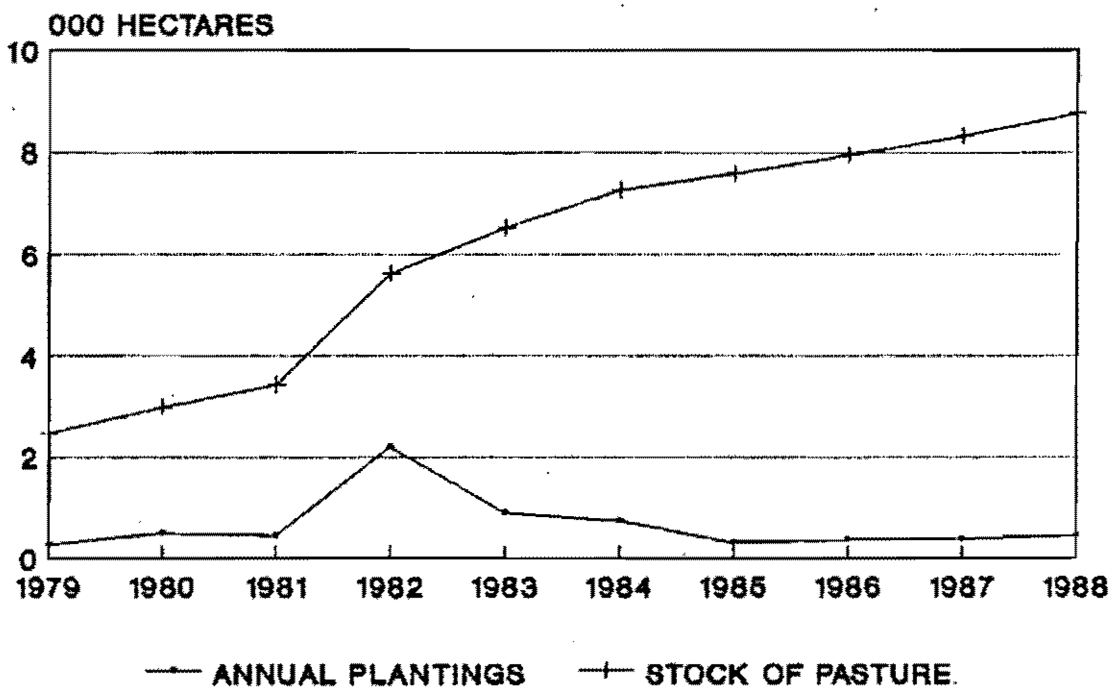
ADOPTION RATES BY SPECIES.
EASTERN PLAINS OF COLOMBIA, 1989*

Species or associations	Adoption rate (%)	Percentage of error**
A. gayanus	14	28.7
B. decumbens	65	8.4
B. humidicola	70	7.6
B. dictyoneura	9	36.0
B. brizantha	3	60.7
A. gayanus + S. capitata	7	42.1
A. gayanus + C. acutifolium	1	106.9
B. decumbens + S. capitata	6	46.5

* Survey of 86 farms in the Municipios of Puerto López and Puerto Gaitán

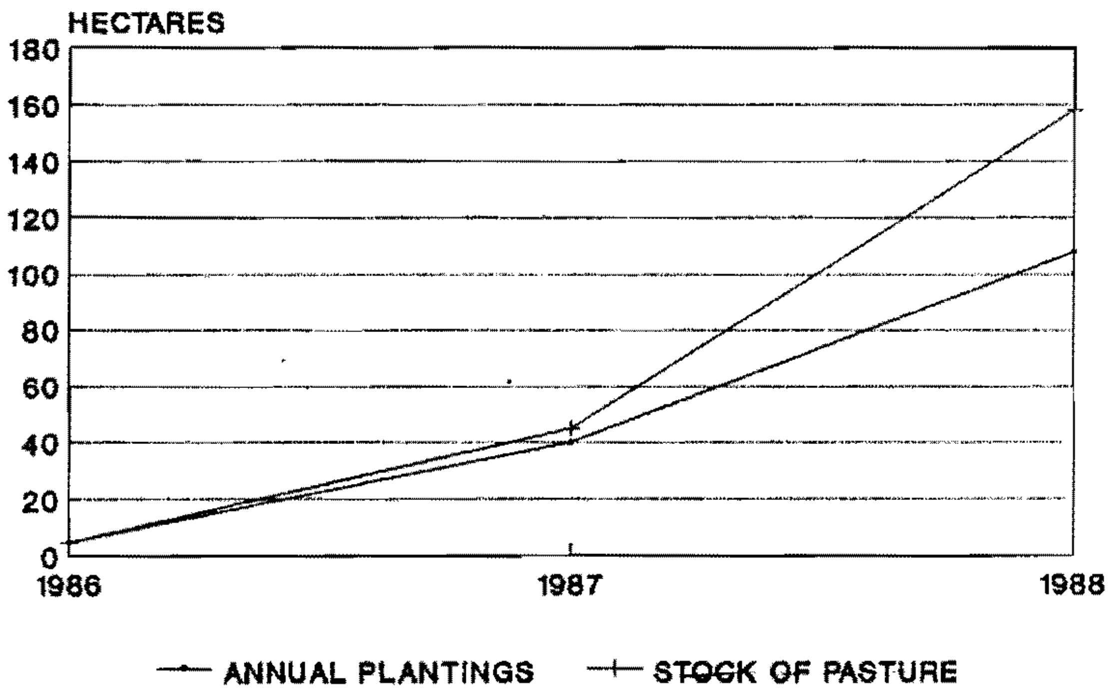
** Error probability = 20%

BRACHIARIA DECUMBENS
EVOLUTION OF ANNUAL PLANTINGS AND STOCK



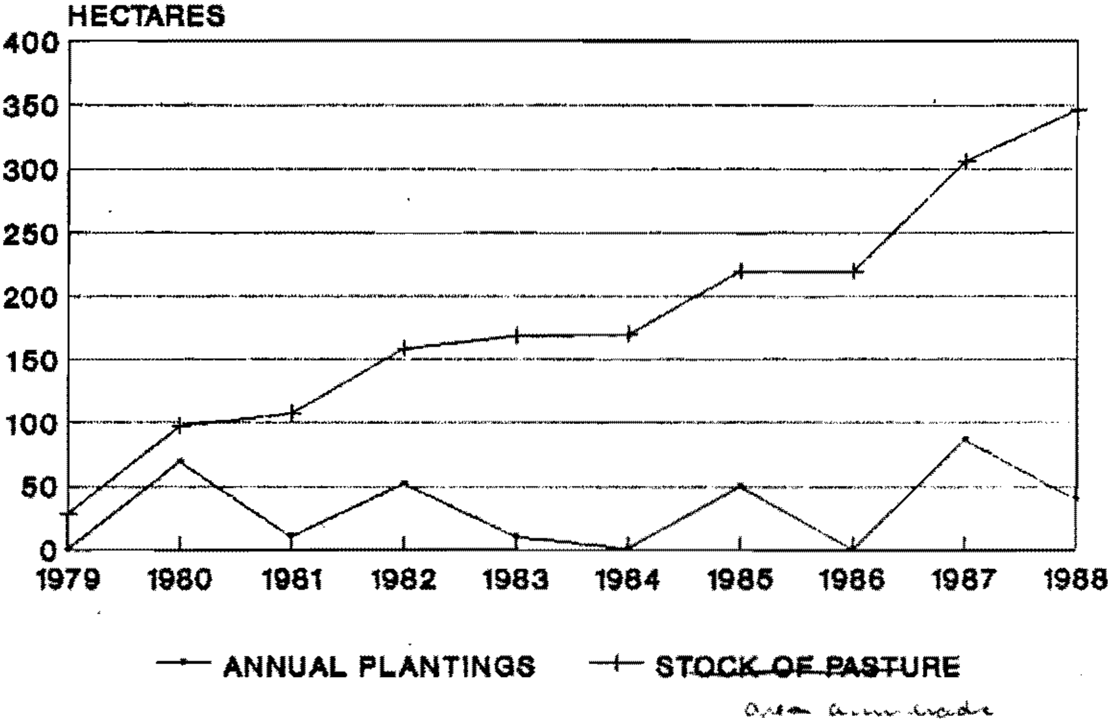
EASTERN PLAINS OF COLOMBIA

BRACHIARIA DICTYONEURA
EVOLUTION OF ANNUAL PLANTINGS AND STOCK



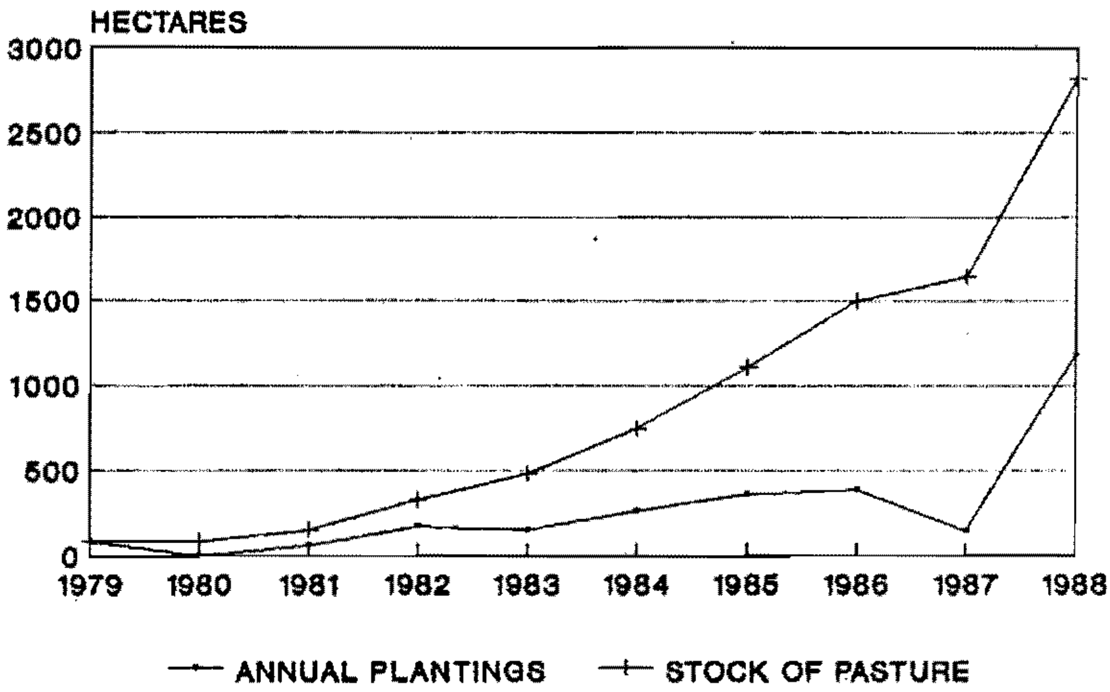
EASTERN PLAINS OF COLOMBIA

ANDROPOGON GAYANUS
EVOLUTION OF ANNUAL PLANTINGS AND STOCK

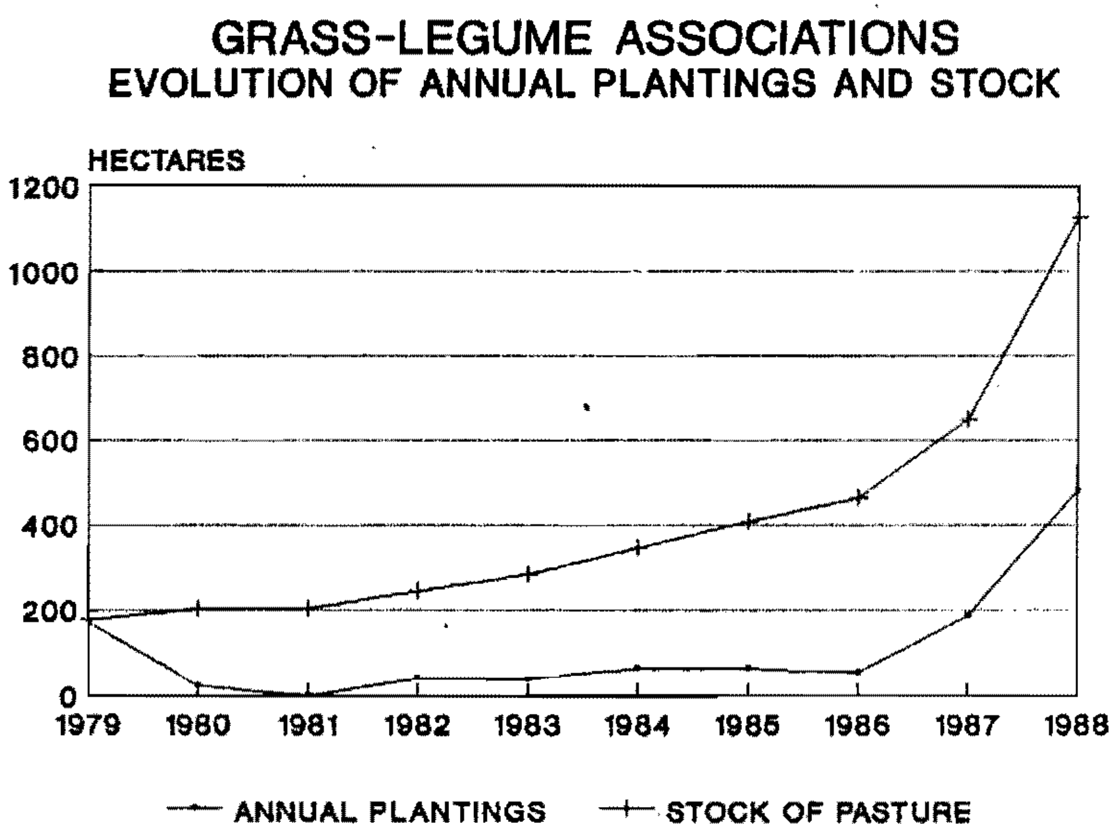


EASTERN PLAINS OF COLOMBIA

BRACHIARIA HUMIDICOLA
EVOLUTION OF ANNUAL PLANTINGS AND STOCK



EASTERN PLAINS OF COLOMBIA



EASTERN PLAINS OF COLOMBIA

CAPICA ADOPTION: DECISION TREE

86	Farms surveyed	
50	Heard about Capica	
39	Considered useful	
18	Tested it..................	100%
15	Had good results...........	83%
6	Expanded areas.............	33%
4	Plan additional plantings...	22%

(preliminary results)

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ECONOMIC ANALYSIS OF A GRAZING TRIAL: THE CASE OF BRACHIARIA DECUMBENS VERSUS B. DECUMBENS WITH PUERARIA PHASEOLOIDES ON THE EASTERN PLAINS OF COLOMBIA

1. Introduction

It is generally accepted that adoption of new pasture technology is closely related to profitability to the producer of investments associated with improved technology.

Several studies have demonstrated that profitability of some new pasture technologies is superior to profitability of traditional technologies (see Nores and Estrada, 1978). Given that demand for animal products is not perfectly elastic, one of the final effects of technological change at the aggregate level is the gradual reduction in real prices received by the producer as supply is expanded, which implies a medium- to long-term reduction in profitability of new technology and in the long run a non-stimulus to technological change.

This present article utilizes experimental information from a grazing test conducted at the Carimagua Research Center to compare the profitability of establishing pure grass pastures (traditional technology) and associated ones based on grasses and legumes (improved technology), and to quantify the impact of the possible reduction in cattle prices due to an eventual massive adoption of new technology on these profitabilities. The impact of possible increases in the costs of establishment on the profitability of the improved technology is also measured. Likewise, it establishes the range of price variation in which economic benefit of the improved technology is superior to that of the traditional technology, given two sources of risk: reduction in cattle prices and an increase in the establishment costs of improved pastures.

2. Methodology

The framework of economic analysis assumes a closed market economy, where expansion of supply determines reductions in price of the product offered (for example, meat or milk). The analysis assumes an inelastic demand for meat, that is, reductions in price of this product are reflected in increases in consumption of meat from cattle in lower proportions than the decrease in price. As a result, the drop in price implies an increase in real income of consumers as more meat can be consumed the same level of income.

On their part, producers, upon increasing their productivity due to technological change, can produce greater volumes of meat at lower levels of unit cost. The difference between the market price and the cost to the producer represents a net benefit for the producer. When the level of market prices and production costs become equal, benefit to producers is balanced with the return to factors in other uses and there are no incentives to adopt technology and increase production of meat beyond this level. This can occur either because of the continued process of reduction in prices resulting from adoption and technological change, or because of the increase in marginal production costs, or a combination of these. Both factors constitute sources of risk associated with the adoption of a new technology.

In the analysis, it is assumed that investments in improved pastures (in this case, the association Brachiaria decumbens + Pueraria phaseoloides) are marginal. That is, the cattle rancher has land available, and the basic infrastructure such as housing, corrals, water points, fences, and equipment, and that there do not exist restrictions for the acquisition of inputs and the hiring of manpower. The problem is limited to evaluating the profitability of new investments, associated exclusively with the improved technology with regard to the establishment and maintenance of pastures and the acquisition and management of cattle.

Figure 1 illustrates the effect of the increase in supply due to technological change on market prices and quantities. Curve OO represents initial supply without technological change, given an initial demand DD. Due to the increase in cattle productivity derived from the adoption of new technology, costs per unit of production are reduced and total supply is increased, shifting itself pivotally downward to O O_1. The market price, before the technological change, was P_0. Due to the increase in supply, with demand remaining constant, the new equilibrium price is P_1. At this new price, producers would be willing to sell the quantity Q_1, which is precisely the quantity that consumers would be willing to buy at the new price P_1. The area OLM represents social benefits derived from a technological change of this nature.

It is assumed that the shifting of supply is pivotal divergent because this shift reflects the existence of a unitary cost of production under which the supply of meat or milk with technology is not relevant.

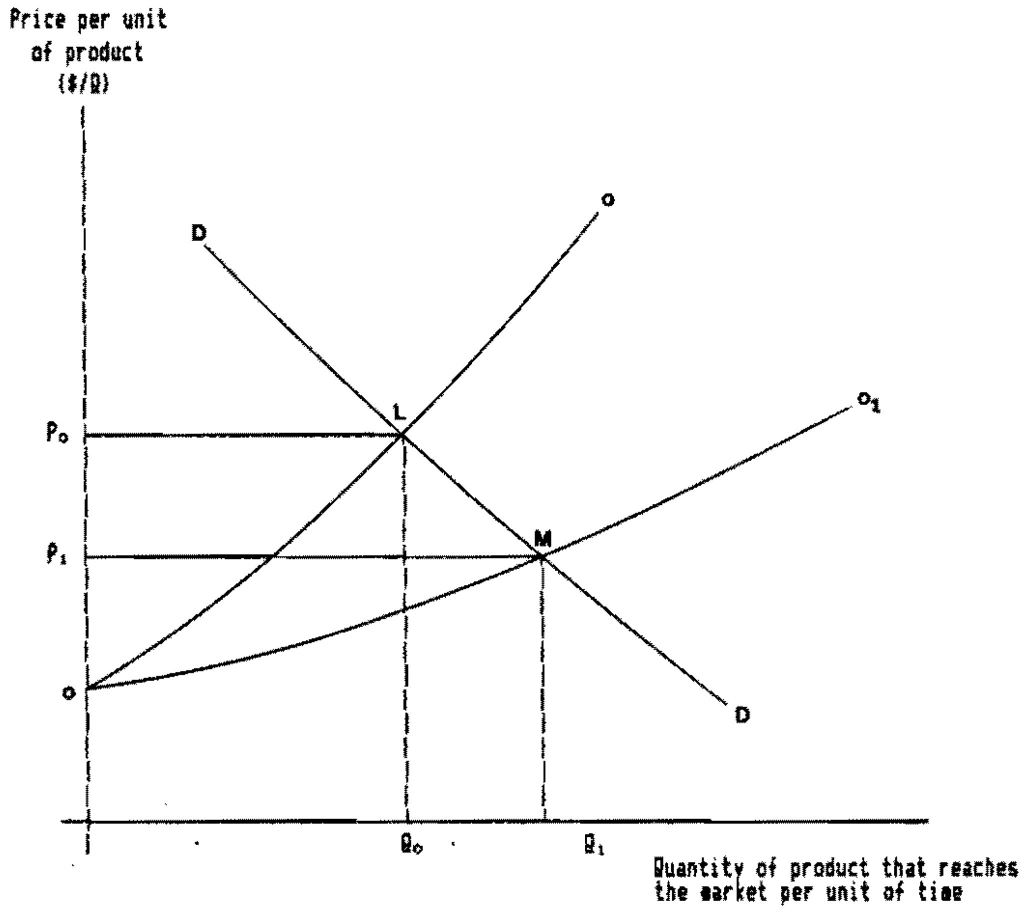

Figure 1. Effect of increase in supply due to technological change on market prices and quantities

2.1 Biological and economic information

The analysis is based on experimental data of weight gain derived from a grazing trial conducted at the Regional Research Center, Carimagua. In this study, weight gains of fattened steers in pastures of pure *Brachiaria decumbens* ("traditional technology") and in associations of *B. decumbens* and *Pueraria phaseoloides* ("improved technology") are compared.

B. decumbens is a grass well adapted to conditions of the Eastern Plains of Colombia, not only because of its tolerance to low levels of natural soil fertility (Spain, 1979) but also because of its animal productivity and ease of management. *P. phaseoloides* (Kudzu) is a legume moderately adapted to acid soils, being more demanding in terms of nutrients than other legumes with greater adaptation.

The Livestock Research Center at Carimagua is located 320 km to the east of Villavicencio, at 4°37' N and 175 m.a.s.l., in an area representative of the well-drained savannas of the Eastern Plains of Colombia. The mean temperature is 26°C, with rainfall of 2000 mm and a marked dry season from the middle of December to the end of March (Tergas et al., 1984).

The soils are Oxisols, acid (pH 4.5, 86% aluminum saturation), low in available phosphorus (1.2 ppm Bray II), and low in interchangeable calcium, magnesium, and potassium (0.2 meq/100 g) (Sánchez and Tergas, 1979).

The experimental design consisted of random blocks with three treatments: pure B. decumbens and B. decumbens in association with P. phaseoloides established in blocks and strips, the latter legume representing 30% of the total pasture area. The economic analysis was carried out by comparing pure B. decumbens and B. decumbens in association with the legume planted in strips.

Table 1 summarizes animal stocking rates and weight gains per animal, according to period and year, observed in the experiment in the period 1979-1987[1]. In Table 2, averages of production and productivity are presented, along with assumptions on cattle prices, costs of establishment and refertilization of pastures, and maintenance of the cattle used in the analysis.

The experimental stocking rates that corresponded to animals of approximately 150-200 kg were adjusted to equivalent stocking rates for animals of 300 kg, with which the stocking rates finally used resemble more those observed on commercial farms of the high plains.

The experiment was developed under flexible grazing conditions with adjustments in animal stocking rates according to the period of the year and pasture conditions. Experimental fertilization includes P_2O_5, K_2O, MgO, and S in quantities and years that appear in Table A3. The weight gains per animal per day were assumed to be equal for the experimental animals and the 300-kg steers, in spite of the fact that younger animals have a greater rate of conversion with which one could be overestimating weight gains for 300-kg animals. However, said overestimation would be similar for the animals in both treatments, for which differences between treatments would be maintained.

1/ For more detailed information on the experiment, consult Tergas et al. (1984) and CIAT (1983, 1984, 1985, 1986 and 1987).

Table 1. Weight gains in fattening of steers in _Brachiaria decumbens_ and in association of _Brachiaria_ and Kudzu

Year		Stocking rate (dry/rainy)	Weight gains (kg/animal) Dry period	Rainy period	Annual gain
1979	_B. decumbens_	2.0/2.0	4.5	131.8	136.3
	B. decumbens + Kudzu	2.0/1.6	33.2	145.1	178.3
1980	_B. decumbens_	1.0/2.0	7.0	119.3	126.3
	B. decumbens + Kudzu	1.0/2.0	67.5	114.2	181.7
1981	_B. decumbens_	1.0/2.0	61.4	120.7	182.1
	B. decumbens + Kudzu	1.0/2.0	71.2	133.3	204.5
1982	_B. decumbens_	1.0/2.0	42.5	91.3	133.8
	B. decumbens + Kudzu	1.0/2.0	78.2	92.3	170.5
1983	_B. decumbens_	1.0/2.0	44.5	74.7	119.2
	B. decumbens + Kudzu	1.0/2.0	75.8	128.4	204.2
1984	_B. decumbens_	1.0/2.0	43.3	87.0	130.3
	B. decumbens + Kudzu	1.0/2.0	80.2	114.0	194.2
1985	_B. decumbens_	1.0/2.0	27.5	96.2	123.7
	B. decumbens + Kudzu	1.0/2.0	39.9	113.0	152.9
1986	_B. decumbens_	1.5/2.5	0.5	65.8	70.7
	B. decumbens + Kudzu	1.5/1.5	14.1	113.8	127.9
1987	_B. decumbens_	1.0/2.0	55.9	41.5	97.4
	B. decumbens + Kudzu	1.0/2.0	64.7	93.8	158.5

SOURCE: Lascano and Estrada (1989)

Table 2. Principal assumptions for the calculation of profitability of pasture technology in fattening of steers, Carimagua, Colombia, 1979-1987

Assumptions	Association B. decumbens + P. phaseoloides	Brachiaria decumbens
1. Production and productivity		
a) Weight gain		
. grams/animal/day	478.8 a	339.6 a
. kg/animal/year	174.8	123.9
. kg/hectare/period	293.6	216.9
. carrying capacity (AU/ha) b	1.68 c	1.75 c
b) Steer weight (kg)		
. initial	300.0	300.0
. final (12 months of fattening)	474.7	423.9
2. Establishment, duration and carrying capacity of the pasture		
a) Establishment period (months)	8	8
b) Production period (months)	12	12
c) Evaluation period (months)	120	120
d) Establishment cost (US$/ha) d	136.28 e	104.98 e
e) Maintenance fertilizer cost (US$/ha)	55.80 f	32.22 f
f) Frequency of refertilization (months)	48	48
3. Prices and other costs		
a) Initial price (US$/kg liveweight):		
. thin steer	0.92	0.92
. fat steer	0.90	0.90
b) Steer maintenance cost (US$/month)	0.97	0.97

a/ SOURCE: Lascano and Estrada, 1979. Weight gain is a weighted average of gain in the dry season (124 days) and in the rainy season (241 days) over nine years of grazing.

b/ In the final calculations, a stocking rate of 1.1 UA/ha was employed in the two treatments due to the fact that stocking rates were adjusted according to steer weight.

c/ Weighted average for nine years of the stocking rates in the two seasons, dry and rainy.

d/ US$ of November 1987. Exchange rate 1US$ = $258.74 Colombian pesos.

e/ For the association the planting density is 2 kg/ha of Brachiaria decumbens and 2 kg/ha of Pueraria phaseoloides. For the pure grass the density is 3 kg/ha.

f/ The minimum input fertilization includes: 250 kg of rock phosphate, 100 kg of magnesium sulfate, and 30 kg of potassium chloride. Fertilization of the pure grass includes 250 kg of rock phosphate. A maintenance fertilization every four years is assumed, with fertilization levels equal to those of establishment.

2.2 Methods of analysis

For the economic analysis, a simulation model of fattening of steers was employed, which assumes a pasture persistence of 10 years, at the end of which it is assumed that residual value is zero. The model was prepared on an electronic LOTUS sheet, employing techniques of partial budgets for the calculation of net income flow discounted during the production period considered and the corresponding internal rate of return (IRR)[1]. The model simulates the effect of variations in prices and costs over the internal rate of return in the context of a sensitivity analysis. For effects of simulation, the unit of area considered was one hectare, in such a way that investments, income, and expenses are calculated on the basis of this unit. This implies an assumption of constant yields to scale, with constant unitary costs.

The economic analysis was elaborated employing two levels of establishment and maintenance fertilization costs. In the first case, the economic evaluation was carried out employing establishment and maintenance fertilization costs observed in the experiment. In the second case, the evaluation was conducted with establishment and refertilization costs estimated under the concept of use of minimum inputs (see Tables 2 and A1). This last concept contains a very important part of the philosophy of CIAT's Tropical Pastures Program for the design of technology appropriate for marginal areas, where because of distances to markets, cattle prices are relatively low and those of inputs relatively high, due to the elevated costs of transportation. This causes the appropriate technology for these regions to be characterized by a low level of use of purchased inputs (machinery, fertilizers, seed, agrochemicals, etc.).

The analysis of sensitivity to reductions in the price of beef, due to technological change, was conducted _ex ante_. To that effect, it was assumed that the producer attempts to maximize economic benefits; therefore, to make the decision to adopt improved technology, he hopes to obtain a profitability at least equal to the current profitability of traditional technology. The sensitivity analysis was oriented toward determining the level of price reduction in which the internal rates of

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1/ The internal ate of return (IRR) is a criterion to evaluate the financial profitability of investment projects. It is defined as that rate of interest that equals the present value of benefits and costs associated with a specific project. If the IRR is greater than the opportunity or market interest rate, it is said that the project is economically profitable. For more information on economic analysis of agricultural investments, see Gittinger (1972) and Makeham and Malcolm (1986).

return of traditional technology and of improved technology will be equal. The difference between these internal rates of return is interpreted as a measure of the magnitude of production and market risks that improved technology is capable of absorbing before ceasing to be attractive to the cattle rancher.

Investments in pastures and cattle were evaluated at their replacement cost, using November 1987 prices and assuming that these remain constant in real terms.

Reductions in price of fat cattle are gradual throughout the ten years of the evaluation period corresponding to ten fattening cycles. Thus, for example, a total drop in prices of 10% occurs in a lapse of ten years. It is assumed that the price of fat cattle is reduced more rapidly than that of thin cattle, as a result of an initial increase in the supply of fat cattle. In the present case, the lag in the drop of thin-cattle prices with regard to those of fat cattle is one year, assuming gradual reductions in price of the latter type of cattle starting from the second year.

3. <u>Analysis of Results</u>

Cattle ranchers face not only market risks but also production risks derived from variations in climatic conditions and incidence of pests and diseases, among other factors, which are widely documented in diverse CIAT Annual Reports. The level of production risk is manifested in the high variability of weight gains and milk production and, consequentially, in income, cash flows, and profitability of investments in pastures. Said variability should influence the adoption of new technology, assuming that there exists some degree of aversion to risk on the part of cattle ranchers.

In the present experiment, weight gain of the association (*B. decumbens* + *P. phaseoloides*) was found to be significantly superior to that of the pure grass (*B. decumbens*) in both periods of the year, but particularly in the dry period, which is the most critical period of the productive process, where weight gain per animal per day of the association was 82% higher than that of the pure grass. Differences in yield between the association and pure grass, between and within periods of the year, were statistically significant at the 5% error probability level (Table 3).

It was also found that there exists a marked variability in weight gains between and within periods of the year (rainy and dry). The coefficient of variation (CV) both for the pure grass as well as for the association is close to two times greater in the dry period than in the rainy period. However, in both seasons the association presents the least variability (CV of 14.0% in the rainy period and [illegible]% in the dry period, in contrast to a CV of 29.7% and 67.9%, respectively, for the pure grass). That is, weight gains in the association are less sensitive to variations originating in climatic conditions and other uncontrolled factors. This documents that technology based on the association with legumes, under the experimental conditions observed, is of less production risk than the pure grass once established.

Table 3. Variability in weight gain of the association versus pure grass in fattening of steers at Carimagua, second period of the year, 1979-1987

Variable	Dry season		Rainy season		Average	
	Pure grass[1]	Association[2]	Pure grass[1]	Association[2]	Pure grass[1]	Association[2]
Weight gain (grams/animal/day):						
. average gain						
. standard deviation	257.89	470.33	381.89	483.11	339.57	478.77
. coefficient of variation	174.68	178.43	113.56	67.41	70.67	65.50
	67.88	37.87	29.74	13.95	23.65	13.68
. value of t for the difference of means	-2.0 *		-2.66*		-4.13*	
Average stocking rate (heads/ha)	1.17	1.17	2.05	1.91		

* Values of t indicate that the means are significantly different at a probability level $\alpha = 5\%$.

1/ Pure B. decumbens.

2/ B. decumbens in association with P. phaseoloides.

SOURCE: Tergas (1984) and CIAT (several years)

Figure 2, besides illustrating variability in weight gains over time, of the pastures under study, shows a decreasing tendency in its level. In the period 1979-1987, the annual rates of reduction in weight gains were -6.8% and -3.3% for the pure grass and the association, respectively[1].

1/ Calculated according to the semilogarithmic models: $Y = Ae^{\alpha + \beta t}$
where: Y = weight gain
t = year
β = annual rate of average growth

These rates resulted significantly different at an error probability level of 5%. The reduction in yields reflects in part the effect of factors of pasture degradation, which determine losses of pasture quality and, as a result, losses in weight gains (CIAT, 1984). However, in this case, not all the reduction in yields can be attributed to the natural degradation of the pasture. In the first place, environmental factors or the presence of pests and diseases have caused drastic reductions in weight gains. For example, in 1986, weight gains of the association were reduced appreciably because of the presence of spittlebug in the grass. During this same year, due to flooding, gains were also reduced in pure _B. decumbens_ (CIAT, 1986). This can bring about an overestimate of the rate of reduction of yields over time.

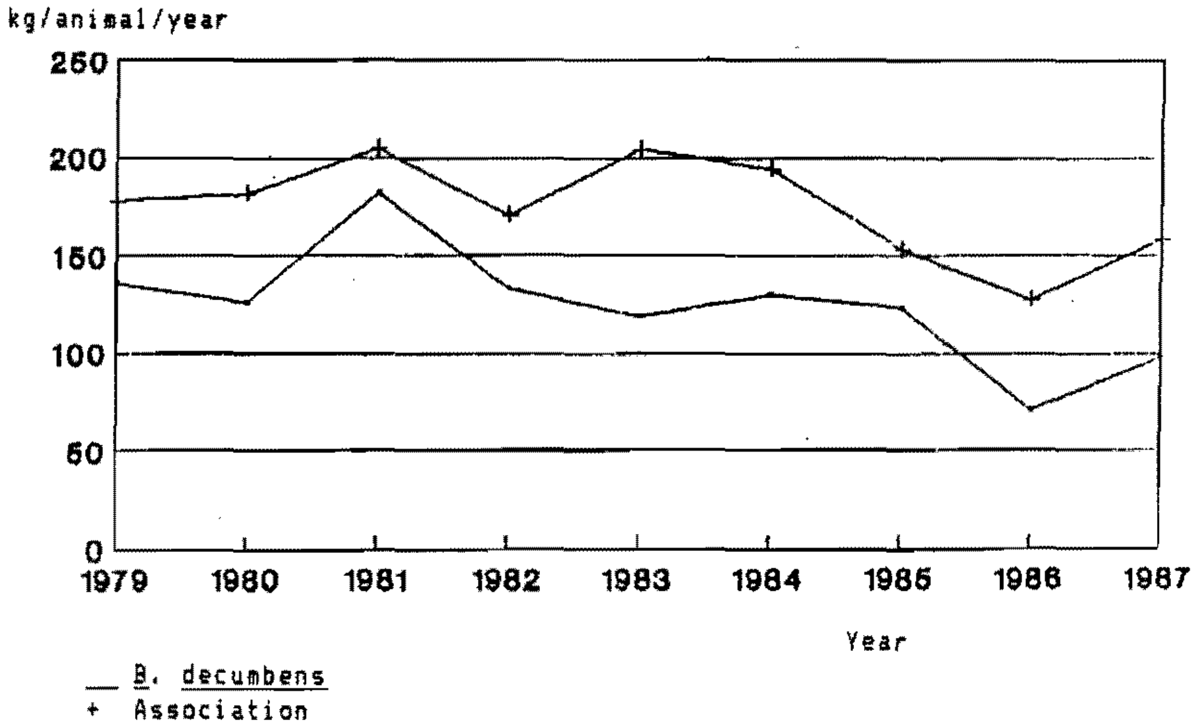


Figure 2. Evolution of weight gain of steers in the association _Brachiaria decumbens_ + _Pueraria phaseoloides_ and the pure grass _B. decumbens_. Carimagua, Colombia, 1979-1987

In the second place, these results are based on a single experiment, with a permanent occupation of the pasture without rest periods, different from the situation observed on farms where management was more flexible, resting the pasture between fattening periods and by sometimes mechanically disturbing the sward by passing a heavy off-set disk. Furthermore there is evidence in the region of Brachiarias more than 20 years old. For these reasons, it is estimated that the real rate of degradation of Brachiaria, at the farm level, can be appreciably lower than that calculated for the experiment.

The experiment was established in heavy soils, and it is expected that in light soils, the performance of the pure grass will be inferior, for which reason the association would be even more advantageous in light soils. It is necessary to point out that the experiment employs the legume P. phaseoloides (Kudzu), which has high nutrient requirements because of its low adaptation. With the use of better adapted materials such as those recently released in Colombia, C. acutifolium (Vichada) and S. capitata (Capica), that have lower fertilizer requirements, the economic advantage of the use of the association would be greater.

3.1 Profitability of traditional and improved technology

The estimated profitability of the improved technology is significantly superior to that of the traditional. For the average level of annual weight gains and under experimental fertilization levels, the internal rate of return of the improved technology is 29% greater than that of the traditional technology (IRR 23.3% as opposed to 18.0%). When one assumes a minimum use of inputs, profitability of the improved technology is not only increased in absolute terms (it rises to 30%) but the difference in relation to the traditional technology is also increased, 30% vis a vis 22% (see Figures 3 and 4).

To asses the sensitivity of the profitability to changes in weight gains, IRRs were computed using the lower and upper bound of the 95% confidence range of weight gains yielding IRR values between 20% and 27%.

3.2 Analysis of sensitivity with experimental fertilization

Figure 3 summarizes the analysis of sensitivity to prices of the profitability of marginal investment in mixtures of B. decumbens and P. phaseoloides. Upon economically evaluating the association under conditions of experimental fertilization, employing annual average weight gains of the period 1979-1987, it was found that even with a reduction of approximately 2.% in cattle prices, the internal rate of return of the improved technology is at least equal to the IRR of the traditional technology at initial prices. That is, the technology based on the association is moderately sensitive to the reduction in cattle prices.

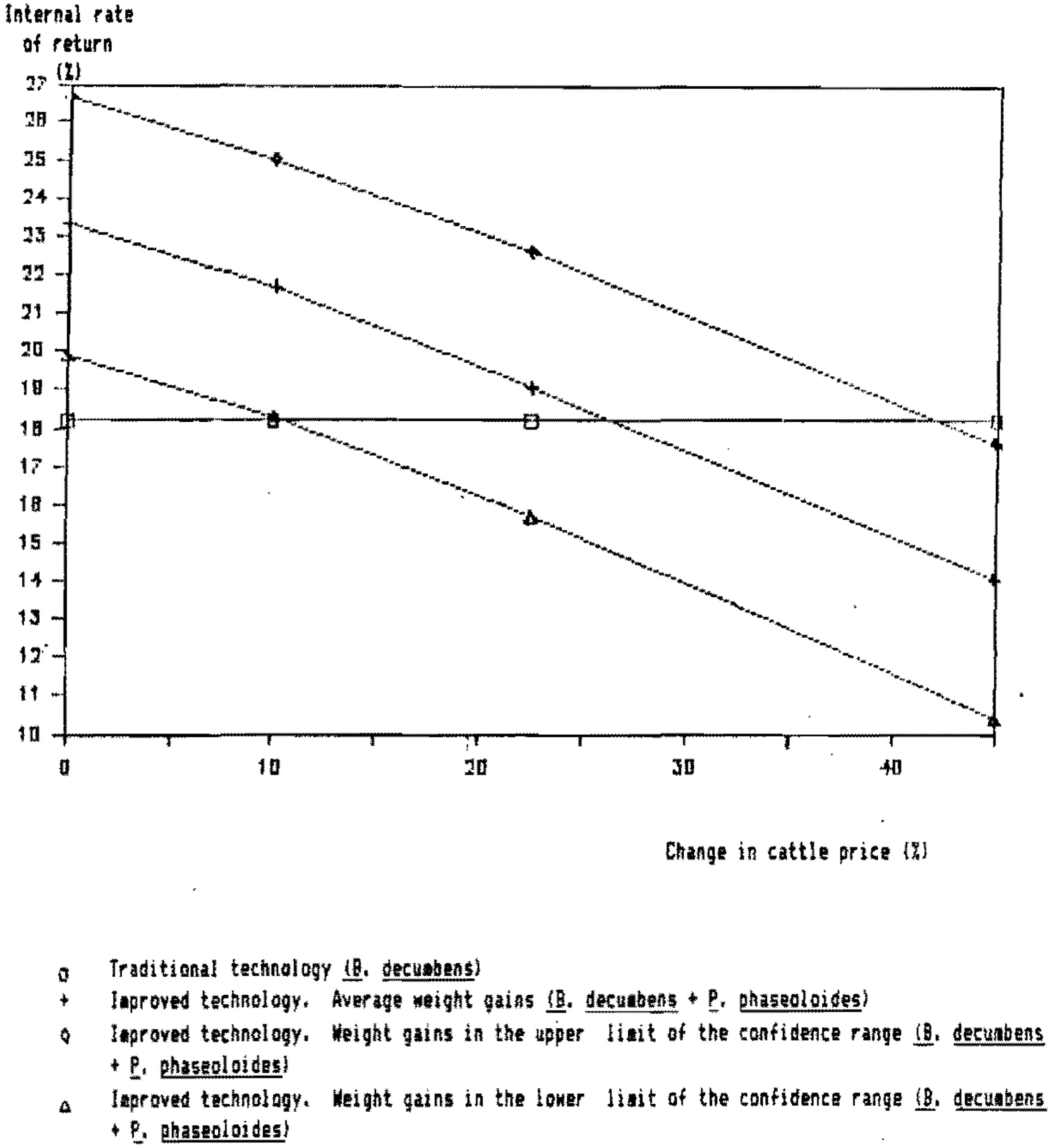
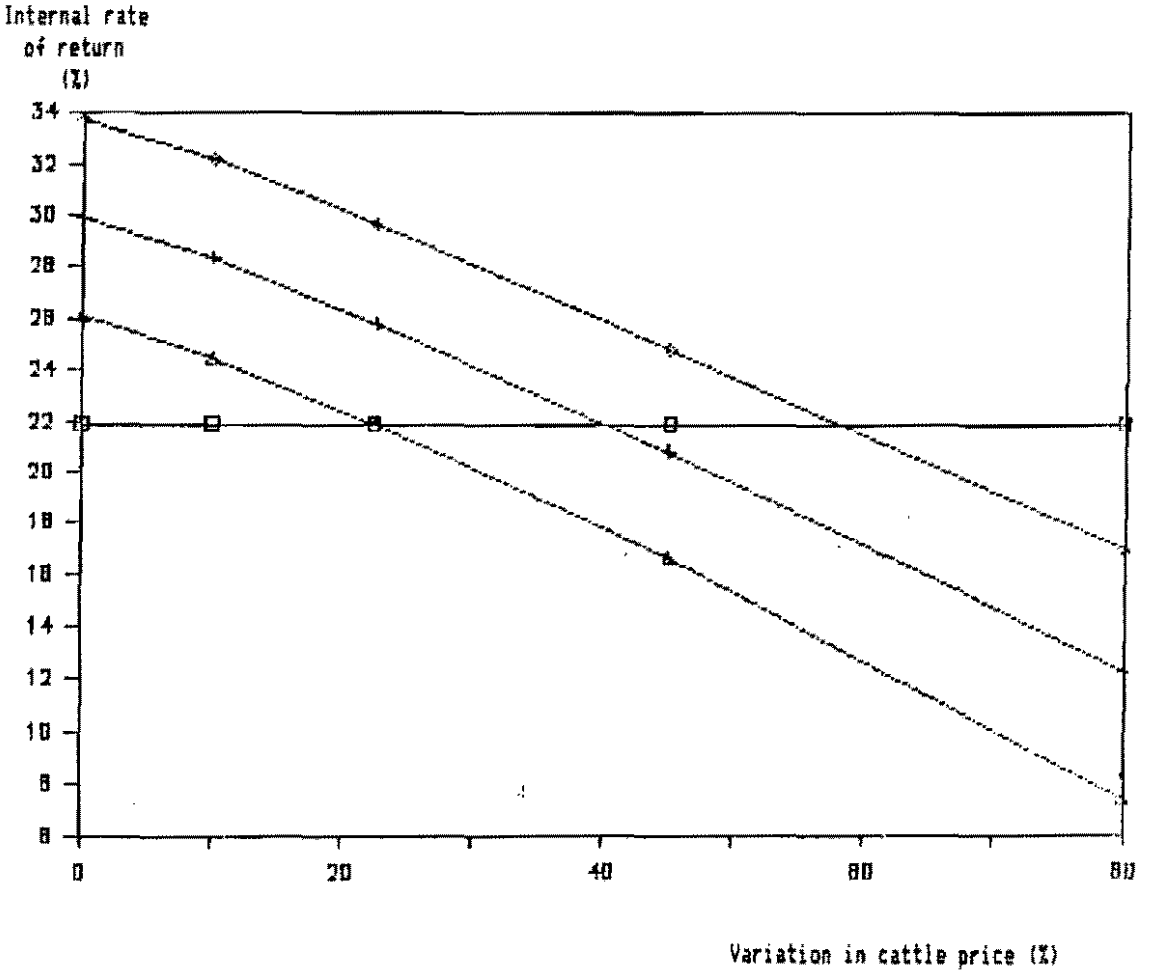


Figure 3. Sensitivity of the internal rate of return of the association *B. decumbens* + *P. phaseoloides* to variations in cattle prices under conditions of experimental fertilization in systems of fattening under grazing. Carimagua, Colombia, 1979-1987



- Traditional technology (pure B. decumbens)
+ Improved technology. Average weight gains (B. decumbens + P. phaseoloides)
Improved technology. Weight gains in the upper limit of the confidence range (B. decumbens + P. phaseoloides)
- Improved technology. Weight gains in the lower limit of the confidence range (B. decumbens + P. phaseoloides)

Figure 4. Sensitivity of the internal rate of return of the association B. decumbens and P. phaseoloides to variations in cattle prices, under conditions of minimum-cost fertilization in systems of fattening under grazing. Carimagua, Colombia, 1979-1987

Under experimental fertilization conditions, profitability of the improved technology is sensitive to changes in weight gains, particularly when these are reduced. In this case, at the lower limit of the confidence interval of 95% for weight gains, with a reduction of only 10% in price, profitabilities are equal (Figure 3). With 95% confidence, it was found that the equilibrium point between the internal rate of return of the traditional technology and the improved technology is located in the range of 10%-42% of cattle price reduction[1].

3.3 Analysis of sensitivity with minimum-cost fertilization

Incorporating the minimum-cost-fertilization recommendations of CIAT's Tropical Pastures Program (see Table 3) and assuming that pasture productivity and persistence are maintained equal to those of the experimental fertilization conditions, it is observed that profitability of the improved technology is higher and less sensitive to reductions in cattle prices than the traditional technology (Figure 4). With the average weight gain, a reduction of around 40% is required so that profitability of both technologies will be equal. This contrasts with the situation of experimental fertilization where for the same average yield, the reduction in price to reach the equilibrium of profitabilities is 25%.

With 95% confidence, the equilibrium point between the internal rates of return is found in the range of price reductions of 23%-58%, which is greater than the range found when levels of experimental fertilization are employed (10%-42%). That is, under minimum-cost conditions, the profitability of this improved technology under the experimental conditions present is higher and less sensitive to variations in weight gains (Figure 4).

Risks associated with new technology are in a direct relationship with the level of fertilization cost and with the stability of weight gains. A strategy that will minimize the use of purchased inputs will reduce financial risks of the new technology. Likewise, the use of forage legumes with a high nitrogen-fixation capacity, palatability, and quality selected at low fertility levels, can help to maintain weight gains relatively stable over time, reducing the biological risks of the new technology.

1/ The confidence interval of the daily weight gains is established as:

$$X = \bar{X} \pm t \frac{S}{\sqrt{N}}$$

In this case, the average daily weight gains ($\bar{X}$) in the association are 478.7 grams and the standard deviation (SD) 65.50, the number of observations (N) 9, and [illegible]

In Table A1, costs of establishment and maintenance of alternatives of fertilization evaluated are presented.

3.4 <u>Analysis of sensitivity to losses in pasture establishment</u>

Among the principal constraints to the adoption of improved pastures are production risks associated with their establishment. According to what was observed in commercial plantings in the Colombian high plains, said risks are derived from the probability of loss of plantings, brought about by low quality of available seed, lack or excess of rains, incidence of pests (particularly ants), and deficiencies in soil preparation.

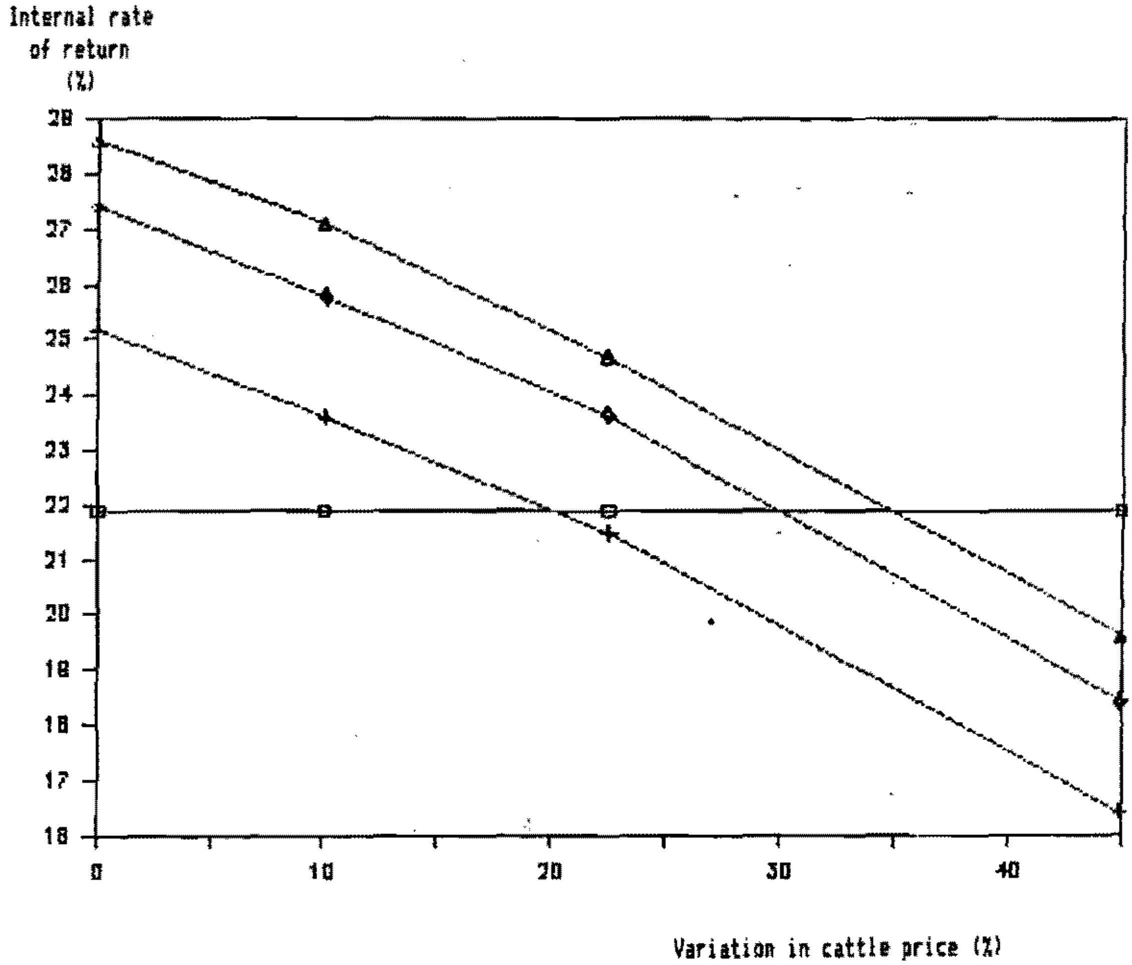
In improved pastures of minimum inputs, the value of the seed represents nearly 40% of the total establishment cost. Therefore, this becomes a critical input in the planting process and the factor of highest risk of loss.

Figure 5 illustrates the effect on profitability of the improved technology of problems in establishment caused by seed losses in a range between 25% and 100%, together with reductions in cattle prices in proportions that range from 10% to 45%.

It was found that a seed loss of 100% implies an increase in initial cost of close to 50%. Given this loss, a reduction in cattle prices of around 20% causes profitability of the improved technology to become equal to that of the traditional technology. That is, the profitability of this pasture technology based on the grass-legume association under the experimental conditions described is sensitive to variations in pasture establishment costs due to problems of establishment, independent from reductions in cattle prices.

3.5 <u>Marginal analysis</u>

The economic analysis of marginal profitability of going from the technology of pure <u>Brachiaria</u> to the association, under conditions of minimum fertilization, indicates that profitability of additional investment to carry out the change is highly attractive, IRR = 101% per year (Table A2). However, in absolute terms the incremental net income per hectare is relatively small (US$39.98/ha per year), which can explain some reticence on the part of cattle ranchers to adopt new technology, unless adoption will be on a large scale at the farm level. Another alternative of experimentation and economic evaluation is the introduction of legumes in already established pure grass pastures. In this case, the marginal analysis would only take into account the establishment costs of the legume and additional benefits through improvements in productivity and persistence.



□ Traditional technology (pure _B. decumbens_)
\+ Improved technology. Loss of 100% seed (_B. decumbens_ + _P. phaseoloides_)
◇ Improved technology. Loss of 50% seed (_B. decumbens_ + _P. phaseoloides_)
△ Improved technology. Loss of 25% seed (_B. decumbens_ + _P. phaseoloides_).

Figure 5. Sensitivity of the internal rate of return of the association _B. decumbens_ + _P. phaseoloides_ to variations in establishment costs and cattle prices in systems of fattening under grazing. Carimagua, Colombia, 1979-1987

3.6 Economic viability of technological change

A crucial aspect in the processes of technological change is the financial viability of new technology for the cattle rancher and the financial entity, in the case of credit. Not only is it necessary that new technology have a profitability at least equal to that of the traditional technology but also that cash flow requirements, necessary to carry out additional investments that the employment of new technology will require, be available so that the greatest number of producers can benefit from it.

In the case analyzed, the present value of the marginal costs of planting an association instead of a pure grass pastureis US$55/ha. This cost can be considered low in absolute terms, but as the area planted grows, problems of financial viability at the producer level can be expected, unless the offer of credit particularly for medium- and long-term investments is appropriate or the producer plants less hectares of the association.

4. Conclusions

Under the experimental conditions and economic assumptions employed, the principal conclusions derived from this work are:

1. Improved technology is substantially more profitable than traditional technology. For the level of average weight gains and under conditions of experimental fertilization, the IRR is 29% greater, and under conditions of minimum-cost fertilization, 36% higher.

2. Pasture technology based on the association B. decumbens + P. phaseoloides is of moderate risk both from the point of view of production as well as market in systems of fattening of steers under grazing in soil conditions of low natural fertility. The analysis demonstrates that a relatively high percentage reduction in prices received by the producer is necessary for profitability of the association to decrease to the level of profitability of the pure grass. The range of price reductions is between 23% and 58%, under conditions of employment of minimum inputs. When relatively high levels of fertilization are employed, the technology becomes more sensitive to variations in cattle prices.

3. In the same manner, pasture technology based on the association analyzed is less sensitive to the effect of environmental variations on weight gains than the technology based on the pure grass. In both periods of the year (dry and rainy), variability of the association yields is approximately half of the variability of the

pure grass. However, greater experimentation at the farm level is required to elaborate more reliable conclusions, since in this case it is a question of information coming from a single experiment under very controlled management conditions.

4. The improved technology is of moderate risk because of effects of increases in the establishment cost due to problems during planting. In the extreme case of 100% pasture loss, the association is slightly more profitable than the pure grass. For seed losses between 25% and 100%, the range of reduction in cattle prices for the profitability of the improved technology to be equal to that of the traditional technology is from 20% to 34%.

5. A critical aspect that influences profitability and diffusion of the new technology is the level and cost of fertilization both for pasture establishment as well as maintenance, in addition to frequency of refertilization. The analysis shows high sensitivity of the new technology to fertilization costs, pointing out the need to make efforts to reduce fertilization costs of the new technology.

6. The employment of legumes that are better adapted and have less requirements of nutrients (K and Mg) such as Stylosanthes capitata (Capica) and Centrosema acutifolium (Vichada), when reducing establishment and refertilization costs and maintaining the same levels of productivity, will make the employment of the association more economically advantageous.

7. Given that pasture technology in the association, considered under specific conditions of the present experiment, reduces production and market risks, it is to be expected that cattle ranchers with some aversion to risk will find it attractive. However, to guarantee wide adoption and rapid diffusion of these new technologies, it is necessary that the process of technology transfer be accompanied by the adequate supply of complementary services and inputs, such as good-quality seed, supply of machinery and fertilizers, financing, technical advice, and infrastructure for the storing, transportation, and marketing of livestock inputs and products.

8. The results of the analysis suggest that the introduction of legumes in already existing pastures of pure B. decumbens could be very viable from the economic and financial point of view. This would require low additional levels of investment. For this purpose it is recommendable to conduct studies at the farm level on techniques of legume establishment in fields of already established pure grasses.

Table A1. Costs of establishment and maintenance fertilization under experimental conditions and conditions of use of minimum inputs, Eastern Plains of Colombia[1]

Year	Experimental fertilization ($/hectare)		Fertilization with use of minimum inputs ($/hectare)	
	Grass	Association	Grass	Association
1978	122.9	181.1	105.0	136.3
1979		44.4		
1981	43.3	43.3		
1982			32.2	55.4
1983	43.3	43.3		
1985	43.3	43.3		
1986			32.2	55.4
1987	43.3	43.3		

1/ Costs estimated at prices of November 1987. Exchange rate: US$1 = $258.74 Colombian pesos.

Table A2. Net cash flow of steer fattening in associated pastures and in pure grass under conditions of minimum inputs, Eastern Plains of Colombia[1] (US$/ha)

Month	Brachiaria decumbens and Pueraria phaseoloides	Pure Brachiaria decumbens	Marginal flow
1	-132.28	-104.98	-31.30
8	-303.97	-303.97	0
20	165.79	115.52	50.27
32	165.79	115.52	50.27
44	165.79	115.52	50.27
48	-56.86	-33.29	-23.57
56	165.79	115.52	50.27
68	165.79	115.52	50.27
80	165.79	115.52	50.27
92	165.79	115.52	50.27
96	-56.86	-33.29	-23.57
104	165.79	115.52	50.27
116	165.79	115.52	50.27
128	507.24	448.36	58.88
Net present value (i = 1% monthly)	423.72	197.81	225.91
Annual internal rate of return per hectare (%)	32.9	25.1	101.4

1/ A maintenance refertilization every four years is assumed, equal to the establishment fertilization. A salvage value of the pasture is assumed, equal to zero upon liquidating the project.

Table A3. Levels of experimental and minimum-cost fertilization

Year		Experimental fertilization (kg/ha)		Minimum-cost fertilization* (kg/ha)	
		Pure grass	Association	Pure grass	Association
1978	P_2O_5	75	100	50	50
	K_2O		50		22
	MgO		18		11
	S		22		22
1979	K_2O		22		
	MgO		18		
	S		22		
1981	P_2O_5	15	15		
	K_2O	16	16		
	MgO	13	13		
	S	16	16		
1982	P_2O_5			50	50
	K_2O				22
	MgO				11
	S				22
1983	P_2O_5	15	15		
	K_2O	16	16		
	MgO	13	13		
	S	16	16		
1985	P_2O_5	15	15		
	K_2O	16	16		
	MgO	13	13		
	S	16	16		
1986	P_2O_5			50	50
	K_2O				22
	MgO				11
	S				22
1987	P_2O_5	15	15		
	K_2O	16	16		
	MgO	13	13		
	S	16	16		

* Hypothetical levels in case minimum-cost fertilization would have been carried out.

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ANIMAL PRODUCTION POTENTIAL IN PASTURES BASED ON TROPICAL LEGUMES

Introduction

Beef and milk are basic foods and have a high preference in the diet of the population of tropical America. Nevertheless, demand for these products increases more rapidly than the supply, which results in higher prices that have repercussions mainly on the less favored classes. One reason for this imbalance is low livestock productivity, above all in an area with soils of low natural fertility and with variable periods of drought that affect the production and quality of foranes, the principal basis of cattle nourishment in the tropics.

Some limitants on cattle production are discussed in this work and they summarize some possible strategies to develop productive and persistent pastures in marginal zones of tropical America. Experimental evidence that shows the potential of these pastures to improve animal production is presented in addition.

Limitants on Animal Production

Broad areas of the tropics have an excellent animal production potential based on grazing, as has been documented and widely discussed in a recent publication of Toledo and Nores (1986). However, the current reality is that animal productivity of cattle in tropical America is low, above all when it is compared with developed countries or with temperate zones. Several aspects undoubtedly contribute to this low animal production, such as:

1. Adverse environmental conditions (e.g., drought).
2. Prevalent biotic conditions (e.g., pests and diseases).
3. Edaphic conditions (e.g., acid and infertile soils).
4. Genetic factors of the cattle (e.g., low growth and milk production potential).
5. Nourishment factors (e.g., variable availability and quality of forage throughout the year).

This manuscript does not pretend to analyze each one of the conditions and factors that in one way or another interact to determine low animal production in tropical America. However, it does wish to emphasize how deficient nourishment is a factor that in a very generalized way explains to a great extent the low animal production in important cattle areas of tropical America (Vera and Seré, 1985).

Among other factors that contribute to this inadequate animal nutrition are native pastures composed of species of very low quality or introduced pastures that are degraded because of a lack of adaptation of the species to the natural fertility of the soil or because of prevalent biotic factors. The nutritional table of cattle in the tropics is aggravated even more as a result of dry periods that negatively influence the quantity and quality of forage available to the grazing animal.

Limitants for the Development of Improved Pastures

In the discussion on factors that limit the development of a technology of improved pastures for marginal areas of tropical America, Toledo and Nores (1986) highlight three points:

1. Lack of germplasm adapted to ecological conditions of the region.
2. Adverse economic factors.
3. Diversity of production systems.

It is evident that the majority of cattle in tropical America are produced under grazing conditions in native or improved pastures based on grasses introduced from Africa (_Hyparrhenia rufa_, _Panicum maximum_, _Cynodon plectostachyus_, _Digitaria decumbens_, _Brachiaria decumbens_, _Brachiaria humidicola_). Distribution of these species has been mainly determined by their adaptation to soil fertility conditions. In that manner, _P. maximum_, _D. decumbens_, and _C. plectostachyus_ are utilized in soils of better fertility, many times competing with crops. Other species such as _H. rufa_ have been naturalized in soils of moderate fertility, while other soils such as _B. decumbens_ and _B. humidicola_ are utilized in soils of low natural fertility. However, productivity and persistence of these species adapted to poor soils are affected by susceptibility to insects such as spittlebugs (_Deois incompleta_, _Aeneolamia reducta_, _Zulia colombiana_) (Calderón, 1984) or, in the case of _B. humidicola_, by having low nutritive quality (Hoyos and Lascano, 1985).

Limitations on forage germplasm for tropical America are even greater in the case of legumes. Something that contributes to this is that the commercial cultivars available are not adapted to low fertility soils or they are highly susceptible to the biotic conditions prevalent in the American tropics (Lenne et al. 1985).

Another factor that limits the development of a technology of improved pastures in tropical America is related to adverse economic aspects. Producers see themselves limited in their capacity to invest in improvements for their exploitation due to lack of capital caused by the tight margin between what they receive for their products and what inputs necessary for production cost, particularly in marginal zones.

Lastly, it should be recognized that in tropical America there exists a diversity of production systems, which range from extensive systems (e.g., the plains of Colombia and Venezuela, the Cerrados of Brazil) to semi-intensive systems of dual purpose (e.g., Central America). Obviously, each one of these systems requires a different pasture technology in both management requirement (e.g., grazing systems, stocking rates) as well as in nutritive quality of the species planted.

Strategies for the Development of Improved Pastures

Responding to the problematics of cattle raising in tropical America mentioned earlier, the Tropical Pastures Program (TPP) of CIAT (Centro Internacional de Agricultura Tropical), in cooperation with national research organizations, has outlined as an objective the development of a pasture technology for acid and infertile soils with a philosophy of low inputs.

There are several strategies to achieve the objective laid out and they can be summarized as follows:

1. Selection of forage germplasm, adapted to prevalent environmental (climate and soil) and biotic (pests and diseases) conditions.

2. Development of pastures with low-cost methods of establishment and the employment of grazing management practices that will maximize productivity and persistence of species.

3. Integration of the new pasture technology in production systems that are biologically, ecologically, and economically efficient.

In the strategies mentioned, selection of germplasm is not only directed toward developing grass and legume cultivars with adaptation to the prevalent climatic and biotic conditions but is also directed toward having selected species contribute to increasing animal production. To achieve this, the development of associated pastures is emphasized. These pastures offer an adequate quality of forage throughout the year and maintain a high level of nitrogen recycling for pasture maintenance over time.

A fundamental aspect in the development of pasture technology is the establishment phase and follow-up management. In research on establishment, fertilization requirements, methods of working the land, and planting are not the only factors considered, because plant characteristics (e.g., rapidness of establishment, seedling vigor, capacity of invasion, nitrogen fixation) that will minimize costs and initial risks are also taken into account. Research on management is concentrated on the development of grazing management practices (e.g., stocking rates, grazing systems) and levels of maintenance fertilization that look toward optimizing pasture productivit, and persistence through an adequate recycling of nutrients and a balance of species planted.

Finally, research strategies of the TPP attempt to generate a pasture technology that will be feasible to incorporate into the prevailing production systems in a given ecosystem. The goal is to be able to offer the producer different pasture alternatives that will be adapted to a wide range of management activities and that will be more productive than local checks.

Potential of New Pasture Technology

During the last ten years, the previously discussed research strategies have been implemented. In this section, a summary of some of the achievements obtained is presented. These achievements reflect the potential impact of new pasture technology in acid and infertile soils, both in extensive systems as well as in semi-intensive systems of tropical America.

a) Improved pastures in extensive systems

The savannas of tropical America constitute one of the largest natural resources for cattle production on the continent. One characteristic of these tropical savannas is their high soil acidity and low soil fertility (Sánchez and Isbell, 1979), along with a well-defined drought period that varies between four and six months, depending on the region. Cattle production is extensive and of low productivity measured in terms of growth and reproduction (Vera and Seré, 1985). This low animal productivity has invariably been associated wtih inadequate animal nutrition because of the low quality of native species that make up the primary resource (Lascano and Spain, 1986).

The potential of animal production with improved pastures on the Eastern Plains of Colombia is illustrated with weight-gain data in Table 1. On the native savanna managed with burning under continuous grazing with stocking rates of 0.20 animals/ha, 90 kg/animal/year are obtained in the best of cases, in addition to 18 to 20 kg/hectare/year. With the introduction of improved grasses (e.g., *Andropogon gayanus* or *Brachiaria* decumbens) in monoculture, gains per animal are improved by 20% to 30% and gain per hectare is improved ten times related to the native savanna managed with burning. These increases over the native savanna are practically double in terms of individual weight gains when grass-legume associations (e.g., A. gayanus + Stylosanthes capitata or A. gayanus + Centrosema acutifolium) are introduced.

Table 1. Potential of weight increase in different pastures on the Eastern Plains of Colombia.

Pastures	Stocking rate (animals/ha)	Annual weight gain kg/animal	Annual weight gain kg/ha
Native savanna[a]:			
Without burning	0.2	28	6
With burning	0.2	90	18
Improved grass[b]:			
A. gayanus	2.0	110	220
B. decumbens	2.0	120	240
Grass/legume[b]:			
A. gayanus/S. capitata	2.0	150	300
B. decumbens/P. phaseoloides	2.0	160	320
A. gayanus/C. acutifolium	2.0	180	360

a/ Paladines and Leal (1979)
b/ CIAT Annual Report, 1984, 1985 and 1986.

The effect of the legume on long-term animal production could also be documented on the Colombian plains. In a grazing test conducted over five years, B. decumbens and the most widely available improved grass in the zone, associated with P. phaseoloides (Kudzu) consistently produced 40% more weight gain than the pure grass stand (Lascano and Estrada in preparation).

The advantages of the association over the monocrop are evident in terms of weight gain, principally because of a greater level of nitrogen in the grass associated with legumes and because of a direct contribution of the legume to the animal in the dry period (Table 2). Similar results have been obtained in an experimental manner in the Cerrados of

Brazil with associations of A. gayanus and several legumes (S. guianensis var. pauciflora, S. capitata, S. macrocephala) under conditions of greater drought stress than those of the Colombian plains (CIAT, unpublished data).

Table 2. Protein in the grass on offer and diet selected in different pastures in the rainy and dry period on the Colombian plains (adapted from Bohnert et al., 1985 and 1986)

A. gayanus pasture	Period of the year	Crude protein Grass[a] (%)	Crude protein Diet[b] (%)	Legume Diet (%)
Pure		4.7	4.9	-
+ S. capitata	Dry	5.2	6.3	17.1
+ P. phaseoloides		7.7	12.0	77.5
Pure		6.4	8.5	-
+ S. capitata	Rainy	8.1	10.1	4.3
+ P. phaseoloides		11.0	13.1	23.8

a/ Leaf of grass available.
b/ Forage selected by esophagus-fistulated animals.

The high potential of improved pastures in extensive production systems could also be documented at the level of commercial exploitation on the Colombian plains. Results obtained with 5.5% of the total area of a farm planted in pure grasses and in association with legumes (A. gayanus and A. gayanus + S. capitata) utilized in a strategic manner have shown increases in the stocking rate capacity of the exploitation, greater weight of the cows and weaned calves, and a tendency toward a higher rate of conception (CIAT, 1985). The economic analysis of these results showed a marginal rate of return over the extensive system by 31% per year (Seré, personal communication).

It is usually foreseen that in extensive systems with native pastures, the strategic use of small areas planted with improved pastures can contribute to increasing and intensifying cattle production in a significant way. These pasture areas could be utilized for various purposes in the exploitation, such as: 1) reconception of lactating cows in programs of seasonal mating; 2) rearing of replacement heifers;

3) growth of early weaned calves; and 4) fattening of steers and culled cows.

b) Improved pastures in semi-intensive systems

Cattle areas dedicated to semi-intensive production systems of beef and milk, also called dual-purpose systems, are found in tropical America. These systems are characterized by being located in areas with soils of moderate acidity and fertility (e.g., Central America and the Caribbean), but with relatively long periods of drought, which in many cases leads to the suspension of milking.

Research has also been carried out in these regions on grass-legume germplasm evaluation, with the idea of forming pastures of good quality throughout the year, along with a high stocking rate capacity.

To illustrate the potential of improved pastures in semi-intensive systems, a region in the southern part of the Cauca Valley (e.g., Santander de Quilichao) is taken as an example. This region is characterized by acid soils, but ones that are high in organic matter and have 1500 mm of rainfall with bimodal distribution. Milk production in dual-purpose systems predominates in the region, along with fattening of steers, having Paspalum notatum of low productivity per unit of surface area as a forage base (Escobar et al., 1971), in addition to B. decumbens.

Undoubtedly, with the introduction in this region of an improved grass such as B. decumbens or A. gayanus, good weight gains of steers per hectare are achieved, but these gains increase significantly when a legume is introduced (Table 3). These greater levels of animal production with legumes have been associated with better animal behavior not only in the dry period but also in the rainy period.

c) Final comments

It has been demonstrated that the technology of grass-legume associated pastures with low inputs that is being developed for acid soils of low fertility has a high potential to increase cattle production in broad areas of the tropical American lowlands. However, for these experimental results to become a reality on the producer's holdings, it is necessary to break down some barriers such as the lack of credibility in legumes on the part of technicians and cattlemen, and the lack of seed at the commercial level.

Table 3. Animal productivity in improved pastures on acid soils of the Cauca Valley, Colombia.

Pastures	Stocking rate (Animals/ha)	Weight gain		Observations/ reference
		g/animal/ day	kg/ha/ year	
B. decumbens	1.4	452	231	Alternate grazing --two years of grazing (CIAT, unpublished data)
B. decumbens + *Centrosema* spp	2.1	600	460	
	2.0	411	300	Flexible alternate grazing (Huamán, 1988)
A. gayanus + *C. macrocarpum*	2.3	500	419	

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PROJECT OF VALIDATION AND TECHNOLOGY TRANSFER OF PASTURES ON FARMS OF THE EASTERN PLAINS OF COLOMBIA

The planting of improved pastures on farms of the Eastern Plains has a very recent history, due to the low offer of germplasm adapted to acid soils (pH 3.8-4.5) and those with a high percentage of aluminum saturation (86%). This caused low adoption before the decade of the eighties. In 1989, CIAT's Tropical Pastures Program made the decision to evaluate the productivity and persistence of grass-legume associations in different commercial production systems in the zone of the well-drained high plain. This zone is characterized by a mean temperature of 28°C, with annual rainfall of 2200 mm per year and a potential evapotranspiration of 2300 mm, with a marked dry season from mid-December to the end of March and an altitude of 150 to 200 m.a.s.l. Due to this strongly seasonal rainfall pattern and the chemical characteristics of the soils, a state of undernutrition is presented in the cattle and the average animal stocking rate has fluctuated between 0.20 AU/ha and 0.08 AU/ha.

It has been reported that productivity of the native savanna is 25 kg/ha and 80-90 kg/animal/year. This represents an important opportunity to contribute to the livestock progress of the zone if low-cost systems of introduction and establishment of pastures are developed, based on the utilization of grasses and legumes adapted to the conditions of the regional ecosystem.

From 1979 to 1981, a group of seven farms was chosen in which several grass-legume associations were evaluated, and they are listed in Table 1.

The species established in this first phase were evaluated agronomically and under grazing conditions over six years, and the results have shown successful behavior.

Within the established species, the mixture *Andropogon gayanus/-Stylosanthes capitata* was the one most widely distributed and the one which had greatest acceptance on the part of producers, until in 1985, other species that reached the category of promising because of their good behavior at CNI-Carimagua began to be tested on-farm.

Table 1. Areas planted and established, and loss in the project of pasture technology validation in 1979-1981 on the Eastern Plains of Colombia

Farms	Total area planted (ha)	Total establishment (ha)	Loss (%)
El Viento	221	170	23
Leonas	50	45	10
Guayabal	113	98	13
Paraíso	210	185	12
Margaritas	80	80	-
Altagracia	170	160	6
Altamira	33	33	-
Total	877	771	12

Results in animal production and behavior of associated pastures (based on Andropogon gayanus/Stylosanthes capitata and Andropogon gayanus/-Centrosema spp.) on some farms of the project are summarized below.

El Paraíso Farm

Owner:	Sapuga, S. A.
Administrator:	Hugo Moncaleano, Zootechnician
Production systems:	Cow-calf operations, rearing, fattening
Cattle inventory:	1300 head
Total area:	4500 ha
Area in improved pastures:	450 ha
Percentage existing area in improved pasture:	10%
Area projected for 1989:	700 ha
Area in oil-palm trees:	80 ha
Area projected for 1989:	350 ha
Topography:	Flat and slight ondulations
Soil analysis:	Sand 38%; silt 23%; clay 38%; pH 4.5; P 2.2 ppm; Al saturation 94%
Participation in the project:	8 years

Work has been done on this farm with grass-legume associations, and within these, Andropogon gayanus/Stylosanthes capitata and Brachiaria decumbens/Desmodium ovalifolium as a protein bank.

An example of the results of the pastures on this farm is presented in Figure ., where behavior of the Andropogon gayanus + Stylosanthes capitata mixture is observed over seven years of grazing, since it was established in 1981. However, the total availability of dry matter is maintained relatively well up to the fifth year, but it tends to diminish up to the eighth year. The legume offer tends to diminish with time, which is consistent with the bienniality of Stylosanthes capitata. Nevertheless, the population of legume seedlings is very high in the pasture evaluated due to its high production of seeds, which assures its persistence, as can be appreciated up to the eighth year. In terms of animal production, a summary of the levels of production obtained over five years, which are high and sustainable over time, is presented in Table 2.

Starting in 1986, the farm began a massive plan of pasture establishment, having as a reference results obtained in previous years.

In 1987, 170 ha were established as follows:

100 ha of Andropogon gayanus/Stylosanthes capitata
20 ha of Brachiaria dictyoneura
10 ha of various
40 ha of Stylosanthes capitata for seed production

Table 2. Productive behavior of steers under grazing in an association of Andropogon gayanus + Stylosanthes capitata on a farm of the tropical savannas of Colombia

Factor	1982	1983	1984	1985	1986	Mean
Number of animals	80	70	68	57	54	66
Grazing days	280	281	276	201	216	250
Initial weight	290	319	311	338	269	305
Final weight	430	484	482	483	367	449
Weight gain/period (kg)	140	166	171	165	98	147
Weigh' gain/animal/day (kg)	0.495	0.590	0.625	0.804	0.435	0.589
Animal stocking rate/ha	1.7	1.5	1.4	1.3	1.2	1.4

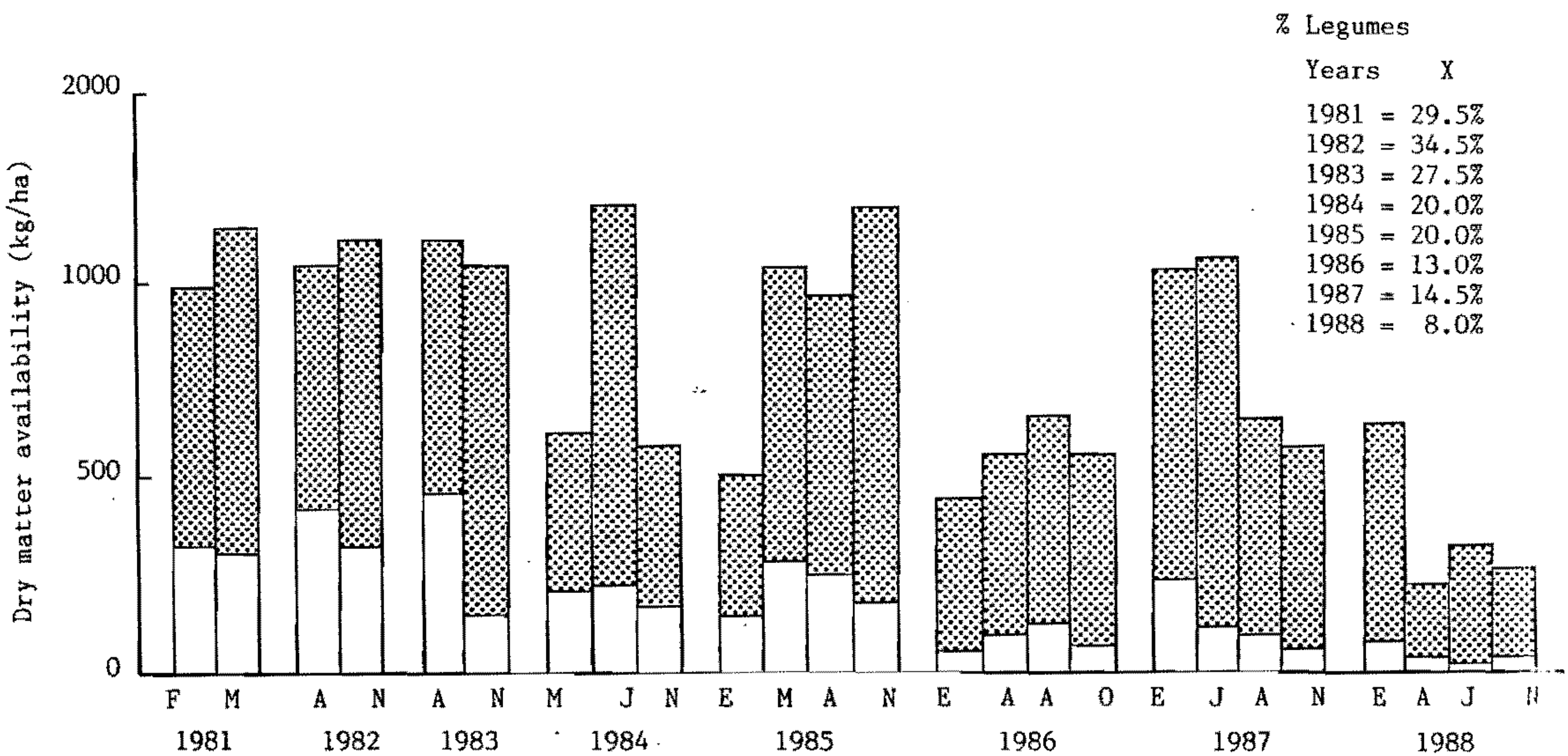

Figure .. 'ercent annual variation of legume content and dry matter production of an *A..dropogon gayanus* + *Stylosanthes capitata* association undergrazin over time, Finca El Paraiso

In 1988, 130 ha were established as follows:

60 ha of _Brachiaria dictyoneura/Stylosanthes capitata_
30 ha of _Stylosanthes capitata_ for seed production
40 ha of pure _Brachiaria dictyoneura_

One of the important activities on the farm is seed production and, in part, this has contributed to overcoming the shortage of commercial legume seed, especially of Capica and _Andropogon gayanus_. On another farm of the same owners, production of _Brachiaria dictyoneura_ seed has been achieved with the help of the project technicians.

The quantities of seed produced are:

1987	_Stylosanthes capitata_	1 ton
1988	_Stylosanthes capitata_	9 tons
1988	_Brachiaria dictyoneura_	4 tons
	Andropogon gayanus	3 tons

For 1989, the planting of 700 ha of improved pastures has been projected.

Another activity with a great future for the farm is the cultivation of palm-oil trees, and currently there is an establishment of 80 ha with _Stylosanthes capitata_ as a cover legume. And although the legume is bienn'al, the plant population has been very good due to the fact that new generations of plants grow very well and the cultivation of palm-oil trees is rather demanding in fertilization, which allows good development of new Capica plants. The legume has performed a double role as a cover and as a crop for commercial seed production.

For 1989, the farm has projected the planting of 350 ha of palm-oil trees, and _Stylosanthes capitata_ will be used as a cover. Carrying out a trial using _Centrosema acutifolium_ as a cover has been projected as well.

El Amparo Farm

Owner:	Pizano, S. A.
Administrator:	Jaime Galindo, Forestry Engineer
Production system:	Fattening
Cattle inventory:	270 head
Total area:	3800 ha
Area in improved pastures:	400 ha
Percentage of area in improved pasture:	aprox. 10%

Pine forests:	800 ha
Topography:	Mostly flat with some low areas
Soil analysis:	Sand 70%; silt 12%; clay 18%; pH 4.6; P 2.4 ppm; Al saturation 90%
Participation in the project:	2 years

The El Amparo farm entered the project in 1987 and began a program of establishment of associated pastures and pure grass stands, with the following associations being the first:

- *Andropogon gayanus/Stylosanthes* 100 ha
- *Brachiaria decumbens/Stylosanthes capitata* 100 ha

As pure grasses, the following were planted:

- *Brachiaria dictyoneura* 10 ha
- *Brachiaria humidicola* 2 ha

As well, 20 ha of *Stylosanthes capitata* were planted as a seedbed, but they were not harvested because of poor establishment.

The following areas were planted in 1988:

- *Andropogon gayanus/Stylosanthes capitata* 100 ha
- *Brachiaria decumbens/Stylosanthes capitata* 100 ha

The Pasture Management and Quality Section established 20 ha of various associations with an evaluation strategy of associations/grazing management. Grazing management will be defined between the producer and the technicians, and weight gains and pasture attributes will be measured utilizing different methods. The pastures planted in 1987 began to be evaluated in 1988, and measurements of forage availability, grass/legume composition, coverage, and weight gain were taken.

The results of the first year of grazing (1988) on *Andropogon gayanus* + *Stylosanthes capitata* are the following:

Number of animals	120
Grazing days	270
Initial weight	305
Final weight	470
Weight gain for the period (kg)	165
Weight gain/animal/day (g)	610
Animal stocking rate/ha	1.02

The state of the pasture after the first grazing period in 1988 is excellent and both the grass as well as the legume are conserved in good proportion if one takes into account the high percentage of sand in the soils.

The field of <u>Brachiaria decumbens/Stylosanthes capitata</u> partially suffered an accidental burning (a common phenomenon in the zone during the dry period) before the first grazing, and the gathering of data has been very erratic.

<u>Buenos Aires Farm</u>

Owner:	Guerrero Hermanos
Administrator:	Jairo Guerrero
Production systems:	Cow-calf operations, rearing
Cattle inventory:	750 head
Total area:	1400 ha
Area in improved pastures:	200 ha
Percentage of area in improved pasture:	14.3%
Topography:	Mostly flat, with 20% in fertile plain over the Meta River
Savanna soil analysis:	Sand 35%; silt 27%; clay 38%; pH 4.5; P 2.4 ppm; Al saturation 90.6%
Participation in the project:	3 years

Work has been done on the Buenos Aires farm since 1986 in the establishment of improved pastures, and the most used associations are the following:

- <u>Andropogon gayanus/Stylosanthes capitata</u>
- <u>Andropogon gayanus/Centrosema acutifolium</u>
- <u>Brachiaria decumbens/Stylosanthes capitata</u>

<u>Brachiaria dictyoneura</u> and <u>Brachiaria humidicola</u> have been established as pure grasses. An example of the results obtained with associated pastures is given in Table 3, where it can be observed that daily weight gains in the <u>Andropogon gayanus/Centrosema acutifolium</u> association have been high if one takes into account that the mixture has been grazed with a high animal stocking rate (2 animals/ha), although the initial weight and final weight of the animals have been less than in the mixture of <u>Andropogon gayanus/Stylosanthes capitata</u>.

Figure 2 presents pasture behavior in terms of availability of dry matter and percentage of legumes in 1987 and 1988, observing that from December of 1987 to January of 1988, a drastic reduction of the legume was presented, reaching levels of 1.5% as a result of overgrazing in the dry season. The pasture underwent rest and the legume recovered in

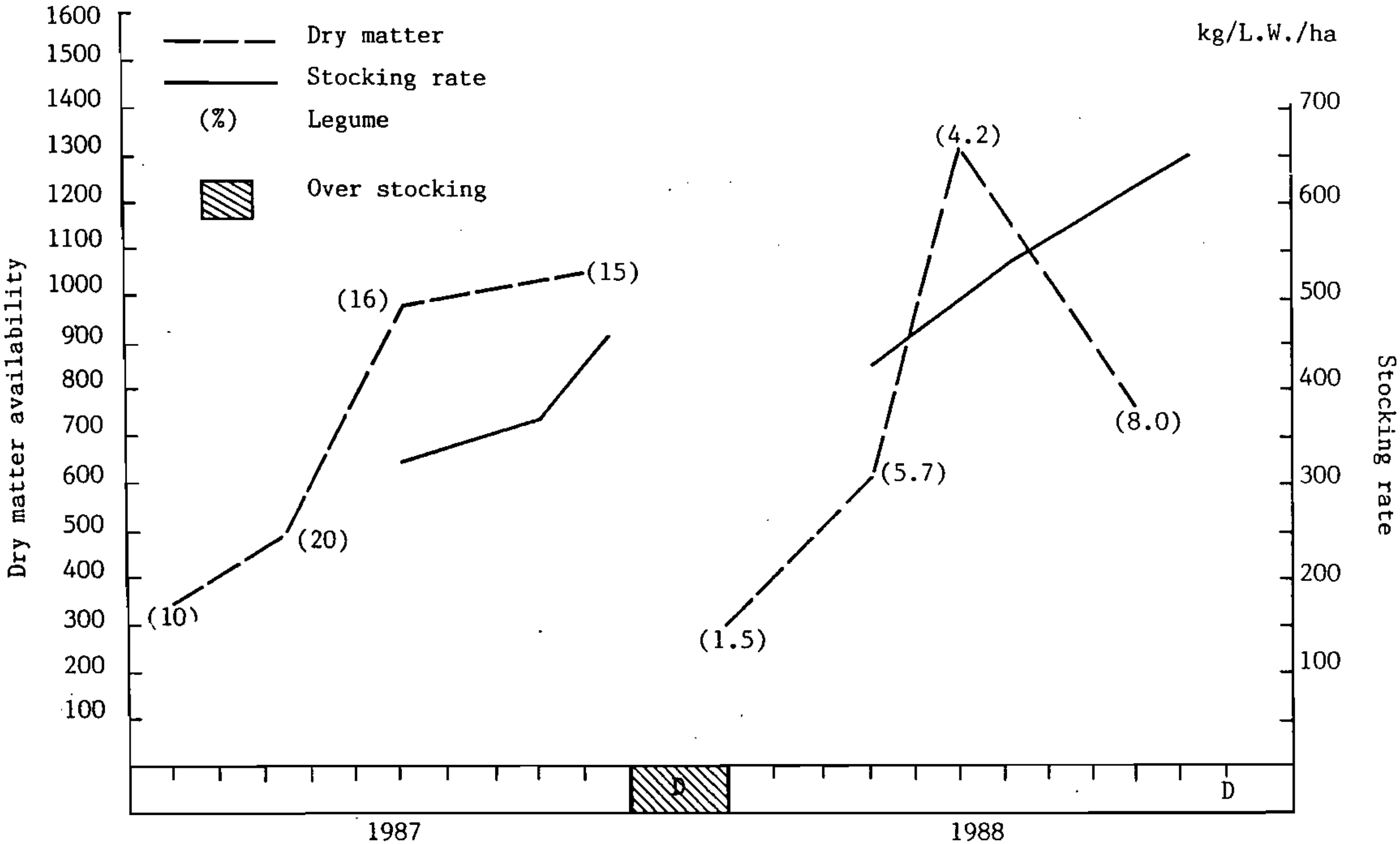

Figure 2. Dry matter availability and stocking rate/ha of an Andropogon gayanus + Centrosema acutifolium pasture (Finca Buenos Aires)

part, since 1988 ends with 8%. Daily weight gain in the second year is slightly lower, and this could be the result of low percentages of legume, as can be observed in different samplings during the year.

Table 3. Weight gain of steers under grazing in an association of *Andropogon gayanus* + *Centrosema acutifolium* + *Centrosema brasilianum* over two years on Farm No. 3, Colombian plains

Factor	1987	1988
Number of animals	30	30
Grazing time[1] (days)	131	170
Initial weight (kg)	178	286
Final weight (kg)	249	354
Gain/animal/day (kg)	0.542	0.400
Animal gain/period (kg)	71	68
Gain/hectare/period (kg)	142	136
Animal stocking rate (animals/ha)	2	2

1/ During rainy period.

La Campiña Farm

Owner:	Ciro Armando González
Administrator:	Ciro Armando González
Production system:	Double purpose
Cattle inventory:	12 head
Total area:	100 ha
Area in improved pastures:	28 ha
% of area in improved pasture:	28%
Cassava:	2 ha
Other crops:	2 ha
Soil analysis:	Sand 58%; silt 20%; clay 22%; pH 4.2; P 1.8 ppm; Al saturation 88%

The fundamental objective of working on this type of small farm is that of validating the model of the Carimagua family unit. The following species have been established:

- *Andropogon gayanus/Stylosanthes capitata*
- *Brachiaria dictyoneura*
- *Brachiaria humidicola*

The improved pastures have been utilized under grazing with dual-purpose cows, and the yields per cow are reported i Table 4 for five month of 1988.

Table 4. Milk production of dual purpose cows grzing *Andropogon gayanus/Stylosanthes capitata* during the rainy season, Eastern Plains of Colombia

	Jul	Aug	Sep	Oct	Nov	Average
Number of cows	4	4	5	5	6	4.8
Daily milk yield (lts)	4.1	3.8	4.7	4.0	4.1	4.1

The evaluation results of grass-legume associated pastures at the Carimagua Station and on farms of the plains, c mpared with productivity of the native savanna, generally show high and sustainable production levels over time. The management that the producer gives, in a certain way, favors the pasture, since he utilizes it in a seasonal manner, giving rests in the dry period and after overgrazing. The comparison of beef production in the *Andropogon gayanus/Stylosanthes capitata* mixture at Carimagua and two collaborating farms, the same as the contribution of the mixture in the breeding system, does not leave any doubt about the importance of the association in the improvement of cattle productivity on tropical savannas (Figures 3, 4 and 5).

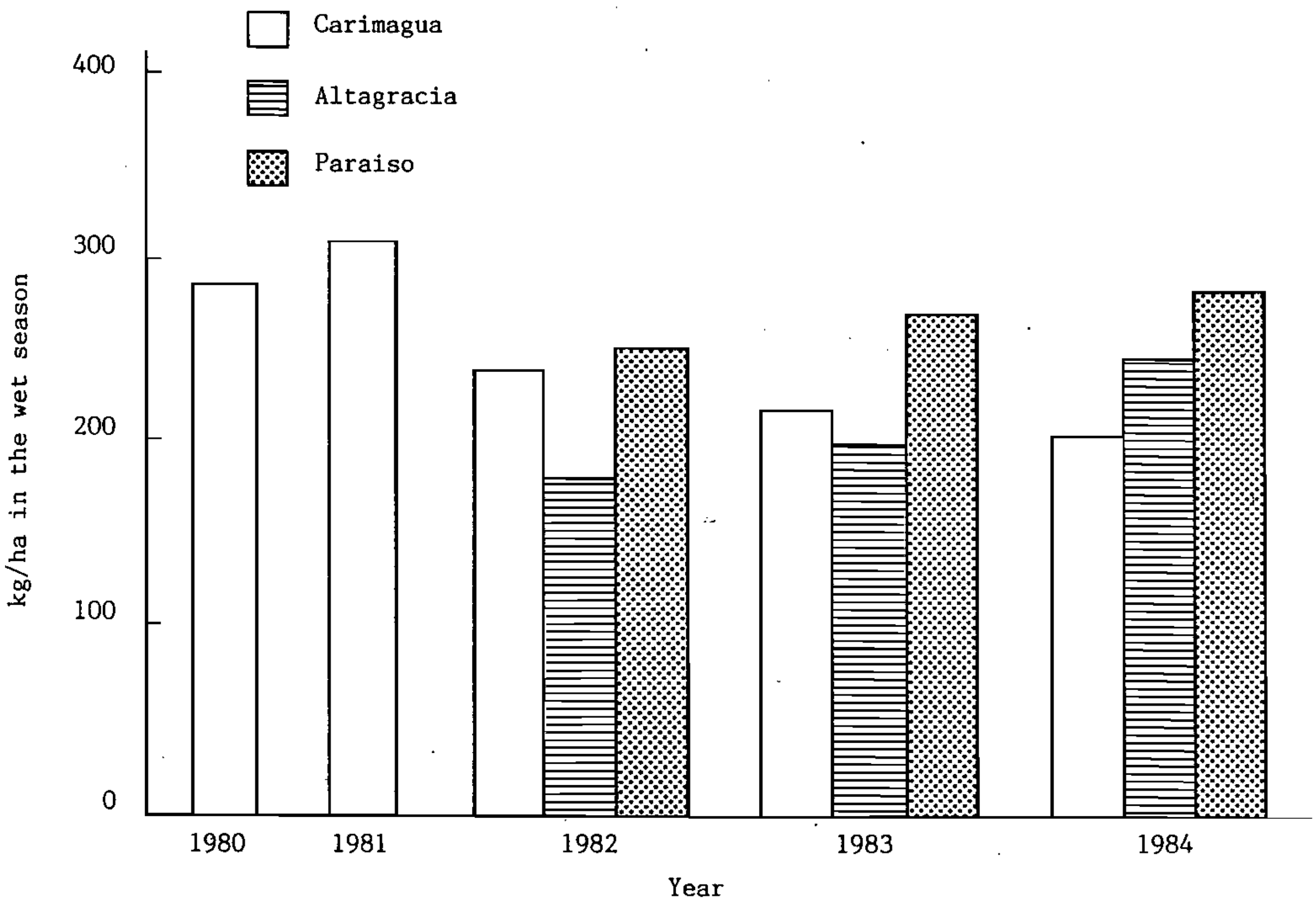

Figure 3. Wet season per-hectare liveweight gains of steers grazing Andropogon gayanus/ Stylosanthes capitata associations at Carimagua and two commercial ranches

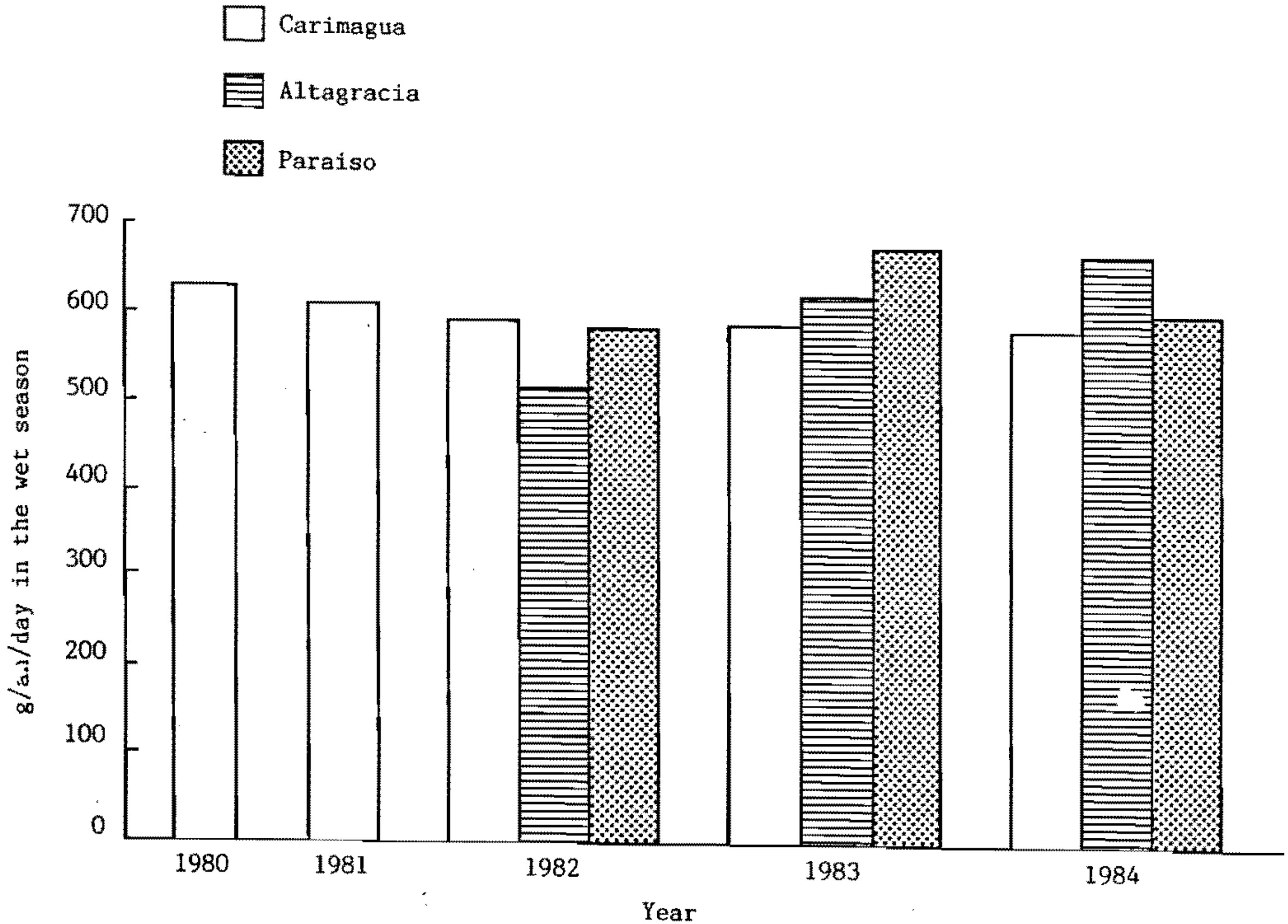

Figure 4. Wet season per animal liveweight gains of steers grazing *Andropogon gayanus*/*Stylosanthes capitata* association in Carimagua vs two cattle ranches

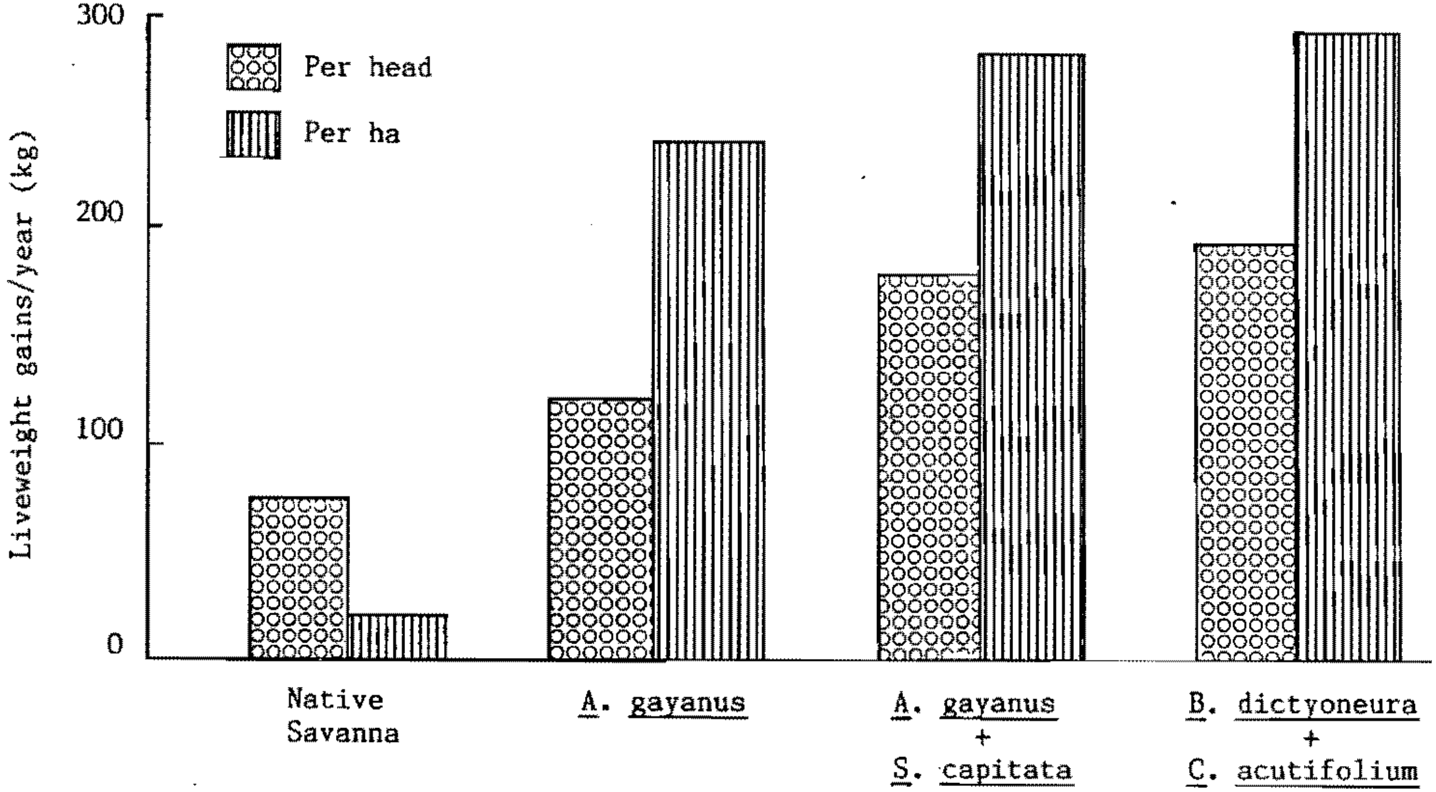

Figure 5. Productivity of best managed native sacanna and new pastures in the oxisols of the Colombian Llanos. (CIAT, 1987)

Technology Transfer

The advancement of research at Carimagua and validation at the farm level of many of these results brought about the decision that conditions were right for beginning an effort of technology transfer directed toward cattlemen of the region, b sed on improved pastures and pasture and animal management practices associated with those pastures.

Due to the extensiveness of the high-plain region and to the scarce resources available, it was decided to begin in a modest way, limiting oneself in the beginning to the region taken in between Puerto López and Carimagua, and preferably, to the zones nearest the existing roadways. As a first step, the shortage of forage legume seed had to be confronted in 1985. For that purpose, great efforts were made at Carimagua during that year to multiply three species (the grass _Brachiaria dictyoneura_ 6133, and the legumes _Centrosema acutifolium_ 5277 and _Stylosanthes capitata_, which was released commercially by ICA one year before as cultivar Capica). On the contrary, seed of the grass _Andropogon gayanus_-Carimagua 1 was already available on the market and was in abundance.

With the seed supply assured, technology transfer activities were begun in April of 1986. Previous contact was established with associations of cattlemen in the region, progressive cattlemen, seed producers, and other groups of organizations, which allowed an awakening of interest of many producers of the area in the new activities. In fact, demand surpassed the offer of available seed and the capacity of the small human team in charge of these activities. Moreover, the extreme climatic situation that provoked the interruption of traffic on several roadways had to be confronted, with the corresponding delays. In spite of the difficulties mentioned before, some 6500 hectares in improved pastures have been established on around 120 farms (Table 5). The program undertaken provides legume seed at low prices and supervision of planting on the part of the respective technicians, while the producer should provide grass seed, fertilizer, and preparation of the soil.

Table 5. Establishment of pastures on farms

Species planted	Hectares 1986	1987	1988	Total
Andropogon gayanus Stylosanthes capitata	210	2500	480	3190
Andropogon gayanus + Centrosema brasilium	30	80	150	260
Andropogon gayanus + Pueraria phaseoloides	-	-	20	20
Andropogon gayanus + Centrosema acutifolium	10	10	-	20
Andropogon gayanus	30	120	-	150
Brachiaria decumbens + Stylosanthes capitata	25	570	380	975
Brachiaria decumbens + Centrosema brasilium	-	-	100	100
Brachiaria decumbens	-	250	100	350
Brachiaria dictyoneura + Stylosanthes capitata	-	200	-	200
Brachiaria dictyoneura + Centrosema brasilium	-	-	40	40
Brachiaria dictyoneura + Arachis pintoi	-	30	-	30
Brachiaria dictyoneura	50	450	455	935
Brachiaria humidicola + Arachis pintoi	-	-	20	20
Stylosanthes capitata	30	140	55	225
Arachis pintoi	5	5	-	10
TOTAL	390	4255	1800	6525

SEED SUPPLY DEVELOPMENT OF TROPICAL PASTURE SPECIES AND CULTIVARS

Introduction

The conduct of research and development activities with germplasm and cultivars of tropical pasture species requires the concurrent development of seed supplies. The components of seed supply development are very dynamic and contrasting, especially as regards the array of relevant materials and the mechanisms by which seeds can be made available.

Research activities create an expanding demand by institutions for seed and/or vegetative material of promising accessions needed to conduct the various phases of systematic evaluation. This beguns with a focus upon many accessions in small agronomic plots and evolves towards fewer promising selections in progressively larger scale grazing trials and finally, to on-farm trials. When the genetic materials involved are accessions, the responsibility is upon the research institution to generate their own seed supply by conducting seed multiplication with their own resources.

After cultivars are released, the demand and supply complex changes completely. Demand for commercial seed is dependent upon the attitude and awareness of graziers to the rol and value of the improved pasture. Demand has to be sufficient to induce effort and investment in seed production, and production and distribution have to be practical and economic within the farming system and/or within the operation of a seed enterprise.

The initiation and attainment of an adequate supply of seeds of experimental, (for research), basic (for further multiplication) and commercial (for pasture development) classes, is a complex and evolutionary process. While the process may occur spontaneously and rapidly in some cases, initiatives will be required, especially with novel species and cultivars.

A seed supply development project

The **objectives** of the seed supply development project are:

1. Provide an initial seed supply of relevant materials to a pasture research and technology transfer project of ICA (CRECED Altillanura) and CIAT.

2. Increase the **participation** of seed enterprises in production and marketing of seed of the new pasture cultivars.

3. Stimulate interaction and information flow between the various "actors" in pasture research and development activities.

4. Identify limitations to the evolution of relevant seed supply systems of the new cultivars.

5. Conduct applied research upon relevant limitations to seed production technology.

6. Document and monitor the development of seed supply systems for tropical pasture species.

The range of activities in the seed supply development project include:

1. Multiplication and distribution of basic seed of the new cultivars, by Tropical Pastures Program and Seed Unit of CIAT.

2. Participation in share farming agreements, between Tropical Pastures Program and early adopting graziers, to produce seeds. The CIAT contribution may be seed harvesting and seed conditioning.

3. Technical assistance to new seed growers.

4. Organization of production and purchase **contracts** with seed enterprises.

5. Promote communication and training between participating graziers, seedsmen, researchers and technology transfer agents.

6. Applied research projects on limitations to seed production.
   e.g. i) development of beater seed harvestor
   ii) comparison of harvest methods of *B. dictyoneura*
   iii) associate crops for *C. acutifolium* seed production

The project was commenced in 1988 and focussed upon involving seed enterprises, the Fondo Ganadero del Meta and a few selected early adopting graziers in seed production, via either:

a) Production and purchase contracts
b) Share farming, whereby CIAT-Tropical Pastures Program organized the seed harvest.

During 1988, eight (8) materials, (recently released cultivars or highly promising selections), were established in various agroecologic regions of Colombia, see Table 1. Up to the present, approximately 18 tons of seed has been generated, of which 8.6 tons was delivered to CIAT, see Table 2.

During May-June of 1989, seed deliveries have commenced to (a) ICA-CRECED Altillanura; (b) a dairy processing company, Nestle, and (c) various seed enterprises, for these development institutions to initiate pasture demonstration and technology transfer activities.

<u>Objective of visit to 'IRACA' Farm of FGM</u>

The visit to the farm of the FGM (Fondo Ganadero del Meta-or Graziers Association of the State of Meta) is to demonstrate one part of the field activities of this multi-faceted pasture seed supply development project.

We will view seed production fields of cv. Capica, cv. Vichada, CIAT 13089 and 5713, and cv Llanero. Also we will view two experiments upon <u>B. dictyoneura</u> cv Llanero to provide data on; (a) dynamics of flowering and seed maturity and (b) a comparison of harvest methods.

During 1988, the FGM generated a composite total of 2.4 tons of seed of five materials. Of their fraction, seed has been sold their grazier members, and the remainder used to expand pastures or seed fields on the 'Iraca' Farm.

Table 1. Summary of materials and multiplication areas by geographic region, 1988-1989

Material	Production areas (ha) per region					
	Valle Cauca	Valle Tolima	North Coast	Andean[1] foothills	Highland[2] plains	Total
A. GRASSES						
Brachiaria dictyoneura cv Llanero	1.8		5.0	154.0	20.0	180.8
Brachiaria brizanhta cv La Libertad				26.5		26.5
B. LEGUMES						
Centrosema acutifolium cv Vichada	10.5	1.0	5.4	6.5		23.4
Stylosanthes capitata cv Capica				36.0	9.0	45.0
Centrosema macrocarpum CIAT 5713	2.0		0.6	1.0		3.6
Desmodium ovalifolium CIAT 13089				4.0		4.0
Arachis pintoi CIAT 17434				0.3		0.3
Stylosanthes guianensis	0.5			1.0		1.5
C. TOTALS	14.8	1.0	11.0	229.3	29.0	285.1

1/ Piedemonte
2/ Altillanura

Table 2. Summary of participation and production in seed activities 1988-1989

Multiplier	Composite Seed Production[1] Contracts (kg)	Open Market (kg)	Total (kg)
A. SEED ENTERPRISES			
Semillano	1,374	--	1,374
Pastos y Leguminosas	66	66	132
Distribuidora del Valle	330	--	330
Semillas Pance	730	--	730
Hoechst	1,558	--	1,558
B. DEVELOPMENT INSTITUTIONS			
Fondo Ganadero del Meta[2]	1,315	1,115	2,430
C. SELECTED GRAZIERS			
'La Loma'	828	1,811	2,639
'Paraíso'	1,687	4,748	6,435
'Pavijay'	713	2,287	3,000
D. TOTAL	8,601	10,027	18,628

1/ Refers to total volumes of all materials.
2/ Fondo Ganadero del Meta (Graziers Association of Meta), Finca 'Iraca', the location visited on 14 June 1989.