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A COST-BENEFIT ANALYSIS FOR THE ESTABLISHMENT OF MIXED PASTURES WITH AND WITHOUT TWO SPECIES OF LEGUME TREES, IN THE HUMID TROPICAL OF COSTA RICA

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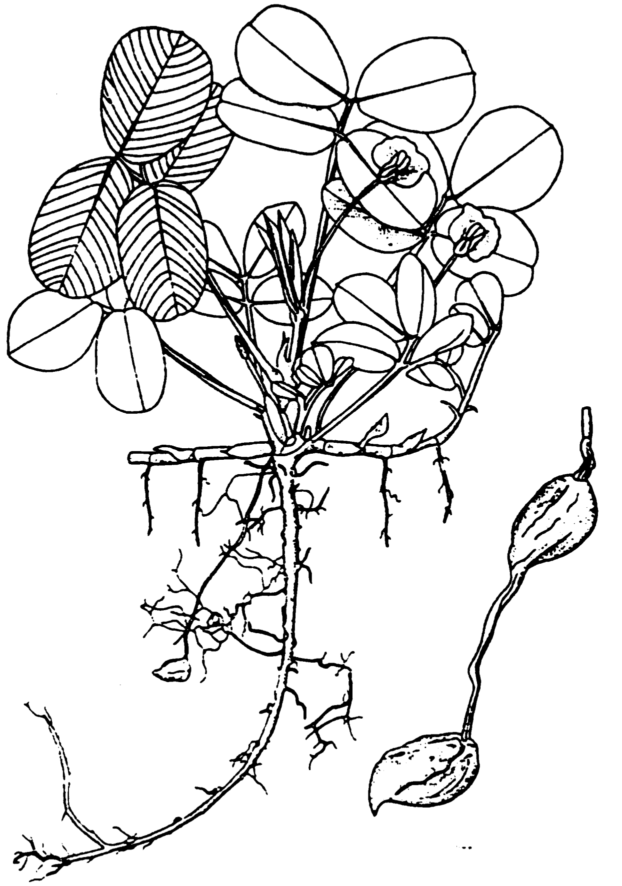

Arachis pintoi

Brachiaria brizantha

The Research Program on Sustainability in Agriculture (REPOSA) is a cooperation between Wageningen Agricultural University (WAU), the Center for Research and Education in Tropical Agriculture (CATIE), and the Costa Rican Ministry of Agriculture and Livestock (MAG). In addition, REPOSA has signed memoranda of understanding with numerous academic, governmental, international and non-governmental organizations in Costa Rica.
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REPOSA es financiado por la UAW bajo su Programa del Uso Sostenible de la Tierra en los Areas Trópicos. La sede de REPOSA está ubicada en la Estación Experimental Los Diamantes del MAG en Guápiles.

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SUMMARY
Animal production from native pastures is low in the Atlantic Zone of Costa Rica. Research has shown that meat production can be increased up to six times, by replacing the native grass vegetation with a mixture of the grass *B. brizantha* and the legume *A. pintoi* (BA mixtures). In an ongoing experiment, this mixture is grown in combination with two legume trees (*Erythrina berteroana* and *Gliricidia sepium*) (Silvopastoral system) and tested for its production and persistence under grazing.
In this study an economic analysis is performed of establishing BA mixtures with and without trees. The costs for establishment of the BA mixtures were US$ 397/ha when the land was prepared manually and US$ 465/ha when the land was prepared mechanically. Establishment costs for the silvopastoral system were US$ 967/ha. This large difference in costs was attributed to the high labor costs for preparation and seeding of tree legumes (421 hours/ha). Maintenance costs of the BA mixture are restricted to weed control, requiring US$ 25/ha/yr. For the the silvopastoral system maintenance costs consist of weed control and pruning of legume trees three times a year, requiring US$ 96ha/yr.
Gross meat production was calculated to be US$ 610/ha/yr for BA mixtures and US$ 671/ha/yr for the silvopastoral system, which meant an increase in production of 330% and 380% respectively compared to production from native pastures (US$ 139/ha/yr). The net benefits of the BA mixtures, however, are higher than that of the silvopastoral system (US$ 585/ha/yr vs. US$ 575/ha/yr). Significant differences were found regarding the Internal Rate of Return (IRR) of the two systems which was 231% for the BA mixtures and 38% for the silvopastoral system respectively.
It was concluded that establishing BA mixtures is an attractive method to improve animal production. Silvopastoral systems as described in this study, even though they do increase animal production, are not an attractive investment, since the IRR is below 50%. On the other hand, in countries where labor costs are not as high as Costa Rica, the system may be an attractive improvement measure, since its high costs are mainly caused by high labor costs. Moreover, the ecological and conservational benefits of incorporating trees in a grazing system, may form an important motive for the establishment of such systems, even though they cannot easily be expressed in currency terms. To serve these ecological and conservational functions, different planting techniques and densities should be developed.

Key words: *Brachiaria brizantha, Arachis pintoi, Gliricidium sepium, Erythrina Berteroana*, pasture improvement, establishment costs, internal rate of return.

RESUMEN
La producción animal en pastos nativos es baja en la Zona Atlántica de Costa Rica. Experimentos han demostrado, que es posible aumentar la producción animal 6 veces, al cambiar la pasturas nativas por una asociación de *B. brizantha* y *A. pintoi* (BA mezclas). Actualmente existe un experimento en ejecución donde se ha plantado esta combinación con dos especies de leguminosas arbóreas (*Gliricidium sepium* y *Erythrina berteroana;* sistema silvopastoril), para probar su producción y su persistencia en pastoreo.
En este estudio se hace un análisis económico del establecimiento de BA mezclas con y sin árboles. Los costos para establecer mezclas de BA fueron de US$ 397/ha con preparación manual del terreno y de US$ 468/ha cuando la preparación del terreno se hace de forma mecanizada. Los costos para el establecimiento del sistema silvopastoril fueron de US$ 967/ha. La gran diferencia en los costos es atribuida a los altos costos de mano de obra en la preparación y siembra de los árboles (421 horas/ha). Los costos de mantenimiento de mezclas de BA son solo para el control de malezas (US$ 25/ha/año). Para el sistema silvopastoril los costos de mantenimiento incluyen control de malezas y poda de los árboles 3 veces al año (US$ 96 ha/año).
La producción bruta de carne en pasturas de BA es de US$ 610/ha/año y en el sistema silvopastoril es de US$ 671/ha/año, lo que significa un incremento de 330% y 380% respectivamente con respecto a la producción con pastos nativos (US$ 139/ha/año). Los beneficios netos de BA mezclas, sin embargo estan más altos que los beneficios netos del sistema silvopastoril (US$ 585/ha/año vs. US$ 575/ha/año).
Se encontraron diferencias significativas entre los dos sistemas con respecto al tasa interna de retorno (TIR) que es de 231% para mezclas de BA y de 38% para el sistema silvopastoril.
Por lo tanto es posible concluir que el establecimiento de mezclas de BA es un método atractivo para mejorar la producción animal. Los sistemas silvopastoriles, como se describe en este estudio, son una manera para mejorar la producción animal, pero con un bajo TIR. Sin embargo en países donde los costos de mano de obra son más bajos, estos sistemas pueden ser una buena inversión. Además, los beneficios ecológicos y de conservación al incorporar árboles en sistemas de pastoreo, pueden ser una razón importante para establecer este tipo de sistemas. Sin embargo estos beneficios son difíciles para ser expresados en forma de dinero. Cuando los árboles se plantan por razones ecológicos y de conservación, las diferentes técnicas de siembra se deben enfocar hacia menores densidades para obtener estos beneficios a un menor costo.
Palabras claves: *Brachiaria brizantha*, *Arachis pintoi*, *Gliricidium sepium*, *Erythrina berteroana*, mejoramiento de pasturas, costos de establecimiento, tasa interna de retorno (TIR).

1. INTRODUCTION

Cattle farming is an important agricultural activity in the Atlantic Zone (AZ) of Costa Rica. Most of the deforested land in the region has been turned into pastures. Of the total area of the AZ of about 540,000 ha (Ibrahim, 1994), more than 46% was deforested by 1986 (Huising, 1993). Between 50% and 60% of the AZ is now comprised of grasslands (Veldkamp, 1993; Huising, 1993). Although grasslands occupy most of the land surface, banana production is the most important economic activity in the (AZ), but covering only 10% of the land surface. Beef production is the second most important economic land use activity in the zone and covers the third place on a national scale, after bananas and coffee (French, 1994). Like in many other tropical regions, cattle production per unit area is low in Costa Rica. However, unlike most other tropical countries, the AZ has good soils of medium to high fertility (Veldkamp, 1993) and environmental conditions in the region show good potential for cattle production ('t Mannetje, 1992; Ibrahim, 1994; Hernandez *et al.*, 1994). Animal production has been low mainly because it is being practised on a very extensive scale with low levels of inputs and little management. Since most of the fertile soils are being used for agricultural production, cattle production is carried out on the relatively poorer soils. Pasture production is decreasing more and more in the region due to the fact that over 70% of the pastures are in an advanced stage of degradation ('t Mannetje and Ibrahim, 1995). Most cattle production is being practiced on native pastures, the main grass species being 'ratana' (*Ischaemum ciliare*), 'carpet grass' (*Axonopus compressus*), *Paspalum conjugatum*, *Brachiaria radicans* and other *Paspalum* spp. (Hijfte, 1989; Ibrahim, 1994). The poor nutritive value of these species is the main reason why animal production from these pastures is low (Vargas, 1987; Sánchez, 1981).

//Another reason why production has been low has to do with the nature of the cattle breed.//Most farmers own cows that are a mixture of Brahman and a local breed (Zebú), with low inherent productivity.//To increase production, new cow breeds should be introduced, that have higher production potential and are better adapted to the environmental conditions in the region. Since this is a long term measure and the need for increased production is urgent, alternative measures have to be taken. Increasing cattle production in the near future can either be done by increasing production area, or through increasing the production per area (intensification).//Since land use conflicts already exist in the AZ, the solution to increase animal production in the region needs to be found in intensification of the present production. Investigations of the Tropical Agronomical Research and Higher Education Center (CATIE) and the Ministry of Agriculture and Animal Production (MAG) have shown that environmental conditions in the region are suitable for pasture production, provided productive species adapted to the local conditions are available. The volcanic and alluvial soils are generally fertile (Veldkamp, 1993), temperature is high and water is amply available during the year. Considerable research on pasture improvement by the International Center for Tropical Agriculture (CIAT) and CATIE has shown that numerous readily available grass and legume species are adapted to, and suitable for, the conditions in the AZ ('t Mannetje, 1992). A recent study (Ibrahim, 1994) obtained excellent animal production with mixed pastures of the grass species *Brachiaria brizantha* and the legume *Arachis pintoi*. In these experiments annual beef production increased sixfold compared to native pastures (Gutiérrez, 1983; Ibrahim, 1994).//By using species that are better adapted to the environmental conditions of the AZ, degraded pastures can be restored//('t Mannetje and Ibrahim, 1995). Besides the benefits of increased income farmers will be able to generate with these pastures, less

land is needed for production, leaving large areas for other purposes, including reforestation ('t Mannetje, 1992). This grass-legume mixture of *B. brizantha* and *A. pintoi* has been introduced on small cattle farms in the region. The mixture is currently being further tested for its sustainability and persistence under grazing conditions in combination with two species of legume trees, *Erythrina berteroana* and *Gliricidia sepium.* Incorporating trees in pasture systems (silvopastoral systems) has several advantages. Trees provide fodder and cover for the cattle and their root system offers protection against erosion, which is a frequently occuring problem in large parts of the humid tropics but not so much in Costa Rica. In addition, incorporating trees in a pasture system attracts (beneficial) organisms and has a positive effect on biodiversity. Diversified production systems are also known to be less susceptible to pests and diseases. Moreover, forage trees provide wood that can be used as timber or fuelwood (Bustamante, 1991; Paap, 1993).
In an ongoing experiment *B. brizantha* and *A. pintoi* mixtures were established in different paddocks in combination with legume trees. This experiment was designed to test the impact of grazing, production, sustainability, and persistence of the silvopastoral system under grazing conditions at two different stocking rates. This study focuses on the *B. brizantha-A. pintoi* system both with and without trees.

The main objective of the current study is to assess the economic benefits of the mixed pasture system of *B. brizantha* and *A. pintoi* as well as that of the silvopastoral system. Besides that, the production of both systems was compared to conventionally used cattle production systems in the region and the corresponding net benefits of the improved pastures were calculated. This was done using the partial budgeting method (CIMMYT, 1988). The results of this study provide the opportunity to develop and formulate recommendations and guidelines for farmers and extension services of the MAG for larger-scale introduction of improved animal production systems in the region.

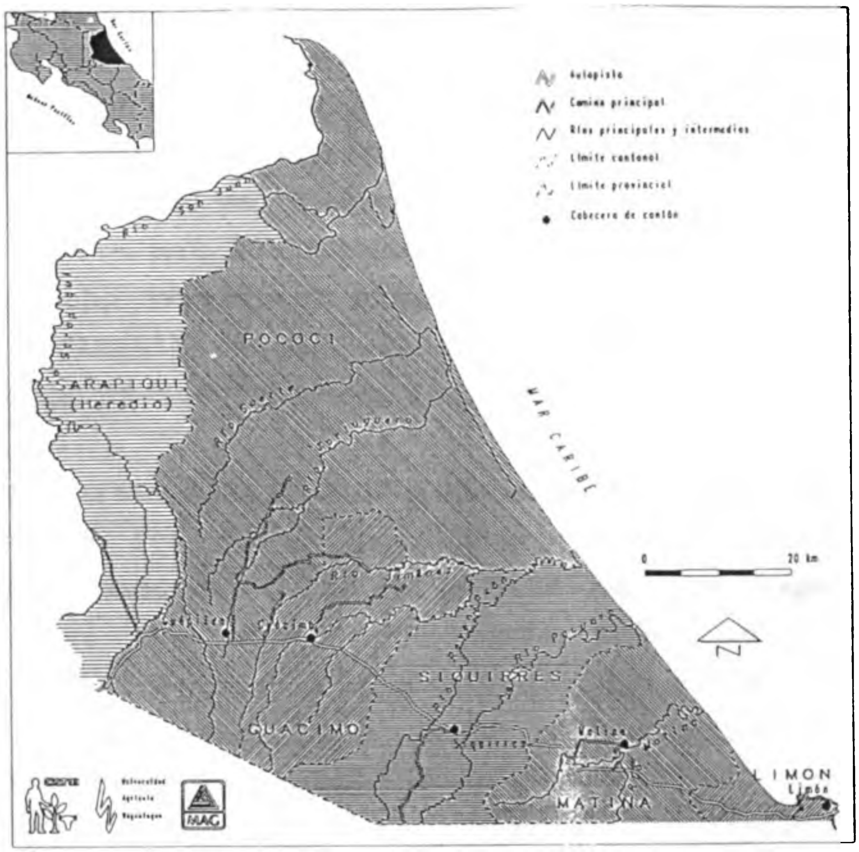

Figure 1: The northern Atlantic Zone of Costa Rica.
source: Stoorvogel (1995)

2. DESCRIPTION OF THE SILVOPASTORAL EXPERIMENT

Since October 1992, a silvopastoral experiment is being carried out at the experimental station "Los Diamantes" of the MAG, in Guápiles in the AZ of Costa Rica, situated at 10° 13′ northern latitude and 83° 47′ western lattitude. The experimental area is situated 250 m.a.s.l. with average annual rainfall of about 4500 mm. distributed more or less evenly over the year, though with a clearly drier period around February and March, when rainfall is about 200 -300 mm. The average daily temperature is about 25°C (min 19.5°C - max 30.5°C) and the relative air humidity is 87%. Soils at the experiment sites are classified as vertisoils and are of volcanic origin with medium to high fertility and an average pH of 5.6 (Herrera and Gómez, 1993).

Three different mixtures of pasture with and without tree legumes are tested for their persistence under grazing in twelve different paddocks. The objective of the experiment is to investigate the effect of legume trees in pastures of *B. brizantha* and *A. pintoi* on animal production and to analyse the impact of grazing on tree growth in the system under under two different stocking rates. Four paddocks are planted with *B. brizantha* and *A. pintoi* (BA), 4 with BA + *Erythrina berteroana* (BAE) and another 4 with BA + *Gliricidia sepium* (BAG). Every group of four paddocks, consist of two bigger paddocks of 1428 m^2 and two smaller paddocks of 957 m^2. Rotational grazing is being carried out on each of the paddocks. Cattle is allowed to graze the paddocks every 35 days for 5 days. Management of the paddocks is restricted to pruning of legume trees every four months, mainly to minimize the negative effect of shading and to keep leaves and young sprouts accessible to the grazing cattle. Cattle grazed the paddocks at two different stocking rates, determined by forage availability in the paddocks. To estimate

the available forage, samples of the pasture are taken in 0.25 m^2 quadrants before animals enter the plots. Total available forage of the pasture in the paddocks is calculated using the comparative yield method as described by Haydock and Shaw (1975). Available forage of the tree legumes was estimated using a new technique suggested by 't Mannetje and described by Abarca (1994). It consists of determining the branch:leave ratio in experimental quadrants and to simulate grazing of the leaves by manually defoliating the branches. Stocking rates of the paddocks based on forage availability are calculated by dividing the total available dry matter by 27.5 kg./animal/day for the high stocking rate and by 43.75 kg./animal/day for the low stocking rate. Thus for every animal grazing the parcel, respectively 27.5 kg. and 43.75 kg. dry matter is available per day for a grazing period of 5 days. Before entering the parcels, animals are weighed to calculate the amount of animal units (AU) entering the parcel (1 AU equals 350 kg in this experiment). After a grazing period of 5 days animals are removed from the plots and again the total available forage in the parcels is determined, thus allowing to calculate the total amount of forage extracted by the animals in the grazing period.
Besides available forage, also botanical composition of the parcels is estimated using the dry weight rank method as described by 't Mannetje and Haydock (1963).

3. DESCRIPTION OF SPECIES

3.1 Brachiaria brizantha

Brachiaria brizantha (CIAT 6780) is a grass species which originates in tropical Africa. In 1987 it was introduced to Latin America by CIAT (MAG, 1992). The grass has some important characteristics that make it suitable for use as a fodder species.

The plant is adapted to different soil types and different environmental conditions which make it suitable for use in different areas. It can be grown in areas with a dry period of up to 5 months as well as in areas with a humid climate year-round ('t Mannetje & Jones, 1992). Grown under humid conditions, soils have to be well drained. *B. brizantha* is also known to have a high tolerance for pests and diseases, including resistance to Salivazo, which is an important pest on grasses in the AZ (MAG, 1992).

The species has a semi erect growth habit and a favourable leave-stem ratio. It has a number of growing points, from where it sprouts easily, which makes the grass tolerant to grazing. *B. brizantha* can be reproduced sexually as well as vegetatively. Seed production is better in the drier areas. Although it is considered as an aggressive grass species, it is suitable for cultivation in combination with legumes (MAG, 1992).

Production of the species is high, allowing high stocking rates. Dry matter production varies according to growing conditions, ranging from 8 to 20 tons/ha/yr. ('t Mannetje & Jones, 1992). Besides a high production, the plant has a high nutritive value which is attributed to a high crude protein content of 13% to 17% and a high *in vitro* dry matter digestibility of 60% to 69% (Bustamante, 1991; Vallejos *et al.*, 1989; MAG, 1992).

3.2 Arachis pintoi

Arachis Pintoi is a herbaceous pasture legume, indigenous of Brazil. It has been introduced to Costa Rica by CIAT's Tropical Pasture Programme and evaluated since 1979 for its performance and persistence under grazing conditions, compatability with aggressive grass species, and possibilities for use as a cover crop.

Arachis has a wide range of adaptation, but performs best in tropical conditions from 0 - 1800 m.a.s.l. with a total annual rainfall of 2000 - 3500 mm. It is known to grow well in areas with a temporarily high water table and is also adapted to survive long dry periods (CIAT, 1992; CIAT, 1993).

Arachis pintoi is a perennial, prostrate legume with a stoloniferous growth habit. It produces a dense mat of stolons, which root frequently. Growing points remain well protected from grazing animals. It elevates its leaves when grown in combination with grasses, which allows the legume to compete with the grass while making the leaves accessible to grazing animals. The plant flowers throughout the year and seeds are set throughout the season (Grof, 1985). *Arachis* has a high nutritive value. Crude protein values of the leaves vary from 13.2% to 21.8% and of the stems from 9.3% to 13.5%. *In vitro* dry matter digestability (IVDMD) is high for both leaves and stems (>60%) (CIAT, 1992).

A. pintoi is one of the legumes that is able to fix atmospheric nitrogen due to a symbiotic relation with bacteria of the *Rhizobium* tribe. In this way *A. pintoi* is able to add a considerable amount of nitrogen to the production system. Ibrahim (1994) measured annual additions of soil N of 128 kg/ha for *A. pintoi* grown in combination with *B. brizantha*. Animals have shown a high selection for *A. pintoi* in mixed pastures which is attributed to the plants' high quality and palatability (CIAT, 1992; Ibrahim, 1994). The plant is well adapted to grazing. Lascano and Thomas (1988) reported excellent persistence under grazing. Table 1 shows the legume proportion in a mixed pasture after 5 years of continuous grazing.

Table 1: Legume proportion of *A. pintoi* (CIAT 17434)/*Brachiaria* spp. pastures after five years under grazing in Carimagua, Colombia.

Pasture	legume dry	% wet
Row planting		
B. decumbens + 20% *A. pintoi* initial	50	16
B. humidicola + 20% *A. pintoi* initial	29	2
Strip planting		
B. decumbens + 50% *A.pintoi* initial	57	27
B. humidicola + 50% *A.pintoi* initial	50	23

Source: CIAT, 1992.

Animal production from *A. pintoi*-grass mixed pastures can be very high. Live weight gains (LWG) of 180 kg/animal/year have been reported from experiments in Carimagua (Colombia) and production of over 500 kg dry matter/ha/year were reported from the same experiment (CIAT, 1992; CIAT, 1993). Also Ibrahim (1994) reported LWG of over 500 kg/ha/year from experiments in the AZ of Costa Rica.

Arachis pintoi is regarded as a slow plant to establish. Ground cover and establishment rate seem to be related to soil fertility and humidity. High humidity and good soil fertility both increase the establishment rate. Even if establishment is slow, *A. pintoi* is a good competitor since it is a colonizing species, and can very well increase its share in the pasture at a later time after establishment (table 1).

3.3 *Gliricidia sepium*

Gliricidia sepium is a tree legume that originates from Central America. It is now one of the most widely used tree legume species in the world. *G. sepium* is a member of the sub-family *Papilionoideae* (tribe: *Robinieae*). In tropical America the tree is found on different soil types, ranging from sands to heavy clays with pH from 4.5 to 6.2. It is found in areas up to 1200 m.a.s.l., receiving rainfall from 650 to 4200 mm a year. *G. sepium* produces flowers and seeds in the dry season, and in Costa Rica seed production (in pods) is lower in the relatively wet areas. It can very easily be reproduced vegetatively (Simons & Stewart, 1994).

Leaves have a high nutritive value, with crude protein contents ranging from 20% to 30%. IVDMD was reported to be between 60% and 65% (Vargas, 1987; Simons & Stewart, 1994). Leaf biomass production varies in place and time, but can be as high as 20 tons/ha/year. Because of its high nutritive value and good palatability, *G. sepium* is suitable for use as a fodder crop. However, the tree was reported to toxic to horses ('t Mannetje & Jones, 1992).

G. sepium is able to fix atmospheric nitrogen due to a symbiotic relationship with *Rhizobium* bacteria.

In Central America *G. sepium* is commonly used as a shading crop in coffee and cacao, as well as for the construction of living fences.

3.4 *Erythrina berteroana*

Like *G. sepium*, *Erythrina berteroana* is a legume tree of the *Papilionoideae* sub-family. It originates from Peru and Bolivia. Nowadays it is commonly found and used as a multipurpose tree throughout Latin and South America, for living fences, as a shadow tree in multi-cropping systems, and more recently as a fodder in silvopastoral systems. *E. berteroana* has several characteristics that make it suitable for use as a fodder crop. It has a wide range of ecological adaptation. It is found from sea level up to areas as high as 1800 m.a.s.l., in areas receiving an annual rainfall between 650 and 4200 mm. It has a high nutritive value and high palatability. Crude protein levels range from 22.6% to 31.6% and IVDMD is about 49.3% (Smits, 1988; Vargas, 1987). Because it has a symbiotic relation with *Rhizobium* bacteria, it is able to fix atmospheric nitrogen and add considerable amounts of nitrogen to the system. Levels up to 185 kg of N/ha/year were reported by Bustamante (1991). Both flowering and seed setting are better in the dryer areas. It is easily propagated vegetatively, which makes it especially attractive for use as a multipurpose tree. Dry matter production can be as high as 23 t DM/ha/year.

3.5 General aspects of silvopastoral systems

Incorporating trees in pastures is not a new technology. Indeed, it has traditionally been used all over Central America to increase the production per area and to diversify the harvested products (Russo, 1984). Diversification of harvested produce is especially important for small producers, who depend on unstable economies and a variety of products for their income (Bustamante, 1991). Trees are planted for their multifunctional characteristics. Trees can provide shadow and fodder for animals, timber and fuel wood, and can function as fence posts. Trees can also improve the quality and fertility of the soil. Moreover, they protect the soil against erosion (Bustamante, 1991). Trees are also likely to attract a variety of different beneficial organisms, thus increasing the biodiversity level of the system. Trees also have a positive effect on the recycling of nutrients in the system. Experiments have shown that the amount of organic material in the soil increases significantly when trees are incorporated in pastures (Bronstein, 1984). Legume trees can have a positive effect on the soil, since they are able to fix atmosperic nitrogen through a symbiotic relation with bacteria of the *Rhizobium* tribe. Experiments with the legume tree *Erythrina poeppigia*, showed that the amount of nitrogen in the leaves produced in a single year, added up to 185.6 kg/ha. This indicates that legume trees can add amounts of nitrogen to the system, comparable to the amounts of N-fertiliser commonly applied on improved pastures in a single year (Bronstein, 1984).

4. MATERIALS AND METHODS

4.1 Partial budgeting

For the three different mixtures described in chapter two (BA - BAG - BAE) an economic analysis was carried out using the partial budgeting method as described in CIMMYT (1988). Partial budgeting (PB) can be used to compare different production systems in terms of inputs needed and net benefits gained. The method has been developed to calculate the costs and net benefits of measures applied to improve agricultural production systems. By comparing marginal benefits with marginal costs it is possible to calculate the exact cost for a farmer to apply an improvement measure to calculate the extra profits gained because of the improvement measure. Thus PB does not provide data on the costs of a whole system, but calculates the costs and benefits of an improvement measure in terms of additional money spent and gained.

The advantage of the method is that only data on costs of measurements that are different from the conventional system are needed to compare the two systems. Consequently, data on inputs, outputs and maintenance measures, as well as on the costs of conventional production systems were collected. Because numerous surveys and investigations on production and maintenance of the animal production systems in the AZ exist, the data needed could all be derived from published literature.

4.2 Data collection

The data on production of the *B. brizantha* - *A. pintoi* mixtures used in the partial budget analysis, are mostly drawn from a recent study on production from *B. brizantha* - *A. pintoi* mixtures carried out in the AZ of Costa Rica (Ibrahim, 1994). This study provides the most accurate and reliable data on production from such pastures under local environmental conditions. To obtain data on labor costs related to establishment, farmers who had established BA mixtures in their farm system were interviewed, as well as researchers and field workers of MAG and CATIE.

Because the silvopastoral experiment system was not explicitly designed for economic analysis, no data existed on purchase costs and labor time. However, there has been some experience with the establishment of BA pastures at both CATIE and MAG. In addition, there were farmers and field workers familiar with the establishment of planting tree legumes. As a result, data on labor time involved with the establishment of the silvopastoral system were obtained from these sources. Persons that had been involved in the establishment of the experimental sites were interviewed as well.

To calculate the production of the silvopastural system, production figures from former experiments with AB mixtures and others with *G. sepium* and *E. berteroana* that could be found in the literature, were adjusted for this experiment. In addition preliminary data on production of the silvopastoral system were used to estimate potential production.

To calculate total costs, establishment costs were split into two parts, *i.e.,* purchase costs and costs of labor. Several different methods and techniques exist to establish BA mixtures (see Chapter 6). In the final partial budget analysis a distinction was made between manual and mechanised land preparation.

4.3 Prices

To calculate establishment costs, total costs were split into purchase costs, transportation costs and labor costs. Data on purchase costs were collected in a local shop in Guápiles where many farmers buy their materials. Prices may vary across space and over time, but are considered representative for the region at the time of this study.

Since inflation and exchange rate depreciation in Costa Rica are high, all prices have been converted to US$ (exchange rate 1 US$=172.3 colones, 10 april 1995).

Labor costs are based on an average hourly wage of 175 colones (1.02 US$) for field workers in the region.
To calculate net benefits for the different systems, values of animal live weight gains were arrived at by using actual meat prices. Prices for meat tend to vary in time since they depend on international market conditions, quality of the meat and total market supplies, among other things. Even though it may not be advisable to use fixed prices, the latter are necessary to calculate the net benefit of the system. To generate a meat price as reliable as possible, the herd composition and beef production of a model farm as presented by Ramírez & Aragón (1994) were used to calculate an average meat price. The average price thus calculated and used in this analysis was US$ 0.85/kg. Because milk prices are even more unreliable, the system was only analysed for beef production.

5. PRODUCTION

5.1 Animal production from native pastures

Animal production from native pastures has been extremely low in the AZ. This is primarily caused by the poor nutritive value of the fodder (French, 1994; 't Mannetje, 1992; Ibrahim, 1994) as well as by the low inherent productivity of the animal breed. //Most native grass species have low crude protein values and a low digestability. Table 2 gives the crude protein (CP) content and in vitro dry matter digestability (IVDMD) of the most common native grasses in the region.

Table 2: Crude protein content (CP) and *in vitro* dry matter digestability (IVDMD) of some native grass species in the AZ.

species	CP content (%)	IVDMD (%)
Axonopus compressus	7,0	56
Brachiaria decumbens	8,0	64
Ischaemum ciliare	7,9	46
Cynodon nlemfluensis	8,9	50

Source: Sijbrandij, 1987.

Gross net animal production of native pastures in the region have been described by Ramírez and Aragón (1994) and Gutiérrez (1993). Although results of these studies tend to vary, an average production output of native pastures was calculated using these data. Differences in output are mainly caused by differences in production systems, composition of the herd, nature of the breed, and nutritive value of the fodder species. Three different animal production systems can be distinguished in the AZ, including beef production (64%), dual purpose production (14%)

and milk production (22%) (French, 1994). In the dual purpose and milk production systems, besides pasture, animals receive concentrate feed supplements. Therefore, the productive effect of the pasture alone is difficult to calculate from these systems. Production from native pastures in the region has therefore been calculated from data for beef producing farms only. General production characteristics of native grasslands used in this analysis are given in table 3. All figures listed in table 3 represent the highest figures in the available data. This is done to minimize the positive effect on production of the improvement measures. Similarly, the largest available production data of improved pastures were used. In this way, the resulting figures for economic returns can be considered as conservative estimates.

Table 3: General production characteristics of native pastures in the Atlantic Zone of Costa Rica (*).

Variable	Production (**)
Stocking rate (AU/ha)	1.6
Liveweight gain (LWG) (kg/ha/yr)	163
LWG (kg/animal/yr)	50
LWG (kg/animal/day)	0.25
Milk (kg/ha/yr)	2142
Milk (kg/animal/yr)	1017
Milk (kg/animal/day)	5

*: Figures are not interrelated, since they were drawn from different studies. Milk production figures are added for illustrative reasons.

**: Extrapolated data from Sánchez (1981), Gutiérrez (1993), Ramírez & Aragon(1994), Ibrahim (1994), and French (1994).

Animals weighing 200 kg take up to 4 years to reach a marketable weight of 400 kg on native pastures (Ibrahim, 1994). Reproduction rates on native pastures are low; for example, first calving was reported to be at 34 months with an interval of 410 days (Ibrahim, 1994). 2.8 yrs 1.1 yrs.

5.2 Animal production from BA-pastures

Substantial research has been done on improved of pastures of *B. brizantha* in combination with *A. pintoi* (CIAT, 1992; Ibrahim, 1994). Animal production from these pastures appeared to be excellent in the AZ of Costa Rica. Nevertheless, the technology of pasture improvement using selected grasses and legumes is hardly practiced by farmers. Only some farmers have successfully introduced mixed pastures of *B. brizantha* and *A. pintoi* in their farm systems, but the majority of the farms in the region continues to produce on native pastures. Animal production data used in this analysis were taken from the literature as well as from farms that had successfully incorporated BA-mixtures in their production system (table 4).

Table 4: General production characteristics of *B.* brizantha and *A.pintoi* mixtures and BA-mixtures in combination with legume trees (*Gliricidia sepium* and *Erythrina berteroana*) (*).

Variable	Production **	AB + trees
Stocking rate (AU/ha)	3	3.3
Liveweight gain (LWG) (kg./ha/yr.)	797	877
LWG (kg./animal/yr.)	131	144
LWG (kg./animal/day)	0.42	0.46
Milk (kg./ha/yr.)	5585	
Milk (kg./animal/yr.)	1862	
Milk (kg./animal/day)	10	

*: Figures are not interrelated, since they were drawn from different studies. Milk production figures are added for illustrative reasons.

**: Adapted from Ibrahim (1994), 't Mannetje & Ibrahim (1994), Lovermore (pers. comm.), Fermin (pers. comm.), Tobón (1988), Pineda (1986), Rivera (1993).

Because the production data from Ibrahim (1994) were collected under more or less controlled experimental conditions, they have been adjusted downwardly by 15%. This was done to be sure not to overestimate production gains and to better reflect actual on-farm production.

In the improved production system, animals of 200 kg take up to one year to reach a marketable weight of 400 kg. BA mixtures will increase animal reproduction rates while decreasing animals' susceptibility to pests and diseases (Fermin, pers. comm.).

5.3 Animal production from the silvopastoral system

To calculate the additional production of legume trees in combination with *B. brizantha* and *A. pintoi* mixtures, different studies on supplementary feeding with *E. berteroana* and *G. sepium* were analysed. Because in all of these studies animals received concentrate feed as well, it is difficult to calculate the sole effect of legume tree fodder on animal production. However, it is clear from these studies that supplementary feeding with tree legumes has a significant positive effect on animal production and can function very well as a protein supply for large ruminants (Abarca, 1989).

The main conclusion that can be drawn on the basis of the preliminary results of the silvopastoral experiment, is that the amount of pasture-fodder available to the animals decreases when trees are incorporated in the system. This is mainly the effect of shadowing of the pasture by the trees. Another effect of the shading is a change in the leave:stem ratio. Shadowed *B. brizantha* produces a higher proportion of stems, reducing the palatibility and the nutritive value of the fodder. A positive effect of the tree legumes is that they are able to increase the amount of nitrogen in the system through the fixation of atmospheric nitrogen. This, in turn, increases the productivity of the pasture. Moreover, the trees provide shadow for the cattle, which is shown to have a positive effect on animal production (Bustamante & Romero, 1991). In addition, soil surface temperatures decreases, reducing the rate of mineralisation. Adding the positive and the negative effects of incorporating trees in the system, it remains unclear what the ultimate effect will be on animal production. Nevertheless, the silvopastoral system is expected to have a slightly higher animal production than mixed pastures of *B. brizantha* and *A. pintoi* alone. To calculate the production of this silvopastoral system, production of the BA mixture is multiplied by 110%.

Generally, *Gliricidia* trees are more palatable than *Erythrina* trees. This is probably caused by their higher digestability. Preliminary results of the silvopastoral system show that cattle show a higher preference for *Gliricidium* trees. However, the available data regarding the silvopastoral system do not allow a clear distinction between the production of the two trees. Therefore, the productive effect of the different tree species were considered to be the same in this study (table 4, column 3).

6. RESULTS

In the following, different methods for establishing BA mixtures will be discussed, with and without trees. The methods and actions required for establishing the silvopastoral system are more or less additional to the activities required to establish BA mixtures, involving some minor adjustments. This will become clear later in the text.

6.1 Establishing BA pastures

The following text is based on literature study and information obtained from interviews with several people who have experience with the establishment of mixed pastures in the AZ. All information provided by these informants has been double checked and discussed with experienced scientists.

It is impossible to present a uniform method for establishment, since conditions vary significantly in the region with each specific situation requiring its own method. Establishment conditions depend on soil type, standing vegetation, topography and accessibility of the land. Moreover, since different establishment methods involve different levels of input costs, it often depends on the wealth of a farmer which methods are feasible and which are not. In the following, one of these most commonly used methods in the region, is described. In the AZ, lands can roughly be subdivided into lands that are suitable for mechanised preparation and lands that are not. Consequently, a distinction was made between mechanised and manual land preparation. Both for land suitable and land not suitable to mechanized preparation, establishment activities were separated into three different phases: land preparation, seeding of the pasture, and maintenance.

6.1.1 Mechanised land preparation

Not all land is suitable to the use of machinery. Working the land with machines requires that the land is more or less flat and has well drained soils, at least during the period of land preparation. In addition, the lands should be accessible for machinery.

Before the land can be ploughed, the standing vegetation needs to be eliminated, to enable ploughing. This is mostly done with 2,4-D (4 liters/ha requiring 12 hours of labor). Larger woody perennials are treated with Picloram (Tordon-101) herbicide (1 liter/ha) and removed from the field. When the killed vegetation has dried up, it is best to burn it before ploughing. However, given the humid conditions in the AZ, this is hardly practiced. Only in the drier months (January to February), burning is feasible.

After the standing vegetation is eliminated, the land is ploughed a single time (1.5 hours/ha). After ploughing the land is harrowed twice (2 x 1 hour/ha) (Ibrahim & Holmann, 1994). Before the second harrowing triple superfosfate is distributed over the land (10 kg P/ha requiring 6 hours). This is done to improve the establishment conditions for *A. pintoi*. Since the triple-superfosfate has an incubation time of several weeks, it needs to be applied relatively early. After the second harrowing, the field is given another application of herbicide (Paraquat (Gramoxone), 4 liters/ha requiring 6 hours). After this the land is ready for sowing.

Most farmers in the region do not own machinery to work the land, hiring machinery from other farmers or paying somebody to prepare the land. Currently prices for mechanical land preparation are about US$ 116/ha (20,000 colones) (Ibrahim & Holmann, 1994).

6.1.2 Manual land preparation

In the case of land that is not suitable for mechanized preparation, land preparation has to be done manually. Before eliminating the standing vegetation with herbicides, heavy grazing is applied to remove as much of the standing vegetation as possible. After grazing, the remaining vegetation is eliminated with herbicides (Gliphosate, 4 liters/ha requiring 9 hours). If seasonal conditions allow, the dried vegetation can be burnt. To eliminate new emerging weeds, a second application of herbicides is necessary (Paraquat, 4 liters/ha requiring 9 hours). A Picloram/2,4-D mixture is used to kill the larger woody perennials in the field (1 liter/ha requiring 3 hours). After the second herbicide application, triple-superfosfate is distributed over the land to improve establishment of *A. pintoi* (10 kg.P./ha requiring 6 hours).

6.1.3 Seeding *B. brizantha* and *A. pintoi*

After the use of gliphosate herbicide, the land cannot be sown for a period of 22 days because during this period the herbicide is still active.

To obtain a good association of grasses and legumes, the mixture is sown in a 1:2 proportion (grass:legume). Because *Brachiaria brizantha* is a relatively aggressive grass species, this proportion is recommended to allow good establishment of the legume. However, at least some farmers have sown the mixture in a 2:1 (grass:legume) proportion and obtained good results, but management needs to be much more strict and the association takes longer to reach good establishment, with the risk of losing *Arachis*. There are different techniques for sowing the mixture, but the one discussed below proved to be the most successful, considering the success of establishment and the costs involved. All seeding has to be done by hand, since no seeding machinery is available. Different methods for seeding are used in the region and will be discussed below.

B. brizantha is sown in rows. Before seeding, the seeds are treated with a fungicide (Diazinon (Vitavax), 5 g/kg of seed). With a planting stick holes of about 2 cm are made in which 3 to 5 seeds are sown. The space between plants within rows must be about 50 cm (figure 2). Every row of *B. brizantha* is alternated with two rows of *A. pintoi*. Space between the rows is about 70 cm. After the *Brachiaria* seedlings have reached a height of about 5 cm, *Arachis* can be sown between the *Brachiaria* lines.

A. pintoi is sown using vegetative material. Since it is a stoloniferous, colonizing species that produces roots at every internode, it is well suited to be sown in this manner. To stimulate the formation of the nitogen fixing nodules, the material is inoculated with a CB3201 *Rhizobium* strain before seeding. To inoculate the vegetative material, it is spread out on a plastic surface and the inoculate is spread over it. It takes about 1 kg of Rhizobium strain CB3201 to inoculate the amount of *Arachis* neccessary for one ha (in a 1:2 association). Because inoculate is still hard to find in Costa Rica (although it can probably be bought from CIAT in San José) *Arachis* is mostly sown without inoculate. Since most soils contain *Rhizobium*, it can be sown without CB3201, but it takes a little longer before it reaches the maximum nitrogen fixing capacity (Asakawa and Ramírez, 1989).

A. pintoi is sown in two rows between the *B. brizantha*. Vegetative material is incorporated in the soil at a depth of about 6-8 cm at spots about 1.5 meters apart (figure 2).

Sowing one ha of the mixture takes 4 kg of *Brachiaria* seeds and about 1.5 tons of vegetative *Arachis* material (equivalent to about 300 m^2). The seeding takes about 18 hours/ha (Ibrahim & Holmann, 1994).

About 2-3 months after seeding, the pasture should be given a light grazing (some 30 animals for 3 hours/ha). This management practice is most important.

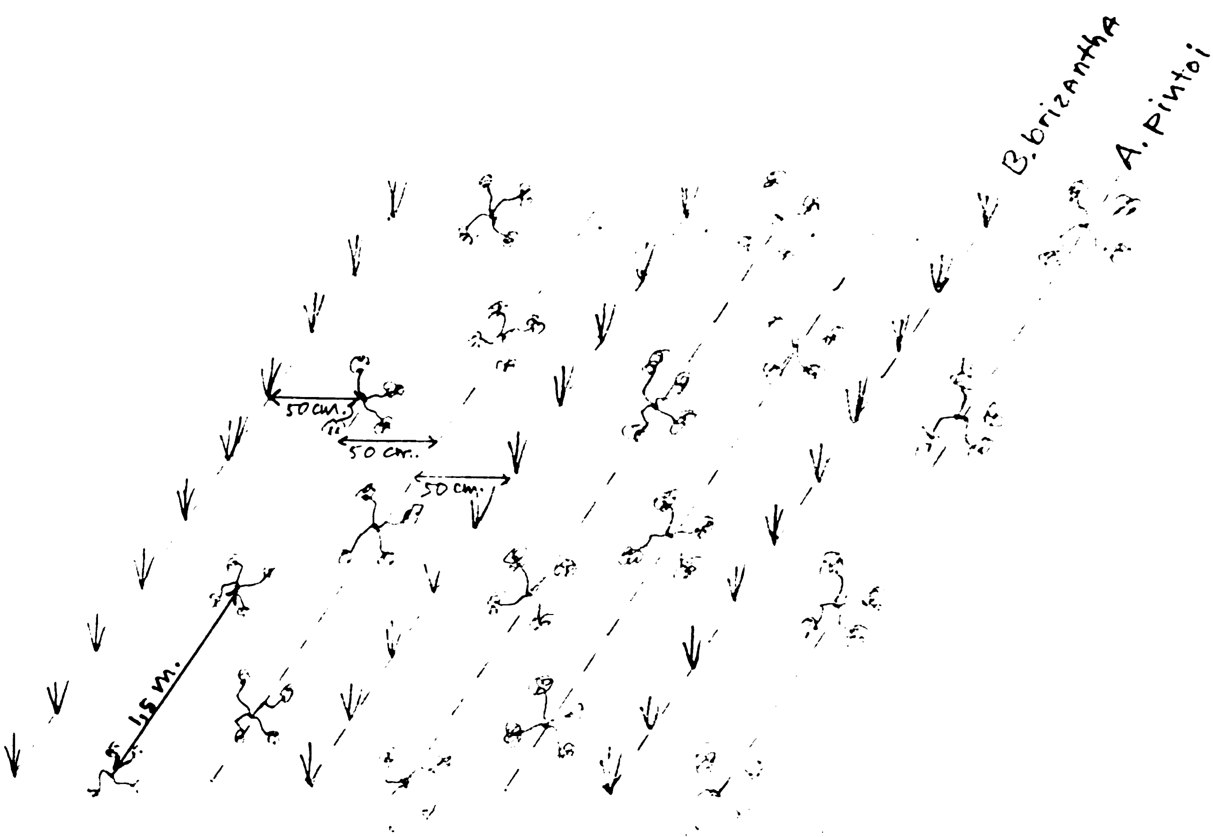

Figure 2: Schematic drawing of the seedbed pattern of a *B.brizantha* - *A. pintoi* mixture (proportion 1:2.)

Because *Arachis* is a slow establishing species while *Brachiaria* is a fast growing aggressive species, the latter tends to overgrow and overshadow the *former* before *Arachis* has established

well enough to withstand the competition with *Brachiaria*. This is also the reason why no N fertiliser should be applied, since it stimulates the growth of weeds and grasses, thus increasing the competition for *Arachis*.
Four to five months after seeding the pasture has established well enough to be grazed for the first time. A rotational grazing management should be carried out using a stocking rate of 2.5 AU/ha (1 AU equals 400 kg), a grazing period of 5 days with a recovering period of 30 days.
If the system is managed in the right manner, maintenance costs are restricted to weed control, requiring about US$ 25/ha/yr.

6.1.4 Seeding of legume trees

In the following text, the term 'tree' is used to indicate both *G. sepium* and *E. berteroana*, since the actions required to establish both tree species are hardly different.

Within the established BA mixture, the legume trees are sown in rows of about 12 metres. Tree lines are planted in an east-west direction and peripendicular to the pasture rows (figure 3). This is done to minimize the effect of tree shading on the pasture, which limits production. In addition, shading has a negative effect on the leave:stem ratio and reduces both palatability and nutritive value of the pasture (see section 5.3). East-west planting of trees lines minimize these negative effects.
Tree legumes are sown using branches of about 1 meter. Branches must be sown as quickly as possible after they are cut from the trees. To sow one ha with tree legumes asociated with pastures, about 925, one meter long branches are needed. Branches have to be prepared for seeding by stripping the bark off at one side of each branch. This is done to stimulate formation of roots at this side. Branches are sown horizontally, with the stripped side down

in small furrows at a depth of about 15-20 cm. Trees are sown in lines of maximum 12 meters each. Different lines have to be placed at least 6 meters apart. Tree lines should be placed alternately thus allowing the cattle to move freely in between them (figure 3). Preparing and sowing the branches costs 421 hours, making the establishment of this system quite labor intensive.

After about 8 months, the tree legumes have established well enough and the system can be grazed for the first time.

Like with BA mixtures, a rotational grazing system is practiced with a grazing period of 5 days and a recovery period of 30 days (stocking rate 2.5 AU/ha).

The legume trees need to be pruned every 4 months to prevent them from shading the pasture too much and for the leaves to become inaccessible to the grazing cattle. Trees are pruned at a height of 125 cm. Pruning takes 72 hours/ha/yr. When the system is properly managed, other maintenance costs are restricted to weed control, requiring about US$ 25 ha/yr.

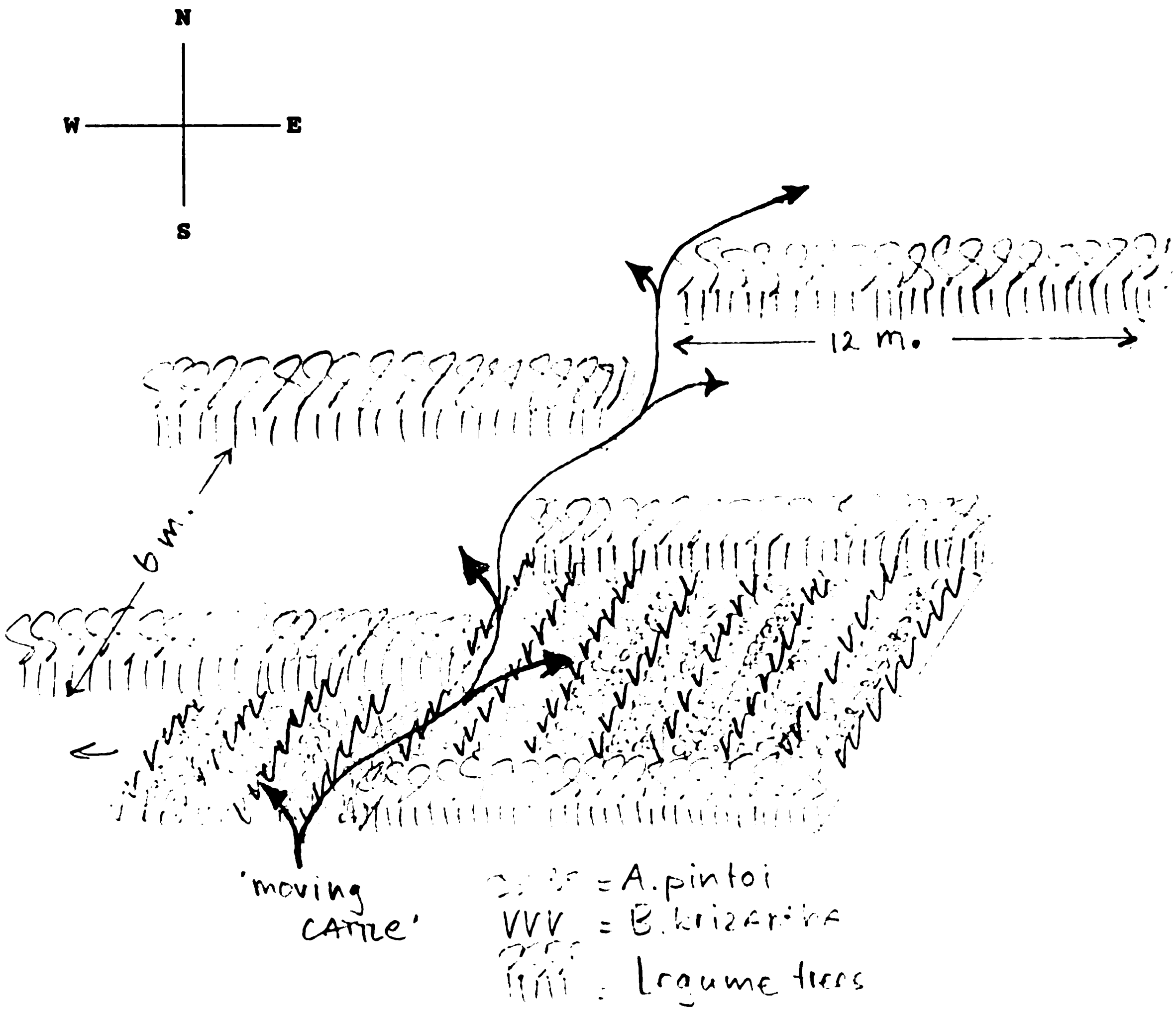

Figure 3: The silvopastoral system with tree lines planted in an east-west direction and sufficient space for the cattle to move between them (indicated by arrows).

6.2 Partial budgeting analysis

A partial budget analysis was performed for mixed pastures with mechanised and manual land preparation as well as for the silvopastoral system. The resulting partial budgets are given in tables 5, 6 and 8.

Table 5: Partial budget (one year period) for beef production on a BA mixture established with manual land preparation (costs in US$).

Average yield (kg/ha)		797
Adjusted yield (kg/ha)		717
Gross field benefits ($/ha)		610
MANUAL LAND PREPARATION		
Costs of inputs		**costs**
Gliphosate (1 gallon)		37.6
Paraquat (1 gallon)		17.2
Tordon-101 (Picloram) (1 liter)		12.5
Fungicide (20 g)		0.5
Super-tri-phosfate (20 kg/46%)		9.34
B. brizantha seeds (4 kg)		108.1
A. pintoi vegetative material (1.5 tons)		121.9
Labor costs	**hours**	**costs**
Apply gliphosate	12	12.24
Apply paraquat	6	6.12
Apply Tordon-101	3	3.06
Apply super-tri-fosfate	6	6.12
Cut *A. pintoi*	6	6.12
Inoculate *A. pintoi*	1	1.02
Sow *A. pintoi*	18	18.36
Sow *B. brizantha*	12	12.24
Weed control		25
TOTAL COSTS THAT VARY ($/HA)		**397.3**

Table 6: Partial budget (one year period) for beef production on a BA mixture established with mechanised land preparation (costs in US$).

Average yield (kg/ha)		797
Adjusted yield (kg/ha)		717
Gross field benefits ($/ha)		610
MECHANISED LAND PREPARATION		
Costs of inputs		**costs**
2,4-D (1 gallon)		12.5
Tordon-101 (Picloram) (1 liter)		12.5
Fungicide (20 g)		0.5
Super-tri-phosfate (20 kg/46%)		9.34
B. brizantha seeds (4 kg)		108.1
A. pintoi vegetative material (1.5 tons)		121.9
Labor costs	**hours**	**costs**
Mechanical land preparation		
(plouging and two harrowings)		116
Apply 2,4-D	12	12.24
Apply Tordon-101	3	3.06
Apply super-tri-fosfate	6	6.12
Cut *A. pintoi*	6	6.12
Inoculate *A. pintoi*	1	1.02
Sow *A. pintoi*	12	12.24
Sow *B. brizantha*	18	18.36
Weed control		25
TOTAL COSTS THAT VARY ($/HA)		465

6.2.1 BA mixtures

Tables 5 and 6 give the partial budgets for the mechanised and manual establishment of BA mixtures respectively. Because the differences in yields between manual and mechanically prepared lands is unknown, it is assumed in this study that the land preparation method does not affect yields.

Costs for establishment of BA mixtures with mechanised and manual land preparation were US$ 397/ha and US$ 465/ha, respectively, including the costs for one year of weed control. The difference is attributed to the high costs of the machinery, since for both systems labor costs are around US$ 85/ha. Input costs for manual land preparation are, however, higher compared to those of mechanical land preparation (US$ 307/ha vs. US$ 268/ha).
Because the total costs for establishment of BA-mixtures with mechanised and manual land preparation vary relatively little, in the following text the the costs for establishment are set at US$ 431/ha (average of the two).

Table 7 shows the cash flow and net present value and internal rate of return calculated over a five year period, since this is the age of the oldest BA pasture known in the region. In the second column (year 0) the production characteristics and the costs and benefits of a native pasture are listed. The following columns (year 1 to 5) give the characteristics of the improved pasture. In the first grazing period, starting 6 months after seeding, the production from the pasture is low. It takes about one year for the pasture to reach optimum cover and become fully productive. It is unclear what the production is in the first year of grazing. To not overestimate production, the net output of the pasture in the first 6 grazing months is set at 75% of the maximum production, resulting in a production value of US$ 229/ha in the first year. This figure is listed as 'revenues that vary' in the column of the first year of table 7. The 'total costs that vary' in the first year, are the sum of the establishment costs (US$ 408/ha) added to the maintenance costs (US$ 12.5/ha). Net benefits in the first year are obtained by subtracting from the total revenues that vary the total costs that vary.

In the following years, the pasture is fully productive and the total revenues that vary are US$ 610/ha. The total costs that vary consists only of the the maintenance costs of US$ 25/ha.

Table 7: Cost-benefit analysis including incremental cash flow, net present value and the internal rate of return for a BA mixture over a period of 5 years.

year	0	1	2	3	4	5
Total meat production (kg/ha)	163	299	797	797	797	797
Adjusted yield (kg/ha)	163	269	717	717	717	717
REVENUES THAT VARY ($/HA)	**139**	**229**	**610**	**610**	**610**	**610**
Establishment costs ($/ha)	0	408				
Maintenance costs ($/ha)	0	12.5	25	25	25	25
TOTAL COSTS THAT VARY ($/HA)	**0**	**421**	**25**	**25**	**25**	**25**
NET BENEFITS ($/HA)	139	-192	585	585	585	585
Incremental cash flow ($/ha)	**139**	**-330**	**446**	**446**	**446**	**446**
Net present value 5 years	**1,062.19**					
Internal rate of return (%)	**130**					

It can be calculated from table 7 that the pay-back period of the improved technology is just over 13 months. Thus, the investment costs of US$ 421/ha are earned back 13 months after seeding. After the establishment year, maintenance costs are restricted to weed control, requiring only US$ 25/ha/yr.

In table 7 the incremental cash flow is given for a year of production on native pasture (year 0) and subsequently for a production period of five years on improved pasture.

The incremental cash flow (M_t) is defined as

$$M_t = M_{(et)} - M_{(ec)}$$

were $M_{(et)}$ is the money earned in year t, $M_{(ec)}$ is the money that would have been earned with the original production method (*i.e.* animal production on native pastures).

The net present value (NPV) of the BA mixture was calculated over a five year period using the formula

$$NPV = \sum_{t=1}^{T} (R_t - R^{\circ}_t)\beta^t = \sum_{t=1}^{T} [(B_t - B^{\circ}_t) - (C_t - C^{\circ}_t)]\beta^t$$

where R_t and R°_t are the net returns in year t for the BA mixture and the native pasture respectively; B_t and B°_t and C_t and C°_t are the corresponding monetary benefits for the two different systems (*i.e.* native and improved pastures); and ß denotes the discount factor, which is equal to $(1 + r)^{-t}$, where r is the discount rate. In this calculation it is assumed that the discount rate is 8%, which represents an estimate of the real discount rate in Costa Rica as of July 1995.
The NPV over 5 years was calculated to be US$ 1,062.19 per year, equivalent to an internal rate of return (IRR) of 130% (table 7).

6.2.2 The silvopastoral system

The partial budget for the silvopastoral system is given in table 8. The costs for establishing BA mixtures are not specified in the table, since they can be found in the tables for BA mixtures. The establishment costs for BA mixtures are decreased by 5%, since this is the area that is taken up by the trees in the system and this does not have to be planted with *Brachiaria* and *Arachis*.

Table 8: Partial budget (one-year period) for beef production on a silvopastoral system (costs in US$).

Average yield (kg/ha/yr)		877
Adjusted yield (kg/ha/yr)		789
Gross field benefits ($/ha/yr)		671
ESTABLISHMENT COSTS	**hours**	**costs**
Establishing BA mixtures		387.6
Purchase costs for legume branches		53.69
Preparing and seeding branches	421	429.42
Pruning legume trees (3 times/yr)	70	71.4
Weed control		25
TOTAL COSTS THAT VARY ($/HA/YR)		967.11

Costs for establishing tree-pasture mixtures are almost double that of the BA mixtures alone (US$ 967/ha vs. US$ 433/ha) (table 7 and 8). This considerable difference in costs is caused by the substantial labor requirements for preparing and sowing the legume tree branches (421 hours/ha).

Table 9 shows the cash flow and net present value and internal rate of return calculated over a five year period of the silvopastoral system, similar to table 7. In the second column (year 0) the production characteristics and the costs and benefits of a native pasture are listed. The following columns (year 1 to 5) give the characteristics of the improved pasture. Since the silvopastoral system takes longer to establish than the BA mixture, it can be grazed for the first time 8 months after seeding of the legume trees. Production in the first year is therefore set at 20% (equalling US$ 134/ha) of the production when fully established. This figure is listed as 'total revenues that vary' in the column of the first year in table 9. The 'total costs that vary' in the first year are the establishment costs (US$ 871/ha plus the maintenance costs of US$ 96/ha. The net benefit in the first year are the total revenues that vary minus the total costs that vary and equals US$ -833/ha.

In the following years, the pasture is fully productive and total revenues that vary amount to US$ 671/ha. Total costs that vary consist only of maintenance costs (weed control and pruning of the legume trees).

Table 9: Cost-benefit analysis including incremental cash flow, net present value and the internal rate of return for the silvopastoral system over a period of 5 years.

year	**0**	**1**	**2**	**3**	**4**	**5**
Total meat production (kg/ha)	163	175	877	877	877	877
Adjusted yield (kg/ha)		158	789	789	789	789
REVENUES THAT VARY ($/HA)	**139**	**134**	**671**	**671**	**671**	**671**
Establishment costs ($/ha)	0	871				
Maintenance costs ($/ha)	0	96	96	96	96	96
TOTAL COSTS THAT VARY ($/HA)	**0**	**967**	**96**	**96**	**96**	**96**
NET BENEFITS ($/HA)	139	-833	574	574	574	574
Incremental cash flow ($/ha)	**139**	**-972**	**436**	**436**	**436**	**436**
Net present value 5 years	**437.19**					
Internal rate of return (%)	**28**					

In table 9 the incremental cash flow is given over a five year period. It can be calculated that the pay-back period of the improvement measure is 35 months. Maintenance costs of the silvopastoral system are significantly higher than those of the BA mixtures, due to additional high labor costs for pruning the legume trees (US$ 71/ha/yr). High maintenance costs in combination with only a slight increase of production compared to BA mixtures, result in a gross net benefit of the silvopastoral system of US$ 11/ha/yr *lower* than the gross benefits of the BA mixture (US$ 574/ha/yr vs. US$ 585/ha/yr). The net present value over a period of five years was calculated to be US$ 437.19. This is equivalent to an internal rate of return of 28% (table 9).

7. DISCUSSION

7.1 The economics of improved pasture systems.

From the results of the experiment it became clear that the productivity of animal production systems based on native pastures can be substantially improved upon by both a grass legume mixture (BA) alone and by a grass legume mixture combined with trees. Although in view of varying environmental conditions, under actual farming conditions, it is likely that by replacing native pastures with grass and legume species, production can be increased several times.

The hypothetical increases in production calculated from the experiments were 340% for the BA mixtures and 390% for the silvopastoral system (respectively US$ 610/ha/yr and US$ 671/ha/yr vs. US$ 138/ha for the system based on native pasture). However, the BA mixtures showed an internal rate of return of 130% over a five year period, while the silvopastoral system showed a IRR of 28%. Generally it is assumed that for an improvement measure to be adopted by small and medium scale farmers, the minimal rate of return should at least be 50% (CIMMYT,1988). On this basis it should be concluded that the silvopastoral system as described in this study, though it has the potential to increase animal production, is not an attractive measure to improve animal production. This is due to the high level of both initial costs for investment (US$ 871/ha/yr) and the subsequent costs for maintenance (US$ 96/ha/yr). Moreover, if the net production of the two improved systems is compared, *i.e.* total revenues minus total costs, the BA mixtures show a higher benefit (US$ 585/ha/yr vs. US$ 575/ha/yr) with the additional advantage of only minor establishment and maintenance costs.

The BA mixtures, however, show a high IRR of 130% over a five year period. Thus for every dollar that is invested in this system over a five year period, one dollar is earned back plus an additional US$ 1.30. This considerably exceeds the minimum acceptable rate of 50%. The IRR was calculated over a five year period with a continuous real discount rate of 8%. Even if the discount rate is doubled by means of a 100% risk premium (making it 16%), the NPV remains high (US$ 791.27).
The on-farm production from the BA mixtures was calculated to exceed the production from native pastures by 340% (US$ 610/ha/yr vs. US$ 139/ha/yr). Because it remains unclear what the final production under actual farming conditions will be, it was calculated that the annual production should at least be US$ 361/ha/yr (160% above that of native pasture) to guarantee an IRR of 50%. This would mean a production decrease of more than 40% of production levels obtained in the experiment. The likelihood that such a severe reduction will occur is small.
Nevertheless, for farmers to invest in the improved technology, they must be able to afford the initial investment costs of US$ 408/ha. In addition, the pay-back period from the improvement measure is at least 13 months, *i.e.* farmers should be able to finance this period. Since credit for pasture improvement is not available to farmers in the region, it might remain a serious problem for them to integrate such measures for pasture improvement in their farming systems.

It was calculated that the silvopastoral system would have to function at least 10 years to guarantee an IRR of 50%. This is a relatively long period and since no experience exists with the system so far, it might very well be possible that this period is longer in reality.

Taking stock of these results, it may be concluded that increased animal production can very well be achieved through the establishment of BA mixtures. Although the investment costs may be considered rather high, the system has low maintenance costs and a high IRR, which makes it a potentially attractive investment. The silvopastoral system analysed in this study does not seem to be a realistic option to increase animal production.

7.2 Management

Improving pasture production by replacing the natural vegetation with BA mixtures, can be very successful provided the mixture is properly managed. It starts with recognizing the ecological contraints given by the characteristics of the species involved. Although *A. pintoi* has a brought ecological amplitude, the conditions for *B. brizantha* are more stringent. The most important characteristic of *B. brizantha* in this respect is its degree of relatively low adaptation to humid soil conditions. Field trials showed that *B. brizantha* is a poor competitor on poorly drained soils. Production is low under humid soil conditions since the pasture is easily invaded by weeds. Since the AZ is very humid most of the year and soils are often poorly drained, one should make sure the soil conditions are suitable for *B. brizantha* before planting the BA mixture.

A second critical phase is the period from seeding to first grazing. When *Brachiaria* and *Arachis* are sown, the pasture is vulnerable to weed invasion, *i.e.* additional weed control measures might be necessary during this period. Because the grass is a vigorous species while the legume is a slow establisher, it is important that after 2 to 3 months after seeding the pasture is given a short, intensive grazing (30 animals/ha) to shorten the *Brachiaria* and improve the chances for good establishment of *Arachis*. In addition, it is important that the pasture is fertilised with super-tri-fosfate to give the legume an initial advantage. It should be stressed again that no N-fertiliser should be applied since this favours the growth of invading weeds and grasses. After the pasture has established well enough, rotational grazing should be carried out using a stocking rate of 2.5 AU/ha (1 AU is equivalent to 400kg), using a cycle of 5 days of grazing and a recovering period of 30 days.

These are all approximate figures. Dependent on soil fertility, rainfall, performance of the pasture and the breed of the cattle, these figures should be fine-tuned to the individual for every (farm-) situation. This requires some experimention by the farmer involved. Especially in the AZ, where farmers do not have much experience with such improvement measures, farmers will need assistance from experienced farmers, researchers and extension services.

Although the use of legume trees according to the method described in this study is not an economically attractive option to improve animal production, the importance of the use of silvopastoral systems to improve animal production in general should not be underestimated. The largest part of the difference between the establishment costs of the silvopastoral system and the costs for BA mixtures, is accounted for by labor costs for preparing and planting legume tree branches (table 8). Labor costs are quite high in Costa Rica compared to other countries in Central and South America. However, still remains the fact that the additional gain in production remains low compared to the BA mixture. On the other hand, a different planting system in combination with a different management, may substantially increase production. It is suggested to plant less trees per hectare so as to reduce labor costs and to reduce the negative effects on the pasture (chapter 5.3). Tree lines are now planted with 6 meters space in between the rows. By increasing the distance between the rows to 12 meters or more, the pasture is likely to suffer less negative effects from the trees. To improve the accessibility of the fodder, trees have to be pruned at a height of about 75 cm instead of 1.25 meters. This is likely to have several beneficial effects the production of the pasture. Since tree shoots and new leaves will be more accessible to the grazing cattle, they will be consumed before they can form big crowns and overshadow the pasture. Also, maintenance costs will be reduced significantly, since the trees will not need to be pruned as often because their foliage is eaten by the cattle. Because the trees will be left to grow to a height of only 75 cm time between seeding and the first grazing period will be shorter, which means that the newly established tree-pasture system will come into production sooner.

Tree-pasture systems have several important ecological characteristics, which may constitute another important reason to establish such systems. Trees provide shade for cattle, which is known to have a positive effect on milk production and liveweight gains (Bustamante, 1991: Bronstein, 1984). Trees provide fuel or timberwood. Both *E. berteroana* and *G. sepium* have a symbiotic relationship with *Rhizobium* bacteria in their root system and can add substantial amounts of N to the soil, which can add up to the amount of 150 kg of N/ha/yr. Trees also prevent the soil from erosion, which is a common problem on grazed slopes in the humid Atlantic Zone.

8. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Mixtures of the grass *B. brizantha* and the legume *A. pintoi*, form an excellent opportunity to improve animal production in the AZ of Costa Rica. Both species are adapted to the conditions in the zone and are available in the region. Costs for establishment are US$ 397/ha with manual land preparation and US$ 468/ha with mechanised land preparation. The improvement measure showed a rate of return over a five year period of 130%. This is accounted for by a more than fourfold production increase (US$ 610/ha/yr for the improved legume based pasture vs. US$ 139/ha/yr for the native pasture) combined with relatively low maintenance costs (US$ 25/ha/yr). Because of these favourable characteristics, improving animal production on small farms in the region through the establishment of BA mixtures seems a sound and profitable management practice. However, before establishment, soil characteristics and individual farms will have to be investigated, to be sure that they meet the ecological constraints of the two forage species. Special attention should be given to drainage characteristics of the soil, since *B. brizantha* does not perform well combination with *A. pintoi* on poorly drained soils in humid areas.

Improving animal production by establishing BA mixtures in combination with tree legumes (*Erythrina berteroana* or *Gliricidia sepium*) requires relatively high investment costs (US$ 967/ha). All the same here additional profits (above those of BA mixtures alone) are minimal (US$ 11/ha/yr). High establishment costs are attributed to high labor costs for preparation and planting of tree branches (421 hours/ha or US$ 429/ha). The IRR from this system over a five year period was calculated to be 28%.
Although gross production value from the silvopastoral system is high (US$ 671/ha/yr), net production value (US$ 571/ha/yr) is

lower than that of the BA mixtures due to relatively high maintenance costs.
These characteristics make establishing a silvopastoral system as described in this study, not a sound management practice to improve animal production on cattle farms in the region.

However, the incorporation of trees in grazing systems has several ecological advantages which can constitute an additional reason for establishing tree-pasture systems. Legume trees are capable of adding substantial amounts of nitrogen to the farm system. Planting of trees on grazed slopes reduces the risk of erosion, which is often a serious problem in the humid tropics. Trees also serve other functional purposes such as fuelwood, timber wood and provision of shade for cattle; the latter is known to have a positive effect on production. Trees also attract other (beneficial) organisms and thus increase the biodiversity level of the system. Biodiverse systems are also known to be less susceptible to pests and diseases.
When legume trees are incorporated in the grazing system for the above mentioned reasons, different methods should be developed which require smaller initial investment and have lower maintenance costs as well.

Although from the results of this study it can be concluded that establishing BA mixtures is a good and economically sound improvement measure, its scope for implementation depends on the financial situation of the farmers. Therefore, the possibilities of farmers in the region to actually establish BA mixtures deserves further investigation. With the results from this study and the additional information on (financial) possibilities of farmers, a technology transfer strategy could be developed for extension services in the AZ and elsewhere.
More research should also be done on the development of

alternative silvopastoral systems that require less establishment costs (less trees) while it still has the ecological and economical benefits and characteristics of a silvopastoral system.

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