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POTENTIAL OF SILVOPASTORAL SYSTEMS FOR ECONOMIC DAIRY PRODUCTION IN CAYO, BELIZE AND CONSTRAINTS FOR THEIR ADOPTION

BY

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BIOGRAPHY

The author was born on the 16th of April, 1974, in the district of Corozal, Belize. She realised her primary education at the Belmopan Infant School and the Belmopan Junior School and secondary education at the Belmopan Comprehensive School.

She attended St. John's College Sixth in Belize City in 1991 and graduated in 1993 with an Associates Degree in Mathematics and Physics. Following this period she was employed in September 1993 as a high school mathematics teacher at the Belmopan Comprehensive school working one school year. It was here where she first became strongly interested and concerned about the environment and formed the first environmental club, with the acronym SEED (Students Encouraging Environmental Development), at the high school. In 1994 she attended Dominican College of San Rafael in San Rafael, California USA to read for her Bachelor's of Arts degree and in 1996 she graduated with honors in Mathematics. After undergraduate training she returned to Belize and in 1996 was employed as a geographic information systems technician (GIS) at the Henry M Jackson Foundation, Malaria Project under the Ministry of Health, Belize City. In 1997 she was promoted to Administrator of the Henry M. Jackson Foundation, Malaria Project, Ministry of Health, Belize City where she was responsible for the project. In 1998 she resigned to take up postgraduate studies at CATIE up in Environmental Economics with emphasis in Administration and Management and in December 2000 she graduated and received her Masters degree.

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Key words: Dairy farms, traditional production systems, silvopastoral systems, milk production forage trees, descriptive statistics, regression analysis, farm characterisation, multivariate analysis, financial analysis, labour, supplements, adoption.

SUMMARY

This study was carried out in the Cayo district, Belize during the months of February to May, 2000. Forty farms in 12 villages were surveyed (28 dairy farms and 12 beef farms) to determine and quantify biophysical and socio-economic characteristics of the farms in that area. The objectives were: 1) Determine the dairy farm typologies in the Cayo district based on the level of production and cost and benefits involved, 2) Evaluate and compare the profitability of the two dairy production systems in the Cayo district: traditional production systems (TS) and an improved silvopastoral systems (SPS), and 3) Identify constraints and potentials for adoption and potential adoption on the farms studied.

The main activity on all farms is cattle production (milk, beef or milk and beef). Of the total land area being used by these farms 65% is dedicated to pasture. 22% is primary forest, 8% is fallow area and [illegible] dedicated for crops. A regression analysis revealed a correlation between farms size (X) and pasture area (Y) (Y= Y=1.63+0.64X; $R^2 = 0.78$) as well as between farm size (X) and primary forest (Y) (Y=-4.36+0.30X; $R^2 = 0.71$) and farm size (X) and fallow area (Y) (Y=-6.6+2.2X; $R^2 = 0.76$), $\alpha = 0.05$.

Multivariate analysis techniques (Principal component and Cluster analysis) were applied to characterise the dairy farms according to level of intensification and costs of production. Ten main variables were used. This analysis identified three farm types based on farm resources, level of milk production and cost of production: 1) small farm size (45 acres), low milk production (6853lbs/year), low input for production ($1872/year), 2) intermediate farm size (73 acres), high milk production (28465lbs/year) and high input for production ($7251/year), 3) big farms (231 acres), high milk production (61305lbs/year) and high input for production ($16916/year).

Higher financial benefits were obtained from the farms with silvopastoral systems compared to the traditional production systems. Results calculated over a one year period (data from preceding year including costs of establishments distributed over a 10 year period, the expected life period of silvopastoral systems) gave net benefits and B/C of 105.67BZ$/acre and 1.72 and 42.24BZ$/acre and 1.64 for silvopastoral and traditional systems respectively. Calculating the financial analysis over a 40 year period, taking into consideration the value of the timber in the multistrata systems as well as the environmental services provided by silvopastoral systems (carbon sequestration in trees and soil and nitrogen incorporation into the soil) and using a real discount rate of 6% the new NPV/acre and B/C calculated for the silvopastoral and traditional systems were 1652BZ$ and 1.74 and 653BZ$/acre and 1.64, respectively. Even when the value of the timber trees and environmental services were excluded the financial indicators were sill higher for the silvopastoral system in the long run. The percentage spent on supplements of the total cost for silvopastoral systems was lower (29%) than that of tradition systems (35%) due to a reduction in the amount to supplements previously given to the animals and replaced by the forage from the silvopastoral

systems. The cost of the forage was estimated to be 80% less than the cost of commercial supplements. The cost of production was also lower for the silvopastoral systems (0.25BZ$) compared to the traditional systems (0.27BZ$). The sensitivity analysis showed that increasing the labour costs can affect the profitability and adoption of the silvopastoral systems proposed since even if the prices of milk paid to the farmers increases at the same rate that labour prices increase the NPV decreases.

Among the primary constraints for adoption of the proposed silvopastoral systems identified by the farmers are: risk, capital, markets and animal quality. Labour was not mentioned to be significant in the adoptions of these systems the main reason being that the farmers in the Cayo district have an advantage in that they already have an appreciation for pruning trees to feed the cattle in the dry season and although, this is an important factor to consider in the economic aspect of these systems since labour in Belize is expensive compared to its neighbours in Central America ($2.50BZ$/hr), for adoption of the systems the farmers don't see it as a factor that can limit them from adopting the systems since family labour clearly outweighs hired labour.

ALONZO, Y. 2000. Potencial de los sistemas silvopastoriles para la producción económica de leche en Cayo, Belice y limitaciones para la adopción. Tesis. Mag. Sc., Turrialba, Costa Rica. CATIE. 81p.

Palabras claves: fincas lecheras, sistemas de producción tradicional. Sistemas silvopastoriles, producción de leche, arboles forrajeros, análisis descriptivo, análisis de regresión, caracterización de fincas, análisis multivariado, análisis financiero, mano de obra, suplementos, adopción.

RESUMEN

El presente estudio se realizo en el distrito de Cayo, Belice. Se realizo una encuesta por medio de entrevistas a 40 productores en 12 comunidades en esta área con el objetivo de determinar y cuantificar las características biofísicas y socio económicas de las fincas en la zona. Los objetivos fueron: 1) determinar los tipos de fincas lecheras en Cayo con base a niveles de producción , costos y beneficios de el aspecto ganadero de las fincas, 2) Evaluar y comparar la rentabilidad de los dos sistemas de producción: tradicional y silvopastoril, 3) Identificar las limitantes y potenciales de adopción en las fincas de Cayo.

La actividad principal de todas las fincas estudiadas es de producción ganadera (leche, carne o leche y carne). Del área total de todas las fincas un 65% es dedicada a pastos mientras que un 22% a bosque primario, 8% a guamiles y 6% a cultivos. Un análisis de regresión mostró que hay una relación positiva entre tamaño de finca (X) y área de pasto (Y)) ($Y= 1.63+ 0.64X$, $R^2=0.78$). Resultados similares se encontró para tamaño de fina (X) y bosque primario (Y) ($Y =-4.3 + 0.3X$, $R^2=0.7$) así como tamaño de fina (X) y área de guamil (Y) ($Y= 6.6+ 2.2X$, $R^2=0.76$), $\alpha = 0.05$.

Mediante un análisis de conglomerados se identificaron 3 grupos de fincas sobre 10 variables principales basado en recursos de la finca: Area de pasto (TPASAR), numero de animales (TNOAN), no de vacas (MKCOWS); nivel de producción: Leche/vaca/ordeño (MKPCW), leche/año (TMKPYR); costos de producción: costos de veterinaria (AHTCT), costos de suplementos (SUPP), costos de mano de obra (CTACTIV), costo total (TCOST) y beneficios total (TBEN). El grupo uno consiste de fincas pequeñas con área de pastos de (45 acres), baja producción de leche (6853lbs/año), bajo uso de insumos con un costo total de ($1872/año), 2) el grupo dos consiste de fincas medianas con área de pasto (73 acres), alta producción (28465lbs/año) y altos costos de producción ($7251/año, 3) el grupo tres consiste de fincas grandes con un área de pasto de (231 acres), alta producción (61305lbs/year) y con costos de producción mas altos que los dos grupos anteriores ($16916/año).

Altos beneficios financieros se obtuvieron en las fincas con sistemas de producción silvopastoriles comparados con los de sistemas tradicionales. Los resultados calculados para un periodo de un año dieron un beneficio neto y relación benéfico-costo (B/C) para el sistema silvopastoril y tradicional de 105.67BZ$/acre y 1.72 , 42.24BZ$/acre y 1.64 respectivamente. Haciendo los cálculos para un periodo de 40 años tomando en cuenta el valor estimado de la madera en los sistemas mulitiestratos así como los valores potenciales de los servicios ambientales en los sistemas silvopastoriles (secuestro de carbono en arboles y suelo) usando una tasa real de descuento del 6% se obtuvieron los nuevos VAN y B/C de los sistemas silvopastoriles y tradicionales 1652BZ$/acre y 1.74, 653BZ$/acre y 1.64, respectivamente. Aun cuando se excluyen los valores de la madera y servicios

ambientales, los indicadores financieros siguen siendo alto en el largo plazo. El porcentaje del costo de suplemento sobre el costo total fue menor en los sistemas silvopastoriles (29%) que en los sistemas tradicionales (35%) debido a la reducción en el uso de concentrados comerciales en los sistemas mejorados. El costo de forraje se estimo a un 80% menos que el costo de los concentrados comerciales. El costo de producción fue menor para los productores del sistema silvopastoril (0.25BZ$) que para los del sistema tradicional (0.27BZ$). El análisis de sensibilidad mostró que aumentando el costo de mano de obra puede afectar la rentabilidad y adopción de los sistemas silvopastoriles propuestos ya que aun cuando se incrementa el precio de la leche por al misma cantidad en que se incrementa el costo de mano de obra, el VAN baja.

Entre las limitantes mas importantes identificadas por los productores para la adopción de los sistemas silvopastoriles, mano de obra no fue mencionado como una de los mas importantes ya que los productores de la zona podan los árboles para proveer forraje durante el época de sequilla.. Aunque este factor es muy importante en la parte financiera del sistema ya que el costo de mano de obra es mas alto en Belice comparado con sus vecinos Centro Americanos ($2.50BZ$/hr), para la adopción de los sistemas, los productores no lo ven como el factor mas importante ya que se usa mucha mano de obra familiar en estas fincas.

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I. INTRODUCTION

Cattle production has been identified as one of the many activities associated with land degradation. Many studies have coincided that one of the main causes of deforestation in Latin America has been linked to the development of cattle farms (Camero, 1996). Furthermore, over the past few years there has been growing pressure on land used for agricultural purposes and livestock production in Latin America and the Caribbean. Recently, new land clearing is due to the perceived profitability of rearing cattle (Arya and Pulver, 1993).

Although Belize has managed to avoid over exploiting its natural resources over the past few decades, today, it is beginning to show trends that could lead to the same environmental disasters that many of its neighbouring countries have experienced. There is evidence of increasing pressures on land use for agriculture activities that are threatening to put the state of Belize's natural resources at risk of irreversible damage.

The Cayo district has been identified as one of the districts with increasing rates of deforestation. There is evidence of actual and potential natural and environmental problems in many parts of Cayo (IICA/CEPPI 1995) in great part due to the cattle industry in this district.

Livestock production is a major land use activity in the Cayo district. However, milk and beef productions are low because of inappropriate feeding practices, especially in the dry season. The mayor source of animal feed in the traditional cattle production systems is based on unproductive natural or native pastures that are of low productivity and quality. Carrying capacity of these pastures is only 0.4 to 0.45 animal units per acre (BLPA, 1996). Inefficient management of farms in Cayo has resulted in negative changes in pasture composition and quality, causing farmers to resort to the forest and woodlands in search of forage for their ruminants (Pulver *et al* 1996). High soil loses caused by water erosion are apparent from overgrazed pastures found on steep slopes. In the dry months there are severe feed shortages, resulting in weight losses of cattle and, in extreme conditions, increasing adult mortality. Poor conditions affecting animals grazing native pastures are also reflected in low calving rates and long calving intervals (Ibrahim *et al*, 1998b).

In an effort to address the above problem, the first Agroforestry program was established in Belize in 1996, by the Ministry of Agriculture and Fisheries of Belize (MAF) with assistance from Tropical Agricultural Research and Higher Education Centre (CATIE) in an effort to identify sustainable options for livestock production in Belize. Silvopastoral systems, mainly fodder bank technologies and multistrata systems were established on eight dairy farms in Cayo to conduct farmer's participatory research and to determine the preference of these banks in terms of fodder and annual production (Ibrahim *et al* 1998b). This study intends to evaluate the financial benefits of these silvopastoral systems on local farms in this district as well as to determine their potential for massive adoption in this area.

1.1 Objectives

1.1.1 General Objective

The proposed investigation will generate information on the financial benefits of silvopastoral systems and constraints for the adoption of these systems in Cayo, Belize.

1.1.2 Specific Objectives

1. Determine the dairy farm typologies in the Cayo district based on land resources, the level of production and cost and benefits involved

2. Evaluate and compare the profitability of the two dairy production systems in the Cayo district: traditional production systems (TS) and improved silvopastoral systems.
   a) Estimate the potential value of timber trees in the silvopastoral systems as carbon sinks and commercial lumber.
   b) Estimate the indirect benefits of nitrogen incorporated into the soil by the legumes in the silvopastoral systems.

3. Identify constraints and potentials for adoption of silvopastoral systems being promoted in Cayo, Belize.

1.2 Hypothesis

Ho: Financial benefits obtained from silvopastoral systems on dairy farms are greater than those obtained from traditional production systems.

Ho: Silvopastoral systems reduce risk for the farmers by diversification of farm income and reducing costs. In the short term, adoption of silvopastoral systems reduces the risk of forage shortages experienced in the dry season and reduces cost of commercial supplements for resource poor farmers. In the long term silvopastoral systems introduce other sources of income such as timber.

II. LITERATURE REVIEW

2.1 Silvopastoral Systems

Much of the deforestation and soil degradation has been linked to livestock production in particular cattle rearing. In Central America a high percentage of established pastures are in an advanced stage of degradation, resulting in low pasture carrying capacities and, together with low prices for animal products, cattle production becomes an inefficient land use. Soil erosion may exceed 100t/ha/yr in severely overgrazed pastures (Lal, 1993). It is estimated that more than half of the world's rangelands are overgrazed and are subject to erosive degradation (Worldwatch Institute, 1988).

Silvopastoral systems have been increasingly recognized as viable farming systems and have been widely promoted throughout the world as sustainable practices that control erosion and increase soil fertility. Silvopastoral systems are a branch of agroforestry which allow farmers to manage trees with crops, grasses or animals on the same land unit while increasing income, reducing risk by diversification of outputs, and promoting sustainability. These systems have demonstrated the importance of integrating the tree component in pastures as an improved element of the productive conditions of areas dedicated to cattle activities. Studies on these systems have shown significant economic benefits with the use of trees and forage plants as a complement of the basal feed of cattle (Camero, 1996) and through the production of timber and other services. Potential incentives paid for Carbon sequestration of these systems can be seen as yet another source of income for farmers especially since improved grasses and fast growing multi-purpose trees are capable of sequestering significant amounts of carbon (Ibrahim, 1994; Musalem , 1998).

Great value is attached to the biophysical and socio-economic qualities of silvopastoral systems as far as sustainability is concerned. According to Ruiz (1983) (cited by Russo, 1994) some advantages are as follow:

a) They can raise productivity of agriculture land where the productive capacity has been reduced due to poor management that has resulted in soil compaction and the loss of fertility (e.g. under large-scale cattle).

b) As they diversify the productive activities of the farm, there is less risk of biological, natural-physical catastrophes and economic (market) fluctuations. By combining plants and animals, there is a reduction of risk and uncertainty, in the productive systems of small farmers.

c) The introduction of the tree component into existing large-scale cattle raising systems could considerably enhance their agrotechnical sustainability.

d) Besides the direct advantages of these systems on the farms, farmers can obtain economic benefits as a result of selling the wood as fuel wood, wood for posts, wood in general and as forage.

e) With nitrogen fixing trees, it can logically be assumed that they will contribute to the fertility of the soil, besides using the leaves and/or stems as a protein supplement for feeding cattle. As trees are known to sequester carbon dioxide and store it in their biomass, this is yet another advantage of incorporating trees in livestock production systems.

2.2 Traditional and Improved Silvopastoral Systems in Central America

Traditional silvopastoral systems have been extensively practiced throughout the tropics of Central America by indigenous farmers for generations. However, improved silvopastoral systems as a science based technology was first introduced in the mid - 19th century. The increasing global concerns for the degradation of forested lands has prompted the reassessment of the traditional silvopastoral systems as a system of land management with a great potential to both farms lands and forests. Much scientific research has been aimed at improving the economic efficiency of livestock farms. Today these systems have a major goal of improve the conditions of the rural poor without destroying the natural resources.

The combination of woody perennial trees with pasture and animals has formed part of the "production culture" in many tropical countries over the centuries. There is evidence that farmers have a long history of using woody leguminous trees or fruit trees as living fences. In some cases it is evident that the farmers have utilized woody perennial trees for either an economic, social or ecological benefit, although in other cases the trees are found to be growing naturally in a disperse manner in the pastures which farmers utilize mainly to provide shade for their animals and for posts (Pezo and Ibrahim, 1998).

Improved silvopastoral systems involve the use of woody perennial trees with traditional components such as herbaceous forage and animals under an integral management system. Management of the woody perennial is aimed at fulfilling the needs of the farmer (food, firewood, timber, shade, erosion control, water management etc.), and is based on the understanding of the interactions between the woody perennial and the other plant and animal components of the production system (Rocheleau and Vonk 1983). In the traditional silvopastoral systems, management of farms is either non-existent or inefficient. Woody trees (i.e., *Erythrina spp.*, *Gliricidia sepium, Spondias purpurea*) used as living fences and disperse trees and shrubs in pastures that have been more common traditional silvopastoral systems can be improved under an appropriate management system. Other types of improved silvopastoral systems include fodder banks of woody perennial trees, alley farming, pasture in plantation of fruit trees and trees grown for timber, woody trees planted as living barriers, trees used for windbreaks and line planting.

2.3 Traditional Systems in Cayo

In the traditional cattle production systems in the Cayo district, the major source of animal feed is based on unproductive natural or native pastures such as *Paspalum notatum, P. virgatum and Cynodon dactylon* that are of low productivity and quality. There is a lack of an integral management system of these pastures. Pastures are managed without any divisions for rotations and overgrazing is evident on many of the farms in Cayo and has resulted in negative changes in the pasture composition and quality. Farmers have resorted to the forests and woodlands in search of forage for their ruminants (Pulver *et al.* 1996). In the dry season, severe feed shortages result in heavy weight losses (30 - 60 g/an/day) of the cattle and in extreme conditions, adult mortality can be high (4 - 6%). The poor nutritional conditions affecting animal grazing native pastures are also reflected in low calving rates (<55%) and long calving intervals (>15months) (Ibrahim *et al*, 1998a).

Fodder trees and shrubs have been used for generations as a multipurpose resources (food, fibre, fodder, timber, wood, and live fences) in Cayo, but with low-level technologies. Trees are widespread in pastures in particular Conhune palm *(Orbignye cohune)*, pixoy (*Guazuma ulmifolia*) and Ramon (*Brosimum alicastrum*). *B. alicastrum* and G. ulmifolia are two of the most common species used for feeding ruminants during the dry season in Cayo. (Ibrahim *et al*, 1998a)

The introduction of shrub/tress fodder banks in pastures has been identified as the first agroforestry prototype for improving cattle production (CATIE/MAF/NARMAP, 1996). Tree leaves can provide valuable fodder with 12 to 25% crude protein (CP), 20 to 45 % crude fibre (CF) and *in vitro* dry matter digestibility (IVDMD) ranging from 40 to 83% according to the plant specie and animal type (Pezo *et al* 1989; Norton 1994; Ibrahim *et al* 1998b).

Fodder banks of *Leucaena leucocephala* were established in eight farms in the Cayo district (M. Ibrahim, 1999, CATIE, pers. Comm.) and preliminary data seem to indicate that there has been an increase in production and an overall improvement on these farms compared to when these farms operated under traditional systems. However, a proper financial analysis is in order and has yet to be carried out.

2.4 Fodder Banks for Dry Season Feeding

The biggest challenge in many of the traditional livestock production systems is feeding the animals during the dry season. In many parts of the sub humid and humid tropics, it is common for the dry season to last from 3 to 6 months. In Central America the typical diets of the animals in the dry season is based on the use of mature grasses or crop residue (characterized by high levels of fibre and very low content of CP), with supplementation from leguminous and non-leguminous trees and shrubs. However, during the dry season animal feed is likely to be both in short supply and of low nutritional quality. The dry matter digestibility of mature grasses may fall below 40% and CP levels may be less than 5%, the level required to maintain feed intake (Van Soest, 1994).

Fodder banks are usually established to off set scarcity of forage in the dry season. This involves the sowing of trees and shrubs in high densities to maximize edible biomass production. Leguminous trees have an important role in providing feed during the dry season because they are deep rooted and this permits water uptake when surface water levels are low, reducing leaf-drop during the dry season. Tree species usually produce a significant amount of edible biomass in the dry season (> 5 tons/ha) unlike herbaceous species, which are usually wilted. The edible biomass of woody trees especially that of leguminous trees is rich in crude protein, vitamins and most of the minerals except sodium. The nutritive value of the woody trees experience lower changes in the different season (dry and rainy) than those detected in common grasses traditionally used to feed the cattle. Feeding of the animals with leguminous trees or shrubs from fodder banks permits the increase in the consumption of forage and therefore reduction of LW losses in the dry season. Improved feeding not only has the potential to increase LW gains but can also have positive effects on reproductive parameters (age of first calving, shorter calving interval, > % calving etc.) (Ibrahim *et al*, 1998a). The introduction of fodder banks on farms can increase the carrying capacities on pastures. Acceptable levels of milk production are obtained without the cows having to make use of their corporal reserves (Camero *et al* 1993).

Leucaena leucocephala, guacmio (*Guazuma ulimifolia*), *Cratylia argentea* and ojoche or ramon (*Brosimun alicastrum*) are among the commonly used species for the purpose of fodder banks in areas where a dry period is well defined. There is evidence that these species have good potential as fodder and protein banks because they tolerate frequent pruning and produce significant amounts of forage during the dry season, which is of high feeding value (Ibrahim *et al*, 1998b). *Gliricidia sepium* and *Erythrina spp.* are well adapted in the humid tropics and are commonly found on livestock farms in Central America as living fence posts (Ibrahim *et al*, 1998b). These species are known to produce significant amount of forage that is of a high quality (Mochiutti, 1995). Much research studies have been carried out using *Leucaena leucocephala*. In the dry periods these tree species can produce superior quantities of forage than those obtained from native and traditional pastures and produce better production yields than those pastures under which no chemical fertilisers are used (Pezo and Ibrahim, 1998).

2.5 Social and Economic Considerations

Farmers judge agricultural systems on the basis of how well they meet their basic needs including food, shelter and cash income. There is significant evidence that agroforestry techniques can help meet the needs of rural farmers (Rocheleau, 1987). Agroforestry is a flexible technique that can be tailored to local environments and the needs of local people.

For resource poor farmers, economic security is dependent upon environmental health and stability. Thus any activity that conserves or improves the soil productivity and the environment without restricting usage, improves economic security in general. In livestock production, silvopastoral techniques can protect soil and water resources and other aspects of the environment and maintain or increase the potential usage of environmental resources. Silvopastoral systems can increase the productivity of existing land thus, enabling the rural farmers to meet their needs on the limited amount of land. Also silvopastoral systems protect cultivated soils from degradation thereby maintaining the quality of the arable land that is available to the rural families. In the humid tropics of Costa Rica there are good examples of fodder banks established with *Erythrina berterona* and *Gliricidia sepium* to supplement cattle. Studies conducted by CATIE showed that the use of these species for supplementing the diet of dairy cattle resulted in 20 to 30% increase in animal production (Ibrahim *et al.*, 2000b).

The extra income that can be earned from the forest-based activities is an incentive for most farmers to adopt silvopastoral systems into their traditional agricultural systems. Trees in this system do not only have potential as extra income but can lower input costs by using the trees as living fences. This would also control deforestation. By integrating trees into a livestock production system, farmers can maximise the potential of their land and maintain healthy livestock

2.6 The Profitability of Silvopastoral Systems

There have not been many extensive studies on the profitability of silvopastoral systems in Latin America. It is not until recently that the profitability of these systems has become an interest to both investigators and farmers who are seen more affected by these practices. A few studies have been conducted in Costa Rica and Colombia. In general these studies seem to indicate that there is increased economic benefits at the farm level using silvopastoral systems compared to traditional production systems on unimproved pastures.

A study conducted by Holmann, *et al* (1992) on the profitability of silvopastoral systems with small farm producers of milk in Costa Rica evaluated the costs and benefits of managing live fences, protein banks (*Erythrina berteroana*) and associations of improved pastures (*Brachiaria brizantha*) with legumes (*Arachis pintoi*) and lumber trees (*Cordia alliodora*).

A representative farm from the humid lowlands of Costa Rica was used as an example. Four alternatives were evaluated: 1) live fences of (*E.berteroana*); 2) protein bank of (*E.berteroana*) and *Ischaemum indicum*; 3) establishment of *B. brizantha* associated with *A.pintoi* and 4) association with laurel (*C. alliodora*) with pastures. The results obtained from the evaluations showed that the cost of establishing living fences was 54% lower than the cost of establishing dead fences and that 1 km of live fence with two annual prunings can incorporate N, P and K into the soil worth a substantial amount in dollars of organic fertiliser, exceeding the cost of labour required for the prunings. In the case of the protein bank, the cost of producing 1 kg of dry matter was 750% lower than the cost of soybean meal. Improved pastures associated with legumes maintain higher stocking rate and allowed for an additional kg of milk. This alternative allows for more milk to be produced with the lowest investment costs. Planting lumber tress requires a greater investment, however, if prices of lumber continue to increase as it has done over the past 13 years, this alternative is the most profitable. Intangible benefits from these silvopastoral systems which could be more beneficial to society than to the farmers themselves was not considered. It is clear from this study that silvopastoral systems in the humid tropics offer improved economic benefits compared to traditional production systems.

Similar results have been obtained by research work done by CATIE in the inclusion of foliage from the woody legumes, *Erythrina sp.* (poró) and *Gliricidia sepium* (madero negro) as protein supplement in the diets of weaned calves in the production of milk. These silvopastoral systems proved to be real and practical alternatives for farmers. Although the use of *Erythrina sp.* and *Gliricidia sepium* as forage seem to be of lower protein quality than sources from traditional systems, there is still a good production of milk and meat when these two tree species are used as supplements in the cattle's basic diet. An economic analysis showed that using madero negro and poró as supplements gave higher production yields and higher economic benefits as a result of reducing variable costs at the farm level. The impact of using these leguminous trees as supplement can be seen in the economic benefits - increase in income for the farmers (Camero, 1995).

Jansen, *et al* (1997), assessed the economic viability of pasture improvement using a mixture of *Brachiaria brizantha* and *Arachis pintoi* (BA system) or of *B. brizantha* and *Erythrina berteroana* (Silvopastoral system). In the Atlantic Zone of Costa Rica. For comparative purposes a system consisting of supplementary feeding on unimproved pastures was also evaluated. The results of the study showed that the BA system was the most profitable option for farmers in the NAZ to increase beef production. Supplementary feeding was about one half as profitable as the BA system given current market prices of supplementary feed. However, at given beef prices, the profitability of supplementary feeding reduces rapidly with increasing cost of supplementary feed. The silvopastoral systems had the lowest financial benefits, even though such systems may have additional sustainable benefits, which were not taken into account. In this study the silvopastoral system did not seem to be a viable option compared to the BA system for farmers in the NAZ of Costa Rica primarily due to high establishment costs and limited access to capital of most farmers in this area. In conclusion these improved systems provide long term as well as short term benefits and capital invested can easily be recuperated in about one year depending on the system used. These systems have proven to be viable production alternatives with significant economic returns as well as ecologically better than traditional production systems.

Jimenez (1997) evaluated the economic and financial benefits of using Morera (*Morus sp)* as part of the diet of cattle after the weaning period. Calves with weaning weights up to 120 kg and cows with 5 months of gestation were feed with morera and commercial concentrate. Three treatments represented by different levels of concentration were offered (1.5, 1.0 and 0.5 kg/an/day average) and fresh morera ad libitum in a semipasture system on one of CATIE's commercial farms were studied. The investigation showed that the most economic and financial benefits were obtained when morera was offered without any restrictions along with 0.5 kg of concentrate animal/day. The other two treatments of 1.5 and 1.0 kg of concentrate per animal did not offer comparative advantages. However when limitations were set on the morera offered along with 0.5 kg of concentrate for calves with weaning weights up to 120 kg, the study indicated that it was not economically nor financially justifiable. The most profitable system in the breeding of animals for replacement both at 120 kg and at 5 months of gestation, was possible once the intake of morera was not limited in the feeding of the animals and a reduction of at least one month in the age of service was expected.

2.7 Adoption of Silvopastoral Technologies

The farm system is part of the regional system, in which physico-biological, social, political and macroeconomic elements form a part. These constitute the surroundings of the farm system. Within these farm systems, family components are recognised and these are important in all aspects that depend upon labour use, motivation, preferences, problems etc. (Borel, 1985).

Farmers make decisions based on more complex criteria than a simple cost - benefit analysis. The potential of agricultural methods can be constrained by factors such as infrastructure, available resource including labour, land and capital, the availability of information, policy factors, markets (price of products) and credits available. Risk is also a great deterrent to farmer adoption of agroforestry systems. Indeed the perceived risk will be greater to a farmer with new scientific techniques than with traditional techniques (Pimentel and Wightman, 1999).

According to Borel and Romero (1991) farmer's decision for change are normally based on observations of:

a) significant, practical differences from the actual situation (meaning that the effects of the proposed change depart rather radically from the existing level)
b) differences that remain fairly constant in time and over various locations.

However, a key factor in the adoption of new farm technologies is often the effect of the new technology on farming risks. The results of a study by Borel and Romero (1991) showed that despite the fact that the financial analysis of an improved live fences system was highly positive and the system was well received by the farmers, when farmers were asked about their preferences, this system was still outranked by another alternative: enrichment of secondary forest. This preferred alternative showed lower financial returns but required a much lower initial investment and was practically insensitive to price changes, i.e. less risky.

Farming system research (FSR) views on-farm trials as an essential means of technology transfer. Without farm participation, research advances may remain unutilised, while the absence of outside technical inputs and ideas reduces the possibility of overcoming the farmer's own limitations (Etesse, 1988).

Results of surveys conducted by Scherr (1995a) indicated that adoption of agroforestry is most likely when clear incentives for new land use practices come about. In addition to benefits from sustainability and improved yield, incentives provided by governments and the private sector will also be crucial in the adoption of agroforestry systems. The pressures of economy and immediate needs push farmers toward less sustainable practices with greater short-term gains. This needs to be countered with incentives that help meet needs in the short term and encourages the implementation of more beneficial and sustainable practices in the long run.

Incentives paid to livestock farmers for C-sequestration in improved pasture/silvopastoral and other systems can contribute to greater adoption of technologies to increase animal productivity, farm incomes, and more sustainable land use.

2.8 Potential of Silvopastoral Systems for Carbon Sequestration

Silvopastoral systems are considered potential carbon sinks, which might help to mitigate the effects of increasing global C emissions. Studies by CATIE and CIAT have shown that improved pasture and silvopastoral systems are capable of sequestering significant amounts of carbon in the soil and wood material (Ibrahim and Schlonvoigt, 1999) that are comparable with forest ecosystems (Veldkamp, 1993). According to Ibrahim (1994), improved legume based pastures can accumulate more than 50 tons organic carbon in the soil (15cm) which is similar to the amount measured in a topical humid forest in Costa Rica.

C is stored as organic matter in the soil and represents an important reserve of C in the biosphere (Post *et al*, 1982). Studies conducted in Costa Rica and in Panama showed that large amounts of carbon is sequestered in the soil and in the biomass of trees in silvopastoral systems. The results of a case study on carbon sequestration in the soil under a silvopastoral system with pastures of (*Panicum maximum Jacq)* and laurel (*Cordia alliodora* R&P, Oken) under natural regeneration in the Atlantic zone of Costa Rica indicated that in medium fertile and well drained soils this system has the potential of accumulating carbon in the biomass of the trees without reducing the C in the soil during the first 10 years of the regeneration. Trees can store carbon for many years if the wood is utilised for construction. The study also showed that the medium low fertile soil stored 233 t C/ha in the upper 50 cm under *Panicum maximum Jacq pasture.* In a slightly less fertile soil under a mixture of *P. maximum* and *Cordia. alliodora*, which was less than 10 years old, 180- 200-t C ha^{-1} was stored. Association with *C. alliodora* had no significant effect on C storage in soil. The preliminary results of this particular study indicate that the soil under silvopastoral regimes may not gain more C, but their net contribution to C sequestration could be in the production of timber (Musalem 1998). Further studies are being conducted at CATIE to quantify carbon sinks in silvopastoral systems.

Studies with improved grasses in the humid tropics of Costa Rica showed that they can be important for carbon sequestration under favourable management. Most of these grasses have the C_4 Krantz pathway and under favourable climatic (i.e. temperature and rainfall) and soil conditions they are capable of producing up to 30 tons DM ha^{-1} yr^{-1} (Ibrahim 1994), unlike unimproved grasses that yield 10 to 12 tons DM ha^{-1} yr^{-1} (Veldkamp 1993).

Research findings by CATIE support the notion that Carbon sequestration is greater with improved pastures and silvopastoral systems and provide supportive evidence of potential economic gains to producers through improved silvopastoral systems. It is shown that if markets for Carbon sequestration services develop, producers of cattle under grazing could derive complementary incomes. There are signals that national Governments and international institutions are interested in developing incentive programs for C-sequestration from land use forms such as pasture/silvopastoral systems because of the potential of these systems to mitigate environmental degradation (Ibrahim and Schlonvoigt, 1999).

III. METHODOLOGY

3.1 Description of the Study Area

3.1.1 Location - Geography and Climate

The present investigation was carried out in Belize. Belize is situated along the eastern coast of Central America bounded on the north and northwest by Mexico and on the southwest by Guatemala (Fig. 2). The geographic co-ordinates are 88° to 89° longitude west of the Greenwich line and 16° to 18° latitude north of the equator. The second smallest country, next to Salvador, with the lowest population density in Central America, Belize has a total surface area of 22,963 km^2. (Hilty, 1982) and the current population estimated at 235,000 (1999 est.). Belize has as subtropical climate with temperatures ranging from 16^0C to 38^0C but remaining fairly constant with a mean annual temperature of 25^0C. Annual rainfall varies from 1,500 mm in the north to 4,500 mm in the south. A very dry season extends from February to May, followed by a rainy season which peaks in July (DOE, 1991).

This study was conducted in the western most district of Belize, the Cayo district. The Cayo district is the largest of the six administrative districts of Belize. The topography is hilly with the land systems consisting of high to medium karsts, rolling and/or undulating plains, valley bottoms, flat plains and alluvial wash (Birchall and Jenkins 1979; Arya and Pulver 1993). The Cayo district includes the Mountain Pine Ridge ranging from 305 to 914 meters above sea level. Soils of steep slopes are superficial (< 30 cm) dark and calcareous clays. Deeper soils, are found in pockets on lower slopes but represent only a small percentage of the total land area used for agriculture production (<10%) (Ibrahim *et al*, 1998a).

The climate in the Cayo district is characterized by a mean annual rainfall of 1632mm and a temperature range of 17.9°C to 34.7°C with a mean minimum and maximum temperatures of 20°C and 31°C respectively. This data corresponds to 34 years of information collected at the Central Farm research facility in Cayo (Fig.3). The driest months occur between February and May with an average of 48 mm per month.

Figure 1. Political Map of Belize showing the six administrative districts and its location in Central America and the world.

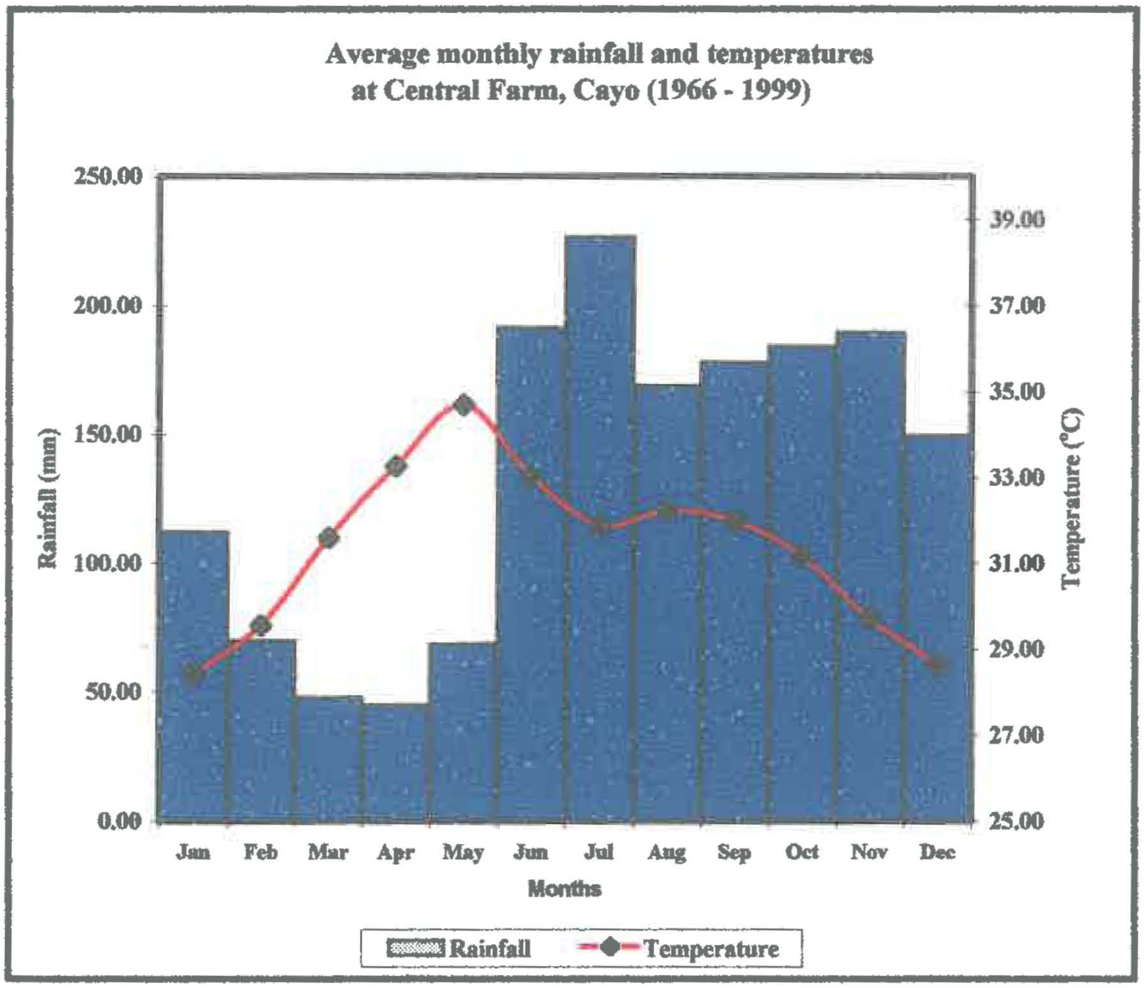

Figure 2. Climatic characteristics of the Cayo district, Central Farm, Cayo (1966 - 1999)

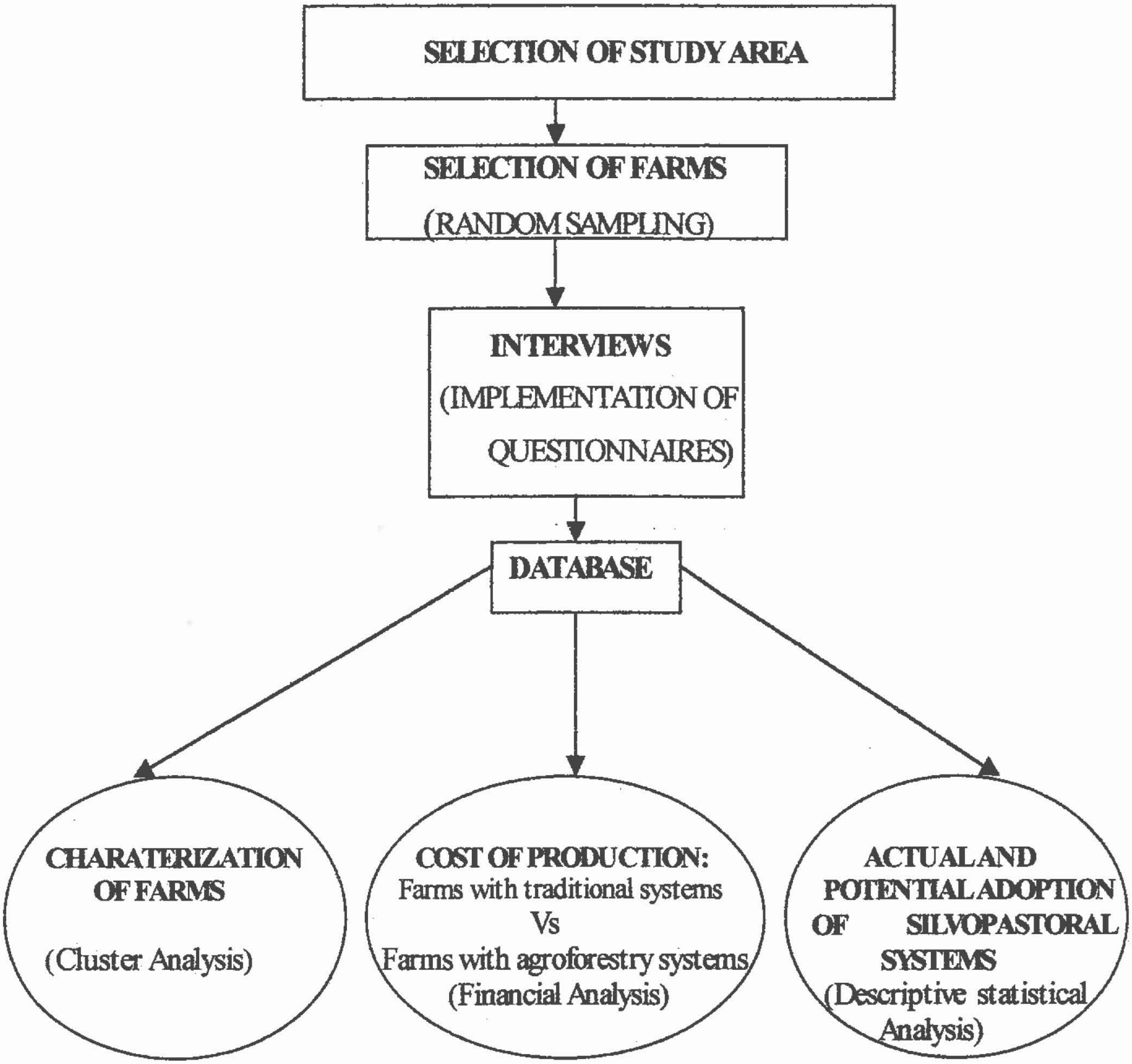

Figure 3. Diagram of General Methodology

3.1.2 Selection of Study Area

The Cayo district was selected to promote silvopastoral prototypes based on the following criteria:

a) Livestock production represents a major land use activity and a source of income for farmers in this district. The total area under pastures in Cayo is estimated to be 46,859 acres and the total cattle population is this district is 20,267 heads representing 42% of the total cattle population in Belize (BLPA, 1996). The only two milk-processing plants in the country are located in this district.

b) However, although, livestock production is a major land use activity in the Cayo district, milk and beef productions are low. The reason for low productivity is mainly because of the use of low levels of technology and inefficient management. Traditional cattle production systems are based on unproductive natural or native pastures that are of low productivity and quality. This, combined with inefficient management of livestock farms pasture composition and quality have experienced negative changes in this district causing farmers to resort to the forest and woodlands in search of forage for their ruminants.

c) The first agroforestry program was established in the Cayo district in 1996 in an effort to address the problem mentioned above. Eight farms were selected where fodder banks and multistrata systems were established. These farms were used to compare with farms with traditional production systems in the area.

Forty farms, in 12 villages in the Cayo district were visited and both beef and dairy farmers were interviewed (Fig. 4) to gather the necessary information to carry out this investigation.

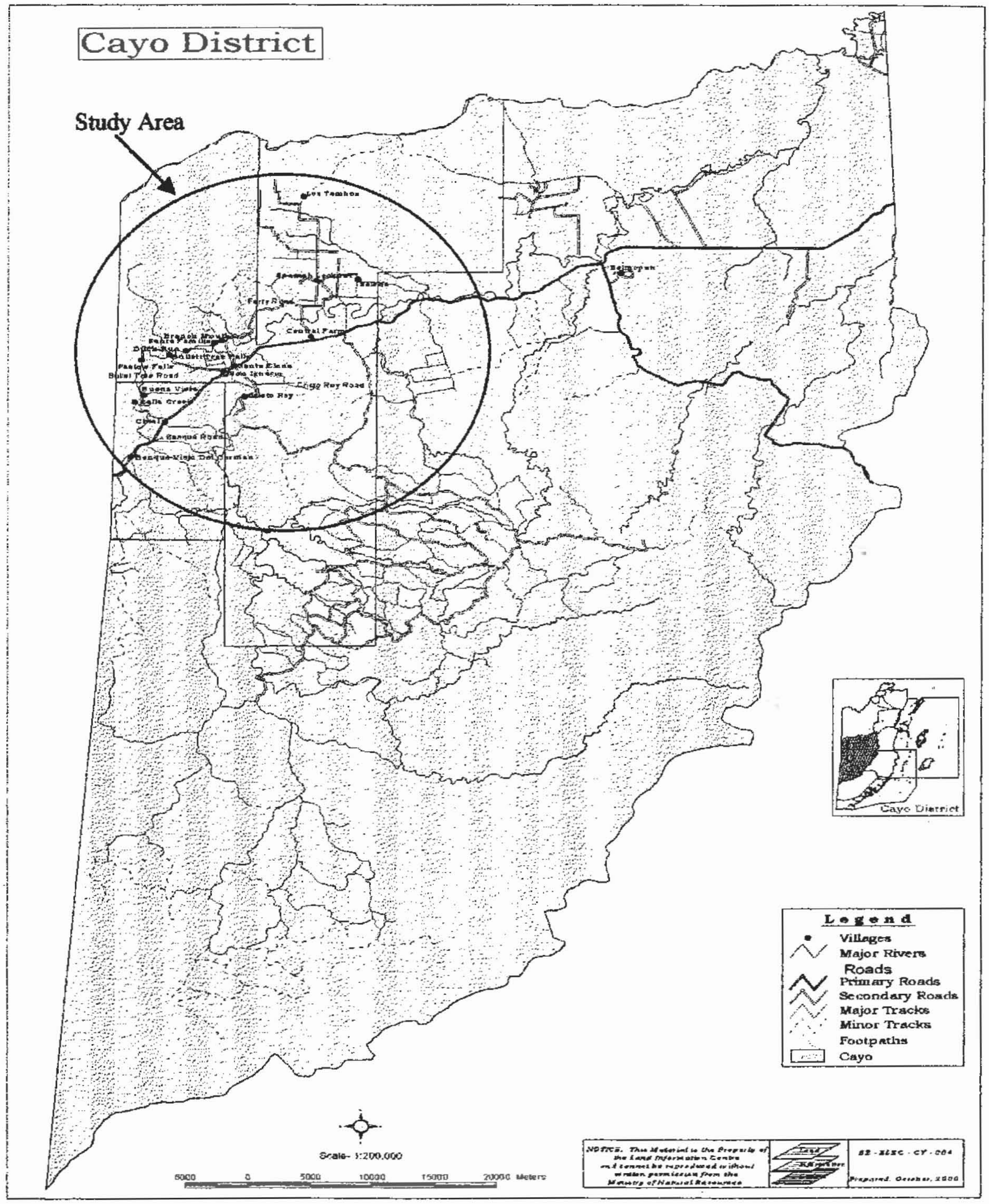

Figure 4. Map of the Cayo district showing the location of the villages where the survey was carried out

3.2 Selection of Farms

3.2.1 Design of Questionnaire

During the month of December 1999 a questionnaire was elaborated to collect the information required for the study. This questionnaire consisted of 3 main parts: the first part focused on collecting biophysical and socio-economic data on the farms, the second part dealt with collecting information on the importance of trees on the farms and the third part consisted of questions geared at evaluating the actual and potential adoption of silvopastoral systems on the farms visited (annex 1a, 1b).

The variables selected for the elaboration of the questionnaire included:

(1) Biophysical and Socio-economic Data:

(a) Technical aspects

- Management of pastures:

  Common species of grass used for pastures, total land area available for pasture, rotational grazing, number of divisions, use of fertilizers and herbicides on pastures.

- Management of the herd:

  Animal inventory, animal health - vaccinations, de-worming, control of external parasites, use of food supplements such as ground corn, molasses, dairy concentrate, vitamins and mineral salts

(b) Economic Aspects

Amount spent on: animal health, supplements, labour, transportation and other inputs related to dairy and beef production as well as income gained.

(c) Productive Aspects

Amount of milk produced per cow per milking, amount of milk produced per day, amount of milk produced by best and worst cow in both the dry and rainy season.

(d) Reproductive aspects:

Number of claves born in the last year, calving period and lactation period.

(e) Socio-economic aspects:

Age of farmer, education of farmer, family situation, monthly income obtained from livestock production, use of family and/or hired labour.

(2) Importance of Trees on farm:

- Reasons for keeping trees on farm
- Use of trees for forage for cattle
- Identification of trees for forage used by farmers and preferred by animals
- Predominance of *Gliricidia sepium* trees on farms
- Use of *Gliricidia sepium* trees on farms

(3) Adoption aspects:

- Land tenure
- Years in livestock production
- Knowledge and experience with silvopastoral systems
- Preferences of systems
- Use of credit
- Limitations and potentials for the implementation of silvopastoral systems on their farms
- Limitations and potentials for improving livestock production
- Incentives desired for the improvement of livestock production

3.2.2 Implementation of Questionnaires

A total of 40 farms, distributed in 12 villages in the Cayo district, were visited during the months of February, March, April and May, 2000. These months represent the driest and hottest months of the year, that is, the dry season. The recollection of the necessary information for the study was based primarily on the implementation of the questionnaire developed. The farms were visited and personal interviews were conducted with the farmers.

All the local[1] dairy farmers within the Cayo district were interviewed. The list of farmers was obtained from MACAL, the milk processing plant where the local farmers deliver their milk. A total of 28 dairy farms were visited. Seven of these farms represent the group of farms with improved systems - silvopastoral systems, while the remaining 21 farms are farms with traditional production systems.

[1] Local dairy farmers do not include the Mennonite dairy farmers in this document.

The selection of the beef farmers were done randomly. The list of beef farmers in the Cayo district was obtained from the Belize Livestock Producing Association (BLPA). Since, the main objectives of this investigation were geared towards dairy farmers, priority in the order of interviews was given to the dairy farmers and therefore only a small number of beef farmers were visited which was limited by time and budget. Twelve beef farmers were interviewed. The main reason for visiting beef farms was to learn their limitations and potentials in beef production and compare them with the dairy farms where possible.

Hence, a total of 40 farms were visited. A technical assistant from Central Farm who is familiar with the area and works with the farmers in this area accompanied each visit to provide confidence to the farmers during the interviews. Each interview lasted on average two hours.

3.2.3 Data Base

The information gathered from the questionnaires was stored in a data-base created in Excel, an electronic worksheet that facilitates the transfer of the information into the statistical package, Statistical Analysis System (SAS) used for both the descriptive statistical analysis and the cluster analysis. The information was stored according to the number of the questionnaire. A list of codes was developed to correspond with all the variables in the questionnaire allowing an easier transfer of the information into the database. This also facilitated the output of the results from the statistical analysis carried out as well as an easier interpretation of these results.

3.2.4 Descriptive Statistics Analysis

The data was processed and analysed using SAS. The descriptive statistical analysis was conducted for the farms interviewed.

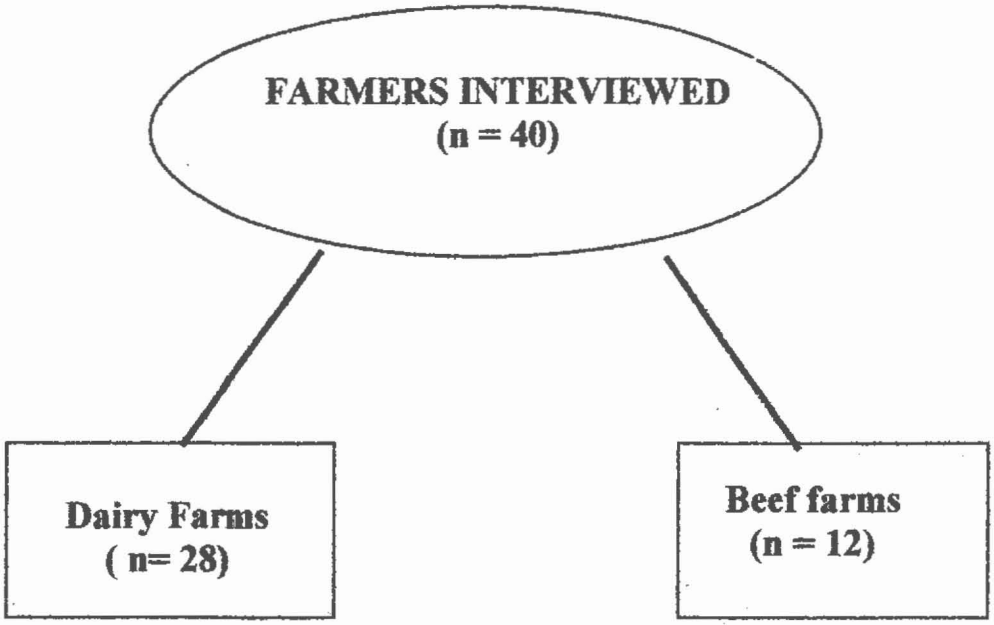

Figure 5. Breakdown of farms interviewed

The purpose of the descriptive statistical analysis was to obtain a general overview of the characteristics of each group of data. For each of the three groups the mean, standard deviation and variability coefficient were calculated from the analysis for the quantitative variables selected and the frequencies and percentages were calculated for the qualitative variables selected.

3.3 Farm Characterisation

3.3.1 Cluster Analysis

There existed much variability in the biophysical characteristics of the dairy farms. For example, milk production fluctuates between 5lbs to 18lbs per cow per milking and total area in pastures range from 12 acres to 500 acres. Other variables such as the total number of animals, the amount of money spent on supplements per year, and the amount spent on labour differ greatly from farm to farm. The cluster analysis was carried out with the purpose of determining the types of dairy farms in the study area regardless of the type of production system applied on the farms. A cluster analysis groups the farms based on their similarities of multiple variables. The more similar the farms are within each group, the more different the groups are with each other.

3.3.2 Selection of Principal Variables

A correlation analysis was carried out on all the variables from the original data. From the correlation matrix created the variables that were highly correlated with each other and did not contribute significantly in the characterization of the farms were eliminated. Other variables that did not show a great degree of correlation but were not considered important in classification for the farms were also eliminated. Based on the results of the correlation analysis a set of 10 variables was selected for the cluster analysis. The variables related to the productivity of the farm were favoured. These variables include total area of pasture (TPASTAR), total number of animals (TNOAN), number of milking cows (MCOWS), milk produced per cow per milking (MKPCW), total milk produced per year on the farm (TMKPYR), amount spent on animal health per year (AHTOTCT), amount spent on supplements per year (SUPTOTCT), amount spent on labour for the different activities related to milk production (CTACTIV), total production costs (TCOST) and total benefits obtained (TBEN). These variables were able to discriminate the levels of production on the farms.

A principal components analysis was also applied to the 10 variables selected to reduce this set of variables into a smaller number of principal components (artificial variables) that account for most of the variance in these variables. This factor was incorporated into the cluster analysis to identify the homogenous farms based on the level of production defined by the variables mentioned above. To select the appropriate number of clusters the values of pseudo 't' and pseudo 'f' were considered.

3.4 Financial Analysis

Partial Budgeting was used to carry out the financial analysis of the two systems: the traditional production system and the improved system. Partial budgeting was favoured since it can be used to compare different production systems in terms of inputs needed and net benefits gained. The costs and net benefits of measures applied to an improved system and hence, the extra profits due to the improvement measure were calculated. The advantage of using partial budgeting is that it is focused on one aspect of the farm and does not provide data on costs and benefits of the farming system as a whole. Although, livestock production was the main activity reported by the farmers surveyed, there were some farmers with orange orchards on same farm area, others reared pigs and chickens for commercial purposes while a few had small vegetables plots. Partial budgeting calculated the costs and benefits of the improvement measure - silvopastoral systems in terms of additional money spent and gained the cattle aspect of the farm. Data on inputs, outputs, maintenance measures for both the traditional livestock production systems and improved livestock production systems were collected. Another advantage of the partial budgeting method is that only data on costs and benefits of measures that differ from the traditional systems were needed to compare the two systems. Financial indicators such as the B/C and the NPV were also calculated to determine the more financial attractive option. These indicators were calculated with data gather for the preceding year only. They were calculated for a one-year period as well as for a 40-year period, the time period estimated, at which the timber trees in the multistrata systems would be ready for harvesting. In determining the financial indicators for the 40-year period, constant costs and benefits were used and the indicators calculated using a real discount rate of 6% which was calculated from the nominal rate obtained from the banks in Belize and the inflate rate over a five year period.

3.4.1 Costs

For both systems the cost were divided into six main groups:

1.) Animal Health: vaccinations, deworming and treatment for external parasites.
2.) Supplements: dairy concentrates, ground corn, molasses, salt, and vitamins.
3.) Pasture Management: fertilizers and herbicides used.
4.) Labour: weeding and cleaning of pastures, application of chemicals on pastures, milking, feeding the rest of the herd, applying medications to animal and fence repairs.
5.) Transportation: the cost of transporting the milk from the farm to the milk plant as well as other transportation expenses incurred in the acquisition of inputs need for the farm animals.
6.) Animals Bought: cost of purchasing replacement animals.

Additional costs involved in the silvopastoral systems include:

7.) Establishment costs: Costs involved in the establishment of the protein banks and multistrata systems.
8.) Management costs: pruning of legumes, weed control and application of fertilizer
9.) Harvesting costs: Costs involved in the cut and carry feeding system for the protein banks.

3.4.2 Benefits

Benefits for the traditional production systems can be divided into two categories: direct and indirect benefits.

1) Direct benefits: milk and cheese sold, and the sale of animals from the herd.
2) Indirect benefits: milk consumed by the family on the farm.

Benefits for the farms with silvopastoral systems can be divided into three categories. direct benefits, indirect benefits and potential benefits.

The direct benefits are similar to that of the farms with traditional production systems However, one additional indirect benefit is that of nitrogen incorporated into the soil by the legumes in the silvopastoral systems. The potential benefits include the payment for the sequestration of carbon from the timber trees in multistrata systems.

3.4.3 Estimation of the Volume of Timber

Since no data exits on growth rates for Mahogany and Cedar trees in the Cayo district, the volume of timber that could be obtained from these species in the multistrata systems was estimated using secondary data on growth rates of Mahogany trees obtained from the data base MIRA (annex 2). In the data base MIRA, a site with similar climatic conditions (precipitation and temperatures), altitude (meters above sea level) and life zone to that of the Cayo district was identified.

The total volume of dry matter of the trees was estimated using the methodology as described by Ramirez and Gomez (1999). A conversion factor of 0.6, which is estimated to account for the dry matter in the wood only, was applied in the calculations. To calculate the value of the timber, prices from sawmills in Belize were obtained. The price paid per feet Doyle[2] was $1.53.

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[2] Doyle is a unit of measurement commonly used for the cubing logwood, $1m^3$ is equivalent to 220 board feet.

3.4.4 Estimation of Carbon Sequestered

The estimation of the amount of potential carbon sequester by the timber tees was carried out using the methodology as described by Ramirez and Gomez (1999). Once the average carbon that can be stored by these trees was estimated, the potential value was calculated using the value estimated by Cline (1992) to be the costs per ton in tropical areas. A value of $5/ton was used although, there exits a great range of prices (US$5 – US$31 per metric ton of carbon) paid in both tropical and template countries (Ramirez and Gomez, 1999).

3.4.5 Estimation of the Value of Soil Nitrogen

Soil samples were taken from plots of both the protein banks and multistrata systems as well as from pastures with natural grasses. These samples were taken to the soil laboratory at CATIE and were analysed to obtain the quantity of nitrogen contributed by the silvopastoral systems. The value of this nitrogen was calculated using the cost of Urea and its combination.

3.4.6 Prices

Data on all input costs were collected from local stores in the area where farmers buy their materials. Labour costs are based on the hourly wage in this area, which is at $2.50. The prices are considered representative for the region at the time of the study. Since inflation and exchange rate depreciation in Belize are relatively low, all prices have been maintained in Belizean Dollars (exchange rate: 1 US$ = 2 BZ$).

3.5 Adoption Analysis

As mentioned previously, the questionnaire that was used to interview the farmers consisted of a section on the adoption and potential adoption of silvopastoral systems. Some of the questions in the other two sections was also used in assessing the adoption and potential adoption of these improved systems. Descriptive statistics was used on the variables collected from the survey. For this analysis the farmers were divided into two groups. The first group consisted of the farmers who implemented the silvopastoral systems on their farms through the GOB and CATIE agroforestry project and second group consists of the other farmers in the area.

Group 1

The principal objective of the interviews with the farmers who have established silvopastoral systems - fodder banks and multistrata systems - on their farms was to learn their motivations for implementing this technology on their farms, their experiences with this technology both positive and negative, what are the potentials and limitations of these systems, how this technology has affected their production compared to their situation before it was implemented, what are their constraints in improving their systems and lastly to identify and evaluate the efficiency of the transfer of technology and what incentives they would like to see from the government, specifically the Ministry of Agriculture and Fisheries in Belize.

Group 2

The principal objective of the interviews with farmers who do not have silvopastoral systems on their farms was to learn their level of knowledge of these systems, their general opinions of these systems, what are their limiting factors for not being able to adopt this technology and their ideas as to how this technology can be transferred to them so as to make the adoption process easier and successful.

IV. RESULTS AND DISCUSSION

4.1 Descriptive Analysis

4.1.1 Land Use

The distribution of the land on the farm can be classified into four main groups: pasture, primary forest (reserve), secondary forest (fallow) and crops. Fifty percent of the farmers use the fallows to graze their cattle especially in the dry season while the reserve areas are kept as a logwood bank that farmers resort to when they need wood for post for fences as well as for conservation purposes. The fallows are characterized with a diversity of species many of which are known to produce forage of a high quality in the dry season (Cassasola, 2000). Sixty percent of the farmers have crops, the most common being beans and corn which the farmers sell as well as use for home consumption while other farmers have between 0.5 to 4 acres of other crops such as plantains, vegetables and fruit trees mostly used for home consumption (figure 6). In Central America degraded pasture lands are generally left in secondary growth for a period of five years which are subsequently burnt for growing crops for a period of 3 to 5 years and thereafter pasture is established (Kaimowitz, 1996).

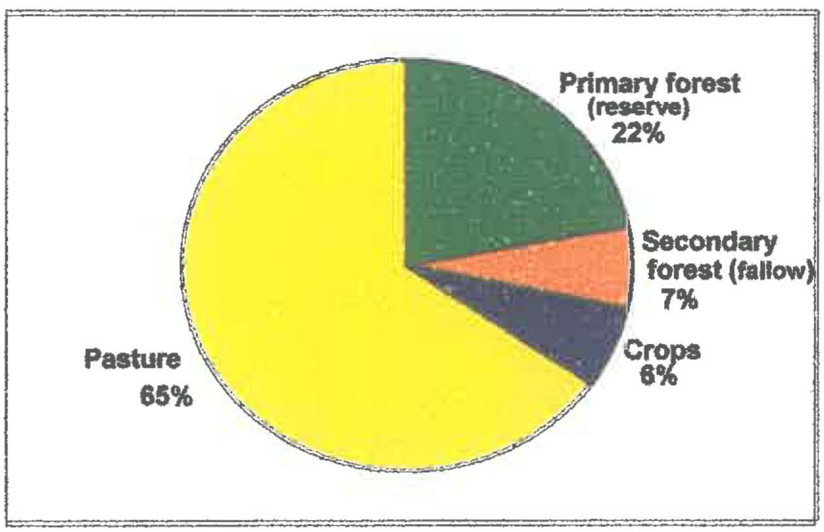

Figure 6. Land use on cattle farms surveyed in Cayo, Belize, 2000.

On average 65% of the total farm area (mean=115.38 acres) is dedicated to pastures. A regression analysis showed that there was a good relationship between pasture area (Y) and farm size (X) ($Y=1.63+0.64X$; $R^2= 0.78$) such that pasture area increased as farm size increased (figure 7).

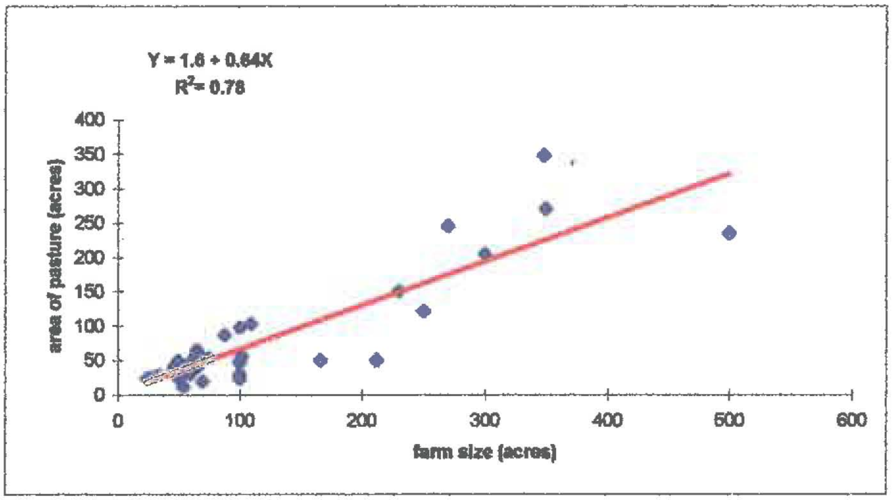

Figure 7. Pasture area in relation to farm size in Cayo, Belize, 2000.

Similar results were found for farm size and primary forest (reserve) (Y=-4.36+0.30.2X; R^2 = 0.71) such that area of reserve increased as farm size increased as well as for farm size and secondary forest and fallow area (Y= =-6.6+2.2X; R^2 = 0.76) (figure 8).

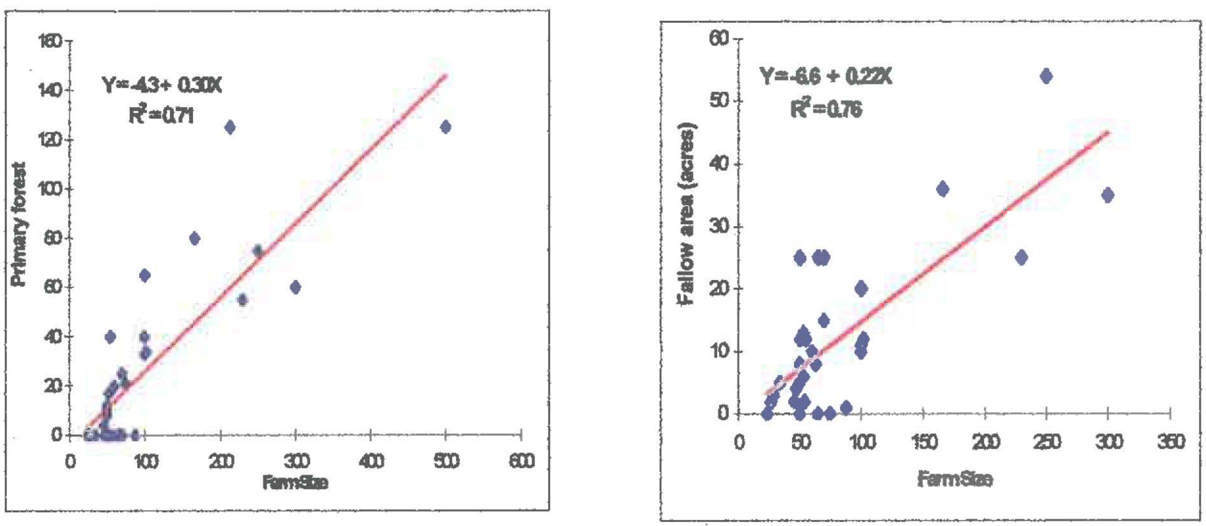

Figure 8. Primary forest area and fallow area in relation to farm size.

4.1.2 Land Tenure

There are four categories of land ownership in Belize: private lands, leased public lands, national lands and lands under forest reserve. This study showed that 50% of the farmers lease their land from the government of Belize (GOB) while 42.5% are private land owners. Another group of farmers (7.5%) own part of their land and are leasing another part (figure 9). More than 50% of the farmers do not have titles to all their land. This may affect the adoption of silvopastoral practises since farmers with lease are less prone to want to make capital investment in planting trees. Without a land title it is also difficult for the farmers to negotiate credits. A few farmers reported that they have made several applications to the Lands Department and up to present date these applications have not been approved for land titles. Other farmers reported that their land is not surveyed. A few years back, the lands department had government land surveyors, responsible for surveying all lands however, due to budget constraints, the land surveyors paid by the government were fazed out. This service is no longer provided by the GOB and every person that wants his land surveyed has to contract a private land surveyor. This is very costly and most farmers do not have the financial resources to do so.

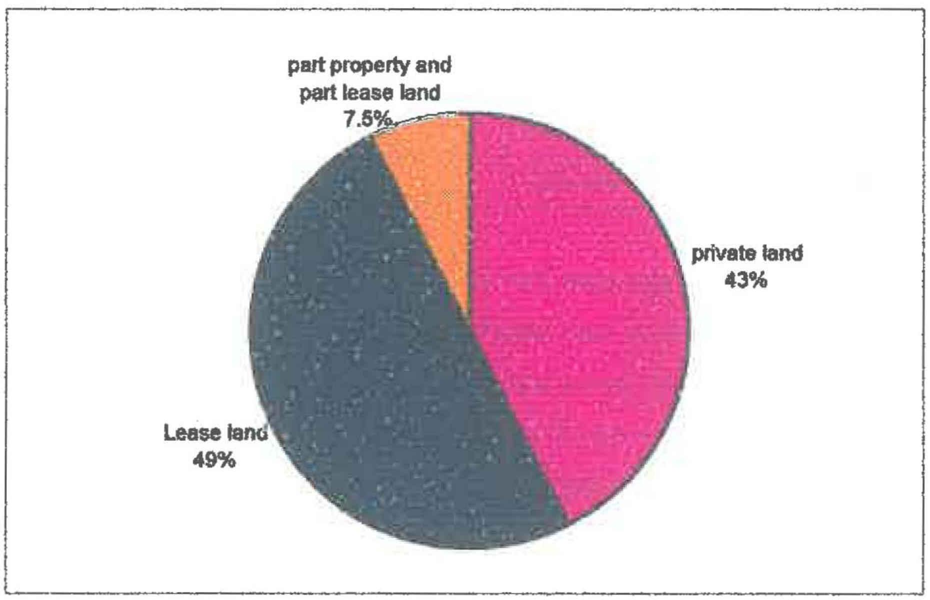

Figure 9. Land tenure of the farmers surveyed (n=40) in Cayo, Belize, 2000.

4.1.3 Pastures

Traditional cattle production systems in Belize are based on unproductive natural or native pastures (*Paspalum notatum, P.virgatium and Cynodom dactylon*) that are of low productivity and quality. (Ibrahim *et al.*, 1998a). Never the less, 90% of the farmers in this study reported that they are aware of the value of improved grasses for the improvement of both dairy and beef productions. This awareness, is in part, a reflection of the several pasture improvement programs instituted by the Ministry of Agriculture, Fisheries and Co-operatives (MAFC) over the last two and a half decades. Other farmers indicated that they learnt about the benefits of improved grasses through their own initiative experimenting with different grass species in an effort to find a grass specie of higher quality for their animals. Most of the farms visited (78%) had at least one specie of improved grass planted while a few farms had two or three species mixed on the same plot. The six most common species of improved grasses found on the farms surveyed is shown in table 1.

Table 1. The most common species of improved grasses found on farms surveyed

No.	Common Name	Scientific Name
1	Blue Stem	*Hyporrhemia hirta*
2	Pangola	*Digitaria decumbens*
3	African Star grass	*Cynodon nlemfuensis*
4	Guinea	*Pancium maximum*
5	Elephant grass	*Pennisetum purpureum*
6	Jaragua	*Hyporrhenia rufa*

These species have been favoured over others based on two main reasons: (1) they are persistent under drought conditions; and (2) they are very palatable and productive. Recently, through CATIE's collaboration new grass species (e.g. *Brachiaria spp.*) were introduced in Belize (Ibrahim, pers. comm.). Although many of these species can withstand the dry season, improper management over the years resulted in lost of these grasses. One of the problems reported was the slow recovery rate of these species, requiring a longer resting period. Most farmers (52.5%)practice some form of rotational grazing. However, divisions on the farms vary during the year. During the wet season, pastures are divided into several paddocks and a more controlled rotational grazing is practiced but during the dry season when grass shortages are experienced most farmers open up their divisions, allowing the animals free access to the pastures. This practice had led to the overgrazing of most pastures leading to degradation of pastures. Some farmers planted other species in an effort to find the most adaptable and aggressive species that can withstand the severe dry months in Belize. Eventually, most farmers allowed the natural grasses take over since after a while it was no longer economically feasible for them to change their pastures every year or two and it is not profitable to apply fertilizers to pastures. Hence, 80% of the farms had more than 50% natural pastures. The ratio of improved pastures to natural pastures, of the cumulative pasture area for all the farms surveyed, was 1:2.4. The mean farm size for the farmers with silvopastoral systems is 90.5 acres and the mean pasture size is 52.4 acres with 41.5 and 10.9 acres of natural and improved pastures respectively. Dairy farms with traditional dairy production systems have an average farm size of 129.6 acres and almost twice as much land dedicated to pasture (94.6 acres) as the farms with silvopastoral systems with an average of 63.2 and 31.4 acres of natural and improved pastures respectively. Traditional beef farmers have a mean farm size and mean pasture size of 105 and 54.8acres respectively with 43.3 acres of natural pasture and 11.4 acres of improved pastures. In general dairy farms were characterized with a greater percentage of improved pastures because dairy animals have greater nutritional demands than beef farms (NRC, 1989) (fig 10).

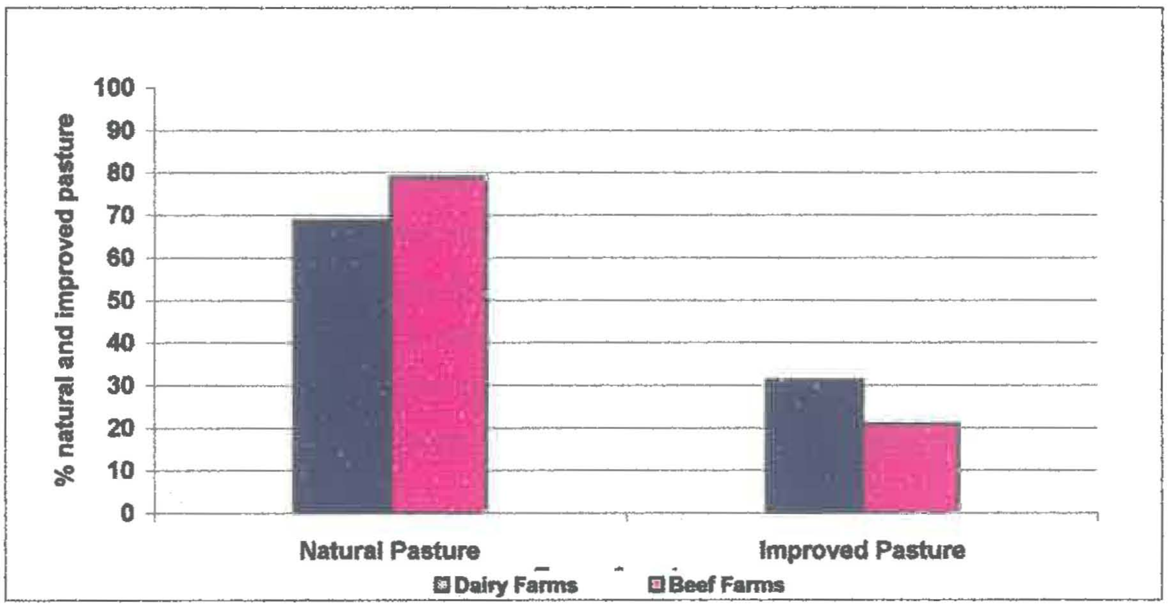

Figure 10. Percentage of Natural and Improved pastures on dairy farms (n=28 and beef farms (n=12) surveyed in Cayo, Belize, 2000.

The farms chosen to participate in the agroforestry project aimed at improving livestock production in Cayo through the implementation of fodder bank and multistrata systems were randomly chosen from within the local dairy producers of that area. They represent 25% of the local dairy farmers and 17.5% of all the farmers surveyed in this study. These farmers have since established small areas of fodder banks and multistrata systems. The survey conducted identified four farms with multistrata systems and three farms with fodder bank technologies. The area for these systems range from 0.25 acres to 4 acres (table 2).

Table 2. Breakdown of farms with silvopastoral systems (SPSs)

Farm No	System on farm	Species planted	Area (acres)	Farmers response
11	Multistrata fodder bank	Leucaena + brizantha grass + timber trees Mulberry	1.5 0.25	good
4	Multistrata Other	Leucaena + ramon + timber trees Leucaena+brizantha	1 4	good
7	Multistrata fodder bank	Leucaena + brizantha grass + timber trees Leucaena	4 1	excellent
6	Multistrata Other	Leucaena +African star grass+timber trees Leucaena + brizantha	1 1	excellent
36	Fodder bank	Leucaena	0.5	Fair
3	Fodder bank	Leucaena	0.5	Fair
8	Fodder bank	Leucaena	0.5	Poor

The use of fertilization and chemical herbicides is low. Of all the farms surveyed (n=40) only 20% of the farmers fertilize their pasture (improved pastures only) and use herbicides. The farmers view these activities as important, however, the main limiting factor for not carrying out these activities is capital, only the farmers with more financial resources, usually the bigger farmers, were able to fertilize their pastures at least once a year giving them the advantage of better quality pastures than the other farmers especially during the dry season. For this reason, agroforestry technologies that are being promoted will have to consider the socio-economic farm conditions (Samayoa 1995).

4.1.4 Dairy Production

Table 3. Milk production parameters for silvopastoral and traditional dairy production systems in Cayo, Belize, 2000.

Parameters	SPS (n=7)	TS (n=21)
No milking cows	10	8
Milk production/cow/milking (lbs.)	9.2	9.5
Milk production/day (lbs.)	111.4	86
Farmers that milk twice a day (%)	28.6	14

The table above shows the milk production parameters for the silvopastoral and traditional dairy production systems. As can be seen although the milk production per cow per milking is slightly lower for the SPSs, the daily production is 22.8% higher than the traditional systems. In part this can be explained that the SPSs have 29.6% more milking cow. However, dairy farms with TSs have 43% more land available for pasture yet spend almost as much on supplements as farm with SPSs. This indicates an inefficient production system for the TSs since they only have 5% more animals than the farms with SPSs.

The milking system practiced by these farmers was "semi Range". Most farmers separate calves from the Dam (mother) in the evenings and are penned during the night. The cows are milked in the morning leaving one teat, which is not milked for the calf. This system seems to be the most practical for these farmers since it requires minimum management, little labour and calf mortality is low. Calves are usually weaned at the age of five to seven months and in some cases longer. This affects the total amount of milk the farmers can sell.

Milk consumption by the family on the farms was rather low. Only 30% of the farmers reserve a meagre 3.8% of the total milk production for home consumption.

4.1.5 Animal Health

Belizean cattle are relatively disease free. Mortality is 6% for calves and 2 - 3% for cows (UVM, MAF, IICA, 1998). The most commonly mentioned health problems gathered from the surveys include Black Leg (Clostridial) rabies and internal and external parasites. The veterinary care practiced by the farmers interviewed consists of vaccinations against Black leg, deworming and chemical treatments to control external parasites. Most farmers (60%) vaccinate against Black Leg as they are aware that this is a very deadly disease contracted mainly by young cattle six to 24 months of age. A little over 50% of the farmers surveyed deworm their animals (57.5%). Many of them only deworm their animals once a year and on the basis of body condition, very few farmers deworm twice a year. External parasites, such as ticks and flies are controlled by spraying the cattle on a regular basis. In some cases the animals are sprayed between twice a week, in the dry season to twice a year. Farmers reported that external parasites were more of a problem in the dry season. A great percentage of the farmers (87.5%) practice external parasite control. The percentages of farmers that practice Black Leg vaccination, deworming and tick control in each group is similar to the overall results (fig. 11).

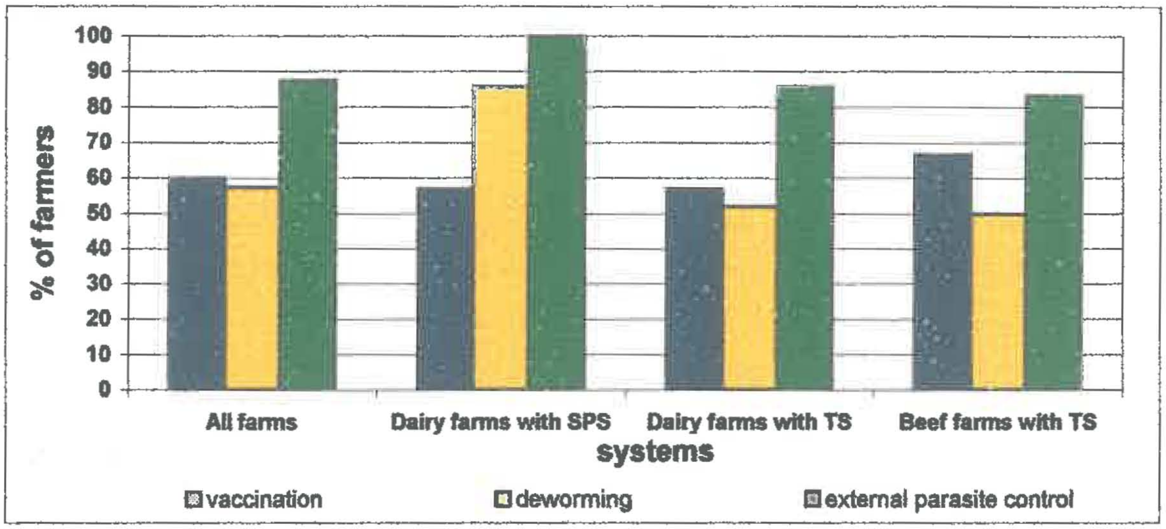

Figure 11. Percentage of farmers that practice the three most common veterinary treatments.

According to Matthewman and Perry (1985), when the proportion of calves is over 20% this suggests that there is a high calving rate (70 -80%), low calf mortality and an age of first calving of three years. Farms with silvopastoral systems had 22.8% of the herd are calves while the traditional dairy systems had 19% and traditional beef production systems had 20.1% of the herd are calves . This suggest that farms with agroforestry technologies have better calving rates as well as shorter calving intervals than farms with traditional production systems. This corresponds to the calving intervals obtained from the surveys: 14 months - farms with silvopastoral systems, 16 months - dairy farms with traditional systems. Although the proportion of calves was better for the farms with traditional dairy systems compared to traditional beef systems the calving interval for traditional beef systems was longer by one month (17 - months) compared to farms with traditional dairy systems. The lactation period for the dairy farms was 8 months for the traditional systems and 9.6 months for the silvopastoral systems.

4.1.6 Supplements

The most common supplements given to the animals include: ground corn, molasses, dairy concentrate, forage, salt and vitamins. Of all the farms surveyed, 15% of the farmers give their animals ground corn, 32.5% give their animals molasses, 45% give their animals dairy concentrate, 58.5% give their animals some type of forage especially in the dry season, 72.5% give their animals salt and 10% give their animals vitamins. The farmers who give their animals dairy concentrate usually only do so in the dry months or may increase the amount given in the dry months as this is when milk production decreases on most farms as a result of the grass shortages experienced . During this period grass are characterized by low quality and milk yields decline significantly (Ibrahim, *et al*, 2000a).

Most traditional farmers lack the financial resource to provide their animals with commercial supplements. The bigger farmers with more financial resources can afford to feed their animals supplements such as dairy concentrate, representing only 52% of the farmers and spending $2203.05 per farm year. The other 48% of the farmers depend only on the natural grasses in their pastures and fodder cut from trees (*Guazuma ulmifolia* and *Brosimum alicastrum*) from either within or outside their farms especially during the dry season (Ibrahim *et al*, 1998a). Hence, the high milk production of the few farmers is reflected in the 52% of farmers who can afford to buy commercial concentrates. Farmers in this group feed their cows up to 8 lbs. of concentrate per cow per day (fig. 12).

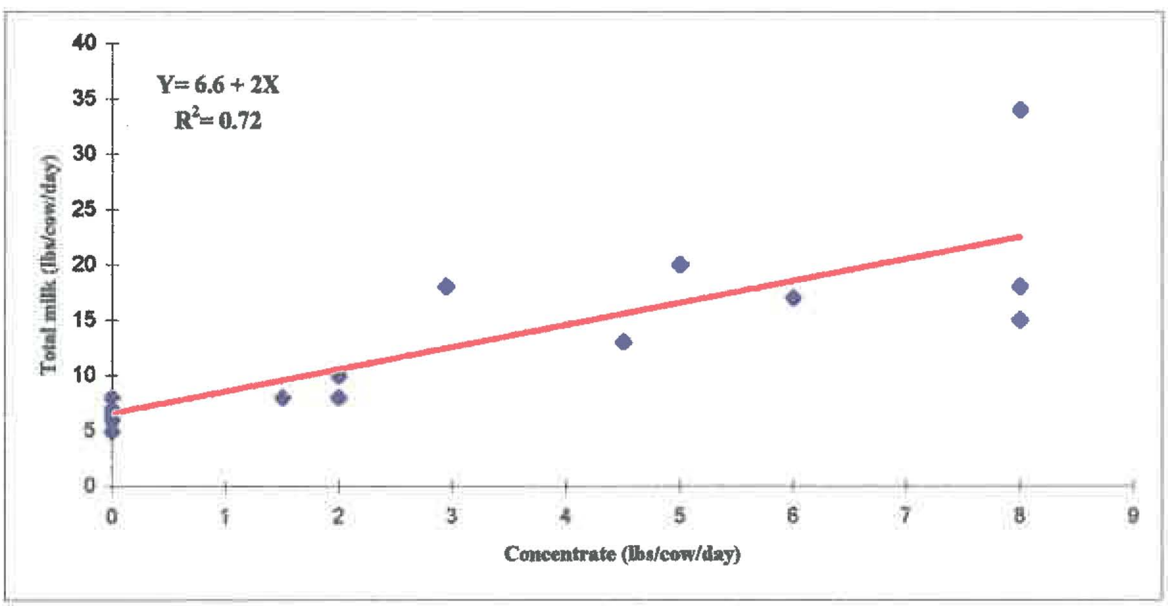

Figure 12. Relation between milk yield (lbs./cow/day) and the amount of concentrate (lbs./cow/day) fed to dairy cows.

Farmers with silvopastoral systems spend on average $2237 per year in this activity, slightly more than farms with traditional systems and this is due to the fact that the milk yields are higher.

However, this amount is divided more evenly between the farmers in this group while in the group of farmers with traditional systems this amount is spent by only a few farmers, the bigger farmers with more financial resources. Farms with silvopastoral systems do not give their cows more than 4 Ibs. of concentrate per cow per day. However, there are some farmers that produce 18lbs/cow/day (maximum) and others that produce 7lbs/cow/day. Many farmers do not upgrade the genetic stock of the animals and for this reason the response in milk production in relation to concentrate fed varies between farmers (Archibald, 1984).

Shortage of water is not a problem for most farms visited since there are two major rivers that run through the Cayo district, The Macal and the Mopan rivers. The Cayo district is also characterized by a moderate annual rainfall (1550 mm) the dry season is relatively short (four months). Farmers that do not have access to river water usually dig ponds to conserve water for the dry season. However, these ponds, tend to get very low during the dry months and in some cases dry up completely, becoming a problem for these farmers as they are required to fill the waterholes which can be very expensive for them.

4.1.7 Social Aspects on the Farms

The majority of the farmers surveyed (50%) have a primary level education, 25% do not have any formal schooling while 12.5% have secondary and tertiary level education. Farmers with silvopastoral systems, traditional dairy farmers and traditional beef farmers follow this same distribution within each group. In general most of the farmers visited (57.5%) work outside their farm in other activities such as tour guides, food vendors, security guards, taxi drivers, labourers for the Mennonites during the periods of planting and harvesting, mason, among others. The primary reason given by the farmers for not dedicating full time to their farms is that dairy production alone is not economically feasible to meet all their financial needs. Of the silvopastoral group, 85.7% work outside their farmers and of the traditional dairy farmers 54.5%. In Costa Rica, Holmann *et al* (1992) found that the small dairy farmers usually work outside of their farms to generate income. The traditional beef farmers however, only 41.7% work outside of their farms.

Family labour is important on these farms. On 97.6% of the farms at least one family member works on the farm. At $2.50 and $3.00 an hour, hired labour is considered expensive by the farmers. However, most farmers (70%) resort to hired labour at some time during the year, especially when paddocks need to be cleaned. Workers are hired temporarily from 2 weeks to 3 months during the year. Cleaning of the paddocks is mostly done manually by chopping. Few farmers own tractors. Some farmers rent machinery such as bush hogs from the Mennonites but this too is costly ($30 -$45 an hour). Besides costly, the farmers reported that they have to wait until the Mennonites are not using the machinery before it is rented out to them. Twenty nine percent of the farmers depend solely on family labour mainly because of financial limitations.

On average the farmers with silvopastoral systems dedicate 28 weeks to labour while dairy farmers with traditional production systems dedicate 18 weeks to labour and traditional beef production systems dedicate only 12 weeks to labour (fig. 13).

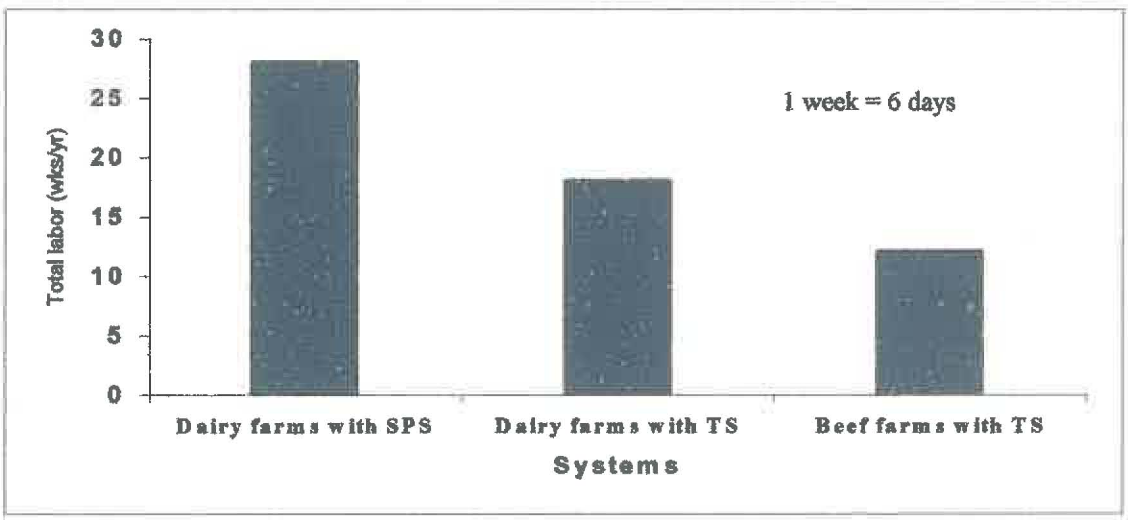

Figure 13. Total Labour used in the three different livestock production systems, in Cayo, Belize.

These data show that the promotion of silvopastoral systems can create employment for workers in the rural zones, but will depend on labour costs (Holmann and Estrada, 1997). Beef production requires less labour because of extensive management systems (Holmann and Estrada, 1997).

Income received from both milk and beef productions reflect the need for improvement in this industry in Belize. An estimated average monthly income from livestock production of all the dairy farmers surveyed was $957/farm. This includes income from both milk sold and animals sold. The silvopastoral farms shows a slightly higher estimated average monthly income ($1090) compared to that of the traditional dairy producers ($825, with a difference of 13.8%. In Central America dual purpose cattle production has been found to be more profitable than beef systems and the number of dual purpose farmers has increased (Holmann and Estrada, 1997). The income from sales of animals for the beef producers was the lowest. The estimated average monthly income was that of $385 and a yearly income of $4626. Beef farmers are not consistent in selling animals on a monthly basis. They may sell animals 4 or 5 times a year or as the need arrives. One of the problems in Belize is that beef farmers are subsistence farmers who see their animals as a security (similar to cash in the bank). They sell their cattle in emergencies. This attitude creates another problem. There is not a good market system in Place for the marketing of beef and farmers are paid low prices of their cattle.

4.1.8 Trees in Pastures

Most of the farmers appreciate the value of trees in pastures. Of the 40 farmers interviewed all responded positively to the use of trees for shade for animals in pastures. The second most common use of trees in pastures is for forage with 25 farmers (63%) indicating that they use trees on their farms as another source of food for their animals especially in the dry months when pastures are low and dry. This data coincides with that of Cassasola (2000) who showed that a high percentage of farmers managed trees for shade and for feeding animals in the dry season. Fence posts are also obtained from trees growing in pastures with 23 farmers responding positively. Trees used for timber and firewood are not as common with only 9 and 8 farms responding positively, respectively (Fig. 14). In Belize there are large reserves and the demand for timber in agricultural systems is not high. Besides government policies do not stimulate the planting of trees for timber use. In fact government policies may affect the adoption of agroforestry technologies for timber planting since farmers are required to apply for a permit and pay royalty tax according to the specie to be felled, for example, BZ$0.14 per cubic feet for species such as Cypress, BZ$0.26 per cubic feet for Mayflower (*Tabebuia pentaphylla*) and BZ$0.62 per cubic feet for *Mahogany (Swietenia macrophylla)* and Cedar *(Cedrela mexicana)* trees.

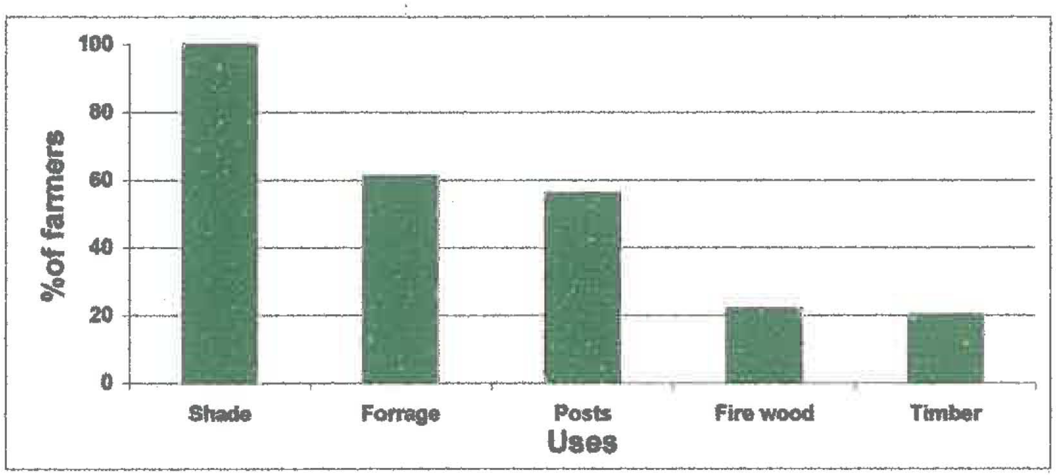

Figure 14. Percentage of farmers managing trees for different uses, Cayo Belize, 2000.

The most common trees used for fodder that are preferred not only by the farmers but also by the animals is the Ramon, sometimes referred to as Yash osh (*Brosimum alicastrum)* with 20 farmers (50%) identifying this tree as their first preference followed by the pixoy (*Guazuma ulmifolia)* with 15 farmers (37.5%) identifying this tree as their first preference (fig. 15). Both species are of high nutritive value indicating that farmer's have a good ecological knowledge of the use of trees for feeding animals. A study in Jamaica also showed that farmer's had good knowledge in using forage for feeding dairy cattle (Morrison *et al.*,1996).

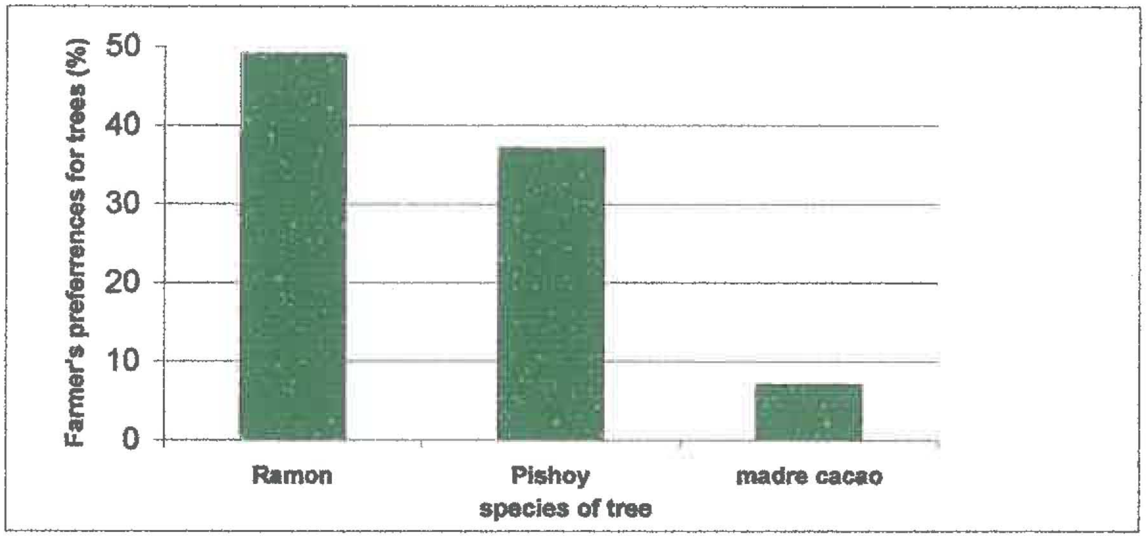

Figure 15. Farmers preferences for forage trees, Cayo Belize, 2000.

Again as their second preference these two species appeared as the most preferred with 9 farmers (23%) indicating Ramon as their second preference and 18 farmers (45%) indicating the pixoy as their second preference. As their third preference 9 farmers (23%) identified the Madre cacao (*Gliricidia sepium)*. One farmer indicated this specie as his first preference and 3 farmers (8%) indicated it as their second preference. Other species identified in lower numbers were the Indio desnudo (*Bursera simaruba)*.

The Ramon and pixoy trees grow naturally and are commonly found in the Cayo district although, in some areas the farmers reported these species as scarce. These two species have been exploited over the past decades by farmers who use it mainly as forage to feed their animals. This could be a reason why the farmers claim that these species are no longer abundant as they were at one time.

Although most of the farmers (78%), are familiar with the madre cacao and its use for forage and more so for its use as posts and living fences due to its hardness, it is not as commonly found on these farms as the pixoy and ramon. However, there are some farmers that have attempted at planting this tree on their farms. Fourteen of the 40 farmers (35%), have planted madre cacao over the past six years. Cumulatively these farmers have planted an estimated 1099 madre cacao trees. 15 farmers have madre cacao in their pastures, 15 farmers (38%) have madre cacao growing in their guamils and forest reserves and 13 farmers (33%) have madre cacao growing on their fence lines.

Most farmers (75.6%) responded positively to being interested in planting trees on their farms, not only for fodder but also for timber purposes, as this is becoming a new area of interest for some farmers. The system of planting most preferred was the planting of trees as living fences. 68%of the farmers chose this method as their first preference, while three farmers chose plantations as their first preference. 7 farmers choose plantations as their second preference of planting trees on their farms. In Costa Rica there are good examples of line planting of timber trees along living fences (Ibrahim, unpublished).

4.2 Cluster Analysis

A cluster analysis was carried out on the dairy farms as there is much variation in these farms and a more statistical grouping of the farms was desired. It is important to know what type of farms exist in the area so as to be able to transfer the agroforestry technologies more effectively catering to the limitations and potentials of the farms. The variables used in the cluster analysis were: total area of pasture (TPASTAR), total number of animals (TNOAN), number of milking cows (MCOWS), milk produced per cow per milking (MKPCW), total milk produced per year on the farm (TMKPYR), amount spent on animal health cost per year (AHTOTCT), amount spent on supplements per year (SUPTOTCT), amount spent on labour for the different activities related to milk production (CTACTIV), total production costs (TCOST) and total benefits obtained (TBEN).

A principal components analysis resulted in 77.7% of variables being explained by only one factor indicating that the farms are well explained by the set of variables chosen. All the variables in this factor resulted in high coefficient values, ranging from 0.757 for MKPCOW to 0.980for TBEN. The variables with the greatest coefficient values were: TBEN, TCOST, TMKPYR and CTACTIV (labour costs). It is clear that annual milk production depends on the total cost of production since the bulk of this is spent on concentrates. As mentioned previously, the farms with the greatest production per animal was clearly reflected in the amount of concentrate given to the animals. This input influences greatly on the milk production and the total cost of production. Total milk production per year also determines the total benefits obtained at the end of the year. Although the variable milk per cow has a coefficient value of 0.75 which is fairly high, it is the lowest value in the factor. This can be explained that total milk production per year does not only depend on milk produced per cow per milking. Other important variables are the length of the lactation period, the no of times the cows are milked per day as well as the no of milking cows available. This factor is centred around the cost of production , that is, total production, total cost and total benefits.

The classification of the farms was based on the distance between the quantitative variables. The distance analysis evaluated the similarities and differences between the farms surveyed. Every farm was compared with each other. The smaller the value of the distance between the farms the more similar the farms were with each other. The greater the value of the distance between the farms the less similar they were with each other. Most of the values obtained were very low indicating that most of the farms are fairly similar although there were some higher values indicating that some farms were very distinct from others. The smallest value was 0.022 and the greatest value was 0.806.

The values obtained in the distance analysis were used for the cluster analysis. The cluster analysis was able to identify three groups among all the dairy farms based on similar variables within each group and distinct variables that separated the groups (fig.16).

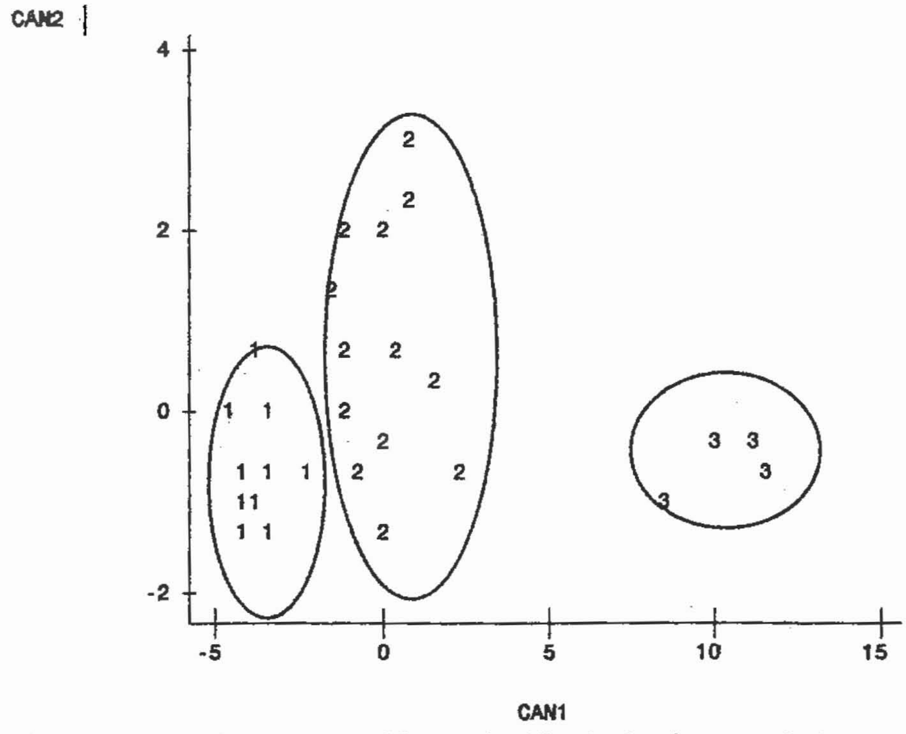

Figure 16. The three groups of farms identified in the cluster analysis

The first group consisting of 11 farmers accounted for 52.4% of the farmers with traditional production systems. This group, can be classified as the group with the lowest resources in terms of land, capital and animals. The average land available for pasture on these farms is, 45 acres. Consequently, this was also the group with the lowest milk production on average per cow per milking (6.7lbs) and with the least number of milking cows (5) and milk production only 6853 lbs. of milk per year per farm. Compared to the other two groups these farmers also spent the least amount of money on animal health ($65), supplements ($85), and labour ($1298.55) per year. The estimated average monthly income received from livestock production for this group is $247.

The second group of farmers in which 13 farmers were grouped can be classified as the intermediate group. All 7 farmers with silvopastoral systems were integrated into this group along with 6 farmers with traditional production system. The average land available for pasture is more than 50% compared to the first group. This group has 62% more land available for pasture (73 acres) compared to the first group and had more than twice as much cattle than the first group, 39 animals compared to 17 animals and also almost twice as much milking cows, 9 compared to 5. The amount of milk produced per cow per milking is 9.8lbs, 46% more than the first group and the annual production is 28,465 lbs. of milk, 315% more than group one. However, this group also spends 351% more on animal health, 2822% more on supplements per year and 100% more on labour dedicated to dairy activities. The estimated average monthly income received from livestock production for this group is $1013.

The third group consists of only 4 farmers. This is the group with the most resources available, in terms of capital, land, and animals. These four farmers are also farmers whose main activity is both dairy and beef. They are farmers with an average of 231.5 acres of land available for pasture. Total amount of cattle is also much greater than the two prior groups of farms, 113 animals, 15 milking cows. Amount of milk produced per cow per milking averages 15 lbs., 124% and 53% more than farms in group one and group two respectively. With an annual production of 61305 lbs. this group greatly exceeds that of the two previous groups. This high production is reflected on the amount spent per year on animal health, supplements, fertilizers and herbicides. The farmers in cluster three spend $7236 annually on supplements, $941 annually on animal health, and $5547 annually on labour dedicated to dairy activities. The estimated average monthly income from livestock production for this group is $2434

4.3 Financial Analysis

Few studies have been carried out on the profitability of silvopastoral systems in Latin America, mainly in Costa Rica and Colombia (Camero, 1996). It is not until recently that the economic feasibility of these systems has become an interest to both investigators and farmers who are seen more affected by these practices. However, many of these studies do no provide a complete economic analysis as some of the benefits that silvopastoral systems provide are intangible and difficult to measure. A financial analysis was conducted to determine the profitability of silvopastoral systems compared to traditional dairying. In this study environmental services accruing form the establishment of trees were also considered in the analysis. In table 4 is presented data on the farms analysed.

Table 4. Main characteristics of farms for which financial analysis was carried out.

Parameters	Dairy farms with SPSs (n=7)	Dairy farms with TSs (n=21)
Farm size (acres)	90.5 ± 57.38	128.2 ± 130.71
Area of pasture (acres)	52.4 ± 17.75	94.7 ± 99.85
No animals	39 ± 13.07	41 ± 44.11
No milking cows	10 ± 2.22	7 ± 4.93
Milk/day (lbs.)	111.4 ± 49.73	86 ± 80.71

4.3.1 Costs

The largest cost for both traditional and silvopastoral systems in this study was labour costs accounting from 39% and 45% respectively of the total cost. The higher labour cost in the silvopastoral system is related to the use of labour for harvesting and maintenance of the fodder banks (Jimenez *et al.*, 1998). It is important to remember that family labour was also valued in this study, something that many times is not taken into account. The second largest expense was supplement costs. As can be appreciated in fig. 17, the farms with silvopastoral systems spend 6% less on supplements than the farms with traditional production systems but the same percentage more on labour. This could be explained by the implementation of the fodder banks and multistrata systems on the farms. Farmers with the improved systems reported that they have decreased in the amount of concentrate given to their animals prior to establishing silvopastoral systems on their farms an therefore a decrease in their total cost for concentrates. The decrease in dairy concentrate reported ranges from one to four pounds of concentrate, previously given to their animals per day, this has been replaced by the forage obtained from the fodder banks and multistrata systems. Transportation costs which includes daily transportation of milk from the farm to the plant as well as transport used for the purchasing of materials, supplements and medication of the animals account for 12.8% and 12.3% of the total costs for the farms with traditional systems and the farms with silvopastoral systems respectively. Most farmers transport their own milk, although in a few cases some farmers have organized themselves and hired one person from their village to collect the milk paying on average 0.05 per every pound of milk for the transportation. This has reduced the transportation costs of these farmers but the majority of farmers transport their own milk regardless of the fact that they may have other dairy farmers near by. Most of the farms are within a 10 mile radius of the MACAL processing plant. With a little more organization and planning on their part they could work together to reduce their transportation costs. Animal Health does not seem to be a priority among farmers. Farmers from both systems spend very little in animal health although, farms with silvopastoral systems allocate a slightly greater percentage of their total cost in this area. This general lack of concern could be explained by the fact that Belizean cattle are relatively disease free. The chief health problems are Black Leg (Clostridial) rabies and internal and external parasites. Of these three, farmers spend more on the spraying for ticks and flies rather than vaccination and deworming. The percentage of farmers who purchase animals on yearly basis is very low. Although few farmers own a bull to service their cows, the common practice is to rent a service bull either from Central Farm, at a costs $60 per months, or either borrow or rent the bull from a neighbour..

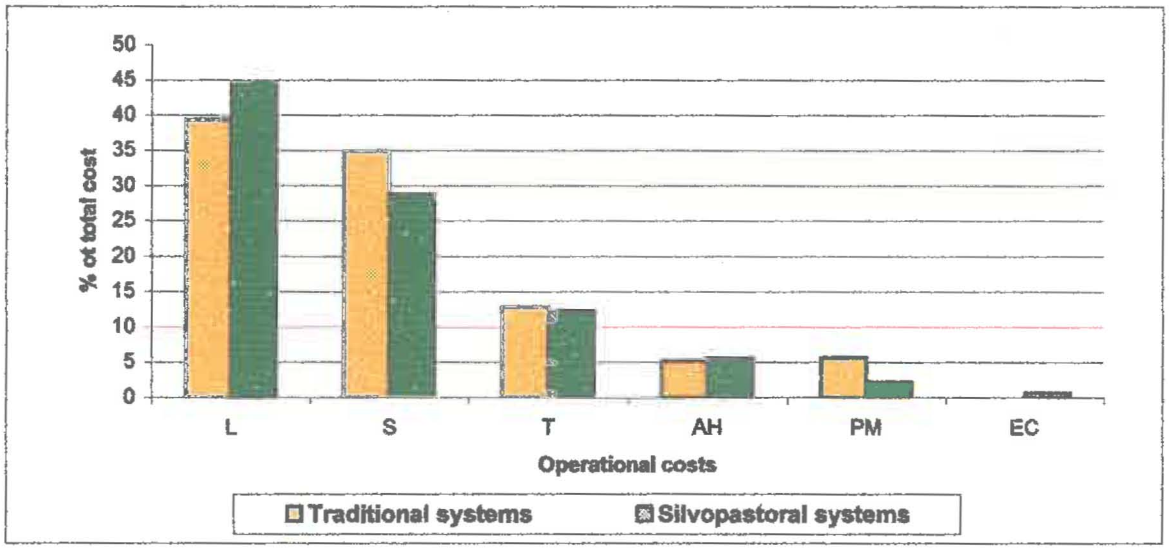

Figure 17. Distribution of costs for both systems (L= Labour, S = Supplements, T = Transport, AH = Animal Health, PM = Pasture Management, EC = Establishment Cost)

Table 5 shows the amount spent on each activity. Although, the percentage of the total cost for the farms with silvopastoral systems is less than that of the farms with traditional systems, the actual cost is a bit higher. This can be explained by the fact that in the traditional systems 48% of the farms do not feed their animals any commercial concentrates which greatly reduces the average value spent on supplements.

Table 5. Total amount spent on each activity for both traditional (trad.) and silvopastoral dairy systems (SP).

Item	SPS	% of total cost	TS	%of total cost
Supplements	2236	29	2203	35
Pasture maintenance	169	2	309	5
Animal health	432	6	310	5
Transport	956	12	810	13
Labour	3470	45	2430	39
Animals bought	425	5	159	3
Establishment cost	51.34	1	0	0
Total cost	**7742**	**100**	**6220**	**100**

4.3.1.1 Establishment Costs

The establishment of protein banks and multistrata systems do not need high capital investment, the cost of establishment is estimated at $240 and $300 respectively (table 6 and 7).

Table 6. Cost of establishing 1 acre of protein bank of Leucaena in Cayo, Belize, 2000

Materials	Quantity	Unit Cost (BZ$)	Total Cost (BZ$)
Leucaena seeds	3 lbs.	25	75
Fertilizer1:Urea	100 lbs.	0.35	35
Fertilizer 2:Phosphate	50 lbs.	0.45	22.5
Land Preparation			
Plow	1 acre	45	45
Harrow	1 acre	35	35
Labour			
Planting	8 hrs	2.5	20
Fertilizing	3 hrs	2.5	7.5
Total			**240**

2BZ$ = 1 US$

Table 7. Cost of establishment of 1 acre of a multistrata system of B. brizantha associated with Leucaena and timber trees (Mahogany and Cedar) in Cayo, Belize, 2000.

Materials	Quantity	Unit Cost (BZ$)	Total Cost (BZ$)
Timber tree seedlings	50 seedlings	1	50
B. Brizantha seeds	5 lbs.	10.5	52.5
Leucaena seeds	3 lbs.	25	75
Fertilizer1:Urea	100 lbs.	0.35	35
Fertilizer 2:Phosphate	50 lbs.	0.45	22.5
Land Preparation			
Plow	1 acre	45	45
Harrow	1 acre	35	35
Labour			
Planting	11 hrs	2.5	27.5
Fertilizing	3 hrs	2.5	7.5
Total			**300**

2 BZ$ = 1US$

However these cost do not include the cost for fencing the area of establishment. Fencing cost alone for one acre is estimated at BZ$600/acre. Post in Belize are very expensive. Prices range from BZ$ $3.50 to BZ$7 per post depending on the quality of the post. A high percentage of fence post is extracted from the forest which is an illegal operation. The idea of complete fencing of 1 acre of protein bank or multistrata system may not be attractive for the farmers. Most farmers who implemented silvopastoral systems on their farms already had an area fenced which they used or chose a corner of the farm which was already fenced and thus reduced the cost of fencing by one half. Another alternative for fencing would be to evaluate the economic feasibility of living fences instead of dead fences. An economic study conducted by Holmann *et al*, 1992 with small dairy farmers showed that the cost for establishing living fence post was 54% lower than the cost of establishing dead fences.

4.3.1.2 Management Costs

Management costs of the protein banks are not costly. The requirements include application of low levels of phosphate, quarterly punning of the leucaena trees as well as controlling the weeds in the plot. This is estimated at $49.50 per year. The labour requirements per year is 18 hours for the fodder bank systems and 14 hrs for multistrata systems. Farmers don't consider this labour intensive. It is important to note that farmers have some skills in pruning trees for feeding cattle which should be an advantage for managing fodder banks.

4.3.1.3 Harvesting Costs

On average farmers feed their cattle 5 lbs. of leucaena daily accompanied by other supplements. The farmers have not excluded the dairy concentrate completely from the diets of their animals but have reduced the amount previously given by 75% on average. This has reduced their production costs compensating for the labour required in harvesting the plants to feed the animals. Farmers reported that to harvest the plants (cut and carry) fodder and chop them for the animals it takes between 1 - 2 hours at the most per day. Again, here the farmers do not consider this to be labour intensive. As mentioned before, farmers in the Cayo district already have an appreciation of the cut and carry system especial during the dry season when they are seen forced to find forage for their animals outside their farm. Of the farmers in this study, 85% of them reported that during the dry season they have to find forage for their animals from trees such as the ramon and pixoy. Depending on the need, some farmers cut and carry forage for their animals between 2 weeks to 3 months. Sometimes, they cut the forage from the road- sides where the grass is high. Besides the labour involved in the cut and carry system some farmers incur an added transportation cost to transport the forage to their farms. According to a study by Holmann *et al* (1992), in the case of the protein bank, the cost of producing 1 kg of dry matter was 750% lower than the cost of soybean meal. In this study, the cost of producing 1 lb. of leucaena is 80% lower than the cost of dairy concentrate given to the animals. Hence, the substantial amount in dollars saved by feeding the animals from the protein bank rather than high levels of concentrate exceeds the cost of labour required for the pruning and the cut and carry feeding system.

4.3.2 Benefits

4.3.2.1 Traditional Systems

Most of the milk produced is sold to MACAL. That is, 63.8% of the livestock production benefits corresponds to the sale of milk. Few farmers make cheese to sell on a very irregular basis, and accounts for only 0.34% of the total benefits. Milk consumed by the family is also very low accounting for only 3% of the total benefits. Besides the sale of milk the farmers depend on the sale of animals throughout the year. Of the total benefits, the sale of animals corresponds to 32.9%.

4.3.2.2 Silvopastoral Systems

Similar to the farms with traditional systems, 65% of the livestock production benefits comes from the sale of milk to the plant. The sale of animals accounts for 27.9% of the total benefits while

5.7% of the total benefits is obtained from the sale of cheese. The indirect benefits which is related to the home consumption of milk accounts for only 1.5% of the total benefits. This is relatively low but a reality. Although one would expect dairy farmers to consume greater quantities of milk since it is produced on the farm, this is not the case. In this group only 28.6% of the farmers consume some of the milk they produce. Farmers reported that their families prefer drinking imported milks - powder milk, condensed milk, and evaporated milk rather than fresh milk.

4.3.2.2.1 Nitrogen

According to the soil analysis conducted on the soil samples taken from the silvopastoral plots the increment of N from the protein banks is 100kg/ha/year (89.2lbs/acre/year) while the multistrata systems resulted in 50kg/ha/year (44.6lbs/acre/year). This translates into a value of $56.14/acre worth of N organic fertilizer for the protein banks and value of $28.1/acre worth of N organic fertilizer per year for the multistrata systems. On average the value of N fertilizer obtained from the farms with silvopastoral systems is $70.1. This results in a reduction in the use of inorganic fertilisers for sustaining production of forage (Ibrahim and Mannetje, 1998).

4.3.2.2.2 Timber

More long term benefits from these systems include the commercial value of the timber trees. With a minimum commercial diameter of 60 cm, it is estimated from the growth patterns obtained from the MIRA database (Annex 2) on a similar site to the Cayo district that these trees will be ready for harvesting within 40 years. The benefits estimated from the trees in one acre of a multistrata system is $3009 This value was calculated for the standing trees. It may not seem like a substantial amount after 40 years, however, this value reflects the payment for 50 trees per acre. It is a density much lower than that found in plantations since these trees are spread sparsely within the pastures - multistrata systems. It is a benefit the farmers would not normally enjoy in the traditional systems of natural pastures. Since the density of the trees is low, it does not require much management. The planting of these lumber tress did not require a great investment, however, if prices of lumber continue to increase as it has done over the past years, this alternative can become more profitable than projected today (Ibrahim *et al.*, 2000b).

4.3.2.2.3 Carbon

A potential benefit that could be obtained from the multistrata systems is the payment to the farmers for the carbon sequestered by the Mahogany and Cedar trees during their life period. As these trees are valuable species a great percentage of the carbon gets sequestered in the form of furniture as is the most common use of these precious woods. Although Belize does not yet pay farmers for such services, many countries such as Mexico, Costa Rica, Argentina, Brazil, Australia, Canada and the United States are reaping benefits from carbon sequestered (Ramirez and Gomez, 1999). The amount of carbon sequestered by these 50 trees/acre was estimated to be 8.0 tons per acre valued at \$159.4. This value was obtained using the most conservative price found - US\$10 per ton in tropical countries in timber and US\$5 per ton for carbon in the soil. Studies show that protein banks can store 3 tons of carbon in the soil per acre while in multistrata systems it can sequester 5 tons per acre. Increment of soil carbon was 5 and 3 tons/acre/yr. in the multi-strata and protein bank systems and similar data was reported by other authors (Andrade *et al.*, 2000). Recently there has been an interest to pay incentives for C fixed in the soil to promote the adoption of environmentally friendly technologies (Pomareda, 2000).

4.3.3 Cost of Production

There is not much difference in the cost of production between the two systems. The cost of production for the silvopastoral systems is estimated at 0.25/lb while that of the traditional systems is estimated at 0.27/lb a difference of 8%. Although, this may not seem to be much of a difference, the difference is seen in the B/C and the NPV of both systems. Table 8 shows some production indices for farms with both systems. Total milk production for the farms with silvopastoral systems is 34.6% more than farms with traditional systems. Although the average milk production per cow per milking is similar 9.2lbs/cow/milking and 9.6lbs/cow/milking for farms with silvopastoral systems and traditional systems respectively, the lactation period for the later farms is 1.6 months less. The average number of milking cows is 3.5 cows less than farms with silvopastoral systems.

Table 8. Production indices for both systems

Production indices	Farms with SPS	Farms with TS
Total milk production/year (lbs.)	30458	22632
Milk production/acre/year (lbs.)	620	317
Milk production/cow/day (lbs.)	12	11
Income from milk production/year (BZ\$)	8631	6515
Income from milk production/acre/yr. (BZ\$)	176	91
Income from sale of animals/year (BZ\$)	3702	3356
Gross annual income (BZ\$)	13276	10217
Cost of production (BZ\$/lb)	0.25	0.27

2 BZ = 1 US\$

The production indices in table 8 indicate that silvopastoral systems are a better alternative than traditional systems. Milk production per acre per year is almost twice as much for farms with silvopastoral systems compared to farms with traditional production systems. Income farm milk production for the improved systems also exceed that of traditional systems by $2115.61 (32%). This increase in the income from the sale of milk is a direct reflection of the effect produced by the improved system and the productivity of the systems. These results are in agreement with those found by Current and Scherr (1997) where by studies of costs and benefits of agroforestry projects in Central America and the Caribbean reported financial profitability for the farmers in 56 systems evaluated. The financial indices in tables 9 and 10 also show similar results. The economic efficiency, expressed by the relationship of net benefits (i.e. total revenues minus total costs) and the ratio of total revenues to total cost (profitability), proves better for silvopastoral systems since these systems gave higher net benefits and a higher B/C than traditional systems. Similar to Current and Sheer (1997), Benavides (1994) also explains that economic analysis conducted on silvopastoral systems show that the implementation of technologies that incorporate fodder trees on farms proves economically profitable and contribute to the improvement of the family's economic situation. The TIR could not calculated since the net benefits were all positive. The values in table 9 correspond to one year - data collected from preceding year only. It does not include benefits form the trees and potential benefits for the sequestration of carbon. Table 10 shows both the NPV and B/C over a 40 year period at which the life cycle of the timber trees are estimated under different scenarios. After 40 years when compared with the traditional systems, both the NPV and B/C are greater for the silvopastoral systems under all three scenarios:

1) The silvopastoral systems as a whole including the benefits from the timber trees and the potential income payable for the sequestration of carbon;
2) The silvopastoral systems taking into account all the benefits obtainable form the system excluding the potential benefits of the carbon sequestration; and
3) This scenario, analyses the absence of the timber trees which would exclude benefits from the sale of the timber trees and potential payment for the sequestration of carbon.

Table 9. Results of financial analysis for both systems for one year (2 BZ$ = 1 US$)

SYSTEM	TOTAL BEN (BZ$)	TOTAL COST (BZ$)	NET BEN (BZ$)	NET BEN/acre (BZ$)	B/C (BZ$)
SLVOPASTORAL	13276.86	7736.98	5536.98	105.67	1.72
TRADITONAL	10217.27	6220.48	3996.29	42.24	1.64
INCREMENTAL BENEFITS			1540.66	63.43	0.08

*Figures represent averages obtained from farms in both systems for the preceding year

Table 10. Financial indicators for both systems over a 40 year period (2BZ$ = 1US$)

SYSTEMS	NPV (BZ$)	NPV/year (BZ$)	NPV/acre (BZ$)	B/C (BZ$)
TRADITIONAL DAIRY SYSTEMS	60129	1503	635	1.64
SILVOPASTORAL DAIRY SYSTEMS				
Scenarios				
With income from trees and carbon sequestration	86598	2164	1652	1.74
Without income from carbon sequestration	84848	2121	1619	1.73
Without income from trees and carbon sequestration	84300	2107	1608	1.72

*indicators were calculated using a real discount rate of 6%

As can be noted the income from the trees and potential payment for carbon sequestration does not affect the NPV and B/C substantially. The primary reason for this is that the amount of trees planted in the multistrata systems is fairly low (50 trees per acre).

Although milk production costs for the silvopastoral systems was 0.25BZ$/lb or 0.55 BZ/kg (equivalent 0.27US/kg) this was still higher than that reported by Holmann (2000) for Costa Rica (US$0.21/kg), Honduras (US$0.16/kg) and Nicaragua (0.18US$/kg). Increased milk production cost in Belize may be due to higher labour cost compared to Costa Rica (US$ 9.3/day) and especially in Nicaragua (US$2.3/day). These data show that though the silvopastoral systems was more profitable for milk production, increases in labour cost may affect the adoption of these technologies. Studies carried out by Jansen *et al.* (1997) showed that mixtures of *Brachiaria brizantha* and *Arachis pintoi* were more profitable than a silvopastoral system with *Erythrina berteroana*, because the latter required higher capital investments and more labour for its management. In countries like Nicaragua and Honduras where labour is relatively cheap (Holmann, 2000), the use of fodder banks or silvopastoral systems for dry season feeding of animals should be more profitable .

The net income per cow increased from 100 to BZ$178/year and this coincides with Holamann (2000) who showed that the planting of *Cratylia argentea* and sugar cane as a source of supplementary feeding resulted in an increase in net income of 34 to US$89/cow/year (equ. 68 – BZ$178 /cow/year). This author found that with the adoption of fodder banks for feeding dairy cattle in Honduras, milk production cost decreased from 0.16 to 0.12US$/kg and net income increased from US$167 to 261/cow/year.

The planting of fodder banks with improved grasses can increase animal productivity while liberating fragile areas for re-afforestation programmes (Jansen *et al*, 1997). Holmann found that through the investment of US5,730/farm in Costa Rica, stocking rates (0.75 AU/ha to 1.23 AU/ha) were increased such that 18.8 ha was released for re-afforestation.

4.3.4 Sensitivity Analysis

The sensitivity analysis is a means of dealing with uncertainty about future events and values. To test what happens to the earning capacity of the silvopastoral systems the following parameters were varied: price of milk, cost of labour, cost of supplements and cost of transport. Figure 18 shows the response of the NPV to the simultaneous increases in the cost of labour and the price of the milk. The increases range from 10% to 50%. There is still a slight decrease in the NPV but at labour increases of 50% the NPV only decreases by 25%. At the present price of milk 0.30/lb and the cost of labour $2.50/hr the NPV is at $84533.01. Increasing the labour cost and prices for milk by 10%, 20%, 30%, 40% and 50% also results the NPV decreasing, as the labour costs increases even though the price of milk increases by the same proportion. Hence, the sensitivity analysis shows high sensitivity to changes in labour prices. Labour costs are unlikely to decrease, therefore, it was not tested.

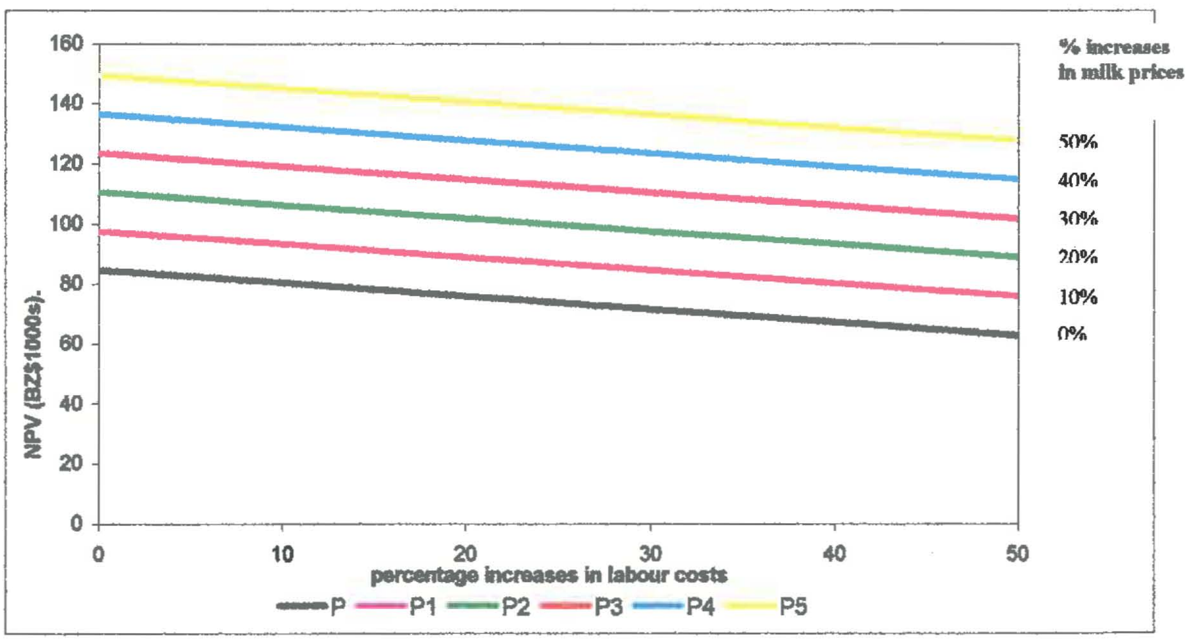

Figure 18. Response of NPV to the increase in labour costs and increase in the price of milk

The second figure shows the effect of the NPV to increases in the cost labour, cost of supplements, cost of transportation and price of milk sold. However, these increases are plotted independent of each other. As can be observed an increase in the prices of milk by 10% significantly increases the total NPV of the system. The increase in the other 3 inputs decreases the NPV but at a lesser degree than that at which it increase with the increase of milk prices. Variation in labour prices had the greatest effect in NPV compared to the variation of supplements, transportation and milk prices.

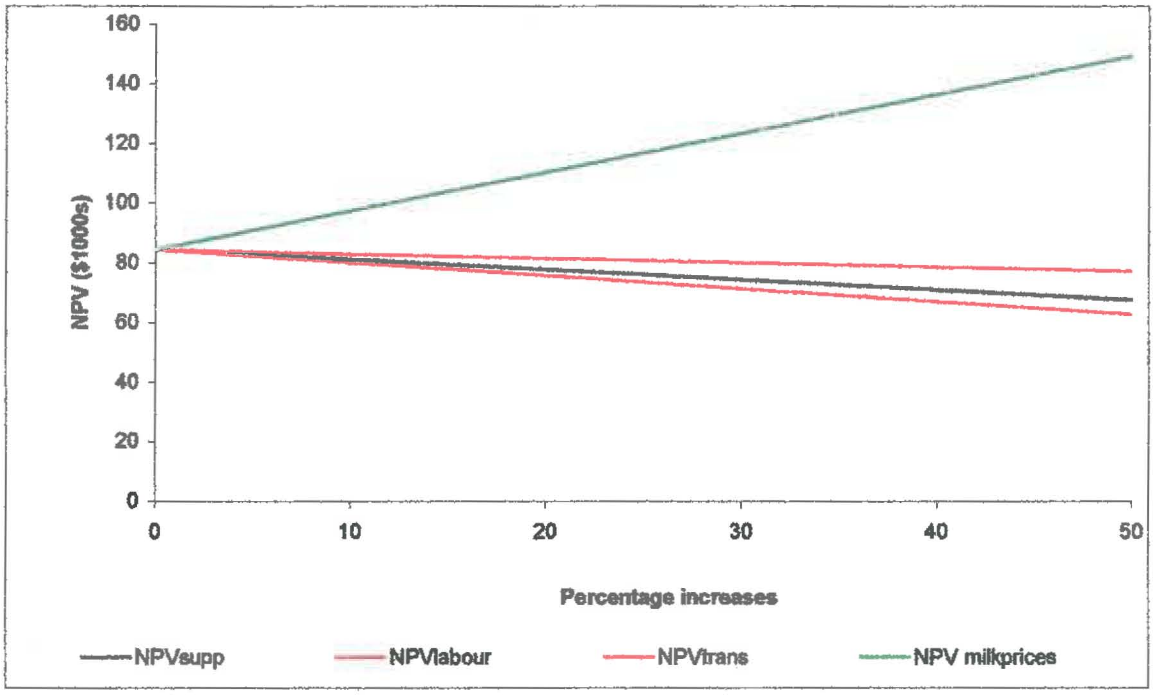

Figure 19. Effect in variation in prices of supplements (NPV supp), labour (NPV labour), transportation (NPVtrans), and milk prices (NPV milkprices) on the NPV of diary farms with SPSs, Cayo, Belize, 2000.

4.4 Constraints for Adoption of Silvopastoral Systems

Adoption of the silvopastoral systems was evaluated at two levels: farmers that have implemented the technology on their farms and those without the technology.

4.4.1 Farmers with Silvopastoral Systems

This group of farmers consisted of the 8 farms, 7 local dairy farms and Central Farm, the government research farm. These farms were identified for on farm evaluation and demonstration of fodder banks of woody perennials and multistrata systems of improved grasses associated with woody perennials and timber trees. These systems were implemented through the agroforestry project with MAF and CATIE. For the purpose of this study the government farm was not taken into consideration, as it operates under different circumstances than those of the other farmers which represent more realistic farm conditions. That is, Central Farm enjoys more support from the government in terms of capital, land and labour. They do not have much obstacles in the adoption of these technologies. The implementation of silvopastoral systems on this farm serves more as an experimental and research model of this technology to educate farmers about these systems from a practical point of view.

The farmers that make up the pilot project received both direct and indirect incentives from MAF and CATIE. The incentives received included: technical assistance - support in establishment and management practices of these systems, training - seminars and workshops on silvopastoral systems, mainly protein banks and multistrata systems and in-kind benefits - seeds, fertilizers, fencing materials and machinery to prepare land. However it is important to note that farmers gave their land, labour and also 50% of the inputs. This facilitated the incorporation of these technologies into their existing production systems. According to Samayoa (1995) case studies showed that technical assistance was necessary to provide information about tree management for unfamiliar species to facilitate the adoption of these technologies. These studies also showed that the provision of minimal in-kind incentives, material inputs was widely successful as an incentive for farmer experimentation and adoption however, it was not clear from the studies where financial incentives and subsidies were provided, that in fact they were needed for adoption. Radulovich and Karremans, 1993, also add that too much incentives given to farmers can be negative for the massive transfer of a technology. According to these authors it is not possible to consider ready for massive transfer technologies where producers who were used to validate them received ten or more times the technical assistance, subsidies and in-kind benefits than can be given to the rest of the target population.

4.4.2 Farmers without Silvopastoral Systems

These farmers consists of the target population for potential adoption of the silvopastoral systems. They consist of 33 farmers.

It is reported that the adoption patterns between small and large farmers differ (Current and Scherr, 1995). Thus, it is important that before the transfer of any technology is put into action, a clear understanding of the type of farms that make up the target population be obtained. This can be done through the establishment of homogeneous groups. To do this a cluster analysis was carried out on all the dairy farms. Three groups of farmers with different levels of production and management practices were identified: 1) producers with low production, little land and capital resources, and little or no use of inputs (concentrate, molasses, ground corn, vitamins, fertilizers, herbicides, vaccines, dewormers, etc.); 2) producers with intermediate milk production, more land and capital resources and greater use of inputs; and 3) producers with high production, much land and capital resources and the greatest use of inputs into their farm production systems (table 11).

Table 11. Parameters that distinguish the three groups from each other obtained from the cluster analysis.

Parameters	**Group 1 (n=11)**	**Group 2 (n=13)**	**Group 3 (n=4)**
Total area of pasture (acres)	45	73	231
Total number of animals (no.)	17	38	112
Total number of cows (no.)	5	9	15
Milk production/yr. (lbs.)	6553	28465	61305
Total income from livestock production/yr.(BZ$)	2966	12156	29211

2BZ$ = 1 US$

Identifying the different groups of farmers that make up the target population is important before technologies are transferred. Programs to promote large scale adoption may put the financial security of small farmers at risk or bias adoption and benefits towards higher income farmers. It is important to have these groups well defined for a more effective transfer and adoption of the technology. Likewise resource poor farmers generally do not have capital to invest in new technologies which can affect adoption of technology (Current, 1995). Each group has different degrees of limitations and potentials for adoption of these technologies. The smaller poor resource farmers may require different degrees of incentives and assistance to reduce the risk of failure of these systems. The intermediate and larger groups may require less incentives and they may encounter less obstacles for the adoption of these systems.

4.4.3 Farmers Knowledge of Silvopastoral Systems.

Indigenous systems of agroforestry are widely practiced in Central America and the Caribbean (Scherr, 1995b). In Belize this is not an exception. Fodder trees and shrubs have been used for generations as multipurpose resources (food, fibre, fodder, timber, wood, and live fences) in Cayo, but with low-level technologies. Trees are widespread in pastures in particular Conhune palm *(Orbignye cohune)*, pixoy (*Guazuma ulmifolia*) and Ramon (*Brosimum alicastrum*). *G. ulmifolia* and *B. alicastrum* are two of the most common species used for feeding ruminants during the dry season in Cayo (Ibrahim *et al*, 1998). This investigation revealed that 80% of the farmers (n=40), were familiar with the benefits provided by the leaves of *Guazuma ulmifolia* and *Brosimum alicastrum* with 50% who prefer *Brosimum alicastrum* and 35.7% who prefer *Guazuma ulmifolia* as forage feeding animals in the dry season A smaller percentage of farmers (12.5%) identified *Gliricidia sepium* as a good source of fodder for animals. These results are in strong accordance with the findings of Ibrahim *et al*, (1998b) who report that more than 75% of cattle farmers in the Cayo district knew about the use of fodder tree species as ruminant feeds with preference for *Guazuma ulmifolia* and *Brosimum alicastrum.* Similar results were found in Jamaica in a study with dairy farmers. A study conducted in Green Park, Jamaica, concluded that more than 70% (n=45) of dairy farmers knew about the use of fodder trees and shrubs for feeding cattle (Morrison *et al.*, 1996). Hence, it is clear that farmers have much experience with trees as forage for feeding animals in the dry season.

4.4.4 Sources of Learning about Silvopastoral Systems.

Farmers reported that these technologies were learnt from four different sources: 1) institutions such as Central Farm, MAF and CATIE; 2) knowledge gained from ancestors (parents and grand parents); 3) other farmers and 4) through farmers own initiative - trial and error based on observation. Institutions both government and private, local and international play an important role in the dissemination of information about improved technologies through, workshops and seminars as well as through visits to the farms by trained technicians. However, the most common method of learning about these technologies was farmer to farmer contact. There seems to be a good network of communication between the farmers in this area. Most of the dairy farmers (87.5%) belong to the MACAL co-operative and most of them know each other.

Forty-five percent of the farmers with traditional systems reported that they knew a farmer who has this system implemented on his farm. This is a relatively good percentage as it is only 17.5% of all the farmers that have implemented these systems on their farms. This is important and can make the adoption process of the target population easier as farmers from the pilot project are already acting as nodes in the network of diffusion (Prins, pers. comm.). The second most common source of knowledge about these systems comes from the knowledge of parents and grand parents. The use of trees for fodder is passed on from generation to generation. The least common method of becoming familiar with these systems is through farmer's own initiative. A few farmers (3) reported that they had observed the use of improved species of grasses and legumes and had experimented with these species on their own (figure 20).

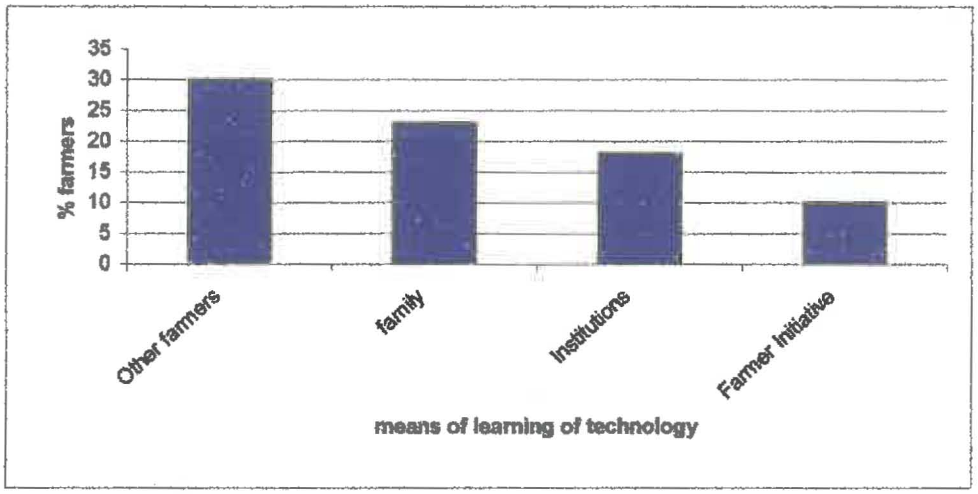

Figure 20. Sources where farmer first learnt about silvopastoral systems in Cayo, Belize, 2000.

4.4.5 Farmers Motivations for the Adoption of Silvopastoral Systems

The most common objective reported by the farmers for implementing these silvopastoral systems on their farmers was attributed to the improvement of their production. When asked why they agreed to implement silvopastoral systems on their farms 100% of these farmers responded that the principal reason was that they were not happy or satisfied with their milk production and thus, were willing and ready to try new ideas and technologies brought to them from people they believe have more training, experience and knowledge on these systems such as scientists from CATIE and technicians and professionals at Central Farm.

More than 50%, of dairy farmers who were given assistance have extended the area of silvopastoral systems on their farms with their own resources. This is an indicator that more than half of the farmers who started with the program are satisfied and relatively happy with the effects of these systems. Indeed these same farmers claimed to have had very good experiences with these systems and are convinced of their benefits and potentials. The table below shows their most common comments. The rest of the farmers in this group, 42.8% indicated that they were not successful at implementing these systems on their farms. The main reason for this was the poor establishment of the system.

Table 12. Farmers responses to experience with silvopastoral systems established on farms.

Good	Bad
Maintains animals in better conditions in dry season	Poor germination rate of the leucaena seeds
Improves production - milk production has increased (between 1 - 3lbs per cow per milking) when animals are fed from the silvopastoral plots	Animals don't like the leucaena they prefer the grasses such as Pangola.
Animals like the leucaena	Don't like the idea of cutting forage for animals, too much labour involved
Plots always look green and healthy, they have good recovery rate	

Among the advantages of these systems mentioned by the farmers were:

- Fodder banks and multistrata systems tolerate the dry season better than the natural grasses and even some of the improved grasses providing year round food for animals.
- These systems are more resistance to the common pest that attack the improved grasses
- Silvopastoral systems allows for better farm organization and management.
- These systems provide better quality food for animals.
- The recovery rate of the silvopastoral plots is better compared to the natural grasses and even improved grasses.
- The use of these systems has allowed the decrease in the amount of concentrate previously administered to the milking cows with more milk production. (farmers indicated a increase in milk production from 1 - 3 lbs. of milk per animal per milking when fed with forage form these systems).
- Production is more intensive rather than extensive with these systems as small areas of silvopastoral systems provided animals with enough food compared to natural pastures where more grass area is needed.

Among the disadvantages were:

- More time as well as labour is needed to dedicate in controlling animals when feeding in these systems while when put in natural pastures animals can be left there without control

(Most farmers have few big divisions and in the dry season most of them open up their divisions to allow animals total control of all the pasture available, this has led to over grazing in many cases and pasture degradation).

- More organization and dedication on part of the farmer is needed in management of the systems - pruning and fertilizing.
- Cut and carry system also requires more time.
- Animals don't want to eat the leucaena, seems that they are not use to it and leave it there.

Although time and labour seem to be somewhat critical factors, the farmers who are satisfied with the silvopastoral systems indicated that although a little more time and labour is required with the use of these systems, it is not a discouraging factor since it compensates in the reduction of concentrate given to the animals. While 1 lb of concentrate ranges from 28 cents to 35 cents, the cost of 1 lb of leucaena (harvesting cost) is estimated at 6 cents. Initial investment cost for establishment of fodder banks is estimated at $240 per acre and $300 per acre for multistrata systems and similar data was reported by Holmann (2000). Management cost which is estimated at $59.50 per year for both systems. The initial investment costs is distributed over the life expectancy of the fodder bank and multistrata systems which are estimated at 10 years. Therefore, the cost of leucaena per lb is estimated to be 80% less than that of concentrate per lb assuming that the production of forage per acre is 13,000 lbs. Although the farmers have not calculated this cost or associated it to an exact figure, they realize that compared to feeding concentrate, feeding their animals with forage from these systems signifies less out of pocket expense and decreases their production cost per unit. This is enough incentive for them to adopt this technology.

The farmers with positive experiences clearly stated that they are willing to continue expanding these systems on their farms even after the completion of the project because they have experienced first hand the positive effects of these systems and are convinced that they work. Although, the other farms did not have a good experience with these systems, the principal reason for their dissatisfaction was the poor germination rate of the leucaena seeds resulting in sparsely established fodder banks. This could be a result of poor quality seeds used in the establishment of the fodder banks as well as poor soil fertility and improper establishment. This could have been caused by the lack of proper communication between the technicians and farmers. Better communication and more frequent technical advice is necessary in the first stage of the implementation of any new technology to avoid failure in the initial process, the establishment process (Radulovich and Karremans, 1993). This problem they experienced was the primary cause for their scepticism towards this technology, however, two of the three farmers have not totally disregarded the potential benefits of the system and are open to trying it again.

Of the farmers without silvopastoral systems 50% said that they were not happy with their present production systems this percent is distributed almost evenly between milk and beef farmers. The other farmers did not necessarily say that they were happy with their production but instead said that they were satisfied with their production because they are not able to do any better, leaving them no choice than to be resigned to their present production levels. The few farmers who indicated that they were happy with their production systems were the bigger farmers. Although one would think that these would be the farmers who would have better possibilities at adopting and transferring new technologies on their farms since they do no have a scarcity of land or capital, these are the same farmers who don't feel that there is a need for them to increase their production, they are satisfied with their over all production (although NPV per acre is low than that of silvopastoral systems) and think they are producing enough and thus, don't see the need for them to invest in a technology such as silvopastoral systems. This was the typical response given by these farmers.

4.4.6 Farmers Opinion about Silvopastoral Systems

The majority of the farmers (57%) said that they believe that silvopastoral systems are a good way of improving their production systems while, 28.6% were not sure and 14% said that they prefer to stay with their traditional methods.

Fourteen percent of the farmer without the silvopastoral systems said that they have heard only negative experiences about this technology while 50% say that they have heard only positive experience with these systems and 5.9% say that they have heard both bad and good experience with these systems. This shows that there exists communications among the farmers, which is good, this opens up a network for exchange of information. However, it is important that the wrong information or myths about the systems is not transferred in the communication process. This can be avoided by having workshops combined with filed days inviting the farmers to acquire the right information about these systems. This has proven to be a good method of diffusion of information. A very successful workshop, combined with a field day, was held by Central Farm in March of the present year. This activity had a positive response from the farmers. There was a good attendance especially of potential-adopters, which highlights the interest of the farmers in these systems. The farmers visited two of the farms with silvopastoral systems. The owner of the farm was asked to give his personal experiences with the systems. Hearing the experiences from a farmer provides more confidence to the potential adopters because they can identify themselves with this farmer. Potential adopters are more interested in practical experience in the field under normal conditions rather than class room type setting which have been the more common method of transferring information to farmers. The field day provided a good platform to interact with the farmers in groups and in a more informal setting than interviews tend to give. Farmers were more relaxed and interested in learning and were not pressed for time as is sometimes the case when they are visited on their farms for an interview. Much information was gathered by simply listening to them exchange ideas and opinions among each. The majority of the farmers are of the opinion that silvopastoral systems such as fodder banks, multistrata systems and trees in pastures are good technologies and expressed an interest in investing in them.

4.4.7 Constraints for Adoption

There were four major factors reported by farmers as the principal factors of constraint for the adoption of these technologies: risk of failure of the systems (uncertainty), capital essentially for initial investment, markets, animal quality and to a lesser degree land availability and labour (fig. 21).

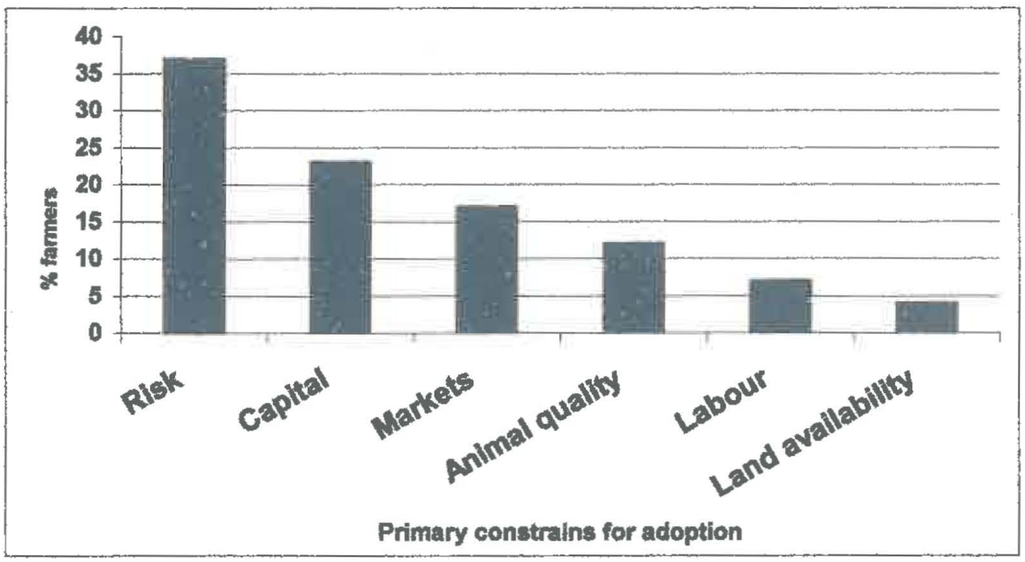

Figure 21. Primary constraints for adoption of silvopastoral systems as reported by the farmers (n=40) in Cayo, Belize.

4.4.7.1 Risk of Failure

Farmers with traditional systems indicated that their primary constraint for adoption of any new technology is the risk involved in the introduction of the technology into their farming systems. That is, changing from a familiar, more secure and experienced traditional or conventional system to a new technology. According to Aldy *et al* (1998), how farmers address the risks involved in any new practice depends on their risk behaviour. Farmers are aware of the many risks involved in agriculture in general. Production of products such as milk and beef are not guaranteed, that is profits are not guaranteed from livestock production, too many factors influence production. Thus, farmers have a tendency to minimize risk as much as possible. If a new technology carries higher risks than traditional or conventional methods of production, farmers will prefer their traditional methods with which they are more familiar and have experience with. Therefore, it is important for farmers to receive all the information necessary before the implementation on any new technology so that risks in the technology are minimized. As some farmers stated they need to weigh the pros and cons of the systems before they can make a sound decision.

4.4.7.2 Capital

Investing in any new technology requires initial and immediate capital for establishment. Having to relying on their limited financial resources for the implementation of a new technology is an important factor in the adoption of these systems. There is an opportunity cost for the capital needed for investment and they need to be sure that investing in this technology will have greater returns than the next best option in the use of this capital. Farmers stated that they always need money for something that needs to be done on the farm but because there are other things on their priority list these things are put on hold until they can allocate the resources for it to be done, for example repairing of fences. Thus, there is never a surplus of capital in these farm systems for the easy implementation of new technologies. They are concerned about loosing that initial capital invested if the technology does not provide the expected benefits when they could have used it for something else on the farm such as fertilizers or concentrate which provide more stable outputs. In the words of one farmer "every cent counts when you have a farm, especially a dairy farm". Small farmers have a limited budget with which to work and need to be assured that the proposed system is profitability.

4.4.7.3 Markets

Another constraints mentioned was the unstability of markets for their products with no fixed price for their products. Without good secure markets, farmers are not quick to change from their traditional production systems to this new technology which requires more dedication time to their farms and initial capital for establishment. According to one farmer, producing on natural pastures does not require much input from the farmer or material inputs into the farm. Again the general consensus is that changing from a relatively low input technology to a higher input technology should be combined with more secure and better markets for them.

The dairy farmers have had a history of bad experiences. Since the establishment of the milk processing plant, MACAL in 1975, the dairy farmers had to struggle to keep it in operation Juan, pers comm..). The plant was up until recently had been owned by the members of the co-operative have never been able to meet its break even point much less the processing capacity. This of course was due to low production by the farmers. A survey conducted in 1988 revealed that the average milk production per cow for the MACAL dairy plant delivered by the farmers was approximately 9 lbs. (Montero, 1988). Today this figure remains the same as the descriptive statistical analysis shows. The situation of the processing plant never improve resulting in great financial lost over the years and causing the co-operative to fall into several debts. Being in a critical situation, last year, the a decision was made to transfer the plant to a private enterprise in exchange for this party to take responsibility of all the debts of the plant. This was formalized in January of the present year. This situation resulted in the unstability of the price of milk per pound at which it was being bought from the farmers. Price per lb that the plant was offering began to fall as of January of this year. It went from its normal price of 32 cents per lb to 31 cents, to 29 cents to 27 cents and finally to 24 cents in April. Hence, most of the farmers stopped delivering milk to the plant. At the time of the interviews only 6 farmers including Central Farm delivering milk to MACAL. With the exception of two farmers, the rest of the farmers had either ceased producing milk as it had no longer become economically feasible for them to continue (cost of production estimated at 0.27BZ$/lb for traditional systems and 0.25BZ$ for silvopastoral systems), others were only producing for home consumption. One of the two farmers who continued to produce milk one was selling it to a private party who used to milk to make cheese and the other farmer was bottling his own milk from the farm without being processed and was selling it to his neighbours and small grocery stores in his village and surrounding areas. Both farmers were getting better prices than the plant was offering, 32 cents per lb and $6 per gallon

An air of tension and frustration was developed among the farmers due to three main reasons: 1) the drop in prices forcing them to stop producing milk, cutting them from a great part of their income 2) They were never involved in the decision process to transfer the plant to another party, this decision came from the board of directors alone and 3) member of the co-operative had substantial amounts of shares in the co-operative which they claim that as a result of the transfer of the plant they lost. One farmer claims to have lost as much as $4000. This has caused farmers to loose confidence in the co-operative and the milk industry on a whole. Many of the farmers were discouraged.

It is not only the dairy farmers who are faced with poor markets for their products. The beef farmers are in the same situation. Beef farmers are very frustrated since there are no stable prices for their product. Prices of live weight animals at the moment ranges from 50 cents for cows to 85 cents for young steers and bulls but most commonly farmers receive between 75 and 80 cents for young steers and bulls. This has some farmers worried that it is no longer becoming profitable for them to raise animals. The middle men pay too little while the processors sell beef products from $2.35 per lb of ground beef to $5.75 for per lb of T-bone steak. Farmers want a more even distribution of the wealth since they are the ones that have to take care of the animals, feed them and dedicate time and effort to them for as long as 3 years. Farmers close to the Guatemalan border claim that there is a lot of contraband taking place since Guatemalans are buying the animals at $1 per lb live weight of young steers and bulls. Fifteen cents more per lb makes a lot of difference to them. However, they are aware that this activity is illegal and would prefer not to do it and claim that one way that this can be solved is guaranteeing them better and more stable prices and more secure markets. Farmers clearly stated that better markets and better prices definitely gives them an incentive to invest and thus adopt new technologies as they would see a difference not only in the quality and production of their animals but also in their returns making these new technology worth while. However, many are of the attitude, " if the prices are bad then why bother making that extra effort".

4.4.7.4 Animal Quality

Another very important limiting factor is the quaintly of animals. For many of these adopters, the poor quality of their animals limits their potential to maximize production though the implementation of these silvopastoral systems. That is with better breeds of cows their production would increase even more than what they are producing now. Many of the farmers said, "When you have poor quality animals it doesn't make sense to improve your pastures since the animals will still not produce more milk to make a difference". They stated that improvement of pastures should not be considered an isolated solution for improvement but as a part of the other factors that influence good production such as having good milk producing animals. Potential milk yields of cows in some systems are only 7 to 9 lbs. per day so that genetic improvement is needed to make better utilization of fodder and concentrate (Archibald, 1984).

4.4.7.5 Land and Labour

A few farmers (20%), those with pasture area between 12 and 30 acres feel that they don't have the necessary space to implement these systems. However, what these farmers need to realize is that they don't need to start planting large areas of land. They can start with small areas such as 0.5 to 1 acre to one acre and with a few good animals, milk and beef production can increase from their present system.

4.4.8 Incentives Desired for an Easier Transfer of the Technology

When asked what type of incentives they could like to see from the Government's part to improve their situation the most common response (75%) of the farmers was "better markets and better prices for their products" while 29% indicated more affordable credit institutions with low interest rates for farmers and 25% mentioned that they would like more technical assistance and more regular visits from trained technicians (figure 22). There were 6 other responses given by the farmers (table 13) but the figure only shows the three more common responses.

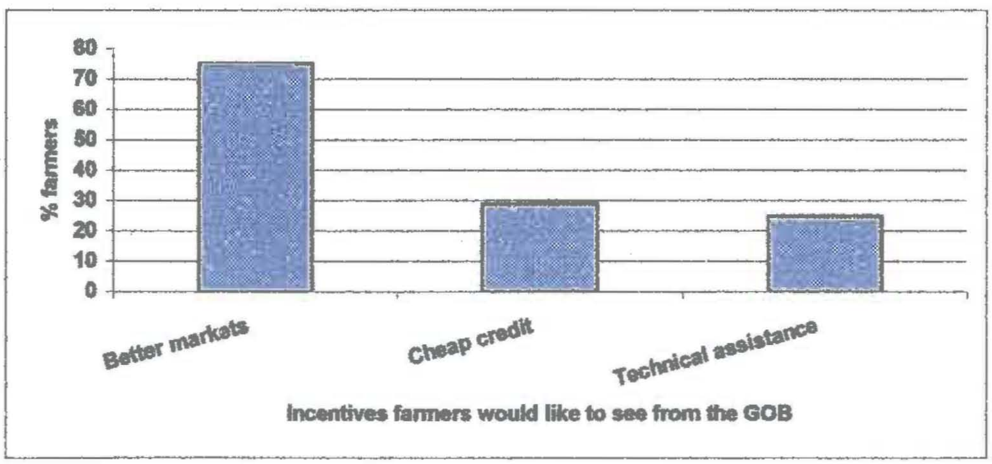

Figure 22. Incentives farmers would like to from the Government of Belize (GOB).

Table 13. Other Incentives mentioned by the farmers

Other Incentive farmers think are important	% farmers
reduce importation of livestock products	12
Subsidize inputs farmers use most e.g. material for fences, medications	8
Provide readily available and affordable machinery to prepare land	12
Better roads	10
Exempt farmers from e taxes paid on inputs	16
Promote artificial insemination	5

4.4.8.1 Markets

Farmers again stated that better markets and better prices definitely gives them an incentive to invest and thus adopt new technologies as they would see a difference not only in the quality and production of their animals but also in their returns making these new technology worth while. However, many are of the attitude, " if the prices are bad then why bother making that extra effort". Recently, the government has reduced importation of dairy products to promote National milk production and this will serve as a stimulus for adopting new technologies However, there is a need for better organzations and infrastructure for marketing milk in Belize.

4.4.8.2 Credit Institutions

Another incentive mentioned by these farmers is lower interest rates from credit institutions that should cater more to small farmers. It would be easier on them if the establishment costs of these systems did not have to come out directly from their pockets but perhaps through some type of credit for this purpose, which would contribute to an easier adoption process. However, credit institutions do no like to give credit to farmers especially for pastures as it is too risky. The commercial banks (Belize Bank and Barkley's Bank) are not an option for small farmers as the interest rates are too high ranging from 13% to 19%. This, farmers claim is an injustice since even if they did manage to get a loan from them they would be working for the bank and not for themselves. There is a Small farmers bank whose interest rates are lower 10% but despite the name it mainly caters to big farmers. Farmers claim that these institutions ask for too much in collateral that they do not have and, therefore cannot qualify for loans. Farmers without land titles are also affected in guaranteeing credit. It is not an easy problem to solve, these institution realize that there is great risk involved in agricultural activities and they have had cases where the proposed activity failed and the farmers were not able to repay their loan. However, more often it is the farmers that have had bad experiences with the credit institutions. Only 34% of the farmers claim that that they have relied on credit for some activity on their farm. The other farmers have never used credit and the reasons given were "Wants to sleep good every night so prefers not to get into debts, likes to do things with what he has", "has applied but was rejected and now is too old to get into that, since credit institutions don't like to give loans to older producers.", "interest rates are too high and animals cannot pay back loans easily." and "his father tried it once and had a bad experience so he prefers not to get involved with loans." Farmers are very sceptical about making loans. 41.1% of the farmers believe that loans are not for the poor farmer instead of putting them in a better situation they find themselves in a worst situation where they end up working for the bank paying high interest rates (table 14). A small percentage (30%) said they would try it if the interest rates were lower. There are some examples in Belize where dairy farmers are currently selling their cattle to repay credits and are cautious of taking additional loans. Recently the GOB approved a 0.5 million BZ$ loan to improve the dairy industry with better genetic stock and for forage improvement. According to government officials, farmers will be given a credit at cheap interest rates (7-8%) but some farmers are indecisive of taking the loan due to poor experience (Bacab, pers. comm.).

Table 14. Reasons cattle farmers gave for not using credit institutions in Cayo Belize, 2000.

Reasons	**% farmers**
Does not like it	19
Pefers not to get into debts, likes to do things with what he has	17
Too old	7.5
Difficult to get loans for pastures	5
Made a loan w/ Macal for pastures	15
Too risky	12
Bad experience	6
Loans don't help the poor farmers	17
Not in need	10
Cannot afford to pay monthly payments, cattle industry too risky	15

4.4.8.3 Technical Assistance

Farmers with silvopastoral systems state that technical assistance is vital for the success of these systems. Guidance on the management and proper functioning of these systems already implemented on their farms is of great importance. Although there is a technician that visits them to evaluate their progress they stated that they would like to see more of the technicians. They would like to see more regular visits by the technicians who are trained in these systems as this technology is new to them and need to be monitored more closely. Presently there are only two persons responsible for the project who work closely with the farmers but they also have many other duties which does not allow them the sufficient time necessary to visit these farms on a more regular and stable basis. Farmers stated that once a technician visits them they may not see the technician until a month or more later. Recently the MAFC assigned a technician to support technology transfer for dairy farmers (table 15).

Only a small percentage of the farmers without silvopastoral systems (14.7%) claim that they are receiving some form of technical assistance either from Central Farm or from the Ministry of Agriculture. When asked if they need or would like technical assistance 82.3% of the farmers responded positively, again here it is important to note that the bigger farmers believe that they are doing fine on their own and don't need technical assistance of any kind.

Table 15. Response of farmers to their necessities in technical assistance.

Needs for technical assistance	% farmers
Guidance on farm activities	32
Pastures improvement	73
Management of pastures	60
Problems with animals (animal health)	26
advice on how to improve production	45
Technical advice on animals	8
Improve communication between farmers and technicians	47
Increase technical knowledge of farmer on all aspects	5

4.4.9 Government Responses

Recently the government has been giving the livestock, particularly the cattle industry more importance than in recent years. Good quality animals have been imported from Costa Rica and will be sold to farmers at cost price. They are aware that farmers do not have the financial resources to buy these animals on their own therefore a half a million dollars loan program has been establish for cattle specifically dairy farmers at interest rates lower than those offered by any other credit institution (Bacab, pers comm.). Repayment of this loan will be done through deductions from the milk production of farmers and extended over several years. The new owner of the MACAL plant has informed the farmers that he is willing to pay a stable and reasonable price to milk producers as an incentive, as long as they guarantee a stable production of milk and total solids. The prices quoted were 32, 34 and 36 cents per lb of milk depending on the quality. This person will be working along with the government and the farmers in improving the milk market as his success in the milk industry depends on the success of the farmers in improving their milk production. With improvement of the herd breed and pastures through the multiplication of this technology which will be possible though this loan program, it is hoped that the production of farmers will increase significantly. The increasing dairy and beef productivity will be reflected in a higher income and a better quality life for these cattle farmers. It is hoped that this effort will increase livestock production efficiency, thus expanding market outlets and increasing the volume in both dairy and beef products that will be both price and quality competitive with imported livestock goods.

4.4.10 Organization of farmer

Although most of the dairy farmers (82%) belong to the MACAL co-operative, there has never been 100% or even a 50% co-operation from all its members at any one time (Manfred Lohr, personal communication). It was always a few members who met on a regular basis and tried to find solutions to their problems,. Most of the members were generally unwilling to commit themselves fully to the idea of cooperation and working together as a group in order to accomplish a common goal. This situation has augmented with the difficulties recently experienced through failure to manage the plant resulting in its transfer to a private party, many of the farmers (79%) reported to be discouraged with the present situation of the milk industry. At the time of the survey for this study was taken there were only 6 farmers delivering to the plant and who were prepared to continue delivering until the situation improved. The other farmers were sceptical about returning to the milk industry. Hence, there is a need to stimulate the reactivation and reorganization of the farmers. It is important for farmers to realize that only as an organized body will they be in a position to play a more active role in influencing macro-economic policies and decisions that affect their production activities and that would impact the dairy industry. The failure of the MACAL co-operative may be due to the lack of organization, lack of technical assistance and services to farmers to increase milk production and lack of incentives to farmers.

The adoption and potential adoption on silvopastoral systems are influenced by two major factors :
1) The farmer himself - his formation, his culture, his opinions, ideas, preferences, knowledge and lack of knowledge of the new technology - basically everything that makes him a unique individual.
2) His environment, which includes, his geographic location, the natural resources and other resources he has available such as financial, labour and land as well as the availability of markets for his product, the price on the market for his products among others.

It was found that these two factors cannot be separated. Although the former may be more flexible in that farmers can be educated on the benefits of improved systems while the later is less flexible. For example the resource poor farmers were familiar with the benefits of these systems but indicated that the adoption of these systems were constrained by limited land and capital resources (Current and Scherr, 1997). These two factors should be carefully analysed when promoting the adoption of new technologies.

V. CONCLUSION

1) The cluster analysis identified three groups of dairy farms based on farm resources, level of milk production and costs of production.

2) Higher financial benefits were obtained from the farms with silvopastoral systems compared to the farms with traditional production systems. The impact of silvopastoral systems can be seen in the financial benefits - increase in net benefits of the farmers, higher B/C and NPV compared to the farms with traditional production systems.

3) The sensitivity analysis showed that increases in labour resulted in a significant reduction of NPV and this can affect the profitability and adoption of the silvopastoral systems being promoted.

4) The additional benefits provided by the silvopastoral systems include timber, nitrogen in the soil, and carbon sequestration increases the income of the farmers and reduces the risk through the diversification of the farms compared to the farms with traditional production systems which are only oriented to livestock commodity production.

5) Among the major limiting factors identified by farmers for the adoption of silvopastoral systems are: risk, capital, markets, and genetic stock.

VI. RECOMENDATIONS

1) Develop a plan with farmers according ~~to the type of farms in the~~ area: small farms with low resources, medium farms with intermediate resources and large farms with much resources since different type of farms have different requirements, different limitations and potentials.

2) To make detailed social assessment of the impacts of silvopastoral systems especially in relation to labour use and livelihood of farmers.

3) Continue monitoring bio-physical and socio-economic changes of dairy farms with traditional and improved systems.

4) Farmers need organize themselves and form more solid groups and associations so as to be able to influence macro-economic policies and decisions that would impact the improvement of the dairy industry.

5) More stable and regular technical assistance is needed especially before the implementation of the technologies, to prepare the farmers, during the implementation of the silvopastoral systems, to reduce the risk of failure, and after the implementation of the silvopastoral systems so as to evaluate the progress of the systems established and to provide guidance on management practices.

6) Better credit institutions need to be developed to cater to the small livestock farmers allowing them to improve there productions through the improvement of pastures and animals.

7) More studies are needed to determine the optimum number of lumber trees that should be planted in the silvopastoral systems so as to obtain the maximum benefits from the extraction of the timber trees and the maximum potential benefits that can be obtained from the sequestration of carbon.

8) The results from the farm with silvopastoral systems provide a solid basis on which to extend the project so that the farms with traditional production systems can effectively implement these agroforestry technologies on their farms and reap the benefits these systems provide which implies improving their livelihoods.

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ANNEX

Annex 1[a]. Survey of farmers with Traditional Systems

Questionnaire for farmers with Traditional Systems **No.**____________

Date..................... **Village.........................**

General Information

Name of farmer____________________________Total area of farm____________

Land use on farm	Pastures (grass only)	Pastures with trees	Area of Guamil	Total area of crops	Other
Area (acres)					

Crops/animals	Area/amt	Use of products & by products (consumption, animal feed, fertilizers, etc)
Beans		
Corn		
Sugarcane		
Chicken		
Pigs		

Pasture Management

Management Of Pastures	Species	Area	No. of plots	Type of grazing	Grazing Time	Days of Rest	State of Pasture
Natural pastures							
Improved grasses							

Pasture condition: 1 (less than 10% weeds,) 2 (11- 20% weeds), 3 (21 -30% weeds), 4 (> 31% weeds)

Establishment of improved pastures:

Year of establishment of improved pastures…………… cost of establishment………………

Reason for establishment…………………………………………………………………….

Preparation of land: Tractor ( ) animals ( ) zero tillage ( )
Method of planting: Seeds ( ) quantity/acre.................................
Stems/stolons ( ) quantity/acre.................................
Labor require to prepare land
....
....

Use of fertilizers and herbicides

Item	Type	Cost	Area applied to	Amt applied/acre	Number of applications/yr
Chemical Fertilzers					
Organic Fertilzer					
Herbicides					

Type of fencing used : dead posts ( ) living fences ( ) both ( )
Electirc fences ……………………………………………………………
other…………………………………………………………………………

No acres fenced...Cost to maintain fences/yr...........................

Number of divisions fenced.............................. average size of divisions............................

Problems on the farm

Water: scarcity / abundance Source of water for pastures......………………...………..

Source of water of cattle...................………………….
If aguadas were made how many..................... total cost...........................…………..

Pastures: Pests ( ) species..Weeds ( ) species.......…….......

Soil: fertility..................drainage...................erosion....................topography...................

Livestock Aspects

Breeds of cattle on the farm...

Type of exploitation of livestock: Specialized: Milk ( ) Beef ( ) Dual production ( )

Herd composition

category	Number now	Amt died last year	Amt sold Last year	Amt buy Last year	Avg weight/animal & Price sold per lb.	Avg weight/ animal & Price bought/ lb
Milking cows						
Dry cows						
Culled cows						
Calves (< 1 yr)						
Heifers (2-3 years)						
Heifers(1-2 years)						
Steers(novillos)						
Breeding bulls						
Total						

Calving interval:............................months Lactation length: .... months

Cattle management

Category	**Category**	**Type and cost**	**No. of anim**	**Amount applied**	**No. of times**
Vaccines					
Internal Parasite control					
Baths to control parasites					

Supplementary alimentation and cost

Type of feed	Cost	Type and No . of animals given to	Amt given per animal/day	Cost/cow/day
Ground corn				
Molasses				
Dairy concentrate				
Sugar cane				
Forage				
Salt				
Vitamins & miner.				

Productive Aspects

No. of cows milked................................ Times /day milked......................................

No of cows milked in wet season .... and in dry season................................

Avg amt of milk /cow / day.............................. Total amt of milk /day.............................

Dry season - amt milk produced by: best cow......................... worst cow ....

Rainy season - amt milk produced by: best cow.............. .... worst cow..........................

Amt of milk fed to calves:........................

Amt of milk consumed on the farm by the family/mth.....................................

Is some of the milk processed on the farm.......................

If yes:

By products	Consumers	Amt. sold/yr.	Price per lb	Total value

Price of milk...................... .Amt of milk is sold/year.................To whom is it sold.............

How long it takes to fatten a steer (novillos) to marketable weight...

What do you feed the novillos..forage...................

Transport need on farm

Item	Transport used	Place of transport	# trips / yr #trips/day	Cost of trans/trip	Cost /yr	Comments
Fertilzer						
Herbicides						
Feed						
Milk						
An. Bought						
An. Sold						

Labour on farm

What type of labor do you use: Family( ) Hired( ) Both( )

If you use family labor, how many members of the family work on the farm
Children................. women...................... men................

No. Of laborers employed permanently/yr .... payment per mth ....

No. of laborers employed temporarily/yr.................. Cost/hour.............. cost/day..............

When...

How many men and how many days / yr...

Why..

Operations	How	Who	# men/oppera	Hrs/day	Times/yr
Pasture-men/acre					
Choping					
Fertizing					
Weed control					
Fence maintainance					
Animals-men/cow					
Milking					
feeding					
vacines/parasites					
Parasite baths					
Prepare/process marketing					

Depreciation of equipment

Equipment or Installations	Number (amount)	Actual value	Initial value	Years of use	Amt. of years still useful

Socio-economic aspects

Age of farmer .... Level of education of the farmer.............................
Total number of children Female.................. males......................

How many persons do you have to financially support.....................................

Do you depend on other sources of income besides dairy.......................................

What is the family monthly income..........................
$400 - $600 ( ) $601 - $800 ( ) $801 - $1000 ( ) >$1001 ( )

Administration - management of farm: Time spent managing the farm / day.......................

ABOUT TREES IN THE PASTURES

Why trees are kept on pastures: Shade ( ) Forage ( ) firewood ( ) timber ( ) posts ( )

Which trees are eaten by animals: 1)..................................2).................................3).........
(Give order of preference from most preferred to least preferred)

When are trees used to feed animals:...

How are trees fed to the animals:...

How much are fed to the animals:...

Do you put the animals to graze in Guamiles:
When.. how many animals..................no days...........

Are there *madre cacao* trees growing on your farm in: pastures () guamiles () fence lines()

Have you planted madre cacao trees on you farm ( ) If yes, how many..............................

When did you start and why...

Do you use *madre cacao* on your farm for: Fences ( ) fire wood ( ) posts ( ) other ( )

Do you sell madre cacao wood................If yes, to whom..

How much do you sell .... at what price...................................

If you buy this wood, from whom or where do you buy it....................................

How much do you buy annually.................................. At what price............................

What do you think of planting trees on the farm for providing fodder and timber
....

Would you be interested in planting this tree on your farm.............................
If yes, why...
If no, why not...

Do you have available land to do so.........................how much......................................

What type of system do you prefer if you decide to plant trees on your farm
Living fences.............. line planting............... living barriers...........other..............

ADOPTION ASPECTS FOR FARMS WITH TRADITIONAL SYSTEMS

Are you renting the land or do you own it................ cost of rent/lease........................

No.yrs living on the farm...................... No. yrs in livestock industry.......................

Do you work for yourself................with the co-operative....................others..............

Time do you spend working : on your farm...........................outside your farm.............

Are you happy with the livestock production on your farm
Yes ....Why..
No.............Why..

Are you familiar with silvopastoral systesm: FB( ) IP( ) trees in pastures ( )

Do you know of farmers that are using any of these systems on their farms.........................

Do you know of people who had bad experiences with these systems ....

Would you be willing to invest in: FB( ) IP( ) trees in pastures ( )

What problems can you think of for not being able to change from your TS to Silvopastoral
capital for initial investment ( ) labour ( ) land ( ) market ( )
other...

Do you receive any technical assistance
Yes ( ) since when....................For what...
From whom...how often..
NO ( ) Do you need technical assistance.............
Yes ( ) For what...
No ( ) Why not..

Do you use credit.......Yes..........NO.............Why..

What type of incentives do you think the government could offer so as to improving your livestock production ....
....

Annex 1b. Survey of farmers with Fodder Banks

Questionnaire for farmers with Fodder Banks **No.**___________

Date..................... **Village.........................**

General Information

Name of farmer_________________________Total area of farm__________

Land use on farm	Pastures (grass only)	Pastures with trees	Area of Guamil	Total area of crops	Other
Area (acres)					

Crops/animals	Area/amt	Use of products & by products (consumption, animal feed, fertilizers, etc)
Beans		
Corn		
Sugarcane		
Chicken		
Pigs		

Pasture Management

Management Of Pastures	Species	Area	No. Of plots	Type of grazing	Grazing Time	Days of Rest	*State of Pasture
Natural pastures							
Improved grasses							

*pasture condition: 1 (less than 10% weeds), 2 (11- 20% weeds), 3 (21 -30% weeds), 4 (> 31% weeds)

Establishment of improved pastures:

Year of establishment of improved pastures…………….cost of establishment………………..

Reason for establishment…………………………………………………………………….

Preparation of land: Tractor ( ) animals ( ) zero tillage ( )

Method of planting: Seeds ( ) quantity/acre...............................

Stems/stolons ( ) quantity/acre...............................

Fodder Banks

Area	Species	Method of planting	Quantity/acre	No. of plots	Type of grazing	Grazing Time	Days of Rest	*State Of FB

Method of planting: seeds or stems   Type of grazing: rotational or permanent or cut & carry system

Establishment of Fodder banks:

Year of establishment of fodder banks……………cost of establishment………………
Reason for establishment……………………………………………………………………

Preparation of land: Tractor ( )   animals ( )   zero tillage ( )

Use of fertilizers and herbicides

Item	Type	Cost	Area applied to	Amt applied/acre	Number of applications/yr
Chemical Fertilzers					
Organic fertilzer					
Herbicides					

Type of fencing used : dead posts ( ) living fences ( )   both ( )
Electirc fences ……………………………………………………
other………………………………………………………………

No acres fenced...Cost to maintain fences/yr...........................

Number of divisions fenced.............................. average size of divisions...........................

Problems on the farm

Water: scarcity / abundance Source of water for pastures..........................

Source of water of cattle......................................
If aguadas were made how many..................... total cost.......................................
Pastures: Pests ( ) species...Weeds ( ) species...............
Soil: fertility..................drainage....................erosion......................topography...................
Livestock Aspects

Breeds of cattle on the farm...

Type of exploitation of livestock: Specialized: Milk ( ) Beef ( ) Dual production ( )

Herd composition

Category	Number Now	Amt died last year	Amt sold Last year	Amt buy Last year	Avg weight/animal & Price sold per lb.	Avg weight/ animal & Price bought/ lb
Milking cows						
Dry cows						
Culled cows						
Calves (< 1 yr)						
Heifers (2-3 years)						
Heifers(1-2 years)						
Steers(novillos)						
Breeding bulls						
Total						

Calving interval:...........................months Lactation length: .... months

Cattle management

Category	**Category**	**Type and cost**	**No. of anim**	**Amount applied**	**No. of times**
Vaccines					
Internal Parasite control					
Baths to control parasites					

Supplementary alimentation and cost

Type of feed	Cost	Type and No . of animals given to	Amt given per animal/day	Cost/cow/day
Ground corn				
Molasses				
Dairy concentrate				
Sugar cane				
Forage				
Salt				
Vitamins & miner.				

Productive Aspects

No. of cows milked................................ Times /day milked......................................

No of cows milked in wet season .... and in dry season................................

Avg amt of milk /cow / day.............................. Total amt of milk /day.............................

Dry season - amt milk produced by: best cow......................... worst cow ....

Rainy season - amt milk produced by: best cow............. .... worst cow.........................

Amt of milk fed to calves:........................

Amt of milk consumed on the farm by the family/mth......................................

Is some of the milk processed on the farm.......................

If yes:

By products	Consumers	Amt. sold/yr.	Price per lb	Total value

Price of milk...................... .Amt of milk is sold/year.................To whom is it sold.............

How long it takes to fatten a steer (novillos) to marketable weight...

What do you feed the novillos...forage...................

Transport need on farm

Item	Transport used	Place of transport	# trips / yr #trips/day	Cost of trans/trip	Cost /yr	Comments
Fertilzer						
Herbicides						
Feed						
Milk						
An. Bought						
An. Sold						

Labour on farm

What type of labor do you use: Family( ) Hired( ) Both( )

If you use family labor, how many members of the family work on the farm
Children................. women...................... men................

No. Of laborers employed permanently/yr .... payment per mth ....

No. of laborers employed temporarily/yr.................. Cost/hour.............. cost/day...............

When...

How many men and how many days / yr...

Why...

Operations	How	Who	# men/oppera	Hrs/day	Times/yr
Pasture-men/acre					
Choping					
Fertizing					
Weed control					
Fence maintainance					
Animals- men/cow					
Milking					
Feeding					
Vacines/parasites					
Parasite baths					
Prepare/process marketing					

Depreciation of equipment

Equipment or Installations	Number (amount)	Actual value	Initial value	Years of use	Amt. of years still useful

Socio-economic aspects

Age of farmer .... Level of education of the farmer..............................

Total number of children Female.................. males.......................

How many persons do you have to financially support..

Do you depend on other sources of income besides dairy..

What is the family monthly income..........................

$400 - $600 ( ) $601 - $800 ( ) $801 - $1000 ( ) >$1001 ( )

Administration - management of farm: Time spent managing the farm / day.......................

ABOUT TREES IN THE PASTURES

Why trees are kept on pastures: Shade ( ) Forage ( ) firewood ( ) timber ( ) posts ( )

Which trees are eaten by animals: 1)................................2)................................3).........

(Give order of preference from most preferred to least preferred)

When are trees used to feed animals:..

How are trees fed to the animals:...

How much are fed to the animals:..

Do you put the animals to graze in Guamiles:

When... how many animals..................no days...........

Are there *madre cacao* trees growing on your farm in: pastures () guamiles () fence lines()

Have you planted madre cacao trees on you farm ( ) If yes, how many..............................

When did you start and why...

Do you use *madre cacao* on your farm for: Fences ( ) fire wood ( ) posts ( ) other ( )

Do you sell madre cacao wood................If yes, to whom..

How much do you sell .... at what price.....................................

If you buy this wood, from whom or where do you buy it....................................

How much do you buy annually.................................. At what price............................

What do you think of planting trees on the farm for providing fodder and timber
…………….,...

Would you be interested in planting this tree on your farm.............................

If yes, why..

If no, why not...

Do you have available land to do so.........................how much.....................................

What type of system do you prefer if you decide to plant trees on your farm

Living fences.............. line planting............... living barriers...........other..............

ADOPTION ASPECTS FOR FARMS WITH FODDER BANKS

Are you renting the land or do you own it................ cost of rent.........................

No.yrs living on the farm...................... No. yrs in livestock industry.......................

Do you work for yourself................with the co-operative....................others..............

Time you spend working : on your farm...........................outside your farm............

Are you happy with the livestock production on your farm

Yes ....Why..

No............Why...

How did you find out about the technology of:

fodder banks...

improved pastures..

Did you have prior knowledge about these system before the project: FB ( ) IP ( )

Have you extend the area originally planted: FBs.......................... IP..........................

Why..………………………………………………

Do you receive any technical assistance

Yes ( ) since when....................For what..

From whom...how often..

NO ( ) Do you need technical assistance.............

Yes ( ) For what...

No ( ) Why not..

Do you use credit.......Yes.........NO.............Why..

What are your experiences with

Fodder banks..
....
Improved pastures..
....

Has your livestock production improved since the implementation of these technologies......

Did you have any negative experiences/problems with: (i) FBs...................(ii) IPs.............
If yes, what..
....
....

What are the advantages you see compared to your traditional system
fodder banks..
....
improved pasture...
....

What are the disadvantages compared to your traditional system
Fodder banks..
....
Improved pastures..
....

What extra or different labour activities did this change require.
....
....
....

Are you happy with the change, has it filled your expectations...

Would you do anything differently...

If you stop receiving assistance from the project will you continue with these silvopastoral systems on your own...

Do you think that silvopastoral systems are a good way of improving production of small farms.......
....
....

What are the most important constraints / limitations for improving livestock production
Capital for initial investment.......................
Land availability .... animal quality.........................
Labour constraints...........................insecure market.....................
other..
....

What type of incentives do you think the government could offer so as to improving your livestock production ....
....
....

Annex 2. Data Base MIRA

COPAIS	PROYECTO	EXP	SITIO	TRATAM	FECHMED	FECHPLAN	NSTRATAM	REP	LOTE	EDADMES	SUPERVIV	DAP	ALTTOTPR	ESPECIE	ESPAC1	ESPAC2
HN	L	1	4001	CREC.005	06/10/80	15/09/1976	5	1	1	45	44	3,73	3,79	SWIEMA	250	250
HN	L	1	4001	CREC.005	06/10/80	15/09/1976	5	2	1	45	80	4,9	5,24	SWIEMA	250	250
HN	L	1	4001	CREC.005	06/10/80	15/09/1976	5	3	1	45	60	5,52	5,57	SWIEMA	250	250
HN	L	1	4001	CREC.005	14/07/81	15/09/1976	5	1	1	58	44	4,65	4,44	SWIEMA	250	250
HN	L	1	4001	CREC.005	14/07/81	15/09/1976	5	2	1	58	80	6,36	6,15	SWIEMA	250	250
HN	L	1	4001	CREC.005	14/07/81	15/09/1976	5	3	1	58	60	7,5	5,92	SWIEMA	250	250
HN	L	1	4001	CREC.005	30/09/82	15/09/1976	5	1	1	72	32	6,69	5,43	SWIEMA	250	250
HN	L	1	4001	CREC.005	30/09/82	15/09/1976	5	2	1	72	80	8,48	7,26	SWIEMA	250	250
HN	L	1	4001	CREC.005	30/09/82	15/09/1976	5	3	1	72	56	10,09	7,93	SWIEMA	250	250
HN	L	1	4001	CREC.005	11/04/83	15/09/1976	5	1	1	86	28	7,43	5,86	SWIEMA	250	250
HN	L	1	4001	CREC.005	11/04/83	15/09/1976	5	2	1	86	80	9,09	8,11	SWIEMA	250	250
HN	L	1	4001	CREC.005	11/04/83	15/09/1976	5	3	1	86	56	11,58	8,74	SWIEMA	250	250
HN	L	1	4001	CREC.005	05/07/85	15/09/1976	5	1	1	104	28	8,63	6,39	SWIEMA	250	250
HN	L	1	4001	CREC.005	05/07/85	16/09/1976	5	2	1	104	80	10,45	8,53	SWIEMA	250	250
HN	L	1	4001	CREC.005	05/07/85	15/09/1976	5	3	1	104	56	13,17	9,55	SWIEMA	250	250

EXP	AREANETA	ALTDOM	IMADAP	IMAALTOT	ABASALHA	UNIDAREA	VOLHA	IMAVOL	VOFF1EC2	N2ARBPAR	N2ARBHA	N2EJEPAR	N2EJESHA	NSNIVF1	NOARBORI	NSMED
1	156	4,7	0,99	1,01	0,77	1	1,39	0,37	1	11	705	11	705	5	25	1
1	156	6,25	1,31	1,4	2,42	1	5,9	1,57	1	20	1282	20	1282	5	25	1
1	156	6,9	1,47	1,49	2,3	1	6,06	1,62	1	15	962	15	962	5	25	1
1	156	5,2	0,96	0,92	1,2	1	2,44	0,5	1	11	705	11	705	5	25	2
1	156	7,3	1,31	1,27	4,07	1	11,58	2,4	1	20	1282	20	1282	5	25	2
1	156	7,25	1,55	1,23	4,25	1	12,47	2,58	1	15	962	15	962	5	25	2
1	156	6,4	1,12	0,9	1,8	1	4,57	0,76	1	8	513	8	513	5	25	3
1	156	8,75	1,41	1,21	7,24	1	24,43	4,07	1	20	1282	20	1282	5	25	3
1	156	9,15	1,68	1,32	7,18	1	26,46	4,41	1	14	897	14	897	5	25	3
1	156	6,6	1,04	0,82	1,94	1	5,26	0,73	1	7	449	7	449	5	25	4
1	156	9,7	1,27	1,13	8,31	1	31,49	4,39	1	20	1282	20	1282	5	25	4
1	156	11,1	1,62	1,22	9,45	1	40,74	5,68	1	14	897	14	897	5	25	4
1	156	7,56	1	0,74	2,62	1	7,96	0,92	1	7	449	7	449	5	25	5
1	156	10,7	1,21	0,98	11	1	43,99	5,08	1	20	1282	20	1282	5	25	5
1	156	11,75	1,52	1,1	12,23	1	57,69	6,66	1	14	897	14	897	5	25	5

Data Base MIRA (MADELEÑA Program, CATIE)