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INVESTMENT ANALYSIS OF INCORPORATING TIMBER TREES IN LIVESTOCK FARMS IN THE SUB-HUMID TROPICS OF COSTA RICA.

Tesis sometida a la consideración de la Escuela de Posgraduados, Programa de Educación para el Desarrollo y la Conservación del Centro Agronómico Tropical de Investigación y Enseñanza, como requisito parcial para optar el grado de:

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Dedication

To

The Almighty for allow me to complete this important step in my life.

My wife Bertha for her help, understanding in difficult times and unconditional love. Thank you very much my sweet heart.

My little daughter Montserrat for her love and happiness.

To

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Chagoya F, J.L. 2004. Investment analysis of incorporating timber trees in livestock farms in the sub-humid tropics of Costa Rica. Tesis Mag.Sc., CATIE, Turrialba, Costa Rica. 93p.

Key words: Ex-ante benefit analysis, Financial Analysis, Wood production, *Cedrela odorata*, Silvopastoral Systems, NPV, LEV, IRR, B/C ratio.

SUMMARY

An ex-ante benefit cost analysis was developed with the objective to explore the financial feasibility of incorporating timber trees under different arrangements in livestock farms in the Central Pacific Region of Costa Rica. The models were: 1) timber trees in fences, 2) timber trees under natural regeneration in natural grassland with fattening livestock, 3) land use change from degraded grassland to secondary regeneration forest, and 4) timber trees in a perpetual silvopastoral system in improved grassland with fattening livestock. The timber component was *C. odorata* L. A payment for environmental services was considered. The value of the land was estimated at 1,918 USD, and the discount rate applied was 6.56%. NPV, IRR, B/C ratio, and LEV were calculated. A cash flow and sensitive and risk analysis were conducted for each model. Model 1 results were NPV 275 USD, IRR 10.6%, B/C 2.3, and LEV 2,698 USD. The investment showed high sensitivity to changes in the discount rate. The risk analysis indicated high likelihood of failure (52.36%) for the investment when risk was applied to beef price. Model 2 results were NPV 352 USD, IRR 12.9%, B/C 2.5, and LEV 1,325 USD. LEV was highly sensitivity to changes in discount rates and wood prices. The investment was highly risky . Model 3 resulted in NPV –401 USD, B/C 0.42, and LEV -99 USD. Model 4 results showed an NPV 5,045 USD, IRR 3.6%, and LEV 1,937 USD. The investment showed high sensitivity to changes in discount rates and wood prices. When risk was applied to beef price, the investment showed a low likelihood of success (37.5% for NPV and 41.3% for LEV, respectively). For all investments, there was a negative net flow in the first years in comparison with the net cash flow in the situation “without the project”. PES contributed to improve the financial indicators. However, its contribution to the incremental flow was marginal.

Chagoya F, J.L. 2004. Análisis de inversión en la incorporación de árboles maderables in fincas ganaderas en el Trópico Sub-húmedo de Costa Rica. Tesis Mag.Sc., CATIE, Turrialba, Costa Rica. 93p.

Palabras clave: Ex-ante análisis, Análisis financiero, Producción de madera, *Cedrela odorata*, Sistemas silvopastoriles, VAN, VET, TIR, relación B/C.

RESUMEN

Un análisis ex-ante de beneficio costo fue realizado con el objetivo de explorar la viabilidad financiera en la incorporación de árboles maderables bajo diferentes arreglos en fincas ganaderas de la zona Pacífico Central de Costa Rica. Los modelos fueron: 1) árboles maderables en cercas 2) árboles maderables bajo regeneración natural in pasturas naturales con terneros en engorde, 3) cambio de uso de suelo de pastura degradada a regeneración secundaria, 4) -árboles maderables a perpetuidad en pasturas mejoradas con terneros en engorde. El componente forestal fue *C. odorata* L. Un pago por servicios ambientales (PSA) fue considerado. El valor promedio de la tierra en la zona fue estimado a 1,918 USD. La tasa de descuento aplicada fue 6.56%. Fueron estimados el VAN, TIR, relación B/C y VET. El Modelo 1 presento un VAN 275 USD, TIR 10.6%, B/C 2.3 y VET 2,698 USD. La inversión presento alta sensibilidad a cambios en la tasa de descuento. El análisis de riesgo indico una alta probabilidad de fracaso (52.36%) cuando se aplico riesgo al precio de la carne. El Modelo 2 reporto un VAN 352 USD, TIR 12.89%, B/C 2.5 y VET 1,325 USD. El VET indico alta sensibilidad a la tasa de descuento y precio de la madera. La inversión en general presento un alto riesgo. El Modelo 3 mostró un VAN - 401 USD, B/C 0.42, y VET -99 USD. El Modelo 4 presentó un VAN 5,045 USD, TIR 3.64, y VET 1,937 USD. La inversión presento alta sensibilidad a cambios en la tasa de descuento y en precio de la madera. Cuando el riesgo es aplicado al precio de la carne la inversión presenta un 37.5% y un 43.2% de probabilidades de éxito para VAN y VET, respectivamente. En todas las inversiones, el análisis del flujo de caja indico un flujo neto negativo en los primeros años en comparación con el flujo de caja en la situación “sin el proyecto”. El PSA contribuye a incrementar los indicadores financieros. Sin embargo, su contribución en el flujo de caja incremental fue marginal.

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Abbreviation and acronym list

@Risk	Risk Analysis Software
ADF	Acid Detergent Fiber
AGAINPA	Pacific Zone Independent Livestock Association
AU	Animal Unit
B/C ratio	Benefit-Cost ratio
bdh	Breast High Diameter
C	Carbon
^{o}C	Centigrade
CATIE	Tropical Agricultural Research and Higher Education Center
Cm	Centimeter
CO^2	Carbon dioxide
CONIF	Corporación Nacional de Investigación y Fomento Forestal
CP	Crude Protein
DM	Dry matter
EAI	Equivalent Annual Income
FAO	Food and Agriculture Organization of the United Nations
GEF	Global Environment Facility
ha	Hectare
hr	Hour
i.e.	id est
IRR	Internal Rate of Return
ITTO	International Tropical Timber Organization
kg	Kilogram
km^2	Square kilometer
LER	Land Equivalent Ratio
LEV	Land Expected Value
MCA	Monte Carlo Risk Analysis
mm	Millimeter
m^3	Cubic meter
m.a.s.l.	Meters Above the Sea Level
NDF	Neutral Detergent Fiber
NPV	Net Present Value
OIMT	Organización Internacional de las Maderas Tropicales
PASTOR	Pasture and Livestock Technical Coefficients Generator
PES	Payment for Environmental Services
SA	Sensitivity Analysis
SDI	Social Development Index
Silvia	Forest Management System software
SPS	Silvopastoral Systems
SWC	Soil Water Content
TNSC	Total Non-Structural Carbohydrates
ton	Tone
USA	United States of America
USD	United States Dollar
vs	Versus

1.1.- Problem definition

Livestock in Central America is facing an unprecedented challenge (Pérez 2000; Pomareda 2000). Low profitability of traditional livestock production systems, lack of diversification of productive activities, degradation of land, poor organization of livestock farmers, high cost of capital, absence of soft credits, and lack of government extension services, among others, place livestock farmers in a difficult socioeconomic situation (Kaimowitz 1996; Pezo and Ibrahim 1998; Szott *et al.* 2000). Studies in the 1980s and 1990s showed that when profitability was calculated using full opportunity costs for land, capital and labor, and without including capital gains from rising land prices, cattle production was not profitable for most farmers during this period (Kaimowitz 1996; Gobbi and Ibrahim 2004). Pomareda (2000) and Szott *et al.* (2000) indicate that the mentioned situation persists today, and that livestock farms are operating under low profitability conditions.

There are several strategies to confront the situation facing livestock farms indicated above (Murgueitio and Ibrahim 2000). One of them is the implementation of silvopastoral systems, since silvopastoral systems with timber trees have the potential to diversify farms incomes and to improve their profitability (Reiche 1991; Russo 1994; Somarriba 1997; Pezo and Ibrahim 1998; Beer *et al.* 2000; Pomareda 2000; Ibrahim and Camargo 2001). Types of production systems are designed with the following objectives: (1) to lower external inputs for feeding animals by using protein banks (*Leucaena leucocephala* (Lam.) De Wit., *Cratylia argentea* (Desv.) O. kuntze., *Morus alba* L.) or multipurpose trees (*Guazuma ulmifolia* Lam., *E. cyclocarpum* (Jacq.) Griseb., *Gliricidia sepium* (Jacq.) Standl.), (2) to diversify production with the introduction of timber trees in grasslands, and (3) to generate environmental services for sale such as protection of watersheds, reduction of greenhouse gas emissions, reduction of soil erosion, and increase of biodiversity (Pezo and Ibrahim 1998; Murgueitio and Ibrahim 2000; Harvey 2001; Harvey *et al.* 2004). Livestock farms in tropical zones have a high potential for timber production incorporating trees in silvopastoral systems (Ibrahim and Camargo 2001) Production of fine tropical timber trees such as *Dalbergia retusa* Hemsl., *Cedrella odorata* L., *Swietenia macrophylla* king., *Tectona grandis* L., *Tabebuia rosea* (Vertol.) D.C., *Samanea saman* (Jacq.) Merril., *Tabebuia ochracea* (Cham.) Standl., *Platymiscium pinnatum* (Jacq.) Dugand., *Enterolobium cyclocarpum* (Jacq.) Griseb., *Bombacopsis quinatum* (Jacq.) Dugand., *Peltogyme purpurea* Pittier., *Astronium graveolens* Jacquin., *and Cordia alliodora* (R. & P.) Oken, have a good potential in tropical zones (Holdridge *et al.* 1997), and a good perspective in the regional, national, and international markets (Tomberlin and Buongiorno 2001; OIMT 2002).

Production diversification with timber trees in livestock farms located in the tropics is possible because the forestry potential of the land is elevated, since until few years ago all of this land was cover with natural forest (Kaimowitz 1996; Sánchez 2000). Therefore, the development of silvopastoral systems with timber trees represent an opportunity to diversify production in livestock farms and to increase their incomes (Russo 1994; Pomareda 2000; Szott *et al.* 2000).

Income generated from timber trees has shown to increase livestock farms profitability (Dangerfield Junior and Harwell 1990; Reiche 1991; Marlats *et al.* 1995; Pomareda 2000). In Costa Rica, prices of tropical woods (fine; hard; semi-hard and soft woods) have increased in real terms during the last 25 years (Howard 1995), which represents an opportunity to

OIMT 2002).

This study addresses the following question: is the investment in silvopastoral systems with timber trees in the current conditions for livestock farmers profitable? The prime objective of this work is to conduct an ex-ante benefit-cost analysis, and to explore if the incorporation of timber trees with different arrangements in livestock farms is profitable in the Tropic Sub-humid region of Costa Rica. In addition, the study explores if a payment for environmental services is sufficient to make the investment in timber trees profitable, and assesses the level of risk associated with such an investment.

1.2.- Objectives

1.2.1.- General objective

To explore the financial feasibility of incorporating Silvopastoral Systems with timber trees under different arrangements in livestock farms in the Sub-humid Tropics of Costa Rica.

1.2.2.- Specific objectives

To determine farmer's choices regarding the type of Silvopastoral Systems with timber trees to incorporate in their livestock farms.

To determine establishment and operating costs of the following Silvopastoral Systems with timber trees: trees in fences, trees under natural regeneration, and trees in pastures.

To estimate the financial feasibility of investing on those Silvopastoral Systems with timber trees.

investment.

1.3.- Hypotheses

Investing in the incorporation of Silvopastoral Systems with timber tree under different arrangements in livestock farms of Esparza, Costa Rica is financially profitable.

A Payment for Environmental Services is needed to make the investment financially feasibly.

2-. Literature review

2.1.- Livestock in Central America

The future panorama for livestock and investment-dependent improvements in grazing systems in Central America is decidedly cloudy (Szott *et al*. 2000). Profit margins have shrunk and there is little national or international support for activities that are perceived as environmentally destructive and inefficient in terms of employment generation and resource use. Moreover, low international prices of livestock are expected to continue, which will make it hard for low productivity grazing systems to compete with other export orientated systems for land and capital (Pomareda 2000; Szott *et al*. 2000). In the absence of stimuli to adopt improvement alternatives, many cattle producers are likely to continue the *status quo*, banking on the future appreciation in the value of land as it grows more scarce (Leon 1994).

On the other hand, livestock systems have relevant socio-economic importance in the Central American Region. In Central America, livestock systems occupy 13.5 million hectares (27% of all the land) with 10 million heads of cattle distributed over 400 thousand farms (Pérez 2000). Table 1 shows this information distributed in the countries of Central America.

Table 1.- Basic information about Central American countries and livestock activities.

Concepts	GUA	ES	HON	NIC	CRC	PAN	CA
Land							
Total land (x 10^6 ha)	10.9	2.1	11.2	13.0	5.1	7.6	**49.9**
Grasses (%)	24	28	14	37	31	20	**27**
Forests (%)	48	5	54	25	31	43	**39**
Population							
Total (x 10^6 ha)	10.2	5.8	5.8	4.2	3.5	2.6	**32.1**
Birth rate (%)	2.3	1.9	2.6	2.4	2.3	1.7	
Density (hab./km^2)	94	277	52	36	69	35	**64**
Income Per capita (US$)	991	1,295	660	498	2063	2,699	**1,368**

Livestock							
Total (x 1000)	2,055	1,200	2,315	1,645	1,594	1,362	**10, 316**
Farms with livestock (x 1000)	30	64	100	108	38	39	**379**
Head/ha.	0.8	2.0	1.5	0.3	1.0	0.9	**0.8**
Human/livestock relationship	5.0	4.3	2.5	2.6	2.2	1.9	**3.1**

GUA= Guatemala, ES= El Salvador, HON= Honduras, NIC= Nicaragua, CRC= Costa Rica, PAN= Panama, CA= Central America.
Source: Pomareda 2000.

Livestock farmers will be the new foresters in this millennium (Ibrahim 1997). This assertion is the result of several current situations. On one hand, economical crisis in typical livestock systems in Central America caused by low prices of milk and beef, along with the elimination of subsidies, and pasture degradation, have led livestock farmers to search for other production systems to diversify their incomes. On the other hand, increments in real terms of the price in tropical woods (consequence of tropical forest depletion), restrictions in the market for natural forest wood, and government incentives for reforestation and development of the sawmill industry, represent an interesting opportunity in producing fine tropical woods in livestock farms in order to help improving their economical situation (Howard 1995; Ibrahim 1997; Sánchez 2000). In fact, there is a high demand of wood production in Central America coming from natural regeneration in silvopastoral systems (Ibrahim 1997).

2.2.- Silvopastoral Systems

Silvopastoral Systems (SPS) are a production option in livestock farms. In SPS, the woody perennial species interact with grasses and livestock with the objective to increase their long-term productivity with sustainable management (Ibrahim 1997). In other words, SPS are complex biological structures which combine long-term production from forest products (timber and fuel-wood) and short-term production from animals (fodder, meat, milk and wool) (Anderson and Sinclair 1993).

Several SPS have been developed in Latin America. The SPS include: 1) trees in pastures, 2) silvopastoral system with managed succession, 3) livestock grazing in forest plantations, 4) grazing in fruit plantations, 5) living fences, 6) boundary trees, 7) alley farming, 8) wind brakes, 9) high tree-density silvopastoral systems, 10) cut-and-carry systems (protein banks), and 11) energy banks (Somarriba 1997; FAO 2000; Murgueitio and Ibrahim 2000). Table 2 shows the potential to adopt SPS for different social groups in Latin America. Their incorporation in livestock farms is related not only with agroecological (soil, precipitation, wind, topography, etc.) but also with socioeconomic conditions (farmer's age, land tenure, capital cost, labor costs, environmental culture, among others) (Russo 1994; Somarriba 1997; FAO 2000; Murgueitio and Ibrahim 2000; Sánchez 2000; Ibrahim and Camargo 2001). An example of SPS will be a pasture with dispersed timber trees such as *T. grandis, S. macrophylla, C. odorata, C. alliodora,* and *T. rosea*. In these systems, the farmer will produced milk and beef, along with timber wood (Russo 1994; FAO 2000). It is important to consider that the Central American's region has thirteen million of hectares with extensive grasslands and all this land has the potential to implement SPS (Dagand and Nair 2001).

Table 2.- Potential to adopt Silvopastoral Systems for different social groups in Latin America.

Silvopastoral System	Social Group			
	Forest Enterprises	**Small producers**	**Medium and Large farmers**	**Farmers without land**
Trees in pastures	None	Limited	High	None
SPS with managed succession	Low	Low	Very High	Indirect benefits, (firewood, wood, fruit)
Livestock grazing in forest plantation	Very High	Low	Medium	Temporal employment
Living Fences	High	Very High	Very High	Indirect benefits, (firewood, wood, fruit)
Alley Farming	Medium	Low	Medium to High	Temporal employment and Indirect benefits
Wind brakes	High were they are useful	Medium to High	High were they are useful	Indirect benefits
Grazing in fruit plantations	Medium to High	Low to Medium	Low to Medium	Low employment opportunity
High tree-density SPS	Low	Medium to High	High to Very High	Mean opportunity of employment
Cut-an-carry systems	Low	Very High	Medium to High	Mean opportunity of employment
Fruit Harvest	None	Medium	Medium to High-	High opportunity of employment

Source: FAO 2000.

In addition, interest in the potential of timber trees on tropical farms has increased not only for diversifying and sustaining productivity, but also for recovering degraded land, improving biodiversity, fixing atmospheric carbon, protecting watersheds, making marginal lands productive, improving cash flow and reducing risk for farmers (Russo 1994; Somarriba 1997; Beer *et al*. 2000; Murgueitio and Ibrahim 2000; Pomareda 2000; Devendra and Ibrahim 2004; Pomareda 2004).

SPS have several advantages (Russo 1994; Somarriba 1997; Botero 2000; Ibrahim and Camargo 2001; Devendra and Ibrahim 2004). They are: 1) reducing risk through productive diversification; 2) diversifying food production with forage trees for animals; 3) producing firewood, wood for construction and posts in the farm; 4) controlling weeds in forest plantations; 5) reducing the risk of fire; 6) providing comfort for livestock; 7) improving beef and milk production; and 8) producing environmental services such as, protecting watershed, reducing greenhouse gas emissions, reducing soil erosion and increasing biodiversity. They also present certain disadvantages: 1) cows could increase soil compactation when pastures are wrongly managed; 2) incorporation of trees in pastures may lower grass productivity under shade; 3) high mortality of trees under natural regeneration when the pasture is overgrazed; 4) mechanical agricultural practices will be affected (machinery will not work easily in pastures with high density of trees), and 5) implementation of silvopastoral techniques requires knowledge and well personnel trained. In spite of these disadvantages, it is widely recognized that SPS represent an environmentally friendly livestock production system.

2.3.- Interactions in Silvopastoral Systems with timber trees

SPS involve interactions among the different components in terms of space occupation (vertical and horizontal stratification above and belowground), and resource allocation (light, water and nutrients) (Anderson and Sinclair 1993). Following is a description of such interactions in SPS.

2.3.1.- Tree-grass interactions

In SPS with timber trees, tree-grass interaction is important, because trees and grasses compete for light, water, and soil nutrients (Ibrahim and Camargo 2001; Devendra and Ibrahim 2004). Numerous studies have shown that pasture productivity under moderate levels of shade (canopy cover) increases or do not differ from that of pastures without trees. For example, in a study developed with different densities of *Populus deltoides* Marsh. (625, 416, 312, 250 and 0 trees/ha), and a mix pasture of *Bromus unioloides*, *Lolium multiflorum*, *Paspalum dilatatum* and *Cynodon dactylon*, the best production of grass was with a density of 250 trees/ha (8 tons of dry matter (DM)/ha), and there was no statistical differences in grass production when compared with the treatment without trees (Acciaresi *et al.* 1994). The integration of *Brachiaria humidicola* and *Acacia mangium* with a density of 240 tree/ha increases the production of DM (1,834 vs 2,562 kg/ha/year) and improve concentration of crude protein (CP) in the grass (3.2% vs 4.6%) (Bolívar *et al.* 1999). Improved pastures such as *Cynodon nlemfuensis* beneath the open shade of timber trees like *C. alliodora* did not have a statistical difference ($p > 0.05$) in bio-mass production in comparison with full sun areas (11.2 vs 7.7 ton/ha/year) (Villafuerte *et al.* 1999). *Brachiaria brizantha* produced 3,550 kg of DM/ha/year and *Andropogon gayanus* improved their percentage of CP under moderate shade (416 trees/ha) of *Sclerolobium paniculatum* (Mochiutti and Lima 2000).

Canopy shadow seems to have no dramatic effect on the reduction of grass production. A research in Guapiles, Costa Rica, mentions that reduction in forage yield was 23%, 30% and 39% for *B. decumbens*, *B. brizantha*, and *Panicum maximun*, respectively, under natural shadow of *A. mangium* and *Eucalyptus deglupta* with a density of 370 trees/ha (Andrade *et al.* 2000; Andrade and Ibrahim 2001). Leaves of the grass *Penisetum purpureum* increase the percentage of CP (9.86 vs 7.97%), neutral detergent fiber (76.67 vs 74.87%), and acid detergent fiber (49.49 vs 38.37%) in situations under shade of *Enterolobium maximun* versus full sun (Luis *et al.* 2001). Thinning intensities of 50% and 62% in forest plantations (initial density 1,600 trees/ha) of *Pinus elliottii* improve the production of natural grass (*Piptochaetium lasianthum*) at a sufficient level to establish an integrated system of forage and wood production (Plevich *et al.* 2002). In a study developed in Brazil, *B. decumbens* showed low levels ($p <0.05$) of total non-structural carbohydrates but maintained it forage availability under the isolated trees shadow of *A. mangium*, *Acacia auriculiforimis* and *Albizia guachepele* (Gomes *et al.* 2004). Another research in the same country mentioned that *B. brizantha* had a production of 1,692; 3,616 and 2,547 kg DM/ha, under a tree cover of 12%, 22% and 30%, respectively (Alvim *et al.* 2004). In Tabasco, México, *B. humidicola*, *Brachiaria dyctyoneura* and *Paspalum conjugatum* improved their levels of CP under a forest plantation of *C. odorata* (1,100 trees/ha). However, production of DM decreased in *B. dictyoneura*, but *P. conjugatum* not presented statistical difference ($p >0.05$) of DM production under shade, and full sun (1.24 vs 0.97 Mg DM/ha/harvest, respectively) (Aquino *et al.* 2004). The information above indicates that under a moderate canopy shadow it is possible to produce forage of a good quality and quantity.

Natural regeneration is a method to establish trees in pastures (Camargo *et al.* 2001; Camargo *et al.* 2004). Valuable timber species, such as *C. alliodora*, *C. odorata*, *Samanea saman*, and *A. guachepele*, in low densities (4 to 15 trees/ha), are common in pastures of the tropical lowlands (Barrios *et al.* 1999; Camargo *et al.* 2004). In Esparza, Costa Rica, germination of *C. alliodora* was higher (28% vs 21%), and seedling mortality lower (55% vs 63%) in sites with cover of with grass cover (8% vs 6%) but mortality was greater (83% vs 76%) (Camargo *et al.* 2001).

2.3.2.- Livestock-tree interactions

Livestock-tree interaction is also important in SPS because livestock could make some damages to the trees (Somarriba 1997; Ibrahim and Camargo 2001). Livestock can eat, trample, strip the bark and brake the young trees causing much damage in the plantations or in the natural regeneration of timber trees (Somarriba 1997; Schlönvoigt and Ibrahim 2001). For example, survival of seedlings of the timber specie *Pithecolobium saman* (Jacq.) in grasslands of *H. rufa* was evaluated under three grazing intensities (normal 1.3, high 2.6 and very high 3.9 animal units (AU)/ha), on two tree growing places (cow pats or directly in the soil). The results showed that when the grazing intensity increases (from 1.3 to 3.9 AU/ha), the damage in the trees increase too (from 55% to 70% directly in the soil, and from 15% to 30% in cow pats, respectively). Moreover, the trees growing in cow pats had less mortality (17% vs 56%) and better growth (8.5 cm vs 3.6 cm) than trees growing directly in the soil (Barrios *et al.* 1999). In addition, it is possible to start grazing in a forest plantation of *Eucalyptus saligna* when it is nine months old, producing 455 kg/ha of beef in the first two years (da Silva *et al.* 2000). SPS will be established immediately or after twenty-two months of planting the trees, depending on the method of tree protection (with wire fence or without grazing) and fast growing rate of the tree specie used (i.e. *E. grandis* and *A. mangium*) (Carvalho *et al.* 2001). Those experiences indicate that it is possible to establish a SPS with timber trees, if grazing intensity, timber tree selected, timber tree care, and grassland management are the correct ones.

2.3.3.- Livestock-grass-tree interactions

The interaction of livestock-grass-tree is more complex than the previously described interactions, because it encompasses the three components. Livestock-tree-grass interactions can be positive or negative. For example a research in the Argentine Chaco showed that the damage in natural regeneration of valuable timber tree species (*Schinopsis balansae, Prosopis nigra, Geoffroea decorticans*) was reduced in grasslands with livestock grazing management (48%) versus without management (65%) (Simón *et al.* 1998). Another study in Costa Rica mentioned that dairy cows had a better milk production ($p<0.05$), a lower respiration rate ($p< 0.01$), and a grater DM intake ($p<0.05$) under natural shade of *C. alliodora* and *C. odorata, Ficus spp* and *Citrus sinensis* than under the full sun (Abreu de Souza *et al.* 2004). Management of the different components of the SPS help to reduce the negative interactions among them, and to increase the positive ones.

2.4.- Environmental Services

The most common Environmental Services (ES) recognized are the services derived from natural ecosystems and agricultural-ecosystems to the society such as watersheds protection, carbon sequestration, and improved biodiversity. There is a current trend in CA to recognize and financially compensate the providers of those services (World Bank 2002). The payment for ES could impact directly and indirectly in the protection and improvement of the environment, and improve people's quality of live (CONABISAH 2004).

2.4.2. Biodiversity

SPS provide habitats, connectivity, and resources that make possible the persistence of some plant and animal species within the fragmented landscape, thereby partially mitigating the negative impacts of deforestation and habitat fragmentation (Harvey *et al.* 2004). A wide variety of animals (insects, birds, bats, and other mammals) use SPS for several objectives such as food, shelter, protection against predators or adverse weather conditions, and as biological corridors (Harvey 2001; Harvey *et al.* 2004). One research in Yucatan, México compares the biodiversity of a grassland monoculture versus a SPS in natural regeneration. Results indicate that one specie was found in the monoculture grassland, while 89 species of plants were founded in SPS, 34 of them were of the *Leguminosae*, 5 of *Rubiaceae*, 4 of *Compositae* families, and the rest (46 species) belonged to 27 different families (Morales *et al.* 2001). Another research in Nicaragua identifies 60 species of trees in different SPS: pastures with low density of trees (< 30 adult trees/ha) 10 species; pastures with high density of trees (> 30 trees/ha) 10 species; pastures with oak trees (*Quercus spp*) 5 species; scrub vegetation 7.5 species and forest 11.5 species (Casasola *et al.* 2001). The results indicated that SPS are quite similar to forest in terms of species numbers.

A research compares the abundance and species richness of trees, birds, bats, butterflies, and dung beetles in some land uses such as secondary forest (SF), riparian forest (RF), tacotal (TC) (tacotal = forest in secondary regeneration) , and grasslands with low (GLD) and high density of trees (GHD) in the agricultural landscapes of Cañas, Costa Rica and Rivas, Nicaragua. The results indicated that in Cañas there were a total of 32,540 individuals of 408 species, and in Rivas there were 22,810 individuals of 342 species included in different taxa (table 3) (Harvey *et al.* 2004). Table 3 shows their distribution for each taxa. In addition, the research showed that the abundance was higher in GHD (138), and GLD (111) in comparison with SF (77), and RF (63). However, the richness was very similar in all the land uses, i.e. GHD (25), GLD (22), SF (27) and RF (25).

Moreover, isolated trees in pastures have considerable potential for biodiversity conservation (Harvey 2001; Esquivel and Calle 2001). This potential is given by: 1) providing important habitats and resources within the agricultural landscape for a variety of animals, including resident and migrating bird species, bats and other animals; 2) representing a large number of different trees species; 3) providing landscape connectivity; 4) promoting the floristic diversity within pastures (natural regeneration) and 5) retaining rich communities of epiphytes on their branches and trunks.

Table 3.- Number of species and individuals for different taxa sampled in 10,000 ha of fragmented landscapes of Rivas, Nicaragua and Cañas, Costa Rica.

Taxon	**Rivas, Nicaragua**		**Cañas, Costa Rica**	
	No. Species	**No. Individuals**	**No. Species**	**No. Individuals**
Vegetation	146	2,362	134	911
Bats	24	2,299	42	2,557
Rodents	6	71	10	141
Birds	83	1,840	128	1,374
Butterflies	50	559	60	544
Dung Beetles	33	15,679	34	27,013
Total	342	22,810	408	32,540

2.4.2.- Carbon Sequestration

Other environmental service generated by SPS is Carbon sequestration. Carbon is sequestered from the atmosphere by growing trees and by growing pastures with deep and extensive root systems. In the first case, carbon remains in the aerial parts of the trees and the total amount of C sequestered per day depends of the number of trees per hectare, their rate of growth, the species, and the weather conditions existing in the area. In the case of pastures, the carbon sequestered is stored in the roots and in the soil. The net amount sequestered by pastures depends on the grass species, on the soil type and humidity, on the management of pastures and livestock, on the availability of microorganisms in the soil, and on the losses by leaching, fire and other causes (Botero 2000; Pomareda 2004).

Agroforestry systems in the Tropics have a great potential in contributing to mitigate global warming. Combination of C_3 and C_4 species is an efficient sink of C in SPS. For example, in Costa Rica, a research showed that the levels of C in SPS (isolated trees-livestock-grass) was higher in comparison with natural forests (41.2 vs 35.2; 20.9 vs 15.7 and 42.8 vs 24.8 ton C/ha in Low Montano Forest, Very Humid Forest, and Humid Tropical Forest ecosystems, respectively) (Montenegro and Abarca 2001).

2.4.3.- Water

Another environmental service provided by SPS with timber trees could be the protection of watershed recharge zones. Water infiltration is directly proportional to the quantity of biomass in the upper soil. In a research developed in South Dakota, USA, the highest infiltration rate ($p < 0.05$) was in lightly grazed areas (2.95 inches/hr), compared with moderately grazed (1.69 inches/hr), and heavily grazed (1.05 inches/hr) (Rauzi and Hanson 1966). Other study developed in Pakistan showed that the terminal infiltration rate was higher ($p < 0.05$) in the treatment with the highest level of phytomass, 5.22, 4.62, 4.35, 3.66 cm/hr for 2,667, 1,432, 1,020, 627 kg/ha, respectively (Bary *et al*. 1993). Another study mentioned that the average water infiltration rate (inches/hr) and penetration resistance (pounds/inch^2) were 2.27, 58.4; 3.64, 37.9; 4.41, 53.6; and 10.58, 24.3 for the grassy areas of heavily grazed, moderately grazed, lightly grazed, and nograzed pastures, respectively (Rhoades *et al*. 1964). A research developed in the Southwestern of the Iberian Peninsula, compared two components of a rangeland ecosystem of Mediterranean evergreen oak trees (tree-grass and only grass). Soil water storage was higher ($p < .0001$) under tree cover than open grasslands (622 vs 206 mm, respectively), and runoff was greater in open grassland than under tree cover (172 vs 84 mm, respectively) (Joffre and Rambal 1993). In Yucatan, México a research showed that a SPS (*L. leucocephala* and *P. maximun*) with a density of 5,000 plants/ha, had a gravimetric soil water content 27.8 % below of the permanent wilting point. This indicates that the SPS can maintain trough the year a sufficient quality of water in the soil to keep plants growing (Delgado *et al*. 2004). In conclusion, SPS with an adequate management, could increment infiltration rate, and reduce run off and soil compactation.

2.5.- Timber market

and Michie 2001). This represent a fivefold increase in real terms. This total is made up of five major forest product aggregates: roundwood, sawnwood, panels, pulp and paper. Asian-Pacific and Latin American countries expanded their exports at twice (from 8% in 1962 to 16% in 1997) the average rate of growth of that of the world (Wardle and Michie 2001). In addition, exports of processed wood products from International Tropical Timber Organization (ITTO) producers in the Latin America- Caribbean region, reached USD 552 million in 1998, in contrast to the modest start of just USD 81 million in 1989. Much of the growth took place in the early 1990s, when furniture exports multiplied almost sixfold in just four years (1989- 1993) (OIMT 2002).

A study developed in Costa Rica, calculated the real timber stumpage price from 1983 to 1993 in fine, hard, semi-hard, and soft wood. Real prices for fine timber (*C. odorata*) had increased 21% annually between 1988 and 1993, and 14.2% annually between 1983 and 1993. The research concluded that the prices paid for standing timber over the past 5 and 10 years had appreciated at very high rates relative to the overall rate of inflation in Costa Rica, and stumpage prices can be expected to continue rising in real terms (Howard 1995). The size of the affluent urban domestic market tends to be underestimated, despite the fact that it often plays a much more important role in the total trade of further processed than in primary processed products (OIMT 2002). Information above indicated that, timber market is open with a high demand of stumpage wood and processed wood products, and the tendency for the value of the timber wood.

2.6.- Economics of timber trees in Silvopastoral Systems

2.6.1.- Capital theory

Classical economic theory defines capital as a durable good produced by people and used in production. Under this definition, three types of capital assets are distinguished (Klemperer 1996): 1) durable goods such as machinery, equipment, tools, works of art, buildings; 2) financial assets such as savings account, bonds, stocks, and certificates of deposit; and 3) land and natural resources such as coal, oil, and timber. The forest is like a certificate of deposit or a stock, investors can buy it in the hope that over time, it will return more money than they paid for it. However, forests are much more than that and can yield other benefits, such as non timber products and environmental services. But the financial view is a useful framework into which the investor can later weave nonmonetary aspects (Klemperer 1996).

All capital assets can be bought and sold. Also, over the time, the buyer expects to receive more than what was paid for the asset. Broadly speaking if the investors buy an asset, they give up the chance to spend that money now on goods and services. So their reward for postponing expenditure is the extra value receive from an asset above its purchase cost. The simplest example is a savings account: if the investor puts 100 USD in the bank for a year and earn 7 percent interest, the investor can withdraw 107 USD at the end of the year. People do not normally invest capital without expecting some extra return (Klemperer 1996). Timber and forestland are considered capital. Buyers of a forest or those who invest in forest management expect to eventually get more than they gave up for it (in money or nonmoney terms). The amount will be at least as much as they could reap over the same period on an equal amount invested in their best alternative at a similar risk. When investing , they give up an opportunity for earning elsewhere on the same capital: this is the opportunity cost, or the

(Klemperer 1996).

2.6.2.- Interest rate theory

An important feature of forestry is the long production period. It takes often decennia after establishment before yields and revenues are obtained. Also, between the implementation of others silvicultural activities and their revenues a long period can usually be observed. This is in contrast to other business sectors, in which yields can be already achieved after some weeks or months. The long periods between investing and obtaining revenues is seen as a disadvantage. People prefer to have goods and disposal now, rather than after some time. Costs and revenues which occur on different points of time should not simply be compared. To compare costs and revenues which occur on different points of time, we should use a discount rate (Filius 1992).

The rate of interest is the result of the interaction of supply of and demand for capital. The rate of interest in discounting calculations is named the discount rate. The supply of capital depends on the willingness for saving. This willingness in turn is determined by the marginal time preference. The function of the rate of interest in the classical theory is to equilibrate supply of and demand for capital. People think that their income in the future will be higher. The marginal utility of consumption decreases with increases of income as is usually assumed. A transfer of a unit of income from the current period to a future period (in which income is higher) means that the utility of this transferred unit of income is lower than if consumed only. On the other hand, if a unit of future income could be spent now, it would give a higher utility, than if spent later. Beside the decreasing marginal utility of consumption, myopia an the risk of death have been mentioned as reasons for a positive marginal time preference (Filius 1992).

2.6.3.- Multiple use forest management theory

Forest have always been used not only for the production of timber and fuel-wood but also for hunting, grazing, gathering, and fruit. Also, the forest does not want to produce more than one product, say timber, in fact he produces at the same time other products, such as wildlife, recreation opportunities, and environmental services (carbon sequestration, biodiversity, watershed protection, among others). Multiple use forestry has received considerable attention in USA since World War II because recreation opportunities, wildlife and water have become scarce. Scarcity is a result of demand and supply. Demand for these products has increased considerably due to income and population growth. Products, which have a market price, will then realize an increase in price leading to an increase in their supply. Compared to single use, multiple use does not only involve intensification of use, but usually also that of management costs. The higher price (per unit of output) allows the manager to have a higher cost level. However, for recreation opportunities, wildlife and water supply, no market price exists. Therefore, supply will not react on an increase of demand, since an increase of supply will involve an increase of costs. Yet, in most countries, the government felt that supply had to be increased. Multiple use forestry is therefore especially a problem for the government. The question is which mix of products shall be produced, how the manager can produce that mix of products and which interventions could effectively and efficiently be used to stimulate supply of private forestry (Filius 1992).

There are three conceptions of multiple use (Filius 1992). 1) Single use take place in a subarea, but in the whole area several goods/services are produced. The management in a subarea is directed to single use: the primary or dominant use. Secondary use is possible and allowed if this is not at the cost of the primary use. 2) Use and management for more than one function takes place in every subarea, although not all goods/services should necessarily be produced on each subarea. 3) Possibility of multiple use in when different uses are practiced successively along the time.

Several combinations can be produced by implementing the several forest management activities in different ways (Filius 1992). 1) Competitive relationship; it means that more output of one good/service only can be reached if the output of the other good/service is diminished. The products compete for the allocation of production factors. 2) Complementary relationship; it means that the output of one good/service increases as a consequence of the increase of output of another good/service. 3) Independent relationship; two goods/services are independent or indifferent if the output of one good/service does not affect the output of another.

Agroforestry, is a type of multiple use which has received much attention in tropical countries. Also, in agroforestry we have complementary, supplementary and competitive relationships in production (Filius 1992). An example of complementary production in sole cropping is the positive effect of one crop on the crop rotation of another. In modern shifting cultivation, trees fertilize the soil for agricultural crops. An example of supplementary production occurs in sole or intercropping if the crops draw on resources (labour at different times of the year). An example of competitive production will be that, in which trees in grazing forest are often damaged by livestock. These relationships are as a rule complex, because these relationships are not two dimensional, as depicted above, but multidimensional. Insufficient information on these relationships is a major obstacle in rational decision-making in forest resources management (Filius 1992).

2.6.4.- Investment in silvopastoral systems with timber trees

Implementation of SPS with timber trees could be a good investment option for livestock farmers. However it depends on several factors, for example: the SPS designed; the amount of the initial investment; the timber tree species selected; the existence of incentives or a payment for environmental services, among others. In the following paragraphs are presented several experiences that try to explain these assertions.

One of the forms for incorporating timber trees in pastures is through natural regeneration. This technique is based on the selective cutting of vegetation that leaves tree seedlings of valuable timber species. The conventional grasslands management is based on the systematic cleaning of weeds (one or two cuttings per year). Under natural regeneration the most vigorous species of trees are trimmed but not cut. This means that, in each cleaning operation, a lower number of trees are cut off and the weeding interval will be longer. Secondly, it also represents a cheaper implantation of SPS, because this system does not have the expenditure related with buying, carrying and planting the trees (Viana *et al*. 2001). Some estimations showed that is possible to have incomes of 3,000 USD/ha/year or higher depending on timber prices (equivalent to one timber volume of 52 m^3/ha) arising from 54 trees developed under SPS (Camargo *et al.* 2001).

capital on tree management, specially when the trees are young. For example, establishment costs of a silvopastoral system (trees in grasslands) in degraded pasture lands was lower when the trees were not protected with wire fences (515.9 USD/ha) than when they were protected (738.61 USD/ha). However, in the second case (with wire fence), grazing the whole area of pasture could be advanced six months (with an extra income of 155.93 USD/ha for beef sale) relative to the first case (without wire fence) (Carvalho *et al.* 2001). A study in the Southeastern of United States modelled five scenarios (Pine plantation, silvopasture, livestock, soybean, rice), with the objective to determine Land Expected Value (LEV) profitability of the SPS against other land uses. Silvopasture had better profitability (3,096.50 USD), than livestock (2,784.75 USD), soybean (2,860.81 USD), and rice (2,593.57 USD) (Grado and Husak 2004).

The incorporation of timber trees in livestock farms has shown to be profitable. In 1990's, the profitability of two SPS with timber trees (225 trees/ha and 416 trees/ha) and two monocultures (livestock in grasslands without trees) in the Argentine Pampas were compared. The highest values for Internal Rate of Return (IRR), Net Present Value (NPV) and Land Equivalent Ratio (LER) were obtained with SPS with timber trees (Marlats *et al.* 1995). In a study developed in the Southern of Mississippi, Land Expected Value (LEV) were higher (net change 24 - 30%) when silvopasture with timber trees treatments were compared with commercial forest plantations applied on similar sites (Grado *et al.* 2001). In a financial comparison between traditional dairy systems without timber trees and SPS with timber trees in Cayo, Belize, income from timber trees and potential income from environmental services provided by SPS resulted in higher NPV (55,414 USD vs 30,315 USD) and C/B ratio (1.68 vs 1.38) than those without trees (Alonzo and Ibrahim 2001).

The Payment for Environmental Services (CO^2 fixing, biodiversity and water) could be a good strategy to improve the implementation of SPS with livestock farmers. For example, an *ex-ante* benefit-cost analysis determined the effect of the Payment for Environmental Services (PES) in the implementation of SPS under seven representative scenarios of Costa Rica, Nicaragua and Colombia. In all cases, PES helps in the implementation of SPS, while the SPS improve the productive and reproductive parameters in the herd (Gobbi and Ibrahim 2004). A study developed in Lake Okeechobee, Florida, USA, using a stated preference approach determined that the households would to pay from 30.24 to 71.17 USD per year for 5 years to livestock farmers that implement environmental friendly SPS in the watershed recharging zone (Shrestha and Alavalapati 2004; Alavalapati *et al.* 2004).

3.- Methodology

3.1.- Study area

This study was conducted in the Esparza area, located in the Central-Pacific Region of Costa Rica (figure 1). The region has an extension of 2,835.63 km^2 and includes the "*cantones*" (equivalent to county) of Puntarenas, Esparza, Montes de Oro, Aguirre, Parrita, Garabito, San Mateo and Orotina. Esparza is located between the coordinates 10°10' North and 84°42' West with an altitude of 140 m.a.s.l. The average annual temperature is 27.2°C, with a maximum of 36°C and a minimum 23°C. It has a bimodal rain regime, with high incidence of rains in June, September and October. The average annual precipitation is 2,040 mm/year. The relative humidity is between 60 and 65% in the dry season, and 80-85% during zone is Forest Tropical Sub-Humid (Holdridge 1978). The Esparza region has a population of 23,963 (13,561 in urban areas and 10,402 in rural areas), 59% are in productive age. Population annual growth rate is 1.9 %. The Social Development Index (SDI) is 62.8[1] and the literacy rate is 95%.

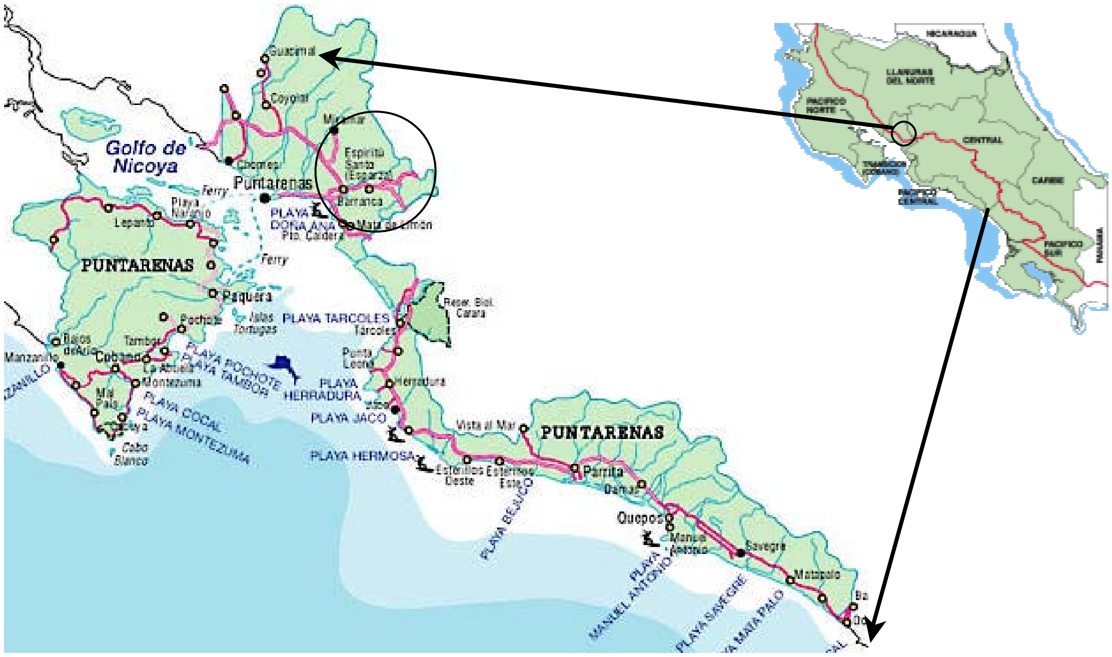


Figure 1.- Study area location, Esparza, Puntarenas, Costa Rica, CA.

3.2.- Models of financial analysis

An ex-ante benefit cost analysis was developed to explore the financial feasibility of incorporating Silvopastoral Systems with timber trees under different arrangements in livestock farms in the Sub-humid Tropics of Costa Rica. The analysis was conducted following the methodology proposed by Brown (1981); Gittinger (1982); Gobbi (2000), and Navarro (2003a). The models considered the situation “without project” (livestock system) versus “with project” (livestock systems with timber trees) in order to calculate the incremental net benefits due to the investment.

3.2.1.- Model definitions

With the objective to define the models, 60 interviews and 45 field trips were conducted with farmers in the zone. Interviews were carried out with the following goals:

i. To understand farmer’s perception about SPS
ii. To identify which SPS with timber trees they prefer
iii. To identify the extend of timber trees they want to implement
iv. To define which conditions should exist to implement SPS

[1] This index is a summary of several social indicators such as educative infrastructure, children death rate, electricity consumption per month and general death rate. This index fluctuates between 0 and 100 (100 is the best indicator) (http://www.inec.go.cr).

useful timber tree species existing on the farms; and to determine the capital, and land value in each type of farm. After that, several SPS with timber trees were designed according to farmer's opinion, and these designs were modeled into one hectare. The identified SPS with timber trees according farmer's opinion are shown in table 4.

Table 4.- Models designed with timber trees in SPS according to farmer's opinion. Esparza, Costa Rica. 2004.

Number of model	SPS with timber trees
Model 1	Timber trees in fences
Model 2	Timber trees under natural regeneration in natural grassland with fattening livestock production system
Model 3	Secondary regeneration forest (tacotal) enriched with timber trees in degraded grassland
Model 4	Planting timber trees in a perpetual system in improved grassland with fattening livestock production system

3.3.-Sources of information

Several sources were consulted for developing the models. They are mentioned below.

3.3.1.- Livestock component

i. Maintenance costs for grassland and livestock were obtained from the socioeconomic diagnosis implemented by the Integrated Silvopastoral Approaches to Ecosystem Management Project (financed by GEF and administrated by CATIE) from April to September 2004.
ii. Sales prices for male calve and young bulls were obtained from the regional livestock auction AGAINPA (Pacific Zone Independent Livestock Association).

3.3.2.- Timber component

i. *C. odorata* was the timber species selected. This species was chosen because it is a native species, and is one of the most preferred timber species for the farmers. It grows by natural regeneration in grasslands, is the most demanded by the woodworkers in the zone, and has a good price in the local and regional market. To estimate the growth of *C. odorata* several equations were developed using the Software Silvia[?] developed by CATIE.
ii. Price for standing wood (68.143 USD/m^3) was obtained from local woodworkers, Esparza regional sawmill and the Costa Rican Forest Chamber (appendix 6[a]).
iii. Establishment costs and management budgets for *C. odorata* were based on information from Reiche (1991), Reiche and Gómez (1993), Gómez and Reiche (1996), Black Solis (2003), livestock farmers and key informants (Agricultural and Livestock Bureau of Costa Rica, and CATIE's forest experts).

3.4.- Model development

Four SPS with timber trees were modeled into one hectare: 1) timber trees in fences, 2) timber trees under natural regeneration in natural grassland with fattening livestock production system, 3) secondary regeneration forest (tacotal) enriched with timber trees in degraded grassland, 3[a]) tacotal without timber trees, and 4) planting timber trees in a perpetual system in improved grassland with fattening livestock production system.

3.4.1.- Livestock and grasslands maintenance costs

Maintenance costs for the livestock and grasslands components in the models were obtained from a socioeconomic diagnosis developed by the GEF-Project and applied to 30 livestock farmers in the zone. Table 5 and appendix 1, 2, 3 and 4 present the information. All information is presented in USD with a exchange rate of 1 USD = 430 colones (colon is the Costa Rican currency).

Table 5.- Annual maintenance costs for livestock and grassland components, Esparza, Costa Rica. 2004.

Component	Annual maintenance cost (USD)
Livestock (from calf to young bull) (USD/calf/year)	38.53
Degraded Grassland (USD/ha/year)	23.98
Natural grassland (USD/ha/year)	85.9
Improved grassland (USD/ha/year)	17.0

1 USD = 430 colones

Grazing capacity estimated for degraded, natural, and improved grassland were 0.2, 0.5, and 1.5 AU/ha/year, respectively. These parameters were estimated from the interviews with livestock farmers and two salesmen of forage seeds in the zone.

3.4.2.- Livestock prices for calve and young bulls

Livestock auction AGAINPA proportioned the information (table 6). This information included livestock prices and weights in each class of bovine from January to September 2004 (appendix 5 and 5[a]).

Table 6.- Sale prices and sale weights for the livestock component in the models. Esparza, Costa Rica. 2004.

Livestock component	Kilogram sale price (USD)	Sale weight (kg)
Male calf	0.986	157
Young bull	0.901	287

1 USD = 430 colones

3.4.3.- Canopy shadow interactions with components of the SPS

biomass production of the grasslands of minus 30% in natural grasslands and minus 15% in improved grasslands. They were estimates based on several researchs (Acciaresi *et al.* 1994; Bolívar *et al.* 1999; Villafuerte *et al.* 1999; Andrade *et al.* 2000; Mochiutti and Lima 2000; Andrade and Ibrahim 2001; and Alvim et al. 2004).The methodology to estimate this effect is presented below.

1.- To calculate total area covered by the canopy

First, Breast high diameter (bhd) of trees for each year was determined with the software Silvia?. Following, canopy area was determined with the equation Y= 2.11(bhd), developed by Esquivel *et al*. (2004). Then, the result was multiplied by the number of trees/ha modeled for each year.

2.- To adjust the herd to the new grazing capacity.

The following steps were developed. First, to determine how many AU were affected by the canopy area. This calculation was made following the next assumptions: one hectare of natural pasture (10,000 m^2) can maintain 0.5 AU, how many AU can maintain the total area covered with the trees (i.e. 3000 m^2). For example: (3,000 m^2 x 0.5 AU)/10,000 m^2 = 0.15 AU are affected by canopy shadow. Second, to model the reduction in biomass production under the canopy area (i.e. 0.15 AU x -30% = -0.045 AU), and to subtract this proportion of AU at the normal capacity of grazing (i.e. 0.5 AU -0.045 AU = 0.455 AU). In this case, 0.455 is the AU capacity for one hectare of natural grassland adjusted with the canopy shadow effect.

The second interaction modeled was an increment of 10% in beef production due to the comfort proportioned by the canopy shadow (Restrepo Sáenz 2002; Abreu de Souza *et al.* 2004). This effect begins in the sixth year after planting the trees, because it was estimated that at this age the trees had enough canopy to provide comfort to the livestock component.

3.4.4.- Estimation of timber production

With information from 91 experimental plots of *C. odorata* in Colombia, Costa Rica, Panama, and Nicaragua (Ford 1979; Castaing 1982; CONIF 1985; CATIE 1986; Vega 1987; Guevara 1988; and Flores 2002), equations of diameter, basal area, high, and total wood production with cortex were developed by Alvaro Vallejo (CATIE's Forest Technician) (Table 7). Afterwards, those equations where incorporated into the simulation module of the Software Silvia? developed by CATIE for estimating the growing models of *C. odorata*. The followings assumptions were taken into account for building the growing models in the simulation module (table 8).

Table 7.- Equations for modelling growth of *Cedrela odorata* used with the Software Silvia?, Esparza, Costa Rica. 2004.

Diameter	Exp(2.80201 - 5.261363/T + 0.058453*S - 0.000468*N)
Height	EXP(Ln(S) - 5.3866 * (1/T - 0.1))
Basal Area	Exp(0.957189 - 9.211785/T + 0.111422*S + 0.000886*N)
Total wood production with cortex	0.766711* H^1.027328*G^0.994234

Source: Software Silva? CATIE 2004.

Table 8.- Initial and final densities, and years to final turn used in the model to estimate growth of *Cedrela odorata*, with the Software Silvia?, CATIE, Turrialba, Costa Rica. 2004.

Model	Initial Density (trees/ha)	Final density (trees/ha)	Final turn (years)
1	132	66	25
2	200	50	25
3	400	100	27
4	20	5	25

Each financial model was designed including three different site qualities for timber growth (bad, regular and good). It is important to indicate that bad site quality was taken as the base line scenario for all the financial models.

3.4.5.- Estimation of PES

For each of the financial models developed, the methodology to apply PES utilized in the present study was developed by the Integrated Silvopastoral Approaches to Ecosystem Management Project (GEF-Project) (Word Bank 2002). The underlying principle of the proposed payment system is that the farmer provides environmental services by changing land use on his/her livestock farm from mono-culture of native pastures to more complex vegetation systems. Thus, changes in land use patterns are an indicator of the volume of environmental services provided. There are 28 forms of land uses in the selected sites, ranging from the degraded natural pastures to secondary forest. All land use forms are given points according to their capacity to sequester carbon and to sustain biodiversity. The highest index is assigned to the primary forest (one point to biodiversity and one point to carbon sequestration) and no points are given to degraded pastures (zero points for biodiversity and zero points for carbon sequestration), more information in appendix 6 (Word Bank 2002).

The payment systems compensates for carbon sequestration and increments in the biodiversity, and is based on the land use change index. The index was based on the following information. In the case of carbon, a secondary forest can fix an average of 10 tons of carbon per year in wood and the soil. For example; secondary forest has a value of 1 point in the index, therefore 1 point corresponds to 10 ton of carbon. Improved pastures fixes one half the amount of carbon that secondary forest does. In the case of biodiversity, it is know that biodiversity is affected by multiple factors including number of plant species, spatial arrangement, stratification, plot size, fruit production, among others. But is closely related to the diversity and complexity of the plant species in a given form of land use. Values for biodiversity are assigned according to natural biodiversity (plants, birds, small mammals and insects) that a particular land use can sustain. Higher values (one point) are given to land use forms that have the greater potential to maintain the original biodiversity of the region (Word Bank 2002).

There are two payment schemes. In the first scheme, the farmer will receive an annual PES, computed according to the index, along the payment period (4 years). The amount to pay for each point in the index will be USD 75. In the second scheme, the farmer will receive an annual PES, computed according to the index, for a two-year period. The amount to pay for each point in the index will be 110 USD. Table 9 shows an example of the computation of the PES following the methodology developed by the GEF-Project (Word Bank 2002).

Table 9.- Computation of the PES following the methodology developed by the GEF-Project, Esparza, Costa Rica. 2004.

Scheme	Land use (year 0)	(A) Points	Land use (year 1)	(B) Points	(C) difference (B-A)	(D) Point value (USD)	(E) PES (year/ha) (C*D)	(F) Years	PES (total/ha) (E*F)
One	Improved Pasture without trees	0.5	Improved pasture with high density of trees	1.3	0.8	75	60	4	240
Two	Improved Pasture without trees	0.5	Improved pasture with high density of trees	1.3	0.8	110	88	2	176

Source: World Bank 2002.

3.4.6.- Cash Flows

Annualized cash flows were built for each model, their characteristics are described below:

i. The cash flow period was 25 years for Model 1 and 2, 27 years for Model 3, and to perpetuity in Model 4. Those periods were defined based on the final turn of the timber component.
ii. The discounted cash flow follows the assertion that all investments are accounted at the end of the year. Thus, the investment in SPS with timber trees are registered in the year 1.
iii. The cash flow is expressed in USD, with the following money exchange rate 1 USD = 430 colones.
iv. Prices of income and costs were expressed in constant terms.
v. The agriculture and livestock borrowing rate in Costa Rica on October 23rd was 21.25 %
vi. The estimated inflation rate for 2004 was 13.78 % (Costa Rica, Banco Nacional, 2004).
vii. The real discount rate was 6.56 %. It was estimated with formula proposed by Klemperer (1996).
viii. The value of the land in the zone was estimated at 1,918 USD/ha.

3.4.7.- Sensitivity analysis

Whether or not the structure of a Cost Benefit Analysis is explicit in terms of contingencies and probabilities, always faces some uncertainly about the magnitude of the impacts predicted and the values assigned to them. The purpose of a sensitivity analysis (SA) is to acknowledge uncertainty. It follows the *ceteris paribus* assumption. It should convey how sensitive the predicted net benefits are to changes in the value of a parameter. If the sign of net benefits does not change limitations. First, they may not take into account all available information about assumed values of the parameters. Second, this technique does not directly provide information about the variance, or spread, of the statistical distribution of realized net benefits (Boardman *et al.* 2001). Discount rate and wood price were the variables utilized in the sensitivity analysis for the models, with the following ranges: from 1% to 22% for the discount rate, and from 0 USD to 136.26 USD/m^3 for the wood price.

3.4.8.- Monte Carlo risk analysis

Monte Carlo Risk Analysis (MCA) provides a way of overcoming uncertainty. MCA has played an important role for many years in the investigation of statistical estimators whose properties cannot be adequately determined through mathematical techniques alone. The basics steps for doing MCA analysis are as follows (Boardman *et al.* 2001).

i. To identify risk variables in the models.
ii. To specify probability distributions in the risk variables.
iii. To identify the outputs.
iv. To select the number of interactions (5,000). The average of the trials provides an estimate of the expected value of net benefits.
v. The resulting histogram of these counts provides a picture of the distribution. The more trials that go into the histogram, the more likely it is that the resulting picture gives a good representation of the distribution of net benefits. The histogram provides a visual display of the entire distribution of net benefits so that its spread and symmetry can be easily discerned. The trials themselves can be used to calculate directly the sample variance, standard error, and other summary statistics describing net benefits.

The risk analysis was made with the software @Risk developed by Palisade Corporation. The risk variables identified were sale price for wood and beef. Wood price was modeled with a triangular distribution with a minimum value of 65.5 USD, a more likely value of 68.14 USD, and a maximum value of 70.5 USD/m^3. Beef sale prices were modeled with a Lognormal distribution (0.986; 1). The quantity of iterations were 5,000 for each model, and Monte Carlo simulation was the sampling type used.

3.4.9.- Financial indicators

For each model several investment indicators were estimated: Net Present Value (NPV), Land Expected Value (LEV), Internal Rate of Return (IRR), and Benefit/Cost ratio (B/C).

3.4.9.1.- Net Present Value

NPV of a project is the difference between the present value of the benefits and the present value of the costs (Boardman *et al.* 2001). In other words, NPV is the present worth of the incremental net benefit or incremental cash flow stream. The decision rule is accept all projects with a NPV ? 0 (Filius 1992). The NPV indicator allows comparisons to be made between different investment alternatives over dissimilar time periods. NPV is examined at various discount rates. The discount rate can be viewed as the opportunity cost of using money. This means that the discount rate represents the next best use of money invested in the agroforestry enterprise. This allows assessment of the effects of the chosen discount rate on NPV (Dangerfield Junior and Harwell 1990). NPV marginal concepts is valid when the investments do not consider the price of the land. It also has a few weaknesses. NPV does not consider the scale of the project, a long term project will be more profitable than a short term one; and it does not consider the opportunity cost of the land (Filius 1992; Navarro 2003b). NPV is represented by:

Where:
I = Inputs
O = Outputs
i = Discount rate
t = Time

$$NPV = \frac{\sum_{y=1}^{t} (I_t - O_t)}{(1+i)^t}$$

Source: Gittinger 1982

3.4.9.2.- Land Expected Value

LEV represents a specialized form of net present value analysis used in investment ranking. It estimates the value of the land and is often used to evaluate mutually exclusives land use alternatives. The LEV is the amount an investor could pay for bare land and still earn the minimum acceptable rate of return. This formulation is compatible with both forestry and agricultural investments (Grado *et al.* 2001). LEV is calculated for forestry investments using the present value of a perpetual periodic series formula:

Where:
I = Inputs
O = Outputs
i = Discount rate
t = Time
-1 = Perpetual periodic ser

$$LEV = \frac{\sum_{y=1}^{t} I\,(1+i)^t - \sum_{y=1}^{t} O\,(1+i)^t}{(1+i)^t - 1}$$

Source: Faustmann 1849 cited by Navarro 2003b

LEV assumes that annual and/or periodic costs and revenues projected for a certain time period are repeated in perpetuity. All costs and revenues associated with the first rotation of timber were considered with the exception of the land opportunity costs. Land value does not enter into the calculation because land value is being derived. Timber yields were projected from established growth and yield equations. A selection of the best management regime (timber trees in fences, trees in natural grasslands, natural regeneration, and trees in improved grasslands) was made through this comparison as the land use with the highest LEV was considered the best use from a financial standpoint (Grado *et al.* 2001). In addition, the formula of LEV is a good instrument to find not only the good shift, but also to demonstrate the importance of the environmental services and the forest like an ecosystem (Marozzi 2002).

bare land value for the site when committed to a particular regime into perpetuity. A comparison of all LEV obtained from various regimes allows to rank them on the basis of their potential returns. NPV and IRR are used only for accepting or rejecting investment decisions. Equivalent annual income (EAI) and LEV are used for ranking investment decisions (Grado and Husak 2004). The decision rule is to accept a project if its LEV is greater than 0 (Filius 1992). LEV has the following strengths: all the projects have the same planning horizon; it is based on marginal concepts, it allows to better define the value of the active; and the project is measured by a unit of area (i.e. hectare). Also has some weaknesses. It assumes that the activity is sustainable; it depends on the price of the land; and takes into account only market benefits (Navarro 2003b).

3.4.9.3.- Internal Rate of Return

Another way of using the incremental net benefit stream or incremental cash flow for measuring the worth of a project is to find the discount rate that makes the net present worth of the incremental net benefit stream or incremental cash flow equal zero. This discount rate is called the Internal Rate of Return. It is the maximum interest that a project could pay for the resources used if the project is to cover its investment and operating costs and still break even (Gittinger 1982; Boardman *et al.* 2001). The decision rule is to accept that project which gives an equal or higher IRR than a minimal desired rate of interest (Filius 1992). However, it is not always recommended for use in agroforestry as it can give misleading results if there are differences in benefit stream, and it cannot be used at all if there is no negative cash flow at the beginning (Scherr *et al.* 1992).

3.4.9.4.- Benefit-Cost ratio

This ratio is obtained when the present worth of the benefit stream is divided by the present worth of the cost stream. The absolute value of the B/C ratio will vary depending on the interest rate chosen. The higher the interest rate, the smaller the resultant benefit-cost ratio (Gittinger 1982). The decision rule is accepted all projects with a B/C ratio ? 1 (Filius 1992). One convenience of this ratio is that it can be used directly to note how much costs could rise without making the project economically unattractive (Gittinger 1982). A weakness of this ratio is that it is not clear what to consider among the benefits and what among the cots (Filius 1992). Its formula is presented below:

$$\frac{\sum_{t=1}^{?} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{?} \frac{C_t}{(1+i)^t}}$$

Where:
B_t = benefits of the project in year t
C_t = costs of the project in year t
i = discount rate

3.4.10.- Results presentation

Result were presented in the following order:

secondary regeneration, and isolated trees in improved grassland at perpetuity).

ii) SPS establishment costs (investment in the situation “with project”).

iii) SPS operation costs, comparison of the situation “with” vs “without project”.

iv) Wood production and incomes from timber component in three site qualities (bad, regular and good).

v) Financial indicators; NPV, IRR, B/C, and LEV.

vi) Site quality effect on financial indicators.

vii) Cash flow analysis (situation “with” vs “without project”) and the net incremental benefits

viii) PES effect in cash flow and financial indicators.

ix) Bad site quality was considered as base line scenario to develop the sensitivity and risk analysis. It was based on the following assumption: if in bad site quality the investment passes the test, under regular and good conditions the indicators would be better.

x) Sensitivity analysis.

xi) Risk analysis.

4.- Results

4.1.- Model 1, Timber trees in fences

4.1.1.- Model description

The first model corresponds to the incorporation of timber trees into existing living fences surrounding one hectare of improved grassland. Model 1 has the following characteristics: trees were planted in 400 lineal meters at 3 x 3 m (132 initial density), with one thinning in year 10, and 66 trees at final turn. The most common specie in existing living fences in the zone is *Bursera simaruba*. Timber trees of *C. odorata* were planted 20 cm separated from the wire fence, and between the posts of *B. simaruba* (Figure 2). The trees are planted under this design with the following objectives: to avoid damage of fence wire, to protect the trees against cow’s damage, and to reduce competition with living fence trees. The livestock-fences was modeled.

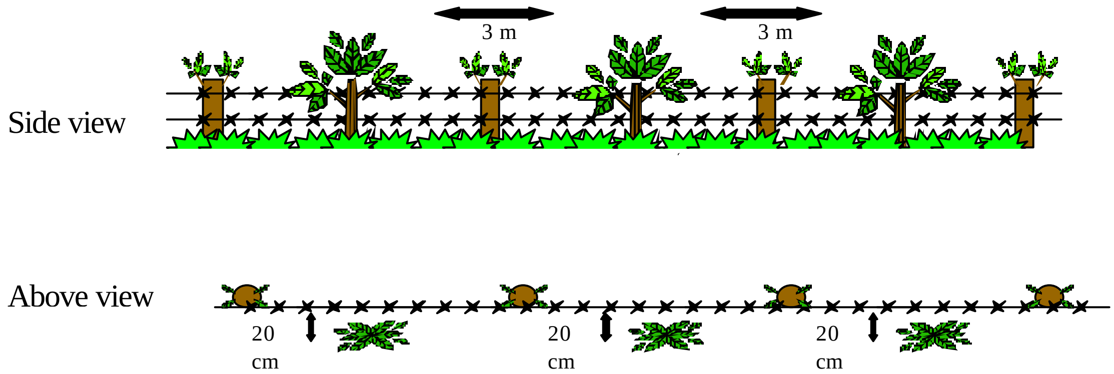


Figure 2.- Model 1, design of timber trees in an existing living fence. Esparza, Costa Rica. 2004.

4.1.2.- Establishment costs

To establish 400 lineal meters of trees in an existing living fence costs 104.70 USD. The larger proportion of establishment costs are materials (58.6%). Establishment costs are presented in table 10 (more details in appendix 7).

Table 10.- Establishment costs for 132 timber trees in 400 m of existing living fences (3 m between the trees). Esparza. Costa Rica. 2004.

Concept	**USD/ 400 mt**
Labor	18.56
Material	61.40
Total	**104.70**

1 USD = 430 colones.

4.1.3.- Operating costs

Model 1 operating costs for the management of 132 trees are presented in table 11 (more information in appendix 7). Higher incremental costs are incurred in the first three years, as more intensive silvicultural management was applied in those years. The management included weeds cleaning, fertilization, technical assistance, and formation pruning. In addition, from year four to year ten incremental costs were lower in comparison with the first three years. Management in those years included weeds cleaning and formation pruning, and one thinning in year ten. Finally, from years eleven to twenty-five, incremental costs were zero.

Table 11.- Model 1, operation costs of 132 timber trees in 400 m of existing living fences (3 m between the trees). Esparza, Costa Rica. 2004.

Situation	**Concept**	**Year**						
		1	**2**	**3**	**4-5**	**6-9**	**10**	**11- 25**
With project	Labor	38.74	38.74	38.74	34.96	46.58	20.96	210
	Material	0	21.80	29.38	0	0	0	0
	Total (A)	**38.74**	**60.54**	**68.12**	**34.96**	**46.58**	**20.96**	**210**
Without project	Labor	14.0	14.0	14.0	28.0	28.0	14.0	210
	Material	0	0	0	0	0	0	0
	Total (B)	**14.0**	**14.0**	**14.0**	**28.0**	**28.0**	**14.0**	**210**
Incremental Costs (A-B)		24.74	46.54	54.12	6.96	18.58	6.96	0

4.1.4.- Wood production and income from the timber component

Wood production and incomes generated in the tree site qualities modeled for the timber component are presented in table 12 (more information in appendix 8). Timber production and revenues generated by wood sales were three times lower in the bad site quality, and two times lower in regular site quality in comparison with the results obtained in the good site quality. In conclusion, site quality selection is very important in timber productivity.

Table 12.- Total timber production at final turn (25 years) under three different quality sites. Sixty-six timber trees surrounding one hectare of improved grassland. Esparza, Costa Rica. 2004.

	Site quality		
	Bad	**Regular**	**Good**
Number of trees/final turn	66	66	66
M^3/ ha/ final turn	34.68	50.14	99.55
USD/ ha/ final turn	2,362.74	3,416.03	6,782.34

1 USD = 430 colones. 1 m^3 = 68.13 USD

4.1.5.- Financial analysis

4.1.5.1.- NPV, LEV, IRR, B/C results

Model results are presented in table 13. In all scenarios modeled the investment were profitable. Good site quality presented a NPV that was five times higher than that from bad site quality. IRR in good site quality was 5.2% and 1.8% higher in comparison with bad and regular site quality, respectively. B/C ratio in good site quality was three times, and two times higher than those from bad, and regular site quality, respectively. Finally, LEV in good site quality was 1.05 and 1.25 times higher than those from regular and bad site quality, respectively.

Table 13.- Site quality effect on investment profitability. Model 1, timber trees in 400 m of existing living fences. Esparza, Costa Rica. 2004.

Site quality	NPV* (USD)	IRR* (%)	B/C	LEV** (USD)
Bad	275.63	10.6	2.33	2,698.39
Regular	490.76	12.4	3.37	2,850.29
Good	1,178.45	15.8	6.69	3,359.32

*1 USD = 430 Colones. **Value of the land = 1,918 USD/Hectare. Discount rate 6.56 %

Net cash flow comparison between the situation “with” vs “without project” presents a difference in the first three years (figure 3). However, the income generated in year 25 (wood sale), made the investment profitable.

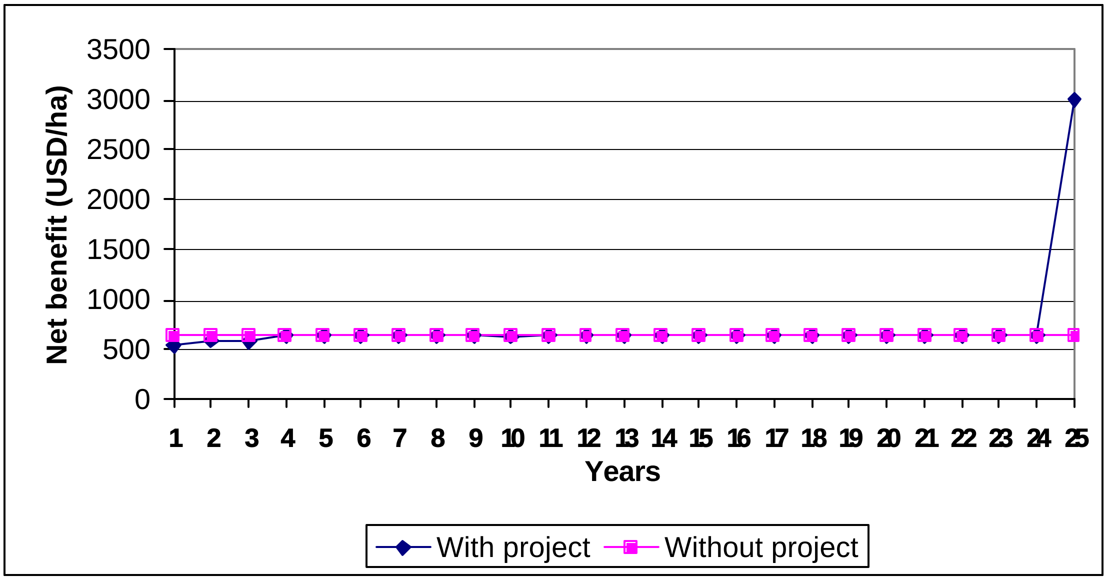


Figure 3.- Net cash flows, situation with vs without project. Model 1, timber trees in 400 m of existing living fences. Esparza, Costa Rica. 2004.

4.1.5.2.- PES effect on investment profitability

PES increment the profitability of the investment 18% under payment scheme one, and 8% under payment scheme two when considering the NPV indicator. It also increments the profitability of the investment 14% and 7% under the mentioned payment schemes when considering the LEV indicator. Table 14 shows the PES computation for Model 1, and table 15 presents PES effect on investment profitability. In addition, figure 4 shows cash flows with PES in schemes one and two, and without PES.

Table 14.- PES estimation for Model 1, timber trees in 400 m of existing living fences. Esparza, Costa Rica. 2004.

Land Use					**Score/ km Points**
Living fence (one specie)					0.6 pts
Multi-stratum fence (Two or more species)					1.1 pts
Difference					0.5 pts
Payment	**Time/ years of PES**	**USD/ point**	**Difference in land use (points)**	**Km of Fence**	**PES/year/ Ha (USD)**
Scheme one (four years)	4	75	0.5	0.4	15.0
Scheme two (two years)	2	110	0.5	0.4	22.0

Table 15.- PES effect on investment profitability. Model 1, timber trees in 400 m of existing living fences. Esparza, Costa Rica. 2004.

Site quality	Payment for Environmental Services	NPV* (USD)	IRR* (%)	B/C	LEV** (USD)
Bad	Without	275.63	10.6	2.33	2,698.39
	PES (Scheme one)	326.95	12.0	3.10	2,914.33
	PES (Scheme two)	315.65	11.7	2.89	2,888.39

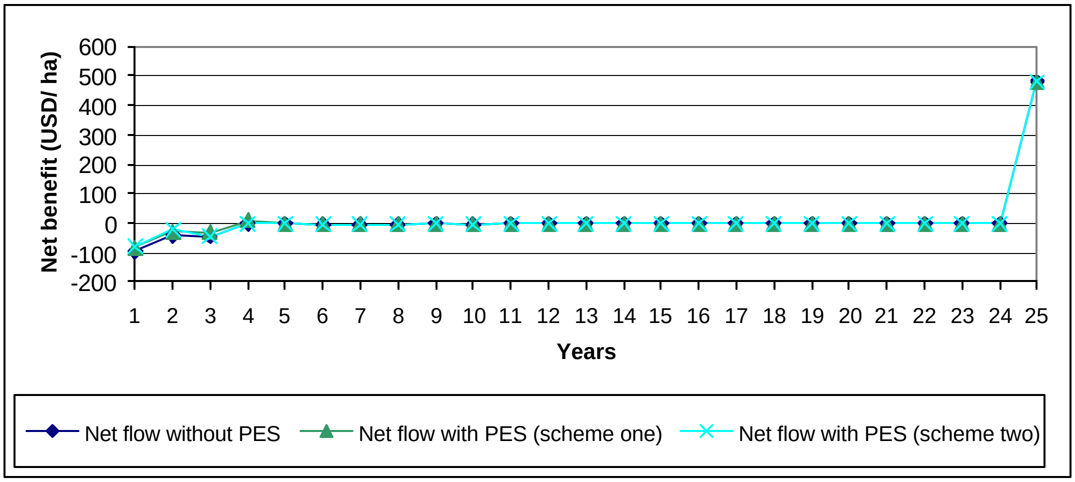


Figure 4.- PES effect on discounted cash flow, comparison with vs without PES. Model 1, timber trees in 400 m of existing living fences. Esparza, Costa Rica. 2004.

Although the PES increases investment profitability, its contribution in the net cash flow is marginal (only 38% and 28% of the establishment costs are covered by PES under schemes one and two, respectively). An increment in the value of the point could increment the project feasibility.

4.1.5.3.- Sensitivity analysis

Effect of changes in discount rates and in wood prices on model's profitability are presented in tables 16 and 17. NPV and LEV were sensitive to changes in the discount rate, because an increment in the discount rate of 4.4% and 2.44% respectively, made unprofitable the investment. In contrast, both indicators were robust to changes in wood prices. In the case of NPV, IRR, and B/C, it was necessary a decrease of 60% in the price of wood to collapse the investment. LEV indicator was insensitive to wood prices.

Table 16.- Sensitivity analysis, discount rate effect on financial indicators. Model 1, timber trees in 400 m of existing living fences. Esparza, Costa Rica. 2004.

Discount Rate (%)	NPV* (USD)	IRR* (%)	B/C	LEV** (USD)
1	1,606.09	10.6	7.79	19,498.68
2	1,209.81	10.6	6.25	9,557.44
3	903.73	10.6	5.02	6,254.15
4	666.91	10.6	4.04	4,609.27
5	483.39	10.6	3.25	3,626.85
6	340.99	10.6	2.63	2,975.13
7	230.38	10.6	2.12	2,512.52
8	144.40	10.6	1.72	2,167.06
9	77.56	10.6	1.39	1,900.46
10	25.60	10.6	1.13	1,688.10
11	- 14.76	10.6	0.92	1,515.54
12	- 46.06	10.6	0.75	1,372.69

*1 USD = 430 Colones. **Value of the land = 1,918 USD/Hectare. Discount rate 6.56 %

Table 17.- Sensitivity analysis, effects of changing wood price on financial indicators. Model 1, timber trees in 400 m of existing living fences. Esparza, Costa Rica. 2004.

Wood price change (%)	NPV* (USD)	IRR* (%)	C/B	LEV** (USD)
- 100%	-	-	-	2,426.32

- 50%	34.31	7.3	1.16	2,546.12
- 40 %	81.83	8.1	1.39	2,572.96
- 30%	130.06	8.9	1.63	2,602.30
- 20%	178.29	9.5	1.86	2,633.04
- 10%	226.52	10.1	2.09	2,665.11
0 %	275.63	10.6	2.33	2,698.39
+ 10%	322.98	11.1	2.56	2,731.16
+ 20%	371.43	11.5	2.79	2,764.69

*1 USD = 430 Colones. **Value of the land = 1,918 USD/Hectare.

4.1.5.4.- Risk analysis

Figure 5 and 6 show risk analysis results. Figure 5 showed that the investment had low risk when risk for wood price was modeled using the NPV indicator. LEV was insensitive to risk for wood price. However, risk in beef price made less confident the option, since a probability of 52.3% of failure exists for the investment.

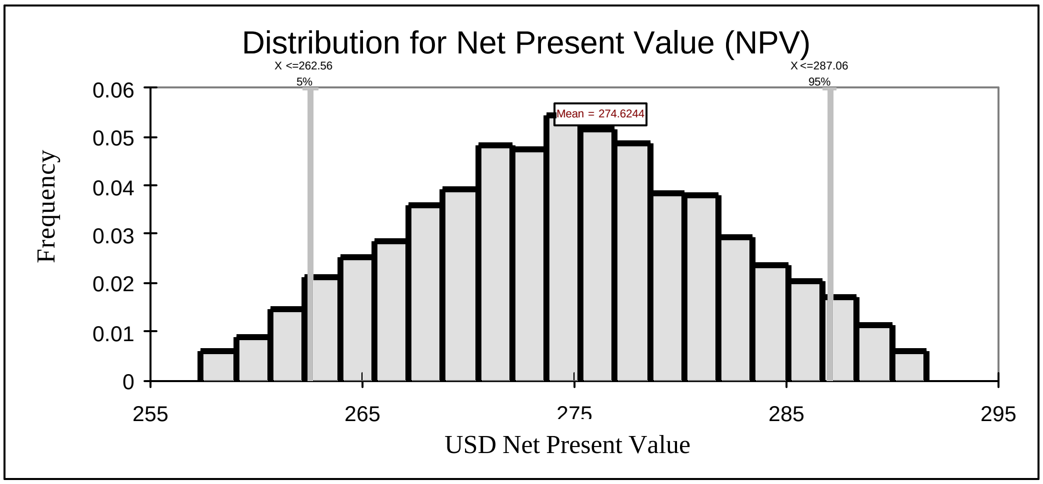


Figure 5.- Model 1, timber trees in 400 m of existing living fences. Risk analysis, distribution for Net Present Value (NPV) applying risk in wood price. Esparza, Costa Rica. 2004.

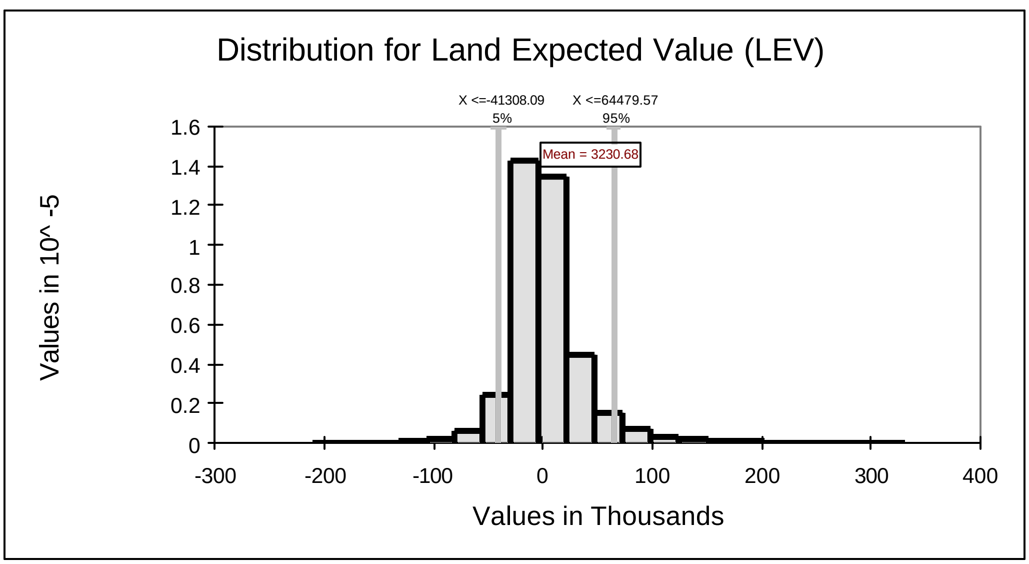


Figure 6.- Model 1, timber trees in 400 m of existing living fences. Risk analysis, distribution of Land Expected Value (LEV) applying risk in beef price. Esparza, Costa Rica, 2004.

4.2.- Model 2, Timber trees under natural regeneration in native grassland

4.2.1.- Model description

The second model designed was one hectare of *H. rufa* grassland with natural regeneration of *C. odorata* (figure7) . In the first year 200 timber trees were selected. The number of timber trees at final turn (25 years) was 50 trees/ha. Two thinning were developed in year 8 and 15. The livestock component corresponded to two calves that were fattened from 157 to 287 kg in one year.

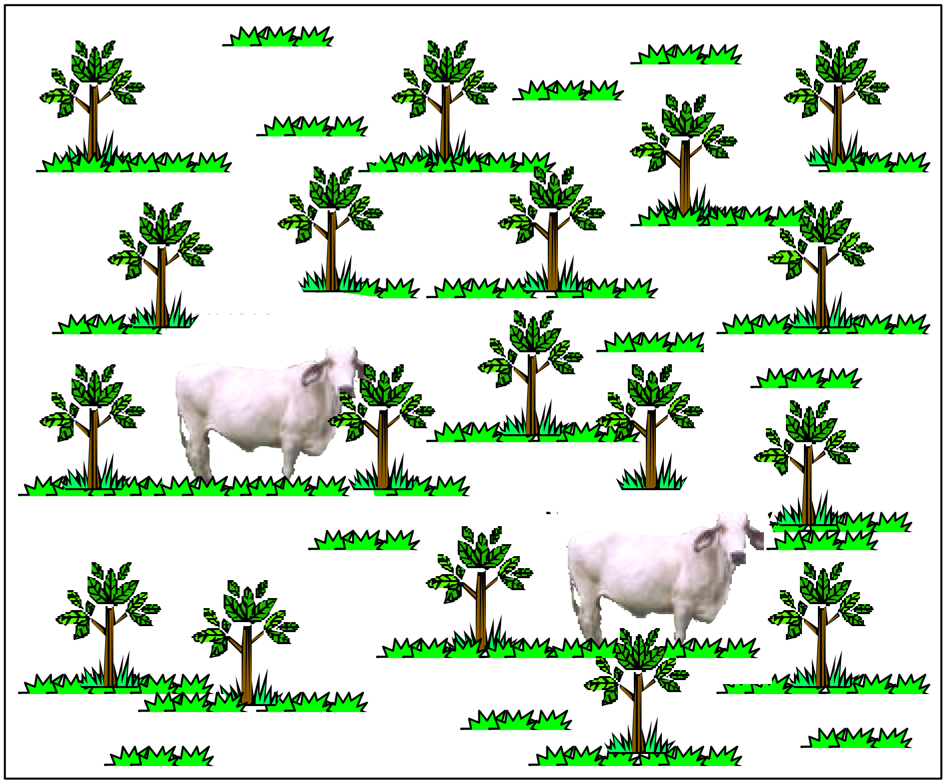


Figure 7.- Model 2, design of the timber trees under natural regeneration in a native grassland. Esparza, Costa Rica. 2004.

4.2.2.- Establishment costs

Model 2 establishment costs are presented in table 18 (more details in appendix 11). The investment to establish the timber component was 34.89 USD. Materials represented 90% of the establishment costs.

Table 18.- Establishment costs of 200 timber trees under natural regeneration in one ha of native grassland. Esparza, Costa Rica. 2004.

Concept	USD/ ha
Labor	3.49
Material	31.4
Total	34.89

1 USD = 430 colones

4.2.3.- Operating costs

Model 2 incremental costs are presented in table 19 (more information in appendix 11). Table below shows that the largest incremental costs were done in the first three years. Because, in these years, management was more intensive (weeds were lower, as management was less intensive (weeds cleaning and formation pruning) and two thinnings were developed in years 8 and 15. Finally, since year 16 there were no incremental costs, since management for both situations was the same.

Table 19.- Operation costs of 200 timber trees under natural regeneration in a native grasslands with two fattening calves. Esparza, Costa Rica. 2004.

Situation	Concept	Year								
		1	**2**	**3**	**4-5**	**6-7**	**8**	**9-10**	**15**	**16 -25**
With project*	Labor	120.1	120.1	120.1	186.8	193.8	110.8	193.8	103.8	829
	Material	80.0	112.7	124.1	160.0	160.0	80.0	160.0	80.0	800
	Total (A)	**200.1**	**232.8**	**244.2**	**346.8**	**353.8**	**190.8**	**353.8**	**183.8**	**1,629**
Without project+	Labor	82.9	82.9	82.9	165.9	165.9	82.9	165.9	82.9	829
	Material	80.0	80.0	80.0	160.0	160.0	80.0	160.0	80.0	800
	Total (B)	**162.9**	**162.9**	**162.9**	**325.9**	**325.9**	**162.9**	**325.9**	**162.9**	**1,629**
Incremental Costs (A-B)		37.2	70.0	80.4	20.9	27.9	27.9	27.9	20.9	0

1 USD = 430 colones. * timber, livestock, and grassland components. + livestock and grassland component.

4.2.4.- Wood production and income from timber component

Wood production and incomes generated in the three site qualities modeled for the timber component are presented in table 20 (more information in appendix 12). Timber production increments significantly when site quality changes. For example, timber revenues and incomes were 1.63 times and 67% higher in good and regular site quality than in bad site quality, respectively.

Table 20.- Model 2, timber trees under natural regeneration in native grassland with two fattening calves. Total timber production at final turn (25 years) under three different site quality. Esparza, Costa Rica. 2004.

	Site quality		
	Bad	**Regular**	**Good**
Number of trees /final turn	50	50	50
m^3 / ha / final turn	24.55	41.19	64.64
USD / ha / final turn	1,672.59	2,806.27	4,403.92

1 USD = 430 colones. 1 m3 = 68.13 USD.

4.2.5.- Financial analysis

4.2.5.1.- NPV, LEV, IRR, B/C results

Site quality effect on investment profitability is presented in table 21. Results from the model showed that the investment was profitable in regular and good site quality when considering NPV, IRR and B/C. However, the investment was profitability only in good site quality when considering LEV. Appendix 13, 13[a] and 14 show the cash flows in more detail.

Table 21.-Site quality effect on investment profitability. Model 2, timber trees under natural regeneration in native grassland with two fattening calves. Esparza, Costa Rica. 2004.

	(USD)	%		(USD)
Without Project	534.68	-	-	-
Bad	352.47	12.89	2.55	1,325.24
Regular	583.96	14.61	3.56	1,857.28
Good	910.37	16.28	4.99	2,625.37

*1 USD = 430 Colones. **Value of the land = 1,918 USD/Hectare. Discount rate 6.56 %

Net cash flows comparison between the situation "with" vs "without project" is presented in figure 8. The situation with project had a negative net benefit in the first five years. After year five the cash flow shows a slight positive net benefit above the opportunity cost (consequence of the increment in livestock production). The income generated in these years and the income generated in year 25 by the timber component made the investment profitable.

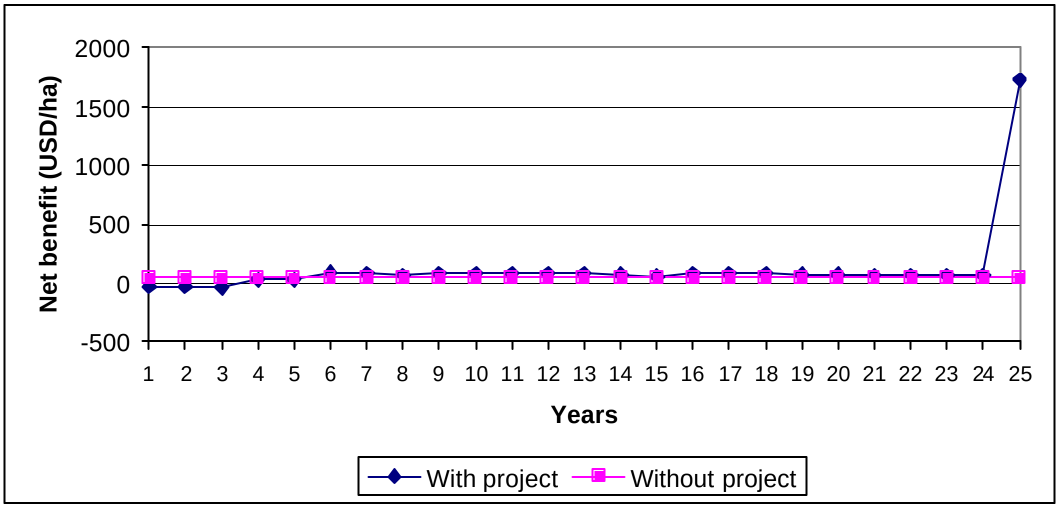


Figure 8.- Net cash flows, situation with vs without project. Model 2, timber trees under natural regeneration in native grassland with two fattening calves. Esparza, Costa Rica. 2004.

4.2.5.2.- PES effect on investment profitability

Tables 22 presents computation for PES for Model 2, and table 23 present PES effect on investment profitability. PES improves NPV 29% and 20%, and improves LEV 27% and 19% under payments schemes one and two, respectively. However, the PES for the LEV was not enough to cover the opportunity cost (land value). Figure 9 shows cash flows with PES in both payment schemes (one and two) and without PES. PES helps to compensate the investment in the first year (80% and 1.18 times under scheme one and two, respectively). However, its contribution does not cover the totality of the discounted investment (establishment and operation costs). For example, discounted scheme one cover 36.3% and discounted scheme two 28.3% of the total discounted investment, respectively.

Table 22.- PES estimation for Model 2, timber trees under natural regeneration in native grassland with two fattening calves. Esparza, Costa Rica, 2004.

Land Use					**Score/ Ha**
(A) Natural grassland with low density of trees < 30 trees/hectare.					0.6 pts
(B) Natural grassland with high density of trees> 30 trees/hectare.					1.0 pts
Difference (B – A)					0.4 pts
Payment	**Time/ years of PES**	**USD/point**	**Difference in land use (points)**	**Hectares**	**PES/ year/ ha (USD)**

Scheme two (two years)	2	110	0.4	1	44

Table 23.- PES effect on investment profitability. Model 2, timber trees under natural regeneration in native grassland with two fattening calves. Esparza, Costa Rica. 2004.

Site quality	Payment for Environmental Services	NPV* (USD)	IRR* (%)	C/B	LEV** (USD)
Bad	Without payment	352.47	12.89	2.55	1,325.24
	PES (scheme one, four years)	455.11	17.92	4.64	1,689.57
	PES (scheme two, two years)	425.24	16.35	3.74	1,580.04

*1 USD = 430 Colones. **Value of the land = 1,918 USD/Hectare. Discount rate 6.56 %.

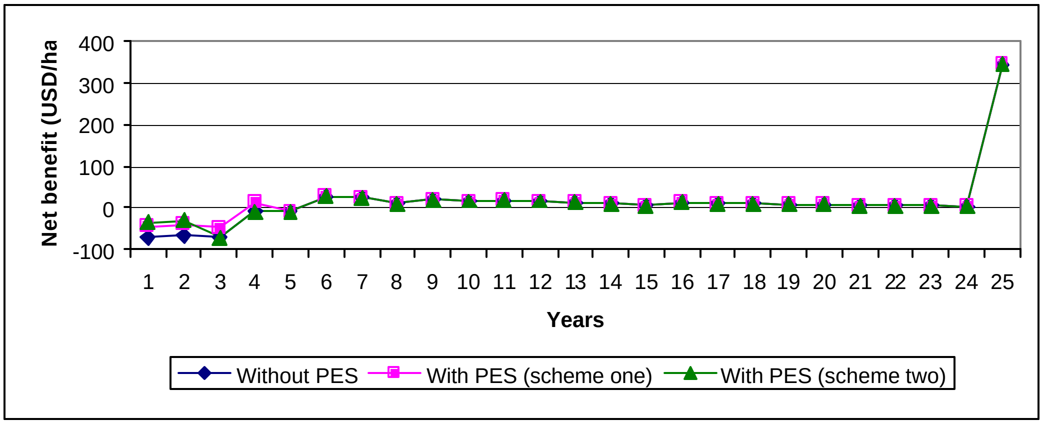


Figure 9.- PES effect on discounted cash flow, comparison with vs without PES. Model 2, timber trees under natural regeneration in native grassland with two fattening calves. Esparza, Costa Rica. 2004.

4.2.5.3.- Sensitivity analysis

Effect on profitability of changes in the discount rates, and in wood prices for Model 2 are presented in tables 24 and 25. For example, when NPV was considered the investment collapses with discount rate higher than 13%. In contrast, the investment under NPV perspective was insensitive to changes in wood prices. When LEV was considered, the investment was profitable only at discount rates below 4%. In addition, it is necessary an increment of 80% in wood price to make profitable the investment. The investment under LEV point of view is more sensitive to changes in discount rates and wood prices than under NPV perspective.

Table 24.- Model 2, timber trees under natural regeneration in native grassland with two fattening calves. Sensitivity analysis, discount rate effect on financial indicators. Esparza, Costa Rica. 2004.

Discount rate %	NPV* (USD)	IRR* (%)	B/C	Discount rate %	LEV** (USD)
7	309.06	12.89	2.37	1	11,870.25
8	225.04	12.89	2.02	2	5,622.75
9	157.82	12.89	1.73	3	3,548.17
10	103.89	12.89	1.49	**4**	2,516.76
11	60.50	12.89	1.29	5	1,902.56
12	25.51	12.89	1.12	6	838.80
13	- 2.77	12.89	0.98	7	712.31
14	- 25.67	12.89	0.87	8	611.00
15	- 44.25	12.89	0.77	9	460.95

*1 USD = 430 Colones. **Value of the land = 1,918 USD/Hectare. Discount rate 6.58 %

Table 25.- Model 2, timber trees under natural regeneration in native grassland with two fattening calves. Sensitivity analysis, wood price effects on financial indicators. Esparza, Costa Rica. 2004.

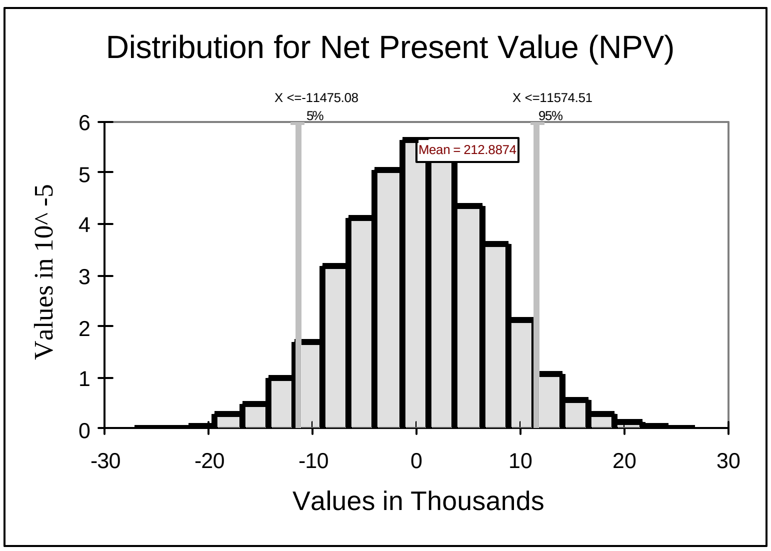
Wood price per M^3 (USD)	**NPV* (USD)**	**IRR* (%)**	**B/C**	**Wood price per M^3 (USD)**	**LEV** (USD)**
- 100 %	10.80	7.04	1.04	68.134	1,325.24
- 40 %	215.25	11.42	1.94	81.66 (+ 20%)	1,478.27
- 30%	249.40	11.83	2.09	95.38 (+ 40%)	1,637.61
- 20%	283.55	12.21	2.24	109.01 (+ 60%)	1,796.96
- 10%	317.70	12.56	2.39	122.64 (+ 80 %)	1,954.21
68.134	352.47	12.89	2.55	136.26 (+100 %)	2,113.64

*1 USD = 430 Colones. **Value of the land = 1,918 USD/Hectare.

4.2.5.4.- Risk analysis

Figure 10 and 11 show risk analysis results. The investment was highly risky when risk in beef price was modeled. Investment had 51.3% probability of success using NPV indicator. In addition, when risk in wood price was modeled, the investment did not have possibility of success in all the combinations using LEV indicator.

Figure 10.- Model 2, timber trees under natural regeneration in native grassland with two fattening



calves. Risk analysis, distribution for Net Present Value (NPV) applying risk in beef price. Esparza, Costa Rica. 2004.

Values 10^-5

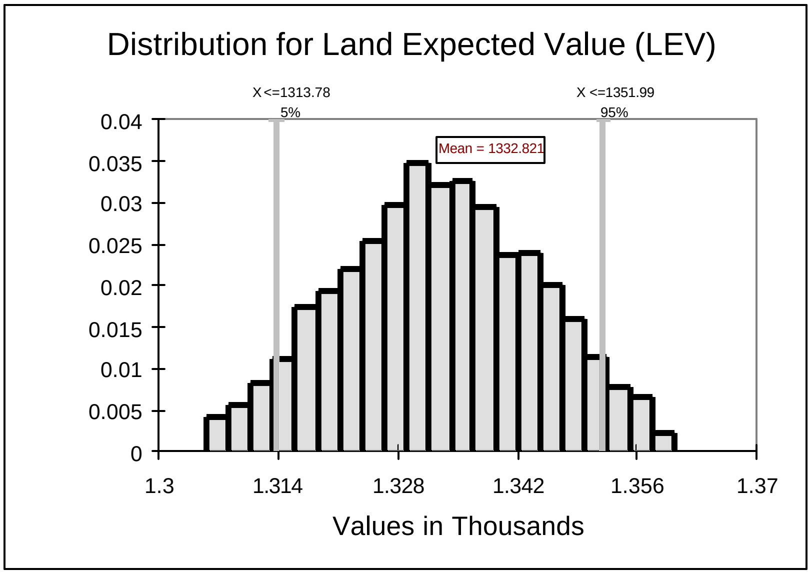


Figure 11.- Model 2, timber trees under natural regeneration in native grassland with two fattening calves. Risk analysis, distribution of Land Expected Value (LEV) applying risk in wood price. Esparza, Costa Rica. 2004.

4.3.- Model 3 Changing from degraded land to tacotal enriched with timber trees.

4.3.1.- Model description

In this model, one hectare of degraded land was changed to secondary regrowth (tacotal) enriched with timber trees of *C. odorata*. Trees were planted at an initial density of 400 trees/ha (5 m x 5 m) for a final density of 100 trees/ha (Figure 12). Two thinning were applied in years 8 and 15 (50% and 25% of trees were cut, respectively). The final thinning was in year 27. When the hectare was a degraded grassland it had a livestock component composed of one fattening calf. Livestock production was suspended when the land was devoted to secondary growth, starting at year one. Weeds cleaning in degraded grassland was suspended starting at year one when trees were incorporated.

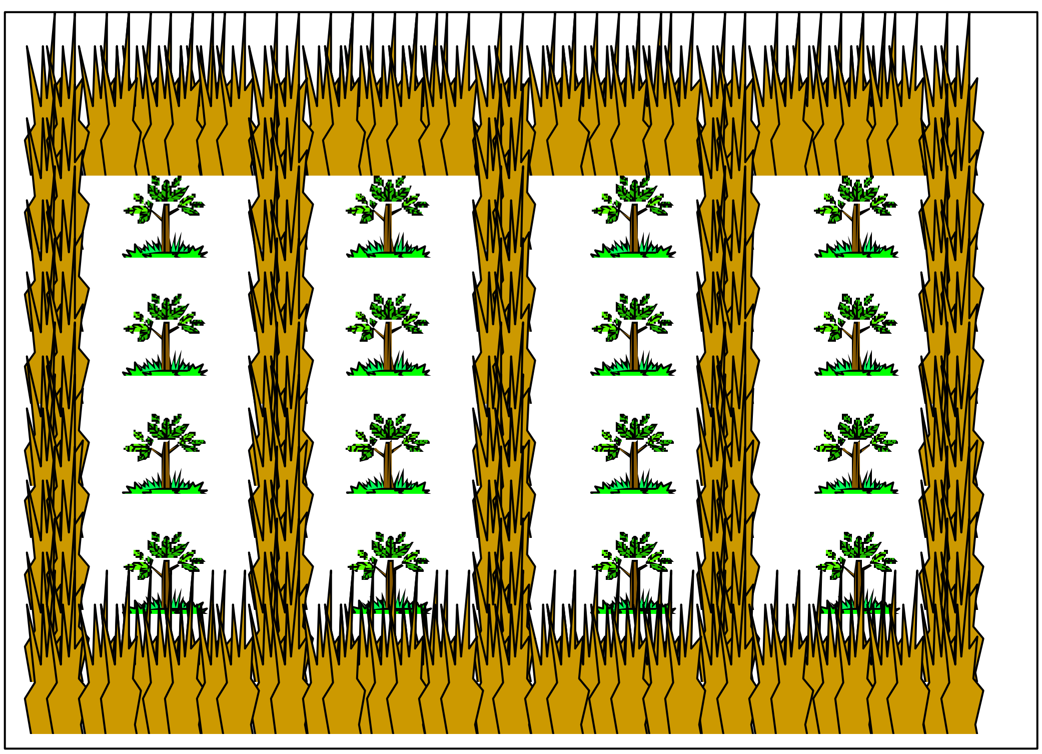


Figure 12.- Model 3, design of the tacotal enrichment with timber trees in degraded grassland. Esparza, Costa Rica. 2004.

4.3.2.- Establishment costs

Establishment costs for Model 3 were 262.79 USD (table 26). Materials represented the largest proportion of establishment costs (78.7%). For a detail description see appendix 15.

Table 26.- Establishment costs of 400 timber trees of *C. odorata* in one hectare of degraded grassland. Esparza, Costa Rica, 2004.

Concept	USD/ ha
Labor	55.81
Material	206.98
Total	262.79

1 USD = 430 colones.

4.3.3.- Operating costs

Operating costs for Model 2 are presented in table 27 (more information appendix 15). The situation "with project" showed the largest costs in years one, two, and three. It was consequence of tree management. From year four to fifteen, operation costs were lower, as management was less intensive. Two thinnings were applied in year eight and fifteen. Finally, from year sixteen to thirty operation costs were zero. Incremental costs were negative in the first three years, and years eight and fifteen. In years four to seven, nine to ten, and sixteen to thirty incremental costs were positive. It was consequence of the larger operation costs in the situation "without project".

Table 27.- Operation costs of 400 timber trees of *C. odorata* in one hectare of degraded grassland. Esparza, Costa Rica. 2004.

Situation	Concept	Year								
		1	**2**	**3**	**4-5**	**6-7**	**8**	**9-10**	**15**	**16- 30**
With project*	Labor	74.4	74.4	74.4	20.9	27.9	74.4	27.9	74.4	0
	Material	0	65.58	88.37	0	0	0	0	0	0
	Total (A)	**74.4**	**140.0**	**162.7**	**20.9**	**27.9**	**74.4**	**27.9**	**74.4**	**0**
Without project+	Labor	20.7	20.7	20.7	41.5	41.5	20.7	41.5	20.7	310.5
	Material	22.5	22.5	22.5	45.0	45.0	22.5	45.0	22.5	337.8
	Total (B)	**43.2**	**43.2**	**43.2**	**86.5**	**86.5**	**43.2**	**86.5**	**43.2**	**648.3**
	Incremental Costs (A-B)	31.2	96.8	119.5	65.6	58.6	31.2	58.6	31.2	648.3

1 USD = 430 colones. * timber and secondary regeneration components. + livestock and degraded grassland component.

4.3.4.- Wood production and income from timber component

Wood production and income generated from the timber component are presented in table 28 (more information in appendix 16). Since it is a degraded land, wood production was estimated only for bad site quality.

Table 28.- Total timber production and incomes generated at final turn (27 years) by 100 trees of *C. odorata* in a tacotal. Esparza, Costa Rica. 2004.

	Bad site quality
Number of trees/ final turn	100
m^3/ ha / final turn	26.80
USD / ha / final turn	1,825.88

1 USD = 430 colones. 1 m^3 = 68.13 USD.

4.3.5.- Financial analysis results

4.3.5.1.- NPV, LEV, IRR, B/C results

The investment showed a negative profitability for all indicators NPV (– 401.57), IRR (n.e.), B/C (0.42) and LEV (–99.58) (table 29). Discounted cash flow showed high investment in the third, fourth and fifth years, related with buying, carrying, planting, and caring for the trees (figure 13). Net cash flows comparison between with vs without project is presented in figure 14. It is observed that the net cash flow in the situation with project had a negative profit during 29 years. The opportunity cost to release degraded land is high, and timber revenues do not cover that cost (more information in appendix 17, 17[a], and 18).

Table 29.- Investment profitability. Model 3, one hectare of degraded grassland was changed to tacotal enriched with timber trees of *C. odorata*. Esparza, Costa Rica. 2004.

Site quality	Production of wood for 100 Trees	NPV* (USD)	IRR* (%)	B/C	LEV** (USD)
Without project		110.50	-	-	-
Bad	28.301	- 401.57	n.e.	0.42	- 99.58

*1 USD = 430 Colones. **Value of the land = 1,918 USD/Hectare. Discount rate 6.56 %.

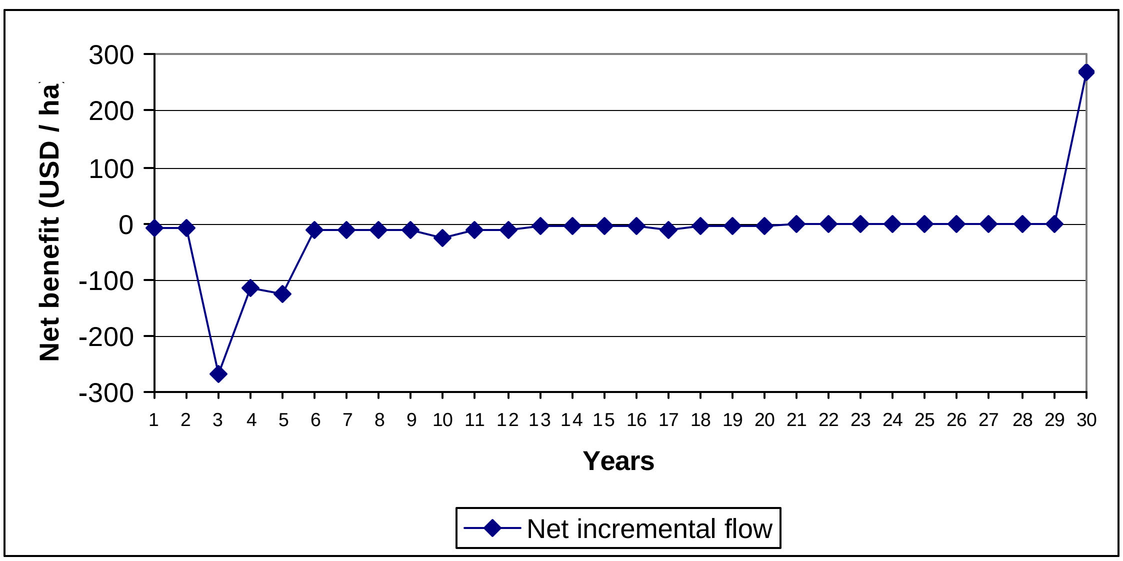


Figure 13.- Model 3, one hectare of degraded grassland was changed to tacotal enriched with timber trees of *C. odorata*. Discounted incremental cash flow. Esparza, Costa Rica. 2004.

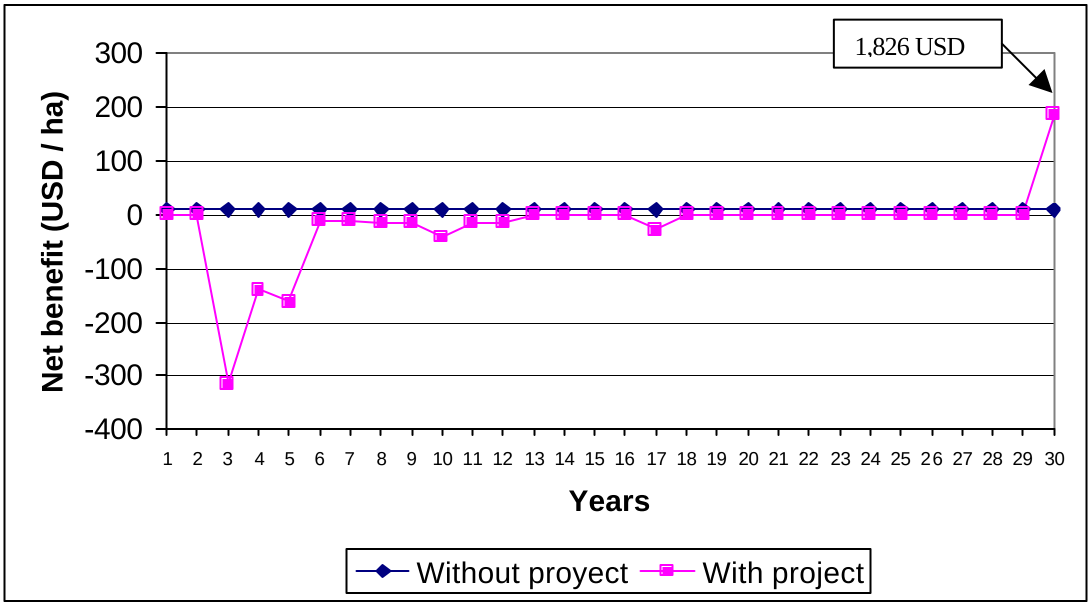


Figure 14.- Model 3, one hectare of degraded grassland was changed to tacotal enriched with timber trees of *C. odorata*. Net cash flows comparison, "without" vs "with project". Esparza. Costa Rica. 2004.

4.3.5.2.- PES effect on investment profitability

Table 30 presents the computation for the PES for Model 3, and table 31 shows PES effect on investment profitability. Results indicate that the PES improves financial indicators, but it was not enough to make profitable the investment. Investment, under LEV perspective, was positive with PES given that it only considers the change from degraded land to tacotal and does not take into account livestock opportunity cost. However, it is not enough to cover the cost of the land in the zone. Figure 15 shows cash flows with PES in both payment schemes (one and two) and without PES. Even though the PES for changing from degraded grassland to tacotal is one of the highest in the GEF-Project index, it does not cover the opportunity cost of the change.

Table 30.- PES estimation form Model 3, one hectare of degraded grassland was changed to tacotal enriched with timber trees of *C. odorata* . Esparza, Costa Rica. 2004.

Land Use					**Score/ Ha**
(A) Degraded Grassland.					0.0 pts
(B) Tacotal.					1.4 pts
Difference (B – A)					1.4 pts
Payment	**Time/ years of PES**	**USD/point**	**Difference in land use (points)**	**Hectares**	**PES/year/ ha (USD)**
Scheme one (four years)	4	75	1.4	1	105
Scheme two (two years)	2	110	1.4	1	154

Table 31.- PES effect in financial indicators. Model 3, one hectare of degraded grassland was changed to tacotal enriched with timber trees of *C. odorata*. Esparza, Costa Rica. 2004.

Site quality	**Payment for Environmental Services**	**NPV* (USD)**	**IRR* (%)**	**B/C**	**LEV** (USD)**
Bad	Without	- 401.57	n.e.	0.42	- 99.58
	PES (scheme one)	- 85.22	5.3	0.76	443.40

*1 USD = 430 Colones. **Value of the land = 1,918 USD/Hectare. Discount rate 6.56 %.

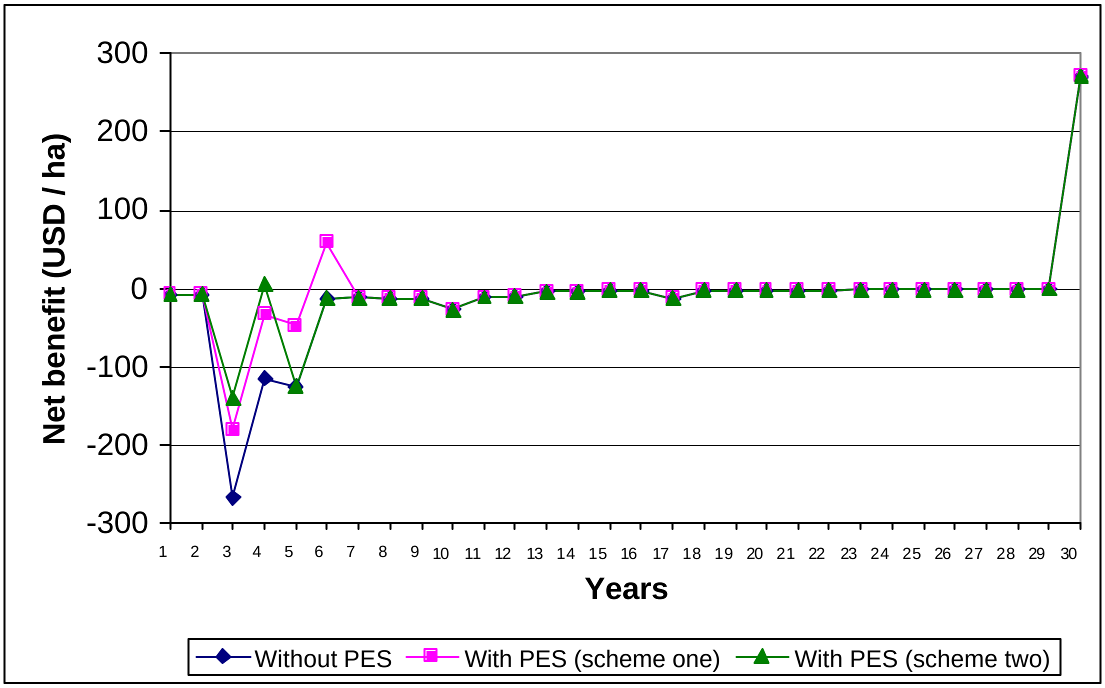


Figure 15.- Model 3, land use change from degraded pastures to tacotal enriched with timber trees. PES effect in discounted cash flow, comparison with" vs "without PES". Esparza, Costa Rica. 2004.

4.3.6.- Model 3[a] Changing from degraded land to tacotal without incorporating timber trees.

Information presented above indicates that changing from degraded land to tacotal enriched with timber trees of *C. odorata* was unprofitable. However, it was necessary to understand what happened with the financial indicators if the model had one modification; changing the land use from degraded land to tacotal without incorporation of timber trees. It is important to underline that this model only was developed with the PES effect, because the only output generated by the tacotal were the environmental services of carbon sequestration and biodiversity.

4.3.6.1.- PES effect on investment profitability

Table 32 shows that the situation without project (livestock activity) had an NPV of 110 USD/ha/year. The situation of tacotal without payment had an NPV of -110.50 USD/ha/year. In addition, four PES schemes were modeled for the financial analysis: scheme A (105 USD/year/four years), Scheme B (154 USD/year/two years), scheme C (10 USD/year/30 years), and scheme D (20 USD/year/30 years). The most profitable scenarios were with schemes A and B. Figure 16 shows the cash flows.

Table 32.- PES effect on investment profitability. Model 3[a], change land use from degraded grassland to tacotal without timber trees. Esparza, Costa Rica. 2004.

Situation	PES	Number of years	NPV* (USD)

	(USD/ha year)		
Without project (livestock activity)	0	0	110.50
Tacotal without payment	0	0	-110.50
Scheme A (4 years)	105	4	248.72
Scheme B (2 years)	154	2	169.65
Scheme C (30 years)	10	30	19.28
Scheme D (30 years)	20	30	149.06

*1 USD = 430 Colones. Discount rate 6.56 %.

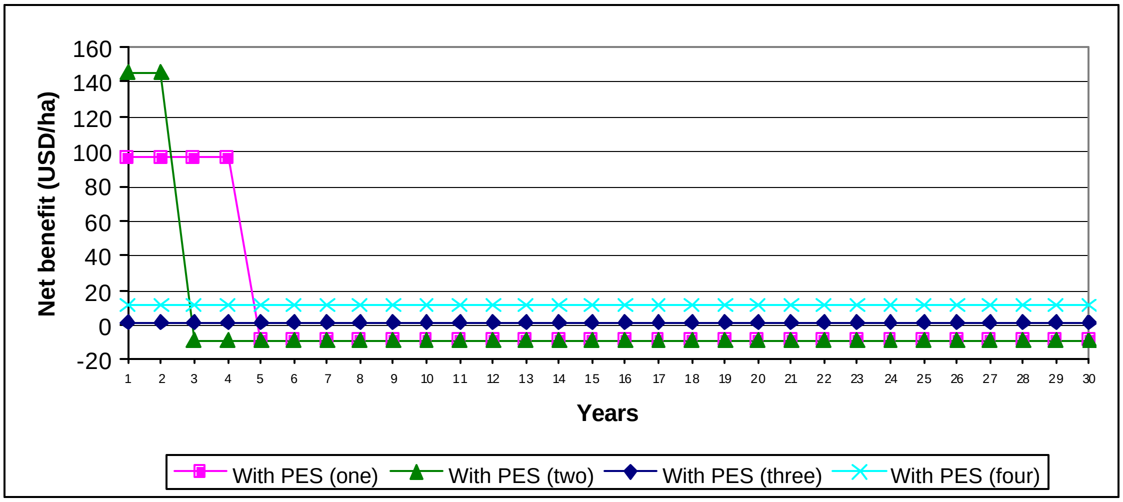
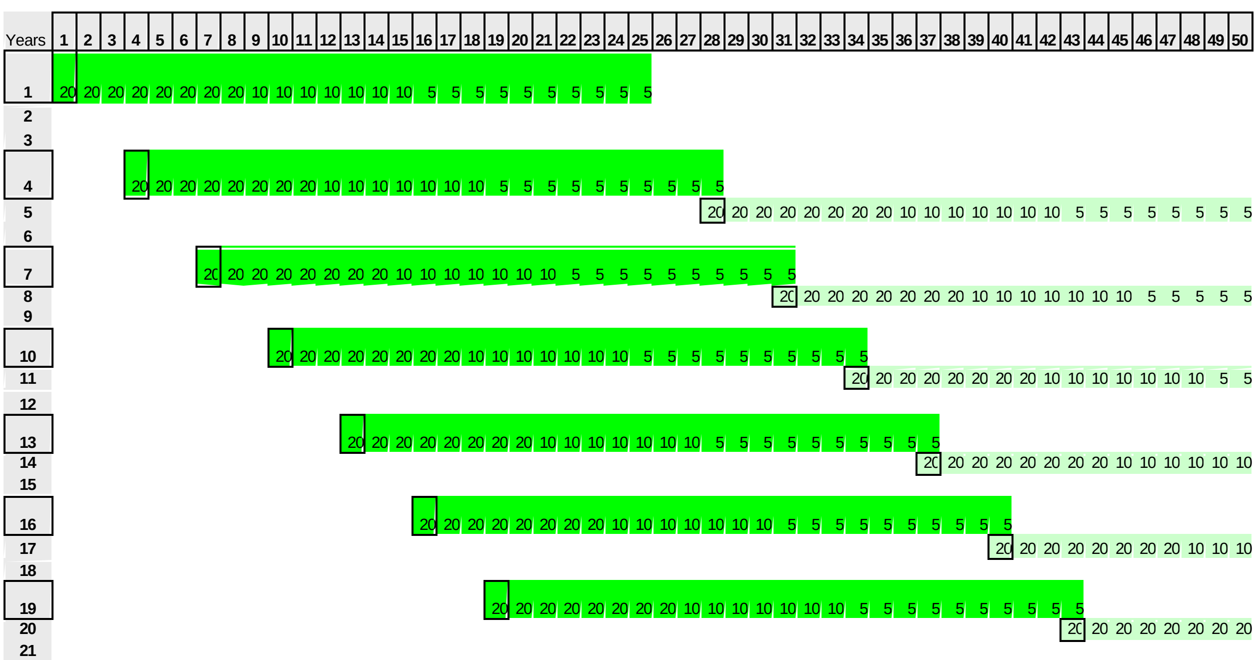


Figure 16.- Model 3a, land use change from degraded pasture to tacotal without timber trees. PES effect on discounted cash flow. Esparza, Costa Rica. 2004.

4.4.- Model 4 Timber trees in improved grasslands at perpetuity

4.4.1.- Model description

The objective for Model 4 was to have a SPS under perpetual timber rotation. To do so, twenty trees of *C. odorata* were planted every three years (figure 17) in one hectare of improved grassland *(B. brizantha*) with a distance of 5 m x 10 m. Two thinnings were applied in years 8 and 15 (10 and 5 trees were cut in each thinning, respectively). The final turn for each forest rotation (20 trees in each one) was 25 years. The livestock component was three fattening calves growing from 157 to 287 kg in one year. Care of young trees in the first three years was considered with a commercial tree protector.



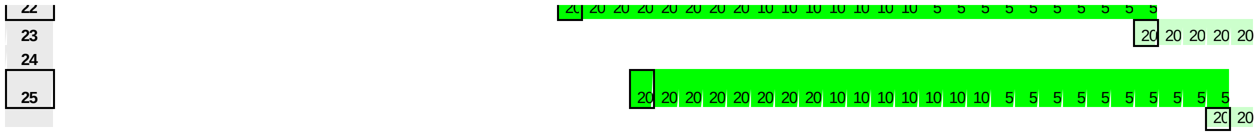


Figure 17.- Model 4, SPS with perpetual timber rotation. Twenty trees of *C. odorata* were planted every three years in one hectare of *B. brizantha* with three fattening calves. For each rotation, thinnings were developed in years eight and fifteen, and the final turn was in year twenty-five. Esparza, Costa Rica. 2004.

4.4.2.- Establishment costs

Model 4 establishment costs for one rotation are presented in table 33. The total budget was 13.14 USD where the main expenditure was material (78.7 %) (more details in appendix 19).

Table 33.- Establishment costs of twenty timber trees of *C. odorata* in one hectare of *B. brizantha*. Esparza, Costa Rica. 2004.

Concept	USD /each rotation
Labor	2.79
Material	10.35
Total	13.14

1 USD = 430 colones

4.4.3.- Operating costs

Model 4 operating costs are presented in table 34. The first three years had the larger incremental operation costs. It was consequence of the high management in the timber component (weeds cleaning, fertilization, technical assistance, formation pruning). From year 4 to year 15 the incremental operation costs were lower in comparison with the first years. Because the level of management was less intensive (formation pruning and weeds cleaning). In addition, two thinnings were applied in years eight and fifteen. Finally, since year 16 incremental costs were zero, as management in both situations were similar (more information appendix 19).

Table 34.- Operation costs of twenty timber trees *C. odorata* planted in one hectare of *B. brizantha* with three fattening calves. Esparza, Costa Rica. 2004.

Situation	Concept	Year								
		1	**2**	**3**	**4-5**	**6-7**	**8**	**9-10**	**15**	**16 -25**
With Project*	Labor	51.3	51.3	51.3	96.2	96.6	50.4	96.6	49.7	476.9
	Material	84.9	84.9	89.3	169.8	169.8	84.9	169.8	84.9	849.2
	Total	**136.2**	**136.2**	**140.6**	**266.0**	**266.4**	**135.3**	**266.4**	**134.6**	**1,326.1**
Without project+	Labor	47.6	47.6	47.6	95.2	95.2	47.6	95.2	47.6	476.9
	Material	84.9	84.9	84.9	169.8	169.8	84.9	169.8	84.9	849.2
	Total	**132.5**	**132.5**	**132.5**	**265**	**265**	**132.5**	**265**	**132.5**	**1,326.1**
Incremental costs		3.72	3.72	8.14	1.04	1.39	2.79	1.39	2.09	0

1 USD = 430 colones. * timber, livestock, and grassland components. + livestock and grassland component.

4.4.4.-Wood production and income from timber component

production and income increment when the site quality improves. For example, timber revenues were 1.28 times and 60% higher in good and regular site quality, respectively, when they are compared with the revenues in bad site quality (more information in appendix 20).

Table 35.- Model 4, SPS with perpetual timber rotation. Twenty trees of *C. odorata* were planted every three years in one hectare of *B. brizantha* with three fattening calves. Total timber production of one rotation at final turn (25 years) under three different site quality. Esparza, Costa Rica. 2004.

	Site quality		
	Bad	**Regular**	**Good**
Number of trees/final turn	5	5	5
m^3 /ha /final turn	2.15	3.45	4.90
USD /ha /final turn	146.47	235.04	333.83

1 USD = 430 colones. 1 m3 = 68.13 USD

4.4.5.- Financial analysis

4.4.5.1.- NPV, LEV, IRR, B/C results

Site quality effect on investment profitability is presented in tables 36 and 37. The conversion period included the implementation and maintenance costs of the SPS (25 years), and the first rotation timber revenues. In all scenarios the conversion period had negative profit in comparison with the opportunity costs in the first 25 years. However, when the rotations were calculated at the infinitum all investments had positive profit (5,046.8 and 1,937.06 USD/ha for NPV, and LEV in bad site quality, respectively).

Table 36.- Model 4, SPS with perpetual timber rotation. Twenty trees of *C. odorata* were planted every three years in one hectare of *B. brizantha* with three fattening calves. Site quality effect on investment profitability. Esparza, Costa Rica. 2004.

Site quality	Conversion period from grass monoculture to SPS (25 years) NPV (USD)	NPV infinitum (USD)	NPV* Total (USD)	IRR %	B/C
Without project	-	-	2,167.47	-	-
Bad	337.89	4,708.91	5,046.80	n.e.	3.64
Regular	355.96	6,057.24	6,413.01	n.e.	3.78
Good	376.16	7,565.13	7,941.30	n.e	3.94

*1 USD = 430 Colones. Discount rate 6.56 %

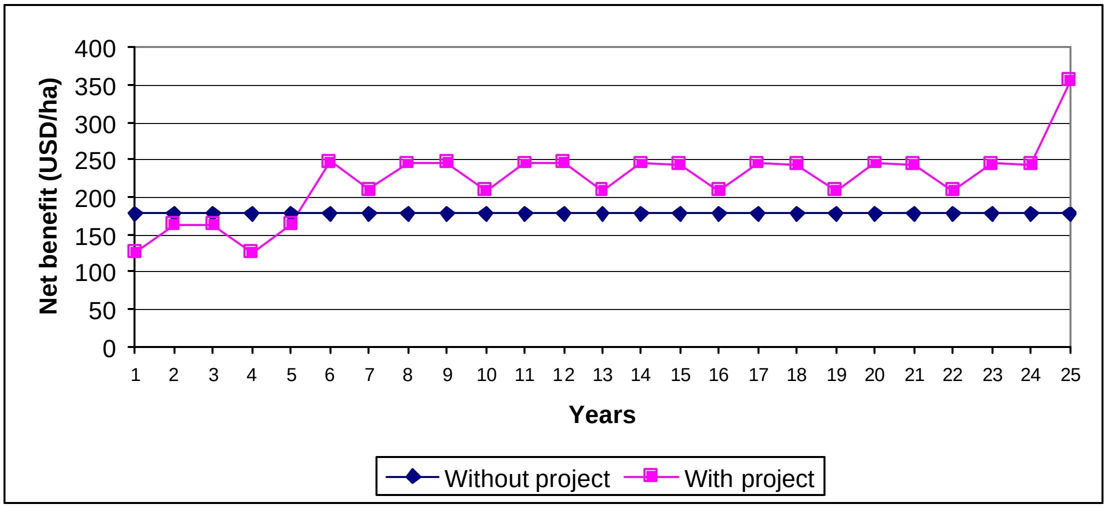
Table 37.- Model 4, SPS with perpetual timber rotation. Twenty trees of *C. odorata* were planted every three years in one hectare of *B. brizantha* with three fattening calves. Site quality effect on investment profitability under LEV perspective. Esparza, Costa Rica. 2004.

Site quality	Conversion period from grass monoculture to SPS. (25 years) NPV (USD)	Forest infinitum LEV (USD)	Livestock infinitum LEV (USD)	LEV** Total (USD)
Bad	- 230.08	839.87	1,327.27	1,937.06
Regular	- 230.08	1,424.09	1,327.27	2,521.28
Good	- 230.08	2,077.63	1,327.27	3,174.82

*1 USD = 430 Colones. **Value of the land = 1,918 USD/Hectare. Discount rate 6.56 %

“with out” project. It shows that exist a negative incremental cash flow in the first five years. However, beginning at year six the incremental cash flow turns to be positive. It is consequence of the increment in livestock production by the shadow effect of trees that reduces heat stress for the animals (more information in appendix 21, 21[a], and 22).

Figure 18.- Model 4, SPS with perpetual timber rotation. Twenty trees of *C. odorata* were planted every three years in one hectare of *B. brizantha* with three fattening calves. One



rotation net cash flows, comparison “with” vs “without project”. Esparza, Costa Rica. 2004.

4.4.5.2.- PES effect on investment profitability

Table 38 presents the PSE computation, and table 39 and figure 19 show the PSE effect on investment profitability and cash flow, respectively. PES under scheme one improved slightly the profitability of the investment (2% and 5% under NPV and LEV perspectives). The cash flow showed that PES does not cover all incremental costs in the first five years.

Table 38.- PES estimation for Model 4, SPS with perpetual timber rotation. Twenty trees of *C. odorata* were planted every three years in one hectare of *B. brizantha* with three fattening calves. Esparza, Costa Rica. 2004.

Land Use					**Score/ Ha**
Improve grassland without trees					0.5 pts
Improve Grassland with low density of trees < 30 trees/hectare.					0.9 pts
Difference					0.4 pts
Scheme	**Time/ years of PES**	**USD/point**	**Difference in land use (points)**	**Hectares**	**PES/year/ha (USD)**
One	4	75	0.4	1	30
Two	2	110	0.4	1	44

Table 39.- PES effect on investment profitability. Model 4, SPS with perpetual timber rotation. Twenty trees of *C. odorata* were planted every three years in one hectare of *B. brizantha* with three fattening calves. Esparza, Costa Rica. 2004.

Site quality	Payment for Environmental Services	NPV* (USD)	IRR* (%)	B/C	LEV** (USD)
Bad	Without	5,046.80	n.e.	3.64	1,937.06
	PES (A)	5,149.44	n.e.	9.77	2,039.69
	PES (B)	5,126.84	n.e.	6.68	2,017.10

. *1 USD = 430 Colones. **Value of the land = 1,918 USD/Hectare. Discount rate 6.56 %.

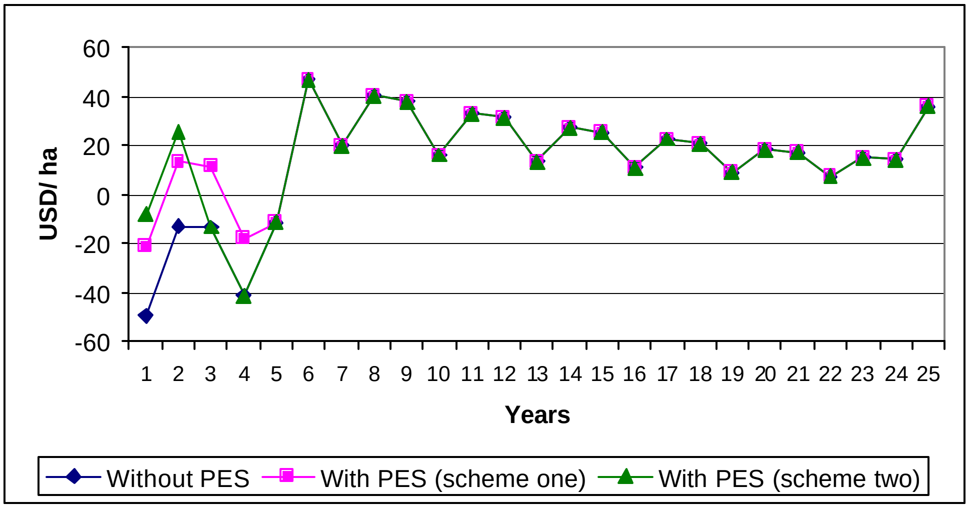


Figure 19.- Model 4, SPS with perpetual timber rotation. Twenty trees of *C. odorata* were planted every three years in one hectare of *B. brizantha* with three fattening calves. PES effect in discounted cash flows. Esparza, Costa Rica. 2004.

4.4.5.3.- Sensibility analysis

Effect of different discount rates and wood prices on the investment are presented in tables 40 and 41. The investment was insensitive to changes in discount rates and in wood prices when NPV was considered. This is due to the profitability of the livestock component in the situation "with project". However, the investment was highly sensitive to changes in discount rate and wood prices when LEV was considered. It is consequence of the land price in the Esparza zone (opportunity cost).

Table 40.- Model 4, SPS with perpetual timber rotation. Twenty trees of *C. odorata* were planted every three years in one hectare of *B. brizantha* with three fattening calves. Sensitivity analysis discount rate effect on investment profitability. Esparza, Costa Rica. 2004.

Discount rate %	NPV* (USD)	IRR* %	B/C	Discount rate %	LEV** (USD)
6	5,520.57	n.e.	3.87	2	15,291.37
8	4,124.78	n.e.	3.13	3	8,434.18
10	3,274.67	n.e.	2.58	4	5,227.56
12	2,703.22	n.e.	2.15	5	3,449.98
14	2,293.75	n.e.	1.81	6	2,365.68
16	1,986.81	n.e.	1.54	7	1,662.62
18	1,748.81	n.e.	1.33	8	1,187.13
20	1,559.31	n.e.	1.15	9	855.55
22	1,405.17	n.e.	1.01	10	618.91

*1 USD = 430 Colones. **Value of the land = 1,918 USD/Hectare. Discount rate 6.58 %

Table 41.- Model 4, SPS with perpetual timber rotation. Twenty trees of *C. odorata* were planted every three years in one hectare of *B. brizantha* with three fattening calves. Sensitivity analysis, wood price effects on investment profitability indicators. Esparza, Costa Rica.

Wood price per m³ (USD)	NPV* (USD)	IRR* (%)	B/C	Wood price per m³ (USD)	LEV** (USD)
- 100 %	2,782.78	n.e.	3.40	- 20%	1,741.76
- 40 %	4,137.53	n.e.	3.54	- 10%	1,838.53
- 30%	4,363.82	n.e.	3.57	68.134	1,937.06
- 20%	4,590.10	n.e.	3.60	+ 20%	2,129.26
- 10%	4,816.39	n.e.	3.62	+ 40%	2,324.21
68.134	5,046.80	n.e.	3.64	+ 60%	2,517.89

*1 USD = 430 Colones. **Value of the land = 1,918 USD/Hectare. Discount rate 6.56%

4.4.5.4.- Risk analysis

Figure 20 shows the result when the investment is modeled with risk in beef price. The investment was highly sensible to risk in beef prices (37.5% probability of success) when NPV was considered. In contrast, risk in wood price does not affect investment profitability under NPV perspective (figure 21). When LEV is considered, the investment presents a probability of 43.13% of success when risk is applied in beef price (figure 22). In contrast, the investment had a probability of success of 86.12% when wood price was modeled with risk (figure 23).

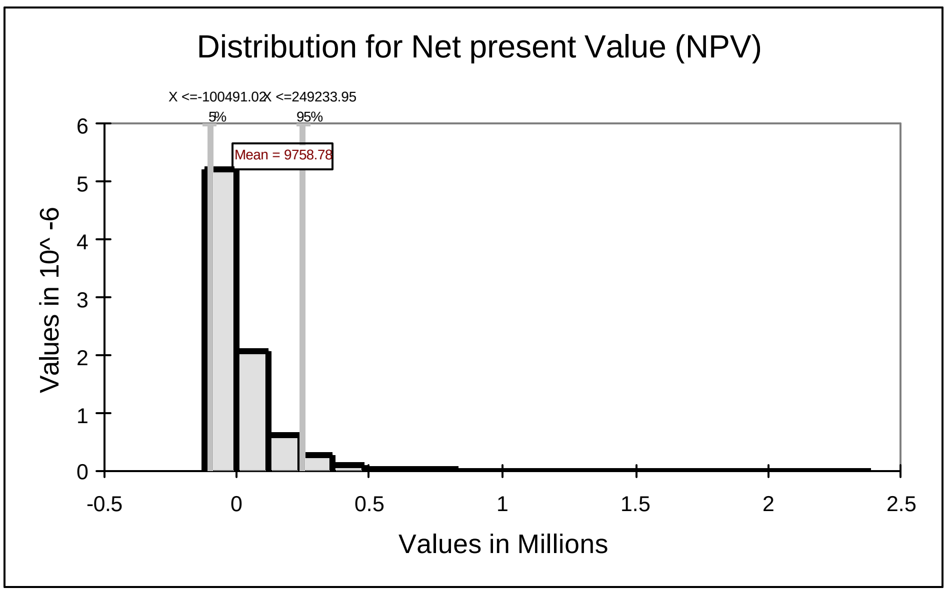
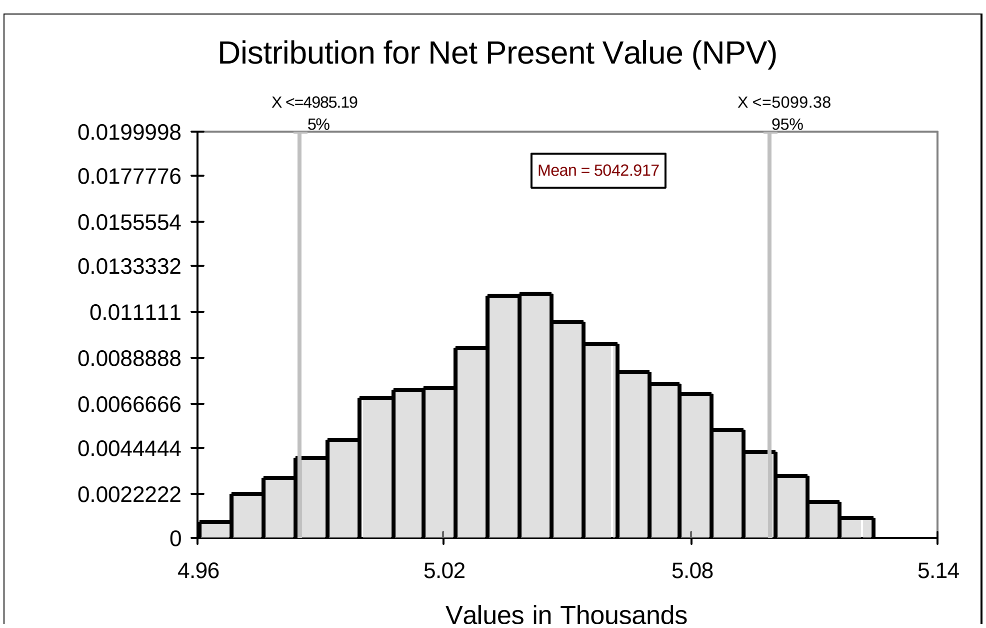
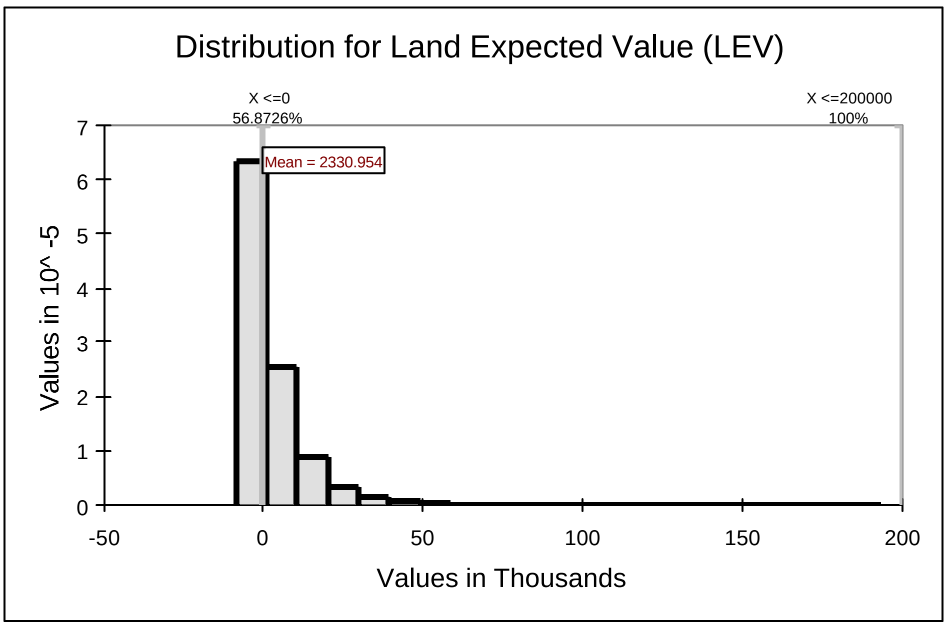


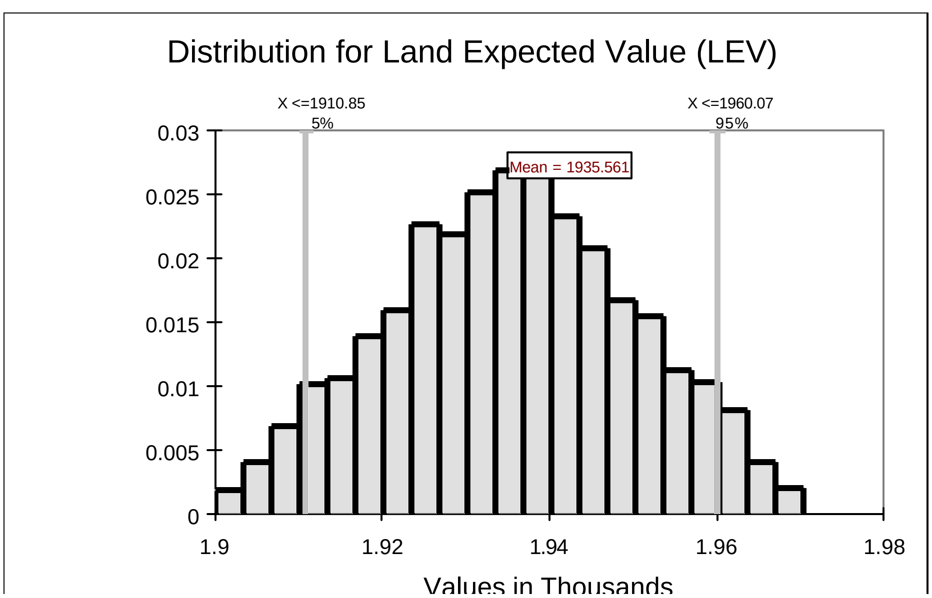
Figure 20.- Model 4, SPS with perpetual timber rotation. Twenty trees of *C. odorata* were planted every three years in one hectare of *B. brizantha* with three fattening calves. Investment risk analysis, distribution for Net Present Value (NPV) applying risk in beef price. Esparza, Costa Rica. 2004.



Frequency

Figure 21.- Model 4, SPS with perpetual timber rotation. Twenty trees of *C. odorata* were planted every three years in one hectare of *B. brizantha* with three fattening calves. Investment risk analysis, distribution for Net Present Value (NPV) applying risk in wood price. Esparza, Costa Rica. 2004.





of *B.*

Land risk

Figure 22.- Model 4, SPS with perpetual timber rotation. Twenty trees of *C. odorata* were planted every three years in one hectare *brizantha* with three fattening calves. Investment risk analysis, distribution for Expected Value (LEV) applying in beef price. Esparza, Costa Rica. 2004.

Frequency

Figure 23.- Model 4, SPS with perpetual timber rotation. Twenty trees of *C. odorata* were planted every three years in one hectare of *B. brizantha* with three fattening calves. Investment risk analysis, distribution for Land Expected Value (LEV) applying risk in wood price. Esparza, Costa Rica. 2004.

5.- Discussion

The financial feasibility of the investment was variable among the models. This was consequence of the different tree arrangements, the level of the investment, and the level of interaction among the trees, the grass and the livestock components in the system. In general, investing in the incorporation of timber trees was financially feasible, although site quality was an important determinant for the feasibility of the investment. Depending on the model, the PES cover a substantial portion of the establishment costs, although it does not cover the totality of the incremental costs. However, the PES helps to make feasible the incorporation of timber trees in pastures of bad site quality that otherwise would be unprofitable. Each model will be discussed below.

5.1.- Model 1, Timber trees in fences

Investment in Model 1 was profitable in all site qualities. These results are in agreement with those presented by Reiche (1991); Holmann *et al.* (1992); and Botero *et al.* (1999). However, the cash flow presented a negative incremental benefit in the first four years. The PES improved investment profitability, but was not enough to cover the establishment and maintenance costs of the timber component. This result is in agreement with Gobbi and Casasola (2004) that indicate that the PES has a marginal contribution on the investment of environmental friendly SPS in livestock farms of Esparza, CR. In the sensitivity analysis, this investment was robust to changes in wood prices. However, the investment showed a high sensitivity to changes in the discount rate. When risk in wood price was applied, the investment was very robust. In contrast, when risk in beef price was applied, the investment was less attractive. Model 1 represents a robust option to incorporate timber trees in livestock farms in the Esparza zone.

5.2.- Model 2, Timber trees under natural regeneration in native grassland

models. This is in agreement with Viana *et al.* (2001) that indicated that the establishment of timber trees under natural regeneration has low implementation costs in comparison with other methods. The investment was financially feasible in regular and good site quality under NPV perspective. However, the investment had a negative profit in bad site quality when the same indicator was considered. In addition, the investment showed a negative profit in bad and regular site qualities when LEV was considered. The financial results could be consequence of the reduction in grass biomass by shadow effect, and the high maintenance costs of natural grassland. The incremental discounted cash flow was negative in the first five years. The PES made the investment financially feasible in the bad site quality scenario. The investment showed high sensitivity to changes in the discount rate. For example; investment showed high sensitivity to changes in wood prices when LEV was considered. In contrast, it presented a high robustness with respect to changes in wood prices when NPV was considered. In bad site quality the risk analysis suggested that this investment had low probabilities of success. It is in agreement with farmer's opinion, because they do not improve natural regeneration in native grasslands. First, they want to improve grassland and then to promote the natural regeneration of trees. Although under regular and good site quality the results were the reverse.

5.3.- Model 3, Changing from degraded land to tacotal enrichment with timber trees

The investment in this model was the less profitable one. Financial indicators showed that the enriching the site with timber trees was not feasible under the scenarios modeled, due to the fact that the degraded land corresponded to a bad quality site, and thus, timber production was very poor. The opportunity cost to releasing the land from its livestock activity was higher than the revenues from the timber component. Cash flow analysis showed a negative incremental cost during 13 years. The PES improved financial indicators but was insufficient to make them profitable and to cover the investment. The PES could be a good strategy to promote this land use change, but we need a PES sufficient enough to at least cover the opportunity costs. This view is hold by farmers who would agree to change from degraded land to tacotal if a PES were applied to perpetuity (lower payment, more years) and covers the opportunity cost of the change.

5.3.1.- Model 3^a, Changing from degraded land to tacotal without timber trees

The previous model indicated that the investment to change from degraded grassland to tacotal enriched with timber trees was unprofitable. However, it was necessary to assess the profitability of changing from degraded land to tacotal without investing in timber trees. In other words, letting the degraded land to recover and develop tree cover by natural regeneration. Under this scenario (Model 3^a), the land use change was profitable only when the PES developed by the GEF Project was applied. The discounted amount received by the PES, under schemes one and two, covered 3.26 and 2.54 times the discounted opportunity cost (livestock activity), respectively. However, the cash flow analysis indicated that the PES was implemented few years (105 USD by four years and 154 USD by two years in schemes one and two, respectively). In fact, some farmers mentioned that they did not want to release the degraded land to tacotal, because the cost for cleaning the tacotal (when PES are stopped) will be higher than the income received by the PES. If the PES covers the opportunity cost of releasing the land (8.51 USD/ha) and is implemented during more years, it will be more attractive to farmers.

profitability than schemes one and two, but covered the opportunity cost for all years in the cash flow analysis.

5.4.- Model 4, Timber trees in improved grasslands at perpetuity

Investment in timber trees under the assumption of Model 4 was the most confident of all the investment options analyzed in this study. It is in agreement with results from Carvalho *et al.* (2001), Grado and Husak (2004), Marlats *et al.* (1995), Botero *et al.* (1999), Grado *et al.* (2001), and Alonzo and Ibrahim (2001). Financial indicators suggested that the investment was profitable in bad site quality, even when full opportunity costs were taken into account. The low reduction of biomass in improved grassland, and the increment in beef production from the comfort proportioned by the canopy shadow, improved the investment profitability when NPV was considered. Income by livestock component helped to make profitable the indicator when LEV was considered. If the investment is profitable, the question is why livestock farmers do not implement this kind of silvopastoral systems in their farms? The answer may be in the cash flow. The cash flow analysis indicated a negative incremental cost in the first five years. The PES may play an interesting role in the adoption of this SPS. The PES incremented the investment profitability. However it was not enough to cover the implementation costs (in agreement with Gobbi and Casasola 2004). If the PES were applied to perpetuity, this kind of SPS would be more attractive to farmers. The sensibility analysis showed that the investment was highly sensitive to changes in the discount rate and wood prices when LEV was considered. In contrast the investment was less sensible to changes in both variables when NPV was considered. The risk analysis indicated that the investment showed high risk associated to beef prices, and less risk when wood price was modeled. This could be explained by the higher incomes generated by the livestock component in the discounted cash flow contrasted to those from the timber component.

6.- Conclusions

i. The incorporation of timber trees under different arrangements in livestock farms in Esparza, Costa Rica was financially feasible in most of the modeled cases. The financial feasibility of the investment was highly dependant on the site quality where timber trees were incorporated.

ii. The financial feasibility of implementing silvopastoral systems with timber trees showed differences among the models. The most profitable investment was Model 4, timber trees at perpetuity in improved grassland, and the less profitable investment was Model 3, changing from degraded pasture to secondary regeneration forest (tacotal) enriched with timber trees.

iii. Implementation of timber trees in fences (Model 1) was a profitable model and showed the lowest risk associated with the investment. The investment was feasible even without applying PES.

iv. Investing on natural regeneration of timber trees in native grassland was profitable in regular and good site quality. However, the investment showed negative profitability in bad site quality. In the latter case, the situation was due the investment was financially feasible under all site qualities modeled.

v. Investing on changing from degraded grassland to tacotal was only financially feasible when trees were allowed to growth by natural regeneration and PES were applied. In contrast, actively enriching the degraded pasture with timber trees was an unattractive option. This situation was due to the fact that income generated by the timber component was not enough to cover the investment in timber trees and the opportunity cost of releasing the land from the livestock activity.

vi. Implementing timber trees at perpetuity in improved grasslands had a positive profitability. The first rotation to 25 years (conversion period from grassland monoculture to SPS with timber trees) presented less profitability than its opportunity cost. However, when the rotations were considered at infinitum, the investment was profitable.

vii. The PES covered, in most cases, a considerable portion of the establishment costs of incorporating trees in pastures. Although it did not covered all the incremental operating cost. Nonetheless, the PES made the incorporation of timber trees feasible, even in bad site quality, for all models except for changing from degraded grassland to tacotal enriched with timber trees (Model 3). The PES contribution was marginal in terms of the cash flows, although it represented the only income generated by the system when changing from degraded grassland to tacotal.

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9.- Appendix

9.1.- Annual maintenance costs for natural grassland (1 hectare).

Activity	Subtotal USD/year
Labor	
Manual Cleaning	41.88
Weed-killer sprinkling	13.96
Input	
Weed-killer	30.06
Total	**85.9**

1 USD= 430 colones

9.2.- Annual maintenance costs for improved grassland (1 hectare).

Activity	Subtotal USD/ year
Labor	
Weed-killer sprinkling	6.98
Input	
Weed-killer	10.021
TOTAL	**17.0**

1 USD= 430 colones

9.3.- Annual maintenance costs for degraded grassland (1 hectare).

Activity	Subtotal USD/ year
Labor	
Manual Cleaning	6.98
Weed-killer sprinkling	6.98
Input	
Weed-killer	10.02
TOTAL	**23.98**

1 USD= 430 colones

9.4.- Annual maintenance cost for a weaning calve in a fattening livestock production system. (from 157 to 287 kg).

Input	Subtotal USD/year
Labor	13.49
Mineral salt	12.26
Common salt	1.53
Vaccine	1.005
Anti-parasitic	1.008
Anti-parasitic	7.15
Other medicines	2.09
TOTAL	**38.53**

9.5.- Livestock prices from the auction AGAINPA (Pacific Zone Independent Livestock Association). Period January-September 2004.

Auction	Date	Bulls ?	Bull $	Bull kg.	Cows ?	Cow $	Cow kg	Heifers ?	Heifer $	Heifer kg	Young Bulls ?	Young Bull $	Young bull kg
1	01/08/2004	40.00	0.91	488.15	37	0.73	431.00	4	0.80	220.25	24	0.90	339.96
2	15/01/2004	7.00	0.89	548.00	18	0.73	425.94	2	0.77	279.50	21	0.88	337.00
3	22/01/2004	11.00	0.96	449.00	26	0.71	394.19	9	0.84	226.56	7	0.86	288.43
4	29/01/2004	14.00	0.97	454.36	32	0.75	411.47	26	0.79	299.85	18	0.89	346.67
5	05/02/2004	29.00	0.90	400.69	26	0.78	419.27	18	0.84	206.56	10	0.89	306.00
6	12/02/2004	36.00	0.91	443.26	37	0.75	424.27	17	0.83	210.00	12	0.85	305.42
7	19/02/2004	23.00	0.94	441.35	36	0.73	412.61	10	0.73	250.90	7	0.90	254.14
8	26/02/2004	21.00	0.93	525.00	29	0.76	402.38	4	0.79	205.25	1	0.95	414.00
9	04/03/2004	14.00	0.90	360.07	35	0.76	395.37	7	0.77	216.71	12	0.96	288.00
10	11/03/2004	14.00	0.94	389.64	18	0.77	412.00	9	0.84	232.22	5	0.92	284.80
11	18/03/2004	9.00	0.94	436.33	39	0.80	399.76	23	0.84	209.78	3	0.90	337.00
12	25/03/2004	16.00	0.92	450.56	30	0.72	421.17	17	0.77	222.12	0	0.00	0.00
13	01/04/2004	10.00	0.89	444.80	14	0.79	433.86	5	0.79	279.80	6	0.88	260.33
14	15/04/2004	15.00	0.93	407.13	34	0.79	402.03	5	0.88	223.03	4	0.98	276.50
15	22/05/2004	28.00	0.97	453.89	18	0.78	397.83	1	0.70	272.00	40	0.99	316.98
16	29/04/2004	30.00	0.93	410.83	21	0.77	393.02	22	0.84	254.86	9	0.86	238.56
17	06/05/2004	16.00	0.94	414.31	29	0.79	377.43	52	0.88	271.43	5	0.83	284.40
18	13/05/2004	5.00	0.91	350.20	27	0.80	381.48	7	0.83	239.86	4	0.96	293.75
19	20/05/2004	2.00	0.93	312.00	28	0.86	424.43	10	0.80	220.90	9	0.95	279.11
20	27/05/2004	23.00	0.91	343.48	30	0.78	387.47	6	0.66	216.00	4	0.72	270.50
21	03/06/2004	21.00	0.94	387.57	64	0.81	376.36	11	0.87	236.09	22	0.98	304.77
22	10/06/2004	38.00	0.98	376.68	39	0.80	380.87	14	0.82	212.87	10	0.99	258.90
23	17/06/2004	28.00	1.00	442.61	49	0.82	399.38	5	0.83	206.00	17	1.01	277.71
24	24/06/2004	33.00	1.01	451.06	47	0.80	382.36	21	0.81	215.43	24	0.84	257.83
25	01/07/2004	24.00	1.00	488.96	47	0.86	401.04	21	0.89	226.00	25	1.00	287.40
26	08/07/2004	22.00	1.00	471.09	48	0.81	387.25	17	0.82	212.35	17	0.88	264.41
27	15/07/2004	17.00	1.03	476.41	46	0.82	427.59	8	0.84	254.75	21	0.92	245.05
28	22/07/2004	42.00	1.03	481.21	72	0.84	402.65	16	0.91	202.88	9	0.96	308.56
29	29/07/2004	5.00	1.07	489.00	38	0.85	411.03	20	0.86	252.00	18	0.94	294.72
30	05/08/2004	60.00	1.00	481.30	56	0.84	416.98	24	0.88	219.90	20	0.96	294.45
31	12/08/2004	23.00	1.05	478.83	41	0.80	424.59	8	0.86	244.75	11	1.00	289.73
32	19/08/2004	58.00	0.99	452.45	47	0.82	428.51	6	0.84	247.50	39	0.90	295.41
33	26/08/2004	22.00	1.03	480.64	21	0.88	435.67	8	0.92	236.50	17	1.02	294.65
34	02/09/2004	46.00	1.01	464.26	64	0.84	396.95	10	0.88	235.60	13	1.01	303.08
35	09/09/2004	25.00	0.98	473.20	86	0.80	409.47	11	0.72	239.55	22	0.96	298.09
36	16/09/2004	32.00	1.00	475.22	36	0.86	422.19	11	0.83	241.82	27	0.97	324.85
37	23/09/2004	40.00	0.96	457.30	36	0.80	420.83	11	0.84	241.27	17	0.91	315.88

1 USD = 430 colones.

9.5[a] .- Livestock prices from the auction AGAINPA information (Pacific Zone Independent Livestock Association). Period January-September 2004. Continue….

Auction	Date	Male calfs ?	Male calf $	Male calf kg	Female calfs ?	Female calf $	Female calf kg	Young Cows ?	Young cow $	Young cow kg
1	01/08/2004	32	1.01	164.84	23	0.91	172.70	13	0.85	340.31
2	15/01/2004	11	1.04	159.00	9	0.90	184.56	13	0.81	346.69
3	22/01/2004	31	0.93	168.63	12	0.85	189.83	19	0.86	314.37
4	29/01/2004	17	0.97	170.21	8	0.88	136.75	14	0.83	298.00
5	05/02/2004	8	0.91	165.31	11	0.88	164.18	2	0.88	350.00
6	12/02/2004	12	0.94	172.92	11	0.84	175.45	8	0.84	306.63
7	19/02/2004	21	0.87	127.76	6	0.86	169.75	6	0.76	253.50
8	26/02/2004	7	0.91	146.29	3	0.93	134.67	22	0.82	301.09
9	04/03/2004	22	0.90	134.41	15	0.82	118.60	6	0.86	324.17
10	11/03/2004	18	1.08	151.89	20	0.89	162.70	8	0.84	301.88
11	18/03/2004	5	0.97	175.90	12	0.86	165.75	2	0.86	306.50
12	25/03/2004	4	0.82	137.88	9	0.91	168.67	4	0.82	301.25
13	01/04/2004	8	0.94	115.50	6	0.85	153.33	6	0.84	266.50
14	15/04/2004	10	0.96	111.10	16	0.89	147.78	5	0.86	302.80
15	22/05/2004	10	0.92	154.30	16	0.92	158.44	6	0.89	333.00
16	29/04/2004	17	0.99	148.26	17	0.90	164.09	11	0.83	268.36
17	06/05/2004	6	0.94	165.25	8	0.87	182.75	0	0.00	0.00
18	13/05/2004	1	1.07	123.00	8	0.89	169.31	11	0.86	284.91
19	20/05/2004	14	1.06	164.07	9	0.85	177.78	3	0.72	306.00
20	27/05/2004	12	0.95	140.75	7	0.86	183.71	11	0.86	335.91
21	03/06/2004	18	1.04	143.08	28	0.95	174.09	27	0.88	290.96
22	10/06/2004	13	0.97	142.62	39	0.91	159.59	54	0.86	283.17
23	17/06/2004	20	1.02	138.55	14	0.93	137.04	12	0.88	342.75
24	24/06/2004	26	0.91	166.06	23	0.87	182.48	31	0.85	303.61
25	01/07/2004	10	1.06	166.70	17	0.90	166.82	19	0.89	306.42
26	08/07/2004	20	1.01	159.85	27	0.89	175.65	24	0.84	293.88
27	15/07/2004	30	1.07	156.72	15	0.96	182.37	22	0.84	306.23
28	22/07/2004	24	1.13	158.92	16	1.01	186.13	27	0.88	317.56
29	29/07/2004	28	0.96	182.32	20	0.89	176.53	18	0.89	318.67
30	05/08/2004	26	1.02	184.42	23	0.94	175.85	22	0.85	308.95
31	12/08/2004	26	1.12	179.46	14	0.97	148.00	16	0.86	303.50
32	19/08/2004	38	1.05	182.18	22	0.93	160.11	29	0.87	320.86
33	26/08/2004	29	1.14	172.15	13	0.97	158.08	14	0.94	328.71
34	02/09/2004	77	1.02	162.18	41	0.91	157.63	34	0.91	315.94
35	09/09/2004	65	0.97	188.74	19	0.90	150.79	20	0.86	339.85
36	16/09/2004	16	0.86	154.16	14	0.93	158.04	8	0.87	290.88
37	23/09/2004	45	1.00	192.63	19	0.91	178.92	19	0.88	326.53

1 USD = 430 colones.

6.- Land use change index used by the GEF- Project to pay for Environmental Services.

Land Use	Biodiversity Points	Carbon Points	Total Index
Crops (annual, grains and tubers)	0	0	0
Degraded grassland	0	0	0
Natural grassland without trees	0.1	0.1	0.2
Improved grassland without trees	0.1	0.4	0.5
Perennial crops (plantain, coffee without shadow)	0.3	0.2	0.5
Natural grassland with low density of trees < 30 trees/ha	0.3	0.3	0.6
Natural grassland enrichment with low density of trees < 30 trees/ha	0.3	0.3	0.6
Living fences	0.3	0.3	0.6
Improved grassland enrichment with low density of trees < 30 trees/ha	0.3	0.4	0.7
Fruits crops (monocrop)	0.3	0.4	0.7
Fodder bank	0.3	0.5	0.8
Improved grassland with low density of trees < 30 trees/ha	0.3	0.6	0.9
Woody fodder bank	0.4	0.5	0.9
Natural grassland with high density of trees > 30 trees/ha	0.5	0.5	1
Fruits crops (diverse)	0.6	0.5	1.1
Living fences multi-stratum	0.6	0.5	1.1
Fodder bank (diverse)	0.6	0.6	1.2
Forest plantations (monocrop)	0.4	0.8	1.2
Coffee with shadow	0.6	0.7	1.3
Improved grassland with high tree density > 30 trees/ha	0.6	0.7	1.3
Guadua (bamboo) forest	0.5	0.8	1.3
Forest plantation (diverse)	0.7	0.7	1.4
Secondary regeneration s	0.6	0.8	1.4
Riparian forest	0.8	0.7	1.5
Intensive silvopastoral systems	0.6	1	1.6
Secondary forest interfered	0.8	0.9	1.7
Secondary forest	0.9	1	1.9
Primary forest	1	1	2

9.6ª.- Costa Rican Forest Chamber (wood prices).

LISTA DE PRECIOS DE MADERA MAS COMERCIALIZADAS EN LAS DISTINTAS ZONAS DE COSTA RICA
JUNIO DEL 2004

ZONA ATLANTICA	ARBOL EN PIE ¢/ PMT			MADERA EN TROZA EN PATIO INDUSTRIA ¢/ PMT		¢/m3		MADERA ASERRADA SIN CEPILLAR* ¢/PMT		¢/m3	
ESPECIE	1	2	3	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
ALMENDRO	80	110	150	245	255	79870	83130	700		298200	
CAOBILLA ZONA	55	85	100	90	120	29340	39120	200	280	85200	119280
CEDRO AMARGO	70	90	110	125	205	40750	66830	300	500	127800	213000
LAUREL	50	55	65	85	105	27710	34230	110	250	46860	106500
SEMIDURAS CLASIFI	45	50	55	85	105	27710	34230	105	280	44730	119280
SEMIDURAS COMUNE	25	35	55	70	100	22820	32600	105	220	44730	93720
FORMALETA	14	20	25	60	70	19560	22820	110	130	46860	55380
ZONA PACIFICO CENTRAL Y GUANACASTE	ARBOL EN PIE ¢/ PMT			MADERA EN TROZA EN PATIO INDUSTRIA ¢/ PMT		¢/m3		MADERA ASERRADA SIN CEPILLAR* ¢/PMT		¢/m3	
ESPECIE	1	2	3	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
SEM. CLASIFICADOS	50	60	70	110	150	35860	48900	350	500	149100	213000
SEM. COMUNES	45	50	60	75	140	24450	45640	175	350	74550	149100
FORMALETA	15	20	30	55	60	17930	19560	112	140	47712	59640
Valle General	ARBOL EN PIE ¢/ PMT			MADERA EN TROZA EN PATIO INDUSTRIA ¢/ PMT		¢/m3		MADERA ASERRADA SIN CEPILLAR* ¢/PMT		¢/m3	
ESPECIE	1	2	3	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
NAZARENO				180	200	58680	65200	500	636	213000	270936
CRISTOBAL								600	800	255600	340800
ALMENDRO				240	365	78240	118990	500	800	213000	340800
CAOBILLA				100	125	32600	40750	200	280	85200	119280
COCOBOLO				100	110	32600	35860	600	1500	255600	639000
CEDRO AMARGO				170	250	55420	81500	320	700	136320	298200
LAUREL				80	125	26080	40750	200	320	85200	136320
SEM. CLASIFICADOS				80	125	26080	40750	170	250	72420	106500
SEM. COMUNES				80	125	26080	40750	85	250	36210	106500
FORMALETA				53	80	17278	26080	85	220	36210	83720
ZONA NORTE	ARBOL EN PIE ¢/ PMT			MADERA EN TROZA EN PATIO INDUSTRIA ¢/ PMT		¢/m3		MADERA ASERRADA SIN CEPILLAR* ¢/PMT		¢/m3	
ESPECIE	1	2	3	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
ALMENDRO	100	150	220	135	250	44010	81500	300	1000	127800	426000
CAOBILLA	55	70	80	90	120	29340	39120	180	450	76680	191700
CORTEZA	100		150	135	250	44010	81500	300	1000	127800	426000
CEDRO AMARGO		110		135	180	44010	58680	200	450	85200	191700
LAUREL	55	60	65	90	110	29340	35860	175	250	74550	106500
NISPERO	50	55	60	95	200	30970	65200	250	800	106500	340800
SEM. CLASIFICADOS	50	70	80	95	100	30970	32600	200	210	85200	89460
SEM. COMUNES	50	60	70	85	100	27710	32600	180	190	76680	80940
FORMALETA	25	30	40	50	65	16300	21190	120	125	51120	53250
ZONA SUR	ARBOL EN PIE ¢/ PMT			MADERA EN TROZA EN PATIO INDUSTRIA ¢/ PMT		¢/m3		MADERA ASERRADA SIN CEPILLAR* ¢/PMT		¢/m3	
ESPECIE	1	2	3	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
NAZARENO	80			160	200	52160	65200	280	650	119280	276900
SEM. CLASIFICADOS	50		55	100	145	32600	47270	220	400	93720	170400
SEM. COMUNES	50		55	90	110	29340	35560	300	400	127800	170400
FORMALETA	25			50	60	16300	19560	130	135	55380	57510

Fuente: Asociados Cámara Costarricense Forestal, *Empresarios* e industriales de *las* respectivas regiones; Información recopilada y editada por *Ing*. Mario Vega

Notas:

1 Columnas 1 2 y 3: (1 corresponde al precio mínimo, 2 al precio promedio y 3 al precio máximo) en que se comercializan las maderas en las diferentes regiones

2 **Semiduros clasificados**: Amarillón (Roble Coral), Ciprés, Guanacaste, Carey, Botarrama, María, Guayaquil, Ajo, Cedro dulce, *Plomillo*, Ocora, Roble Sabana, Tito, Níspero, Chiricano, Tamarindo, Cambar, Pilón, Cenízaro, Eucaliptos.

3. **Semiduros comunes**: Fruta Dorada, Espavel, Gavilán, Iras, Jaúl, *Areno* (Masicarán), Baco (lechoso) Pino, Cocobolo de San Carlos, Ojoche, Campano, Amargo, Madroño, Jícaro, Cascarillo, Chancho, Querosen, Yema de huevo, Cocora, Pejibaye, Chaperno, Quizarrá.

4 **Formaleta**: Ceibo, Chilamate, Magnolia, Jabillo, Balsa, Aceituno, Sangrillo, Pino, Panamá, Gallinazo, Poró, Jobo, Papa, Guácimo colorado, Yos, Hule Cativo, Fruta, Chumico, Guácimo blanco, *Gallinazo*

5 Como dato informativo es importante rescatar que las especies maderables Duras son; Almendro, Amargo, Cambar, Cortez amarillo, Manú, Guapinol, Surá, Guayacán real, Níspero, Nazareno.

6 Los precios del árbol en pie se establecen *como precios promedios* a nivel regional y pueden variar dependiendo de las condiciones de acceso y transporte existentes en la zona

7 * Son precios promedios para madera aserrada sin cepillar, los cuales varían según el producto, la dimensión, calidad de la madera, etc.

8 **PMT:** Pulgada Maderera Medida Tica, baja sistema de *medida* a *mecate full*.

9 El sistema de conversión de PMT a m3 se efectúa según método de medición del Censo de la Industria Forestal 1986-1987, elaborado por la DGF con una razón de conversión de:

1 m3 = 326 PMT para madera en pie en troza en patio de industria, ya que la relación en la practica es aproximadamnete un 10% inferior.

1 m3 = 426 PMT para madera aserrada sin cepillar, ya que en la practica es aproximadamente un 10% inferior

9.7.- Timber component, establishment and maintenance costs for 132 timber trees in living fences. Esparza. Costa Rica. 2004.

Activity	USD
Year 1	
Outline and Mark	4.64
Weed killer in the mark 2m of Diameter	10.05
Make holes	4.64
Trees	30.93
Trees freight	7.73
Material distribution	2.32
To plant the trees	2.32
Chemical Fertilizer	2.32
Organic Fertilizer	10.83
Trees (To replant)	1.86
To replant the trees	2.32
Manual control of weeds (three months old)	2.32
Manual control of weeds (six months old)	2.32
Manual control of weeds (Nine months old)	2.32
Formation Pruning	2.32
Technical assistance	15.47
Sub Total	104.70
Year 2	
Manual control of weeds (1st Trimester)	2.32
Manual control of weeds (2d trimester)	2.32
Manual control of weeds (3rd trimester)	2.32
Formation pruning	2.32
Chemical Fertilizer	3.25
Organic Fertilizer	18.56
Technical assistance	15.47
Sub Total	46.55
Year 3	
Manual control of weeds (1st trimester)	2.32
Manual control of weeds (2d trimester)	2.32
Manual control of weeds (3rd trimester)	2.32
Formation pruning	2.32
Chemical Fertilizer	4.64
Organic Fertilizer	24.74
Technical assistance	15.47
Sub Total	54.13
Years 4 y 5	
Formation pruning	6.96
Years 6, 7 8 and 9	
Formation pruning	18.58
Year 10	
Formation pruning	4.64
First thinning 50%	6.98
Total	**242.51**

9.8.- Timber production from 132 timber trees of *C. odorata* in fences, according to bad, regular and good site quality. Esparza, Costa Rica. 2004.

Year	Site Quality		
	Bad (m^3/Ha)	**Regular (m^3/Ha)**	**Good (m^3/Ha)**
1	0.00	0.00	0.00
2	0.06	0.09	0.18
3	0.72	1.05	2.07
4	2.46	3.56	7.05
5	5.12	7.42	14.70
6	8.35	12.11	23.98
7	11.85	17.18	34.03
8	15.41	22.34	44.24
9	18.90	27.39	54.26
10	14.36	20.76	41.23
11	16.41	23.73	47.12
12	18.35	26.52	52.67
13	20.16	29.14	57.87
14	21.85	31.59	62.74
15	23.44	33.88	67.28
16	24.92	36.02	71.53
17	26.30	38.02	75.50
18	27.59	39.89	79.21
19	28.80	41.64	82.69
20	29.94	43.28	85.95
21	31.01	44.82	89.01
22	32.01	46.28	91.89
23	32.95	47.64	94.59
24	33.84	48.92	97.14
25	**34.68**	**50.14**	**99.55**

9.9.- Cash flow and NPV, IRR and B/C estimation in Model 1, timber trees of *C. odorata* in fences. Esparza, Costa Rica. 2004.

Discount rate	0.066					Calf				0.986															
Discount factor 1/(1+r)	0.938					Waste Cow				0.795															
			Price of Square meter of wood (*Cedrela odorata*) /USD								68.13														
With Project	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
INCOME																									
Sale of beef																									
Young Bull	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8
Sale of wood																									2362.5
PES (Project GEF)	0.0	0.0	0.0	0.0																					
TOTAL INCOME	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	3138.3
LIVESTOCK PRODUCTION COSTS																									
From calf to young bull	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7
GRASSLAND MAINTENANCE COSTS																									
Improved grass	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
TIMBER TREES INVESTMENT																									
Outline and Mark	4.6																								
Weed killer	10.1																								
Make holes	4.6																								
Trees.	30.9																								
Freight of the trees	7.7																								
Material distribution	2.3																								
To plant the trees	2.3																								
Chemical Fertilizer	2.3	3.2	4.6																						
Organic Fertilizer	10.8	18.6	24.7																						
Trees. (To replant)	1.9																								
To replant the trees	2.3																								
Weeds control (1st)	2.3	2.3	2.3																						
Weeds control (2d)	2.3	2.3	2.3																						
Weeds control (3rd)	2.3	2.3	2.3																						
Formation pruning	2.3	2.3	2.3	3.5	3.5	4.6	4.6	4.6	4.6	4.6															
Technical assistance	15.5	15.5	15.5																						
First thinning										7.0															
TOTAL COST	237.4	179.2	186.8	136.2	136.2	137.3	137.3	137.3	137.3	144.3	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7
NET INCOME WITH	538.4	596.5	589.0	639.6	639.6	638.4	638.4	638.4	638.4	631.5	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	3005.6

PROJECT																									

9.9[a].- Cash flow and NPV, IRR and B/C estimation in Model 1, timber trees of *C. odorata* in fences. Esparza, Costa Rica.2004. Cont…

	Years																								
WITHOUT PROJECT	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
INCOME																									
Sale of beef																									
Waste Cow	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8
TOTAL INCOME	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8	775.8
LIVESTOCK PRODUCTION COSTS																									
From Calf to Young Bull	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7	115.7
GRASSLAND MAINTENANCE COSTS																									
Improved grass	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
TOTAL COSTS	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7	132.7
INCOME WITHOUT PROJECT	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1	643.1
NET INCREMENTAL FLOW (WITH VRS WITHOUT PROJECT)	-104.7	-46.6	-54.1	-3.5	-3.5	-4.6	-4.6	-4.6	-4.6	-11.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2362.5
DISCOUNT RATE	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
DISCOUNTED NET INCREMENTAL FLOW	-98.3	-41.0	-44.7	-2.7	-2.5	-3.2	-3.0	-2.8	-2.6	-6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	482.5
NET PRESENT VALUE (NPV)		275.6																							
INTERNAL RATE OF RETURN		0.11																							
BENEFIT/COST RATIO		2.33																							

10.- Cash flow and LEV estimation in Model 1, timber trees of *C. odorata* in fences. Esparza, Costa Rica. 2004.

et Present Value Methodology at 12%																Years														
e	Timber	PES	Livestock	Total	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
0	Costs		incomes	Costs																										
1	104.7	0.0	177.2	72.5		72.5	77.3	82.3	87.7	93.5	99.6	106.1	113.1	120.5	128.4	136.9	145.8	155.4	165.6	176.5	188.0	200.4	213.5	227.5	242.4	258.3	275.3	293.4	312.6	333.1
2	46.6	0.0	177.2	130.6			130.6	139.2	148.3	158.1	168.5	179.5	191.3	203.8	217.2	231.4	246.6	262.8	280.0	298.4	318.0	338.9	361.1	384.8	410.0	436.9	465.6	496.1	528.7	563.3
3	54.1	0.0	177.2	123.1				123.1	131.1	139.7	148.9	158.7	169.1	180.2	192.0	204.6	218.0	232.3	247.6	263.8	281.1	299.5	319.2	340.1	362.4	386.2	411.6	438.6	467.3	498.0
4	3.5	0.0	177.2	173.7					173.7	185.1	197.3	210.2	224.0	238.7	254.3	271.0	288.8	307.7	327.9	349.4	372.4	396.8	422.8	450.6	480.1	511.6	545.2	580.9	619.0	659.7
5	3.5		177.2	173.7						173.7	185.1	197.3	210.2	224.0	238.7	254.3	271.0	288.8	307.7	327.9	349.4	372.4	396.8	422.8	450.6	480.1	511.6	545.2	580.9	619.0
6	4.6		177.2	172.6							172.6	183.9	195.9	208.8	222.5	237.1	252.6	269.2	286.9	305.7	325.7	347.1	369.9	394.1	420.0	447.6	476.9	508.2	541.5	577.1
7	4.6		177.2	172.6								172.6	183.9	195.9	208.8	222.5	237.1	252.6	269.2	286.9	305.7	325.7	347.1	369.9	394.1	420.0	447.6	476.9	508.2	541.5
8	4.6		177.2	172.6									172.6	183.9	195.9	208.8	222.5	237.1	252.6	269.2	286.9	305.7	325.7	347.1	369.9	394.1	420.0	447.6	476.9	508.2
9	4.6		177.2	172.6										172.6	183.9	195.9	208.8	222.5	237.1	252.6	269.2	286.9	305.7	325.7	347.1	369.9	394.1	420.0	447.6	476.9
0	11.6		177.2	165.6											165.6	176.4	188.0	200.4	213.5	227.5	242.4	258.3	275.3	293.3	312.6	333.1	354.9	378.2	403.0	429.5
1	0.0		177.2	177.2												177.2	188.8	201.2	214.4	228.5	243.5	259.4	276.4	294.6	313.9	334.5	356.4	379.8	404.7	431.3
2	0.0		177.2	177.2													177.2	188.8	201.2	214.4	228.5	243.5	259.4	276.4	294.6	313.9	334.5	356.4	379.8	404.7
3	0.0		177.2	177.2														177.2	188.8	201.2	214.4	228.5	243.5	259.4	276.4	294.6	313.9	334.5	356.4	379.8
4	0.0		177.2	177.2															177.2	188.8	201.2	214.4	228.5	243.5	259.4	276.4	294.6	313.9	334.5	356.4
5	0.0		177.2	177.2																177.2	188.8	201.2	214.4	228.5	243.5	259.4	276.4	294.6	313.9	334.5
6	0.0		177.2	177.2																	177.2	188.8	201.2	214.4	228.5	243.5	259.4	276.4	294.6	313.9
7	0.0		177.2	177.2																		177.2	188.8	201.2	214.4	228.5	243.5	259.4	276.4	294.6
8	0.0		177.2	177.2																			177.2	188.8	201.2	214.4	228.5	243.5	259.4	276.4
9	0.0		177.2	177.2																				177.2	188.8	201.2	214.4	228.5	243.5	259.4
0	0.0		177.2	177.2																					177.2	188.8	201.2	214.4	228.5	243.5
1	0.0		177.2	177.2																						177.2	188.8	201.2	214.4	228.5
2	0.0		177.2	177.2																							177.2	188.8	201.2	214.4
3	0.0		177.2	177.2																								177.2	188.8	201.2
4	0.0		177.2	177.2																									177.2	188.8
5	0.0		177.2	177.2																										177.2
Capitalized costs						72	208	345	541	750	972	1208	1460	1728	2007	2316	2645	2996	3370	3768	4192	4645	5127	5640	6187	6770	7392	7877	8393	8944
Timber production						0.0	0.0	0.2	0.8	1.7	2.8	4.0	5.1	6.3	4.8	5.5	6.1	6.7	7.3	7.8	8.3	8.8	9.2	9.6	10.0	10.3	10.7	11.0	11.3	11.6
Wood sale income						0.0	1.4	16.4	55.8	116.3	189.7	269.2	350.0	429.2	326.2	372.8	416.7	457.8	496.3	532.3	565.9	597.3	626.7	654.2	680.0	704.2	726.9	748.4	768.6	787.5
Total Future value						72	209	361	597	866	1162	1477	1810	2158	2334	2689	3062	3454	3866	4300	4758	5242	5753	6294	6867	7474	8119	8625	9162	9731
LEV										2317	2503	2638	2732	2796	2629	2658	2678	2690	2696	**2698**	2698	2695	2691	2685	2679	2672	2665	2604	2549	2498
Liquidation cost										2913	2986	3066	3147	3226	3123	3169	3213	3254	3293	3329	3362	3394	3423	3451	3476	3501	3523	3545	3565	3584
Net capitalized factor					3768	3592	3293	3029	2680	2352	2046	1759	1490	1238	1010	782	567	366	177	0										
Immaturity forest worth					**2698**	2803	2856	2920	2938	2957	2979	3002	3026	3052	3087	3112	3139	3167	3198	3231	3443	3668	3909	4166	4439	4730	5040	5371	5723	6099
Discount rate					6.58 %				Price of the Land				1,918 USD																	
Price of Wood (m^3/USD)					68.134				Kilometers				0.4																	

9.11.- Timber component, establishment and maintenance costs of 200 timber trees from natural regeneration in a native grassland. Esparza. Costa Rica. 2004.

Activity	USD
Year 1	
Outline and Mark	0.00
Weed killer in the mark 2m of Diameter	15.12
Make holes	0.00
Trees	0.00
Trees freight	0.00
Material distribution	0.00
To plant the trees	0.00
Chemical Fertilizer	3.49
Organic Fertilizer	16.28
Trees (To replant)	0.00
To replant the trees	0.00
Manual control of weeds (three months old)	3.49
Manual control of weeds (six months old)	3.49
Manual control of weeds (Nine months old)	3.49
Formation Pruning	3.49
Technical assistance	23.26
Sub Total	**72.09**
Year 2	
Manual control of weeds (1st Trimester)	3.49
Manual control of weeds (2d trimester)	3.49
Manual control of weeds (3rd trimester)	3.49
Formation pruning	3.49
Chemical Fertilizer	4.88
Organic Fertilizer	27.91
Technical assistance	23.26
Sub Total	**70.00**
Year 3	
Manual control of weeds (1st trimester)	3.49
Manual control of weeds (2d trimester)	3.49
Manual control of weeds (3rd trimester)	3.49
Formation pruning	3.49
Chemical Fertilizer	6.98
Organic Fertilizer	37.21
Technical assistance	23.26
Sub Total	**81.40**
Years 4 and 5	
Formation pruning	20.93
Years 6 and 7	
Formation pruning	13.96
Years 8	
Formation pruning and first thinning	27.91
Year 9 and 10	
Formation pruning	13.96
Year 15	
Second thinning	20.93

Total	310.71

9.12.- Timber production from 50 timber trees of *C. odorata* from natural regeneration in native grassland, according to bad, regular and good site quality. Esparza, Costa Rica. 2004.

Year	Site quality		
	Bad	Regular	Good
1	0.00	0.00	0.00
2	0.03	0.05	0.10
3	0.38	0.63	1.18
4	1.28	2.15	4.02
5	2.67	4.48	8.38
6	4.36	7.31	13.68
7	6.18	10.37	19.41
8	7.36	12.34	19.38
9	9.03	15.14	23.76
10	10.63	17.82	27.98
11	12.15	20.37	31.98
12	13.58	22.77	35.74
13	14.91	25.02	39.27
14	16.17	27.12	42.57
15	16.60	27.84	43.68
16	17.65	29.59	46.45
17	18.62	31.24	49.03
18	19.54	32.77	51.43
19	20.40	34.21	53.70
20	21.20	35.56	55.81
21	21.95	36.83	57.80
22	22.66	38.02	59.67
23	23.34	39.13	61.42
24	23.96	40.19	63.08
25	24.55	41.19	64.64
Final turn m^3/tree	**0.491**	**0.824**	**1.29**

.13.- Cash flow and NPV, IRR and B/C estimation in Model 2, timber trees of *C. odorata* under natural regeneration. Esparza, Costa Rica. 2004.

iscount rate	0.066									Y. Bull	0.901				Price of Square meter of wood (*Cedrela odorata*)								68.13	
iscount factor 1/(1+r)	0.938									Calf	0.986				Change rate 1 USD = 430 colones									
												Years												
VITH PROJECT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
NCOME																									
ale Two young bulls	511.8	511.8	511.8	511.8	511.8	568	568	568.3	568.3	568.3	568.3	568.3	568.3	568.3	568.	568	568	568.3	568	568.3	568.3	568.3	568.3	568.3	568.3
ale of wood																									1672.
ES (Project GEF)	0.0	0.0	0.0	0.0																					
hadow effect	0.0	0.0	0.0	0.3	0.7	0.9	1.2	1.5	2.0	2.5	3.0	3.5	4.0	4.5	3.0	3.4	3.8	4.2	4.9	5.3	5.7	6.1	6.5	7.0	7.4
isc. Shadow effect	0.0	0.0	0.0	1.4	3.7	4.9	6.9	8.8	11.3	14.0	16.8	19.6	22.6	25.6	17.1	19.3	21.6	23.9	27.6	29.9	32.3	34.8	37.2	39.6	42.1
ubtotal of incomes	511.8	511.8	511.8	511.8	511.8	568	568	568.3	568.3	568.3	568.3	568.3	568.3	568.3	568.	568	568.3	568.3	568	568.3	568.3	568.3	568.3	568.3	568.3
OTAL OF INCOMES	511.8	511.8	511.8	510.4	508.1	563	561	559.5	556.9	554.3	551.5	548.6	545.7	542.7	551.	548	546	544.3	540	538.3	535.9	533.5	531.1	528.6	2199.
IVESTOCK PRODUCTION COSTS																									
alf to Young bull	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1
hadow effect	0.0	0.0	0.0	0.3	0.7	0.9	1.2	1.5	2.0	2.5	3.0	3.5	4.0	4.5	3.0	3.4	3.8	4.2	4.9	5.3	5.7	6.1	6.5	7.0	7.4
isc. Shadow effect	0.0	0.0	0.0	0.2	0.6	0.7	0.9	1.2	1.5	1.9	2.3	2.7	3.1	3.5	2.3	2.6	2.9	3.2	3.7	4.1	4.4	4.7	5.0	5.4	5.7
ub. livestock costs	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1
otal Livestock costs	77.1	77.1	77.1	76.8	76.5	76.4	76.1	75.9	75.5	75.2	74.8	74.4	74.0	73.6	74.7	74.4	74.1	73.8	73.3	73.0	72.7	72.3	72.0	71.7	71.4
RASSLAND MAINTENANCE COSTS																									
latural grass	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9
ought Two calfs	309.6	309.6	309.6	309.6	309.6	309	309	309.6	309.6	309.6	309.6	309.6	309.6	309.6	309.	309.	309.	309.6	309	309.6	309.6	309.6	309.6	309.6	309.6
IBER TREES INVESTMENT																									
utline and Mark	0.0																								
Veed killer	15.1																								
lake holes	0.0																								
rees.	0.0																								
reight of the trees	0.0																								
laterial distribution	0.0																								
o plant the trees	0.0																								
hemical Fertilizer	3.5	4.9	7.0																						
rganic Fertilizer	16.3	27.9	37.2																						
rees.	0.0																								
o replant the trees	0.0																								
veeds control (1 st)	3.5	3.5	3.5																						
veeds control (2d)	3.5	3.5	3.5																						
veeds control (3 rd)	3.5	3.5	3.5																						
ormation pruning	3.5	3.5	3.5	5.2	5.2	7.0	7.0	7.0	7.0	7.0															
echnical assistance	23.3	23.3	23.3																						
irst thinning								20.9																	
econd thinning															20.9										
OTAL COSTL	544.6	542.5	553.9	477.5	477.2	478	478	499.2	478.0	477.6	470.3	469.9	469.5	469.1	491.	469.	469	469.3	468	468.5	468.1	467.8	467.5	467.2	466.8
NCOME WITH	-32.8	-30.8	-42.1	32.8	30.9	84.5	82.8	60.3	79.0	76.7	81.2	78.8	76.2	73.6	60.0	79.0	77.1	75.1	71.9	69.8	67.8	65.7	63.6	61.5	1732.

).13[a].- Cash flow and NPV, IRR and B/C estimation in Model 2, timber trees of *C. odorata* under natural regeneration. Esparza, Costa Rica. 2004.

	Years																								
ITHOUT ROJECT	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
NCOME																									
Two young bulls	516.6	516.6	516.6	516.6	516.6	516.6	516.6	516.6	516.6	516	516.6	516	516.6	516.6	516	516.6	516	516.6	516.6	516	516.6	516.6	516.6	516.6	516.6
NCOMES TOTAL	516.6	516.6	516.6	516.6	516.6	516.6	516.6	516.6	516.6	516	516.6	516	516.6	516.6	516	516.6	516	516.6	516.6	516	516.6	516.6	516.6	516.6	516.6
RODUCTION COSTS - LIVESTOCK																									
laintenance costs	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1	77.1
ought of two calf	309.6	309.6	309.6	309.6	309.6	309.6	309.6	309.6	309.6	309	309.6	309	309.6	309.6	309	309.6	309	309.6	309.6	309	309.6	309.6	309.6	309.6	309.6
AINTENANCE COSTS - GRASSLAND																									
latural grass	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9	85.9
OTAL COST	472.5	472.5	472.5	4725	472.5	472.5	472.5	472.5	472.5	472	472.5	472	472.5	472.5	472	472.5	472	472.5	472.5	472	472.5	472.5	472.5	472.5	472.5
IET FLOW VITHOUT ROJECT	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1
IET NCREMENTAL LOW (WITH VRS VITHOUT ROJECT)	-76.9	-74.8	-86.22	-11.2	-13.20	40.45	38.69	16.18	34.91	32.5	37.16	34.6	32.15	29.57	15.9	34.96	32.9	30.99	27.83	25.7	23.70	21.62	19.52	17.40	1688.
ISCOUNT RATE	0.94	0.88	0.83	0.78	0.73	0.68	0.64	0.60	0.56	0.53	0.50	0.47	0.44	0.41	0.39	0.36	0.34	0.32	0.30	0.28	0.26	0.25	0.23	0.22	0.20
ISCOUNTED NCREMENTAL LOW	-72.1	-65.9	-71.26	-8.7	-9.61	27.63	24.80	9.73	19.70	17.2	18.47	16.1	14.08	12.15	6.1	12.65	11.2	9.87	8.32	7.23	6.24	5.34	4.53	3.79	344.8
NET PRESENT VALUE (NPV)			352.47			BENEFIT/COST RATIO 2.55																			
INTERNAL RATE OF RETURN			0.13																						

).14.- Cash flow and LEV estimation in Model 2, timber trees of *C. odorata* from natural regeneration in native grassland. Esparza, Costa Rica. 2004.

Age	Timber Costs	Livestock Incomes	PES	Incomes Total	Costs Total	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	72.1	39.2	0.0	39.2	-32.8		-33	-35	-37	-40	-42	-45	-48	-51	-55	-58	-62	-66	-70	-75	-80	-85	-91	-97	-103	-110	-117	-125	-133	-142	-151
2	70.0	39.2	0.0	39.2	-30.8			-31	-33	-35	-37	-40	-42	-45	-48	-51	-54	-58	-62	-66	-70	-75	-80	-85	-91	-97	-103	-110	-117	-124	-133
3	81.4	39.2	0.0	39.2	-42.1				-42	-45	-48	-51	-54	-58	-62	-66	-70	-75	-80	-85	-90	-96	-103	-109	-116	-124	-132	-141	-150	-160	-171
4	5.2	38.0	0.0	38.0	32.8					33	35	37	40	42	45	48	51	55	58	62	66	70	75	80	85	91	97	103	110	117	125
5	5.2	36.1		36.1	30.9						31	33	35	37	40	42	45	48	51	55	58	62	66	71	75	80	85	91	97	103	110
6	7.0	91.5		91.5	84.5							85	90	96	102	109	116	124	132	141	150	160	170	181	193	206	219	234	249	265	283
7	7.0	89.7		89.7	82.8								83	88	94	100	107	114	121	129	138	147	156	166	177	189	201	215	229	244	260
8	27.9	88.2		88.2	60.3									60	64	68	73	78	83	88	94	100	107	114	121	129	138	147	156	167	177
9	7.0	86.0		86.0	79.0										79	84	90	96	102	109	116	123	131	140	149	159	169	180	192	205	218
10	7.0	83.6		83.6	76.7											77	82	87	93	99	105	112	120	127	136	145	154	164	175	187	199
11	0.0	81.2		81.2	81.2												81	87	92	98	105	112	119	127	135	144	153	163	174	186	198
12	0.0	78.8		78.8	78.8													79	84	89	95	102	108	115	123	131	140	149	158	169	180
13	0.0	76.2		76.2	76.2														76	81	87	92	98	105	112	119	127	135	144	153	163
14	0.0	73.6		73.6	73.6															74	78	84	89	95	101	108	115	122	130	139	148
15	20.9	81.0		81.0	60.0																60	64	68	73	77	83	88	94	100	106	113
16	0.0	79.0		79.0	79.0																	79	84	90	96	102	109	116	123	131	140
17	0.0	77.1		77.1	77.1																		77	82	88	93	99	106	113	120	128
18	0.0	75.1		75.1	75.1																			75	80	85	91	97	103	110	117
19	0.0	71.9		71.9	71.9																				72	77	82	87	93	99	105
20	0.0	69.8		69.8	69.8																					70	74	79	85	90	96
21	0.0	67.8		67.8	67.8																						68	72	77	82	87
22	0.0	65.7		65.7	65.7																							66	70	75	79
23	0.0	63.6		63.6	63.6																								64	68	72
24	0.0	61.5		61.5	61.5																									61	66
25	0.0	59.4		59.4	59.4																										59
	Capitalized costs						-33	-66	-112	-87	-62	19	103	170	260	354	458	567	680	799	911	1050	1196	1349	1510	1679	1857	2044	2178	2321	2473
	Timber production						0	0	0	1	3	4	6	7	9	11	12	14	15	16	17	18	19	20	20	21	22	23	23	24	25
	Wood sale income						0	2	26	87	182	297	421	501	615	724	828	925	1016	1102	1131	1202	1269	1331	1390	1444	1496	1544	1590	1632	1673
	Total future value						-33	-64	-87	0	120	316	524	671	875	1078	1286	1492	1697	1900	2042	2252	2464	2681	2900	3123	3352	3588	3768	3954	4146
	LEV										322	680	936	1013	1134	1214	1271	1305	1321	**1325**	1281	1277	1267	1254	1237	1218	1198	1178	1138	1100	1064
	Liquidation costs										1463	1578	1703	1783	1896	2005	2109	2206	2297	2383	2412	2484	2550	2612	2671	2726	2777	2825	2871	2914	2954
	Net capitalized factor					799	874	940	1024	963	908	767	638	550	441	343	244	155	74	0											
	Immaturity forest worth					**1325**	1350	1467	1603	1678	1759	1795	1835	1898	1949	2005	2060	2121	2189	2263											
	Discount rate			0.0656																											
	Price of Wood m^3/USD			68.134																											

9.15.- Timber component, establishment and maintenance costs of 400 timber trees of *C. odorata* in a degraded grassland. Esparza. Costa Rica. 2004.

Activity		Total
Year 1		
Outline and Mark		13.95
Weed killer in the mark		30.23
Make holes		13.95
Trees.		93.02
Trees freight		23.26
Material distribution		6.98
To plant the trees		6.98
Chemical Fertilizer		6.98
Organic Fertilizer		32.56
Trees. (to replant)		5.58
To replant the trees		6.98
Weeds control (tree months old)		6.98
Weeds control (six months old)		6.98
Weeds control (Nine months old)		6.98
Formation Pruning		6.98
Technical assistance		46.51
Sub total		**314.88**
Year 2		
Weeds control (1st)		6.98
Weeds control (2 d)		6.98
Weeds control (3rd)		6.98
Formation pruning		6.98
Chemical Fertilizer		9.77
Organic Fertilizer		55.81
Technical assistance		46.51
Sub Total		**140.00**
Year 3		
Weeds control (1st)		6.98
Weeds control (2 d)		6.98
Weeds control (3 rd)		6.98
Formation pruning		6.98
Chemical Fertilizer		13.95
Organic Fertilizer		74.42
Technical assistance		46.51
Sub Total		**162.79**
Year 4 and 5		
Formation pruning		20.94
Year 6 and 7		
Formation pruning		27.90
Year 8		
Formation pruning		13.95
First thinning 50%	200	27.91
Year 9 and 10		
Formation pruning		27.90
Year 15		
Second thinning 25%	100	27.91
Total		**764.19**

9.16.- Timber production from a tacotal enrichment with 100 timber trees of *C. odorata.* Esparza, Costa Rica. 2004.

Year	Timber production m^3/100 trees
1	0
2	0.038
3	0.449
4	1.527
5	3.183
6	5.197
7	7.372
8	8.038
9	9.858
10	11.608
11	13.266
12	14.823
13	16.292
14	17.661
15	17.341
16	18.439
17	19.457
18	20.416
19	21.313
20	22.155
21	22.945
22	23.688
23	24.384
24	25.039
25	25.663
26	26.251
27	26.801
Final turn m^3/tree	**0.28**

Source: Software Silvia©

9.17.- Cash flow and NPV, IRR and B/C estimation in Model 3, tacotal enriched with 100 timber trees of *C. odorata*. Esparza, Costa Rica. 2004.

Change rate 1 USD = 430 colones		Beef price			
Discount rate	0.0656	Calf	0.986	Price of Square meter of wood (*Cedrela odorata*) USD….	68.13
Discount factor 1/(1+r)	0.938	Young Bull	0.901		

	Years																													
WITH PROJECT	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
INCOME																														
Sale of beef																														
Calf Male	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sale of wood																														1826.1
PES (Project GEF)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0																					
TOTAL INCOMES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1826.1
LIVESTOCK PRODUCTION COSTS																														
Maintenance costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bought One calf	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Livestock cost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GRASSLAND MAINTENANCE COSTS																														
Degraded grass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TIMBER TREES INVESTMENT																														
Outline and Mark			14.0																											
Weed killer			30.2																											
Make holes			14.0																											
Trees.			93.0																											
Freight of the trees			23.3																											
Material distribution			7.0																											
To plant the trees			7.0																											
Chemical Fertilizer			7.0	9.8	14.0																									
Organic Fertilizer			32.6	55.8	74.4																									
Trees to replant			5.6																											
To replant the trees			7.0																											
Weeds control (1st)			7.0	7.0	7.0																									
Weeds control (2d)			7.0	7.0	7.0																									
Weeds control (3rd)			7.0	7.0	7.0																									
Formation pruning			7.0	7.0	7.0	10.5	10.5	14.0	14.0	14.0	14.0	14.0																		
Technical assistance			46.5	46.5	46.5																									
First thinning										27.9																				

Second thinning																	27.9													
COSTS TOTAL	0.0	0.0	314.9	140.0	162.8	10.5	10.5	14.0	14.0	41.9	14.0	14.0	0.0	0.0	0.0	0.0	27.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
INCOME WITH PROJECT	0.0	0.0	-314.9	-140.0	-162.8	-10.5	-10.5	-14.0	-14.0	-41.9	-14.0	-14.0	0.0	0.0	0.0	0.0	-27.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1826.1

9.17[a].- Cash flow and NPV, IRR and B/C estimation in Model 3, tacotal enriched with 100 timber trees of *C. odorata*. Esparza, Costa Rica. 2004. Cont…

	Years																													
WITHOUT PROJECT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
INCOMES																														
Sale of beef																														
Calf Male	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2
TOTAL OF INCOMES	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2	129.2
LIVESTOCK PRODUCTION COSTS																														
Maintenance costs	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Purchase one calf	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4	77.4
GRASSLANDS MAINTENANCE COSTS																														
Degraded pasture	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
COST TOTAL	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6	120.6
INCOME WITHOUT PROJECT	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
NET INCREMENTAL FLOW (WITH VRS WITHOUT PROJECT)	-8.5	-8.5	-323.4	-148.5	-171.3	-19.0	-19.0	-22.5	-22.5	-50.4	-22.5	-22.5	-8.5	-8.5	-8.5	-8.5	-36.4	-8.5	-8.5	-8.5	-8.5	-8.5	-8.5	-8.5	-8.5	-8.5	-8.5	-8.5	-8.5	1817.5
DISCOUNT RATE	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1
DISCOUNTED NET INCREMENTAL FLOW	-8.0	-7.5	-267.3	-115.2	-124.7	-13.0	-12.2	-13.5	-12.7	-26.7	-11.2	-10.5	-3.7	-3.5	-3.3	-3.1	-12.4	-2.7	-2.5	-2.4	-2.2	-2.1	-2.0	-1.9	-1.7	-1.6	-1.5	-1.4	-1.3	270.2
NET PRESENT VALUE (NPV)					-401.6																									
INTERNAL RATE OF RETURN					#¡NUM!																									
BENEFIT/COST RATIO					0.402																									

9.18.- Cash flow and LEV estimation in Model 3, tacotal enriched with 100 timber trees of *C. odorata.* Esparza, Costa Rica. 2004.

				Years																									
Age	**Timber**	**PES**	**Total**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
0	**Costs**		**Costs**																										
1	0.0	0.0	0.0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0.0	0.0	0.0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	314.9	0.0	-314.9				-315	-336	-358	-381	-406	-433	-461	-491	-523	-558	-594	-633	-675	-719	-766	-817	-870	-927	-988	-1053	-1122	-1196	-1274
4	140.0	0.0	-140.0					-140	-149	-159	-169	-181	-192	-205	-218	-233	-248	-264	-282	-300	-320	-341	-363	-387	-412	-439	-468	-499	-532
5	162.8	0.0	-162.8						-163	-173	-185	-197	-210	-224	-238	-254	-271	-288	-307	-327	-349	-372	-396	-422	-450	-479	-511	-544	-580
6	10.5	0.0	-10.5							-10	-11	-12	-13	-13	-14	-15	-16	-17	-19	-20	-21	-22	-24	-25	-27	-29	-31	-33	-35
7	10.5	0.0	-10.5								-10	-11	-12	-13	-13	-14	-15	-16	-17	-19	-20	-21	-22	-24	-25	-27	-29	-31	-33
8	14.0	0.0	-14.0									-14	-15	-16	-17	-18	-19	-20	-22	-23	-25	-26	-28	-30	-32	-34	-36	-39	-41
9	14.0	0.0	-14.0										-14	-15	-16	-17	-18	-19	-20	-22	-23	-25	-26	-28	-30	-32	-34	-36	-39
10	41.9	0.0	-41.9											-42	-45	-48	-51	-54	-58	-61	-65	-70	-74	-79	-84	-90	-96	-102	-109
11	14.0	0.0	-14.0												-14	-15	-16	-17	-18	-19	-20	-22	-23	-25	-26	-28	-30	-32	-34
12	14.0	0.0	-14.0													-14	-15	-16	-17	-18	-19	-20	-22	-23	-25	-26	-28	-30	-32
13	0.0	0.0	0.0														0	0	0	0	0	0	0	0	0	0	0	0	0
14	0.0	0.0	0.0															0	0	0	0	0	0	0	0	0	0	0	0
15	0.0	0.0	0.0																0	0	0	0	0	0	0	0	0	0	0
16	0.0	0.0	0.0																	0	0	0	0	0	0	0	0	0	0
17	27.9	0.0	-27.9																		-28	-30	-32	-34	-36	-38	-41	-44	-46
18	0.0	0.0	0.0																			0	0	0	0	0	0	0	0
19	0.0	0.0	0.0																				0	0	0	0	0	0	0
20	0.0	0.0	0.0																					0	0	0	0	0	0
21	0.0	0.0	0.0																						0	0	0	0	0
22	0.0	0.0	0.0																							0	0	0	0
23	0.0	0.0	0.0																								0	0	0
24	0.0	0.0	0.0																									0	0
25	0.0	0.0	0.0																										0
	Capitalized costs				0	0	-315	-476	-670	-724	-782	-847	-917	-1019	-1099	-1185	-1263	-1346	-1434	-1529	-1657	-1765	-1881	-2005	-2136	-2276	-2426	-2585	-2754
	Timber production						0	0	0	2	3	5	7	8	10	12	13	15	16	18	17	18	19	20	21	22	23	24	24
	Wood sale income				0	3	31	104	217	354	502	548	672	791	904	1010	1110	1203	1182	1256	1326	1391	1452	1510	1563	1614	1661	1706	1749
	Total future worth				0	3	-284	-371	-453	-370	-280	-299	-245	-228	-196	-176	-153	-143	-253	-272	-331	-374	-429	-495	-573	-662	-764	-879	-1006
	LEV								-1210	-797	-499	-452	-318	-257	-193	-153	-119	**-99.58**	-159	-154	-170	-175	-183	-193	-205	-217	-231	-244	-258
	Liquidation cost								58	195	344	389	513	632	745	851	951	1045	1023	1098	1167	1232	1293	1351	1405	1455	1503	1547	1590

	Net capitalized factor	-1346	-1346	-1346	-713	-448	-160	-143	-126	-106	-87	-33	-16	0	0	0											
	Immaturity forest worth	-99.6	-133	286	457	497	539	588	639	721	781	845	901	960	901	960											
	Discount rate %	6.58																									
	Wood price m^3 / USD	68.13																									

9.19.- Timber component, establishment and maintenance costs for 20 timber trees of *C. odorata* in improved grassland. Esparza. Costa Rica. 2004.

Activity		Total
Year 1		
Outline and Mark		0.70
Weed killer in the mark 2m of Diameter		1.51
Make holes		0.70
Trees.		4.65
Trees freight		1.16
Material distribution		0.35
To plant the trees		0.35
Chemical Fertilizer		0.35
Organic Fertilizer		1.63
Trees. (to replant)		0.28
To replant the trees		0.35
ArborGard+? Tree Trunk Protector		29.00
Weeds control (three months old)		0.35
Weeds control (six months old)		0.35
Weeds control (Nine months old)		0.35
Formation Pruning		0.35
Chemical Fertilizer		0.00
Organic Fertilizer		0.00
Technical assistance		2.33
Sub Total		**44.74**
Year 2		
Weeds control (1st)		0.35
Weeds control (2 d)		0.35
Weeds control (3rd)		0.35
Formation pruning		0.35
Chemical Fertilizer		0.49
Organic Fertilizer		2.79
Technical assistance		2.33
Sub Total		**7.00**
Year 3		
Weeds control (1st)		0.35
Weeds control (2 d)		0.35
Weeds control (3 rd)		0.35
Formation pruning		0.35
Chemical Fertilizer		0.70
Organic Fertilizer		3.72
Technical assistance		2.33
Sub Total		**8.14**
Year 4 and 5		
Formation pruning		1.04
Year 6 an 7		
Formation pruning		1.39
Year 8		
Formation pruning		0.69
First thinning 50%	10 trees	2.09
Year 9 and 10		
Formation pruning		1.39
Year 15		
Second thinning 25%	5 trees	2.09
Costs total		**68.60**

9.20.- Timber production from 5 timber trees of *C. odorata* in an improved grassland. Esparza, Costa Rica, 2004.

Year	Site quality		
	Bad	**Regular**	**Good**
1	0.000	0	0
2	0.002	0.003	0.005
3	0.029	0.046	0.066
4	0.099	0.159	0.226
5	0.207	0.332	0.472
6	0.338	0.542	0.771
7	0.480	0.77	1.094
8	0.619	0.993	1.412
9	0.759	1.217	1.73
10	0.895	1.435	2.037
11	1.023	1.64	2.33
12	1.142	1.832	2.602
13	1.256	2.013	2.86
14	1.362	2.183	3.101
15	1.453	2.332	3.311
16	1.545	2.478	3.521
17	1.631	2.616	3.716
18	1.711	2.744	3.898
19	1.786	2.864	4.071
20	1.857	2.977	4.231
21	1.922	3.083	4.381
22	1.985	3.185	4.523
23	2.044	3.277	4.656
24	2.100	3.366	4.781
25	2.151	3.449	4.901
Final turn m^3/tree	**0.43**	**0.69**	**0.98**

9.21.- Cash flow and NPV, IRR and B/C estimation in Model 4, improved grasslands with timber trees of *C. odorata* at perpetuity. Esparza, Costa Rica. 2004

Change rate 1 USD = 430 colones																
Discount rate	0.0656		Beef Price			Price of Square meter of wood (Cedrella odorata)							68.13			
Discount factor 1/(1+r)	0.938		Calf		0.986											
			Young bull		0.901											
													Years			
WITH PROJECT	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
INCOME																
Sale of beef																
Three Young Bulls	768.00	768.00	768.00	768.00	768.00	853.34	853.34	853.34	853.34	853.34	853.34	853.34	853.34	853.34	853	853
Sale of wood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
PES (Project GEF)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Shadow effect (%)	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.06	0.06	0
Disc. Shadow effect	0.00	0.02	0.05	0.07	0.11	0.18	0.22	0.28	0.26	0.32	0.38	0.37	0.43	0.50	0.48	0
Subtotal of incomes	768.00	768.00	768.00	768.00	768.00	853.34	853.34	853.34	853.34	853.34	853.34	853.34	853.34	853.34	853	853
INCOMES TOTAL	768.00	767.98	767.96	767.93	767.89	853.16	853.12	853.06	853.08	853.02	852.95	852.97	852.91	852.84	852	852
LIVESTOCK PRODUCTION COSTS																
Maintenance costs	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115	115
Shadow effect (%)	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.06	0.06	0
Disc. Shadow effect	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.04	0.03	0.04	0.05	0.05	0.06	0.07	0.07	0
Subtotal livestock costs	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115	115
Bought three calfs	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464	464
Livestock total costs	580.09	580.08	580.08	580.08	580.07	580.06	580.06	580.05	580.05	580.04	580.04	580.04	580.03	580.02	580	580
GRASSLANDS MAINTENANCE COSTS																
Improved grass	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16
INVERSION - TIMBER TREES																
Timber component	44.74	7.00	8.14	45.27	7.52	8.84	45.97	10.31	9.53	46.66	10.31	9.53	46.66	10.31	11.63	46
COSTS TOTAL	641.82	604.08	605.21	642.34	604.59	605.89	643.02	607.36	606.58	643.70	607.34	606.57	643.69	607.33	608	643
INCOME WITH PROJECT	126.18	163.91	162.74	125.59	163.30	247.27	210.10	245.70	246.50	209.32	245.61	246.41	209.22	245.51	244	209

9.21[a].- Cash flow and NPV, IRR and B/C estimation in Model 4, improved grasslands with timber trees of *C. odorata* at perpetuity. Esparza, Costa Rica. 2004. Cont…

													Years			
WITHOUT PROJECT	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
INCOMES																

TOTAL OF INCOMES	775.76	775.76	775.76	775.76	775.76	775.76	775.76	775.76	775.76	775.76	775.76	775.76	775.76	775.76	775.76	775.7
LIVESTOCK PRODUCTION COSTS																
From Calf to Young Bull	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.68	115.6
Bought three male calfs	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.41	464.4
GRASSLANDS MAINTENANCE COSTS																
Improved grass	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.99	16.9
COSTS TOTAL	597.08	597.08	597.08	597.08	597.08	597.08	597.08	597.08	597.08	597.08	597.08	597.08	597.08	597.08	597.08	597.0
NET FLOW WITHOUT PROJECT	178.68	178.68	178.68	178.68	178.68	178.68	178.68	178.68	178.68	178.68	178.68	178.68	178.68	178.68	178.68	178.6
NET INCREMENTAL FLOW (WITH VRS WITHOUT PROJECT)	-52.50	-14.77	-15.94	-53.09	-15.38	68.59	31.42	67.02	67.82	30.64	66.93	67.73	30.54	66.83	65.53	30.4
DISCOUNT RATE	0.94	0.88	0.83	0.78	0.73	0.68	0.64	0.60	0.56	0.53	0.50	0.47	0.44	0.41	0.39	0.3
DISCOUNTED NET INCREMENTAL FLOW	-49.27	-13.01	-13.17	-41.17	-11.19	46.85	20.14	40.31	38.28	16.23	33.27	31.60	13.37	27.46	25.27	11.0

NET PRESENT VALUE (NPV)	**337.90**
INTERNAL RATE OF RETURN	**0.22**
BENEFIT/COST RATIO	**3.64**

Incomes - Costs		
Incomes		176.87
Costs		132.03
Difference		308.90
NPV infinite	4708.9	
NPV total	**5046.8**	

9.22.- Cash flow and LEV estimation in Model 4, improved grasslands with timber trees of *C. odorata* at perpetuity. Esparza, Costa Rica. 2004.

Age	Timber	PES	Total	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**1**
1.0	44.7	0.0	-44.7		-44.7	-47.7	-50.8	-54.1	-57.7	-61.5	-65.5	-69.8	-74	-79.3	-84.5	-90.0	-95.9	-102.2	-10
2.0	7.0	0.0	-7.0			-7.0	-7.5	-7.9	-8.5	-9.0	-9.6	-10.2	-10	-11.6	-12.4	-13.2	-14.1	-15.0	-
3.0	8.1	0.0	-8.1				-8.1	-8.7	-9.2	-9.8	-10.5	-11.2	-11	-12.7	-13.5	-14.4	-15.4	-16.4	-
4.0	0.5	0.0	-0.5					-0.5	-0.6	-0.6	-0.6	-0.7	-0.7	-0.8	-0.8	-0.9	-0.9	-1.0	
5.0	0.5	0.0	-0.5						-0.5	-0.6	-0.6	-0.6	-0.7	-0.7	-0.8	-0.8	-0.9	-0.9	
6.0	0.7	0.0	-0.7							-0.7	-0.7	-0.8	-0.8	-0.9	-1.0	-1.0	-1.1	-1.2	
7.0	0.7	0.0	-0.7								-0.7	-0.7	-0.8	-0.8	-0.9	-1.0	-1.0	-1.1	
8.0	2.8	0.0	-2.8									-2.8	-3.0	-3.2	-3.4	-3.6	-3.8	-4.1	
9.0	0.7	0.0	-0.7										-0.7	-0.7	-0.8	-0.8	-0.9	-1.0	
10.0	0.7		-0.7											-0.7	-0.7	-0.8	-0.8	-0.9	
11.0	0.0		0.0												0.0	0.0	0.0	0.0	
12.0	0.0		0.0													0.0	0.0	0.0	
13.0	0.0		0.0														0.0	0.0	
14.0	0.0		0.0															0.0	
15.0	2.1		-2.1																
16.0	0.0		0.0																
17.0	0.0		0.0																
18.0	0.0		0.0																
19.0	0.0		0.0																
20.0	0.0		0.0																

21.0	0.0		0.0																
22.0	0.0		0.0																
23.0	0.0		0.0																
24.0	0.0		0.0																
25.0	0.0		0.0																
Capitalized Costs					-44.7	-54.7	-66.4	-71.3	-76.5	-82.2	-88.3	-96.9	-103	-111.4	-118.8	-126.5	-134.8	-143.7	-1
Timber production					0.0	0.0	0.0	0.1	0.2	0.3	0.5	0.6	0.8	0.9	1.0	1.1	1.3	1.4	
Wood sale income					0.0	0.1	2.0	6.7	14.1	23.0	32.7	42.2	51	61.0	69.7	77.8	85.6	92.8	9
Total future worth					-44.7	-54.5	-64.4	-64.5	-62.4	-59.2	-55.6	-54.7	-52	-50.5	-49.0	-48.7	-49.3	-50.9	-5
LEV									-166.8	-127.5	-99.2	-82.6	-67	-56.8	-48.5	-42.6	-38.4	-35.5	-3
Liquidation costs									-21.2	-12.2	-2.6	6.9	16	25.7	34.4	42.5	50.3	57.5	6
Net capitalized factor				-155.2	-46.3	-30.3	-12.9	-11.8	-10.8	-9.6	-8.4	-4.1	-3	-2.1	-2.1	-2.1	-2.1	-2.1	
Immaturity forest worth				-35.3	7.2	14.6	23.7	25.8	28.0	30.6	33.3	38.2	41	44.9	47.8	50.9	54.3	57.8	6
Discount rate %			6.56	TIMBER COSTS			-44.7	-7.0	-8.1	-45.3	-7.5	-8.8	-46	-10.3	-9.5	-46.7	-10.3	-9.5	-4
Wood price m3/USD			68.1																
				NPV TIMBER COMP.			-230	VET	VET LIVESTOCK			2167.1	**VET SPS**		**1937.1**				
						Forest VET									Livestock VET				
					Wood Production									Bought three		Maint.	Livestock Incomes		
						M3/ tree	Num. Trees	M3 total	USD income	USD Costs	Net income	VET Forest		Male calfs		Costs	Young Bulls	Net income	
				Bad		0.4	6.8	2.9	199.3	26.4	172.9	**2635.8**			464.4	115.7	853.3	273.2	
				Regular		0.7	6.8	4.7	319.6	26.4	293.2	4469.2							
				Good		1.0	6.8	6.7	454.1	26.4	427.7	6520.2							
															Forest VET		Livestock VET		
																2635.8			**41**
															Discounted		Year 18		**2167**