UPSCALING SILVOPASTORAL SYSTEMS IN SOUTH AMERICA

IIC
Inter-American Investment Corporation

IDB
Inter-American Development Bank

Cataloging-in-Publication data provided
by the Inter-American Development Bank
Felipe Herrera Library

Upscaling silvopastoral systems in South America / Katalin Solymosi, Andrea Braun, Suzanne Van Dijk, Markus Grulke.
p. cm. — (IDB Monograph ; 461)
Includes bibliographic references.
1. Silvopastoral systems-South America. 2. Agroforestry-South America. 3. Land use-Environmental aspects-South America. I. Solymosi, Katalin. II. Braun, Andrea. III. Van Dijk, Suzanne. IV. Grulke, Markus. V. Inter-American Development Bank. Environment, Rural Development and Risk Management Division. VI. Series.
IDB-MG-461

Author
Andrea Braun, Suzanne Van Dijk and
Markus Grulke, UNIQUE forestry and land use GmbH

Editor
Katalin Solymosi, Inter-American Development Bank

Keywords:
silvopastoral, forestry, beef, Paraguay, case study, biodiversity, natural capital, Latin America, Inter-American, development, CO

Acknowledgments:
This study has relied on substantial coordination efforts and technical expertise from Duncan Gromko, who together with Katalin Solymosi led this technical assistance project at the IDB. We would also like to thank Luis Enrique Arréllaga, Director General of the Paraguayan Agricultural Corporation (PAYCO) who generously supported the project and provided insightful comments to the publication. Finally, Carmen del Rio Paracolls has been the communications expert bringing this publication together.

JEL codes:
D2 Microeconomics Production and Organizations
O54 Latin America • Caribbean
011 Macroeconomic Analyses of Economic Development
Q14 Agricultural Finance
Q15 Land Use
Q23 Forestry
Q24 Land
Q5 Environmental Economics
R14 Land Use Patterns

Published October 2016

Design and layout:
Cecilia Reifschneider, cica@pigmentd.com
Vero Gorri, www.verogorri.com

http://www.iadb.org

FOR MORE INFORMATION, INCLUDING THE FULL REPORT,
PLEASE CONTACT: CARMEN DEL RÍO PARACOLLS | CDELRIO@IADB.ORG

INTRODUCTION

The world population is expected to increase from approximately 2.5 billion in 1950 to almost 10 billion in 2050, exhibiting the highest population growth rates in history. Securing the supply of wood and timber from sustainable sources without competing for agricultural land and food production has already become a challenge in many parts of the world.

South America has had the advantage of being a large continent with a relatively small population, of which a large share lives in urban areas. Historically, these conditions have permitted inefficient land-use systems such as extensive livestock grazing for beef production. However, in recent decades export-oriented industrial agriculture has become the main driver of South American land use patterns, increasing the pressure for more efficient and intensive production systems. Specialization and intensification in the land use sector have brought economic and productive benefits at a cost. They have caused the massive destruction of natural ecosystems while at the same time making national economies highly dependent on a reduced number of export products. Therefore opportunities for intensification on extensive grazing land and other inefficient land uses (often on marginal land) have to be considered. Particularly in times of pressing global environmental change and increasingly complex trade relationships, land use intensification has to take into account economic, environmental and social objectives and increase the resilience of the system as a whole.

Silvopastoralism refers to the complementary relationship between trees and pasture in a forest products and livestock production system. Eventual silvopastoralism, in which animals graze in

areas partially covered by shrubs or woods, or use the forest for resting, has been practiced for centuries; however the optimization of this system for the production of trees, tree products, forage, and livestock has not been widely studied. In South America, where extensive beef production offers opportunities for more intensive production systems while timber and biomass shortage is advancing, silvopastoral systems might offer an attractive solution both for beef producers and the forestry sector. While economic, environmental and social benefits of silvopastoral system have been described in the literature, the adoption of these systems in South America is still marginal. This can be partially attributed to the lack of technical knowledge, particularly about the interactions between the different components of the system, which discourages wider implementation.

In this context, this two-part publication evaluates synergies and trade-offs of integrating livestock and timber production in silvopastoral production systems.

The first part offers an overview of silvopastoral systems, summarizing findings of an in-depth literature review as well as practical experience and observations made during field visits in Argentina, Brazil and Paraguay.

Based on a case study in Paraguay, the second part assesses and compares silvopastoral systems with production systems encompassing either solely beef production or solely plantation forestry, through three performance lenses:

economics | environmental | social and cultural

The implications for producers, the potential contribution to forest protection as well as upscaling potential are discussed.

PERFORMANCE

From an economic point of view, silvopastoral systems allow for the production of different goods on different time horizons, increasing economic stability. Well managed silvopastoral systems can provide more revenues than traditional livestock systems. From a technical and production point of view, silvopastoral systems increase complexity and the need for technical knowledge when compared to pure beef or forestry production systems. The most important aspect to be managed is the availability of sunlight. Shade provided by the trees becomes the limiting factor for fodder production, while trees introduce moisture and nutrients into the soil, potentially improving grass quality. On the other hand, shade may improve animal welfare and can therefore positively enhance

animal production. Cattle may have direct or indirect negative effects on the trees through soil compaction and damaging trees, while also contributing to weed and fire control.

From an environmental point of view, silvopastoral systems have shown to improve erosion control, watershed protection and carbon sequestration when compared to pure beef production. Potentially these systems can contribute to biodiversity conservation, however this largely depends on local conditions and the previous land use system. In this regard the case study in Paraguay illustrates some specific ecosystem service benefits that silvopastoral production systems have in terms of carbon sequestration as well as soil and biodiversity conservation.

Social impacts of silvopastoral systems are considerably leveraged by the forestry component, as plantation forestry provides 20 to 80 direct full time positions per 1,000 hectares compared to 1 to 3 full time positions provided by beef production.

MANAGEMENT AND BEST PRACTICES

One of the most important technical aspects to consider is to make the silvicultural regime compatible with beef production. Quality timber production has been identified as the most suitable production target as it requires lower densities and the application of silvicultural treatments (thinning, pruning) that enhance solar insolation. Many varieties of eucalyptus and pine as well as Araucaria, Corymbia and Grevillea have been found suitable for silvopastoral systems due to their canopy architecture. Spatial arrangements include mainly homogeneous spacing in low densities or double rows in between large alleyways. The latter allows for greater tree densities but the impact of this distribution on timber quality remains unclear. Grass species suitable for silvopastoral systems - due to their shade tolerance and nutritional value – include varieties of Brachiaria, Tanzania, Panicum, Axonopus and Elephant grass, including natural pastures of *Axonopus Compressus* in Argentina. To maintain a good pasture, avoid soil compaction and erosion, producers should adjust animal stocking rates. The biggest challenge in practice remains timely thinning and pruning and the maintenance of adequate stocking rates and rotation, particularly on natural pastures.

WAY FORWARD

Although silvopastoral systems are still insignificant in terms of hectares established compared with pure livestock production or pure forestry in Paraguay, the integrated production system will likely gain importance due to the Government aim to significantly increase its beef producing herd while at the same time increasing forestry production and making commitments to reduce carbon emissions. Silvopastoral systems are a highly intelligent land use option, mainly for large scale beef producers to enhance their long term returns and diversify revenue streams. This can be done independently or in joint venture with forestry management companies and offtakers. Silvopastoral systems will find their place in-between agriculture, planted forests, pasture and natural forests as an option for productive and sustainable landscapes.

OVERVIEW OF SILVOPASTORAL SYSTEMS

Throughout the world, silvopastoral systems are implemented responding to different motivations and management objectives. They can be implemented for the purpose of dairy or beef production in combination with timber, fuel wood or non-timber forest products. Depending on the production objective, they may take many forms with regard to spatial patterns, the integration of natural forests or forestry plantations, tree and forage species, types of animals, breeds and management aspects.

ADVANTAGES AND DISADVANTAGES

Competition and synergies that arise from the combination of forestry and cattle can have positive or negative effects on either one of the productive components. Therefore perceived advantages and disadvantages of silvopastoral systems vary greatly depending on the initial land use ("baseline scenario") of the area where they are implemented, being shaped by sectoral viewpoints of either beef or forestry producers.

From an economic point of view, silvopastoral systems allow for the production of different goods on different time horizons. Trees introduce a secure longterm income to beef production, whereas beef introduces shorter term income that makes forestry production more affordable, particularly for small or medium size producers. Many studies have shown that well managed silvopastoral systems are economically attractive, providing more income than traditional livestock systems (Grado y Husak, 2004; Santos & Grzebieluckas, 2014; Vale, 2004). However they also require higher investments. When comparing silvopastoral systems with forestry systems, results differ. Some authors suggest that the value of the land increases with the introduction of cattle (Grado et al., 2001; Esquivel et al., 2004), while the Internal Rate of Return (IRR) slightly decreases (Esquivel et al., 2004). Others consider forestry to be considerably more attractive in terms of IRR, Net Present Value (NPV) and cost-benefit analysis (Santos & Grzebieluckas, 2014; do Vale, 2004).

From a technical and production point of view, silvopastoral systems increase complexity and the need for technical knowledge when compared to monocultures, which is the reason why the latter is usually preferred, particularly by large producers. Managing the competition between the different components while enhancing favorable synergies brought about by their combination is a challenge. The main aspect to be considered in this respect is the availability of sunlight. Trees introduce shade into the system, which becomes the limiting factor for fodder production. Shade suppresses fodder production from a certain degree of canopy cover that normally varies between 20 - 60 %.

On the other hand, trees introduce moisture and nutrients into the soil, improving grass quality, particularly under normally dry conditions. When trees are still young, grass might represent a competition in terms of nutrients and moisture.

Shade provided by trees can improve animal welfare and therefore increase animal production by 8 to 20 %, depending on the management system and breed used (personal communication with Alfredo Fossali). Various studies have shown the benefits of shade for animals, increasing milk production by 12 to 15 %, the conception rate by 20 % and reducing the number of veterinary services per conception by almost 50 % (Pires & Carvarlho, 2002).

Cattle however, may have direct or indirect negative effects on the trees. Indirect damage could be caused by soil compaction while direct damages can be caused by bark browsing or direct physical impact on young trees or branches. Although in some cases direct and indirect damages have proven to be marginal (Couto et al., 1988; Almeida, 1991), other studies have shown that these could severely affect the system depending on soil conditions and tree species (Couto et al., 1994; Bezkorowajnyj et al., 1993). Reasons why cattle browse on the bark are still unclear; some point out that animals try to compensate for a lack of nutrients or fiber (Baxter & Hansson, 2001) while others argue social behavior and boredom could be the cause (personal communication with producers). Bark browsing has been shown to be selective depending on species and the dimensions of the individual tree (Guerreiro et al., 2015; da Silva, 2010; Ashton, 2005).

The introduction of cattle into forestry production systems provides weed and fire control and reduces associated costs. This aspect is well known by many forest producers in Argentina and Uruguay, where cattle is specifically used for this purpose on forested land. Almeida (1991) showed that the introduction of animals on exuberant Tanzania pastures reduced planting and maintenance costs by 52 to 93 %, depending on the stocking rate.

From an environmental point of view, silvopastoral systems have shown to provide erosion control and can be more effective in terms of watershed protection as opposed to pure livestock and forestry systems (Garcia and Andrade, 2001). This effect is particularly important when introducing forestry into traditional grazing areas. Forestry also sequesters carbon and might even compensate for the emissions caused by cattle. For biodiversity, the effect is highly dependent on the baseline scenario. On land previously used for agriculture or implanted pastures, silvopastoral systems provide opportunities for improvements, as has been shown in Colombia (Rivera et al., 2014). On natural grasslands however, extensive cattle grazing is likely to be the most beneficial land use.

When analyzing social impacts in terms of employment, the forestry sector provides more employment than the beef production sector. Experiences around the world show that a traditional forestry plantation of 1,000 ha provides between 20 and 80 full time positions throughout the whole cycle, whereas cattle ranching on the same area provides between 1 and 3 full time positions. Thus the social impact is considerable when introducing forestry on grazing land. In addition, the forestry sector is associated to a timber industry with great potential for more employment generation (Esquivel et al., 2004).

Lastly, cultural aspects should be considered when adopting silvopastoral systems. One prominent negative aspect is related to their complexity and unfamiliarity for more traditional producers.

TABLE 1: SUMMARY OF ADVANTAGES AND DISADVANTAGES OF SILVOPASTORAL SYSTEMS

	ADVANTAGES	DISADVANTAGES
ECONOMIC	• Combination of the production of goods in different time horizons. • More attractive returns than pure livestock production systems.	• Higher initial investments when compared to beef production.
TECHNICAL AND PRODUCTIVE	• Increased animal welfare and productivity provided by shade. • Increased moisture retention and grass quality. • Cattle provides weed and fire control, reducing costs for forestry production.	• Increased complexity when compared to monocultures. • Lower production volumes of forest and animal products when combined compared to traditional systems. • Competition between trees and grass. • Cattle might cause damage on trees.
ENVIRONMENTAL	• Increased carbon benefits compared to pure livestock systems. • Erosion control and increased watershed protection compared to livestock and sometimes pure plantations.	
SOCIAL AND CULTURAL	• The combined system provides more employment when compared to beef production systems.	• Complexity and unfamiliarity are a disadvantage for traditional producers.

MANAGEMENT AND BEST PRACTICES

Tree species and spatial arrangements

One of the most important technical aspects to consider is the silvicultural regime compatible with animal production. As tree disposition has to allow sufficient sunlight for pasture growth, quality timber production has been identified as the most suitable production target, both in literature and in practice. The production of quality timber requires lower densities and silvicultural treatments such as thinning and pruning, which enhances solar insolation.

Many varieties of eucalyptus and pine have been found suitable for silvopastoral systems due to their canopy architecture. In the field, silvopastoral systems observed integrate Pine (such as *pinus taeda and Pinus elliottii*), Eucalypts (*E. grandis x urophylla, E. dunnii*), Araucaria (*Araucaria angustifolia*), Corymbia (*Corymbia maculata*) and Grevillea (*Grevillea robusta*). Forest plantations and cattle can be combined in different spatial arrangements (Dias Filho, 2006), as shown in Table 2.

Spatial arrangements observed in the field included mainly single and double rows. Double rows in between large alleyways were particularly popular in Argentina. This spacing allows for greater tree densities and increased pasture production when compared to evenly dispersed trees. However, the impact of this distribution on timber quality, considering possible uneven tensions in the wood, remains unclear.

Fodder production and cattle management

Grass species suitable for silvopastoral production systems - due to their shade tolerance and nutritional value – include different types of Brachiaria (*Brachiaria brizantha*, *Brachiaria* decumbens and others) Panicum (*Panicum maximum*), Axonopus (Axonopus catharinensi) as well as varieties of Tanzania and Elephant grass. In Paraguay and Argentina, beef production increases tenfold when substituting natural grasslands with improved pastures. Hence most of the grass species are exotic, although very good results have been achieved with natural pastures of *Axonopus Compressus* in Argentina.

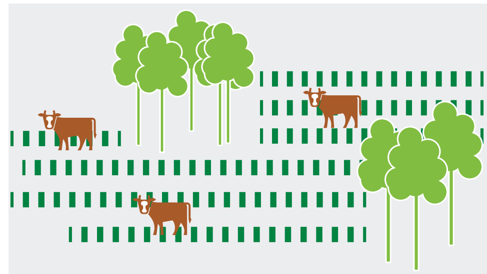
Cattle are introduced into the system once trees are strong enough to resist animal browsing, which can take between 6 months and 4 years after tree planting depending on the tree species. Normally with Eucalyptus plantations animals are kept out of the area for one year. Good experiences have been reported with European cattle breeds, which are more productive and less resistant but adapt better when shade is available, and the Brahma breed, a mixture between the Indian Zebu and American breeds.

To maintain a good pasture, avoid soil compaction and erosion, producers should adjust animal stocking rates. Lemus (2009) recommends the installation of square paddocks with similar carrying capacity, installed according to landscape conditions, topography and animal roads. Rotational grazing should be practiced according to a planned sequence and adjusted to growth conditions. In times of accelerated growth the resting period can be shorter, the stocking rate can increase or the occupation period lengthened, while the opposite should be done when growth is low. Beretta et al. (2013) document that animals subject to less grazing time due to stocking rate adjustments but with access to shade had a 14 % increase in performance when compared with animals subjected to continuous grazing without shadow.

TABLE 2: SPATIAL ARRANGEMENTS OF SILVOPASTORAL SYSTEMS

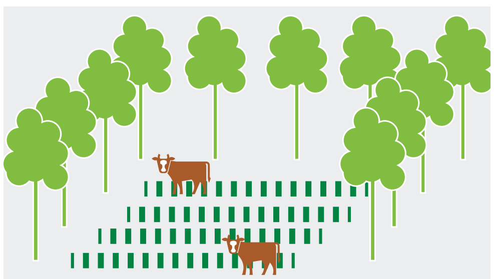
NATURAL CAPITAL | AGRICULTURE & BIODIVERSITY | @BIDECOSISTEMAS

FIVE SILVOPASTORAL SYSTEM ARRANGEMENTS



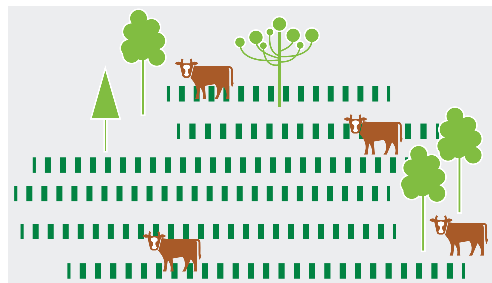
FOREST PATCHES

These are small groups of trees that can be planted with a spacing of 3x2 m, 3x3 m or greater.



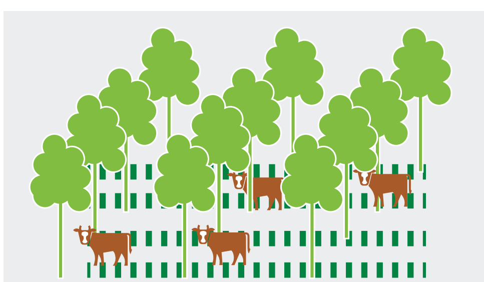
FENCES

Trees are planted along fences and can be used as poles forming the so-called live fences.



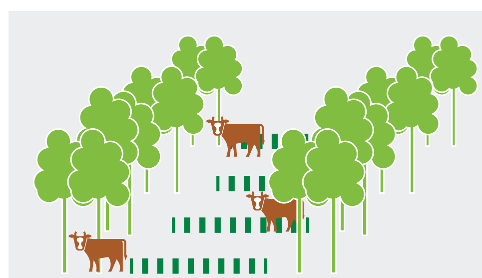
DISPERSED

Trees are planted in a random distribution throughout the pasture. The main purpose is soil protection due to shade and better nutrient recycling, but trees are also used for the production of biomass and other tree products.



SINGLE ROW

Trees are arranged at regular distances from each other with a separation of 5x10 m, 10x10 m or 5x20 m. The distance between trees depends on the species, canopy characteristics, tree height and the main production target. In order to support fodder production tree densities are much lower than in pure forestry systems.



DOUBLE ROW

Two rows of trees are planted near each other, usually with separations of 3x2 m or 3x3 m, in between wider alleyways of 10 to 20 m. Tree densities are higher than in single row systems while allowing the pasture to be exposed to sunlight in the alleyways. Some authors suggest that unequal densities could generate negative impacts on wood quality. On the other hand, excessive shade between double rows can impair the development of pasture or promote the development of weeds. Therefore Dias-Filho (2006) proposes to combine these systems with shade-tolerant legumes.

Summary of best practices

A gap analysis was conducted between best practices described in literature and practices observed in the field. Overall results were positive, as many of the best practices can be found on farms across the study area. Results are summarized in Table 4

The biggest challenge with regard to good management remains timely thinning and pruning. From the forestry perspective, thinning and pruning must be conducted at the right time to produce quality timber, while from a livestock perspective, thinning introduces more light to the system, allowing adequate growth of pastures. Often thinning and pruning is not conducted due to the false perception of losing production and revenues, the high costs of these treatments or due to speculation over timber prices. In many situations where thinning and pruning was not conducted, livestock production was interrupted as early as year three or four.

Some difficulties have been registered with appropriate soil management in livestock systems. Many producers did not have a good control of stocking rates and some fields showed signs of soil compaction. Also, while rotation was implemented and controlled on implanted pastures, natural pastures where not well managed or conserved, as these do not represent an investment for producers.

TABLE 3: ANALYSIS OF BEST PRACTICES IN THE FIELD

BEST PRACTICES	APPLICATION IN THE FIELD
Keeping cattle out when initiating silvopastoral system projects to protect young trees	Applied by all producers
Planting according to the topography lines	Applied by all producers.
Timely pruning and thinning	This was the most critical aspect: Many producers did not conduct timely pruning and thinning, mostly due to the lack of knowledge and experience, or the lack of resources.
Fertilization and ant control	Applied by all producers.
Managing competition between trees and grass (e.g. by keeping a clean strip along the planting line to avoid competition between grass and trees)	Applied by most producers. However one producer visited did not control competition in one plot where trees showed slow growth and lack of nitrogen.
Selection of grass species tolerant to shading	Applied by all producers, however also because in some cases the most commonly implanted pastures are also tolerant to shade, like *P. maximum* in Paraguay.
Control of the stocking rate and rotation of the cattle	Partially applied by producers: Many producers conducted rotation only on implanted pastures. Most producers were aware of the time needed for the recovery of pastures, however applied a shorter resting time. In some establishments signs of overgrazing could be detected.
Equal size of paddocks	Partially applied: Paddock sizes varied a lot in many establishments.
Paddocks and animal ways planned according to the topography.	Partially applied: In some establishments signs of erosion were visible.
Land use planning respecting native forest fragments	Partially applied by all producers: Most producers left forest fragments in lower areas and along streams and rivers. However in some cases the forest was extremely degraded due to the entry of cattle.

The findings presented in this section are based on literature review and field visits conducted in Northern Argentina, in the provinces of Misiones and Corrientes (6 producers), in Southern Brazil, in the province of Paraná (2 producers) and in Eastern Paraguay, in the Department of San Pedro (2 producers). The location and profiles of visited farms are presented below.

FIGURE 1: OVERVIEW OF THE COMPANIES VISITED

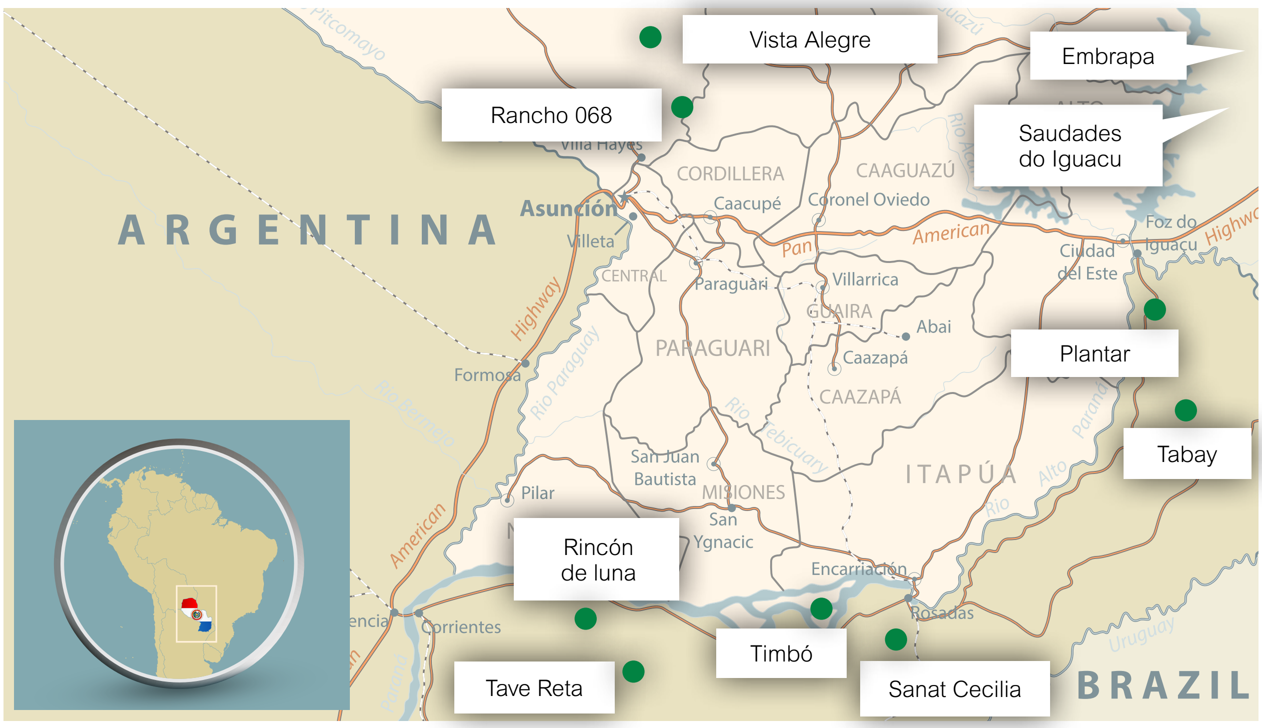


TABLE 4: PROFILE OF VISITED PRODUCTION SYSTEMS

SIZE	Nº	PROFILE	PRODUCTION SYSTEMS
10-100 ha	1	Family business	Milk and timber production
100-1.000 ha	2	Family business or local producers	Beef and timber, partly in silvopastoral systems, and agriculture on better soils
>1.000 ha	7	5 traditional family businesses 1 company with foreign investors 1 research station	

RESEARCH GAPS

It is noteworthy that a lot of progress has been made when research is coupled with extension services. Nevertheless many aspects and interactions between the different components of silvopastoral systems are still not fully understood, such as the effects of trees on grass quality, reasons for cattle to browse on tree barks, the effect of unequal spacing on timber quality and the fodder production curve throughout the forestry cycle under different spatial arrangements. The latter is particularly important when analyzing the cash flow throughout the timber production cycle. Uncertainties related to beef production volumes still hinder an exact modeling of silvopastoral systems cash flows. In Argentina there is fairly good understanding of fodder production throughout a forestry cycle when using pine species in different arrangements. However, for eucalyptus and other species this aspect is still poorly understood.

More research and development is needed to address these issues, as well as to expand the horizon and increase the diversity of options in terms of tree species, fodder species, spatial arrangements and cattle breeds integrated into silvopastoral systems.

PARAGUAY CASE STUDY

Paraguay is divided by the Paraguay River into the eastern and the western region. Eastern Paraguay comprises 40% of the country, and boasts an area of roughly 5.8 million hectares apt for the installation of silvopastoral systems on soil suited for mechanized agriculture, without affecting natural forests or agriculture.

In order to asses and compare the economic, environmental and social performances of silvopastoral systems with traditional cattle or forestry production systems, a large scale paraguayan agribusiness has been used as base case for scenario analysis and modeling.

POTENTIAL FOR SILVOPASTORALISM IN PARAGUAY

With altitudes ranging from above 600 m in the north-eastern corner to 55 m in the south-west, Eastern Paraguay is a rather humid region of rolling hills covered by ferralitic and mostly acidic soils on old crystalline rocks.

A recent evaluation of Eastern Paraguay shows that agriculture and pasture cover more than 80 % of the region. Ranching occupies about 8 million hectares, with a high level of underutilization. Much of the traditional beef production conducted on this vast area, however, takes place on lowlands not suitable for forestry production. Agriculture is also substantial, with 5 million hectares, dominated by soy production (FCPF, 2014[1]).

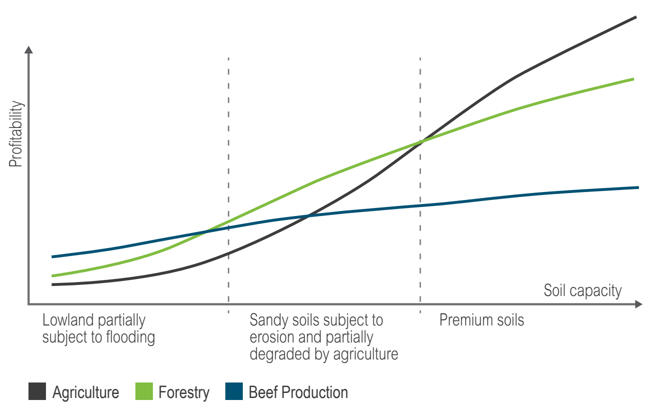
Across different soil quality gradients and depending on current market conditions, there is an economically optimal land use for each site. According to this logic, in Paraguay, so called "premium soils" are destined to agriculture, which is the most demanding land use in terms of soil quality, requires high investments but also generates high returns. Soils that present certain limitations for agriculture but are well drained are usually optimal for forestry, while the most efficient land use for partially waterlogged lowlands is traditional livestock. This analysis is illustrated in Figure 3. However, the ideal land use might shift to one direction or the other depending on market conditions.

Considering current biophysical conditions and land use patterns in Eastern Paraguay, an area of roughly 5.8 million hectares is suitable for the installation of Silvopastoral Systems without affecting natural forests or agriculture. Approximately 1.9 million hectares of this area is already covered with implanted pastures (Asociación Rural del Paraguay, 2010).

It should be noticed that this analysis considers only biophysical and economic condi-tions. The definition of "optimum land use" depends on societal values, which are subject to change in the light of political, economic and cultural events. Ideally, other criteria should be taken into account when analyzing optimum land use, such as food production, food security, diversification and environmental and social aspects.

1- Forest Carbon Partner Facility (2014). Readiness Preparation Proposal for Reducing Emissions from Deforestation and Forest Degradation. Version 2 Working Draft

FIGURE 3: LAND USE OPTIMUM ACCORDING TO DIFFERENT SOIL QUALITIES IN EASTERN PARAGUAY FROM AN ECONOMIC POINT OF VIEW



When analyzing current land use patterns in Eastern Paraguay, an area of roughly 5.8 million hectares is suitable for the installation of silvopastoral systems without affecting natural forests or agriculture. Approximately 1.9 million hectares of this area is already covered with implanted pastures (Asociación Rural del Paraguay, 2010).

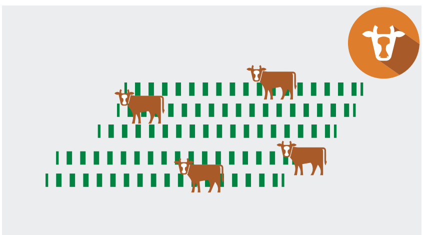
The definition of "optimum land use" depends on societal values, which are subject to change in the light of political, economic and cultural events. This analysis relies only on economic considerations. Ideally, other criteria should be taken into account when analyzing optimum land use, such as food production, food security, diversification and environmental and social aspects.

CASE STUDY BACKGROUND

The Paraguay Agricultural Corporation (PAYCO) is a large scale company investing in agriculture, beef production and forestry in Paraguay. The company ventured into plantation forestry in 2011, planning to expand its forestry plantations by acquiring new land. When land prices dramatically increased, the company adopted a new strategy; establish silvopastoral systems in cooperation with local beef producers on leased land. Since 2011, PAYCO has successfully implemented silvopastoral systems in Eastern Paraguay by combining eucalyptus plantations with different pastures of *Brachiaria* and *P. maximum*. The company will potentially expand its operations by investing 60 to 70 MM USD over the next 10 years, reaching an area of about 20,000 to 25,000 ha. PAYCO is evaluating options to support this expansion and has therefore been used as base case for scenario analysis and modeling.

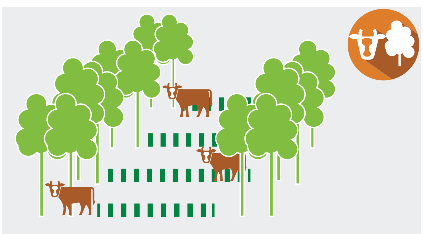
POTENTIAL FOR SILVOPASTORALISM IN PARAGUAY

Four scenarios were developed for this study and modeled to assess the economic, environmental and social performance of four different production systems based on PAYCO's case and data.



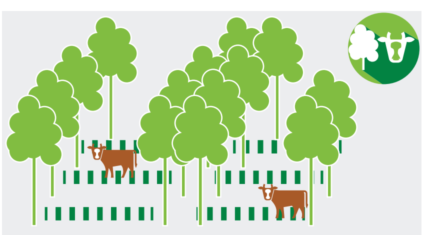
1: BEEF PRODUCTION

Scenario 1 refers to a typical beef production system in Eastern Paraguay, in which the producer buys cattle at the age of 9-10 months, fattens them for 17 months and then sells them for slaughter. Cattle feed is supplemented with maize only during the winter for a period of 120 days, and *P. maximum* pastures are implanted on the land, thereby improving the natural pasture. An average stocking rate of 1.2 heads/ha is assumed, comprising around 550 Kg in summer and 380 Kg in winter.



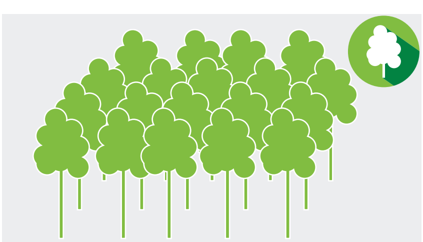
2: SILVOPASTORAL SYSTEM WITH EMPHASIS ON BEEF

Scenario 2 refers to a silvopastoral production system in which a beef producer has invested in trees, whilst keeping beef production as a core business objective. Plantations of *E. grandis x urophylla* are established for quality timber production to be managed in a 12 year cycle. Trees are planted at a low density of 320 trees/ha in double rows with spacing of (5 x 2.5) x 20 m . Only one thinning is applied in year 3, in which 50 % of the trees are cut. Pastures of *P. maximum* are implanted on 90 % of the land, as 10 % of the area is lost for the strips where trees are implanted, where trees are implanted. Due to this, the removal of cattle during the first year and the shade, average stocking rate comprises 0.68 heads/ha throughout the production cycle. To prevent damages to the trees shortly after planting, cattle is not allowed to graze the pastures until year 2. During the first year maize is produced in between the double rows. All maize production practices including sowing, fertilizer and pesticide application as well as harvesting are outsourced to contractors.



3: SILVOPASTORAL SYSTEM WITH EMPHASIS ON TIMBER

In scenario 3, a silvopastoral system with a clear production emphasis on timber is implemented. Eucalyptus trees (*E. grandis x urophylla*) are planted in a density of 714 trees/ha to produce quality timber in a cycle of 12 years. Two thinnings are conducted in years 3 and 6, reducing tree density by 30 % and 60 % respectively (with 200 trees/ha as final density). Trees are planted in double rows with a spacing of (5 x 2) x 9 m. Pastures of *P. maximum* are implanted on 80 % of the areas due to the effective area loss for grazing, the effective area loss for grazing. Overall, average stocking rate equals 0.51 heads/ha over the whole forestry production cycle. Cattle are not allowed to graze the pastures until year 2.



4: FORESTRY SYSTEM

Trees of *E. grandis x urophylla* are planted in a density of 1,000 trees/ha in a homogeneous spacing of 5 x 2 m. Two thinnings and three prunings are conducted throughout the 12 year cycle in year 3 and 6, reaching 200 trees/ha at the end of the cycle.

METHODOLOGY

All scenarios were analyzed using a one-hectare model over one rotation period to allow for upscaling of the results to different project sizes. The rotation period was considered to be 12 years for forestry production, the average rotation period for one production cycle using Eucalyptus trees in Paraguay, and 15 years for beef production[2], the average time needed for depreciation of investments (fencing, water provision facilities, supplementary feeding facilities, improved pasture). For silvopastoral production systems, the rotation period is considered to be 12 years. Further assumptions are summarized in the annex.

Economic, environmental and social performance indicators as well as the methodology used are presented in Table 5.

The economic indicators have been analyzed under two different conditions:

- The operative case: Only operative costs are considered (without and cost or appreciation);
- Land leasing: A yearly land lease fee per hectare isconsidered.

Finally, the model considers an upscaling scenario of 6,000 ha until 2017, coinciding with PAYCO's immediate plans in the next two years.

TABLE 5: PERFORMANCE INDICATORS AND METHODOLOGY USED

INDICATORS	CALCULATION METHODOLOGY
ECONOMIC PERFORMANCE	
Annual and cumulative cash flows	Yearly income – yearly costs; sum of all yearly cash flows
Net Present Value (NPV)	A discount rate of 9.7% was used to determine the present value of cash flows.
Internal Rate of Return	The rate of return calculated by IRR is the interest rate resulting when the NPV is 0.
Ratio of returns per hour of labor input	The division of the total returns by the total labor input
ENVIRONMENTAL PERFORMANCE	
Greenhouse gas emissions	Emissions were calculated using the CoolfarmTool (beta CFT Online Version) Copyright 2013-2015 Cool Farm Alliance. All rights reserved.
Carbon sequestration potential	A/R Methodological tool 14: Estimation of carbon stock and change in carbon stocks of trees and shrubs in A/R CDM project activities (Version 4.1) and Guidance for ARR calculatin Long-Term Average Carbon Stock (March 2011)
Social costs of carbon	Social costs as described by the methodology of the Interagency Working Group on Social Cost of Carbon of the US Government.
Production area needed for supplementary feeding	Average maize yields per hectare in Paraguay were used to determine the area needed for supplementary feeding.
Biodiversity and soil erosion aspects	Qualitative analysis
SOCIAL PERFORMANCE	
Employment generated (Full Time Equivalents)	The ratio of the total number of paid hours during a period divided by the number of official working hours in that period.
Quality of employment provided and the implications of the diversification of farm activities.	Qualitative analysis

2- In the model, the rotation period for forestry and beef production is set at 13 and 16 years, respectively as planting is done in year 1.

Sensitivity analysis for scenarios 1 and 4

Main return drivers for beef and forestry production are analyzed and presented below. The most important return drivers for beef production in Paraguay are beef prices.

While land price changes are not as significant to beef production when compared to beef prices, they do affect beef production more than they affect forestry production. This is clearly illustrated in figure 4.

For pure forestry systems in Paraguay (scenario 4), the main return drivers are displayed in figure 5. The figure clearly demonstrates the importance of timber prices followed by yields (expressed in Mean Annual Increment – MAI) for the economic performance of a forestry business model.

FIGURE 4: SENSITIVITY OF THE INTERNAL RATE OF RETURN (IRR, %) IN SCENARIO 1 TO FEED, BEEF AND LAND PRICES

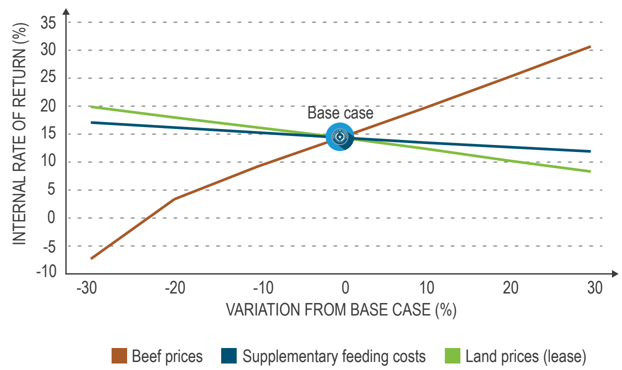


FIGURE 5: THE INFLUENCE OF LAND COSTS ON THE IRRS OF THE DIFFERENT SCENARIOS.

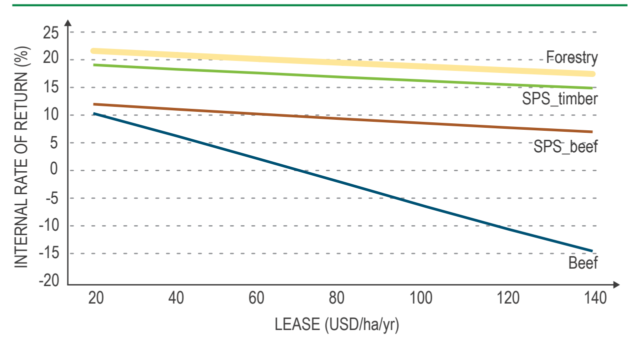
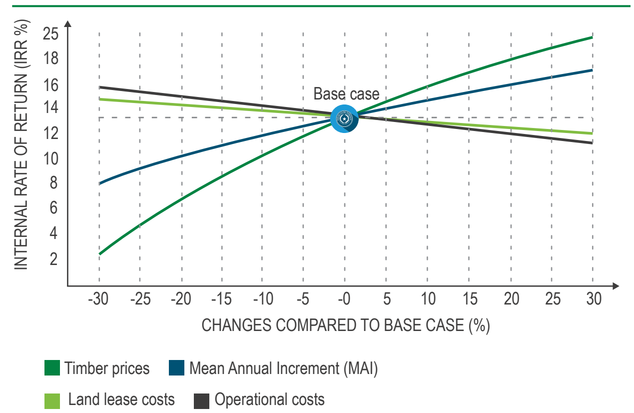


FIGURE 6: RETURN DRIVERS IN PLANTATION FORESTRY IN PARAGUAY



RESULTS

ECONOMIC PERFORMANCE

Production

In the pure beef production system 240 kilogram per hectare and year is produced, compared to 140 kg/ha/year in the silvopastorval system with production emphasis on beef, and 102 kg/ha/year in the silvopastoral system with production emphasis on timber.

Differences can be explained by the different stocking rates and reduced pasture availability in silvopastoral systems. In the silvopastoral system with production emphasis on beef, an additional 2.7 tons of maize per hectare is produced during the first year. Quality timber production volumes per hectare and cycle are presented in table 6.

TABLE 6: MEAT (KG/YEAR) AND TIMBER (M3/HA) PRODUCTION VOLUMES DURING ONE ROTATION

SCENARIOS	BEEF	SILVOPASTORAL SYSTEM_BEEF	SILVOPASTORAL SYSTEM_TIMBER	FORESTRY
MEAT (KG/YEAR)	240	140	102	0
BIOMASS	0	26.7	54.5	66.1
LOG QUALITY I	0	29.9	142.2	182.4
LOG QUALITY II	0	79.6	65.5	113.9
LOG QUALITY III/IV	0	29.7	114.9	190.6

Economic analysis

The summary of the economic analysis is presented in the table below.

TABLE 7: ANALYSIS OF ECONOMIC INDICATORS OF ALL SCENARIOS WITH AND WITHOUT LAND LEASE COSTS, CONSIDERING TAXES (10 % ON REVENUES)

SCENARIOS	BEEF	SILVOPASTORAL SYSTEM_BEEF	SILVOPASTORAL SYSTEM_TIMBER	FORESTRY
WITHOUT LAND COSTS				
Investment volume (USD/ha)	829	1.513	1.906	2.040
Net annual income (USD/ha/yr)	93	362	753	926
First year with positive cashflow	2	2	4	7
First year with positive cumulative cashflow	8	13	7	7
Internal Rate of Return (%)	15.7 %	13.7 %	19.9 %	22.4 %
Net Present Value (USD)	291	623	2,277	2,994
WITH LEASE COSTS OF 140 USD/HA/YR				
Investment volume (USD/ha)	1.122	3.156	2.746	2.880
Net annual income (USD/ha/yr)	-21	236	627	802
First year with positive cashflow	2	13	7	7
First year with positive cumulative cashflow	---	13	13	13
Internal Rate of Return (%)	-3.0 %	7.8 %	15.0 %	17.4 %
Net Present Value (USD/ha)	-719	-332	1,322	2,052

It is noteworthy that when considering a discount rate of 9.7 %, beef production is profitable when land leasing costs are not considered. When introducing land lease costs the beef production system becomes nonviable with an IRR of -3 %, while silvopastoral systems with emphasis on beef exhibits a low Internal Rate of Return of 7.8 %. Profitability increases in relation to the forestry production volume, reaching an Internal Rate of Return of 22.4 % in the operative scenario and 17.4 % when considering leasing costs. Results are similar to those reported by Santos & Grzebieluckas (2014) and do Vale (2004), which found forestry plantations to be more attractive than beef production and silvopastoral systems in terms of Internal Rate of Return, Net Present Value (NPV) and cost-benefit analysis.

The table also clearly illustrates that the forestry production system renders revenues by the end of a production cycle while cattle produces income at an early stage. Annual and cumulative cash flows were calculated for each scenario using a one-hectare model. Figures 7 and 8 illustrate annual and cumulative cashflows of the modeled production systems without considering land leasing costs and after taxes.

FIGURE 7: ANNUAL AND CUMULATIVE CASH FLOW IN SCENARIO 1 WITHOUT CONSIDERING LAND COSTS AND AFTER TAXES (BEEF PRODUCTION)

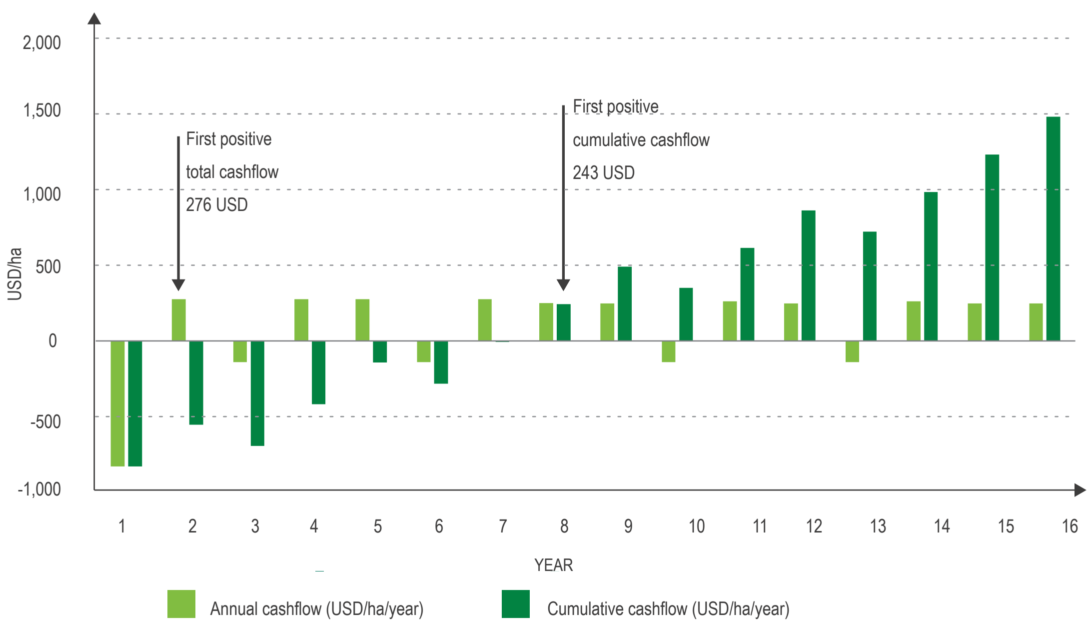
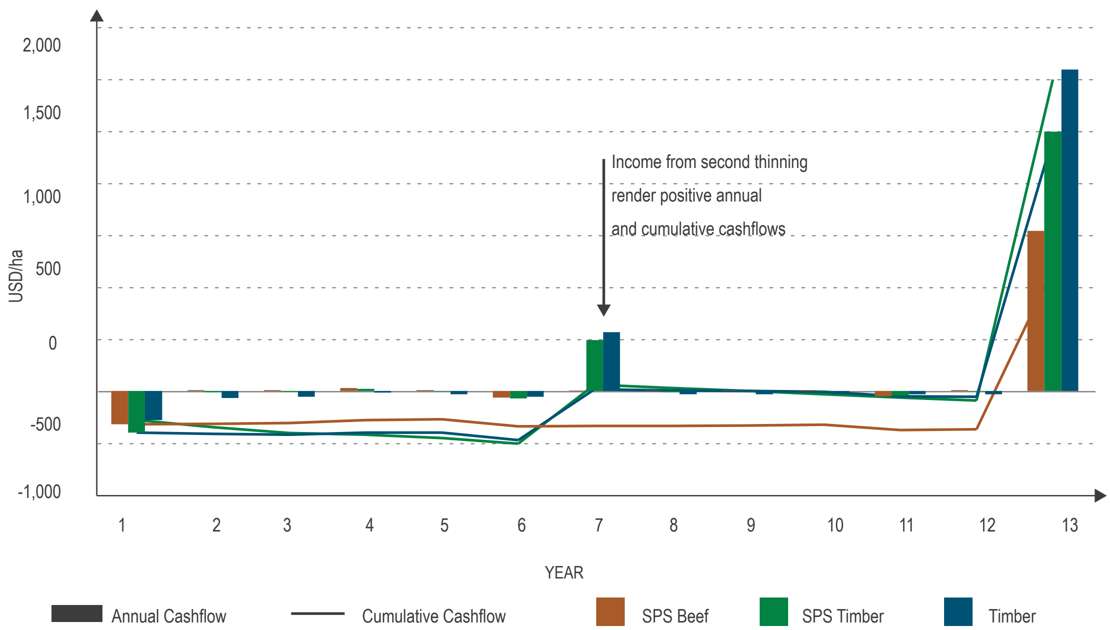


FIGURE 8: ANNUAL AND CUMULATIVE CASH FLOW OF SCENARIOS 2, 3 AND 4 WITHOUT CONSIDERING LAND COSTS AND AFTER TAXES (SILVOPASTORAL SYSTEMS AND PURE FORESTRY)



The beef production system results in a positive return already in the second year of production. The cumulative cashflow turns positive from year 8 onwards, resulting in 1,481 USD at the end of a cycle of 16 years after taxes. The annual income from buying and selling cattle every 16 months renders a net income of 93 USD/ha/year. The fluctuations in the cashflow are inherent to the lifecycle of buying and selling animals over a period of 16 months in a one-hectare model. On larger production areas this lifecycle would be more continuous, resulting in steady positive annual cash flows. Furthermore, although initial investment costs are realistic, most beef producers would have lower initial investments, as they work on land with a set up infrastructure.

Silvopastoral systems with a production emphasis on beef exhibit a slightly positive annual cashflow from year 2-5 while silvopastoral systems with production emphasis on timber exhibit a first low income in year 4, while returns are considerably higher in year 7 due to the second thinning and at the final cut, similar to pure forestry systems. When considering the cumulative cashflow, revenues are only high at year 13 after the final cut, resulting in 4,705 USD/ha for silvopastoral systems with an emphasis on beef, 9,791 USD/ha for silvopastoral systems with an emphasis on forestry and 12,043 USD/ha for pure forestry systems.

The production of maize in scenario 2 increases the annual cash flow in year 1 only marginally with revenues of 27 USD/ha, assuming 60 % of one hectare can be used for maize production. Low revenues are caused by current low maize prizes and suggest to use maize yields for direct cattle supplementation.

The analysis clearly shows that forestry investments are more profitable. However the time period until positive returns are reached is long, which can be a barrier for producers. In silvopastoral system the cattle component enables producers to partially finance forestry production for producers who have limited access to workforce, particularly for smallholders.

Ratio of return per labor input

While land and capital is typically the limiting factor for investments in the land use sector, labor shortage is turning scarce in many parts of the world. Hence the ratio of return per labor input can be an important indicator

The economic return by labor input was determined by dividing the cumulative cash flow at the end of one rotation period by the total number of labor hours. Forestry exhibits the highest returns per labor input with 18.3 USD/ha, which decreases to 15.9 USD/ha for silvopastoral systems with emphasis on timber, 10.0 USD/ha for silvopastoral systems with emphasis on beef. The beef production scenario results in 16.6 USD/h per hour of labor invested (Table 10), which is only lower when compared to the forestry scenario.

TABLE 8: RATIO OF RETURNS/HOUR OF LABOR INPUT (WITHOUT LAND LEASE COSTS)

SCENARIOS	BEEF	SILVOPASTORAL SYSTEM_BEEF	SILVOPASTORAL SYSTEM_TIMBER	FORESTRY
Returns/hour of labor input (USD/hr)	16.6	10.0	15.9	18.3

ENVIRONMENTAL PERFORMANCE

Greenhouse gas (GHG) emissions

Using the CoolfarmTool (Online Version)[3], emissions for beef production were calculated for each scenario. Considering a live weight gain of 200 kg/ha/yr per head and a Carcass Weight[4] (CW) fraction of 59 % of the live weight, GHG emissions per kg carcass weight per hectare are 15 kg CO_2-eq in pure beef production systems (scenario 1), 14 kg CO_2-eq in silvopastoral systems with production emphasis on beef (scenario 2) and 13 kg CO_2-eq in silvopastoral systems with production emphasis on timber (scenario 3). 85 % of these emissions are due to enteric fermentation – a natural part of the animal's digestive process – and 15 % due to supplementary feed production.

When comparing to literature, emissions in the different scenarios seem rather low. According to the global life cycle assessment of Opio et al. (2013), in 2005 the average global GHG emissions per kg of carcass weight were 46.2 kg CO_2-eq, with emission intensities varying from 14 kg CO_2-equivalents (eq) per kg carcass weight in Eastern Europe and Russia to 76 kg CO_2-eq per kg CW in South Asia (Opio et al., 2013). South America exhibit an average of 72 CO_2-eq per kg CW. Global averages however also include manure management, transport and land-use change, which is responsible for 40 % of the specialized beef production emissions in South America due to deforestation for the expansion of grazing area. Also, the non-productive share of the herd – due to a large breeding overhead – is included and responsible for a disproportionately large share of emissions (due to enteric fermentation). The calculated emissions are only for the productive animal and exclude further indirect emissions throughout the value chain.

3- http://www.coolfarmtool.org/CoolFarmTool

4- Carcass weight refers to the weight of animal after being partially butchered and is usually expressed in terms of the total weight of the animal.

Emissions from forestry production resulting from fertilizer application (Nitrogen and Limestone) were also calculated using the Coolfarm tool resulting in 0.62 kg CO_2-eq/ha/yr in pure forestry production (scenario 4), 0.59 kg CO_2-eq in silvopastoral systems with production emphasis on timber (scenario 3) and 0.54 kg CO_2-eq in silvopastoral systems with production emphasis on beef (scenario 2). The difference can be explained by different tree densities in each scenario. Emissions are very low, as expected. According to the Clean Development Mechanism (CDM) methodology developed by the United Nations Framework Convention on Climate Change (UNFCCC)[5] for afforestation, GHG emissions resulting from removal of herbaceous vegetation, combustion of fossil fuel, fertilizer application, use of wood, decomposition of litter and fine roots of N-fixing trees, construction of access roads within the project boundary, and transportation attributable to the project activity shall be considered insignificant and therefore accounted as zero.

Carbon sequestration potential

Using conservative default values established by the UNFCCC AR 14 Tool (Version 02.1.0)[6], the long term average carbon sequestration potential of biomass was calculated for all scenarios, without considering carbon storage in the soil, resulting in 90 tCO_2/ha for silvopastoral systems with production emphasis on beef, 137 tCO_2/ha for silvopastoral systems with production emphasis on timber and 166 tCO_2/ha for the forestry system. These values are comparable to the results of Juntheikki (2014), who calculated a long term average of 92.2 tCO_2/ha for eucalyptus plantations established for pulp in Uruguay. Hence if trees are planted on former grasslands or degraded lands, there is a significant potential to increase soil carbon by increasing aboveground biomass.

Calculating the carbon footprint for each scenario (emissions – sequestration potential) results in net carbon emissions of 1.8 tons CO_2-eq/ha/year for beef production and a carbon sequestration potential of 2.8 tons CO_2-eq/ha/ year for silvopastoral systems with production emphasis on beef, 5.3 tons CO_2-eq/ha/year for silvopastoral systems with production emphasis on timber whilst pure forestry production is estimated to sequester 8.2 tons CO_2-eq/ha/year. The carbon footprint for each scenario is summarized in the table below. Upscaling the different production systems on 6,000 hectares results in a total carbon sequestration potential of 264,874 tons CO_2-eq in silvopastoral systems with production emphasis on beef; 509,504 CO_2-eq in silvopastoral systems with production emphasis on timber and 788,854 tons CO_2-eq in forestry over one cycle.

Social costs of carbon

The social cost of carbon is an estimate of the monetary damages associated with annual increments of carbon emissions (United States Government, 2015). It is a broad estimate which covers changes in net agricultural productivity, human health, property damages (e.g. flooding), and ecosystem services.

To estimate the social costs of carbon for all scenarios, the carbon sequestration potential was assumed to be sold using certificates at a price of 5 USD/ton CO_2-eq. In the first scenario, no carbon certificates can be sold, hence the social costs of carbon are the highest at 672 USD/ha. For the silvopastoral systems with production emphasis on beef, the social costs of carbon remain high at 648 USD/ha, and the total net carbon revenue[7] is 79 USD/ha. Although the carbon balance for this scenario is positive, revenues from carbon certificates are not sufficient to cover expenses. As systems include forestry, social costs decrease while revenues from carbon certificates increase. For the third scenario (silvopastoral systems with production emphasis on timber), social costs are estimated at 584 USD/ha. While the decrease in social costs is moderate compared to the other two scenarios, the increase in revenues due to carbon certificates is substantial and results in a net carbon revenue of +281 USD/ha. The pure forestry system (Scenario 4) has the lowest social cost of carbon, with a total of 50 USD/ha, resulting in a net carbon revenue of 996 USD/ha.

5- https://cdm.unfccc.int/filestorage/T/H/N/THNRJC15IW4K89UBE6DFZYX23OVP0Q/EB75_repan30_AR-ACM0003_ver02.0.pdf?t=U0h8bzRqaGk4fDC428bGnMnSNGnMstfNDYp_
6- https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-14-v2.1.0.pdf
7- Net Carbon Revenue = [Social Cost of Emissions] – [Revenue from the sale of carbon certificates]

Production area needed for supplementary feeding and area leakage effect

Cattle is supplemented during the winter with an average of 4.7 kg maize per head and day. To estimate the area needed for the production of this supplementary feeding, current average maize yields in Paraguay are estimated at 4.5 tons/ha/year. Using the one-hectare model, an area of 0.3 hectares maize is needed for scenario 1, 0.2 hectares for scenario 2 and 0.1 hectares of maize for scenario 3. Upscaling the different production systems on 6,000 hectares results in 1,800 ha maize needed for pure beef production, 1,200 ha for silvopastoral systems with production emphasis on beef and 600 ha for silvopastoral systems with production emphasis on timber due to the reduced number of cattle per hectare in the respective systems.

Assuming the displacement of traditional beef production to other areas (leakage area) to compensate for lower beef production on silvopastoral systems scenarios, this would amount to 0.13 ha for each ha installed under silvopastoral systems with production emphasis on beef and 0.23 ha of silvopastoral systems with production focus on timber. This results in 1,380 ha and 780 ha for silvopastoral systems with production focus on timber and beef, respectively when upscaling to 6,000 ha.

These values are not very high, however as intensification trends are expanding even in countries in which livestock is traditionally based on extensive grazing, it is important to acknowledge the whole impact of one hectare of any production model.

TABLE 9: SUMMARY OF RESULTS IN TERMS OF THE ENVIRONMENTAL FOOTPRINT (CARBON AND LAND) PER HECTARE OF ESTABLISHED PRODUCTION SYSTEM

SCENARIOS	UNIT	BEEF	SILVOPASTORAL SYSTEM_BEEF	SILVOPASTORAL SYSTEM_TIMBER	FORESTRY
Carbon emissions (cattle)	kg CO_2eq/kg CW/ha	15	14	13	0
Carbon emissions (fertilizer)	tCO_2eq/ha/yr	0	0.54	0.59	0.62
Carbon sequestration [I]	tCO_2eq/ha	0	90	137	166
Carbon footprint (balance)	tCO_2eq/ha/yr	1.8	-2.8	-5.3	-8.2
Social costs of carbon	USD/ha	672	648	584	50
Carbon revenues [II]	USD/ha	0	568	865	1,046
Leakage area [III]	ha	0	0.13	0.23	0
Area for supplements	ha	0.3	0.20	0.10	0
Total affected area [IV]	ha	0.3	0.33	0.33	0

I Considering only above ground biomass/ II Considering displaced traditional cattle by silvopastoral systems/ III Considering sale of carbon credits for 5 USD/ton /IV Sum of leakage area and supplement area

Biodiversity

The impact of plantation forests on biodiversity depends on what land use they replace. When replacing natural vegetation, planted forests typically cause biodiversity losses, while if established on formerly forested, now anthropogenic grasslands, they are likely to provide biodiversity benefits.

Eastern Paraguay consists of a highly fragmented landscape, which was deforested decades ago and converted into pastures and agricultural land. Thus for all scenarios, agriculture was used as a baseline scenario. All scenarios most likely foster more biodiversity than the baseline scenario, as less chemical inputs (pesticides, fertilizer) and less mechanization is used and therefore more opportunities exist for animal and plant habitats.

The impacts listed in the table above show that silvopastoral systems might provide more opportunities for biodiversity conservation than pure beef production systems or pure forestry. Increasing evidence demonstrates the positive impacts of diverse landscapes, contributing to higher biodiversity in comparison to monocultures (Glatzle, 2008), supporting our assessment. Safeguards have to be considered to foster biodiversity of the different ecosystems, e.g. protecting native forests bordering streams and rivers and avoiding the use of native forests for cattle shelters.

Soil protection and erosion

When establishing forestry plantations at high densities under monoculture conditions, erosion is likely to occur during soil preparation and harvesting. Silvopastoral systems diminish erosion effects due to the limited soil left uncovered during these activities, particularly when tree planting is conducted on strips cleared on existing pastures. On the other hand, the introduction of trees reduces erosion effects that occur due to trampling of the herd, especially when the pathways do not follow topography lines. While cattle tend to move in the easiest direction on hilly regions forming pathways of bare soil in slope direction, the establishment of trees according to the topography avoids this type of movement. Good management practices include fencing and paddock establishment respecting the topography and can avoid the herd from causing erosion.

Thus, if considering agriculture as a baseline, the implantation of forestry in silvopastoral systems would improve soil conservation and reduce erosion. In order to maintain productivity, cultivated pastures require, even more than native grazing lands, a correct adjustment of stocking rates.

TABLE 10: BIODIVERSITY ASSESSMENT OF THE DIFFERENT SCENARIOS WHEN TAKING AGRICULTURE AS A BASELINE

BIODIVERSITY ASSESSMENT	BEEF PRODUCTION	SILVOPASTORAL SYSTEM BEEF & TIMBER	FORESTRY
Positive impact	• Practically no chemical inputs; • The manure attracts earthworms; • Individual bushes, branches or trees might be left to create niches.	• Manure attracts earth worms and associated biodiversity; • Trees provide organic matter through litter that recycles on the ground, as well as branches fostering biodiversity; • Trees can provide corridors and shelter in between other ecosystems. • Planted trees could hinder producer from letting cattle into the native forest, reversing forest degradation. • More creation of niches through the association of grass, tree and cattle components.	• Trees can provide corridors and shelter in between other ecosystems. • Trees provide organic matter through litter that recycles on the ground, as well as branches fostering biodiversity;
Negative impacts	• Implantation of exotic pastures; • Cattle avoids regeneration and undergrowth;	• Use of herbicides and pesticides for ant control; • Exotic species do not foster great diversity in comparison to native species; • Cattle avoids regeneration and undergrowth	• Use of herbicides and pesticides for ant control; • Denser plantations do not maintain undergrowth.
Overall assessment in comparison to agriculture	★ Improved	★★ Significantly improved	★ Improved

SOCIAL AND CULTURAL PERFORMANCE

The social impact of the different production systems has been estimated using data provided by the forestry and beef producers of PAYCO's production areas. For planting, labor input is calculated per tree, while for thinning and harvesting calculations are conducted per cubic meter. The average results expressed in Full Time Equivalent (FTE) and the daily work input per hectare per year are shown in the table below. All scenarios include one full job in a management position and service providers for seasonal work. Employment generated further up the value chain (e.g. in processing, saw mills etc.) have not been included in the calculations.

A gradient can be identified according to which labor input increases with the amount of forestry work. This coincides with international benchmarks according to which beef production provides work for 2 to 3 people per 1,000 heads of cattle (similar to 1,000 ha when stocking rate is close to 1/ha as in Paraguay) and between 20-80 for forestry, depending on the level of mechanization.

Forestry systems are characterized by being labor intensive only in the years of planting, thinning and harvesting. In countries like Paraguay where the forestry sector is still imminent, professionalized service providers are not available. While on the one hand this translates into cheap labor for the producers, it also fosters inefficient work, bad management practices, higher accident rates and reputational risks.

While beef production systems offer less employment, they do provide permanent positions. In Paraguay however, the sector is known for providing lower wages than other sectors to field workers[7].

TABLE 11: BIODIVERSITY ASSESSMENT OF THE DIFFERENT SCENARIOS WHEN TAKING AGRICULTURE AS A BASELINE

SCENARIO	TOTAL FTE PER 1,000 HA/CYCLE	AVERAGE DAILY WORK INPUT/ HA /YEAR
1 Beef production	3	1
2 Silvopastoral system_beef	18	4
3 Silvopastoral system_timber	24	5
4 Forestry	26	6

POTENTIAL CONTRIBUTIONS TO FOREST PROTECTION

More than producing revenues and diversifying the economy, the introduction and upscaling of plantation forestry in Paraguay could potentially contribute to reduce the unsustainable production of forest products in the country.

Throughout the last decades, over 6 million ha of native forests have been lost in Eastern Paraguay. The region is left with less than 10 % of its original forest cover. As a consequence, Paraguay has shifted from being a net exporter to a net importer of timber. However forest degradation continues, largely due to informal biomass that originates from native forests. Biomass corresponds to around 45 % of the national energetic matrix. Preliminary results from a study being conducted on the biomass market in Paraguay[8] show that there is large demand-supply gap for biomass from sustainable sources. An additional 10.4 to 14.2 million metric tons of sustainable biomass were needed in 2015 and the gap will reach 12.0 to 15.3 million metric tons in 2020 (see Table12).

The question arises whether sustainable wood biomass production under certified conditions such as conducted by PAYCO in pure forestry and silvopastoral systems can have an effect on the protection of native forest in Paraguay by providing a sustainable alternative to the market.

When considering the case study, it is realistic to assume the establishment of 18,000 ha in the next 12 years at a plantation rate of 1,500 ha per year. The potential of biomass production as a byproduct from thinning under these scenarios is between 8,000 and 9,000 tons/year until 2020, approximately 28,000 tons per year from 2020 to until 2026, reaching a steady production of about 62,000 tons/year starting in 2027, the first harvesting year.

While the volume until 2020 is not significant in comparison with the market gap, the production of 60,000 t/year by one producer could have significant impacts, especially on niche markets. This volume could be increased if silvopastoral systems are established mainly for biomass production in marginal areas. If current efforts of the national government[9] to formalize the biomass sector crystallize in the next few years, the right incentives might be set to increase production volumes. In the meantime, sustainable biomass production could still enter markets with the potential of initiating a cascade effect to other smaller or more informal industries. Select niche markets have been considered as interesting entry points for the biomass producing sector, given a number of considerations, particularly matching location and matching demand size with producers.

TABLE 12: GAP ANALYSIS FROM DEMAND AND SUPPLY IN THE BIOMASS MARKET

YEAR	VOLUME (LOWER LIMIT IN T)	VOLUME (UPPER LIMIT IN T)
2015	(10,422,065.6)	(14,206,275.7)
2016	(10,274,890.4)	(12,841,722.2)
2017	(10,603,207.9)	(13,334,390.1)
2018	(11,011,507.4)	(13,901,287.0)
2019	(11,491,398.3)	(14,568,806.2)
2020	(12,044,116.3)	(15,345,444.7)

8- This work is the basis for the Master Thesis "Impact of PAYCO's activities under a silvopastoral scheme in the biomass market in Paraguay for the period 2015-2020", to be submitted to the Universidad de Ciencias Empresariales y Sociales in Buenos Aires, Argentina by Josefina Maiztegui.

9- According to the decree 4056/2015 on the establishment of mechanisms for certification of biomass for energy purposes, consumers must source 30 % of its biomass from legal and certified sources by

- Cassava Starch: Paraguay has become the world's 5th exporter of cassava starch (Trade Economy 2014), with five companies exporting 99 % of the volume. Industrial plants are concentrated in the Departments of Caaguazú, San Pedro, Canindeyú and Itapúa.

- Dairy & Beef: Dairy and beef industries are growing in Paraguay. 99 % of the national beef production is exported since 2013 (SENACSA, 2015). While over 50 % of dairy production is concentrated in Caaguazú, exporting beef production facilities are scattered in the Central department, Itapúa and Villa Hayes

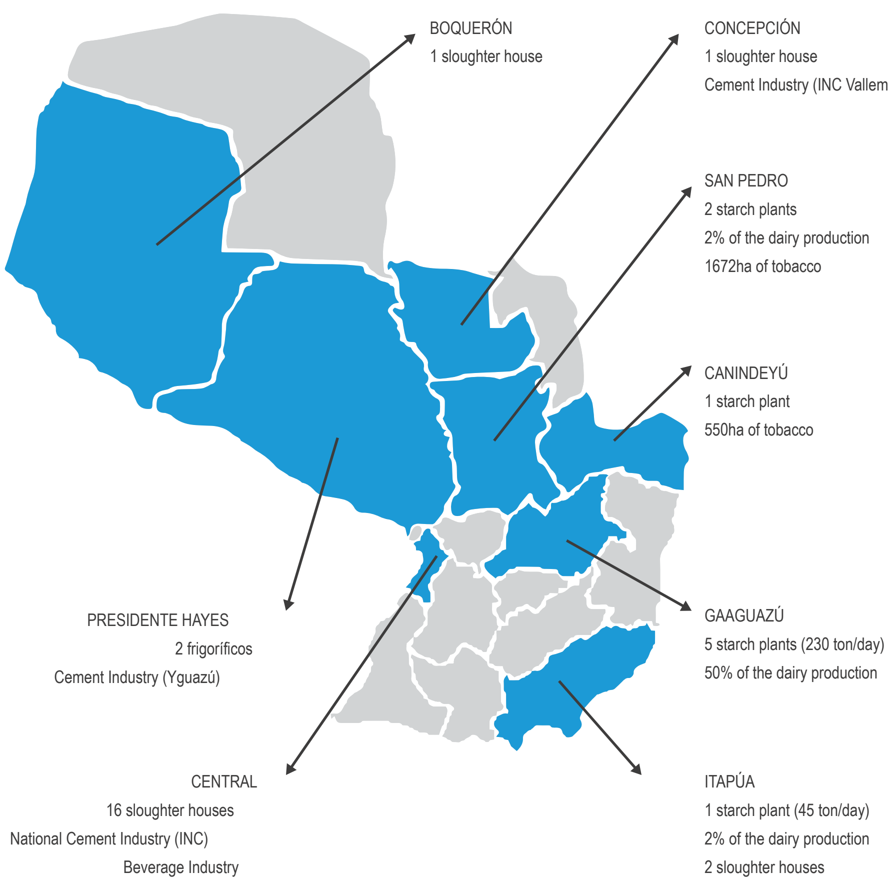
- Tobacco: Tobacco plantations are concentrated in San Pedro and Canindeyú.

- Beer and other beverages: Two big companies run the market, both located in the Central department.

- Cement: There are two cement-producing companies in Paraguay, Cementos Yguazú and Industria Nacional de Cemento (INC-government owned). Currently, INC is updating its clinker oven to move away from fuel oil to mixed fuels, including biomass.

Matching location is particularly important. Due to current low prices for biomass, the profitability of this business is highly sensitive to transport costs. Hence biomass should not be transported for more than 100 km on land and forestry plantations should be ideally located near big biomass consumers. Biomass producing industries are represented in the map as illustrated below.

FIGURE 9: BIOMASS CONSUMING INDUSTRIES IN PARAGUAY



SWOT ANALYSIS

A SWOT analysis was conducted for each scenario as presented in the following table.

TABLE 13: SWOT ANALYSIS FOR EACH SCENARIO

	SCENARIO 1 **Traditional beef production in Paraguay**	**SCENARIO 2 AND 3** **Combined silvopastoral production with focus on beef or timber**	**SCENARIO 4** **Pure plantation**
Strengths	• Low investments (when considering traditional producers) • Use of marginal land that is not suitable for other land uses • Low input system	• Product diversification (beef, timber and opportunity for agriculture in between tree rows during first year(s)) decreases economic and production risks. • Increases revenues when compared to pure beef production • Improved resilience to climate change (improved soil nutrient content, reduced risk of soil erosion) • Reduces pressure on natural forests • Direct and indirect employment generation	• Reduces pressure on natural forests • Highly profitable • Direct and indirect employment generation
Weaknesses	• High sensitivity to market and land prices • Inefficient land use system • Low profitability	• Risk of damaging trees through agricultural inputs in the first year • Risk of bad management due to lack of knowledge	• High initial investments • Revenues are perceived after a long time • Lack of specialized technicians and good service provider
Opportunities	• Growing demand for beef products worldwide • Growing demand for beef from extensive/'sustainable' production systems • Intensification potential	• Growing demand for beef and timber products worldwide • Growing demand for beef from extensive/'sustainable' production systems • Carbon markets: premium price for sustainable beef and timber products	• Steadily increasing market due to the exhaustion of natural forest reserves. • Carbon markets
Threats	• Globalization and climate change: increased risk of animal diseases or infections • Sudden price drops of beef	• Globalization and climate change: increased risk of animal diseases or infections • Reputational risks when exotic species are planted • Risk of pests and diseases, especially when production is based on clones • Legal insecurity in unstable countries for long-term investments.	• High reputational risks when exotic species are planted • High risk of pests and diseases, especially when production is based on clones • Risk of fire. • Legal insecurity in unstable countries for long-term investments

Silvopastoral systems allow for the expansion of forestry onto mixed-use lands within an overall setting of land scarcity and global wood shortage due to deforestation and forest degradation. Furthermore, combined systems enable extensive beef production whilst providing additional benefits including product and income diversification for the producer in addition to environmental and social benefits. A lack of technical knowledge on forestry might hinder the implementation of silvopastoral systems. Furthermore, the longterm production cycle of forestry might magnify risks related to legal insecurities and unforeseeable events such as pests and diseases or fire. Finally, silvopastoral systems enable the producer to offer products that would qualify for different types of certification e.g. sustainable beef or FSC® certified timber products.

FINAL CONSIDERATIONS

This study has shown that silvopastoral systems are a promising land use system in South America as evidenced by many studies conducted in the region and a number of successful businesses. Silvopastoral systems have proven to be superior in economic, environmental and social terms when compared to beef production systems on land exhibiting suitable biophysical conditions for plantation forestry. While silvopastoral systems also showed to be less profitable than forest plantations, they offer the integration of a short and a long term productive component, making them more affordable for producers due to a more balanced cash flow profile. Furthermore the integration of two productive components greatly reduces productive and economic risks, which increases producers' resilience in times of crises. Silvopastoral systems provide the benefits of land use diversification, opportunities for biodiversity conservation, erosion control and carbon benefits, while at the same time reducing the pressure on natural forests and enabling the continuation of beef or dairy production, traditional in many regions of South America. Silvopastoral systems may also offer significant contributions in social terms, not only by providing employment but also by fostering a processing industry associated with quality timber production.

Experiencing the benefits of silvopastoral systems on the ground has changed the mindset of many producers from viewing silvopastoral systems as a means to an end, such as (1) lowering initial investment costs for forestry; (2) allowing the continuation of beef production despite it not being as profitable as other activities; or (3) allowing the expansion of forestry production by leasing land from beef producers due to high land prices, to being an end in itself. Hence an increasing adoption of silvopastoral systems might initiate a trend of adopting more complex systems in which food production is coupled with forestry production. Therefore, the integration of silvopastoral systems into the productive landscape of South America may contribute to face the challenges posed by global environmental changes that require new ways of producing.

Despite all the benefits associated with silvopastoral systems described in the literature and experienced by producers, the adoption level is still low. The lack of experience with silvopastoral systems is the main technical barrier to upscale the practice silvopastoral systems. Producers often have a certain reluctance to test innovative models, which is reinforced by the lack of developers and implementers of innovative production schemes, resulting in the absence of successful pilot projects that could be expanded. This has also shaped societal values. In Paraguay, for example, an establishment dedicated to beef production might be worth more than an establishment with planted forests, despite forestry production being more profitable. Hence, more research and development in combination with extension programs are needed to support implementation.

Another reason for low implementation is the lack of experience with forestry production, which is the case in Paraguay. An inherent feature of forestry production is that it requires time. This implies the need for an initial investment that is recovered in a medium to long-term period. Producers however often expect short-term benefits and lose interest when considering the opportunity costs associated with forestry, although the final economic result is very attractive. In this respect, as already mentioned above, the beef component is relevant in making forestry production more affordable through silvopastoral systems, and increasing the total revenues of the production system. For larger scale investments however, adequate finance mechanisms could substantially leverage wider adoption of silvopastoral systems. Silvopastoral projects could be successfully financed through equity investments and mezzanine structures or be an interesting option for impact investors or the so called tripple bottom line investors. When loans are involved conditions have to be compatible with the forestry component, which would need longer grace periods and lower interest rates. In times of financial crises and uncertainty involving this sector, long term resource-based investments may also provide more stability to the financial world.

The positive impact of extension programs are visible in Northern Argentina. With over 90,000 ha covered by silvopastoral systems, the adoption level is considerably higher than in other regions. Extension services are provided by the Argentinian National Institute for Agrarian Technology (INTA) and by competent regional independent advisors. The regional consortiums for agricultural experimentation (Consorcios Rregionales de Experimentación Agrícola), a regional exchange platform for producers, further fosters transfer of knowledge and technology. In Brazil, the adoption of these systems is still limited to a small number of producers. The most successful case of silvopastoral systems has been serving as a model farm for technicians of the Brazilian State Enterprise for Agricultural and Livestock Research (EMBRAPA). The agency invests in the close collaboration with the producer, organizes training and showcase events and develops studies and publications. However, it is questionable whether such level of engagement is feasible on a larger scale.

More research and development is also necessary to develop production benchmarks on already known forms of silvopastoral systems, while also diversifying the practice of silvopastoral systems to new spatial arrangements, tree and fodder species, cattle breeds and management practices.

Although silvopastoral systems are still insignificant in terms of hectares established, particularly when compared to pure livestock or pure forestry production, the time is right to support high adoption levels of this combined production scheme. Silvopastoral systems have proven to be a highly intelligent land use option not only for small scale agroforestry systems but also for large scale cattle breeders to enhance their long term returns. Producers can realize such investments on their own or in joint venture with forestry firms. There are a number of strategies through which silvopastoral systems may find their place in-between agriculture, planted forests, pastures and natural forests as one building block for more productive and sustainable landscapes.

REFERENCES

REFERENCE

LITERATURE

Almeida (n.d). Geografia do Paraná. AMF.

Balbino, L. C.; Barcellos, A., O.; Stone, L. F. (2011). Reference Document: Crop-Livestock Forestry Integration. Embrapa.

Bertoni, M. & Gorham, J. R. (1973) Paraguay: Ecological Essays. Editad by J. R. Gorham. Miami, Florida. Academy of Arts and Sciences.

Cabrera, A.L. (1976) Regiones Fitogeográficas Argentinas. Enciclopedia Argentina de Agricultura y Jardinería. Tomo II. ACME. Buenos Aires. 85 pp

Carlini, A.A., H. Povedano, D. Glaz y G. Marateo (1999) Estudio de la biodiversidad en pasturas. Vertébratos en pasturas desmontadas con diferentes métodos. Estación Experimental Chaco Central, Cruce de los Pioneros, Paraguay, 59 pp.

Dawson, I.K., Carsan, S., Franzel, S., Kindt, R., van Breugel, P., Graudaul, L., Lillesø, J.-P-B., Orwa, C. and R. Jamnadass (2014) Agroforestry, livestock, fodder production and climate change adaptation and mitigation in East Africa: issues and options. ICRAF Working Paper No. 178. Nairobi, World Agroforestry Centre.

Fasolo; P. J.; Potter, R. O.; Sturion, J.A. (1998) CLASSIFICAÇÃO E CARACTERIZAÇÃO DOS SOLOS DE TESTES DE PROGÊNIES DE ERVAMATE (Ilex paraguariensis St. Hil.). Embrapa: Comunicado Técnico: No 29, dez./98, p.1-4

Fassola H. E.; Lacorte S. M.; Pachas A. N.; Goldfarb C.; Esquivel J.; Colcombet L., Crechi E. H., Keller A. & Barth S. R. (2009) Los sistemas silvopastoriles en la región subtropical del NE argentino. XIII Congreso Forestal Mundial Buenos Aires, Argentina, 18-23 Octubre 2009.

Fassola, H.; Keller,A.; Pachas, N.; Colcombet, L. (s.f.). El sistema silvopastoril y la nueva generación empresarial. INTA Montecarlo.

Frey, G. E.; Fassola, H.; Pachas N.; Colcombet L.; Lacorte S.; Cubbage F.; Pérez O. (2008) Perceptions of silvopasture systems in northeastern Argentina. XIII Jornadas Técnicas Forestales y Ambientales. Facultad de Ciencias Forestales, UnaM – EEA Montecarlo, INTA. Eldorado, Misiones, Argentina.

Friends of the Earth (2008) What's feeding our food? Available at *www.foe.co.uk*

Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G. (2013) Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations (FAO), Rome.

Glatzle, A. & Stosiek, D. (2006) Country Pasture / Fodder Resource Profile: Paraguay. FAO Available at: *www.fao.org/ ag/agp/agpc/ doc/counprof/Paraguay/ paraguay.htm*

Glatzle, A. (1999) Compendio para el Manejo de Pasturas en el Chaco. Edición El Lector, Asunción, Paraguay Glatzle, A. (2008) Extensive cattle ranching in theParaguayan Chaco and its environmental impacts. INTTAS.

Howarth, R.B., Gerst, M.D., Borsuk, M.E. (2014) Risk mitigation and the social cost of carbon. Global Environmental Change, 24: 123-131.

Hu Du, Fuping Zeng, Wanxia Peng, Kelin Wang, Hao Zhang, Lu Liu and Tongqing Song (2015). Carbon Storage in a Eucalyptus Plantation Chronosequence. In Southern China. Forests 2015, 6, 1763-1778; doi:10.3390/f6061763.

Jactel, H.; Barbaro, L. & Brockerhoff, E. G. (2006) Keynote: Contribution of plantation forests to biodiversity conservation: the landscape perspective. International Congress on Cultivated Forests_ Planted Forests and Sustainable Development, with a Scientific Forum on Ecosystem Goods and Services from Planted Forests. Bilbao, Spain; October 3-7.

Juntheikki, J. (2014). Estimation of eucalyptus forest plantations carbon sequestration potential in Uruguay with the CO2fix model. UNIVERSITY OF HELSINKI, FACULTY OF AGRICULTURE AND FORESTRY, DEPARTMENT OF FOREST SCIENCES. Master's thesis Forest economics May 2014.

Lacorte, S. M.; Es quivel, J. I. (2009) Sistemas silvopastoriles em La Mesopotamia Argentina. Reseña del conocimiento, desarrollo y grado de adopción. Actas Primer Congreso Nacional de Sistemas Silvopastoriles.p 70-82. Posadas. Misiones. Argentina.

Opio, C., Gerber, P., Mottet, A., Falcucci, A., Tempio, G., MacLeod, M., Vellinga, T., Henderson, B. and H. Steinfeld (2013) Greenhouse gas emissions from ruminant supply chains – A global life cycle assessment. Food and Agriculture Organization of the United Nations (FAO), Rome.

Paquette A, Messier C (2010) The role of plantations in managing the world's forests in the Anthropocene. Front Ecol Environ 8(1):27–34. doi:10.1890/080116.

Pawson, S. M.; Brin, A.; Brockerhoff, E., G.; Lamb, D.; Payn, T. W.; Paquette A.; Parrotta, J. A. (2013) Plantation forests, climate change and biodiversity. Biodivers Conserv 2013 22:1203– 1227 DOI 10.1007/s10531-013-0458-8.

United States Government (2015) Technical Support Document: - Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis- Under Executive Order 12866. Technical Support Document, Interagency Working Group on the Social Cost of Carbon, Washington DC, USA.

VCS Association (2011) VCS Guidance: AFOLU Guidance: Example for Calculating the Long- Term Average Carbon Stock for ARR Projects with Harvesting.

Weiner, J., Berntson, G. M. and Thomas, S. C. (1990) Competition and growth form in a woodland annual. Journal of Ecology 78: 459-469.

ANNEX

MODEL ASSUMPTIONS

Production data was used from PAYCO; key assumptions and estimations are listed below.

Cattle stocking rates

Effects of shade on pasture growth and resulting cattle stocking rates have been estimated (Table). Average stocking rate in scenario 1 is 1.2 heads per hectare, 0.7 heads per hectare in scenario 2 and 0.5 heads per hectare in scenario 3. The reduction in stocking rates has been assumed based on observations in the field and the estimations of producers, but to date there is no solid empirical evidence. The first year, cattle are not allowed in the production areas to protect the trees, hence the stocking rate is 0. The lowest rates are applied during the years 6 to 8 because shade prohibits pasture growth. Due to the greater incidence of lateral sunlight after this period, when trees are taller, stocking rates can be increased again.

Scenario /Years	1	2	3	4	5	6	7	8	9	10	11	12	13
2 Silvo_beef	0%	95%	85%	70%	70%	55%	55%	55%	65%	68%	68%	68%	68%
3 Silvo_timber	0%	90%	80%	75%	60%	40%	40%	40%	50%	50%	50%	50%	50%

Tree mortality

Tree mortality is assumed to be 6 %, which is the average mortality rate that has been calculated for PAYCO's plantations during the last two inventories.

Timber and beef production

Using current inventory data of PAYCO's investments and experience of producers in the region, beef and forestry production figures have been estimated:

- Cattle: weight gain of 200 kg/ha/ year;
- Forestry: Mean annual increment depends upon the system established, being set at 18 m^3/ha/yr for silvopastoral systems with focus on beef (Scenario 2), 33 m^3/ha/yr for silvopastoral systems with focus on forestry (Scenario 3) and 40 m^3/ha/yr for the pure forestry system (Scenario 4).

Timber quality

Plantation densities and thinning regimes are an integral part of a forestry system and can greatly determine the quality of timber. Competition between trees influences growth in diameter and log quality with respect to tensions in the wood, linear growth and branching. Hence, in the pure forestry system 50% of timber production in the final cut is classified as timber of the highest quality (quality I), followed by 45 % and 15 % in the silvopastoral systems with production emphasis on timber and beef, respectively. In silvopastoral systems with emphasis on beef most of the timber production is classified as being of lower quality (40 % of the production is classified as category II) due to the planting arrangements, assuming that wide alleyways between double rows in low densities could create unequal tensions in the wood (Weiner et al. 1990) and unequal growth of branches.

Discount rate

For the financial assessment a discounted cash flow (DCF) model has been used. The discount rate takes into account not just the time value of money, but also the risk or uncertainty of future cash flows and determines the rate of return required to make the investment worthwhile. For the model, a discount rate of 9.7 % was established according to country specific equity risk premium calculation of the Arbaro Fund (Arbaro Fund 2015; internal paper).

Follow us on Twitter @BIDEcosistemas
blogs.iadb.org/naturalcapital/

IIC
Inter-American Investment Corporation

IDB
Improving lives