PINZACUÁ FARM: CASE STUDY OF SUSTAINABLE CATTLE FARMING IN THE COLOMBIAN COFFEE REGION

Pinzacuá Farm: Case Study of Sustainable Cattle Farming in the Colombian Coffee Region

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Table of Contents

Chapter 1. Introduction

Pinzacuá farm is located within the borderlines of Alcala County which belongs to the Valle Del Cauca State. The Farm has an extention of 45 hectares and is property of Mr. Olimpo Montes Botero. Pinzacuá is a family owned and operated business dedicated to raising female cattle of the Brangus breed with top quality genes to serve as foundation specimen or simply for meat production at their cattle ranch destination. Pinzacuá is also involved in the production of yuca and coffe of organic qualities and is also able to produce charcoal that results from the pruning of the trees that make up the silvopastoral and agroforestry system that was impemented by Mr. Olimpo Montes Botero over a decade ago.

Pinzacuá Farm is located 500 meters from Alcala County´s main entrance and connects with several other counties of Quindío State and Valle State via asphalted roads. The farm sits at 1.290 meters above sea level and maintains an annual average temperature of 21 °C. Humidity ranges between 65% and 75% and has a median yearly precipitation from 1,300mm to 1,700mm. Rainy season happens twice a year most common in the months of April and October.

Soil in this region is classified as moderate to high fertility due, mainly in part, to volcanic ashes that at the same time gives the soil a porous characteristic that makes it succeptible to erotion processes (Instituto de Hidrología, Metereología y Estudios Ambientales, 2001b).

Picture 1. Satelital photograph, Pinzacuá Farm, 2003.

Picture 2. Aerial View, Pinzacuá Farm, 2008. In this picture can be seen a significant change in landscape. It can be appreciated an increase in riparian corridors

1.1. Brief History

When Pinzacuá Farm was bought by Mr. Olimpo Montes in the year 1985, the whole farm was dedicated to the production of coffee but even with this crop planted all througout the farm, there were many guamo trees (inga edulis) scattered around the farming land; as well as in all surrounding farms. Few years later, the Colombian Coffee Federation, introduced a new model for the production of coffee which mandated all coffee plantations to be cleared of any trees or any other species of plant. This new model was supposed to generate a higher volume of coffee beans, consecuently bringing the end to any tree species that where still standing in many of this farms. At the arrival of the coffee crisis in colombia, Pinzacuá eliminated its coffee production and planted the whole land with estrella grass[1] (*Cynodon plectostachium)* to begin a cattle fattening production by utility method, which means that 60% of the revenues are destined to the owner of the land and 40% to the owner of the cattle. Unfortunately, even with around 10 cattle per hectare, this system of production was generating losses due to the high cost of fertilizers that were needed in order to maintain the volume of grass needed to hold 10 cattle per hectare.

In 1998, Mr. Olimpo Montes decided to change the whole production model after analyzing the coffee production model and the way the land had been utilized for the past 100 years, long before the so called "green revolution" became popular. After years of struggling with different production models Mr. Olimpo Montes implemented a silvopastoral system to Pinzacuá Farm. He began this process by planting various species of native trees (especially leguminous tree species) dispersed in pastures, 200 per hectare to be more precise, with the Guamo tree[2] as the main species and managing it in a way that the sunlight can actually penetrate the canopy and reach the grass that had been planted underneath. The silvopastoral model was now a reality at Pinzacuá Farm.

1.2. The farm's mission and vision

The major goal of Pinzacuá farm is to use a strategy of efficiency and diversification of structures with the aim of taking advantage of every natural resource in its environment with a minimum input of energy and materials, becoming a versatile system able to successfully satisfy human requirements sustainably over time.

1.3. Structure and management

Current situation

The topography of the region, which is generally hilly, allows for a division of the farm into separate areas. The flat areas on top of the hills were destined for sustainable livestock production. The steepest parts of the hills were destined to sustainable forestry and agroforestry. Finally, the surrounding areas of the three streams that pass through the farm were destined to be protected areas for the regeneration of the riparian corridors. Next, a more detailed description of these areas will follow.

- *Pastures with high tree density [3] – 20 hectares:*

Currently the whole farm is on full reforestation mode. In the more flattened parts (20 Hectares) the objective is to have a density of 200 trees per hectare with trees planted at a distance of 10x5 meters (figure 3).

[1] Before starting livestock production Mr. Olimpo tried with tobacco crop under BAU practices with intensive use of chemical fertilizers and pesticides. This venture didn't produce any revenues due to the high cost of production. From there on Mr. Olimpo decided to try cattle farming.
[2] The guamo tree accompanied the colombian coffee culture for more than a hundred years until the green revolution.
[3] This area is also termed "trees dispersed in pastures" depending on the context.

Picture 3. Four year old guamo trees dispersed in pastures with no artificial fertilization.

The trees are planted in an east to west orientation allowing the maximum amount of sunlight to penetrate the strips were the grass grows. It is necessary to be constantly pruning the trees to maintain the right amount of shadow in the land. The trees are protected by strips of electric cable that measure two meters across, this is done during the growing stage of the trees which is more or less 3 years. In this area are kept 4 cattle per hectare for upbringing and meat production purposes.

- *Sustainable Forestry– 15 hectares:*

This area is aimed at timber production, at increasing biodiversity, soil fertility and at producing fruits, seeds and charcoal. Since the higher steeped slopes of the farm are more susceptible to erosion, this is where a higher tree concentration or density is being planted at a distance of 3x3 meters in order to reach 1.100 trees per hectare (figure 4). It is not necessary to protect the trees in these slopes because when they are growing the cattle are taken out of the area and crops like yuca are planted instead of the cattle. The plantation employs a system of mixed and native tree species to simulate a natural forest and achieve ecologic stability. Some of the planted tree species have high commercial value, others just provide fruits and seeds that can be either harvested and sold in the market or given to the cattle and horses as a dietary supplement; others, enrich the system increasing biodiversity (for natural control of plagues) and soil fertility, leading to higher yields and better quality timber.

- *Agroforestry – 5 hectares:*

The area destined to agroforestry consists in an organic shade-grown coffee crop planted in 5 hectares with a density of 2.550/Ha.

- *Protected areas - 5 hectares:*

The three streams that pass through the farm were isolated and reforested with Guadua to create riparian corridors where the native wildlife can shift between the existing ecosystems. An area of conservation was established around the water birth of the farm to allow it to regenerate naturally.

Picture 4. Riparian corridor reforested with guadua.

In a part of this conservation area the farm is developing a project aimed at producing a high quality and 100% organic vanilla[4]. This potential source of income is yet to be realized and actual future revenues remain uncertain.

The tree layer

The main component that integrates the whole system of Pinzacuá farm is the tree layer. The tree layer is an essential component of the farm's system since it plays a fundamental role of general stabilization providing ecosystem services like: soil structure and fertility, stabilization of water and nutrient cycles, erosion control, pest and disease regulation, climate regulation, shelter, biodiversity, carbon fixation and pollination. The tree layer also provides cultural services for recreational, aesthetic and spiritual benefits (Bovarnick, 2010).

Tree species within the system

As it was mentioned before, the guamo (*Inga edulis*) is the most abundant tree in the farm. This is due to several properties that make it desirable for the production system. Some of the properties are: (i) the guamo tree, that belongs to the legume family, has the ability to fix atmospheric nitrogen thanks to a mutualistic symbiotic relationship with bacteria (rhizobia) found in root nodules of these plants; in other words it fertilizes the soil. (ii) It produces high quantities of litter and dry matter that helps nutrient cycling. According to Cardona and Sadeghian (2005), 70 guamo

[4] Vanilla is a well known and highly valued spice widely used in both commercial and domestic baking, perfume manufacture and aromatherapy (Wikipedia, 2011). Vanilla orchid grows naturally in Central and South American forests.

trees per hectare produce up to 11 tons of dry matter per year of which 200kg are nitrogen which equate to 450kg of urea[5], 7,7kg of phosphorous, 48,9kg of potassium, 158kg of calcium, and 27,3kg of magnesium.

Due to the important services that provide leguminous tree species, some other native kinds have been planted, such as:

- Cañofístol (*Cassia grandis*), that produces a seed with high contents of protein, fiber and sugars. This seeds are being studied as possible dietary supplement for livestock and horses.
- Matarratón (*Gliricidia sepium*), that forms the living barriers.
- Vainillo (*Senna spectabilis*), as the cañofístol tree produces a very nourishing seed that is given to the horses.
- Chachafruto (*Erythrina edulis*), their fruits are for human consumption.
- Algarrobo (*Ceratonia siliqua*), produces timber with high commercial value, and its fruits are for human consumption.

Native fruit trees also have been planted, among these are:

- Guava tree (*Psidium spp*.), very nutritious for both human and animals[6].
- Avocado tree (*Persea americana*), for human consumption.
- Orange tree (*Citrus sinensis*), for human consumption.
- Zapote tree (*Casimiroa edulis*), for human consumption.
- Níspero tree (*Mespilus germanica*), for human consumption.
- Tamarind tree (*Tamarindus indica*), for human consumption.

Some of the tree species with high commercial value timber are:

- Dinde (*Cholorophora tinctoria*).
- Mahagony (*Swietenia macrophylia*).
- Cedro rosado (*Cedrela odorate*).
- Guayacán de Manizales (*Lafoensia speciosa*).
- Mangle de agua dulce ().
- Guayacán amarillo (*Tebebuia chrysantha*).
- Black cedar (*Juglans olanchana*).
- Ebony (*Diospyros ebenum*).
- Iguá (*Pseudosamanea guachapele*).

Picture 5. Two Black Cedar trees, eight months old.

[5] 50 Kg of urea cost around USD $31, hence, the 450 Kg cost USD $282.
[6] There is an experience in another Mr. Montes farm, where the guava trees are very abundant and there are no pastures growing in the understory, so all that the cattle can eat are guava fruits, litter and a few weeds that grow in the paddock; the cattle are healthy and gaining weight normally.

- Samán (*Samanea saman*).
- Caracolí (*Anacardium excelsum*).
- Parasiempre (*Pithecellobium*).
- Neem (*Azadirachta indica*).
- Uvito (*Cordia alba*).
- Gualanday (*Jacaranda mimosifolia*).
- Laurel (*Laurus nobilis*).
- Chiminango (*Pithecellobium dulce*).

Chapter 2. Role of biodiversity and ecosystem services (ES) in the cattle sector

2.1. Comparing two different management practices for the cattle sector

	CONVENTIONAL CATTLE FARMINGING (BAU)	SUSTAINABLE CATTLE FARMING (SEM)
INPUTS	• Artificial inputs: agrochemicals (Pesticides and fertilizers) • Labor, capital, technology.	• Natural inputs or ecosystem services: soil structure and fertility, stabilization of water and nutrient cycles, erosion control, pest and disease regulation, climate regulation, shelter, biodiversity, carbon fixation and pollination. • Labor, capital, technology.
PRACTICES	• Land clearance and habitat conversion • Deforestation of riparian areas • Intensive grazing • Feedlot production • Intensive use of agrochemicals (fertilizers, pesticides)	• Protection and reforestation of riparian areas • Improve pasture management and rotations • Grazing according to land offer • No use or dependency on chemical fertilizers and pesticides. • Harvesting of fruit, fuel wood and timber. • Marketing of native and/or exotic species.
OUTPUTS	• Soil compaction • Soil erosion • Soil fertility depletion • Water pollution • Biodiversity loss • Meet	• Improved water quality • Enhanced natural soil fertility • Natural pest control • Increased biodiversity • Carbon fixation • Meet, charcoal, fruits, honey, seeds

Box 1. Differences in BAU and SEM management practices.

Most BAU practices are implemented to generate high volumes with a fast rate of return, without considering future land productivity.

On the other hand, SEM practices are intended to keep a natural environment and its productivity, satisfying human needs for a long time.

Picture 6. Pasture with no chemical fertilization under SEM.

Picture 7. Pasture with no chemical fertilization under BAU.

Under the SEM system of production, one highly beneficial characteristic is that ES are at the same time inputs and outputs forming some sort of circular sustainability model.

2.2. Benefits of the silvopastoral system

Soil fertility

Picture 8. The effect of trees on soil fertility. This picture shows a better quality pasture under the guamo trees canopy compared to the pasture that is absent of trees which in this case would be the area in the middle. This proves the direct

relation between the trees and enhanced soil fertility. The distance between each strip of trees is 20 meters, allowing for a large deserted area in between each strip. The low quality pasture in the middle indicates the necessity for strips of trees to be arranged much closer to prevent such scenario like the one presented in the above picture.

11 years ago, since the silvopastoral system was implemented, observations of environmental and ecological benefits have been made which directly benefited the production of meat by cattle at Pinzacuá Farm. For example, the trees (especially the leguminous species) improved the fertility of the soil by the transferring of nitrogen by actual roots or by the recycling of nutrients that transfers into the ground via the litter that falls from the tree (Picture 6); thus, saving the farmer a lot of money usually spent on fertilizers and similar products needed to improve soil fertility.

Natural weed control

An additional benefit gained from enhanced soil fertility is increased grass potency which means a stronger and more aggressive plant that allows it to compete with most weeds. This benefit creates a natural weed controlling system and is not necessary to spend money in herbicides. The few weeds that actually grow in the paddock are left there because cattle feed of them and they also act as medicine.

Microclimate regulation

On the other hand, the shadow and cool areas created by the trees have served as protection and shelter to the cattle from the direct sunlight. This protection prevents heat stress that normally affects cattle exposed to the sun, which would decrease the production of meat because the animal is not comfortable, therefore, eats less and transpires more.

Biodiversity and natural pest control

Another but not less important money saving benefit obtained from this system, was that no more insecticides and pesticides needed to be bought because due to the biodiversity achieved, the system regulates itself by the generation of natural agents that control ticks and fly.

Diversified revenue streams

Last but not least, the farm has been able to diversify its production by generating charcoal that results from the pruning of trees (Picture 6), and honey produced in an apiary kept in the farm. Even though the apiary regularly produces honey the main reason for having it is to enable the pollination of trees by the bees. This is another way the farm benefits from ecosystem services and allows it to strive towards ecosystem equilibrium.


Picture 9. Trees pruning


Picture 10. The wood is piled and covered with soil


Picture 11. Charcoal pile


Picture 12. Selection and recollection of charcoal

Water quality

The ecological functions derived from the silvopastoral system not only generates benefits to the overall production of the farm, but also an improvement in the quantity and quality of the water was observed due to the isolation of the streams away from the cattle and their reforestation with guadua (riparian corridors). For instance, one of these streams is contaminated with residual water that is pour upstream in the town of Alcalá. This stream presented bad odors, turbidity and lots of dirty foam, but after the system was implemented all these bad water characteristics are absent. These changes to the water are confirmed in a study that was recently made to that stream, in which some chemical and biological parameters that evaluate water quality where measured and analyzed. Some of the parameters were: (i) COD (chemical oxygen demand, indirect measure of the organic matter present in the water and other oxidizable substances), (ii) nitrogen, (iii) phosphorous, (iv) total coliform, and (v) fecal coliform. The results of the measurements taken from the stream concluded that the COD was reduced by 88%, the nitrogen and phosphorous by 52% and 48% respectively, total colifrms 92% and fecal coliforms 96% (Montes Londoño, 2011). Although further studies need to be made, it could be said that riparian corridors are like free water treatment systems, that are saving considerable amounts of money to society on big projects of infrastructure. Summarizing, riparian corridors improve water quality in a very cheap and simple way, representing lowered off-site water treatment costs. Riparian corridors internalize what before was an externalized cost in conventional cattle ranching and also agriculture.

Chapter 3. Economic Analysis

3.1. Start-up costs for SEM

The implementation of the silvopastoral system has been made gradually year by year with the farm's own revenues (table 1).

Period	Area (Ha)	# trees	Total cost	Cost/Ha
2000-2003	3	300	2.874	64
2004-2005	5	500	1.730	38
2006-2008	17	2.040	6.783	151
2009-present	20	22.000	48.320	1.074

Table 1. Implementation costs[7] of the silvopastoral system

Over the years the farm has experimented with different methods to protect the planted trees from cattle during their first growing years (3-4 years).

In 2000 the farm planted 300 guamo trees (Inga edulis) in 3 hectares arranged in a grid of 10x10 meters (Figure 1), which yields a density of 100 trees/Ha. Each one of these trees was protected with an individual fence made with guadua (Guadua angustifolia) with a total expenditure of USD $64[8]/Ha; After consideration, it was determined that the individual fence was very expensive, and from that moment on the method to protect the young trees changed.

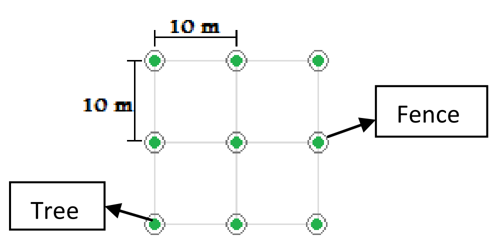


Figure 1.Grid 10x10 meters. Tree density = 100/Ha

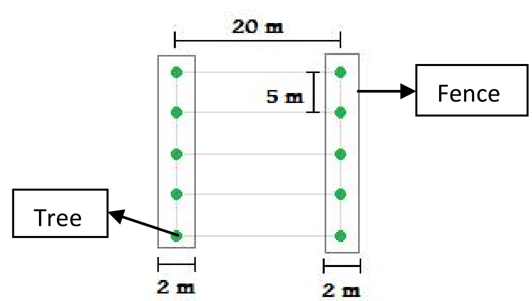


Figure 2. 20x5 meters corridors. Tree density = 100/Ha

[7] Cost/Ha computes dividing the 'total cost' by 45 hectares (farm's total area)
[8] All prices mentioned in this study are calculated at an exchange rate of 1.911,4 COP.

In 2004 and 2005, 500 trees were planted in 5Ha at a density of 100 trees/Ha, and arranged as shown in figure 2. This time the farm found a cheaper way to protect the trees by making corridors of 2 meters wide with electrical wire and guadua. The investment was USD $38/Ha.

From 2006 to 2008, 2.400 trees were planted in 17 hectares, with a density of 120 trees/Ha and arranged as shown in figure 3. The decision to shorten the distance between each strip was based solely on observations made in the field after analyzing the positive physical effects that each tree has over its area of influence, in this case the ground area that is physically affected by the whole tree apparatus (Picture 6). The total cost of planting the whole 17Ha was USD $6.783 or USD $151/Ha.

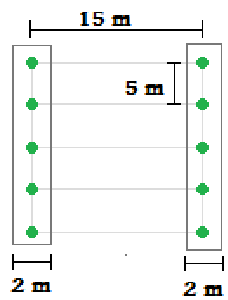


Figure 3.15x5 meters corridors. Tree density = 120/Ha

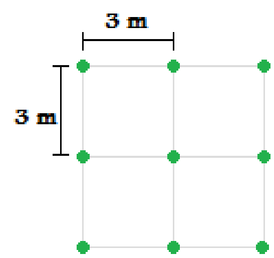


Figure 4.Grid 3x3 meters. Tree density = 1.100/Ha

Since 2009, the farm has been planting trees on the steepest parts of the farm (20 hectares) with a density of 1.100 trees/Ha. The cost per hectare for planting these trees is USD $1.074, including maintenance expenditures for three years[9]; therefore, the total cost of reforesting the 20 hectares will be USD $48.320. It is important to mention that this area will be cattle free during the first three years, that way the trees don´t need to be fenced. After three years, weeding will be made by the cattle, which will be introduced at a rate of 2 animals in each hectare of tree plantation. The idea is that the cattle keep the forest clear from weeds, reducing operational costs while gaining money from livestock production.

3.2. Estimated net benefits of conventional cattle farming (BAU) vs. those of sustainable cattle farming (SEM)

Using Pinzacua's historic data, a BAU and SEM curve will be constructed to estimate net benefits of both scenarios from 1993 to 2010.

The farm´s history is divided in two different time periods: before and after 1998. That year the farm switched from conventional cattle farming (BAU) into sustainable cattle farming (SEM). Tables 2 and 3 present historic data from those time periods, providing important information such as: the amount of animals that the farm maintains each year (Total animals); the charge

[9] Each year the forest requires three weedings. For this activity the farm has to spend USD $230/Ha/year, so for the 3 years the expenditure is of USD $690/Ha.

capacity of each hectare (Animals/Ha)[10] ; the yield in Kg per animal in one month or weight gained per animal in a month (Kg/animal/month); the market price per Kg (Price/Kg); the sales per hectare (Sales/Ha)[11]; the earnings from sales per hectare[12]; the costs per hectare[13]; and the revenues per hectare[14].

Year	1993	1994	1995	1996	1997	1998
Total animals	400	400	400	400	400	400
Animals/Ha	8,89	8,89	8,89	8,89	8,89	8,89
Kg/animal/month	10	10	10	10	8	10
Price/Kg	1,57	1,57	1,57	1,57	1,57	1,57
Sales/Ha	1.657	1.657	1.657	1.657	1.340	1.657
Earnings from sales/Ha	994	994	994	994	804	994
Costs/Ha	759	811	837	916	1.334	1.378
Revenues/Ha	236	184	157	79	-530	-383

Table 2. Balance sheet for BAU (US Dolars).

In 1993, the farm switched from agriculture to cattle farming. From 1993 to 1998 the farm followed the practices from conventional cattle farming and kept an average of 400 animals for the whole time-period. Nevertheless, every year, revenues were dropping until they reached a negative value in 1997 and 1998. What triggered this drop in revenues was the constant rise in input costs year after year. The following are the two main reasons why Costs rose so suddenly: (i) every year the farm had to increase the amount of fertilizers because ecosystem services like soil fertility were getting lost; (ii) the price of inputs is subjected to the oil price that has not stopped climbing so far, making it more expensive for the local farmers to acquire inputs.

In 1997 the table shows a more significant drop in revenues in comparison to the other years, which can be attributed in fact to the reasons mentioned before with respect to the increase of inputs costs, but in that same year a more significant reason for the drop in revenues was a weather phenomenon called "El Niño" which was characterized by a long period of drought. Therefore, El Niño affected the pastures growth which in turn means a lower yield of kilograms per animal.

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Total animals	400	300	250	200	150	120	120	120	120	120	120	100	80	
Animals/Ha	8,89	6,67	5,56	4,44	3,33	2,67	2,67	2,67	2,67	2,67	2,67	2,22	1,78	
Yield/animal (Kg/month)	10	10	10	10	10	13	13	13	14	15	15	15	15	
Price/Kg	1,57	1,57	1,57	1,57	1,57	1,83	2,09	2,09	2,09	2,09	2,09	2,09	2,09	
Sales/Ha	1.657	1.243	1.036	829	622	760	868	868	935	1.002	1.002	829	669	
Earnings from sales/Ha	994	746	622	497	373	456	521	521	561	601	601	497	401	
Costs/Ha	1.378	436	436	436	392	340	340	340	340	340	340	340	311	
Revenues/Ha	-383	310	186	61	-19	116	181	181	221	261	261	157	90	

Table 3. Balance sheet for SEM (US Dolars).

In early 1998, conventional cattle farming was not generating positive revenues due to high production costs, more specifically the costs of chemical fertilizers. Later that same year, chemical

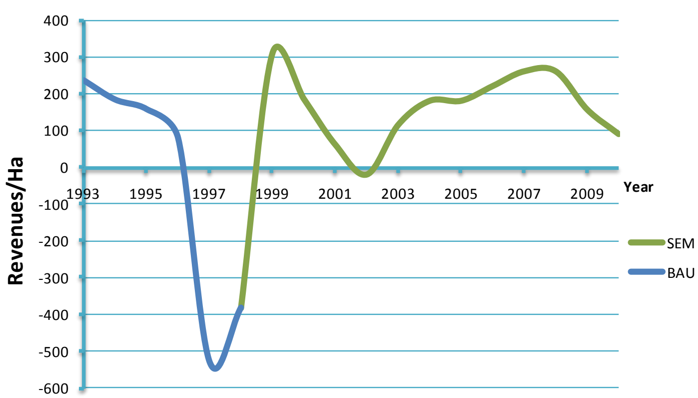
[10] This number results from dividing Total animals into 45, that is the total area of the farm in hectares.
[11] This number results from multiplying 'Animals/Ha' by 'Kg/animal/month' by 'Price/Kg' by 12 months.
[12] This number is the 60% of the Sales/Ha.
[13] The costs/Ha include labor & administration costs, inputs (fertilizers and pesticides) costs, and other inputs (vaccines, salt lick, others) costs.
[14] This number results from subtracting 'Earnings from sales/Ha' minus 'Costs/Ha'.

fertilization was eliminated and so begun the shift towards sustainable cattle farming. As a result, in 1999 the number of animals that the farm was able to sustain declined from 400 to 300, but revenues positively shifted from negative USD $383/Ha to positive USD $310/Ha. Albeit the farm had to reduce its capacity by 100 animals (25% of the total cattle), the moment it stopped using chemical fertilizers and pesticides, revenues instantly turned positive. This enables the farm to achieve revenues higher than ever before. This situation is termed by the UNDP's Report (2010) a 'win-win situation', quoting: "*These are circumstances in which the BAU productive strategy has been exhausted and returns have already declined, so that a switch to SEM is immediately favorable*".

From 2000 to 2003, the number of animals kept diminishing to reach a total of 120 animals in the whole entire farm. As a consequence, revenues started to decline as well, but kept positive until they landed to negative revenues in 2002. In 2003, the farm improved livestock genetics to obtain higher yields and better selling prices, therefore revenues turned positive again.

From 2004 to 2008, the same 120 animals were kept, but we observed a progressive improvement in revenues due to various reasons: (i) yields gradually started to rise due to both, improved livestock genetics, and soil fertility enhancement achieved through the silvopastoral system; (ii) selling price raised due to genetics; and (iii) input costs (vaccines, salt lick, others) were reduced because there were less animals to maintain.

In 2009 and 2010 the farm started to reforest the steepest areas and was forced to take out a few animals causing revenues to drop.



The BAU curve depicts a gradual degradation of returns, whereas SEM curve shows an immediate positive response of net revenues to SEM management practices.

Figure 5. BAU vs. SEM Curves for sustainable cattle farming (USD).

The two main sources of vulnerability for cattle farming are in the first place climate change and extreme weather events; and in second place market volatility. In Pinzacuá's case, a 1997 drought showed how vulnerable the farm was facing such event, this was reflected in net revenues that year. Added to that, was the price of fertilizers that were rising every year, causing revenues to decline.

Since Pinzacuá changed to SEM practices, it became less vulnerable to both variables. Thanks to the trees, the farm now counts on ecosystem services like climate regulation; that made the farm less susceptible to extreme weather events. Another ecosystem service derived from the silvopastoral system is soil fertility and pest control that allowed reducing production costs by about 70% making the farm less prone to market volatility.

3.3. Costs and benefits related to Ecosystem Services (ES) value and maintenance

Changes in the delivery of ES explain the differences in net revenues between BAU and SEM management practices shown in the previous graph. Let's consider soil fertility due to its high importance in ES within cattle farming.

Under BAU, intensive grazing leads to soil compaction. Soil compaction increases soil strength and decreases soil physical fertility by decreasing storage and supply of water and nutrients, which leads to additional fertilizer requirement and increasing production costs (Hamza & Anderson, 2005). The loss of soil fertility negatively affects the yield in Kg per animal (figure 6) and forces the farmer to reduce the number of cattle, which in turns represents a decrease in sales. On the contrary, SEM management practices, like planting trees dispersed in pastures reactivates nutrient cycling and decompresses[15] the soil. This results in the improvement of soil fertility, which becomes a positive effect that increases yield in Kg per animal and reduces fertilizer requirement, therefore revenues increase.

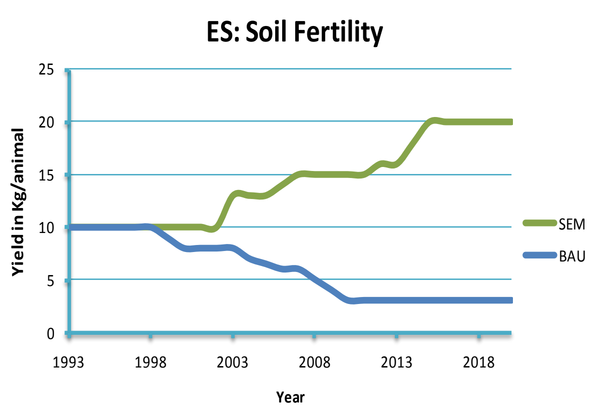


Figure 6. Soil fertility measured as Yield in Kg/animal monthly (USD). Under SEM, the line rises in response to improvement in soil fertility. Depletion of soil fertility leads to lower BAU revenues.

- In order to finalize the SEM curve real data was used, from 1998 to 2010. Real values were implemented in the construction of the curve so that accurate levels of output of kg/animal assure the curve´s reliability. Parting from 2010 its projected that the yield of kg/animal will gradually continue to increase assuming that the fertility of the soil will also continue to augment(due to the effect of the trees)therefore, the quality of the pasture will also too increase simultaneously.
- Analyzing the graph we can concur that by the year 2015, its maximum level of yield of kg/animal, a value of 20 will be reached assuming that by then the system will be completely implemented and all of the trees would have reached maturity enabling the pastures to fully benefit. The BAU curve was constructed using real values from 1993 to 1998, presuming that after 1998 yields of kg/animal diminish year after year due to the fall in soil fertility and over pasturing as well as the compacting of the ground which also contributes to lower levels of soil fertility. It was also assumed that the dose of chemical fertilizer was maintained equal all throughout the time period.

[15] An effective technique for restoring productivity to compacted soils is planting trees with deep and strong taproots to break up or shatter compacted layers.

Let's analyze another Ecosystem Service that is important to cattle farming: pest control. Since diversified landscapes enhance natural enemy populations, natural pest control is a consequence of biodiversity. On the contrary, less diverse habitats, like those in conventional farming, are more vulnerable to pests (Bianchi, Booij, & Tscharntke, 2006). Ticks and flies are the main pests of cattle. Under BAU management practices, the farm had to spend an estimated USD $16/Ha every year in pesticides, and with the depletion of ES expenditures naturally tend to increase in time. But since the farm implemented SEM, increased biodiversity fulfills all the requirements for a broad spectrum of natural enemies: for example, the appearance of the dung beetle (Coleoptera scarabaeidae) which is the fly's natural enemy, and also the appearance of two fungus (Bauveria bassiana and Metharizium anisopliae) which are the tick's natural enemies. This is the reason why is not necessary to spend any more money on pesticides.

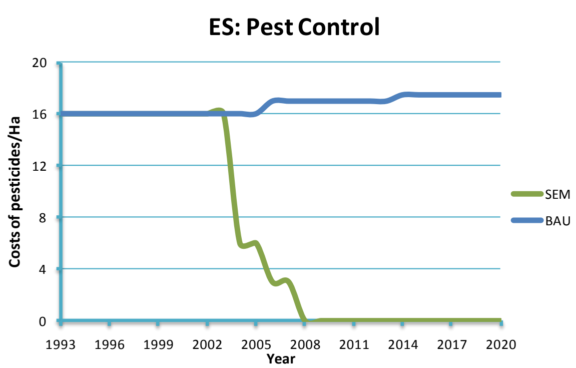


Figure 7. Pest control measured in costs of pesticides (USD). Under SEM, the line declines as a consequence of avoiding costs due to natural pest control. Simplified landscapes lead to increasing reliance on purchased inputs.

- This SEM curve was built using real values of data from the year 1998 to 2010. Data from 2010 on was projected assuming that the biodiversity in the farm would keep on rising; therefore, there was no need to incur in costs of pesticides as it had been happening since 2008.

- This BAU curve was built using real values of data from the year 1993 to 1998. Data from 1998 on was projected assuming that the costs of pesticide would continue to increase, since this value is economically tied to oil prices, and since oil has been in a constant increase, the previous assumption was made.

3.4. Theoretical BAU vs. SEM curve

In order to estimate net benefits from both scenarios of cattle farming, the following BAU vs. SEM curve was constructed on simultaneous time for ten years of economic activity.

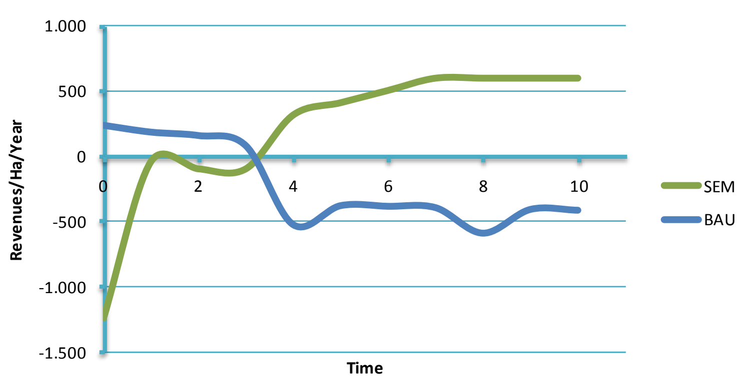


Figure 8. Theoretical BAU vs. SEM curve

The SEM curve was constructed based upon data obtained from table 4. The data was projected parting from the idea that when t=0, the changes were imposed immediately and not implemented gradually as they were in reality.

The BAU curve was constructed from data from table 5. In table 5, from t=0 to t=5, data is the same as in table 2 from 1993 to 1998. Also from t=6 to t=10 data is projected based on suppositions of what could had happened to revenue in case the farm had continue to implement BAU management practices.

Time	0	1	2	3	4	5	6	7	8	9	10
Total animals	130	110	88	100	140	140	140	140	140	140	140
Animals/Ha	2,88	2,44	1,95	2,22	3,11	3,11	3,11	3,11	3,11	3,11	3,11
Yield/animal (Kg/month)	10	10	10	10	14	16	18	20	20	20	20
Price/Kg	1,60	1,60	1,60	1,60	2,10	2,10	2,10	2,10	2,10	2,10	2,10
Sales/Ha	553	468	374	426	1.097	1.254	1.411	1.567	1.567	1.567	1.567
Earnings from sales/Ha	332	281	226	256	658	752	846	940	940	940	940
Costs/Ha	1.572	321	321	321	341	341	341	341	341	341	341
Revenues/Ha	-1.240	-40	-96	-65	317	411	505	599	599	599	599

Table 4. Balance Sheet for Theoretical SEM (USD)

Time	0	1	2	3	4	5	6	7	8	9	10
Total animals	400	400	400	400	400	400	400	400	400	400	400
Animals/Ha	8,89	8,89	8,89	8,89	8,89	8,89	8,89	8,89	8,89	8,89	8,89
Kg/animal/month	10	10	10	10	8	10	10	10	8	10	10
Price/Kg	1,57	1,57	1,57	1,57	1,57	1,57	1,57	1,57	1,57	1,57	1,57
Sales/Ha	1.657	1.657	1.657	1.657	1.340	1.657	1.657	1.657	1.340	1.657	1.657
Earnings from sales/Ha	994	994	994	994	804	994	994	994	804	994	994
Costs/Ha	759	811	837	916	1.334	1.378	1.383	1.393	1.399	1.407	1.413
Revenues/Ha	236	184	157	79	-530	-383	-388	-399	-595	-412	-419

Table 5. Balance Sheet for Theoretical BAU (USD)

Upon observing figure 8, the first thing that can be noticed is that revenues from SEM exceed those from BAU in a short term basis, even when BAU generated its maximum value for revenues which was $236/Ha/year (when t=0). Notice that income from SEM exceeded by 34% that value in four years; in the sixth year revenues from SEM exceeded it by 114%, and in the eighth year by 154%.

It is of great importance to underline the facts that SEM achieved these values with less than halve the cattle that BAU accounted to; and even in a smaller area because we have to remember that, under SEM, 5 hectares were destined to serve as biological corridors and conservation areas, and on the 20 hectares destined to forestry, under SEM, only 2 animals per Ha were allowed to be allocated. This means that even thought the production of meat does not increase, productivity does.

Up until the third year, SEM generates negative values, which means that under this beginning period the attractiveness of the system has to be increased via governmental or private incentives in the way of credits and financial programs and on the government´s part fiscal incentives are critical for the survival of any SEM based project.

3.5. Additional incomes in sustainable cattle farming

An advantage of the silvopastoral system, in terms of risk, is that revenues are no longer dependent in one economic activity. A diversified ecosystem gives the potential to produce and market seeds, fruits, charcoal and timber.

Charcoal

Since 2004 the farm is pruning the trees that form the silvopastoral system. Pruning is a necessary practice for two reasons: (i) in forestry, to enable the tree to yield knot-free wood; and (ii) in the silvopastoral system, to allow sunlight to penetrate the canopy and reach the grass that grows in the understory.

Since 2004 the farm has been hiring an independent contractor for the pruning and the actual charcoal production. The farm produces an average of 50 tons of charcoal a year which is eventually sold at the local market to be used as a cooking fuel at restaurants, barbecues and for outdoor grilling in general. From this activity the farm obtains revenues of USD $3.139 a year.

Charcoal production will increase as the amount of trees increase as well.

Payments for Ecosystem Services (PES)

From 2002 to 2007 the farm was part of a pilot PES project promoted by CIPAV and GEF in which the farm received a total payment for ecosystem services of USD $6.500. Payments were made on yearly improvements for carbon sequestration and biodiversity.

Most frequently natural resources are free or underpriced, which leads to overexploitation and pollution (Steinfeld, Gerber, Wassenaar, Castel, Rosales, & de Haan, 2006). Payment for Ecosystem services is a good policy that adds value to natural resources and serves as an incentive to producers to take care of their land.

3.6. Future revenues

Increased revenues from cattle after 2015

In a short to medium term the farm´s goal is to sustain a mean value of 130 animals in the whole farm or 2,88 animals/Ha. The idea is to keep something around 100 animals in the pastures with high density of trees, and the other 30 animals will be kept in the area destined to forestry, feeding from the weeds that grow in the understory of the forest; this way the cattle do the weeding that the tree plantation requires and also helps the farm saving money in manual labor. Savings are estimated to be USD $691/year per each hectare within the tree plantation or approximately USD $230/year in each hectare of the whole entire farm land.

The farm is also aiming to increase yield per animal improving from 15 Kg/month (current yield) to 20 Kg/month; this will be possible thanks to enhanced pasture quality and volume, and the reduction of heat stress due to microclimate regulation, both of them are the result of a mature silvopastoral system.

The increase in charge capacity of the farm and yield in Kg per animal will result in higher revenues per year positively shifting from USD $90/Ha in 2010 to USD $545/Ha in 2015.

A comparison of 2010 and 2015 costs and incomes from cattle are depicted on the tables 4 and 5.

Charge capacity	1,77 animals/ Ha
Yield/animal	15 Kg/month
Price/Kg	2,1
Costs/Ha/year	
Labor and administration	-278
Fertilizers	0
Pesticides	0
Inputs (Vaccines, salt lick, other)	-33
Total costs	**-311**
Income/Ha/year	
Sales	669
Earnings from sales	401
Income	**90**

Table 6. Balance sheet for cattle in 2010

Charge capacity	2,88 animals/ Ha
Yield/animal	20 Kg/month
Price/Kg	2,1
Costs/Ha/year	
Labor and administration	-278
Fertilizers	0
Pesticides	0
Inputs (Vaccines, salt lick, other)	-48
Total costs	**-326**
Income/Ha/year	
Sales	1.452
Earnings from sales	871
Income	**545**

Table 7. Balance sheet for cattle in 2015

Estimated Revenues from timber in 10, 15 and 20 years

Fifteen hectares of the farm are destined to forestry. This area will have 16.500 trees planted with a density of 1.100 trees/Ha. According to criteria and indicators of sustainable forest management, the farm plans to harvest the trees in this area in three different time periods. A first thinning, planned 10 years from now, will harvest 7.500 trees and generate earnings of USD $8.667/Ha. In 15 years, a second thinning will harvest 3.000 trees and produce an income of USD $6.933/Ha. Finally, in 20 years the farm will harvest the remaining trees, which will generate revenues of US $26.200/Ha. Table 6 shows the trees harvested during each of the time periods and the income expected from forestry in 10, 15 and 20 years.

Years from now	Trees harvested	Price/tree	Income/Ha
10	7500	52	8.667
15	3000	104	6.933
20	4500	262	26.200

Table 8[16]. Projected Revenues[17] from timber in 10, 15 and 20 years.

The trees dispersed in pastures generate income too. Approximately 10% of the trees grown in that area are woody species. Thus, from 200 trees/Ha planted in those 20 hectares, 20 trees/Ha will be exploited in 20 years for timber production, harvesting a total of 400 trees. Revenues from those 400 trees equal USD $2.329/Ha.

[16] Prices given are current market prices. In 10, 15 and 20 years, these prices will probably rise and have a bonus for sustainable forest management.

[17] Income/Ha is computed multiplying trees harvested by Price/tree and the result is divided by 45 hectares (total area of the farm).

Years from now	Trees harvested	Price/tree	Income/Ha
20	400	262	2.329

Table 9. Additional revenues from timber in 20 years.

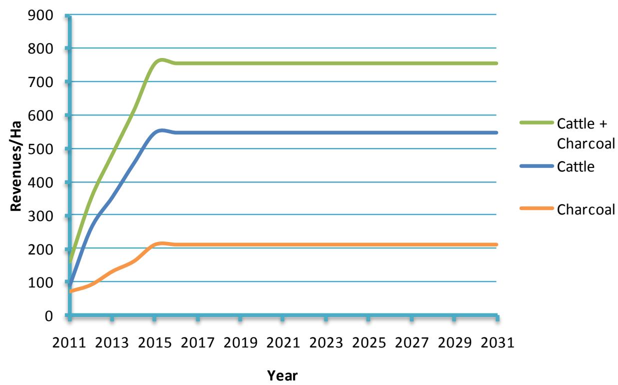


Figure 9. Projected Future revenues from Cattle & Charcoal

Revenues from cattle will have a progressive increase from 2011 to 2015, due to an increase in yield/Kg and an increase in charge capacity. After 2015 revenues are expected to maintain a regular level. Similarly, charcoal net revenues will gradually rise until they reach a point of stability, when the maximum amount of trees is reached.

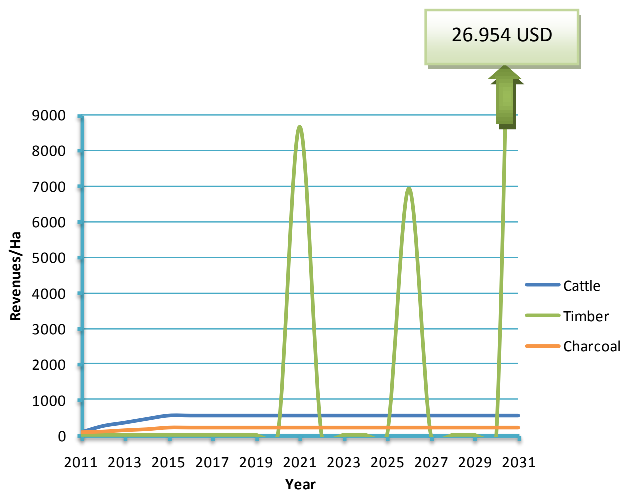


Figure 10. Projected Future revenues from Cattle, Timber & Charcoal

This figure shows that revenues from timber are much greater than revenues from cattle and charcoal, but the cash flow generated by the production of meat and charcoal are equally important to the revenues of timber because they provide a constant inflow of cash until revenues from timber are able to be collected.

3.7. Total SEM revenues compared to BAU

Since cattle farming under SEM generate additional revenues from charcoal and timber, it is necessary to construct a theoretical BAU vs. SEM curve to compare net benefits of both scenarios.

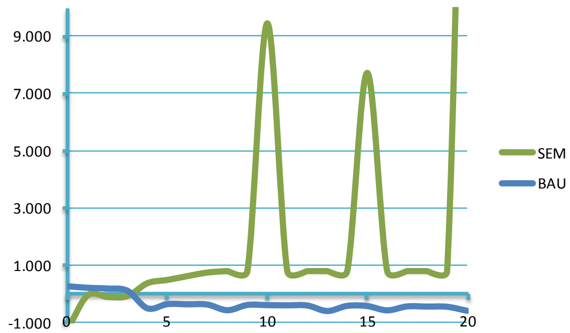


Figure 11. Theoretical BAU vs. SEM curve with charcoal and timber revenues.

This figure compares BAU vs. SEM revenues in a period of 20 years. It is basically the same graph as the one seen in figure 8 but revenues from charcoal and timber had been added to SEM curve.

Chapter 4. Conclusions

A general outlook of the BAU production system, in an obvious and generous manner, depicts its fallacies and deficiencies. Simply by analyzing data collected, either in recent day studies or past collections of data, the BAU production system it's not only procedurally defective, but most importantly its ideological roots flow entirely opposite to nature's ways.

When comparing the two systems of production, history has shown that BAU is more vulnerable to uncontrollable variables like climate change, exchange currencies, government policies, and market price fluctuations. An example of a BAU production system like conventional cattle farming creates a less diverse habitat that is more vulnerable to extreme weather events like El Niño or La Niña phenomenons. 1997 drought caused by El Niño phenomenon, demonstrates how vulnerable BAU production systems are to climate change. On the other hand, SEM practices like those applied in riparian corridors, mixed tree plantations and those in silvopastoral systems create more complex and patchy landscapes that are similar to natural environments, are more stable and therefore, more resilient to weather disturbances.

Other very important deficiency of BAU is its high dependence on inputs which represent 80% of the production costs compared to the much lesser 20% of SEM production costs.

In the event of an inevitable comparison between the BAU and SEM curves we can definitely concur that the projection of the BAU curve will eventually lead to a system failure. On the other hand, the SEM curve which, even though, has to endure beginning years of hardship meaning "low-output" or in some cases low or negative revenue, will (after achieving ecosystem balance) embark on an upward journey marked by good sustainable growth that will benefit from a balanced ecosystem which allows for minimum intervention by the farmer.

The root problem within BAU practices is that regardless of changes or improvements made to the conventional system of production, it is still focusing in producing high yields; completely ignoring the fact that higher yields consequently mean lower nutritional values in the food. Unfortunately all this erroneous practices boil down to the misguided belief that plants need only three elements

N-P-K (nitrogen, phosphorous, and potassium) leaving the rest of the 45 elements needed by the plant left for later (Primavesi, 2002). The end result is pastures with poor nutritional value and, therefore, meat with poor nutritional value. We have failed to make the connection or simply comprehend that food with high nutritional value allows for the need of a much lower volume of production, in other words, we can achieve healthy nutrition standards without having to increase outputs.

We must recognize the huge advantage gained by implementing silvopastoral systems. The possibility of producing meat and non timber forest products at the same time in a sustainable way means that we can enjoy the privileges of having two parallel sources of food, without, altering or implementing external resources into our system of production.

Which could be the main reasons to hesitate to this change? This can be attributed to many and diverse reasons but one of the most important ones is that there is simply **not enough demand for the product**. In order to establish a certain product in any market the demand for it has to be natural and if no then it has to be artificially created by the parties interested in form of awareness, incentives to buy like price and quality, but most importantly its wide availability throughout the areas were the concerned entities want this product to be demanded. Since the demand for the product is not there this gives way for our next important question.

Why bother? Why should I bother to change the whole infrastructure and system of production when the demand for that certain product isn't simply there? Another big reason for skepticism is **the lack of government intervention.** This is very important because when you are trying to switch a whole idea of consumption into the population, the most efficient tool is government incentives. The problem is that the government like anything else works on the basis of incentives, and they have plenty of incentives not to change or intervene in the current agrochemical products.

The real goal is to get the government to see the positive outcome of change. On the other hand, when we take into consideration not just the big landowners but simply the typical small farmer, they are also not incentivized enough to embark on a change of infrastructure to tumble upon a market which still lacks the characteristics to compete with the actual one which unlike the new one, **this current market has been running this way several decades and unfortunately it still signifies far less risk than changing into the SEM based system.** The existing market is probably the entity which contributes most in order to prevent the change or switch into the SEM system. Behind the existing market, there are entities or parties that have been controlling this system of demand and supply for many years and will do anything against those pushing for change. These Interest Groups, behind the established market contribute in many different ways including monetarily (most significantly) in order to maintain a powerful grip on rules and regulations making it almost impossible or certainly very difficult to infiltrate and change the actual system. These entities are mostly made up of big multinational corporations controlling the molecules that make up the pesticides and all the other chemical products that farmers are addicted to. Unfortunately one of these big players is none other than the Colombian Coffee Federation, which has for many decades now, warned us to use and buy, each and every single chemical product

Colombian farmers have put into their crops. It´s simply astonishing that our own federation, the one that many years ago was founded in order to serve and help the Colombian farmers, has really been the number one ally of the big multinationals that so desperately need to sell their products to us. The big chemical multinationals with the help of the Colombian Coffee Federation, have slowly but surely created an impenetrable system in which the farmers are basically forced to buy their products if not bankruptcy will almost surely follow.

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