BioClima Nicaragua

Business as Usual (BAU) and Feasibility Study
Silvopastoral Systems
Buffer Zones Bosawás and Indio Maíz

Key Elements

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Introduction

In Nicaragua, livestock farming is a major cause of forestland conversion and occupies almost 50% of total land area. Land use change and agriculture cause 68% of total greenhouse gas emissions, of which more than half are from livestock (mainly enteric fermentation).

The Caribbean Region constitutes more than half of the national territory, contains approximately 89% of the countries forests (3.19 M ha) and has the highest proportion of poor people. The agricultural sector occupies over 30% of the labor force and is the main source of livelihood for 80% of the population. A variety of forces are driving deforestation and rapidly increasing environmental degradation, including the rapid expansion of oil palm and livestock production systems. The conversion of forests to agricultural land uses with little or no government regulation are having severe environmental impacts, including land degradation, loss of biodiversity and exacerbation of flood-drought cycles. Nearly 75% of Nicaragua's forests has already been transformed into crop and pastureland, and at least 50% of that deforestation has occurred since 1950. Together with neighboring forests in Honduras, the Bosawás Biosphere Reserve in northeastern Nicaragua and the Indio-Maíz Biosphere Reserve in southeastern Nicaragua encompass relatively intact rainforest tracts that lie at the center of Mesoamerica, one of the most important biological corridors of the planet.

The indicators of the Business as Usual (BAU) scenarios presented in this document (very high GHG emission intensities and water requirements per unit of product) show that even without a further increase in livestock numbers (which is against the current trend) the degradation of pastures (often without trees or other woody biomass) will continue. This will result in even lower livestock productivity, and a further deterioration of pastures and other landscape elements.

There is therefore a need for more efficient and productive cattle farming systems in the Bosawás and Indio Maíz buffer zones, to improve natural resource integrity (by increasing tree cover, carbon stocks, and freeing land for restoration and reforestation), increase added value to animal-source products, and strengthen links between the value chain components. This requires year-round high-quality feed availability, improved livestock management and increased adoption of sustainable production practices and technologies, for which silvopastoral systems provide good options (Ibrahim et al., 2007; Gaitán et al., 2016). Additionally, investments at farm level and further along the value chain are needed to ensure access to markets and adequate infrastructure and equipment.

FAO has requested CIAT to develop a feasibility study for investments in silvopastoral components of livestock farms. In this document, we present scenarios for the inclusion of silvopastoral components in both small and medium farms.

Bosawás

Bosawás in north-eastern Nicaragua represents 15% of the national territory and is dividided into two zones: i) the core area (8,065.93 km²), consisting of six reserves: Reserva Natural Bosawás (6,811 km²), Parque Nacional Cerro Saslaya (631.30 km²), Reserva Natural Cerro Cola Blanca (105.2 km²), Reserva Natural Banacruz (271 km²), Macizos de Peñas Blancas (115.5 km²) and Reserva Natural Cerro Kilambé (126 km²); and ii) a buffer zone of 11,861.96 km².

The landscape is flat to undulating. Most of the area, 60%, has an altitude of under 100 masl, 30% between 100 to 600 masl and 10% over 600 masl with the highest point at 1650 masl. The climate is humid, with a prolonged rainy season from May to January and a dry season from February to April. Annual rainfall varies between 1,800 and 2,800 mm, some places reaching 3,200 mm. Soils have a high clay content and are prone to waterlogging, with high aluminium content and therefore generally of poor fertility.

The buffer zone includes (parts of) the municipalities of Waslala, Siuna, Waspan, Bocay and Bonanza, and is characterized by an accelerated deforestation of over 60% during the last 2-3 decades, partially caused by a livestock stocking program putting financial resources into heifers. The reserve itself has lost over 6% tree cover during the last 15 years and most recent estimates put agricultural (crops and livestock) land use at 31% (MARENA, 2019).

Indio Maíz

The Indio Maíz reserve in southeastern Nicaragua measures 2639 Km², and includes parts of the municipalities of Bluefields, Nueva Guinea, San Juan de Nicaragua and El Castillo. The ecosystem is tropical rainforest and is a major source for the Río San Juan watershed. Annual rainfall exceeds 5000 mm during 11 months, with only March and April as relatively dry months. Rainfall in the buffer zone varies between 2300 and 2800 mm annually[1].

Methodology

Demographic information from the Nicaragua agricultural census in 2011 (CENAGRO) was used to estimate farm sizes and livestock numbers based on their scale of production. Extensive use was made of reports and other secondary sources (see references at the end of the document).

Focus group discussions were held with farmers and other actors to define a characterization of the different livestock farms, discuss livestock constraints, and estimate the costs of different possible interventions. Some farmers were interviewed individually, and some farms were visited.

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[1] http://www.salvemoslareservaindiomaiz.org/informacion-de-la-reserva/

https://www.oas.org/dsd/publications/Unit/oea05s/ch07.htm

Climate and environmental impacts were assessed with the CLEANED-X Excel tool, a rapid ex-ante environmental impact assessment tool that allows users to explore multiple impacts of livestock related interventions (Birnholz et al., 2016; Notenbaert et al. 2016). CLEANED models the livestock enterprise component at farm level (very relevant for this study in which we compare BAU and improved silvopastoral system scenarios), using a step-wise procedure in which the different scenarios are assessed and compared in terms of productivity, profitability, land requirement, nutrient balances, greenhouse gas emissions, carbon accumulation and water requirements. The advantage of the CLEANED approach and assessment are its relatively low data and time demands, and the generation of results that are easy to grasp and translate into recommendations for decision makers and stakeholders.

The CLEANED framework guides users through a step-wise procedure. In a first step the baseline is set. A second step entails the actual ex-ante impact assessment comparing potential impacts against the baselines. For the purpose of this study we developed and added a model calculating carbon stock changes for different components of silvopastoral systems based on different tree types and densities. We developed four different farm/livestock scenarios (two farm sizes ("small" and "medium"), each with BAU and silvopastoral systems). For each silvopastoral component we assessed the costs (per ha, or per meter) and we defined for each scenario a realistic mix of components, based on the field visits, secondary information and expert opinion. Applying CLEANED, we assessed for each scenario the different biophysical, environmental and climate impacts, as well as net income from livestock production. Comparing net income from BAU and improved silvopastoral systems for both farm sizes gives the expected income increase from the proposed measures and allows for an analysis of the profitability of the proposed investments.

Livestock production

The main characteristics of livestock production in both regions are as follows:

- Total agricultural area of both buffer zones is 1.8 M. ha, of which 53% is solely used for animal production. Of the 24,000 farms in both regions, 68% possess cattle and many farmers have no access to high value dairy and beef markets, partly caused by bad roads and absence of electric power.
- Based on 2011 CENAGRO data and an estimated increase of 33% between 2011 and 2018 (MAG 2019) the number of cattle in both regions is estimated at 1.16 million heads (representing almost 25% of the national herd), of which 25% and 47% owned by small and medium farmers respectively.
- Climate change is one of the biggest challenges for livestock production in Nicaragua. Inadequate land use and management practices result in low livestock productivity, high environmental impacts, poor resilience to drought and high vulnerability to climate change. One of the most important threats is the increase in length of dry periods as well as of the frequency of periods of extreme drought. Because of feed and water scarcity in the northern

(Estelí, Madriz, Nueva Segovia) and central (Matagalpa, Chontales) parts of Nicaragua, low land prices and a more constant (and relatively high) rainfall ensuring feed availability have attracted many livestock farmers. This has resulted into expansion of livestock not only in the buffer zone but also into the reserves themselves.

- The predominant livestock production system is extensive and generally dual-purpose (milk and beef), characterized by low stocking rates (less than one animal per ha), poor productivity and reproduction parameters, also when compared to the central and Pacific regions of Nicaragua. Livestock productivity is limited mostly by the lack of availability of good quality feed.
- Milk production ranges from 3 to 7 kg per animal per day (on average 4.5 kg), most of the milk processed into cheese for the local, national and some export markets.
- Cattle for beef production reach typically a finishing weight of 380 kg after 3.5 years, but many farmers their animals at a younger age (14 months, 150 kg), to intermediaries or farmers who specialize in fattening. Market is mainly domestic (slaughterhouses), export of live animals takes place to Honduras, Mexico and Venezuela. Part of the exported meat, often of low quality, goes to the United States to be processed into hamburgers.

Table 1 shows the distribution of cattle ownership according to farm size.

Table 1: Cattle ownership per farm size

Farm size	Small (< 35 ha)	Medium (35-140 ha)	Large (>140 ha)
Proportion farms	64%	31%	5%
Cattle (% of total population)	28%	47%	26%
Average number of cattle	19	74	253

CENAGRO 2011

Three types of farmers can be distinguished (see Table 2 for some details of the Bosawás buffer zone that are however also representative for the Indio Maíz buffer zone):

1. Small farmers: with few capital resources, little land and cattle, relatively diversified but with little access to markets for dairy products. Labor is family-based, and some family members might work themselves as laborers at other farms.
2. Medium farmers (extensive farmers): have some more access to capital and own more land and cattle. Their production system is livestock-based, less diversified but very extensive. Labor is also mainly family-based, but during certain periods of the year some external labor is hired. Like small farmers, they have very little investment capacity, have no resources to fatten their calves and are forced to sell them at weaning age (8-11 months)
3. Large farmers (ranchers): have access to capital, own more land and cattle than the other two categories; some specialization in rearing / fattening of heifers and steers. Sometimes the farm is managed by a farm manager, and most of the labor is hired from outside. Some have an additional business like cattle trading.

Table 2: Farmer typology in the Bosawás buffer zone

Indicators	Small	Medium	Large
Farm size (ha)	21.28	44.6	111.6
Herd size (LU)	8.5	30.5	100.9
Lactating cows	4.1	15.9	46.7
Improved pastures (ha)	4.3	7.8	94.5
Traditional pastures(ha)	5.2	12.6	30.8
Stocking rate (LU/ha)	0.28	0.36	0.7
Milk production (rainy season) (kg/day)	3.2	3.8	5
Milk production (dry season) (kg/day)	2.5	3.5	4
Age at first calving (years)	3	2.9	2.7
Calving interval (months)	15	18	18
Weaning age (months)	8.6	8.6	7.6

Based on Lopez 2006, Marin & Lopez 2008 and Lopez 2010

The different farmer categories interact at the dairy cooperatives, in which, independent of the farm size, all members have the same vote. In case of beef, there exists an important relationship between small, medium and large farmers, the larger categories often buying weaned calves from the smaller ones for further development (stocker production) and fattening. A common practice in the buffer zones is the so-called "mediería" ("sharecropping"). Large and some medium farmers either accommodate ("lease") heifers to smaller farmers for further development and usufruct (first lactations), or accommodate steers for further development (stocker production) and share the revenues from the live weight gain during the "lease" period.

Pastures occupy 65% of the agricultural area and consist predominantly of 'Retana' grass (*lschaemum ciliare*), which is highly invasive, with poor yield and nutritional value, and is almost completely dormant during the dry season, leading to feed shortages.
Traditionally, livestock feeding has been based on year-round grazing as farmers from both zones did not feel the need to offer nutritional supplements (minerals, concentrate) or grow cut-and-carry forages, not even during the months of low rainfall (March-May). To compensate feed shortages caused by low biomass production of the traditional "Retana" due to reduced soil humidity during March to May, since 10 years approximately 40% of the farmers have started including cut-and-carry grasses (typically between 0.3 and 1.5 ha) and one third (in comparison to 60% nationwide, Labarta et al, 2018) has planted improved grasses for grazing. The latter with variable results: due to inadequate management, substantial areas have been lost to invasive native species. The improved grasses include mainly *Megathyrsus maximus* cultivar Mombasa and *Brachiaria brizantha* cultivar Marandú, Farmers use cut-and-carry grasses (e.g., *Pennisetum purpureum* (Taiwan and King Grass) and sugarcane) in particular for the drier periods. The only supplement, mineral salt prepared on-farm, is often used incorrectly and for over 90% of farms consists of common salt and very little other minerals. Forage seed access and availability is another major challenge. Adoption by small farmers of improved forages is often hindered by

lack of access to seed, either because of unavailability, or because the seed (especially of improved grasses) is relatively expensive.

As mentioned earlier, one of the most important changes in land use over the last decades has been the widespread conversion of forest to pastureland. The social costs and negative environmental impacts resulting from deforestation are enormous and include soil degradation and erosion, water pollution, biodiversity loss, increased greenhouse gas emissions, and the loss of carbon accumulation potential. Inadequate pasture management has led to soil degradation and reduction of water sources, resulting into low-quality feed and high GHG emissions (5-7 kg CO2e/kg of milk; 80-90 kg CO2e/kg of meat).

In spite of its low productivity, cattle production is lucrative if it ensures land occupation and ownership. This is of particular concern considering the growing trend of establishing oil palm plantations on exhausted land formerly dedicated to livestock production. Due to fragile soils and high rainfall, there is a high risk of land degradation and loss of soil fertility.

Excellent opportunities exist for sustainable intensification, especially silvopastoral systems (high suitability for tree crops) to transform the extensive livestock production into a sustainable system, financially and socially viable, while reducing negative environmental and climate impacts.

Investments in sustainable livestock (e.g., silvopastoral systems)

Initial investment requirements for the establishment of sustainable livestock systems (like silvopastoral systems) are high, especially for small and medium farmers, whereas benefits will not become evident immediately. Credits for these kinds of investments are generally not part of preferential funds/credits for livestock. Hence, farmers are not likely to invest their limited resources in these systems unless they can participate in incentive mechanisms that make these kinds of investments feasible.

Farmers summarize this as follows:

- Investment costs are (too) high, including for chaff cutters, protein/energy banks, feeding troughs
- Lack of initial capital
- Lack of access to credit and other financial resources
- Low price of products in general, and no premium for environmental or climate friendly products (no incentives)
- Market uncertainties
- Lack of knowledge and of technical assistance

Costs, benefits and economic and financial indicators

As mentioned before, livestock production in general is profitable but as shown in Table 3 (farmers in Bosawás buffer zone) differences between farmer categories are considerable. Income of especially small farmers is very low and very few farmers have access to (financial) resources for investments.

Table 3: Household income from livestock production, an example from Bosawás buffer zone (USD/year)

Indicators	Small	Medium	Large
Gross income	1,757	4,583	14,556
Costs	251	648	2,337
Net income	1,452	3,371	10,152
Credit access (percentage of farmers)	12%	15%	26%

Based on Marin & Lopez 2008

Credit access is poor, very few financing facilities are available for small/medium farmers (high interest rates microfinancing, no opportunities with commercial banks, many farmers have no official land titles that can serve as a guarantee), partly due to negative experiences in the past with low repayment rates. Credit providers and banks in general do not consider the necessary time needed to adopt and implement appropriate and sustainable practices and technologies. Furthermore, there is hardly any physical presence of banks.

The constraint is not so much the lack of funds, but rather the lack of services and robust implementing entities. In general, the livestock sector is considered high risk and farmers depend mostly on informal credit providers with high interest rates like input providers, intermediaries and other lenders. In fact, these informal systems with high interest rates have contributed to the current extensive livestock production systems, stimulating farmers to invest in often unsustainable practices that give quick economic returns without considering negative environmental impacts, instead of incentivizing farmers to make longer term investments.

Livestock productivity

In addition to BAU scenarios for small and medium farms, two scenarios with improved silvopastoral systems were defined. Parameters are based on secondary sources, focus group discussions, individual farmer interviews and farm visits. The SPS scenarios for small and medium farms presented do not foresee a full implementation of the components at the entire farm, this possibly not realistic because of available capacity and costs involved. However, to get an idea of their full potential and for cases with sufficient resources and capacity, in this study we also present a scenario (“Full SPS”) with the impact (per ha) of a full implementation of the proposed improved silvopastoral and forage components.

Table 4 shows for both BAU and SPS scenarios[2] the herd composition, production levels (milk production, live weight gain of steers/heifers and calves (being similar[3]) and feed components for small and medium farmers in Bosawás and Indio Maíz buffer zones.

[2] SPS at full implementation (from year 4)
[3] CONAGAN (C. Mercado), personal communication

Table 4: Herd composition, production level and feed item descriptions for BAU and SPS scenarios

Herd composition and production level								
	Small farmers BAU		Small farmers SPS		Medium farmers BAU		Medium farmers SPS	
Livestock category	N	milk/LWG kg/animal	N	milk/LWG kg/animal	N	milk/LWG kg/animal	N	milk/LWG kg/animal
Cows	6	560	8	960	33	678	33	900
Steers/heifers	2	111	5	146	10	129	10	163
Calves	6	111	6	146	15	129	15	163
Bulls	1		1		2		2	-
Pasture / feed area	10 ha		10 ha		40 ha		30 ha	
Stocking rate (TLU/ha)	1.26		2.11		1.49		2.40	
Grazing /corral	88%/12%		88%/12%		88%/12%		88%/12%	
Manure use	None		From corral for cut-and-carry grasses		None		From corral for cut-and-carry grasses	

Feed item proportions in diet								
	Small farmers BAU		Small farmers SPS		Medium farmers BAU		Medium farmers SPS	
	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season
Traditional pastures (*I. ciliare*)	100%	100%	30%	20%	75%	72%	25%	15%
Improved pastures (*P. maximum*)			55%	45%	25%	22%	60%	60%
King grass (*Pennisetum spp.*)			10%	25%		6%	10%	20%
Gliricidia sepium			5%	10%			5%	5%

Yield and quality	Removal (fraction)	Yield (kg/ha)	ME (MJ/kg DM)	CP (kg/ kg DM)
Grasses				
Ischaemum ciliare	0.4	8,000	6.0	60
Megathyrsus maximus	0.5	17,000	7.5	99
Pennisetum purpureum	0.9	6,000	9.9	110
Legumes				
Gliricidia sepium	0.8	6,500	11.5	223

BAU: Business as Usual; **SPS**: Silvopastoral Systems; **N**: Number; **LWG**: live weight gain; **ME**: Metabolizable Energy; **MJ**: Megajoule; **DM**: Dry Matter; **CP**: Crude Protein

Livestock management

BAU

More than 90% of the farmers used their own bull for serving their cows. The remaining farmers used a bull from another farmer, and in a few cases artificial insemination.

The cattle reared are crosses of different breed-types. The main sire breed is rarely the same breed as the main dam breed, but most animals are Brahman x Brown Swiss crosses. Farms with stronger tendencies to raise calves for sale to intermediaries or farms specialized in calf raising for beef production, have a stronger preference for a higher Brahman proportion, whereas more dairy oriented farms usually include a greater proportion of Brown Swiss, and, to a lesser extent, Jersey and Holstein.

SPS

Improved productivity is mainly a result of improved nutrition and management. Determining factors include:

- A larger proportion of improved grasses with higher protein and energy contents that allow for higher milk production and growth (*Brachiaria* cultivars and hybrids, *Megathyrsus* cultivars)
- Inclusion of legumes in the diet, especially trees and shrubs (mainly live fences, protein banks), increasing availability of protein, which is generally the limiting component for milk production and to a lesser extent for live weight gain.
- Increased use of cut-and-carry grasses (*Pennisetum* spp.), providing energy (especially for live weight gain) and an important feed for periods with less rainfall.
- Improved pasture management, including intensive rotational grazing with improved grasses improving feed availability and quality and allowing for higher stocking rates, milk production and live weight gain.
- The tree components of SPS increase the availability of high quality feed (legumes), provide shade (decreasing heat stress of cattle), increase water availability in pastures and enhance nutrient cycling, increasing availability of essential elements like nitrogen for forage production.

There are no significant changes in breeds foreseen, but better feed quality and management might provide scope to increase proportions of higher producing animals like Jersey, Brown Swiss or improved beef breeds. Faster growth and improved dairy management generate meat and milk of premium quality and lead to an increase in milk and meat prices.

The manure deposited in the corral during milking is partially used to fertilize cut-and-carry grasses.

Table 5 gives details on the animal characteristics, production levels and some economic parameters.

Table 5: Cattle characteristics, production levels, economic parameters for different farm sizes, BAU and SPS scenarios (at full implementation, after 3 years)

Cattle characteristics	**Small BAU**	**Small SPS**	**Medium BAU**	**Medium SPS**	**Full SPS (1 ha)**
Herd size - total	15	20	60	60	3
Lactating cows	6	8	33	33	1.2
Milk prod (kg/day)	3.5	5	4	5	6
Lactation length (days)	240	240	240	240	240
Calving interval (months)	18	15	17	16	15
Milk production (kg/year)	3360	7680	22362	29700	1382
Milk production per cow (kg/year)	560	960	678	900	1152
Steers/heifers sold (per year)	2	4	10	15	0.8
Cows sold (per year)	1	1.6	5	6	0.3
Selling weight steers/heifers (kg)	160	200	180	210	240
Selling weight cows (kg)	380	380	380	380	380
Milk price (USD/kg)	0.3	0.37	0.3	0.37	0.43
Price kg LW steers/heifers (USD)	1.7	2	1.7	2	2
Price kg liveweight cows (USD)	1	1	1	1	1
Costs (per head/per ha)					
Management - cattle	32	32	32	32	32
Improved pastures	205	205	205	205	205
Traditional pastures	36	36	36	36	36
Cut-and-carry grasses	486	486	486	486	486
Months use cut-and-carry grasses	0	12	3	12	12
Protein banks	376	376	376	376	376
Electric fences	0	0	0	0	0
Live fences	12	12	12	12	12

Feed and pasture management

BAU

Grasses being the main feed component, pastures occupy almost 900,000 ha of which 66% are traditional grasses, mainly Retana grass (*Ischaemum ciliare*)) and 34% are improved grasses, mainly *Megathyrsus, Brachiaria*.

Forage production is low, caused by inadequate pasture management (either too intensive leading to decreased biomass production or too extensive leading to high fiber and lignin contents), degraded soils (due to low cover) and inadequate germplasm (e.g., “Retana” with low energy and protein contents), and very low biomass availability during drier periods. Grazing takes place generally in large pastures without divisions during long periods. Presence of trees in pastures is low, with an average of 10 trees per ha (range between 0 and 25) and a size of 20 cm diameter at breast height (dbh).

SPS

Silvopastoral systems in combination with improved forages increase high quality feed availability, allow for soil restoration, increase resilience to extreme weather events (drought, excess rainfall), provide firewood and contribute to household food security. Apart from providing shade and animal feed, the trees provide additional income (which can be substantial) through the sale of timber and fruits. Because of the importance of livestock production, massive adoption can have a profound impact.

We propose the following:

- The introduction (small farmers) or increase (medium farmers) of improved grasses that have higher nutritional value and are better adapted to drought and waterlogging, in combination with dispersed trees in well-managed pastures under rotational grazing, contributing to recovery of degraded soils, reduced soil erosion, water and biodiversity conservation.
- The introduction (small farmers) or increase (medium farmers) of cut-and-carry grasses to increase general feed availability, especially during the drier months.
- Protein banks, to increase nutritional quality of the ration. Shrub legumes' deep roots reduce erosion and optimize recycling of nutrients.
- Electric fences to facilitate rotation of cattle between pastures, to optimize use of biomass.
- Live fences, to be planted around pastures. Similar objective as protein banks.

Apart from improving livestock productivity, these measures will also have a positive impact on greenhouse gas emissions (better feed leads to lower emissions per unit of product) and carbon sequestration (optimal use of improved pastures with deeper roots, increased woody biomass). Table 6 shows details of the proposed measures.

Table 6: Silvopastoral components

Component	Description
Improved pastures with dispersed trees	Improved grasses (*Brachiaria*, *Megathyrsus*) in combination with dispersed trees in pastures (77 per ha, 7 trees of 52 cm diameter at breast height (dbh), 30 trees of 27 cm dbh and 40 trees of 13 cm dbh).
Cut-and-carry grasses	*Pennisetum* spp. (King Grass, Taiwan)
Protein banks	Leguminous and other shrubs (*Gliricidia sepium*, Guácimo - *Guazuma ulmifolia*), others to be determined)
Electric fences	Easy to install and use, for effective pasture rotation systems. Cheaper than barbed wire when area > 5 ha. Fixed cost USD 720 (for max 15 ha), variable cost per ha USD 50
Live fences	Around pastures, 50 trees (preferably leguminous, e.g., *Gliricidia sepium*) per 100 m, dbh at first year of 5 cm. Depending on the total area, each hectare of pastures requires an average of 250 m live fences (125 trees).

For both farm categories the proposed packages (silvopastoral components in combination with improved and cut-and-carry grasses) are presented in Table 7.

Table 7: Proposed systems and investments

	Small farmers BAU	Small farmers SPS	Medium farmers BAU	Medium farmers SPS	Full SPS (1 ha)
Proposed systems					
Pastures - total (ha)	10	10	40	30[4]	1
Pastures – improved, with dispersed trees (ha)	0	4	9	15	0.6
Pastures - traditional (ha)	10	4.75	30	12	0
Cut-and-carry grasses (ha)	0	0.75	1	2	0.2
Protein banks (ha)	0	0.5	0	1	0.2
Electric fences (ha)	0	7	0	15	0.6
Live fences (m)	0	800	0	1800	250
Proposed investments					
Pastures - improved, with dispersed trees (ha)	-	4	-	6	0.6
Cut-and-carry grasses (ha)	-	0.75	-	1.25	0.2
Protein banks (ha)	-	0.5	-	1	0.2
Electric fences (ha)	-	7	-	15	0.6
Live fences (m)	-	800	-	1800	250

Table 8 shows the costs of the different components of improved pastures and silvopastoral systems. They include initial investments as well as yearly maintenance, depreciation and labor. For comparison sake and to have an idea how much investments would be required if the beneficiaries would provide the labor, a separate row with the "costs without labor" has been added to the initial investments part. The last column refers to the cost of a "full" implementation of silvopastoral interventions as mentioned in Table 6 instead of the partial implementation proposed in Table 5. For detailed information on the cost of the different components and per unit (ha, m) see Annex A.

[4] The increased productivity per animal and per hectare allows for a decrease in pasture areas freeing up land for restoration and/or reforestation

Table 8: Costs of different components (investment for establishment, maintenance, depreciation), (USD per farm)

	Small farmers SPS	Costs (USD)	Medium farmers SPS	Costs (USD)	Full SPS (1 ha)	Costs (USD)
Proposed investments (establishment)						
Pastures - improved (ha)	4	878	6	1317	0.6	132
Cut-and-carry grasses (ha)	0.75	725	1.25	965	0.2	193
Protein banks (ha)	0.5	341	1	683	0.2	137
Electric fences (ha)	7	1070	15	1470	0.6	98
Live fences (m)	800	945	1800	2126	250	295
Total	5.3 ha	3960	8.3 ha	6563	1.0 ha	855
Technical assistance per ha		33		33		33
Total per ha		**754**		**820**		**888**
Without labor		**448**		**462**		**442**
Maintenance						
	Small farmers SPS	Costs (USD/ year)	Medium farmers SPS	Costs (USD/ year)	Full SPS (1 ha)	Costs (USD/ year)
Pastures - improved (ha)	4	820	6	1230	0.6	123
Cut-and-carry grasses (ha)	0.75	365	1.25	851	0.2	97
Protein banks (ha)	0.5	188	1	376	0.2	75
Electric fences (ha)	7	-	15	-	0.6	-
Live fences (m)	800	96	1800	215	250	30
Total	5.3 ha	1468	8.3 ha	2672	1.0 ha	325
Depreciation[5]						
	Small farmers SPS	Costs (USD/ year)	Medium farmers SPS	Costs (USD/ year)	Full SPS (1 ha)	Costs (USD/ year)
Pastures - improved (7 years)	4	125	6	188	0.6	19
Cut-and-carry grasses (10 years)	0.75	73	1.25	97	0.2	19
Protein banks (10 years)	0.5	34	1	68	0.2	14
Electric fences (6 years)	7	178	15	245	0.6	10
Live fences (15 years)	800	63	1800	142	250	20
Total	5.3 ha	473	8.3 ha	740	1.0 ha	81

[5] SPS component life span: number of years after which replacement, replanting and/or reestablishment is required

Depending on the farmer category, the investments can be implemented during two or three years. In all cases, it is proposed to start in year 0 with at least the live fences around the paddocks to be planted with improved grasses, the establishment of electric fences and planting of a part of the improved grasses in the same area. This will also help to protect newly planted improved pastures and (young) trees. During year 1 and year 2 it is proposed to plant cut-and-carry grasses, protein banks and the remainder of the improved grasses (See Tables 9 and 10 for details).

Table 9: Proposed yearly proportions (%) and investments (USD) for establishment of SPS, per SPS component

	Proportion per year				Cost per year (USD)			
	year 0	**year 1**	**year 2**	**year 3**	**year 0**	**year 1**	**year 2**	**year 3**
Small farms								
Pastures - improved	35%	40%	25%	0%	307	351	220	0
Cut-and-carry grasses	0%	100%	0%	0%	0	725	0	0
Protein banks	0%	0%	100%	0%	0	0	341	0
Electric fences	100%	0%	0%	0%	1070	0	0	0
Live fences	100%	0%	0%	0%	945	0	0	0
Total					**2322**	**1077**	**561**	**0**
Medium farms								
Pastures - improved	50%	50%	0%	0%	659	659	0	0
Cut-and-carry grasses	0%	100%	0%	0%	0	967	0	0
Protein banks	0%	100%	0%	0%	0	683	0	0
Electric fences	100%	0%	0%	0%	1470	0	0	0
Live fences	100%	0%	0%	0%	2126	0	0	0
Total					**4254**	**2308**	**0**	**0**
Full SPS								
Pastures - improved	50%	50%	0%	0%	66	66	0	0
Cut-and-carry grasses	0%	100%	0%	0%	0	193	0	0
Protein banks	0%	100%	0%	0%	0	137	0	0
Electric fences	100%	0%	0%	0%	98	0	0	0
Live fences	100%	0%	0%	0%	295	0	0	0
Total					**459**	**396**	**0**	**0**

Table 10: Proposed yearly investments for establishment of SPS, per SPS component and item (USD)

	Small farms			Medium farms			Full SPS		
	year 0	year 1	year 2	year 0	year 1	year 2	year 0	year 1	year 2
Pastures-improved									
Equipment	0	0	0	0	0	0	0	0	0
Inputs	73	83	52	156	156	0	16	16	0
Labor	235	268	168	503	503	0	50	50	0
Other	0	0	0	0	0	0	0	0	0
Total	**307**	**351**	**220**	**659**	**659**	**0**	**66**	**66**	**0**
Cut-and-carry grasses									
Equipment	0	202	0	0	269	0	0	54	0
Inputs	0	170	0	0	227	0	0	45	0
Labor	0	354	0	0	472	0	0	94	0
Other	0	0	0	0	0	0	0	0	0
Total	**0**	**725**	**0**	**0**	**967**	**0**	**0**	**193**	**0**
Protein banks									
Equipment	0	0	72	0	144	0	0	29	0
Inputs	0	0	94	0	188	0	0	38	0
Labor	0	0	175	0	351	0	0	70	0
Other	0	0	0	0	0	0	0	0	0
Total	**0**	**0**	**341**	**0**	**683**	**0**	**0**	**137**	**0**
Electric fences									
Equipment	1070	0	0	1470	0	0	98	0	0
Inputs	0	0	0	0	0	0	0	0	0
Labor	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0
Total	**1070**	**0**	**0**	**1470**	**0**	**0**	**98**	**0**	**0**
Live fences									
Equipment	365	0	0	821	0	0	114	0	0
Inputs	0	0	0	0	0	0	0	0	0
Labor	580	0	0	1305	0	0	181	0	0
Other	0	0	0	0	0	0	0	0	0
Total	**945**	**0**	**0**	**2126**	**0**	**0**	**295**	**0**	**0**

Production impacts

Figure 1 presents milk and meat production of the two farmer categories based on the data in Table 5.

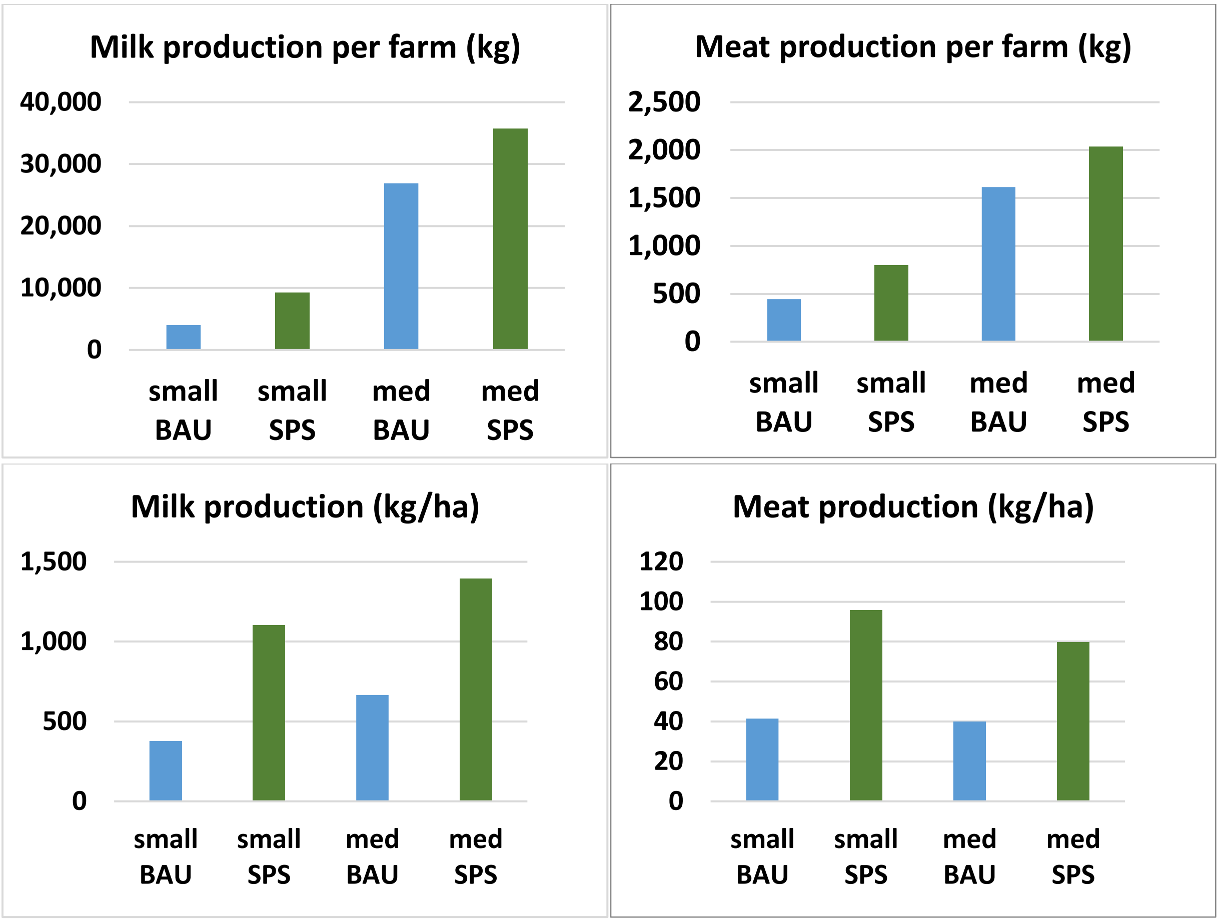


Figure 1: Production characteristics of small and medium farmers – BAU – SPS (after 3-4 years)

The complete establishment of silvopastoral components increases both milk and meat production per farm, when compared per ha production even doubles.

The gradual implementation of the SPS components in combination with improved management practices (e.g., rotational grazing, increased use of cut-and-carry grasses and legumes (protein banks) will lead to an annual increase in cattle productivity as depicted in Table 11, eventually leading to the increases in Figure 1. In the first year, after the initial (partial) establishment (year 0), no productivity increase is expected.

Table 11: Yearly productivity trends as a result of the implementation of SPS

	Small farms				Medium farms				Full SPS			
Production characteristics	year 1	year 2	year 3	year 4	year 1	year 2	year 3	year 4	year 1	year 2	year 3	year 4
Herd size - total	15	17	18	20	60	60	60	60	1.5	2	2.5	3
Lactating cows	6	6	7	8	33	33	33	33	0.6	0.8	1	1.2
Milk prod (kg/day)	3.5	3.7	4	5	4	4.2	4.6	5	3.5	4.2	5.1	6
Lactation length (days)	240	240	240	240	240	240	240	240	240	240	240	240
Calving interval (months)	18	16.5	16	15	17	17	16.5	16	18	17	16	15
Milk production (kg/year)	3360	3875	5040	7680	22362	23480	26496	29700	336	569	918	1382
Milk production (kg/year/cow)	560	646	720	960	678	712	803	900	560	712	918	1152
Steers/heifers sold (per year)	2	2.5	3	4	10	11	13	15	0.2	0.4	0.6	0.8
Cows sold (per year)	1	1	1.3	1.6	5	4	5	6	0.1	0.2	0.25	0.3
Selling weight steers/heifers (kg)	160	170	184	200	180	190	200	210	160	180	204	240
Selling weight cows (kg)	380	380	380	380	380	380	380	380	380	380	380	380
Milk price (USD/kg)	0.3	0.33	0.36	0.37	0.3	0.33	0.36	0.37	0.3	0.33	0.36	0.43
Price kg LW steers/heifers (USD)	1.7	1.8	1.85	2	1.7	1.8	1.85	2	1.7	1.8	1.85	2
Price kg live weight cows (USD)	1	1	1	1	1	1	1	1	1	1	1	1

Based on the farm typology in Table 5, for small and medium farmers we calculated (1) income from milk and meat (animal) sales, and (2) costs of livestock management (animal health, labor) and forage production (pasture maintenance, maintenance and use (feeding) of cut-and-carry grasses), for both BAU and SPS scenarios. (Table 12).

Table 12: Benefits/management costs of cattle production of small and medium farms (USD/year/farm) – BAU, SPS, Full SPS

Benefits	Small farmers		Medium farmers		Full SPS (1 ha)
	BAU	SPS	BAU	SPS	
Milk	1,008	2,842	6,709	10,989	594
Sale steers/heifers	544	1,600	3,060	6,300	384
Sale cows	380	608	1,900	2,280	114
Total	1,932	5,050	11,669	19,569	1,092
Costs (use/maintenance)					
Management - cattle	480	640	1,920	1,920	96
Improved pastures	-		1,845	1,845	
Improved pastures SPS[6]		820		1,230	123
Traditional pastures	360	171	1,080	432	-
Cut-and-carry grasses	-		122	122	
Cut-and-carry grasses SPS		365		851	97
Protein banks SPS	-	188	-	376	75
Live fences SPS	0	96	0	215	30
Total	840	2,279	4,966	6,990	421
Net income	1,092	2,770	6,702	12,579	671

The yearly costs of use and maintenance of SPS increase during the first two or three years during the establishing phase and remain stable from year 2 or 3 onwards (Table 13).

[6] The addition "SPS" refers to additional costs associated with the SPS interventions

Table 13: Costs of use and maintenance of SPS components, per year

	Small farms				Medium farms				Full SPS			
	year 1	year 2	year 3	year 4	year 1	year 2	year 3	year 4	year 1	year 2	year 3	year 4
Pastures-improved												
Equipment	0	0	0	0	0	0	0	0	0	0	0	0
Inputs	233	499	666	666	499	999	999	999	50	100	100	100
Labour	54	116	154	154	116	231	231	231	12	23	23	23
Other	0	0	0	0	0	0	0	0	0	0	0	0
Total	287	615	820	820	615	1230	1230	1230	61	123	123	123
Cut-and-carry grasses												
Equipment	0	0	0	0	0	0	0	0	0	0	0	0
Inputs	0	86	86	86	86	200	200	200	0	23	23	23
Labour	0	279	279	279	279	650	650	650	0	74	74	74
Other	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	365	365	365	365	851	851	851	0	97	97	97
Protein banks												
Equipment	0	0	0	0	0	0	0	0	0	0	0	0
Inputs	0	0	89	89	0	177	177	177	0	35	35	35
Labour	0	0	100	100	0	199	199	199	0	40	40	40
Other	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	188	188	0	376	376	376	0	75	75	75
Electric fences												
Equipment	0	0	0	0	0	0	0	0	0	0	0	0
Inputs	0	0	0	0	0	0	0	0	0	0	0	0
Labour	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0
Live fences												
Equipment	0	0	0	0	0	0	0	0	0	0	0	0
Inputs	15	15	15	15	34	34	34	34	5	5	5	5
Labour	81	81	81	81	181	181	181	181	25	25	25	25
Other	0	0	0	0	0	0	0	0	0	0	0	0
Total	96	96	96	96	215	215	215	215	30	30	30	30

Based on the data in the above tables the yearly cash flow (defined as income – investments – use/maintenance costs – depreciation) can be calculated as shown in Table 14.

Table 14: Cash flow (USD/year)

	Small farms					Medium farms					Full SPS				
	year 0	year 1	year 2	year 3	year 4	year 0	year 1	year 2	year 3	year 4	year 0	year 1	year 2	year 3	year 4
In		**0**	**492**	**1398**	**3118**		**0**	**1362**	**3741**	**7900**		**0**	**200**	**459**	**899**
Milk		0	271	806	1834		0	1040	1991	4280		0	87	230	494
Meat (animals)		0	221	591	1284		0	322	1750	3620		0	113	229	406
Out	**2322**	**1744**	**2044**	**1942**	**1942**	**4254**	**3984**	**3412**	**3412**	**3412**	**459**	**526**	**407**	**407**	**407**
Establishment	*2322*	*1077*	*561*	*0*	*0*	*4254*	*2308*	*0*	*0*	*0*	*459*	*396*	*0*	*0*	*0*
Equipment	1435	202	72	0	0	2291	412	0	0	0	212	82	0	0	0
Inputs	73	253	146	0	0	156	571	0	0	0	16	99	0	0	0
Labour	814	622	343	0	0	1807	1325	0	0	0	231	215	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Use / Maintenance		*383*	*1075*	*1468*	*1468*		*1195*	*2672*	*2672*	*2672*		*91*	*325*	*325*	*325*
Depreciation		*285*	*408*	*473*	*473*		*481*	*740*	*740*	*740*		*39*	*81*	*81*	*81*
Cash Flow	**-2322**	**-1744**	**-1552**	**-544**	**1176**	**-4254**	**-3984**	**-2050**	**329**	**4488**	**-459**	**-526**	**-206**	**52**	**493**

Environmental and climate impacts

The perceived environmental and climate impacts of the current livestock production system include (partly based on focus group discussions in Waslala and in the Bosawás buffer zone):

- Deforestation
- Reduced water availability (caused by deforestation of water sources and upstream areas of watersheds)
- Water pollution (herbicides, pesticides, veterinary products, manure)
- Erosion
- Reduced soil fertility: chemical (leaching or fixation of nutrients), biological (reduction of macro fauna because of inadequate grazing practices and misuse of veterinary products) and physical (compaction because of overgrazing)
- New diseases
- Loss of biodiversity due to loss of trees and affected soil macrofauna (inadequate use of veterinary products)

A higher productivity per animal through better feeding, and improved manure handling reduce GHG intensity levels (emissions per unit of product). The current pasture systems where animals are grazing freely on mostly traditional pastures on deforested and often not suitable soils (texture (high clay-content) and inadequate nutrient availability) lead quickly to pasture degradation, deforestation and loss of biodiversity and low productivity both per area and per animal. These systems are also highly vulnerable to climate change as they mainly depend on pastures without much supplementary feeding during times of challenging weather conditions (e.g. drought or flooding). Only a small minority of the farmers actively recycle nutrients and organic matter through management of manure and other waste products. The degradation of the pastures due to over-grazing in combination with the general preference to invest in more land instead of investing in improved feed production has also led to a need for expansion of pastures into forested areas. This also directly influences both local and regional climatic conditions. Improved feed production based on multiple sources of feed, like improved diverse pastures containing improved planting material well adapted to the local conditions, tree crops suitable as feed and for other purposes, and residues from food crops, could increase the robustness of the farming system in the face of climatic challenges. This would reduce the need for pasture expansion, as well as increase the productivity of the individual animal and reduce GHG emissions per kg of milk and meat produced.

Based on the farm typology in Table 4, for small and medium farmers in both BAU and SPS scenarios we assessed the following environmental and climate indicators: nutrient (nitrogen) balance per ha, water requirement per kg of milk and meat, greenhouse gas emissions per ha, kg milk and meat and carbon stock change per ha (Table 15, Figure 3).

Table 15: Environmental and climate impacts of small and medium farms – BAU, SPS, Full SPS

	Small farms		**Medium farms**		**1 ha**
	BAU	**SPS**	**BAU**	**SPS**	**Full SPS**
Stocking rate (TLU/ha)	1.26	2.11	1.49	2.40	3.17
N-balance (kg/ha)	-21.60	-36.58	-25.24	-29.90	-53.03
water use (m3/kg milk)	2.34	0.92	1.31	0.74	0.60
water use (m3/kg meat)	18.93	10.60	21.79	13.01	6.50
GHG emissions (kg CO2e/kg milk)	9.69	4.51	5.22	3.91	3.67
GHG emissions (kg CO2e/kg meat)	78.33	51.85	87.05	68.44	39.82
GHG emissions (t CO2e/ha)	3.23	4.97	3.48	5.45	7.59
Carbon stock change (t CO2e/ha)	1.14	8.92	1.14	6.26	23.90
Balance GHG emissions - C-stock change (tCO2e /ha)	2.09	-3.95	2.34	-0.81	-16.30

As the nutrient-balance data show, the SPS interventions[7] do not provide sufficient nutrients (in terms of nitrogen) to substitute the increased nutrient uptake by grasses and other crops, leading to increasingly negative nitrogen balances of up to 53 kg/ha. To ensure long-term sustainability, this will have to be compensated with nutrient input into the systems, like increasing the proportion of leguminous trees and associate herbaceous legumes with grasses. Emissions per

[7] Although some of the SPS components include fertilization: Improved pastures (135 kg/ha urea, 68 kg/ha NPK), Cut-and-carry grasses (45 kg/ha urea, 45 kg/ha NPK) and Protein banks (135 kg/ha urea, 68 kg/ha NPK)

kg of milk and meat can be reduced by almost 50%. Whereas the average of 10 trees per ha in BAU leads to a yearly carbon accumulation of 1.1 t CO2e per ha (although pastures without trees (which is also common) lose carbon 0.2 t/ha), the SPS measures increase annually carbon sequestration up to between 6.3 and 8.9 t CO2e. In our scenarios this leads for small farms to a net sequestration (sequestration minus emissions) of almost 4 t/ha in small farms and a full compensation of emissions in medium farms.

The increased productivity in SPS scenarios potentially free land (mainly pastures) for restoration and/or reforestation (for medium farms the pasture area can be reduced by 25% while production almost doubles, see Table 5). Water use per kg of milk decreases by 50%, in terms of meat the decrease is less marked.

Table 16 and Figure 2 show the details of Greenhouse Gas emissions. Most important contributors are enteric methane (68-75%) and nitrous oxide from soil (18-25%).

Table 16: Details of GHG emissions and Carbon-stock changes

	Small farms						Medium farms						Full SPS (1 ha)		
	BAU			SPS			BAU			SPS			SPS		
GHG balance	CO2e (kg/ha)	kg CO2e (/FPCM)	%	CO2e (kg/ha)	kg CO2e (/FPCM)	%	CO2e (kg/ha)	kg CO2e (/FPCM)	%	CO2e (kg/ha)	kg CO2e (/FPCM)	%	CO2e (kg/ha)	kg CO2e (/FPCM)	%
Enteric fermentation-CH_4	2414	7.25	75	3309	3.00	68	2399	3.60	69	3565	2.55	68	4971	2.40	68
Manure- CH_4	77	0.23	2	87	0.08	2	73	0.11	2	97	0.07	2	117	0.06	2
Manure-Direct N_2O	38	0.11	1	83	0.08	2	46	0.07	1	90	0.06	2	151	0.07	2
Manure-Indirect N_2O	5	0.01	0	10	0.01	0	5	0.01	0	11	0.01	0	19	0.01	0
Soil-Direct N_2O	600	1.80	18	1187	1.08	24	825	1.24	24	1306	0.94	25	1786	0.86	25
Soil-Indirect N_2O	94	0.28	3	181	0.16	4	134	0.20	4	200	0.14	4	255	0.12	4
Carbon stock changes- SOC-C	52	0.16		2520	2.29		52	0.08		2049	1.47		5075	2.45	
Carbon stock changes- Woody biomass – C	1087	3.26		6404	5.81		1087	1.63		4213	3.02		18823	9.09	

FPCM: Fat and Protein Corrected Milk

Figure 2: Details of GHG emissions and Carbon-stock changes

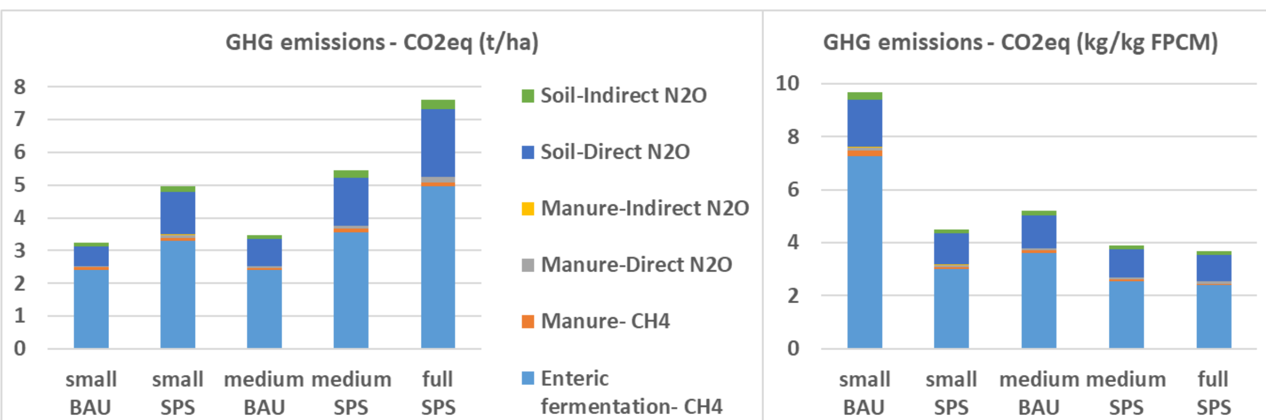
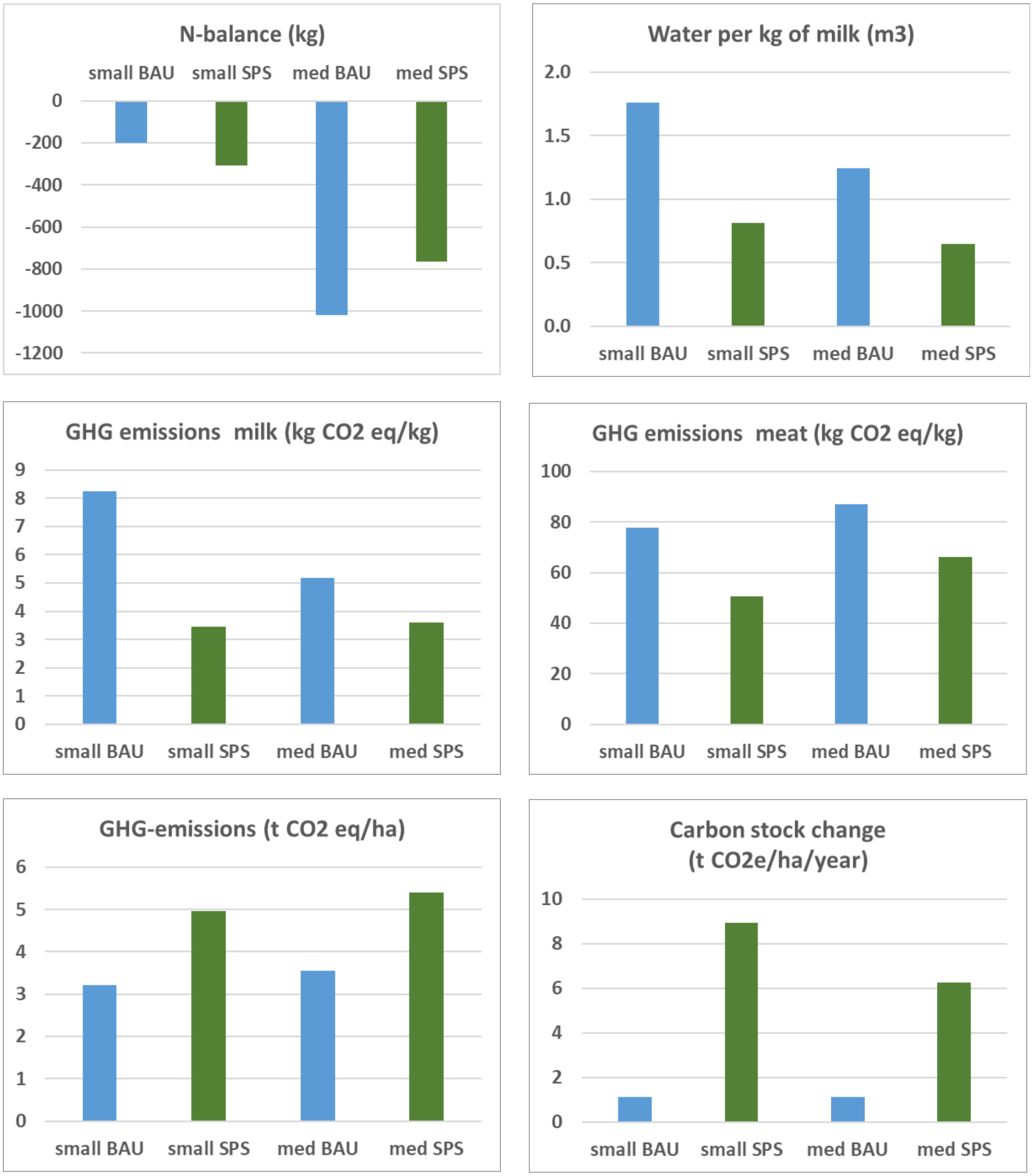


Figure 3: Environmental and climate impacts of small and medium farms - BAU, SPS



SPS impacts when compared to BAU

Tables 17 and 18 show the impacts of the implementation of improved forages and silvopastoral systems in terms of carbon balance and return on investment.

Table 17: SPS impacts compared to baseline (BAU), (t CO2e/ha)

	Small farms		Medium farms		
	BAU	SPS	BAU	SPS	Full SPS
CO2e-stock change – SPS minus BAU (t/year/ha)	N/A	7.79	N/A	5.12	22.76
Balance (CO2 emissions-stock change)	2.09	-4.07	2.34	-0.99	-16.60
SPS compared to BAU		-6.15		-3.34	-18.69

Small farms:

- SPS accumulates 7.8 t CO2e/ha more than BAU
- Balance emissions minus sequestration: SPS 6.2 t/ha more than BAU

Medium farms:

- SPS accumulates 5.1 t CO2e/ha more than BAU
- Balance emissions minus sequestration: SPS 3.3 t/ha more than BAU

Full SPS

- SPS accumulates 13 t CO2e/ha more than BAU.
- When looking at the balance between GHG emissions and sequestration the SPS scenario accumulates 8.9 t CO2e per ha more than BAU.

Return on investment

Table 18a: Benefits / costs SPS compared to baseline (BAU), (USD per farm), small farms

	Net income BAU	Additional income SPS	Additional Invest-ments SPS	Use/main-tenance costs SPS	Other extra costs	Deprecia-tion
Year 1	1,092	0	1,154	383	-50	285
Year 2	1,092	492	610	1,075	-71	408
Year 3	1,092	1,398	0	1,468	-93	473
Year 4-12	1,092	3,118	0	1,468	-29	473
Initial investment SPS (year 0)		2,368				
Investment life (years)		12				
Discount rate		10%				
NPV (10% discount rate)		-370				
IRR		9%				
Payback period (years)		7				

Small farms:

- Assuming that the interventions will generate the full extra income after three years, and a life of the investment of 12 years, the IRR of the proposed SPS interventions is 9% with a payback period of 7 years.

Table 18b: Benefits / costs SPS compared to baseline (BAU), (USD per farm), medium farms

Medium farms	Net income BAU	Additional income SPS	Additional Invest-ments SPS	Use/main-tenance costs SPS	Other extra costs	Deprecia-tion
Year 1	6,702	0	2,473	1,195	-468	481
Year 2	6,702	1,362	0	2,672	-648	740
Year 3	6,702	3,741	0	2,672	-648	740
Year 4-12	6,702	7,900	0	2,672	-648	740
Initial investment SPS (year 0)		4,353				
Investment life (years)		12				
Discount rate		10%				
NPV (10% discount rate)		14,100				
IRR		28%				
Payback period (years)		4				

Medium farms:

- Assuming that the interventions will generate the full extra income after three years, and a life of the investment of 12 years, the IRR of the proposed SPS interventions is 28% with a payback period of 4 years.

Table 18b: Benefits / costs SPS compared to baseline (BAU), (USD per farm), Full SPS

	Net income BAU	Additional income SPS	Additional Invest-ments SPS	Use/main-tenance costs SPS	Other extra costs	Deprecia-tion
Year 1	109	0	429	91	-11	39
Year 2	109	200	33	325	-20	81
Year 3	109	459	0	325	-4	81
Year 4-12	109	899	0	325	12	81
Initial investment SPS (year 0)		492				
Investment life (years)		12				
Discount rate		10%				
NPV (10% discount rate)		950				
IRR		21%				
Payback period (years)		5				

- Assuming that the interventions will generate the full extra income after three years, and a life of the investment of 12 years, the IRR of the proposed SPS interventions is 21% with a payback period of 5 years.

Generally it can be concluded that the returns on investments are positive for the medium size farm (investment for approx. 6 ha SPS for a farm-livestock component of 30 ha) and full SPS categories. For small farms, the proposed investments (approx. 4 ha for a 10 ha livestock component) are about profitable (IRR of 9%). When considering the environmental and climate impacts, all SPS categories show a net carbon accumulation.

Institutional environment and markets

Farmers consider that support from public sector organizations has been weak and access to technical assistance is poor. The number of especially permanent staff (of government institutions) is limited with often very few resources for operations (like transport). Technical assistance is usually only adequate in the case of externally financed projects (international cooperation) of limited duration at specific sites. There has been very little attention to environmental and climate impacts of livestock production and options for sustainable intensification. Hence, the technical assistance proposed in the framework of BioClima will have a very important impact, which will go beyond the implementation of the SPS interventions.

CONAGAN has been working on programs to improve genetic characteristics of livestock, and has established a Segregated Bovine Production System administered by IPSA (Ministry of Agriculture) that employs certification and applies a traceability system. CONAGAN leads also a project on sustainable livestock financed by Inter-American Development Bank) and including Industria San Martin (slaughterhouse), a member of CANICARNE, the Nicaraguan Chamber of Commerce on beef. Other actors include cooperatives, municipalities, the autonomous regional governments, indigenous territorial governments, Ministry of Agriculture (MAG), Institute of Agricultural Technology (INTA), National Technological Institute (INATEC), the University of the Autonomous Regions of the Caribbean Coast of Nicaragua (URACCAN) and the Bluefields Indian & Caribbean University.

Table 19 summarizes institutional presence in the Bosawás buffer zone.

Table 19: Institutional presence in the Bosawás buffer zone

Organization	Activities	Supporting livestock sector in:
UNAWAS	Milk collection centre and processing facility producing "Moralique" cheese and sweetened milk. Project implementation. Coordination with IPSA of trainings	Improvement of infrastructure (roads), in coordination with the municipality. Links with private sector and service providers. Traceability.
INTEWAS	Training of paravets. Technical assistance to farmers through Farmer Field Schools. Project on climate change and watershed management.	
ASOGAWAS	Farmers organization. Farm improvement, trainings with demonstration farms. Improved animal nutrition, feed conservation (silage), animal genetics.	Trying to develop an exemplary farmers' association for the region
ADDAC	Capacity development, awareness raising (environment)	Participate in PROGRESA CARIBE, trainings, artificial insemination, equipment (chaff cutters)
FDL	Financing "green" livestock	
FUMAT	Work on silvopastoral systems, watershed management	

Milk/beef value chains

Milk

In the Indio Maiz and Bosawás buffer zones two or three dairy value chains can be distinguished (Polvorosa, 2013):

i) Until recently, 20% of the milk was collected and stored by a few collection centers operated by farmers' cooperatives or individual farmers. The milk was sold to dairy companies like PROLACSA, NILAC and LALA, which processed the milk into dairy products for export and wholesale distribution. Most of the milk came from farms in proximity of the collection centers and with easy access. However, operation costs became too high for the dairy industry and this value chain ceased to exist.

ii) Most of the milk (60% in the past and currently 80%) is collected and processed locally through a value chain represented by traditional cheese makers (mostly women) and middlemen. Over 150 small plants (10 per municipality) are strongly linked to artisan collection centers processing small quantities of milk (15-20 liters per day) into traditional cheese, curds and other dairy products for local and national markets and for export, mainly to El Salvador (the local cheese "Morolique"). Recently traders from El Salvador have started making arrangements with cheese makers to produce Morolique cheese for export to El Salvador.

iii) The semi-industrial cheese export chain (less than 20% of milk produced) is represented by farmer´s cooperatives or individual producers operating milk collecting and processing plants to produce Morolique type cheeses and sour cream. In comparison with traditional cheese makers they process larger volumes for local and international (mainly El Salvador) markets.

Beef

Most small and medium farmers sell their calves after weaning, between 10 and 18 months depending on feed availability and pasture conditions (carrying capacity). Only less than 20% have high quality pastures that allow for keep the calves (steers, heifers) until slaughtering age (over 18 months). The weaned calves are mainly bought by intermediaries. They sell them to medium and large farmers as well as enterprises for further development and fattening for sale to industrial slaughterhouses. Intermediaries also buy culled cows for sale to industrial and local slaughterhouses.

During the last five years industrial slaughterhouses have started buying and stockpiling weaned calves to be accommodated and further raised by (specialized) farmers, and eventually to be finished at the slaughterhouses' feedlots.

Low investments, low returns, high environmental impact and poor quality has resulted in most Nicaraguan beef classified for hamburgers despite the high potential of cattle and the natural (forage-based) feeding methods.

Market perspectives

There is a strong demand for dairy products and in particular high quality grass-fed beef with reduced carbon-food print. The clients of the final product (high-end cuts) are national and international consumers, with a willingness to pay for high quality, mainly forages-grass fed beef with low climate and environmental impact. Export markets have strict animal welfare and environment requirements that presently only large farmers (a small minority) can meet. The proposed SPS interventions will contribute to economically viable and sustainable forage-based high-quality milk and beef production. Synergies can be developed with the financing scheme "Retention of calves/steers" with involvement of CONAGAN in which the development bank (Produzcamos) provides credit to cooperatives, which act as first level credit provider to farmers for forage-based innovations and best livestock management practices. The increased capacity of small and medium farmers to produce high quality beef will provide access to the high-quality beef value chain and international export markets.

Direct clients include:

- Slaughterhouses (either directly or through intermediaries) buying calves and steers to produce high-value cuts for the national and international market that comply with international quality, hygiene, environmental and animal welfare requirements.
- Traders who buy the calves and steers for further fattening by specialized farmers.

Implications for Bosawás and Indio Maíz buffer zones

General implications will include:

- Lower climate and environmental impacts of beef production: reduced GHG per unit of product, carbon / water footprint and soil erosion; higher stocking rates freeing up pastureland for reforestation (prioritizing areas with slopes over 50%).
- Increased farmers' income through increased milk and beef productivity and quality meeting requirements of the industry and international (EU) markets.
- Increased farmers' knowledge on improved forage production, efficient farm and natural resource management (living fences, silvopastoral systems, protection of water sources).
- Increased and strengthened access to improved livestock production technologies and high-value markets for female farmers and youth.
- Evidence of the biophysical, economic, environmental feasibility of small and medium farmers accessing high-value markets.

In quantitative terms, Table 20 provides some key indicators of the potential impact of the implementation of full SPS at regional scale.

Table 20: Annual regional impact of proposed SPS

	SPS (ha)	increase milk (kg)	increase beef (kg)	Increase income (USD)	Increase GHG emissions (t CO2e)	carbon sequestration (t CO2e)	net carbon sequestration (t CO2e)
Bosawás buffer zone	3,372	5,860,536	509,172	1,894,643	-14,500	76,743	62,244
Indio Maíz buffer zone	5,401	9,386,938	810,150	3,034,688	-23,224	122,921	99,697
Total	8,773	15,247,474	1,319,322	4,929,332	-37,724	199,665	161,941

Supposing that the complete SPS package will be implemented on the proposed 8,773 ha in both zones, an increase of over 15,000 t of milk, 1,300 t of meat, almost USD 5 million and a net carbon sequestration of 162,000 t CO2e can be expected. With a current price of USD 3 per ton, this is equivalent to almost USD 500,000.

These calculations do not take into account the impacts of freeing pastureland for reforestation and restoration, and neither the expected value addition of increased woody biomass.

Risk and sensitivity analysis

For a risk analysis it is important to assess the effect of productivity and product (milk, meat) prices on the profitability of the proposed SPS investments. In this section we will look at the impact of varying production and price levels on NPV.

Varying productivity levels

For the IRR and NPV calculations earlier in this study we have assumed that SPS interventions will lead to higher productivity levels (See for instance Tables 5 and 11 for details). However, external (e.g., drought, excess rainfall) and internal (e.g., inadequate implementation and management of SPS interventions) factors can lead to lower production than anticipated. For the sensitivity analysis Table 21 shows two levels for both milk and meat production, being realistic upper and lower values at the time of this study (October 2019). To keep the number of comparisons limited, we assume that high milk productivity goes together with high live weight gain.

Table 21: Low and high production levels (milk and live weight)

Production levels	Small farmers SPS		Medium farmers SPS		Full SPS	
	low	high	low	high	low	high
Milk prod (kg/day)	4.0	4.5	5.0	5.5	5.0	6.0
Selling live weight steers/heifers (kg)	180	200	200	220	200	240

Varying price levels

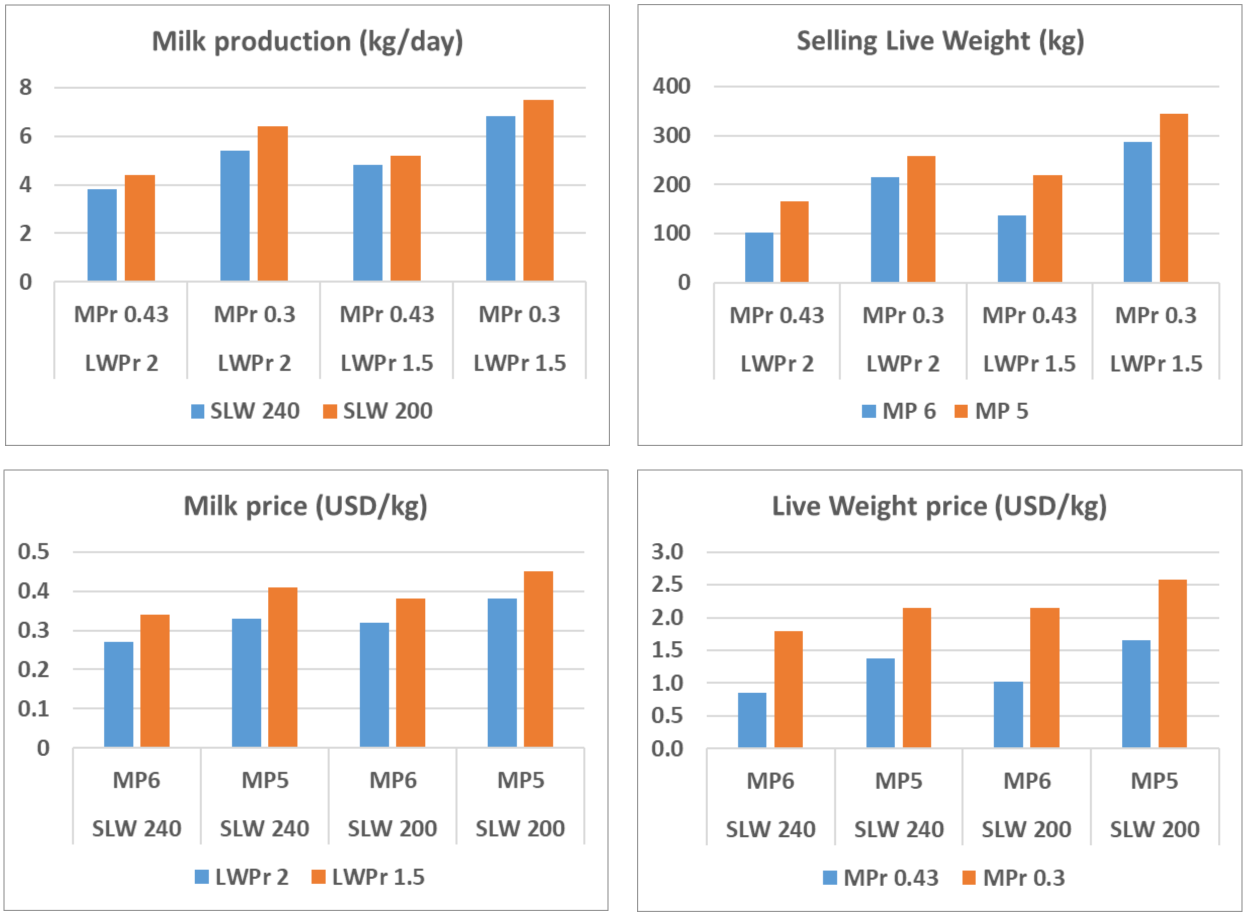
Similarly, price levels van vary strongly, also due to both external (global market developments, local infrastructure) and internal (product quality, hygiene) factors. Table 22 shows two price levels, again for both milk and meat production, and with realistic upper and lower limits at the time of this analysis. As for productivity, it is assumed that milk and meat prices are positively correlated.

Table 22: Low and high price levels (milk and meat)

Price levels	Small farmers SPS		Medium farmers SPS		Full SPS	
	low	high	low	high	low	high
Milk price (USD/kg)	0.3	0.43	0.3	0.43	0.3	0.43
Price kg LW steers/heifers (USD)	1.5	2.0	1.5	2.0	1.5	2.0

For the full SPS scenario and using these parameters, we defined for all productivity and price levels the threshold (minimum) values required for an NPV>0 (indicator for profitable investment), while varying the other three indicators (Figure 4).

Figure 4: Investment profitability threshold values for milk production, selling live weight, milk price and live weight price – full SPS



MPr : milk price (USD/kg); **LWPr**: live weight price (USD/kg); **SLW**: selling live weight (kg); **MP**: milk production (kg/cow/day)

The “milk production” and “selling live weight” graphs indicate the effect of varying price levels (milk, from USD 0.43 to 0.3 per kg, and live weight, from USD 2 to 1.5 per kg) in combination with selling live weight (varying from 240 to 200 kg) and milk production levels (varying from 6 to 5 kg/cow/day) on threshold values for milk production and selling live weight respectively. The “milk price” and “live weight price” graphs indicate the effect of varying productivity levels (milk, from 6 to 5 kg/cow/day, and selling live weight, from 240 to 200 kg) in combination with price levels varying from USD 0.43 to 0.3 per kg milk and USD 240 to 200 per kg live weight on threshold values for milk production and selling live weight respectively.

Milk production
The threshold value for milk production is mostly affected by changes in price levels (milk, live weight), and much less by live weight productivity. A decrease in milk price from USD 0.43 per kg (current price for premium milk) to USD 0.3 per kg (current average price) increases the minimum required milk production from 4 to over 5.5 kg per cow per day. A decrease in selling live weight from 240 to 200 kg leads to a required increase of 0.5 kg/day.

Selling live weight
Here again, price level is the most determining factor for profitability. With high milk (and LW) prices, and a milk production of 6 kg/day/cow in combination with selling live weight of 100 kg the investments for full SPS measures are still profitable, whereas for the lower prices a minimum selling live weight of over 200 kg/animal is required. In the case of lower milk production (5 kg/day/cow), high prices require a minimum selling live weight of 180 kg, whereas low prices require over 260 kg per animal.

Milk price
Minimum required milk price depends on both milk / live weight productivity and live weight price. With good live weight prices, farms with high productivity require a minimum milk price of little over USD 0.28 per kg. However, low productivity and LW price levels require a milk price of at least USD 0.45 per kg.

Live weight price
Minimum required live weight price varies between USD 0.8/kg for high productivity and milk price and USD 2.5/kg for low productivity and milk price. At high productivity level, a decrease in milk price from 0.43 to 0.3 per kg increases the minimum required live weight price by almost USD 1.0 per kg (200%).

Conclusions:

- Milk related indicators (productivity and prices) have in general a bigger impact on profitability of SPS related investments than meat (live weight).
- Similarly, price related indicators (milk, live weight) have a greater impact than productivity indicators.
- Within the margins of our model and when compared with BAU scenarios, profitability of SPS related investments is most affected by milk price, followed by selling live weight price, milk productivity and live weight productivity.

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ANNEX A: Costs of establishment of different components of proposed silvopastoral systems (USD)

Costos de establecimiento de 1 ha de pasturas mejoradas en almacigo (Mombasa, Toledo, Marandú, Caymán)	Total	Mano de obra	Otro
Limpia y condicionamiento del terreno del almacigo con machete y azadón	25.46	25.46	
Limpieza de terreno con glifosato	39.03	29.03	10
Semilla para el establecimiento	42.00		42
Control de maleza	18.03	18.03	
Siembra del pasto	95.00	95	
Total	219.52	167.52	52
Costos de establecimiento de 1 ha de pasto de corte (Taiwán, King Grass)			
Limpia y condicionamiento del terreno	76.37	76.37	
Limpieza del terreno con glifosato	11.46	5.00	6.46
Material de siembra (corte y transporte)	119.40		119.40
Siembra con azadón	152.74	152.74	
Fertilización N P K	100.75		100.75
4 rollos de alambre	263.05		263.05
40 postes	237.59	237.59	
Grapas	5.73		5.73
Total	967.08	471.7	495.393
Costos de establecimiento de 1 ha de banco forrajero con arbustivas (Madero negro, Cratylia argentea, Guácimo) 10,000 plantas/Ha			
Limpia y condicionamiento del terreno	35.64	35.64	
Vivero	108.61	54.00	54.61
Semilla	44.55		44.55
Siembra	95.04	95.04	
Fertilización Fosforo	44.55		44.55
4 rollos de alambre	184.13		184.13
40 postes	166.31	166.31	
Grapas	4.01		4.01
Total	682.84	350.99	331.85
Costos de establecimiento de 100 metros de cercas vivas simples utilizando estacones			
Limpia del terreno con machete	7.07	7.07	
Acarreo, ahoyado y colocación de postes muertos	14.14	14.14	
Acarreo, ahoyado y colocación de prendedizos	7.07	7.07	
Tendido del alambre	7.07	7.07	
1 rollo de alambre de púa	44.19		44.19
35 postes	37.12	37.12	
1.5 lbs de grapas	1.43		1.43
Total	118.11	72.47	45.62

ANNEX B: Costs of maintenance of different components of proposed silvopastoral systems (USD/year)

Manejo de 1 ha de pasto mejorado	total	Mano de obra	otro
Fertilización: urea 135 kg/ha, NPK 68 kg/ha	158.96	17.91	141.04
Control de malezas hoja ancha	26.87	8.96	17.91
Mantenimiento de cercas	12.00	4.48	7.52
Guiar entrada y salida de los animales del potrero		7.16	
Total	197.82	38.51	166.48
Manejo de 1 ha de pasto de corte			
Fertilización: urea 45 kg/ha, NPK 45 kg/ha	69.40	8.96	60.45
Corte, acarreo, picado y suministro para 20 vacas	416.69	362.6866	54
Total	486.09	371.64	114.45
Manejo de 1 ha de banco de proteínas			
Fertilización: urea 135 (kg/ha), NPK 68 (kg/ha)	158.96	17.91	141.04
Corte, acarreo, picado y suministro para 20 vacas	217.34	181.3433	36
Total	376.30	199.25	177.04
Costos de mantenimiento de 100 metros de cercas vivas simples			
Mantenimiento de cercas	3.00	1.12	1.88
Podas	8.96	8.96	
Total	11.96	10.07	1.88