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Assessing low-carbon livestock technologies in Costa Rica:

Business case analysis of low-carbon livestock production

Summary

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Executive Summary

This summary presents the results of an analysis undertaken to model and assess the viability of sustainable practices for the livestock sector outlined in Costa Rica's Low Carbon Livestock Strategy and NAMA.

Background – addressing the climate performance while increasing the productivity of the livestock sector in Costa Rica

Livestock is one of the traditional productive activities of Costa Rica. The sector is the third-largest source of GHG emissions in the country, making up around 10.3% of total emissions. Despite this, productivity is relatively low (average animal density of 1.2 AU/ha).

To address this, the government has adopted policy instruments (a Low Carbon Livestock Strategy and a NAMA) that aim to promote a more sustainable climate-smart sector. These instruments foster the adoption of practices and technologies that increase farmer productivity, reduce carbon emissions, and increase their resilience to climate change. A key subset of these practices includes: rational grazing, hedgerows, improved pastures and set-asides for increasing forest cover.

Modelling the performance of sustainable practices

The analysis carried out modelled the potential outcomes from the adoption of these practices on four farms in the country. The four farms selected for this analysis had different levels of management practices and were at different stages of the transition to a climate-smart system. The farms cannot be consired representative of all the farms in the country, but are located in the country's main producing regions, therefore can provide an important opportunity to explore the scope and potential impacts of the proposed technologies in various scenarios.

For the development of the analysis, business as usual and improved/climate smart scenarios for each of the four farms were developed using a stochastic model, with the aim of assessing the costs and benefits accrued to producers from the implementation of climate-smart technology adoption in different contexts. The improved secenario was built based on the technology that best matched the baseline situation and production system on each of the farms and the plausibility of the technologies being adopted by the producers.

The successful implementation of these strategies is assessed by whether they increase farmer productivity and income, reduce the GHG emissions intensity per unit produced, and increase captures of GHG emissions at the farm level, relative to the baseline.

Resutls from the analysis

A summary table with the results is included below. The results show that by adopting technologies and practices outlined in the NAMA, the farms could both increase their financial and climate performance. However, the impact of the adoption of these technologies was highly sensitive to the baseline characteristics of the farm. For instance, the results from the analysis show that impacts may be greater for dual-purpose farms as there are faster returns given the increase in dairy production.

Farm	Results
Dual-purpose farm in Puerto Viejo de Sara-piqui	The results show that for the dual-purpose farm, increasing the use of improved pastures by 10% per year over a 3-year period, and the release of 10% of pastures for the regeneration of secondary forest resulted in benefits in all variables measured. Emission intensity rates were significantly reduced, and producer cash flows were shown to improve.
Dual-purpose farm in Cañas, Guanacaste	The results show that increasing the area dedicated to fodder raises the productivity of the herd and improves the emission intensity per unit produced. This in turn increases profitability and cash flow for the producer.
Cow-calf farm - Las Juntas de Abangares, Guanacaste	The results show that introducing rational grazing and expanding the availability of fodder banks contributed to improvements in productivity, reductions in the emissions intensity per unit produced, and profitability.
Cow-calf farm in Cría de La Virgen de Sa-rapiquí, Heredia	The results show that by increasing the area under rotational grazing by 10 hec-tares and releasing 10% of pasture lands as set-asides for natural regeneration of forests, the farm sees an improvement in its carbon balance, cash-flows, and profitability.

The simulations carried out as part of this analysis also show that some technical parameters such as the calving rate, mortality rate (young and adult), daily weight gain for male and females, the Kg/milk/day, and the age at first birth – have a significant impact on the outcome associated with the adoption of a sustainability strategy. It is important that these parameters are identified when assessing the feasibility of implementing the technologies outlined in the NAMA.

Background

Livestock is one of the traditional productive activities of Costa Rica. Pastures for livestock production account for over 20% of the national territory. Livestock production, for either beef or dairy, generates employment or income opportunities for over 35,000 farmers in the country. The national cattle stock is estimated at 1.5 million head of cattle.[1] More than half of this cattle stock is dedicated to beef production, around one third to dual-purpose[2] systems and one sixth to milk production systems.[3] Farms tend to be relatively small; over half of the farms in the country are smaller than 10 hectares (ha) and almost 90% are smaller than 50 ha. The productivity of the sector is relatively low, as reflected by the calving rate, which averages circa 55%, and the relatively low animal density, which averages around 1.2 animal units per hectare.

While primary production is typically fragmented, processing is concentrated in a handful of companies and distributed mainly through retailers and small butcher shops. Most of the value is captured downstream in the value chain (retailers and feedlots), with less than a quarter remaining for primary producers.[4] The market for dairy products is even more concentrated, with just a few cooperatives controlling nearly 90% of the entire market.

In the last few decades, Costa Rica has implemented numerous policies which favour the conservation and protection of natural resources, with particular emphasis on forests, and has adopted a national decarbonisation plan. Despite preserving a vast amount of forested land within farms, livestock farms cover around 38% of the territory when forest land is considered, and the sector generates more than 10% of the country's total greenhouse gas emissions and over 97% of the total emissions from the Agriculture, Forestry and Other Land Use (AFOLU) sectors. Low levels of productivity in the sector, coupled with the country's efforts to promote conservation, have made salient the need for transition towards a more sustainable climate-smart sector.

Costa Rica has taken steps to support this transition and improve climate performance in the livestock sector. The country developed a National Low Carbon Livestock Strategy and a Nationally Appropriate Mitigation Action (NAMA[5]) Livestock proposal that outlines an action plan for decarbonizing the sector while increasing its resilience to the impacts of climate change. These policy instruments promote the adoption of practices that increase farmer productivity, reduce carbon emissions, and increase their resilience to climate change. In order to achieve this, the NAMA aims to introduce several technologies and practices, such as rational grazing, hedgerows, improved pastures, and areas set-aside for increasing forest cover. The country has already implemented pilot projects[6] in specialized beef, dairy, and dual-purpose farms, which have started to build evidence of the impact of the Low-Carbon Livestock Strategy technologies.

Problem statement

Low productivity of livestock producers with low climate performance

Beef and dual-purpose farms in Costa Rica gravitate towards low productivity. Typically, animal density per farm is close to 1.2 animal units per hectare and the calving rate is estimated at 55% (compared to normative benchmarks of over 2 AU/ha; and 65% respectively).

Typically, pastures are overgrazed, which reduces the nutritional value of the grasses that the cattle feed on. This leads to a reduction in live weight gain and an increase in methane produced by enteric fermentation by cattle during digestion. The reduced weight gain also leads to lower revenues for the farmers. Typically, farmers compensate for the lower quality pastures by increasing the application of fertilizers, however, as the land degrades, the soil structure breaks down and the soil's water-retaining capital decreases, thus requiring more fertilizer, at greater cost to the farmer, to compensate for lost runoff.

Accordingly, Costa Rica's livestock sector is a large source of greenhouse gas (GHG) emissions: the sector is the third largest source of GHG emissions in the country, making up around 10.3% of total emissions. As outlined above, the main source within cattle ranching is enteric fermentation (CH_4), a potent GHG. Fertilizers for pastures, excreta in pastures, feed supplementation, in-farm fuel consumption and electricity play a lesser role in the emission of GHGs in the form of nitrous oxide (N_2O) and carbon dioxide (CO_2).

Producers in the sector are also vulnerable to the impacts of climate change: the sector is affected by an increasing number of droughts and floods. Droughts can exacerbate animal morbidity and mortality by decreasing the grazing quality of pasture and hampering animal productivity. Equally, floods have also caused direct animal losses and reduced productivity through pasture loss. It is estimated that between 2009 and 2018, producers faced losses of both pastures and animals from extreme weather events worth close to USD 45 million.[7]

There is consequently a strong need to improve the economic and climate performance of the sector through the widespread adoption of climate-smart practices.

Proposed sustainability strategies and climate mitigation and adaptation benefits

The National Low Carbon Livestock Strategy and NAMA Livestock promote a series of climate-smart technologies[8] which should bring benefits for cattle ranchers in the following ways: improved productivity/income, a reduction of emissions, an increase in carbon sequestration, and an increase in resilience to climate change. These technologies or practices are summarized below.

Rotational grazing[9,10,11]

A rotational grazing system involves dividing paddocks (sub-pastures) into smaller sections of equal size and periodically rotating the cattle between sections, allowing fallow periods for regeneration and occupation of the pastures/forages.

Rotational grazing maximizes beef and milk production per unit area by allowing pastures to recover and maintaining forages at a relatively earlier growth stage. In turn, animals can select the most nutritious forage thereby increasing the productivity of the system. More nutritious forage is thus more digestible and reduces methane (CH_4) production per unit of weight gain, as well reducing the production of nitrous oxide (N_2O) and ammonia (NH_3) from urine and faeces in pasture.[12]

Healthier pastures and more trees also increase the sequestration of carbon dioxide (CO_2) in the soil and biomass by stopping land degradation and allowing the land to recover. Well-managed pastures can lead to an improvement of the soil structure which increases water retention, leading to a reduction in soil erosion and requiring less pesticides and fertilizers.

Live Fences (hedgerows)[13,14]

This practice is associated with rational grazing, as it favours the division of paddocks into smaller areas by planting trees and shrubs. Live fences can provide habitat for biodiversity, and are a source of shade, which can reduce animal heat stress. This can lead to an increase in weight gain, milk production, and rates of reproduction. The establishment of trees and shrubs for fencing also contributes to carbon (CO_2) sequestration in biomass and soil.

Improved pastures[15]

Improved pasture management measures involve the sowing of better-quality varieties, typically higher yielding and more digestible forages. Similarly, the benefits accrued by rotational grazing mean that improved pastures can increase productivity through their benefit to animal digestion and methane (CH_4) production by enteric fermentation, as well as the reduction of nitrous oxide (N_2O) emissions from urine and faeces in pastures. Improved pastures have also been shown to increase soil quality and support water retention.

Set asides - regeneration of forest coverage[16]

The NAMA proposes that an average of 10% of pasture area per farm be transformed into forest through natural regeneration processes. This should involve the less productive areas within the farm. When planted on degraded pasture lands, trees sequester significant amounts of carbon (CO_2) in the soil and biomass.

Methodology of the analysis

An analysis was undertaken to model and assess the An analysis was undertaken to model and assess the viability of the practices outlined above, using the baseline information of four real farms. The analysis comprised two stages. The first stage was the collection of primary data from four farms; two in the Huetar Norte region, one dual-purpose and one cow-calf system farm; and two in the Chorotega region, one dual-purpose and one cow-calf system farm. The second stage consisted of modelling a business-as-usual scenario and an improved scenario for each of the four farms, to assess the costs and benefits that would accrue to producers from the implementation of climate-smart technology adoption in different contexts.

Collection of primary information

Primary information was gathered to develop case studies for two farms in the Dry Pacific or Chorotega Region, and two in the Humid Tropics or Northern Huetar Region. In both cases, information was collected from a dual-purpose[17] farm and a cow-calf system farm. A static survey was carried out with the help of a pre-established form that allowed information to be gathered to characterize the farm in terms of its structure and function, as well as to gather information on the technical indicators of the performance of the farm. Information was also collected on socioeconomic aspects of the cattle ranchers. The information on the farm characteristics and the baseline indicators are presented in Tables 1 and 2, respectively.

Farm description

The four farms analysed are in the main producing regions in the country. The farms show different levels of management practices and are at different stages of the transition to a climate-smart system. While the farms selected are not representative of all the farms in the country, they provide an important opportunity to explore the scope and potential impacts of the proposed technologies in various scenarios. These frameworks include different types of production systems, at different scales and under different agroecological conditions and socio-economic environments, in order to understand the feasibility of scaling up their implementation.

Table 1. Case studies – The four farms characterized in terms of their productive orientation, grazing systems, farming area and number of animals.

Type of production	Region	Existing System	Total area (ha)	Pastures Area (ha)	# Animals
Dual-purpose (DP1)	Huetar Norte	Non-intensive rotational grazing year-round	25	17	65
Dual-purpose (DP2)	Chorotega	Non-intensive rotational grazing with semi-stabling in Summer	90	53	203
Breeding (B1)	Chorotega	Non-intensive rotational grazing year-round	290	173	65
Breeding (B2)	Huetar Norte	Non-intensive rotational grazing year-round	85	64	121

Table 2. Case studies – Baseline technical parameters for each of the four farms, prior to any intervention.

Case	Dual-purpose farm - Puerto Viejo de Sarapiquí, Heredia (DP1)	Dual-purpose farm - Cañas, Guanacaste (DP2)	Cow-calf system farm - Las Juntas de Abangares, Guanacaste (B1)	Cow-calf system farm- La Virgen de Sarapiquí, Heredia (B2)
Variable				
% pregnancy	79	69	69	61
%Mortality (young)	3	2	2	2
% Mortality (adults)	0	0	2	0
Kg/Milk/Day	9	4	NA	NA
Age at first birth (months)	33	35	32	32

Assessment of the economic feasibility of the adoption of proposed practices relative to a business-as-usual scenario.

A sustainability strategy was selected for each of the four farms, based on the technological alternatives promoted by the Low-Carbon Livestock Strategy and the NAMA. The selection was based on the technology that best matched the baseline situation and the production system on each of the farms, and the plausibility of the technologies being adopted by the producers. Successful implementation of the strategies wasassessed by whether they resulted in an increase in levels of productivity and income, reductions in the emissions intensity per unit produced, and in the increased capture of GHG emissions, relative to the baseline. The strategies are summarized in Table 3 below.

A stochastic model was developed to simulate two scenarios – including cash flows and carbon performance – for each farm. These included a baseline/ Business asusual (BAU) scenario and one improved scenario with the adoption of a sustainability strategy. The model was run 10 times for each baseline and the improved scenario for a 10 year time frame. This was done to understand how the deployment of the technologies performed compared to the baseline scenario, and in doing so provided detailed information to inform decisions and recommendations for other producers in the country.

Table 3. Sustainability strategies to be adopted based on NAMA-promoted technological alternatives and modelled into each farm

Farm	Sustainability Strategy/Improved scenario
Dual-purpose farm - Puerto Viejo de Sarapiquí, Heredia	Increase in improved pastures by 1o% per year over a 3-year period; release 10% of pastures for regeneration of secondary forest.
Dual-purpose farm - Cañas, Guanacaste	Increase fodder bank area with one hectare of cane and forage-grass. Construction of a shed for feed supplementation.
Cow-calf farm - Las Juntas de Abangares, Guanacaste	Increase rational grazing areas to 10 hectares and expand the area of fodder banks by two hectares.
Cow-calf farm - La Virgen de Sarapiquí, Heredia	Release 10% of pasture area for natural regeneration, and implementation of a rational grazing system in 11 hectares.

The table below shows the current land use and the change in land-use to the improved scenario within each farm, following adoption of the sustainability strategy outlined above.

Table 4. Evolution of land use within each of the farms from the baseline/BAU to the improved scenarios.

Case	Land-use	Type	Original value (ha)	Evolution - Improved Scenario
Dual-purpose farm - Puerto Viejo de Sarapiquí, Heredia DP1	Naturalized pastures	Pastures	17.38	
	Crops	Crops	0	
	Primary forest	Primary forest	2	
	Secondary forest	Secondary forest	0	Release 1.7 hectares for forest regeneration
	Forest plantations	Forest Plantations	0	
	Houses and building	Houses and building	1	
	Other activities	Other activities	1	
	Improved pastures	Pastures	7.32	10% yearly increase for the first 3 years
	Fodder bank	Pastures	0	An increase of .5 hectares in the first 2 years
Dual-purpose farm - Cañas, Guanacaste DP2	Naturalized pastures	Pastures	53	
	Crops	Crops	0	
	Primary forest	Primary forest	35	
	Secondary forest	Secondary forest	0	
	Forest plantations	Forest Plantations	0	
	Houses and building	Houses and building	1	
	Other activities	Other activities	1	
	Improved pastures	Pastures	0	
	Fodder bank	Pastures	0.5	Increased by 1 hectare

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Case	Land-use	Type	Original value (ha)	Evolution - Improved Scenario
Cow-calf farm - Las Juntas de Abangares, Guanacaste B1	Naturalized pastures	Pastures	0	
	Crops	Crops	0	
	Primary forest	Primary forest	40	
	Secondary forest	Secondary forest	50	
	Forest plantations	Forest Plantations	0	
	Houses and building	Houses and building	0.5	
	Other activities	Other activities	0	
	Improved pastures	Pastures	173	
	Fodder bank	Pastures	30	Increased by 2 hectares
	Intensive grazing	Intensive grazing	0	Increased by 10 hectares
Cow-calf farm - La Virgen de Sarapiquí, Heredia B2	Naturalized pastures	Pastures	64	
	Crops	Crops	0	
	Primary forest	Primary forest	0	
	Secondary forest	Secondary forest	0	Increased by 6.4 hectares over 2 years
	Forest plantations	Forest Plantations	0	
	Houses and building	Houses and building	1	
	Other activities	Other activities	0	
	Improved pastures	Pastures	20	
	Fodder bank	Pastures	0	
	Intensive grazing	Intensive grazing	0	Increased by 11 hectares

Structure of the analytical tool

The model is comprised of three sub-models and one integrator general model that brings together the results of all the sub-models. The three sub-models are a herd-dynamic sub-model; a land-use sub-model, and a financial sub-model. The herd dynamics sub-model (SM-HD) simulates the herd's evolution in terms of structure (number of animals in the different age categories) as well as beef and dairy production. The land-use sub-model (SM-LU) simulates the evolution of different land uses within the farm. The financial sub-model (SM-FIN) will simulate both baseline and improved scenarios of the financial and economic performance of the modelled farm. This sub-model undertakes, in an integrated way with the other two sub-models, dynamic budgeting and credit line management, and generates the projected cash flows, income statements and balance sheets. It also produces indicators of investment success. A graphical representation of the integrator model and the three sub-models, their functions and the variables they each consider, is presented below.

Figure 1. Herd dynamic sub-model (SM-HD)

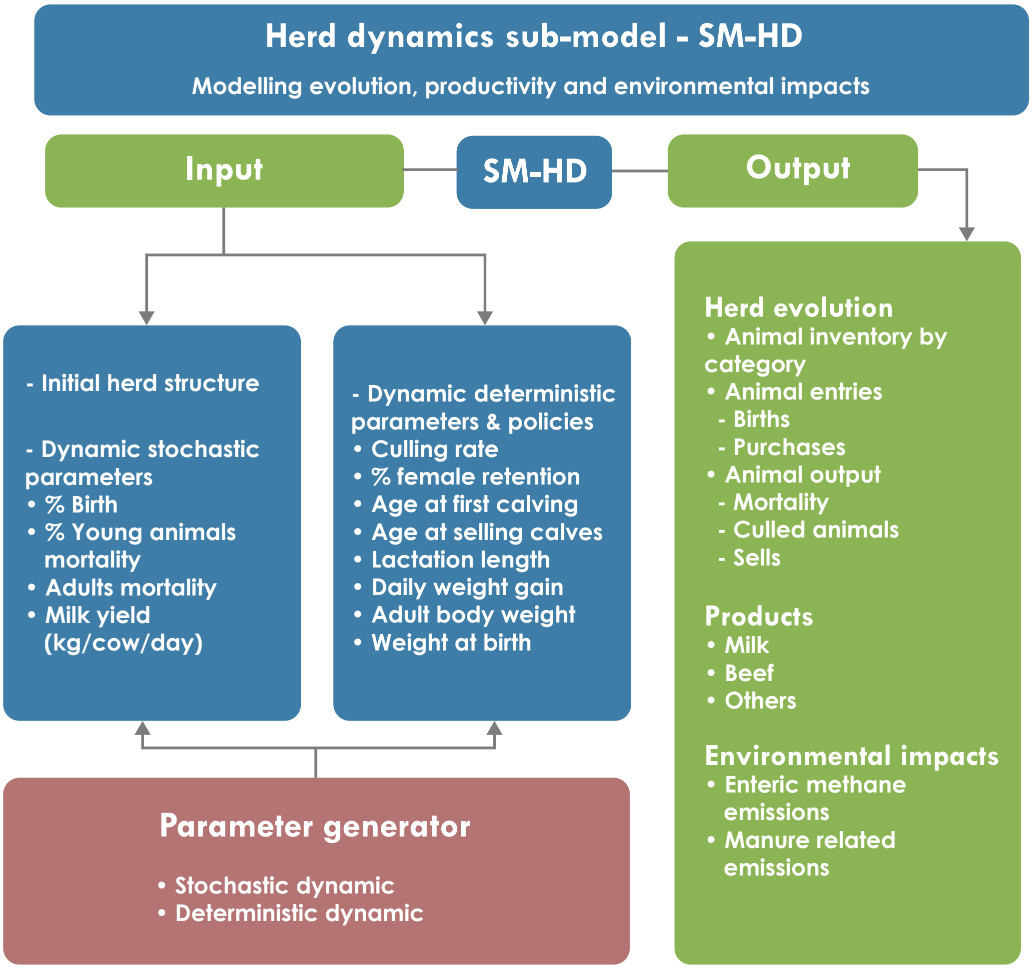


Figure 2. Land-use dynamic sub-model (SM-LU)

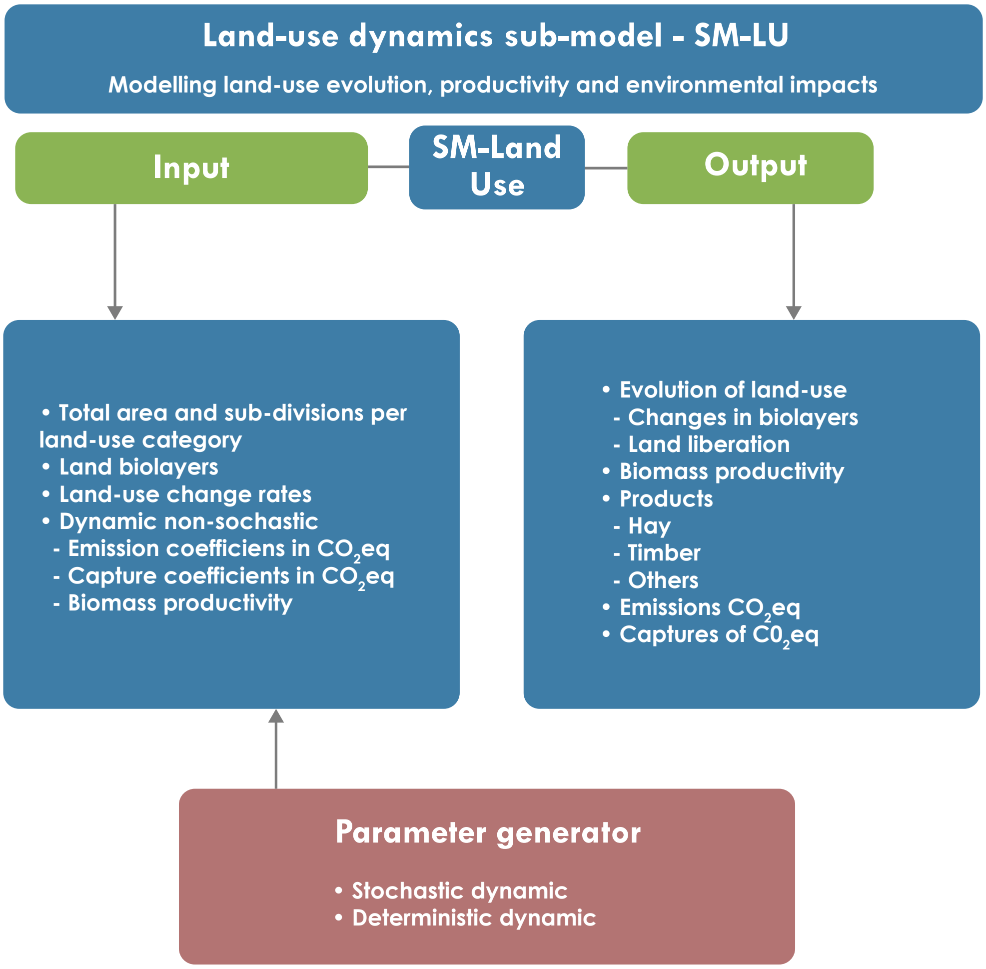


Figure 3. Financial sub-model (SM-FIN)

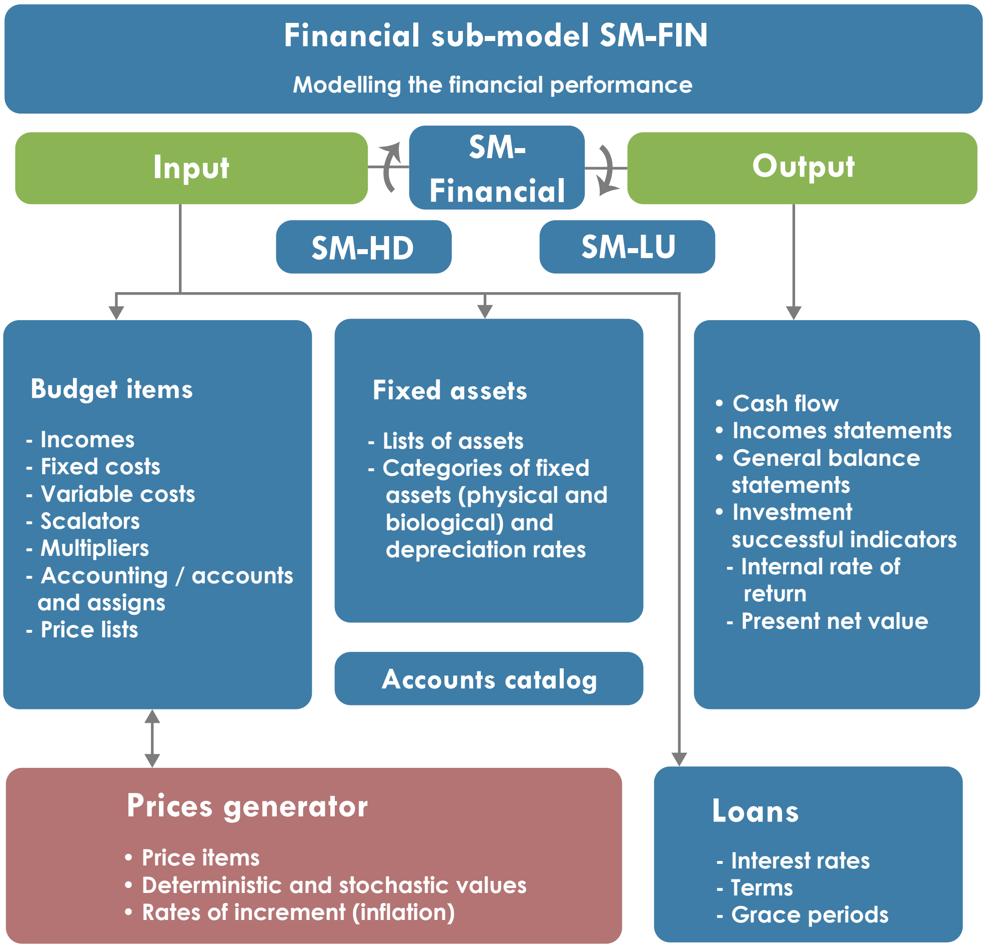
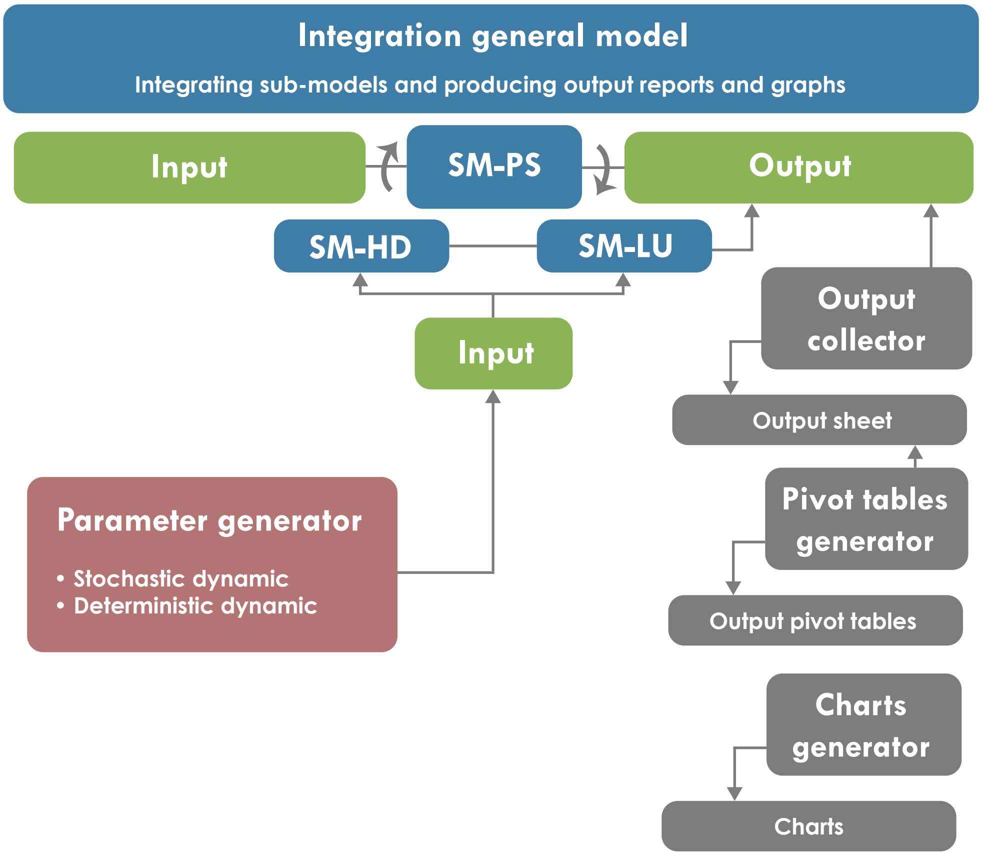


Figure 4. Integration model



Results

Dual-purpose farm in Puerto Viejo de Sarapiqui (DP1) – improved pastures and set aside for regeneration of secondary forest

Table 5 shows a summary of the results from running the model over a 15-year period for both the baseline and improved scenario.

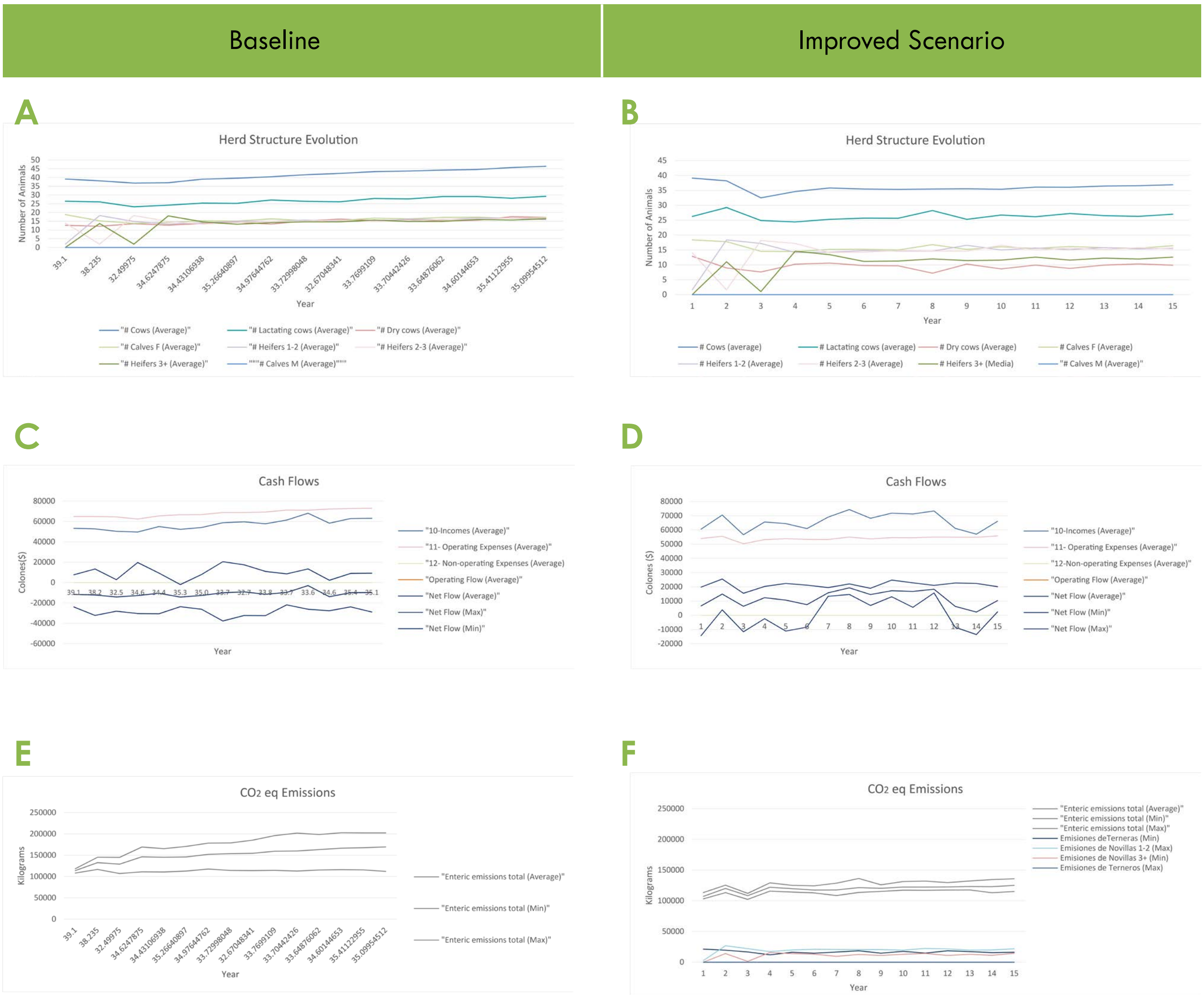
The results show that for the dual-purpose farm, increasing the use of improved pastures by 10% per year over a 3-year period, and the release of 10% of pastures for regeneration of secondary forest resulted in benefits in all variables measured. Emission intensity rates were significantly reduced, and producer cash flows were shown to improve.

Charts A and B in Figure 5 below show how the composition of the herd changed over time in response to the practices adopted, which contributed to improvements in the key technical parameters. These are included in the table in Annex 2. Charts C and D illustrate that at the baseline scenario, most of the simulations presented operating losses and that in the improved scenario, even though there may be losses in some years, overall the farm profited. Finally, Charts E and F show how emissions are reduced, and that their increase over time is smaller in relation to business as usual.

Table 5. Comparison of the baseline and improved scenario for Viejo de Sarapiquí, Heredia (DP1).

Variable	Baseline	Improved Scenario	Balance	% Change
Kg milk	91,561.60	106,914.70	15,353.10	17%
Kg beef	6,245.50	6,365.10	119.6	2%
Enteric emissions	18,822.70	14,936.00	-3,886.70	-21%
CO2 eq per animal	1,064.00	938	-126	-12%
CO2 eq per Liter of milk	1.1	0.7	-0.4	-36%
CO2 eq per Kg of beef	10.37	7.6	-2.77	-28.7%
CO2 eq Income unit	2.8	1.9	-0.9	-32%
CO2 captures	-9,100.00	-34,300.00	-25,200.00	-277%
Net emissions	141,481.40	85,188.00	-56,293.40	-40%
10-Incomes	57,156.00	66,056.50	8,900.50	16%
11-Operating expenses	68,168.60	54,117.40	-14,051.30	-21%
12-Non-operating expenses	0	0	0	0%
Operating flow	-11,012.60	11,939.20	22,951.80	208%
Accumulated operating flow	-93,252.50	94,838.00	188,090.50	202%
Operating profit	-11,012.60	11,939.20	22,951.80	208%
Operating profit %	-26.4	15.4	41.8	158%
Net flow	-11,012.60	11,939.20	22,951.80	208%
Accumulated net flow	-93,252.50	94,838.00	188,090.50	202%
Net profit	-11,012.60	11,939.20	22,951.80	208%
Net profit as % revenue	-26.4	15.4	41.8	158%

Figure 5. Baseline and scenario comparison charts for herd evolution, cash flow and emissions (DP1).



Dual-purpose farm in Cañas, Guanacaste (DP2) – Increasing the availability of fodders

Table 6 summarizes the results of increasing the area of the farm dedicated for fodder generated by running the model over a 15-year period for both the baseline and improved scenarios.

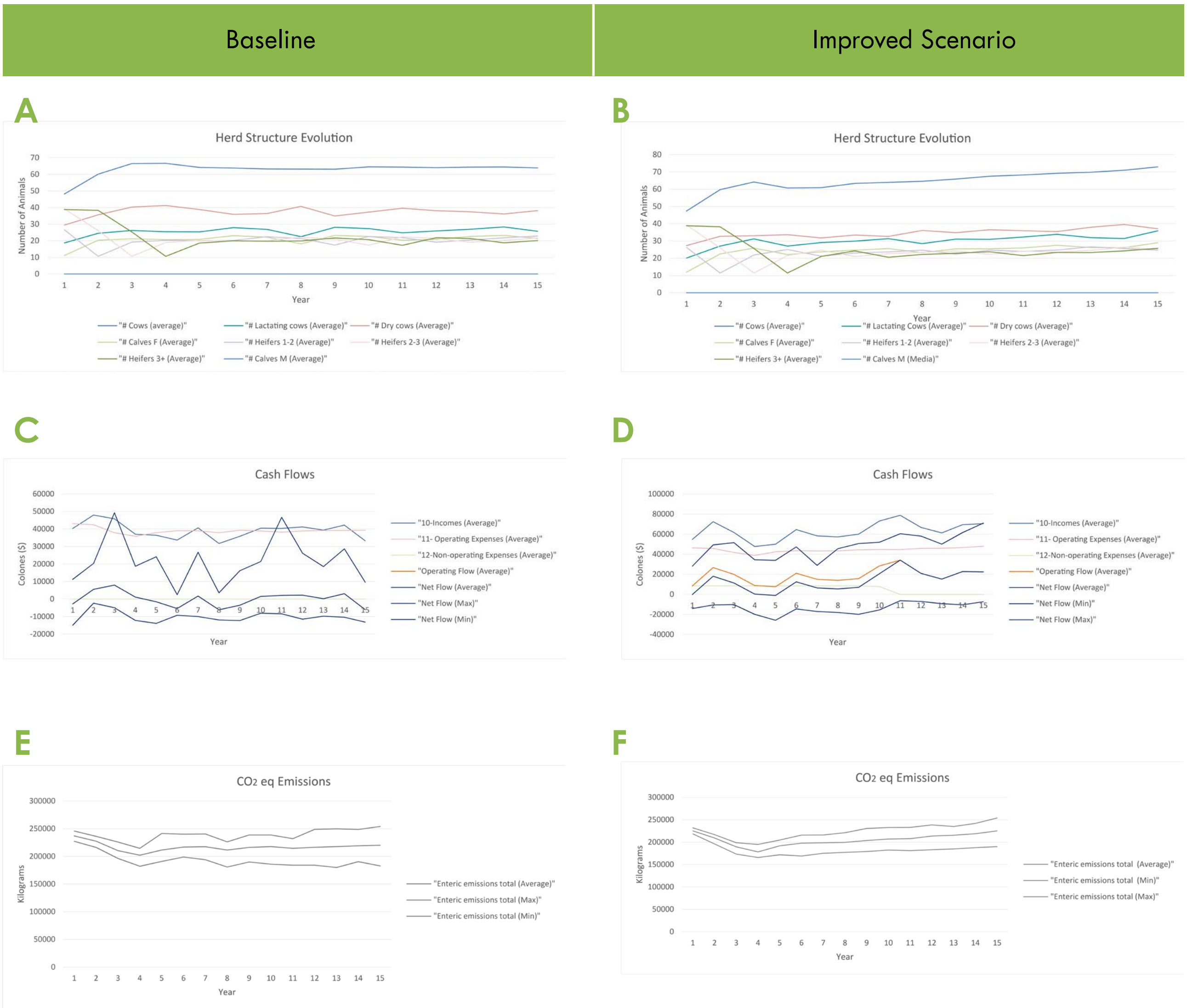
The results show that increasing the area dedicated to fodder raises the productivity of the herd and improves the emission intensity per unit produced. This in turn increases profitability and cash flow for the producer. The evolution of technical parameters as a result of the adoption of these practices is included in Annex 2.

Charts A and B in Figure 6 below show that the size of the herd grows over time in the improved scenario. In terms of cash flow, Charts C and D demonstrate positive results for the baseline scenario, although very close to zero. In the improved scenario, operating cash flows tend to be positive, with lower probabilities of an annual loss, however, this scenario involves higher capital expenditure, so the net cashflow is again close to zero, indicating that the investment improvements do not significantly increase cash flow when compared to the baseline scenario. Additionally, as shown in Charts E and F, the total difference in the emissions between the baseline and improved scenario is only minimal.

Table 6 Comparison of the baseline and improved scenarios (DP2).

Variable	Baseline	Improved Scenario	Balance	% Change
Kg milk	33,068.00	74,291.90	41,223.90	125%
Kg beef	16,761.10	19,469.10	2,708.00	16%
Enteric emissions	27,135.00	25,676.50	-1,458.50	-5%
CO2 eq per animal	1,030.10	912.2	-117.9	-11%
CO2 eq per Liter of milk	5.3	2.9	-2.5	-45%
CO2 eq per Kg of beef	5.3	4.3	-1	-19%
CO2 eq Income unit	5.9	3.8	-2.2	-36%
CO2 captures	0	0	0	0%
Net emissions	217,079.80	205,412.10	-11,667.70	-5%
10-Incomes	39,051.50	63,115.90	24,064.40	62%
11-Operating expenses	39,041.10	44,376.90	5,335.90	14%
12-Non-operating expenses	0	5,658.00	5,658.00	--
Operating flow	10.4	18,738.90	18,728.50	180082%
Accumulated operating flow	3,567.80	136,938.90	133,371.00	3738%
Operating profit	10.4	18,738.90	18,728.50	180082%
Operating profit %	-6.8	18.1	24.9	366%
Net flow	10.4	13,080.90	13,070.50	125678%
Accumulated net flow	3,567.80	77,315.40	73,747.60	2067%
Net profit	10.4	17,526.60	17,516.20	168425%
Net profit as % revenue	-6.8	15.7	22.5	331%

Figure 6. Baseline and scenario comparison charts for herd evolution, cash flow and emissions (DP2).



Cow-calf farm in Las Juntas de Abangares, Guanacaste (B1) – increasing the area under rational grazing management and expanding the availability of fodder banks

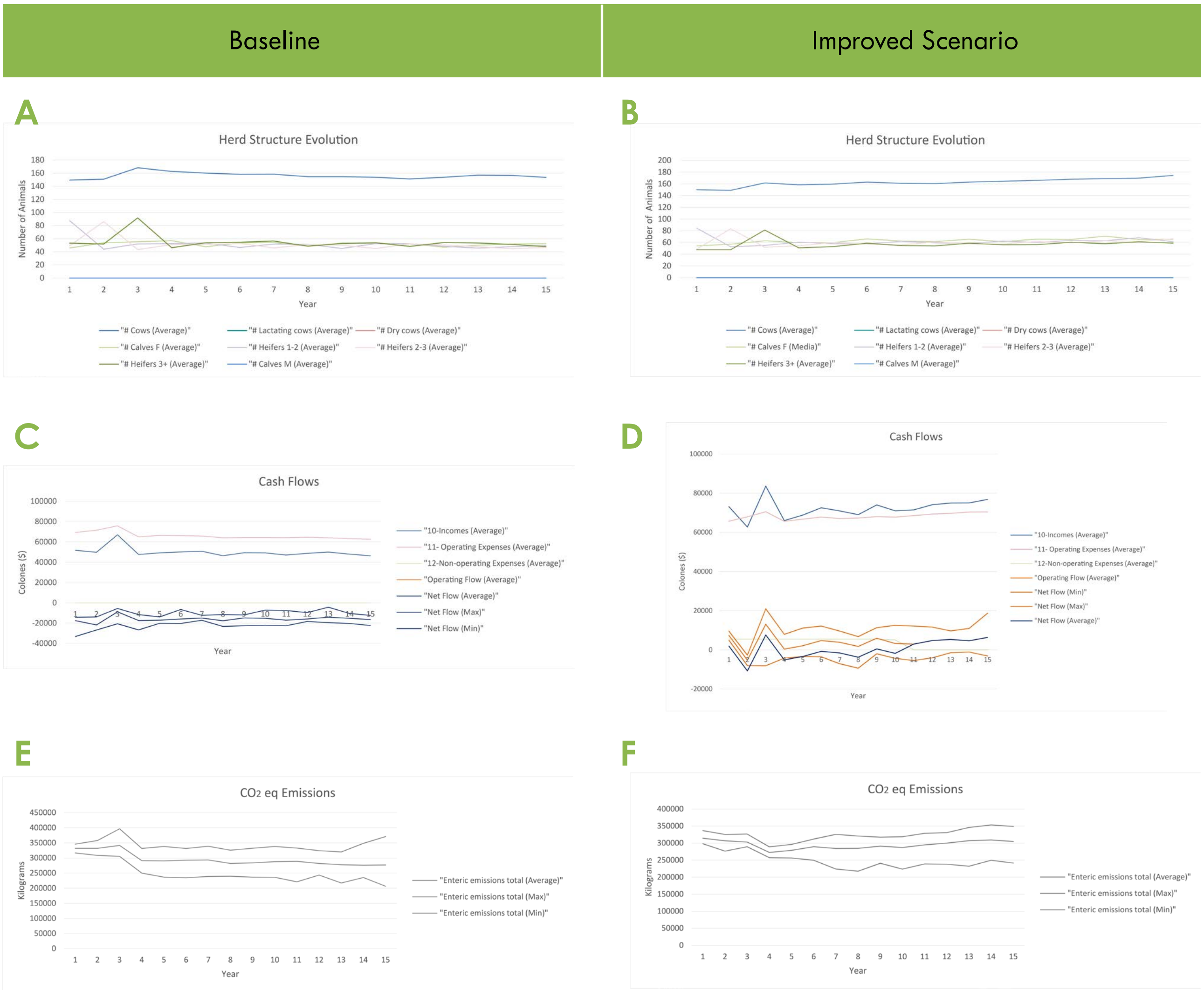
Table 7 shows a summary of the results of increasing the area under rational grazing management to 10 hectares and expanding the area devoted to fodder banks by 2 hectares for a Cow-calf farm, which is generated by running the model over a 15-year period for both the baseline and improved scenarios. The results show that introducing rational grazing and expanding the availability of fodder banks contributed to improvements in productivity, emissions intensity per unit produced, and profitability. The changes to technical parameters as a result of the adoption of these practices is shown in Annex 2.

Charts A and B in Figure 7 below show an increase in the herd size over time. Charts C and D show that, at the baseline, the farm is always operating at a loss, even in the most optimistic simulations. In the improved scenario, operating cash flows are profitable even though on average these are very close to zero. Graphs E and F show that emissions remain similar between the baseline and the improved scenario, although the herd numbers tended to increase, which demonstrates an improvement in emissions intensity per animal.

Table 7. Comparison of the baseline and improved scenarios (B1).

Variable	Baseline	Improved Scenario	Balance	% Change
Kg milk	0	0	0	0%
Kg beef	36,547.40	50,956.50	14,409.10	39%
Enteric emissions	36,903.10	36,886.70	-16.4	0%
CO2 eq per animal	806.1	729.2	-76.9	-10%
CO2 eq per Liter of milk			0	0%
CO2 eq per Kg of beef	3.3	2.3	-0.9	-30%
CO2 eq Income unit	5.9	4.1	-1.8	-31%
CO2 captures	-350,000.00	-350,000.00	0	0%
Net emissions	-54,775.20	-54,906.60	-131.4	0%
10-Incomes	50,130.40	72,267.00	22,136.60	44%
11-Operating expenses	66,120.20	68,189.90	2,069.70	3%
12-Non-operating expenses	0	3,627.00	3,627.00	-
Operating flow	-15,989.80	4,077.10	20,066.90	125%
Accumulated operating flow	-129,781.70	30,443.30	160,224.90	123%
Operating profit	-15,989.80	4,077.10	20,066.90	125%
Operating profit %	-33.4	4.8	38.2	114%
Net flow	-15,989.80	450.1	16,439.90	103%
Accumulated net flow	-129,781.70	-7,776.90	122,004.80	94%
Net profit	-15,989.80	3,299.90	19,289.80	121%
Net profit as % of income	-33.4	3.7	37.1	111%

Figure 7. Baseline and scenario comparison charts for herd evolution, cash flow and emissions (B1).



Cow-calf farm in Cría de La Virgen de Sarapiquí, Heredia (B2) – Increasing the area under rotational grazing management and set aside for natural regeneration of secondary forest

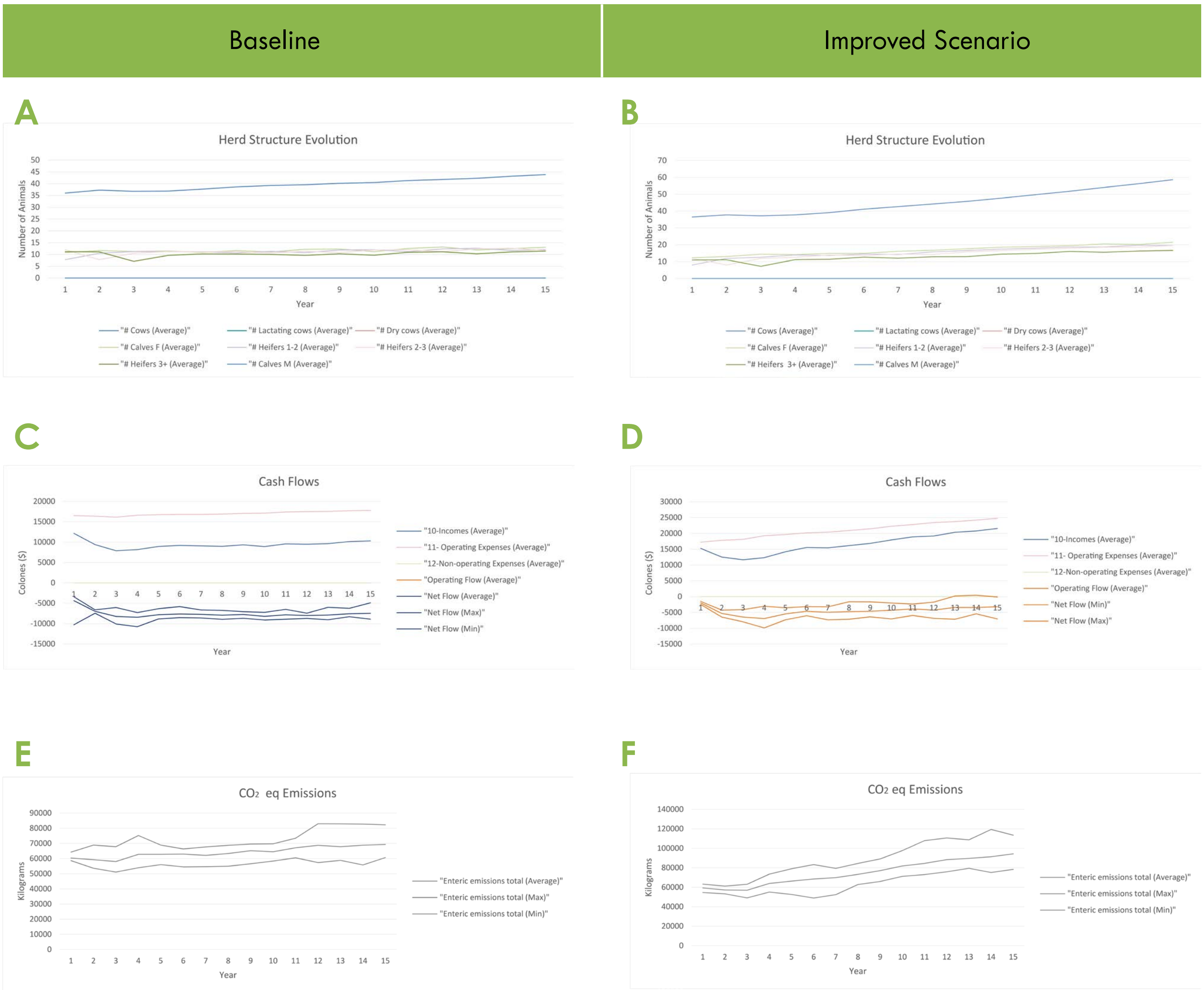
Table 8 summarizes the results for this farm by increasing the area under rotational grazing by 10 hectares and releasing 10% of pasturelands as set asides for natural regeneration of forests, generated by running the model over a 15-year period for both the baseline and improved scenarios. Annex 2 showcases the evolution of the farm's key technical parameters as a result of the adoption of these practices.

The results show that the farm sees an improvement in its carbon balance, cash-flow and profitability, however, the gains in the financial situation of the farm are not enough to make the scenario feasible for implementation, as the increases in cash flows are not enough to recoup the investments made. Charts A and B in Figure 8 show that there is an increase in the herd size in the improved scenario relative to the baseline. Charts C and D show that both the baseline and the improved scenario are always below the zero margin even in the most optimistic simulations. Charts E and F show a significant increase in total emissions in the improved scenario.

Table 8. Comparison of the baseline and enhanced scenarios (B2).

Variable	Baseline	Improved Scenario	Balance	% Change
Kg milk	0	0	0	0%
Kg beef	6,896.60	11,701.50	4,804.90	70%
Enteric emissions	8,026.70	9,354.90	1,328.10	17%
CO2 eq per animal	761.5	706	-55.5	-7%
CO2 eq per Liter of milk			0	0%
CO2 eq per Kg of beef	3.8	2.6	-1.2	-32%
CO2 eq Income unit	6.9	4.6	-2.4	-33%
CO2 captures	0	-38,668.00	-38,668.00	-
Net emissions	64,213.80	36,171.00	-28,042.90	-44%
10-Incomes	9,405.50	16,581.90	7,176.40	76%
11-Operating expenses	16,993.00	21,083.30	4,090.20	24%
12-Non-operating expenses	0	0	0	0%
Operating flow	-7,587.50	-4,501.40	3,086.10	41%
Accumulated operating flow	-59,152.60	-38,307.20	20,845.40	35%
Operating profit	-7,587.50	-4,501.40	3,086.10	41%
Operating profit %	-84.2	-30.8	53.4	63%
Net flow	-7,587.50	-4,501.40	3,086.10	41%
Accumulated net flow	-59,152.60	-38,307.20	20,845.40	35%
Net profit	-7,587.50	-4,501.40	3,086.10	41%
Net profit %	-84.2	-30.8	53.4	63%

Figure 8. Baseline and scenario comparison charts for herd evolution, cash flow and emissions (B2).



Discussion and Conclusions

The technologies outlined in the NAMA can deliver improved financial and environmental benefits. Their overall impact will be contingent upon current in-farm practices. In line with the objectives of the Low-Carbon Livestock Strategy, the results from modelling the adoption of the technologies and practices outlined in the NAMA for each of the different farms show that they can increase the financial and climate performances of farms. However, as shown, the impact of the adoption of these technologies will be highly subject to the characteristics of the farm upon which they are being implemented. For instance, the above analysis shows that impacts may be greater for dual-purpose farms, as there are faster returns given the increase in dairy production.

Given the relatively low margins and profitability of the farms examined, an intervention to promote the NAMA livestock technologies should consider the need for technical assistance related to their adoption, as well as the need for financing attuned to the different production cycles (cow-calf and dual purpose). The adoption of climate-smart technologies, such as those outlined by the NAMA, requires important capital expenditure with long payback periods or increases in costs related to more intensive management requirements. In some cases, the investment needed to implement these technologies does not ensure a positive financial return for the producer. The adoption of these practices may also require that additional training or extension services are provided for producers, particularly small and medium-sized ones. Some producers might have difficulties adopting these practices in the absence of financing that respond to the productive cycle, concessional financing, or incentives that can support them during the transitional period where a potential income gap might materialize. This, however, does not take into account the impact of improved resilience in the productive system. Additional sources of financing, such as Payments for Environmental Services, for the regeneration of secondary forests in marginal lands within the farm can also support farmers during the transition.

The simulations carried out in this study demonstrate that some technical parameters – calving rate, mortality rate (young and adult), daily weight gain for male and females, the kg/milk/day, and the age at first birth – have a significant impact on the outcome of a scenario. It is critical that these parameters are identified and known within each farm where the tool developed as part of this project will be used to support decision-making on the feasibility of implementing the technologies outlined in the NAMA.

The heterogeneity of livestock farms implies that there is need to evaluate a range of technological alternatives aimed at increasing the efficiency, profitability and sustainability of the livestock business. The model developed within this project enables this type of evaluation in an integral, dynamic and non-deterministic way. This allows average results and their dispersion to be indentified. In this way, it can support the better management of risks in investment decisions related to the implementation of NAMA technologies, which in many cases represent important capital investments for farmers that could even put the stability of livestock producers at risk.

One of the limitations of this analysis relates to the lack of information generated from in-farm monitoring, as it requires the use of many assumptions about the impact that climate-smart technologies have on the critical zootechnical parameters of a herd. More empirical evidence of these connections with systematic herd monitoring actions is thus required. Finally, more information is needed on the cost structures of both dual-purpose and cow-calf livestock farms in order to better include these structures within the model. This will facilitate more accurate predictions of the impact of technologies on a farm's economic performance.

Annex 1

The table below shows the technical coefficients used to model the baseline and improved scenario simulations for each of the farms. Given the lack of empirical data on the evolution of these variables due to the adoption of practices outlined in the Low-Carbon Livestock Strategy and NAMA, expert judgement and literature[18] was used to build farm performance assumptions.

Table 9. Case studies – Comparisons between the technical coefficient assumptions of the baseline and improved scenarios.

	Variable	Baseline				Improved scenario			
		Average	Std. Dev	Minimum	Maximum	Average	Std. Dev.	Minimum	Maximum
Dual-purpose farm - Puerto Viejo de Sarapiquí, Heredia (DP1)	% Birth	78.6	9.6	54.2	98.0	89.1	8.7	62.9	98.0
	% Mortality (young)	2.5	2.1	0.0	5.0	2.2	2.1	0.0	5.0
	% Mortality (adults)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Kg/Milk/Day	9.4	2.2	7.0	12.0	11.1	1.7	7.0	12.0
	Age at first birth	33.4	3.0	30.0	38.0	30.4	1.3	30.0	38.0
Dual-purpose farm - Cañas, Guanacaste (DP2)	% Birth	69.09	10.31	50.00	90.00	78.91	8.61	60.00	90.00
	% Mortality (young)	2.42	2.17	0.00	5.00	2.51	2.08	0.00	5.00
	% Mortality (adults)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Kg/Milk/Day	3.54	2.33	2.00	12.00	6.69	4.14	2.00	12.00
	Age at first birth	34.91	3.22	30.00	38.00	32.79	2.86	30.00	38.00
Cow-calf farm- Las Juntas de Abangares, Guanacaste (B1)	% Birth	69.04	9.60	55.00	90.00	80.71	8.73	60.00	90.00
	% Mortality (young)	2.28	2.14	0.00	5.00	2.29	2.19	0.00	5.00
	% Mortality (adults)	2.24	2.19	0.00	5.00	1.63	1.98	0.00	5.00
	Age at first birth	31.56	2.34	30.00	38.00	31.59	2.45	30.00	38.00
Cow-calf farm - La Virgen de Sarapiquí, Heredia (B2)	% Birth	61.24	7.43	55.00	87.66	76.59	11.6	50.00	90.00
	% Mortality (young)	2.17	2.11	0.00	5.00	2.32	2.12	0.00	5.00
	% Mortality (adults)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Age at first birth	31.77	2.47	30.00	38.00	32.20	2.73	30.00	38.00

Annexe 2 – Evolution in the herd as a result of changes in technical parameters

1. Dual-purpose farm - Puerto Viejo de Sarapiquí, Heredia (DP1)

Evolution of key technical parameters under an improved scenario.

Technical parameter	Unit	Mean	Evolution – assumption	ST.DV.	MIN	MAX
Calving rate	%	80	Increased to 90%	10	50	98
Production milk/cow/day	kg/cow/day	9.7	Overall increase of 20% over 3 years	4	7	12
Age at first birth	Months	33	Reduced by 3 months in 3 years	5	30	38

Production as a result of changes in key parameters.

Variable	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Kg Dairy	96,147.30	113,333.00	109,365.20	97,862.50	103,584.20	89,582.60	105,350.30	100,109.00	112,219.50	112,275.60	105,567.20	99,559.70	99,414.30	114,609.00	111,149.30
Kg - culling	3,450.00	2,932.50	2,867.60	2,437.50	2,626.90	2,697.80	2,668.20	2,657.90	2,664.20	2,669.60	2,689.20	2,690.80	2,707.20	2,728.60	2,716.80
Kgs heifers 1-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kgs heifers 2-3	0	3,246.10	405.8	4,503.90	3,935.90	3,246.10	3,246.10	3,327.20	3,449.00	3,570.70	3,367.80	3,449.00	3,651.80	3,286.70	3,286.70
Kgs heifers 3+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kgs Calfs	687	556	486.1	494.8	503.6	506.2	517.1	489.3	516.8	535.7	488	494.9	465.2	522.1	500
Kg beef	4,137.00	6,734.60	3,759.50	7,436.20	7,066.30	6,450.10	6,431.30	6,474.50	6,630.00	6,776.00	6,545.00	6,634.60	6,824.20	6,537.40	6,503.50

2. Dual-purpose farm - Cañas, Guanacaste (DP2).

Technical parameter	Unit	Mean	Evolution – assumption	ST.DV.	MIN	MAX
Calving rate	%	70	5% yearly increase for the first 3 years	10	50	90
Production milk/cow/day	kg/cow/day	2.67	Increase to 4 over a 2 year period	2	2	7
Age at first birth	Months	36	Reduction to 32 over a 2 year period	5	30	38
Daily weight gain female	gr/day	800	Increase by 100			
Daily weight gain male	gr/day	800	Increase by 100			

Evolution of key technical parameters under an improved scenario.

Variable	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Kg Dairy	42,260.30	48,018.40	88,537.50	74,788.50	81,763.10	66,662.50	86,187.40	111,191.00	79,421.70	76,571.30	63,155.70	87,443.30	78,305.70	64,235.60	82,452.60
Kg - culling	2,362.50	3,196.10	4,053.20	4,349.70	4,203.50	4,173.70	4,384.70	4,476.20	4,574.30	4,610.40	4,695.10	4,767.10	4,841.80	4,966.00	5,085.10
Kgs heifers 1-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kgs heifers 2-3	13,229.40	18,710.20	10,961.50	3,590.80	6,898.20	11,717.50	9,166.10	9,827.60	10,111.10	8,693.60	9,827.60	10,205.60	11,906.50	9,827.60	9,827.60
Kgs heifers 3+	3,795.80	0	1,897.90	3,901.30	1,687.00	0	1,476.20	1,054.40	0	2,425.10	1,159.80	949	0	2,530.60	2,741.40
Kgs Calfs	3,355.80	3,557.00	4,099.70	3,590.10	3,761.50	3,615.80	4,046.90	4,101.90	4,119.90	4,193.80	4,370.30	4,328.40	4,470.80	4,522.60	4,617.70
Kg beef	22,743.50	25,463.40	21,012.40	15,431.90	16,550.20	19,507.10	19,073.80	19,460.10	18,805.30	19,922.90	20,052.80	20,250.00	21,219.00	21,846.80	22,271.90

3. Cow-calf farm - Las Juntas de Abangares, Guanacaste (B1)

Evolution of key technical parameters under an improved scenario.

Technical parameter	Unit	Mean	Evolution – assumption	ST.DV.	MIN	MAX
Calving rate	%	70	5% yearly increases for years	10	50	90
% female retention	%	55	Reduce to 50%			
Daily weight gain female	gr/day	800	Increase by 100			
Daily weight gain male	gr/day	800	Increase by 100			

Production as a result of changes in key parameters.

Variable	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Kg - culling	10,125.00	10,091.30	10,238.10	11,517.10	11,612.00	11,355.20	11,352.90	11,533.30	11,538.00	11,521.80	11,521.50	11,622.60	11,640.90	11,400.00	11,168.30
Kgs heifers 1-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kgs heifers 2-3	16,543.30	18,130.80	31,833.30	11,196.00	16,125.50	17,128.20	20,971.60	20,804.40	20,219.60	20,804.40	21,640.00	18,715.60	19,300.50	14,287.40	15,707.80
Kgs heifers 3+	186.6	0	0	11,380.20	1,772.30	1,585.80	0	0	0	0	0	2,705.10	0	4,477.40	4,477.40
Kgs calves	10,146.00	6,943.80	7,172.70	8,102.80	8,061.80	7,722.30	7,850.40	8,248.20	7,922.00	7,455.30	7,165.00	7,491.30	7,392.80	6,665.80	7,225.90
Kg beef	37,000.90	35,165.80	49,244.10	42,196.10	37,571.70	37,791.40	40,174.90	40,585.90	39,679.60	39,781.50	40,326.50	40,534.70	38,334.20	36,830.70	38,579.40

4. Cow-Calf farm - La Virgen de Sarapiquí, Heredia (B2)

Evolution of key technical parameters under an improved scenario.

Technical parameter	Unit	Mean	Evolution – assumption	ST.DV.	MIN	MAX
Calving rate	%	58	An increase to 79% over a period of 3 years	10	50	90
% female retention	%	2.67	No change	1	2	4
Daily weight gain female	gr/day	650	An increase to 900 gr/day over 3 years	0	0	0
Daily weight gain male	gr/day	650	An increase to 900 gr/day over 3 years	0	0	0

Production as a result of changes in key parameters.

Variable	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Kg - culling	1,750.00	1,825.00	1,887.50	1,858.80	1,887.90	1,954.10	2,058.70	2,132.80	2,209.50	2,288.60	2,384.70	2,486.20	2,587.60	2,703.90	2,813.50
Kgs heifers 1-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kgs heifers 2-3	5,395.60	4,753.30	2,991.90	3,833.30	5,329.30	6,264.20	6,451.20	6,264.20	5,609.80	6,264.20	6,544.70	5,796.80	8,788.60	8,227.60	8,321.10
Kgs heifers 3+	0	590.2	1,253.30	940	626.6	626.6	0	626.6	1,566.60	1,462.20	1,671.00	2,506.60	0	835.5	1,044.40
Kgs calves	3,300.30	1,754.80	2,105.30	2,073.00	2,179.10	2,172.10	2,381.00	2,398.80	2,520.90	2,656.70	2,743.80	2,790.20	2,993.10	2,944.10	3,095.20
Kg beef	10,445.90	8,923.20	8,238.00	8,705.00	10,022.90	11,017.10	10,890.90	11,422.50	11,906.80	12,671.60	13,344.30	13,579.80	14,369.30	14,711.20	15,274.20

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[5] Nationally Appropriate Mitigation Action (NAMA) refers to a set of policies and actions that countries undertake as part of a commitment to reduce greenhouse gas emissions. The term recognizes that different countries may take different nationally appropriate action on the basis of equity and in accordance with common but differentiated responsibilities and respective capabilities. It also emphasizes financial assistance from developed countries to developing countries to reduce emissions.

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