Perspectives on a Bio-Economy Development Path for Colombia.

GROW Colombia Project

Socioeconomic Programme

Sustainable Cattle Ranching Economic Assessment Tool

User's Manual V1.10

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1 Introduction

The present document is the user's manual of the Sustainable Cattle Ranching (SCR) tool. The tool is based on an extended cost-benefit analysis (CBA) that compares the implementation of different forms of SCR to the current extensive cattle ranching systems (Business as Usual, BAU). It allows to contrast costs and benefits of implementing SCR strategies vis-à-vis BAU.

The tool evaluates SCR implementation strategies for a single prototype farm and performs calculations of the net present value (NPV) of cattle ranching systems over a 20 years period. The tool reports farm-level costs and benefits by calculating financial indicators (e.g. revenues from production, production costs, gross margin, enterprise profit) and extended economic benefits produced by ecosystem services enhancement that result from cattle ranching activities. These benefits are not currently sold in the market, but their importance and value are getting a predominant role in the international agenda to tackle climate change and biodiversity loss.

The tool is developed to be:

- **Flexible** – it currently targets cattle ranching activities and three main sustainable farming systems (intensive silvo-pastoral, restoration and reforestation, enhanced pastures[1]) but can be further expanded adding other activities and systems (e.g. agro-tourism, agro-silvo-pastoral activities such as production of timber, etc.). Moreover, additional ecosystem services can be added such as biodiversity protection, improved water quality, etc.
- **User oriented** – it includes input parameters that can be directly changed by a wide range of users. It is intended to be specifically employed in real-life applications by analysts, practitioners, and policy makers who can use the tool depending on their needs (e.g. policy, appraisal, evaluation, etc.). However, subject to data availability, the tool can also be used by local farmers' and cattle ranchers' associations and by individual farmers because it requires basic information on business activities that can be entered in a simplified tool dashboard.
- **Adaptable and Scalable** – the tool can be used starting from different datasets or geographical areas as it is developed based on a generalized business model of cattle ranching activities (i.e. including main inputs, outputs, costs, and revenues items). In its current version, the tool is

[1] Details of the three SCR implementation systems considered can be found in the report "Biodiversity protection in Colombia: An Economic Perspective. Report 3. GROW Colombia Project Series. GROW Colombia Project UKRI GCRF Grant BB/P028098/1. Norwich, UK". In general, the systems can be defined as:

- *Intensive silvo-pastoral systems (iSPS)*: the combination of pastures cultivars with trees and plants for animal feeding.
- *Pastures restoration/reforestation*: the reforestation of degraded pasture areas, sowing of disperse trees and establishment of living fences.
- *Enhanced pastures*: the improvement of pastures cultivars (e.g. planting Mombasa grass).

developed starting from data derived from a sample of cattle ranching farmers in the Cauca, provided by Universidad del Cauca and CIAT. However, it is possible to adapt the tool on other datasets and information and to scale the tool up and down on varying geographical levels.

The tool is composed of two parts:

- 'Dashboard' – the control panel where information on farm characteristics, herd characteristics, productivity and costs are entered for BAU and SCR, together with the projected implementation of sustainable cattle ranching systems.
- 'Results' – the panel where main results of the extended CBA are summarised in terms of NPV of the BAU and SCR.

The rationale behind the development of this tool relates to the importance of cattle ranching as a major economic activity in many countries worldwide.

2 Background info on cattle ranching

In the last decades, the growing demand for meat and dairy products has resulted in a continued expansion of the area destined to cattle pastures, often through the conversion of pristine ecosystems into extensive cattle ranching systems. This land use change has caused relevant pressures on the environment, with increased deforestation, loss of biodiversity, higher greenhouse gas (GHG) emissions, and more generally decreased ecosystem services provision. Several alternatives to extensive cattle ranching exist and there is growing consensus that the expansion of cattle ranching activities should follow more sustainable practices (e.g. silvo-pastoral and agro-silvo-pastoral systems, enhanced natural pastures, reforestation, etc.). Many pilot applications (e.g. Mainstreaming Sustainable Cattle Ranching in Colombia) have demonstrated the potential of SCR to sustain biodiversity and ecosystem services provision (e.g. increased GHG mitigation, improved soil and water quality) whilst generating economic and social benefits, in particular for small-holder farmers.

However, financial benefits of SCR may not be sufficient to guarantee the switch from extensive cattle ranching system, particularly in the short-term. Farmers, local governments, and actors in the supply chain must be empowered in order to understand and agree on SCR. Tools for the systematic evaluation of environmental, social and economic benefits of SCR are crucial in assisting an informed transition.

Box 1 – Cattle ranching, GHG emissions, and carbon market

The livestock sector significantly contributes to GHG emissions, both directly through enteric fermentation, manure storage, feed production, and indirectly through increased deforestation (see for example FAO, 2017; Grossi et al., 2019; Tapasco et al., 2019; Naranjo-Ramirez and Ruiz-Buitrago; 2020). It is estimated that the livestock sector contributes to the 14.5% of all human induced GHG emissions worldwide (Gerber, 2013), with beef and dairy cattle representing the 62% of the sector emissions (FAO, 2017). Therefore, relationship between cattle ranching and climate change is a crucial issue to tackle on the way to global sustainability.

With 1.9 Gt CO2-eq mainly caused by the specialized production of beef and dairy cattle, the Latin America and Caribbean region has the highest level of GHG emissions worldwide (FAO, 2017). In Colombia, the sector Agriculture, Forestry and Land Use (AFOLU, which includes cattle-related emissions, accounts for the highest impact on GHG emissions with nearly 54% on the total (IDEAM et al., 2018). Colombia pledged to reduce GHG emissions by 20% by 2030 through a sectoral impact approach (García Arbeláez et. al, 2016). Considering the potential of sustainable cattle ranching such as silvo-pastoral systems to reduce GHG emissions and deforestation associated with the sector (e.g. Osorio Vidal, 2018; Murgueitio et al., 2014), mechanisms to support conversion towards sustainable practices need to be introduced. Carbon markets similar to those existing for other industrial sector and environmental initiatives are a viable option. Carbon markets would represent an opportunity for farmers to get compensated for the capture and storage of significant quantity of GHG supporting the implementation of sustainable practices, whilst supporting the government target. The establishment of carbon tax by the Colombian government in 2016 is an important step to a new market for green bonds and to establish a low carbon economy in Colombia (Martinez et al., 2017).

3 Practical application of the tool

To highlight the potential of the tool in the context of real-world, policy relevant applications, this user's manual will first present two examples in this Section 3. The two practical applications of the tool are introduced step-by-step. We will guide the user on how to enter the information and how to read the corresponding results. The examples are two of the scenarios presented in the report "Biodiversity protection in Colombia: An Economic Perspective. Report 3. GROW Colombia Project Series. GROW Colombia Project UKRI GCRF Grant BB/P028098/1. Norwich, UK". This user's manual can be thus considered as a companion to the main report. An overview of the tool and details of its components will then be summarised in Sections 4 and 5.

Policy makers and planners are increasingly aware of the potential of SCR systems, but a detailed breakdown of extended costs/benefits can help decision makers to understand the challenges and opportunities faced by farmers. Farmers often face substantial implementation costs, and this can act as a barrier to switch to SCR systems, however the SCR provides important ecosystem services benefits, such as avoided deforestation and biodiversity protection. Our tool quantifies and monetises the financial and economic costs and benefits of converting pasture lands into more sustainable management practices such as silvo-pastoral systems or enhanced pastures.

3.1 A mix of enhanced pastures and silvo-pastoral system[2]

This SCR strategy corresponds to a medium-high intensity switch. Under the current BAU system, the prototype farm has a total area of 25 hectares with a grazing area of 23 hectares, and a cattle herd of 23 heads in total (divided in 3 female and 3 male juveniles, 7 female and 3 male sub-adults, 6 female and 1 male adults). The farm produces 3.7 liters/head/day of milk and sells it as raw milk for the 76% whilst using the remaining 24% for producing cheese. Moreover, the farm sells animals directly to the slaughterhouse.

The farm switches to SCR practices: 6 hectares of grazing area into 2 hectares of enhanced pastures and 4 hectares of intensive silvo-pastoral system is considered. It is expected that benefits stemming from the conversion to SCR systems will be fully achieved after 5 years implementation. It is also expected that the SCR implementation will result in the capacity of the farm to accommodate more animals, improved herd demographic dynamics, increased cattle weight gain and increased milk productivity. A slightly higher quantity of milk would be sold as raw milk under the SCR implementation, and more cattle heads would be sold to the slaughterhouse. At the same time, quantities and costs of feed and vaccines needed for the cattle are expected be the same, as are working days needed to manage (on average) the cattle and the farm and the corresponding costs. Finally, it is expected that the dairy products and the animals would be sold at the same prices after SCR implementation although consumers might be prepared to pay a price premium for more sustainable products.

[2] This application relates to the Scenario 3 presented in the report "Biodiversity protection in Colombia: An Economic Perspective. Report 3. GROW Colombia Project Series. GROW Colombia Project UKRI GCRF Grant BB/P028098/1. Norwich, UK". It is based on information from a sample of farms in the Cauca provided by Universidad del Cauca and CIAT. Results might differ because of rounding.

Step 1 – characteristics of the farm and SCR implementation

In the tool dashboard, the basic information about farm extent, total number of cattle heads and SCR implementation project are added. Farm size, grazing area and total number of heads are entered in the BAU and SCR columns. SCR implementation strategies are only added in the relative column. Here it is assumed that the starting total extent of the farm does not change, and the grazing area slightly decrease after SCR implementation. However, SCR system allows farmers to accommodate more animals than in the extensive BAU system.

CHARACTERISTICS OF THE FARM			BAU	SCR
Tamaño de la finca	Farm size	ha	25.0	25.0
Area para pastoréo	Size of grazing area	ha	23.0	21.0
Número de cabezas	Number of heads	n	23	29
Area pastos mejorados	Area pastures enhancement	ha		2.0
Area agroforesteria/silvopastoril	Area agroforestry/silvopastoral	ha		4.0
Area restauración/reforestación	Area restoration/reforestation	ha		0.0
Periodo beneficios de SCR	Time frame SCR benefits expected	years		5

Total 6 ha SCR divided among systems and reaching benefits after 5 years

The farm area stays the same, but the total number of cattle heads is increased, and the available grazing area is slightly decreased after SCR implementation

Step 2 – Characteristics of the herd

The second set of information to input in the tool dashboard relates to the characteristics of the cattle herd, that is herd composition, basic herd demographic rates, and weight of animals. Details needs to be added for the BAU and SCR columns. Here we assumed that the initial composition of the herd changes when converting some of the grazing area into SCR as a consequence of the increased carrying capacity of the farm. It is assumed that herd demographic dynamics would change in SCR, namely a 9% increase in female at birth and a 1% decrease in mortality rates over the BAU. Also, an increase in cattle weight gain is expected under SCR systems. Therefore, the BAU and SCR columns for the herd composition, the demographic rates and the animal weight will differ to account for those considerations.

Herd composition changes

CHARACTERISTICS OF THE HERD			BAU	SCR
Hembras joven	Female juveniles	n	3	4
Machos joven	Male juveniles	n	3	3
Hembras sub-adultas	Female sub-adults	n	7	10
Machos sub-adultos	Male sub-adults	n	3	5
Hembras adultas	Female adults	n	6	6
Machos adultos	Male adults	n	1	1
Natalidad	Birth rate	%	58%	67%
Mortalidad jovenes	Mortality rate juveniles	%	8%	7%
Mortalidad sub-adultos	Mortality rate sub-adults	%	3%	2%
Mortalidad adultos	Mortality rate adults	%	3%	2%
Peso promedio hembras joven	Avg weight female juveniles	kg/head	135	140
Peso promedio machos joven	Avg weight male juveniles	kg/head	135	140
Peso promedio hembras sub-adultas	Avg weight female sub-adults	kg/head	325	330
Peso promedio machos sub-adultos	Avg weight male sub-adults	kg/head	305	325
Peso promedio hembras adultas	Avg weight female adults	kg/head	345	360
Peso promedio machos adultos	Avg weight male adults	kg/head	480	490

Rate of female at birth increases and mortality rates decrease in switching to SCR

Cattle weight slightly in SCR

Step 3 – Productivity and prices

The third set of information to be entered in the tool dashboard relates to farm productivity, output and selling prices. These parameters are entered in the BAU and SCR columns. In this example, it is assumed that the milk production increases from 3.7 l/head/day in BAU to 4.8 l/head/day when switching to SCR systems and that the milk produced is mainly sold as raw milk (i.e. roughly three quarter of milk, the remaining being used in cheese production). Cattle sales are related to varying percentages with respect of the sex-age class composition of the herd, and in general slightly increase under the SCR system. In addition, it is assumed that the prices paid for products under SCR systems are the same than in BAU. Therefore, the parameters in the BAU and SCR columns will differ to account for those considerations.

Milk productivity increases in SCR

Prices for milk, cheese and cattle are expected to be the same under SCR

SELLING PRICES			BAU	SCR
Leche	Milk	$/l	696	696
Queso	Cheese	$/kg	7750	7750
Yogurt	Yogurt	$/l		
Precio de venta ganado	Cattle selling price	$/kg	4341	4341
PRODUCTIVITY			**BAU**	**SCR**
Producción leche	Milk production	l/head/day	3.7	4.8
Venta de leche	Milk sales	% milk	76%	78%
Venta de queso	Cheese sales	% milk	24%	22%
Venta de yogurt	Yogurt sales	% milk	0%	0%
Venta hembras joven	Sale female juveniles	% total heads	2%	3%
Venta machos joven	Sale male juveniles	% total heads	23%	50%
Venta hembras sub-adultas	Sale female sub-adults	% total heads	15%	15%
Venta machos sub-adultos	Sale male sub-adults	% total heads	5%	8%
Venta hembras adultas	Sale female adults	% total heads	7%	9%
Venta machos adultos	Sale male adults	% total heads	4%	8%

Farm on average sells varying quantities of cattle heads, with a slight increase under SCR

Step 4 – Variable and fixed costs of production

Variable and fixed costs of production are then added in the tool dashboard in both the BAU and SCR columns. To simplify the example application, fixed costs are here considered negligible and will not be added. In the table below it is possible to note that fixed costs can be added if needed.

Quantity of vaccines and feed is the same

VARIABLE COSTS OF PRODUCTION			BAU	SCR
Vacunas y medicamentos - cantidad	Vaccines and drugs - quantity	unit/head/year	16	16
Vacunas y medicamentos - costo	Vaccines and drugs - cost	$/unit	2240	2240
Alimentos - cantitad	Feed - quantity	kg/head/year	32	32
Alimentos - costo	Feed - cost	$/kg	3095	3095
Trabajo finca - cantitad	Labour farm - quantity	days/year	3.6	3.6
Trabajo finca - costo	Labour farm - cost	$/days	23516	23516
Trabajo ganado - cantitad	Labour herd - quantity	days/year	1.1	1.1
Trabajo ganado - costo	Labour herd - cost	$/days	24543	24543
Transporte - costo	Transport - cost	$/kg	30	30
FIXED COSTS OF PRODUCTION			**BAU**	**SCR**
Costos fijos	Fixed costs	$/month		
Mantenimientos	Maintenance	$/month		

Costs of inputs stay the same

Quantity of labour stays the same

It is important to stress that the variable input quantities and variable costs to enter in this section of the tool dashboard are related to the average quantities and costs of cattle ranching activities. In BAU, these quantities and costs are the averages for the whole grazing area and cattle herd. In SCR, these quantities and costs are the averages for the areas that *are not* under one of the sustainable systems. Indeed, for the grazing area and cattle herd that *are* under sustainable systems, specific maintenance costs are automatically used by the tool in the CBA[3].

Step 6 – Discount rate

Finally, the discount rate is added to the tool dashboard. This is related to the interest rate or future value of money which is normally a rate between 2-9%, more details are in the full report. Once an appropriate discount rate is identified, this will be used in the calculation of the NPV summarized in the 'Results' section of the tool. The discount rate needs to be entered in the BAU and the SCR columns.

Step 7 – Results

The results section reports the monetary NPV calculations for the BAU (*Net Present Value - Business As Usual*), the SCR switch (*Net Present Value - Sustainable Cattle Ranching*) and the difference between the two (*Net Present Value - Difference SCR vs BAU*). The NPV are reported for financial profits (*Farm Business profit*), for economic benefits with only GHG net emissions monetised (*Net Economic Benefits (Net GHG only)*), and for total economic benefits with both GHG net emissions and additional soil nutrients monetised (*Net Economic Benefits (Total)*). Figures in red highlight that the corresponding system is not profitable in terms of NPV.

The summary results allow to directly compare and assess whether the implementation of the intended SCR system is financially (profit) and/or economically (economic benefits) viable.

Figure 1 reports the results from the practical example presented in this section, that is a conversion of 6 hectares in total into SCR through a combination of 2 hectares of enhanced pastures and 4 hectares of silvo-pastoral practices. From Figure 1, users (such as policy makers, practitioners, researchers, public officers, etc.) can assess the effect of the proposed intervention compared to the current BAU:

(1) Converting part of the grazing area into SCR practices is profitable strictly considering financial business profits. Anyway, it is not as profitable as BAU from a financial point of view (the values under "Difference SCR vs BAU" are red).

(2) When extending the analysis to economic benefits from net GHG emission, the SCR conversion is still economically profitable, but the difference in NPV between BAU and SCR systems is still

[3] In this case, for example, the variable input quantities and variable costs in SCR refer to the ~14 hectares that are not under sustainable systems, whilst specific maintenance costs are automatically used for the 6 hectares converted into sustainable practices. Similarly, variable input quantities and variable costs in SCR refer to the 5 animals that are not allocated into sustainable systems, whilst specific maintenance costs are automatically used for the 24 animals that are into sustainable systems considering a carrying capacity of 4 animals/ha in SCR.

negative in most cases (the values in red under "Difference SCR vs BAU"), meaning that the SCR investment is still not convenient compared to the current BAU situation.

(3) Anyway, if farmers access a carbon market and get a compensation for net GHG emissions that is set at the same (or higher) level than the EPA social cost of carbon (EPASCC[4]) which currently is \$42/tCO_2 (131,017 pesos/tCO_2 in 2015 prices) then the SCR conversion provides economic benefits particularly in the longer term. This is highlighted by the positive figures in black in the part on difference between BAU and SCR.

(4) If, in addition to GHG net emissions, also the additional soil nutrients from SCR are monetised and compensated by, for example, the consumers who might be willing to pay more for SCR products, the SCR conversion in this example starts to be more economically profitable than BAU at different levels of monetary compensation for GHG (such as Colombian Carbon Tax (CCT), Colombian Social Cost of Carbon (CSCC), and US EPA Social Cost of Carbon (EPASCC).

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[4] https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

CBA Summary

Net Present Value - Business As Usual

Farm Business profit (net initial investment)		
Net Present Value medium term		1,293,108.33
Net Present Value long term		1,424,080.94
Net Present Value total years 1-20		2,088,307.69
Net Economic Benefits (Net GHG only)		
Net Present Value medium term	CCT	1,220,599.00
Net Present Value long term	CCT	1,351,571.61
Net Present Value total years 1-20	CCT	1,975,309.53
Net Present Value medium term	CSCC	1,188,361.65
Net Present Value long term	CSCC	1,319,334.26
Net Present Value total years 1-20	CSCC	1,925,071.01
Net Present Value medium term	EPASCC	658,598.17
Net Present Value long term	EPASCC	789,570.77
Net Present Value total years 1-20	EPASCC	1,099,490.36
Net Economic Benefits (Total)		
Net Present Value medium term	CCT	1,220,599.00
Net Present Value long term	CCT	1,351,571.61
Net Present Value total years 1-20	CCT	1,975,309.53
Net Present Value medium term	CSCC	1,188,361.65
Net Present Value long term	CSCC	1,319,334.26
Net Present Value total years 1-20	CSCC	1,925,071.01
Net Present Value medium term	EPASCC	658,598.17
Net Present Value long term	EPASCC	789,570.77
Net Present Value total years 1-20	EPASCC	1,099,490.36

Net Present Value - Sustainable Cattle Ranching

Farm Business profit (net initial investment)		
Net Present Value medium term		591,454.87
Net Present Value long term		1,122,039.10
Net Present Value total years 1-20		1,217,995.64
Net Economic Benefits (Net GHG only)		
Net Present Value medium term	CCT	668,035.67
Net Present Value long term	CCT	1,281,293.54
Net Present Value total years 1-20	CCT	1,383,503.29
Net Present Value medium term	CSCC	702,083.19
Net Present Value long term	CSCC	1,352,097.41
Net Present Value total years 1-20	CSCC	1,457,087.32
Net Present Value medium term	EPASCC	1,261,593.46
Net Present Value long term	EPASCC	2,515,632.99
Net Present Value total years 1-20	EPASCC	2,666,309.78
Net Economic Benefits (Total)		
Net Present Value medium term	CCT	1,061,132.01
Net Present Value long term	CCT	1,751,632.58
Net Present Value total years 1-20	CCT	2,039,234.50
Net Present Value medium term	CSCC	1,095,179.52
Net Present Value long term	CSCC	1,822,436.45
Net Present Value total years 1-20	CSCC	2,112,818.52
Net Present Value medium term	EPASCC	1,654,689.80
Net Present Value long term	EPASCC	2,985,972.04
Net Present Value total years 1-20	EPASCC	3,322,040.99

Net Present Value - Difference SCR vs BAU

Farm Business profit (net initial investment)				
Net Present Value medium term		-	701,653.46	(1)
Net Present Value long term		-	302,041.83	
Net Present Value total years 1-20		-	870,312.04	
Net Economic Benefits (Net GHG only)				
Net Present Value medium term	CCT	-	552,563.33	(2)
Net Present Value long term	CCT	-	70,278.07	
Net Present Value total years 1-20	CCT	-	591,806.24	
Net Present Value medium term	CSCC	-	486,278.46	
Net Present Value long term	CSCC		32,763.15	
Net Present Value total years 1-20	CSCC	-	467,983.69	
Net Present Value medium term	EPASCC		602,995.29	(3)
Net Present Value long term	EPASCC		1,726,062.22	
Net Present Value total years 1-20	EPASCC		1,566,819.42	
Net Economic Benefits (Total)				
Net Present Value medium term	CCT	-	159,466.99	
Net Present Value long term	CCT		400,060.97	
Net Present Value total years 1-20	CCT		63,924.97	
Net Present Value medium term	CSCC	-	93,182.13	
Net Present Value long term	CSCC		503,102.19	
Net Present Value total years 1-20	CSCC		187,747.51	
Net Present Value medium term	EPASCC		996,091.63	(4)
Net Present Value long term	EPASCC		2,196,401.27	
Net Present Value total years 1-20	EPASCC		2,222,550.63	

Figure 1: Results detail - NPV calculated from the extended cost-benefit analysis

Finally, the summary results section also provides a graphic examination of the NPV trends over the 20 years considered (Figure 2). In this example, SCR implementation becomes economically more profitable than BAU in the medium-long term. Specifically, the total economic benefit from SCR (green line) surpasses the BAU profits (light blue line) in year 7 from implementation.

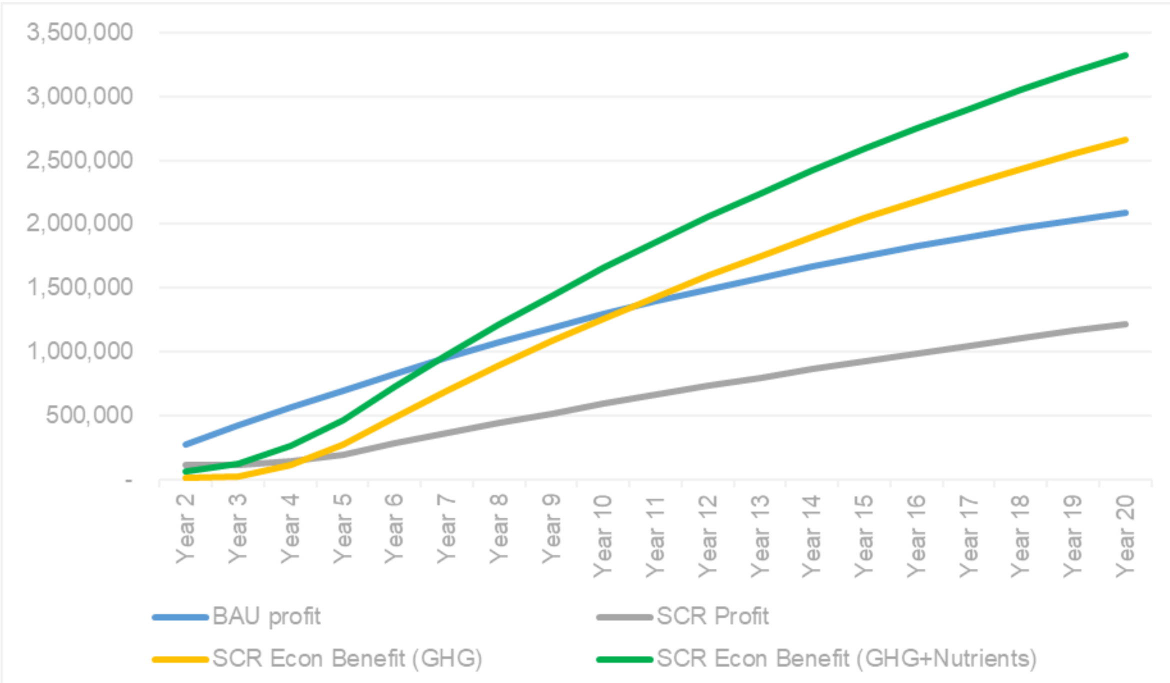


Figure 2: Results detail - trends of the NPV over 20 years

3.2 High intensity silvo-pastoral system conversion[5]

What would happen if the policy required the implementation of only high intensity silvo-pastoral systems for the whole area planned to be converted in the farms? That is, policy makers would plan that all the farms in a specific region or area convert 6 hectares of grazing area into intensive silvo-pastoral system. Assuming everything else being equal to the previous application, the only change in the tool dashboard relates to the area extent that is now only converted in intensive silvo-pastoral systems. This is shown in the figure below.

[5] This application relates to the Scenario 4 presented in the report "Biodiversity protection in Colombia: An Economic Perspective. Report 3. GROW Colombia Project Series. GROW Colombia Project UKRI GCRF Grant BB/P028098/1. Norwich, UK". It is based on information from a sample of farms in the Cauca provided by Universidad del Cauca and CIAT. Results might differ because of rounding.

CHARACTERISTICS OF THE FARM			BAU	SCR
Tamaño de la finca	Farm size	ha	25.0	25.0
Area para pastoréo	Size of grazing area	ha	22.6	20.7
Número de cabezas	Number of heads	n	23	29
Area pastos mejorados	Area pastures enhancement	ha		0.0
Area agroforesteria/silvopastoril	Area agroforestry/silvopastoral	ha		6.0
Area restauración/reforestación	Area restoration/reforestation	ha		0.0
Periodo beneficios de SCR	Time frame SCR benefits expected	years		5

The only change relates to the extent of grazing area converted into different SCR systems: in this case all the 6 hectares are converted to silvo-pastoral system

Outcome of the tool graphical results are reported in Figure 3. The implementation of SCR in the form of intensive silvo-pastoral system not only is beneficial from a societal point of view, that is including economic values and compensating farmers for net GHG emissions and increased soil quality (yellow and green lines), but also is more profitable than BAU from a private point of view, that is considering cattle ranching business profits (grey line).

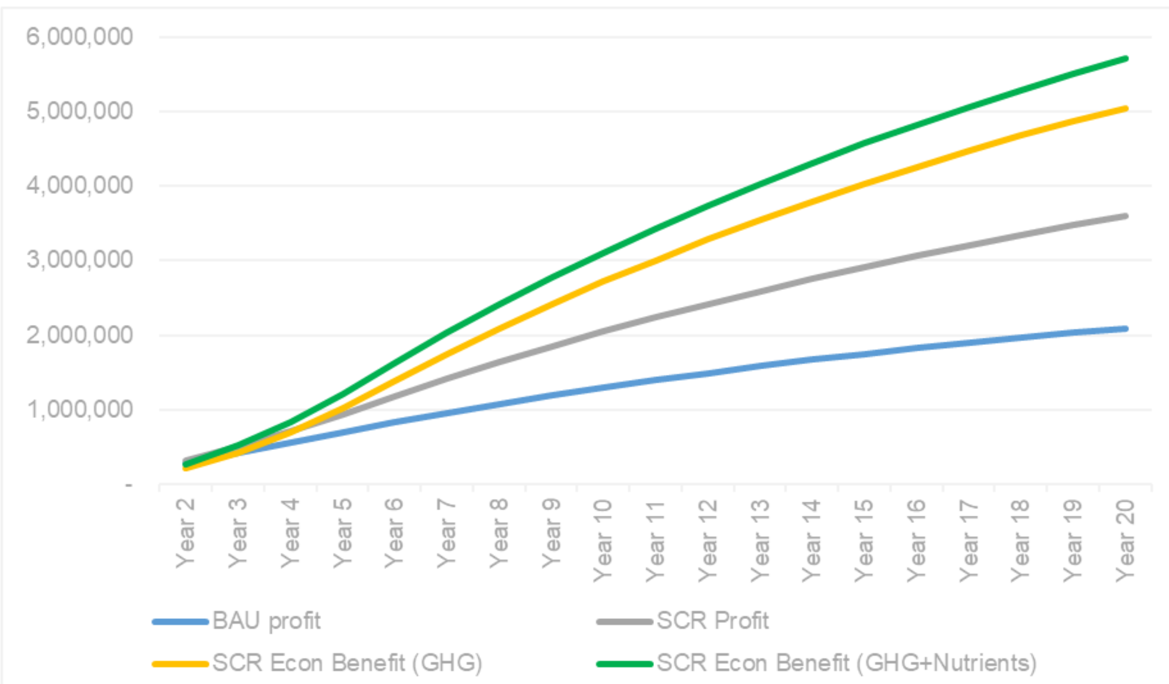


Figure 3: Results detail - trends of the NPV over 20 years

The applications in Sections 3.1 and 3.2 highlight a crucial element of cattle ranching sustainability, that is the importance to internalise GHG emissions from the sector. This point was briefly described in Box 1.

4 General characteristics of the tool

In the following Sections 4 and 5, details of the tool components are presented.

The tool is developed around four main building blocks:

1. **Input parameters** – a wide range of input parameters provides the information needed for the calculations in the extended CBA. Parameters describe the cattle ranching activities in terms of characteristics of the farm and the herd, productivity, production costs, output prices, SCR implementation costs, ecosystem services and externalities. Most of the parameters can be flexibly changed by users, who can specify a different set of parameters for the BAU and the SCR implementation. The parameters directly inform the herd dynamic model and the CBA.
2. **Herd dynamic model** – adapted from Lesnoff (2013), it allows to project changes in the cattle herd structure over the 20 years period considered in the CBA by simulating the herd growth in terms of size and sex-age classes and the resulting production output.
3. **Extended cost-benefit analysis** – parameters and results from the herd model directly inform the extended CBA that is differentiated between BAU and SCR systems. All the elements of the CBA are derived considering the characteristics of the farm and the herd. The CBA calculates:
    a. *Outputs*: quantities and revenues from dairy products and cattle heads sale.
    b. *Costs*: variable input quantities and costs including vaccines, feed, transport and labour. Fixed costs are also considered, such as administration, veterinary services, maintenance.
    c. *Costs of SCR implementation*: implementation and maintenance costs for three main SCR practices are considered, that is pastures enhancement, agroforestry and silvo-pastoral, and pastures restoration and reforestation[6].
    d. *Ecosystem services and environmental externalities*: economic benefits from GHG net emission reduction (methane and nitrous oxide emission and carbon sequestration) and additional soil nutrients retention are included (nitrogen, phosphorus and potassium)[7].
4. **Results** — Net Present Value (NPV) of enterprise profits and economic benefits of BAU and SCR are calculated per hectare over the whole 20 years period, and also considering a medium-term (1-10 years) and a long-term (11-20 years) time horizon. In addition, a continuous

[6] Source of the costs for these three alternatives can be found in report "Biodiversity protection in Colombia: An Economic Perspective. Report 3. GROW Colombia Project Series. GROW Colombia Project UKRI GCRF Grant BB/P028098/1. Norwich, UK".
[7] Physical and chemical analysis used in the Excel spreadsheet comes from Universidad del Cauca and CIAT, for farms located in Mercaderes and Patía municipalities. For other areas users must identify or generate suitable information.

evaluation of the NPV is provided to appraise the break-even period for the SCR investment to become financially and/or economically viable.

Figure 4 summarises the general structure of the spreadsheet tool.

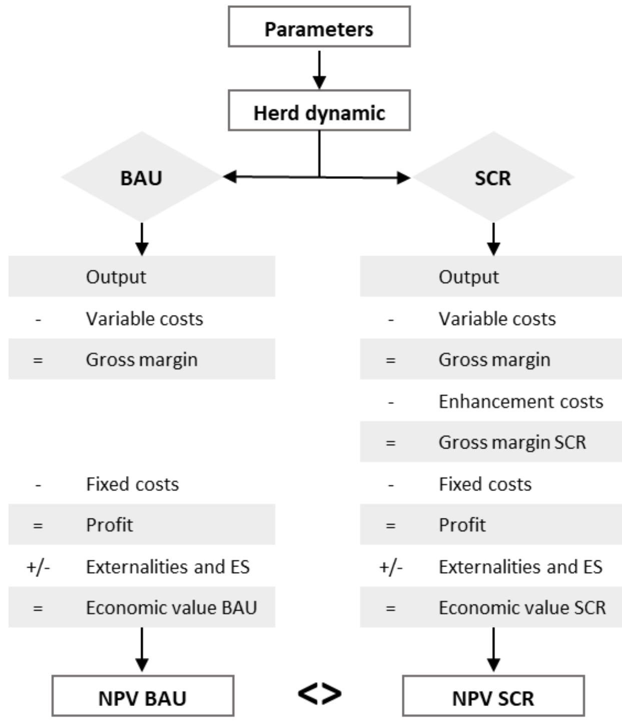


Figure 4: Structure of the tool

5 Structure of the tool

5.1 'Dashboard'

The dashboard allows users to input and control the main parameters used in the CBA calculations (Figure 5). Users can enter parameters for the BAU and for the SCR. All the parameters in the dashboard can be changed to reflect different cattle ranching systems and SCR implementation types, different prices, outputs and costs for cattle ranching production based on e.g. different geographical areas or information, different farm and herd characteristics, etc.

The tool dashboard is composed of the following sections (see Figure 6 for an overall view of the dashboard):

(A) Characteristics of the farm

Figure 5 shows details of the dashboard section regarding the basic characteristics of the farm, with example values for parameters.

CHARACTERISTICS OF THE FARM			BAU	SCR
Tamaño de la finca	Farm size	ha	25.0	25.0
Area para pastoréo	Size of grazing area	ha	22.6	20.7
Número de cabezas	Number of heads	n	23	29
Area pastos mejorados	Area pastures enhancement	ha		3.0
Area agroforesteria/silvopastoril	Area agroforestry/silvopastoral	ha		3.0
Area restauración/reforestación	Area restoration/reforestation	ha		0.0
Periodo beneficios de SCR	Time frame SCR benefits expected	years		5

Figure 5: Dashboard detail - farm characteristics

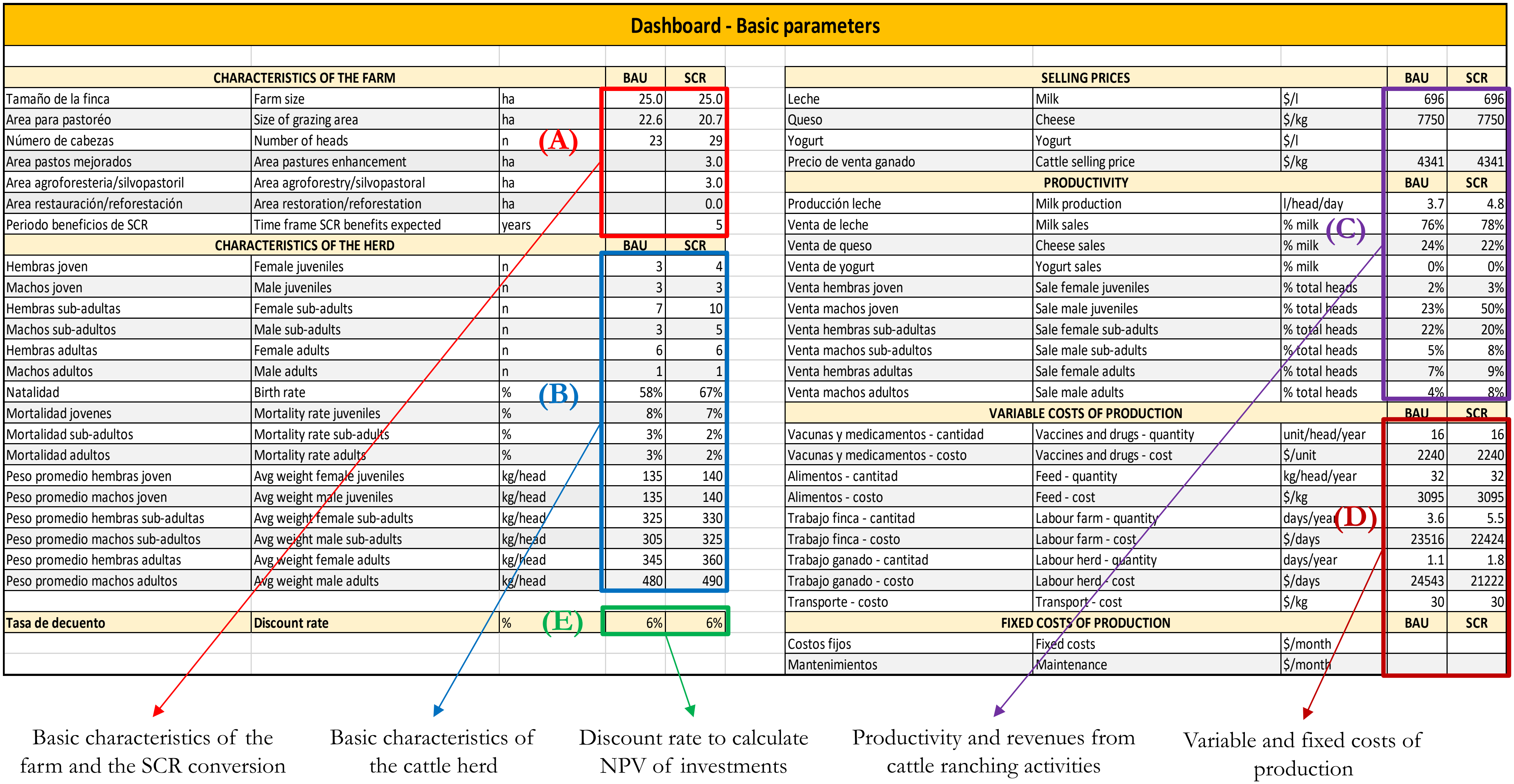
Users can enter information, which can be differentiated to reflect differences in BAU and SCR systems, related to:

- Total farm size in hectares (for example in Figure 5 this is the same for BAU and SCR).
- Total grazing area in hectares (for example in Figure 5 grazing area in the BAU current situation equals 22.6 hectares, which would change to 20.7 hectares following SCR implementation).
- Total number of cattle heads (for example in Figure 5, 23 heads are in the herd in the current situation, but the herd would increase to 29 heads if SCR was implemented).

The cells highlighted in yellow in Figure 5 are related to the possible SCR implantation projects. These cells can be changed by users only for the SCR systems and can be used to simulate different SCR implementation scenarios. Indeed, users can choose and specify the combination of grazing area that is converted into each of the SCR systems added into the tool, that are:

- Enhanced pastures area in hectares.
- Intensive silvo-pastoral system area in hectares.
- Restored and reforested pastures area in hectares.

In Figure 5, for example, the SCR implementation is achieved by converting 6 hectares of grazing area in total: 3 hectares are converted into enhanced pastures and 3 hectares are converted in intensive silvo-pastoral system. Many other combinations of the three SCR systems are possible. In addition, users can specify the number of years that they expect full benefits of SCR implementation to be achieved (in Figure 5 benefits are fully achieved after 5 years from implementation). Depending on these parameters, benefits and changes resulting from SCR implementation gradually occur over the period defined by users at a constant rate and reach their maximum in the specified year.



Dashboard - Basic parameters

CHARACTERISTICS OF THE FARM			BAU	SCR
Tamaño de la finca	Farm size	ha	25.0	25.0
Area para pastoréo	Size of grazing area	ha	22.6	20.7
Número de cabezas	Number of heads	n	23	29
Area pastos mejorados	Area pastures enhancement	ha		3.0
Area agroforesteria/silvopastoril	Area agroforestry/silvopastoral	ha		3.0
Area restauración/reforestación	Area restoration/reforestation	ha		0.0
Periodo beneficios de SCR	Time frame SCR benefits expected	years		5
CHARACTERISTICS OF THE HERD			**BAU**	**SCR**
Hembras joven	Female juveniles	n	3	4
Machos joven	Male juveniles	n	3	3
Hembras sub-adultas	Female sub-adults	n	7	10
Machos sub-adultos	Male sub-adults	n	3	5
Hembras adultas	Female adults	n	6	6
Machos adultos	Male adults	n	1	1
Natalidad	Birth rate	%	58%	67%
Mortalidad jovenes	Mortality rate juveniles	%	8%	7%
Mortalidad sub-adultos	Mortality rate sub-adults	%	3%	2%
Mortalidad adultos	Mortality rate adults	%	3%	2%
Peso promedio hembras joven	Avg weight female juveniles	kg/head	135	140
Peso promedio machos joven	Avg weight male juveniles	kg/head	135	140
Peso promedio hembras sub-adultas	Avg weight female sub-adults	kg/head	325	330
Peso promedio machos sub-adultos	Avg weight male sub-adults	kg/head	305	325
Peso promedio hembras adultas	Avg weight female adults	kg/head	345	360
Peso promedio machos adultos	Avg weight male adults	kg/head	480	490
Tasa de decuento	**Discount rate**	%	6%	6%

SELLING PRICES			BAU	SCR
Leche	Milk	$/l	696	696
Queso	Cheese	$/kg	7750	7750
Yogurt	Yogurt	$/l		
Precio de venta ganado	Cattle selling price	$/kg	4341	4341
PRODUCTIVITY			**BAU**	**SCR**
Producción leche	Milk production	l/head/day	3.7	4.8
Venta de leche	Milk sales	% milk	76%	78%
Venta de queso	Cheese sales	% milk	24%	22%
Venta de yogurt	Yogurt sales	% milk	0%	0%
Venta hembras joven	Sale female juveniles	% total heads	2%	3%
Venta machos joven	Sale male juveniles	% total heads	23%	50%
Venta hembras sub-adultas	Sale female sub-adults	% total heads	22%	20%
Venta machos sub-adultos	Sale male sub-adults	% total heads	5%	8%
Venta hembras adultas	Sale female adults	% total heads	7%	9%
Venta machos adultos	Sale male adults	% total heads	4%	8%
VARIABLE COSTS OF PRODUCTION			**BAU**	**SCR**
Vacunas y medicamentos - cantidad	Vaccines and drugs - quantity	unit/head/year	16	16
Vacunas y medicamentos - costo	Vaccines and drugs - cost	$/unit	2240	2240
Alimentos - cantitad	Feed - quantity	kg/head/year	32	32
Alimentos - costo	Feed - cost	$/kg	3095	3095
Trabajo finca - cantitad	Labour farm - quantity	days/year	3.6	5.5
Trabajo finca - costo	Labour farm - cost	$/days	23516	22424
Trabajo ganado - cantitad	Labour herd - quantity	days/year	1.1	1.8
Trabajo ganado - costo	Labour herd - cost	$/days	24543	21222
Transporte - costo	Transport - cost	$/kg	30	30
FIXED COSTS OF PRODUCTION			**BAU**	**SCR**
Costos fijos	Fixed costs	$/month		
Mantenimientos	Maintenance	$/month		

Figure 6: Overview of the tool dashboard

(B) Characteristics of the herd

Figure 7 shows details of the dashboard section regarding the basic characteristics of the herd, with example values for parameters.

CHARACTERISTICS OF THE HERD			BAU	SCR
Hembras joven	Female juveniles	n	3	4
Machos joven	Male juveniles	n	3	3
Hembras sub-adultas	Female sub-adults	n	7	10
Machos sub-adultos	Male sub-adults	n	3	5
Hembras adultas	Female adults	n	6	6
Machos adultos	Male adults	n	1	1
Natalidad	Birth rate	%	58%	67%
Mortalidad jovenes	Mortality rate juveniles	%	8%	7%
Mortalidad sub-adultos	Mortality rate sub-adults	%	3%	2%
Mortalidad adultos	Mortality rate adults	%	3%	2%
Peso promedio hembras joven	Avg weight female juveniles	kg/head	135	140
Peso promedio machos joven	Avg weight male juveniles	kg/head	135	140
Peso promedio hembras sub-adultas	Avg weight female sub-adults	kg/head	325	330
Peso promedio machos sub-adultos	Avg weight male sub-adults	kg/head	305	325
Peso promedio hembras adultas	Avg weight female adults	kg/head	345	360
Peso promedio machos adultos	Avg weight male adults	kg/head	480	490

Group 1

Group 2

Group 3

Figure 7: Dashboard detail - herd characteristics

Users can enter information, which can be differentiated to reflect changes between BAU and SCR systems, related to:

- Number of cattle heads present in the herd for six different age-sex classes: juveniles females and males (0-12 months), sub-adults females and males 13-36 months), and adults females and males (>36 months) (Group 1 in red in Figure 7).
- Herd demographic rates, that is the percentage of females at birth and the mortality rates for three age classes (Group 2 in green in Figure 7).
- The current average weight in kilograms per cattle head for the six different age-sex classes (Group 3 in blue in Figure 7).

(C) Selling prices and productivity

Figure 8 shows details of the dashboard section regarding the revenues from cattle ranching production, with example values for parameters. Here is considered that cattle ranching production is related to dairy products like milk, cheese and yogurt, and to direct sales of whole animals (for meat production). Users can enter information, which can be differentiated to reflect differences in BAU and SCR systems, related to:

- Prices for selling dairy products and animals expressed as COL$ per litre or kilogram (in the example Figure 8, prices are assumed to be the same for all the BAU and SCR farms) (Group 1 in red in Figure 8).
- Milk productivity expressed in litres per head per day and the percentage of the total quantity of milk produced that is sold as raw milk or used in the production of cheese or yogurt (Group 2 in blue in Figure 8).
- Sales of cattle expressed as the average percentage of the total cattle heads sold each year for each of the six age-sex classes considered (Group 3 in green in Figure 8).

SELLING PRICES				BAU	SCR
Leche	Milk		$/l	696	696
Queso	Cheese	Group 1	$/kg	7750	7750
Yogurt	Yogurt		$/l		
Precio de venta ganado	Cattle selling price		$/kg	4341	4341
PRODUCTIVITY				**BAU**	**SCR**
Producción leche	Milk production		l/head/day	3.7	4.8
Venta de leche	Milk sales	Group 2	% milk	76%	78%
Venta de queso	Cheese sales		% milk	24%	22%
Venta de yogurt	Yogurt sales		% milk	0%	0%
Venta hembras joven	Sale female juveniles		% total heads	2%	3%
Venta machos joven	Sale male juveniles		% total heads	23%	50%
Venta hembras sub-adultas	Sale female sub-adults	Group 3	% total heads	22%	20%
Venta machos sub-adultos	Sale male sub-adults		% total heads	5%	8%
Venta hembras adultas	Sale female adults		% total heads	7%	9%
Venta machos adultos	Sale male adults		% total heads	4%	8%

Figure 8: Dashboard detail - farm production

(D) Variable and fixed costs of production

Figure 9 provides details of the dashboard section regarding the costs of cattle ranching production, with example values for parameters. Depending on the cost typology, quantities and monetary costs are automatically multiplied for the number of cattle heads or for the extent of the grazing area to derive the total costs in the CBA.

VARIABLE COSTS OF PRODUCTION			BAU	SCR
Vacunas y medicamentos - cantidad	Vaccines and drugs - quantity	unit/head/year	16	16
Vacunas y medicamentos - costo	Vaccines and drugs - cost	$/unit	2240	2240
Alimentos - cantitad	Feed - quantity	kg/head/year	32	32
Alimentos - costo	Feed - cost	$/kg	3095	3095
Trabajo finca - cantitad	Labour farm - quantity	days/year	3.6	5.5
Trabajo finca - costo	Labour farm - cost	$/days	23516	22424
Trabajo ganado - cantitad	Labour herd - quantity	days/year	1.1	1.8
Trabajo ganado - costo	Labour herd - cost	$/days	24543	21222
Transporte - costo	Transport - cost	$/kg	30	30
FIXED COSTS OF PRODUCTION			BAU	SCR
Costos fijos	Fixed costs	$/month		
Mantenimientos	Maintenance	$/month		

Figure 9: Dashboard detail - farm costs

Users can enter information, which can be differentiated to reflect changes between BAU and SCR systems, related to:

- Average quantity (expressed as units per cattle head per year) and unitary cost of the vaccines and drugs used in herd management.
- Average quantity (expressed as kilograms per cattle head per year) and unitary cost of the feed for cattle.
- Average quantity (expressed in working days per year) and daily cost of labour. Labour is grouped into two categories: labour needed in farm management (e.g. sowing, pastures control, purchase of inputs, etc.) and labour needed for cattle management (e.g. feeding, milking, etc.).
- Average cost of transport expressed as COL$ per kilogram of input purchased or cattle heads sold.
- Fixed costs expressed as total fixed costs per month needed for e.g. general administration, electricity, veterinary services, etc.

(E) Discount rate

Finally, users can specify different levels of the discount rate to be used in the NPV calculations, that is used to discount the future costs and benefits to the present allowing direct comparison of the financial and economic results for BAU and SCR implementation. In Figure 3, the discount rate is specified to be equal to 6%.

5.2 'Results'

Once parameters are entered by users, the second part of the spreadsheet tool shows a summary of the results from the extended CBA for the BAU and the SCR implementation. As shown in Figure 10, the summary reports NPV per hectare for the BAU system, the SCR implementation, and the difference between the two. NPV are reported for the whole 1-20 years time frame, for the medium term (1-10 years) and for the long term (11-20 years). The NPV are calculated for:

- **Profits from ordinary cattle ranching activities** – calculated as revenues from farm outputs minus variable and fixed costs of production. In the case of SCR systems, specific maintenance costs for enhanced pastures, intensive silvo-pastoral, and restoration/reforestation are included.
- **Economic benefits including only net GHG emissions**[8] – calculated as the sum of farm profits and the economic value of the net GHG emissions.
- **Economic benefits including both net GHG emissions and additional soil nutrients** – calculated as the sum of farm profits, the economic value of the net GHG emissions, and the economic value of the additional soil nutrients[9] in SCR systems.

For the calculation of economic benefits of GHG net emissions, three monetary values are used: Colombian Carbon Tax (CCT), Colombian Social Cost of Carbon (CSCC), and US EPA Social Cost of Carbon (EPASCC).

[8] GHG emissions are calculated only for cattle ranching activities, we do not consider the forestry activity.
[9] The value of additional soil nutrients is calculated considering the equivalent quantity of fertilizers needed to achieve the new nutrient levels, and the associated cost.

BAU — SCR — BAU - SCR

CBA Summary

Net Present Value - Business As Usual

Farm Business profit (net initial investment) — Cattle ranching profits	Net Present Value medium term		1,329,487.65
	Net Present Value long term		1,126,511.12
	Net Present Value total years 1-20		1,958,525.58
Net Economic Benefits (Net GHG only) — Extended economic benefits with only GHG net emissions (CCT, CSCC, and EPASCC values used in NPV calculations)	Net Present Value medium term	CCT	1,256,978.32
	Net Present Value long term	CCT	1,054,001.80
	Net Present Value total years 1-20	CCT	1,845,527.42
	Net Present Value medium term	CSCC	1,224,740.97
	Net Present Value long term	CSCC	1,021,764.44
	Net Present Value total years 1-20	CSCC	1,795,288.90
	Net Present Value medium term	EPASCC	694,977.48
	Net Present Value long term	EPASCC	492,000.96
	Net Present Value total years 1-20	EPASCC	969,708.25
Net Economic Benefits (Total) — Extended economic benefits with GHG net emissions and additional soil nutrients (CCT, CSCC, and EPASCC values used in NPV calculations)	Net Present Value medium term	CCT	1,256,978.32
	Net Present Value long term	CCT	1,054,001.80
	Net Present Value total years 1-20	CCT	1,845,527.42
	Net Present Value medium term	CSCC	1,224,740.97
	Net Present Value long term	CSCC	1,021,764.44
	Net Present Value total years 1-20	CSCC	1,795,288.90
	Net Present Value medium term	EPASCC	694,977.48
	Net Present Value long term	EPASCC	492,000.96
	Net Present Value total years 1-20	EPASCC	969,708.25

Net Present Value - Sustainable Cattle Ranching

Farm Business profit (net initial investment)	Net Present Value medium term		- 261,069.82
	Net Present Value long term		- 609,528.74
	Net Present Value total years 1-20		- 601,427.49
Net Economic Benefits (Net GHG only)	Net Present Value medium term	CCT	- 184,489.02
	Net Present Value long term	CCT	- 450,274.30
	Net Present Value total years 1-20	CCT	- 435,919.84
	Net Present Value medium term	CSCC	- 150,441.50
	Net Present Value long term	CSCC	- 379,470.43
	Net Present Value total years 1-20	CSCC	- 362,335.81
	Net Present Value medium term	EPASCC	409,068.77
	Net Present Value long term	EPASCC	784,065.15
	Net Present Value total years 1-20	EPASCC	846,886.65
Net Economic Benefits (Total)	Net Present Value medium term	CCT	208,607.32
	Net Present Value long term	CCT	20,064.74
	Net Present Value total years 1-20	CCT	219,811.37
	Net Present Value medium term	CSCC	242,654.83
	Net Present Value long term	CSCC	90,868.61
	Net Present Value total years 1-20	CSCC	293,395.39
	Net Present Value medium term	EPASCC	802,165.11
	Net Present Value long term	EPASCC	1,254,404.20
	Net Present Value total years 1-20	EPASCC	1,502,617.86

Net Present Value - Difference SCR vs BAU

Farm Business profit (net initial investment)	Net Present Value medium term		- 1,590,557.47
	Net Present Value long term		- 1,736,039.86
	Net Present Value total years 1-20		- 2,559,953.06
Net Economic Benefits (Net GHG only)	Net Present Value medium term	CCT	- 1,441,467.33
	Net Present Value long term	CCT	- 1,504,276.10
	Net Present Value total years 1-20	CCT	- 2,281,447.25
	Net Present Value medium term	CSCC	- 1,375,182.47
	Net Present Value long term	CSCC	- 1,401,234.88
	Net Present Value total years 1-20	CSCC	- 2,157,624.71
	Net Present Value medium term	EPASCC	- 285,908.71
	Net Present Value long term	EPASCC	292,064.19
	Net Present Value total years 1-20	EPASCC	- 122,821.59
Net Economic Benefits (Total)	Net Present Value medium term	CCT	- 1,048,371.00
	Net Present Value long term	CCT	- 1,033,937.06
	Net Present Value total years 1-20	CCT	- 1,625,716.05
	Net Present Value medium term	CSCC	- 982,086.13
	Net Present Value long term	CSCC	- 930,895.83
	Net Present Value total years 1-20	CSCC	- 1,501,893.50
	Net Present Value medium term	EPASCC	107,187.62
	Net Present Value long term	EPASCC	762,403.24
	Net Present Value total years 1-20	EPASCC	532,909.61

Figure 10: Results detail - NPV calculation and comparison

Graphical results are also reported providing the yearly trend of business profits per hectare and total economic benefits per hectare for the BAU and SCR implementation over the 20 years considered in the extended CBA (Figure 11).

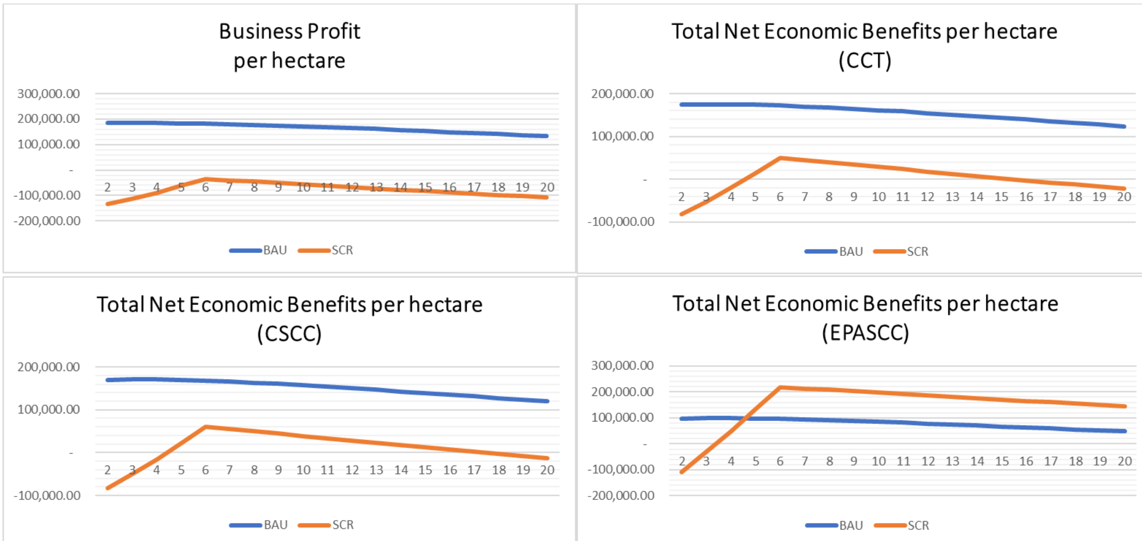


Figure 11: Results detail - profits and economic benefits

Finally, the graphical results compare the evolution of the NPV per hectare/overtime in order to assess the possible financial and economic break-even point of the SCR investment (Figure 12).

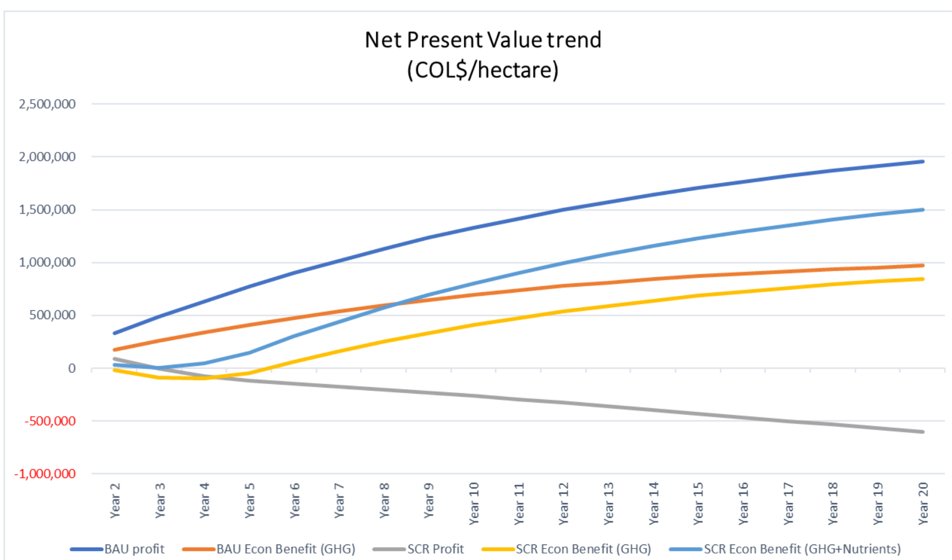


Figure 12: Results detail - trend of the NPV

6 Conclusion

The development of flexible tools for the evaluation of sustainable cattle ranching practices is crucial in informing national and local sustainability policies and empowering stakeholders towards a more in-depth understanding of the corresponding effects on the sector. The interactive spreadsheet tool presented in this User's Manual, by enabling an economic assessment of sustainable cattle ranching implementations, is developed to that aim.

The tool allows to derive and compare costs and benefits of implementing sustainable cattle ranching practices vis-à-vis business as usual extensive cattle ranching. The tool includes business profits from cattle ranching activities and economic values of two relevant ecosystem services provided by sustainable practices, namely reduction of GHG net emissions and additional soil nutrients. The comparison between the business as usual extensive system and the sustainable practices is performed through the calculation of net present values over a period of 20 years.

The structure of the tool, with an interactive dashboard where relevant information on cattle ranching activities and sustainable systems implementation are entered and a result section which includes graphical representation of net present values, is developed to facilitate its use by a range of stakeholders. Policy makers, practitioners, and researches can use the tool to evaluate the impact of policies fostering sustainable cattle ranching practices and inform the development of financial instruments such as carbon markets, payment for ecosystem services, monetary incentives. On the other hand, regional and local farmers associations and individual farmers, subject to data availability, can use the tool to assess the feasibility and economic profitability of sustainable systems implementation at the farm level. The tool allows for both forecasting the impact of future, potential interventions and assessing differences between actual implementer versus non-implementer farms.

Contacts

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