Economic benefits of sustainable, forage-based cattle systems in Colombia and Nicaragua

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Abstract

Forage-based cattle systems play a key role in rural economies of developing countries in terms of food security and poverty alleviation, particularly in tropical Latin America. However, they are often related to being a major cause of negative environmental impacts by contributing to increased greenhouse gas emissions, land degradation, and the reduction of biodiversity. Significant resources have been allocated to research and development in forage material improvement, including selection and breeding. A broad range of improved materials were released by private and public sector actors showing superior characteristics in terms of productivity and environmental impacts compared to native or naturalized materials. Profitability is a fundamental attribute to incentivize or generate adoption of new systems by cattle producers, but this information is often not available to the livestock producer or the extension agents supporting decision-making processes. This research provides an overview on the economic viability of integrating different improved forage varieties in sustainably intensified cattle production systems in Colombia and Nicaragua. Our evaluations show that, despite higher establishment and management costs, integrating improved forage technologies (and management practices) in sustainably intensified cattle systems, either as monoculture, grass-legume associations, silvo-pastoral systems, or in combination with improved management strategies (e.g., intensive, or rotational grazing), not only make sense from the environmental and productive perspectives but also in terms of economic viability. In nearly all evaluated scenarios, the economic indicators improve by integrating improved forage technologies. Strong increases were observed for the following indicators: a) net income, b) unit profit margin, c) Net Present Value, d) Internal Rate of Return, and f) benefit-cost ratio. Strong decreases were observed for the following indicators: a) unit production cost, b) risk of obtaining economic loss, c) payback time, d) minimum area required for a profitable system, and e) sensitivity of the system to external shocks. This information will help cattle producers, extensionists and policymakers to make more holistic and informed land-use decisions that include productive, environmental, economic, and social benefits, and by this contributes to the broader adoption of more sustainable production systems.

Introduction

Improving both quality and availability of cattle feed in the tropics is of the main strategies to increase productivity and reduce the sector's environmental impacts (Herrero et al., 2013; Peters et al., 2012). Over the last decades, high amounts of research and development funds have been allocated to improve forage germplasm leading to the release of different forage cultivars and hybrids (e.g., *Brachiaria* hybrid cvs. Mulato, Mulato II, Caimán, Cobra) (Peters et al., 2011; Pizarro et al., 2013). According to agronomic evaluations, those cultivars are superior in terms of forage quality, forage availability, and adaptation to different soil and climatic conditions, and provide numerous environmental benefits (Peters et al., 2012; Rao et al., 2015).

The success of technology development takes however only place when the end-users (cattle producers) efficiently use the technologies. Although there exist only few studies that document the adoption and impacts of improved forage technologies, the findings show persistently low adoption levels of new forage technologies in the tropics (White et al., 2013; Labarta et al., 2017; Enciso et al., 2022). In Colombia for example, planted forages are being used on ~62% of the total pasture area in the lower tropics (Labarta et al., 2017) – a figure that seems high only at a first glance, since many of these areas are in some state of degradation (IDEAM & U.D.C.A., 2015), showing the lack of constant adoption of new cultivars. For *Brachiaria* hybrids, for example, the adoption rate is less than 1% (Labarta et al., 2017) – despite commercialization for more than 20 years (Enciso et al., 2022; Burkart, 2022; Enciso et al., 2021e; Hurtado et al., 2021).

When it comes to new technologies, land-use and adoption decisions by the cattle producer are mainly based on the profitability promises that the technology can generate (Pannell et al., 2006). Profitability is a fundamental attribute to incentivize or generate adoption but, in many cases, information is not available to the cattle producer or the extension agent supporting decision-making processes. Profitability is, however, not the only measure since other elements exist that contribute to adoption decision-making, such as cultural, behavioral, or environmental factors (e.g., Triana et al., 2022; Campuzano et al., 2022; Enciso et al., 2020b; Enciso et al., 2019b).

In this sense, the objective of our study is to provide an overview on the economic viability of integrating different improved forage varieties in sustainably intensified cattle production systems in Latin America, using as examples studies from Colombia and Nicaragua.

Methods and Study Site

Over the last five years, several economic evaluations on integrating improved forage varieties in sustainably intensified cattle production systems were conducted by the Alliance of Bioversity and CIAT in Latin America. The aim of these analysis was to provide cattle producers, extensionists, and policymakers with economic viability indicators that help in land-use and adoption decision-making processes. In a first step, a basic methodology for the economic analysis of forage-based cattle systems was developed (Burkart and Enciso, 2017), which then was adjusted to and applied in several case studies in Colombia and Nicaragua. Several production systems were evaluated, i.e., dual-purpose production, calf fattening, and specialized milk production, which integrate improved forages in different setups, such as grass monocultures, silvo-pastoral systems, grass-legume associations, or as silage. In some contexts, forage interventions were coupled with management strategies, such as intensive rotational grazing. In each case, the improved systems were compared with the most prominent traditional systems (base scenario). Table 1 gives a brief overview on some examples of the evaluated technologies and the traditional scenarios used for comparison for Colombia.

Table 1. Some examples of evaluated interventions in Colombia

Colombia – Orinoco Region (see Enciso et al., 2021c; Rincón et al., 2020)			
Scenario	**Traditional scenario**	**Intervention scenario**	
System	Dual-purpose milk system		
Evaluated technologies	Grass monoculture: *Brachiaria humidicola* cv. Humidicola	Grass-legume association: *Arachis pintoi* CIAT 22160 cv. Centauro + *Brachiaria humidicola* cv. Humidicola	
Colombia – Orinoco Region (see Enciso et al., 2021b)			
Scenario	**Traditional scenario**	**Intervention scenario**	
System	Cattle raising and fattening		
Evaluated technologies	Grass monoculture: *Brachiaria decumbens*	Grass monoculture: *Brachiaria brizantha* 26124 cv. Agrosavia Caporal	
Colombia – lower-altitude tropics (0-1,200 m elevation) (see Enciso et al., 2019)			
Scenario	**Traditional scenario**	**Intervention scenario**	
System	Cattle fattening		
Evaluated technologies	Grass monoculture: *Brachiaria* hybrid cv. Cayman	Grass-legume association/silvo-pastoral system: *Brachiaria* hybrid cv. Cayman + *Leucaena diversifolia* ILRI 15551	
Colombia – Orinoco Region (see Burkart et al., 2017)			
Scenario	**Traditional scenario**	**Intervention scenarios**	
System	Cattle fattening		
Evaluated technologies	Grass monoculture: Native Savanna species such as *Axonopus purpussi*	Grass monoculture – improved pastures: *Brachiaria humidicola, Brachiaria decumbens*	Silvo-pastoral system: Improved pastures such as *Brachiaria humidicola, Brachiaria decumbens* associated with shadow trees
Colombia – high-altitude tropics (>2,200 m elevation) (see Enciso et al., 2021a; Enciso et al., 2020a; Gallo-Caro et al., 2022)			
Scenario	**Traditional scenario**	**Intervention scenarios**	
System	Specialized milk production		
Evaluated technologies	Grass monoculture: *Cenchrus clandestinus*	Silage-grazing diet: 65% *Cenchrus clandestinus* + 35% *Avena sativa* AV25-T cv. Altoandina	Silage-grazing diet: 35% *Cenchrus clandestinus* + 65% *Avena sativa* AV25-T cv. Altoandina

The economic analyses were based on a discounted cash flow model and the estimation of profitability indicators, such as the Net Present Value (NPV), Internal Rate of Return (IRR), and the probability of success of an investment (NPV<0). For this purpose, we applied a Monte Carlo simulation model which performed 5,000 iterations with a confidence level of 95% for each of the evaluated systems. Sensitivity analyses were incorporated to evaluate the influence of critical variables (e.g., price and yield fluctuations) on profitability. The economic indicators help in comparing different investment projects and choosing the best alternative.

Results

Colombia

In the Colombian Orinoco region, several production systems were evaluated (see Table 1). The results show that economic indicators significantly improve when the traditional grass monoculture system with *Brachiaria humidicola* cv. Humidicola gets transformed into a grass-legume association with *Arachis pintoi* CIAT 22160 cv. Centauro in a dual-purpose milk system (Enciso et al., 2021c; Rincón et al., 2020). The net income of the system, milk profit margin, Net Present Value (NPV) and Internal Rate of Return (IRR) all increase, while the unit cost of milk and calf production and the risk of obtaining economic loss decrease. The system also becomes less sensitive to changes in milk productivity. In cattle raising and fattening systems, the transformation from a grass monoculture with *Brachiaria decumbens* to a grass monoculture with *Brachiaria brizantha* 26124 cv. Agrosavia Caporal leads to increased net system income, increased NPV and IRR, while the unit cost of beef production decreases (Enciso et al., 2021b). The system itself becomes less sensitive to beef market prices. In another evaluation for cattle fattening systems, we focused on the transformation from a grass monoculture with native savanna (*Axonopus purpussi*) to a grass monoculture with the improved forages *Brachiaria humidicola* and *Brachiaria decumbens* on the one hand, and to a silvo-pastoral system with the same forages and associated shadow trees on the other hand (Burkart et al., 2017). In both intervention scenarios, the economic indicators improve compared to the traditional scenario. Nevertheless, from an economic point of view, it makes more sense investing in the improved grass monoculture than the silvo-pastoral system, since the economic viability indicators show a significantly better performance for this case. Both the NPV and the IRR increase substantially and the risk of obtaining economic loss decreases.

In a specialized milk production system in the Colombian high-altitude tropics (>2,200 m elevation), we evaluated the inclusion of silage supplementation (*Avena sativa* AV25-T cv. Altoandina) in two different percentages (35 and 65% of the total diet) in a grass monoculture grazing system with *Cenchrus clandestinus* (Enciso et al., 2021a; Enciso et al., 2020a). Although both evaluated supplementation diets are economically viable, especially when compared to the grass monoculture, the diet with only 35% silage supplementation shows the best economic performance: it more than doubles the net income of the system, increases the unit profit margin, more than doubles the NPV and increases the IRR when compared to the grass monoculture. At the same time, the unit cost of milk production is reduced, the risk of obtaining economic loss drops to 0%, and the system becomes less sensitive to milk productivity indicators. The production of silage also provides business opportunities for rural youth (Gallo-Caro et al., 2022).

Showcase: The establishment of a silvo-pastoral system in the Colombian lower-altitude tropics

The profitability of including *Leucaena diversifolia*, accession ILRI 15551, in a Colombian beef cattle production system was evaluated (Enciso et al., 2019a). The evaluation was based on data from a grazing experiment comparing a grass-legume association/silvo-pastoral system (*Brachiaria* hybrid cv. Cayman and *Leucaena diversifolia*) with a traditional grass monoculture (*Brachiaria* hybrid cv. Cayman) in the Colombian lower-altitude tropics (0-1,200 m elevation), both with the purpose of beef production. A discounted cash flow model was used, developed with the simulation software @Risk, which considers inherent risk and uncertainty factors in these types of rural investment projects, under three different pasture degradation scenarios.

The results indicate that the inclusion of *Leucaena diversifolia* is financially profitable and substantially improves the associated risk and performance indicators. Profitability indicators increase in a range of 15-110%, and the probability of obtaining economic loss decreases from 72 to 0% (Table 2). The results are directly related to increases in animal productivity (49%) and efficiency resulting from including the legume. This shows that *Leucaena diversifolia* has significant potential to increase both animal production and profitability, which is conducive to the sustainable intensification of beef production in grazing systems.

Table 2. Establishing a silvo-pastoral system in Colombia – economic indicators

Colombia – lower-altitude tropics (0-1,200 m elevation) (see Enciso et al., 2019)		
Scenario	**Base scenario**	**Intervention scenario**
Evaluated technologies	Grass monoculture: *Brachiaria* hybrid cv. Cayman	Grass-legume association/silvo-pastoral system: *Brachiaria* hybrid cv. Cayman + *Leucaena diversifolia* ILRI 15551

Net income system (US$ ha^{-1} y^{-1})	356	695
Unit cost of beef production (US$ kg^{-1})	1.2	1.21
NPV (US$)	(473)-(288)	1,716-2,055
Prob NPV<0 (%)	72	0
IRR (%)	10-11	21-22
Payback period (years)	6	4
B/C ratio	0.96-0.98	1.12-1.13
Minimum area required to have a profitable system (ha)	6.54	3.76
Sensitivity	n/a	Reduced sensitivity to beef sales price
SUGGESTED DECISION	REJECT BASE SCENARIO	ADOPT INTERVENTION

Nicaragua

In Nicaragua, we evaluated a mix of integrating improved forage technologies and management strategies in a milk and calf fattening system at different farm scales (smallholder, medium-, and large-scale) in different regions of the country (Enciso et al., 2021d). The evaluations comprised the reduction of the overall pasture area, mainly through reducing the use of naturalized improved pastures, the introduction of cut-and-carry forages, protein banks, and living fences, as well as intensive rotational grazing. A side effect of the presented intervention scenarios is the maintenance or increase of the farm forest area. In the "Vía Láctea" (the Nicaraguan milkyway) and the "Dry Corridor" regions, the suggested interventions lead to increases in the net income of the system, higher unit profit margins, higher NPV and IRR, for all evaluated farm types. At the same time, the unit cost of milk production decrease to 30-50% of the costs associated with the traditional production system.

Discussion [Conclusions/Implications]

The results of our evaluations show that by integrating improved forages, either as monoculture, grass-legume associations, silvo-pastoral systems, or in combination with improved management strategies (e.g., intensive, or rotational grazing), cattle producers can increase the resilience of their systems, reduce their vulnerability to external shocks and increase their livelihoods. In particular, integration helps to: a) increase the net income of the production system; b) reduce unit production costs, so a liter of milk or a kilogram of meat can be produced cheaper; c) increase unit profit margins, so the profit per liter of milk or kilogram of meat produced is higher; d) increase the Net Present Value to ensure the investment is economically viable; e) increase the Internal Rate of Return so that profitability is increased; f) reduce the risk of obtaining economic losses to ensure economic security is provided; g) increase the benefit-cost ratio above one, so that for every dollar invested, more than one dollar will be returned; h) reduce the payback time, so the system generates economic gains earlier; i) reduce the minimum area required for a profitable system, which means that less area is needed for obtaining the same results and that the remaining area can be used for other purposes (e.g., environmental protection or crop cultivation); and j) reduce the sensitivity of the system to external shocks such as price and yield fluctuations.

System resilience and reduced vulnerability become even more relevant when climate change is considered since traditional production systems are more vulnerable to seasonal forage biomass availability, which is strongly influenced by drought or excessive water availability. The integration of improved forages helps to counteract this and to achieve a more stable productivity throughout the year. Likewise, improved forages are more resistant to pests and diseases that can cause productivity declines and affect economic returns. By integrating improved forages, the land used for beef and dairy production can be reduced because of higher productivity, without a reduction in economic returns. This provides new possibilities, e.g., for afforestation, conservation, or crop cultivation, which can help to mitigate climate change, increase biodiversity, and reduce hunger, among others. Improved forages also provide numerous ecosystem services that could be monetized and further increase the economic viability of the systems (Diaz et al., 2021), as preliminary results of a new study in Colombia suggest (Sandoval et al., 2022). We recommend including potential ecosystem services into future economic evaluations of tropical forage-based cattle systems in Latin America since this is also gaining importance in the political debate (Lerma et al., 2022).

Providing cattle producers with information on economic viability is a first step towards overcoming technology adoption barriers. However, for broader adoption to occur, providing this type of information on its own is not sufficient; improvements in the framework conditions are also needed. The establishment of such systems should be accompanied by specific training and extension programs, which in many cases would need to be developed, to overcome the lack of knowledge and experience in the use of tropical forage legumes. This should reduce uncertainties associated with technology adoption and increase adoption rates. At the same time, the access to and structure of necessary financial resources (e.g., credits), as well as the availability and access to seed or vegetative material, need to be improved to provide the necessary resources for technology adoption. This holds true especially for Colombia, where credit schemes do not respond to the producer reality (i.e., no credits available for pasture improvement, too short grace periods in livestock credits) and where a well-functioning legume seed system is non-existent.

In general, economic evaluations of interventions in tropical cattle systems are still scarce. They are important, however, when it comes to adoption decision-making. It is thus essential that these studies are extended and included from the start in research projects dealing with the selection or breeding of improved forages and their introduction into cattle systems.

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