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Article

Evaluación financiera y económica de un sistema silvopastoril intensivo bajo riego

Financial and economic evaluation of an intensive low-irrigation silvopastoral system

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Resumen

Los sistemas silvopastoriles son importantes para la sustentabilidad ambiental y económica de los productores que los utilizan. Por lo anterior, el objetivo de este trabajo fue evaluar la rentabilidad financiera y económica del sistema silvopastoril intensivo *Leucaena leucocephala* en asociación con pradera bermuda cruza dos (*Cynodon dactylon*), bajo riego en la producción de becerros de engorda en el sur de Sinaloa; a fin de contribuir con información a la sustentabilidad productiva, económica y ambiental en regiones tropicales. Mediante el seguimiento de información técnica y económica a una unidad de producción de 20 ha ubicadas en el sur de Sinaloa, durante 3 años se realizó una evaluación financiera y económica, en la que se consideró el pago por servicio ambiental de captura de carbono del sistema silvopastoril intensivo (SSPi). Se aplicó la metodología del análisis financiero, en el cual se estimaron los tres principales indicadores que se utilizan en la evaluación de proyectos: Valor Actual Neto (VAN), Tasa Interna de Rentabilidad (TIR) y Relación Beneficio Costo (R B/C). En un horizonte de 10 años de planeación, el SSPi es rentable; ya que presenta un VAN de $7 605 792.14, una TIR de 27.9 % y una R B/C de 1.21 en la evaluación financiera, y de 1.24 en la económica. Los resultados de la presente investigación muestran que es factible desarrollar becerros en SSPi de manera rentable y sustentable, por lo que se requiere mayor apoyo institucional para difundir, promover y apoyar estos sistemas silvopastoriles en las regiones tropicales.

Palabras Clave: Carbono, componentes tecnológicos, gases efecto invernadero, ganado bovino, sustentabilidad, trópico.

Abstract

Silvopastoral systems have proved to be important for the environmental and economic sustainability of the producers who carry them out. Therefore, the aim of this work was to evaluate the financial and economic profitability of the intensive silvopastoral system *Leucaena leucocephala* in association with cross-bred *Bermuda* grass (*Cynodon dactylon*) under irrigation in the production of beef calves in Southern *Sinaloa*, in order to contribute information to productive, economic and environmental sustainability in tropical regions. By following up on the technical and economic information regarding a 20-ha production unit in southern *Sinaloa* for 3 years, a financial and economic evaluation was carried out considering the payment for the carbon sequestration environmental service provided by the intensive silvopastoral system (ISS). The financial analysis methodology was used, in which the three main indicators used in the evaluation of projects were estimated: Net Current Value (NCV), Internal Rate of Return (IRR) and Cost Benefit Ratio (CBR). In a time frame of 10 years of planning, the ISS is profitable, as it exhibits a NCV of 7 605 792.14 MXN, an IRR of 27.9 % and a CBR of 1.21 in the financial evaluation, and of 1.24 in the economic evaluation. The results of the present research show that calves can be developed in an ISS in a profitable and sustainable way, which is why greater institutional support is required to spread, promote and support these silvopastoral systems in tropical regions.

Key words: Carbon, technological components, greenhouse gases, cattle, sustainability, tropics.

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Introduction

Agroforestry systems (AFS) are production systems with an integrated approach that are considered viable alternatives for contributing to the productivity and sustainability of agricultural activities (Casanova-Lugo *et al.*, 2011). In general, AFS include trees among their fixed components; therefore, there can be various types of AFS: silvoagricultural (trees, plus agricultural crops), silvopastoral (trees, plus livestock), or agrosilvopastoral (trees, plus agricultural crops and livestock), among many others. The productive or topological arrangements of the AFS vary according to the environmental and geographical conditions where they are implemented, and it is this situation that requires most work by research and teaching centers to identify the appropriate components that, together with the trees, can improve productivity, environmental aspects and the welfare of rural communities.

The geographic coverage of AFS at the global, regional and national levels is significant; for example, Nair *et al.* (2009) estimated a total of 1 023 million hectares under AFS globally; about 63 % of these are silvopastoral systems (SSP), and the rest are other agroforestry arrangements. FAO (2017) states that agroforestry is practiced by more than 1.2 billion people worldwide.

AFS contribute to improve food security by providing direct supply ecosystem services, as well as others that are not supply related (HLPE, 2017). In addition, the trees used in the AFS act as carbon sequestrators (Pandey, 2002; Casanova-Lugo *et al.*, 2011), contributing in this wat to the environmental sustainability of the territories where they are placed. Reportedly, the amount of carbon fixed in intensive silvopastoral systems (ISS) depends on multiple interactions between the components that make it up: tree, grass, soil, and animals (Shibu, 2009).

SSP have been widely studied (Ávila *et al.*, 2001; Alonso, 2011; Anguiano *et al.*, 2013; Murgueitio *et al.*, 2014; Arciniegas-Torres and Flórez-Delgado, 2018). They constitute an alternative for livestock production systems in the tropics, since they offer a greater availability of food for livestock, which is transformed into more meat and milk production, and they also provide multiple environmental benefits, such as: sequestration of CO_2, nitrogen fixation, reduction of greenhouse gases (GHG), increase in the content of organic matter, climate improvement and greater diversity compared to traditional monocultures (Bacab *et al.*, 2013).

In Colombia, the ISS are a technological option for gradual implementation, and reportedly they "can reduce the seasonality of plant and animal production; therefore, they can mitigate the effects of climate change and adapt to them (Cuartas *et al.*, 2014).

There are multiple experiences of agroforestry management in Mexico, with dual-purpose cattle (Bacab and Solorio, 2011; Absalón-Medina *et al.*, 2012; Bacab *et al.*, 2013), in addition to several productive and economic evaluations (González, 2013; Estrada-López *et al.*, 2018) and the general characterization of dual-purpose systems (Cuevas-Reyes and Rosales-Nieto, 2018). However, there is still little evidence from studies on agroforestry systems that show the financial impact, or that value the economic benefits of environmental improvements due to carbon sequestration, which are obtained by implementing and adopting technological components in ISS.

Therefore, the objective of the present work was to evaluate the financial and economic profitability of the intensive silvopastoral system *Leucaena leucocephala* (Lam.) de Wit in association with Coastcross II *Bermuda* grass (*Cynodon dactylon* L.), under irrigation, in the production of beef calves in Southern *Sinaloa*, and to contribute, through this information, to the productive, economic and environmental sustainability of tropical regions.

Materials and Methods

Location of the study area

The state of *Sinaloa* is located within the Northwestern Coastal Plain, which directly borders the *Sierra Madre Occidental*. Geographically, *Sinaloa* is located in the northwest of Mexico, bordering the states of *Sonora* and *Chihuahua* to the north, *Durango* to the east, *Nayarit* to the south, and the Pacific Ocean and the Gulf of California to the west. This research was carried out in Southern *Sinaloa*, in the town of *Los Pozos*, *Rancho Las Flores*, in the *El Rosario* municipality, located between 22°47'35" to 25°30'00" N and 105°11'16" to 106°03'02" W; the climate in the area is warm sub-humid, with summer rains and marked dry seasons. The average annual temperature is 22 °C, and the average annual rainfall is 827 mm (Inegi, 2017).

Data collection instrument

The information was obtained through technical and economic monitoring on a monthly basis, on the first days of each month, and whenever the technical aspects of the components required it. The follow-up was carried out from January 2017 to November 2019. A cooperating producer and a technician from *El Rosario* helped in this activity.

The planning, implementation, monitoring and evaluation of the ISS included the following stages: 1) identification and delimitation of the ranch where the ISS was to be implemented; 2) visits to verify the establishment and management of the ISS formed by *Leucaena leucocephala* variety Cunnimghan and Coastcross II *Bermuda* grass in the months of January to June 2017; 3) visits to verify the proper functioning of the perimeter fence system and the installation of the electric fence for the division of paddocks throughout the year 2017; 4) visits for the adaptation of the production area, which amounts to 20 ha of sprinkler irrigation (it should be noted that in the study area the fresh water groundwater layer is 2 m deep); 5) visits for the design of troughs in the paddocks; 6) visit for the establishment and operation of the sprinkler irrigation system; 7) support and identification for obtaining credit for 200 calves for pre-fattening, and 8) visits for the supervision of pre-fattening management and technical assistance for the integrated management of the implemented components.

Technological components and production costs

The components that integrated the module with the ISS were the following: establishment of *Leucaena* and a Coastcross II *Bermuda* grass prairie (*Cynodon dactylon*) both managed by sprinkler irrigation system for the pre-fattening of calves, whose initial weight is approximately 180 kg, to half fattening (330 kg) in 150 days. The weight of the animals was recorded only at the beginning of grazing and at the end of the pre-fattening period. Spray irrigation was performed with 60 m diameter canyons at the stages of establishment and management of the ISS; the frequency was 7 to 10 days, with an irrigation sheet of 5 to 7 cm, a duration of 6 to 8 hours, and changing each canyon twice or thrice per day, depending on the time of year.

The land where the ISS was implemented is flat, with a sandy-textured soil with a poor organic matter content; it was previously used for producing coconut trees and, for a few years, green chili peppers.

8 kg ha^{-1} of *Leucaena* seeds were mechanically planted in furrows, which were 1.8 m wide. Weed control was mainly of wide leaf species and annual grasses. The initial population of *Leucaena* was four plants on average per linear meter, equivalent to 22 000 plants ha^{-1} (*i.e.* 5 500 linear meters by four plants).

For the establishment of the Coastcross II *Bermuda* grass prairie, the central part of those furrows that had *Leucaena* was marked and planted with vegetative material; eight days of work per hectare and 1 500 kg of vegetative material were used. This activity was carried out when *Leucaena* reached a height of 80 cm.

In order to obtain the economic information of the components of this endeavor, all the costs and revenues involved in the establishment and maintenance of the technological components were considered. The costs of establishing the ISS were accounted for during the first year, as follows:

Investment costs that included four sections: 1) land to establish the ISS; 2) establishment of *Leucaena*; 3) establishment of the prairie; and 4) development of management corrals.

The costs of establishing *Leucaena* included land preparation, planting and fertilization, pest and weed control. After its establishment, the maintenance cost for fertilization and weed control was considered from the second year. In the case of the prairie, the costs of land preparation, sowing and fertilization, pest and weed control were included. From the second year on, the maintenance costs consisted of the cost for fertilizer use and for weed control.

Other items integrated in the economic evaluation were the operating costs of the ISS, such as the concepts related to the feeding (mineral salts) of the cattle, labor, health, electricity, maintenance of equipment, fuels and lubricants, as well as the insurance of the vehicle and costs of earrings for the calves.

Data analysis

According to García (2008), the financial evaluation is of a business type and for profit; it has the objective of measuring the efficiency of the capital provided to finance a project; therefore, it determines the financial capacity, the profitability and the return on capital proposed in the investment. On the other hand, the economic evaluation consists in making a comparison between the resources used and the expected benefits, in order to determine the good allocation of resources (Rosales, 2007); in this type of evaluation, the return of the benefits and better life conditions across the society (at country level, as well as the environmental and other benefits) resulting from the investment made are determined.

The financial evaluation of the ISS was carried out using the methodology of financial analysis, in which the indicators proposed by Gittinger (1982) were estimated: Net Current Value (NCV), Internal Rate of Return (IRR), and Benefit-Cost Ratio (BCR). The evaluation considered a time horizon of 10 years. The real and risk-free discount rate utilized was 9 %, which was used by the commercial banks in the region of study during the year 2019 (Table 1). The economic assessment considered the environmental benefit of carbon sequestration of US$10 per hectare (Ávila *et al.*, 2001) (Table 2). In addition, the ISS was compared with studies conducted in Southern *Sinaloa* in order to identify other positive externalities: biodiversity, nitrogen fixation, and soil conservation. The cost of possible negative externalities (use of agrochemicals, fertilizers, contamination of water tables) was omitted in this research. However, it should be noted that with the use of *Leucaena*, a high nitrogen fixation is achieved; therefore, the use of fertilizers is reduced.

Table 1. Financial evaluation of ISS in *Sinaloa México* (2019).

Year	Income ($)	Costs ($)	Cash flow ($)	Rate (1+t)-n ($)	Updated income ($)	Updated expenses ($)
0	-	7 061 500.00	-7 061 500.00	1.00	-	7 061 500.00
1	5 662 800.00	3 782 000.00	1 880 800.00	0.92	5 195 229.36	3 469 724.77
2	5 945 940.00	3 971 100.00	1 974 840.00	0.84	5 004 578.74	3 342 395.42
3	6 243 237.00	4 169 655.00	2 073 582.00	0.77	4 820 924.47	3 219 738.71
4	6 555 398.85	4 378 137.75	2 177 261.10	0.71	4 644 009.81	3 101 583.16
5	6 883 168.79	4 597 044.64	2 286 124.16	0.65	4 473 587.44	2 987 763.59
6	7 227 327.23	4 826 896.87	2 400 430.36	0.60	4 309 419.09	2 878 120.89
7	7 588 693.59	5 068 241.71	2 520 451.88	0.55	4 151 275.27	2 772 501.78
8	7 968 128.27	5 321 653.80	2 646 474.47	0.50	3 998 934.89	2 670 758.59

9	8 366 534.69	5 587 736.49	2 778 798.20	0.46	3 852 184.99	2 572 749.10
10	8 784 861.42	5 867 123.31	2 917 738.11	0.42	3 710 820.40	2 478 336.29
Total	71 226 089.85	54 631 089.57	16 595 000.28		44 160 964.46	36 555 172.32

Note: Income obtained from two fattenings per year.

Table 2. Economic evaluation of ISS in *Sinaloa México* (2019).

Year	Income ($)	Costs ($)	Cash flow ($)	Rate (1+t)-n ($)	Updated income ($)	Updated expenses ($)
0	-	7 061 500.00	7 061 500.00	1.00	-	7 061 500.00
1	5 810 400.00	3 782 000.00	2 028 400.00	0.92	5 330 642.20	3 469 724.77
2	6 100 920.00	3 971 100.00	2 129 820.00	0.84	5 135 022.30	3 342 395.42
3	6 405 966.00	4 169 655.00	2 236 311.00	0.77	4 946 581.12	3 219 738.71
4	6 726 264.30	4 378 137.75	2 348 126.55	0.71	4 765 055.21	3 101 583.16
5	7 062 577.52	4 597 044.64	2 465 532.88	0.65	4 590 190.80	2 987 763.59
6	7 415 706.39	4 826 896.87	2 588 809.52	0.60	4 421 743.43	2 878 120.89
7	7 786 491.71	5 068 241.71	2 718 250.00	0.55	4 259 477.61	2 772 501.78
8	8 175 816.30	5 321 653.80	2 854 162.50	0.50	4 103 166.51	2 670 758.59
9	8 584 607.11	5 587 736.49	2 996 870.62	0.46	3 952 591.59	2 572 749.10
10	9 013 837.47	5 867 123.31	3 146 714.15	0.42	3 807 542.36	2 478 336.29
Total	73 082 586.79	54 631 089.57	18 451 497.22		45 312 013.12	36 555 172.32

Note: Income from potential carbon capture payment is included.

Results and Discussion

Description of the ISS

The ISS was established in an area of 20 ha, with 10 calves per hectare (1 800 kg live weight ha^{-1}) and an initial average weight of 180 kg, in a pre-fattening period of 150 days. Management included intensive rotational grazing, with paddock rotation each day and one to two days of occupation. The grazing area was 20 m^{2}, with a fodder supply of 60 kg (day/calf), and a resting period of 30 to 45 days. The animals ended up with an average weight of 330 kg. The sales price considered for a standing calf was $44.00 kg^{-1} in order to estimate the final income from the ISS.

Financial evaluation of the ISS module

Table 3 shows the fixed investment, in Mexican pesos, required for the implementation of an intensive silvopastoral (ISS) module of pre-fattening calves under the irrigation modality.

Table 3. Fixed investment for the establishment of the ISS module ($).

Concept	Unit	Number	Cost per unit	Total cost	Producer´s contribution
Land	ha	20	200 000.00	-	4 000 000.00
Leucaena	ha	20	13 740.00	274 800.00	
Prairie	ha	20	6 940.00	138 800.00	
Infrastructure				700 500.00	
Sub total				1 114 100.00	4 000 000.00
Total					5 114 100.00

Source: Prepared by the authors.

The infrastructure was depreciated at different periods of useful life: 20 years (irrigation network, electric network, management corral and scale), 15 years (perimeter fence, electric fence, electric transformer), 10 years (irrigation cannon, starter, irrigation motor pump, cattle trailer), and 5 years (feeders and drinkers). The total amount of investment was $5 114 100.00 pesos, with a 78 % contribution from the producer, since he owned the agricultural area where the ISS was implemented.

The operating costs or variable costs of the project were $1 947 400.00 Mexican pesos in 2019. These included the purchase of 200 calves of 180 kilograms per pre-fattening cycle, at a price of $7 920.00 ($44.00 kg^{-1}). The purchase of the animals amounted to 81.3 % of the costs; the second place (8.9 %) corresponded to the production of fodder; the third place, to labor and, finally, to the purchase of medicines and vaccines (Table 4).

Table 4. ISS module operating costs per cycle ($).

Concept	Unit	Number/time	Cost per unit $	Total cost
180 kg calves	Heads	200	7 920.00	1 584 000.00
Fodder*	Various	Six months	173 800.00	173 800.00
Medications**	Various	Six months	73 400.00	73 400.00
Veterinary equipment	Various	Six months	1 000.00	1 000.00
Annual labor	Daily wage	12	9 600.00	115 200.00
Operating cost				1 947 400.00

Source: Prepared by the authors; *Includes the cost of maintenance and use of *Leucaena* and Coastcross II *Bermuda* grass, as well as the provision of mineral salts;** Medications and vaccines include implants, use of internal and external de-worming, bacterine, and vitamin ADE.

Fodder production in traditional systems represented an important economic outlay for the small producer. However, in Sinaloa, approximately 5 million tons of agricultural waste are generated annually that can be used to feed livestock (López *et al.*, 2018). This abundance of waste material is more accessible to large companies, which allows them to obtain greater profits from the production of beef under the stable system, through the reduction of feed costs in the pre-fattening and fattening of their livestock.

At a 10-year period of the project, an updated income flow of $ 44 160 964.46 and an updated expenditure flow of $ 36 555 172.32 will be obtained (Table 1). In the economic evaluation, the income derived from carbon capture was included, thus obtaining an updated income flow of $ 45 312 013.12 and an updated flow of expenses of $ 36 555 172.32 (Table 2). From the financial point of view, the project is profitable with a NPV of $ 7 605 792.14, an IRR of 27.9 % and a B/C ratio of 1.21. In the same way, under the economic analysis, a NPV of $ 8 756 840.81 Mexican pesos was obtained, an IRR of 30.4 % and a RB/C of 1.24 (Table 5), that is, due to the effect of carbon capture in the SPPi, the NPV would increase by 1.1 million pesos, while the profitability of the project would increase by 2.5 %.

Table 5. ISS financial and economic evaluation indicators.

Indicator	**Financial evaluation ($)**	**Economic evaluation ($)***
NCV	7 605 792.14	8 756 840.81
IRR (%)	27.9	30.4
BCR	1.21	1.24

Source: Prepared by the authors. *Considering a catch of 35.7 t C ha^{-1} in an AFS with *Leucaena* in *Colima*, Mexico (Anguiano *et al.*, 2013) and a price of 10 US$ t^{-1} of C (Anguiano *et al.*, 2013); exchange rate used $19.68 per US$ (September 30, 2019).

The results show that the proposed ISS is profitable and generates an increase in animal productivity (gain in weight of the calves, which start at 180 kg and are sold after 150 days, with a weight of 330 kg), and therefore better income conditions for producers. In addition, if greater productivity is obtained, it has an efficient use of natural resources that is relevant to the adaptation and mitigation of the effects of climate change. In this regard, SSPs are a fundamental tool for achieving this (Buitrago-Guillen *et al.,* 2018).

Some studies indicate that, with the passage of time and as the use of ISS components increases, there is a more abundant animal production, through a greater availability of plant biomass, more leaf litter production that favors improvements in organic matter content, nutrient recycling and soil fertility (Crespo, 2008). Other authors have identified that AFSs can fix and store 12 to 228 t^{-1} C, including soil organic carbon, which represents between 20 and 46 % of the C sequestered in primary forests (Andrade and Ibrahim, 2003; Beer *et al.,* 2003).

According to the results of this research, one of the most important limiting factors for the implementation of ISS is, admittedly, the lack of available credit and public policies that encourage their establishment and use; another restriction, without a doubt, is the identification and implementation of technological components suitable for the geographical and climatic conditions where they are intended to be established. In addition, in the state of *Sinaloa* there is a high concentration and purchase of calves by beef companies, which control the production chain and ultimately set the price of standing animals throughout the year. These conditions limit the development of small farmers who start beef calf production at a small scale.

In the study region, the price of calves and livestock in general has lost 24 % of the value reached in 2015 (from \$58.00 kg^{-1} to \$44.00 kg^{-1} in 2019). In contrast, the price of the carcasses continues to rise and therefore, the price of meat to the public has also increased; all of this without generating a direct impact on the small producers who engage in this productive activity.

The production of meat with ISS, however, can be an alternative for the improvement of productivity and profitability of small producers, as well as, an alternative of environmental sustainability, in which the institutional actors (research and teaching centers and government) must have a more direct participation.

Sustainability of ISS

In the study region, there is ample experience in the generation of technology for the production of fodder (Cuevas-Reyes, 2019). One of the strategies followed is to acquire technologies through the establishment of agricultural modules. Based on three years of work, the module established with ISS in southern Sinaloa identified an environmental impact of 10 to 35.7 t of carbon sequestered per hectare, in addition to increased nitrogen fixation of up to 500 kg ha^{-1} per year; as well as greater conservation of both soil and biodiversity, and less contamination of groundwater, which in the study area is located at a depth of 2 m (Table 6).

Table 6. Sustainability of the ISS module in Southern *Sinaloa.*

Indicator	Traditional Management System $^{+}$	Intensive Silvopastoral System (ISS)*
Carbon sequestration	Mean 5-10 t ha^{-1} $year^{-1}$	High 10-35.7 t ha^{-1} $year^{-1}$
Biodiversity	Limited	Increased interaction of organisms
Nitrogen fixation	Null	200 to 500 kg ha^{-1} $year^{-1+}$
Soil Conservation	Less accumulation of organic matter	Increased accumulation of organic matter $^{+}$

Source: Prepared by the authors. + Traditional handling, they are systems with only one component. Previous studies carried out in the south of Sinaloa (Perales *et al.,* 2000). *Anguiano *et al.* (2013) C sequestration with APS including *Leucaena*, of 27.04 to 35.72 t C ha^{-1} (Colima, Mx). Furthermore, Ávila *et al.* (2001) cited 95 t C ha^{-1} in AFS with coffee (Costa Rica), and Miranda *et al.* (2008) documented up to 126 t C ha^{-1} in a grass system with *Leucaena* (Cuba).

These results are consistent with other studies that point to advantages regarding the establishment of ISS, in comparison with monocultures. In that sense, a research carried out in Cuba, in which a silvopastoral system (*Panicum maximum* Jacq and *Leucaena leucocephala*) was compared to a monoculture (*Panicum maximum* meadow), identified in the former a gradual increase, through time, of 54. 4 to 65.3 t ha^{-1} of carbon stored in the soil (CSS); in contrast, the monoculture system showed signs of deterioration and a decrease in CSS over time, from a concentration of 60.4 to 43.7 t ha^{-1} (Lok *et al.,* 2013).

The ISS consist of technologies that contribute to the removal and reduction of greenhouse gases (GHG), through the sequestration or sequestration of carbon in the plant biomass and soil. Some authors indicate that the ISS are an alternative that enables livestock in tropical regions to adapt to climate change and participate in GHG mitigation: "as the establishment of ISS can remove up to 26.6 t of CO_2 equivalent ha^{-1} $year^{-1}$" (Cuartas *et al.,* 2014).

Agroforestry systems, including ISS, offer proven strategies for carbon sequestration, soil enrichment, biodiversity conservation, and improved air and water quality not only for the owners of the forest resource, but also for society at large (Shibu, 2009). In short, they entail a greater benefit for the producer and the environment. Therefore, as Alonso (2011) points out: "the implementation of an incentive payment for the generation of environmental services could change the perspective towards the use and management of tree species in livestock systems, given their effect on the conservation of agro-ecosystems”.

Conclusions

Intensive silvopastoral systems can contribute to a greater environmental and economic sustainability of producers in rural areas, through carbon sequestration and nitrogen fixation through the use of legumes, as well as to the production of a larger amount of fodder, and thereby increase livestock productivity. In this sense, the ISS make it possible to improve production parameters related to animal loads and daily gains in weight per animal; as a result, agricultural production is increased. The results show the feasibility of breeding calves in silvopastoral systems by means of the profitable use of *Leucaena leucocephala* in association with Coastcross II *Bermuda* grass prairies, which result in a benefit cost ratio of 1.21; that is to say, for each invested peso, the producer obtains a profit of 21 to 24 cents, when payment for the environmental service of carbon sequestration is considered. Therefore, economic incentives are required for their implementation in tropical regions whose natural resources have the potential to generate this ecosystem service. The main benefits of implementing this type of system are reflected in greater productivity, competitiveness, environmental protection, and social development. For possible studies on ISS, it is recommended to evaluate potential negative externalities that might be caused by the use of agrochemicals and pesticides.

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Conflict of interests

The authors declare no conflict of interest.

Contribution by author

Venancio Cuevas Reyes: planning, data analysis and writing of the manuscript; Juan Esteban Reyes Jiménez: planning, supervision and data analysis; Mercedes Borja Bravo: data analysis; Alfredo Loaiza Meza: field data collection; Blanca Isabel Sánchez Toledano: data analysis and review of the manuscript; Tomas Moreno Gallegos: field data collection; Cesar Rosales Nieto: writing and review of the manuscript.

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