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Assessing the Feasibility and Socioecological Benefits of Climate-Smart Practices at the Watershed Scale

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Abstract: Resource allocation in climate-smart productive practices depends on the explicit recognition and accountability of the expected costs and benefits in socioeconomic and ecological terms. This study assessed the private and social costs and benefits of 10 practices compatible with the transition to sustainable agricultural practices under an integrated landscape management (ILM) approach. First, the financial and economic viability of the alternatives was evaluated with a cost-benefit analysis. Then, the potential contribution of these practices in terms of carbon sequestration and landscape connectivity was determined in an ILM scenario where at least three practices (live fences, isolated trees in pastures, and riparian vegetation recovery) could be implemented and assessed at the watershed scale. These practices were evaluated in three Mexican pilot watersheds with contrasting biophysical and sociocultural contexts but with high importance in biodiversity conservation and cattle production. The results showed that most climate-smart practices are viable in the medium and long term from a private standpoint. However, more significant benefits are achievable over a shorter period when social co-benefits are included. The results could contribute to decision-making in terms of public policy, providing evidence of the financial and economic feasibility of the analyzed climate-smart practices that also have ecological benefits. In this sense, decision-makers who promote such practices have more arguments to seek funding for implementation.

Keywords: climate-smart practices; ecosystem services; economic valuation; cost-benefit analysis; landscape connectivity; carbon storage and sequestration

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1. Introduction

In recent decades, anthropic activity for productive purposes has driven the degradation and replacement of natural ecosystems, decreasing the quantity and quality of a range of ecosystem services (ES) that are essential to human well-being and the assurance of human rights (e.g., to water). Among the main consequences of these changes in land use are the loss of biomass, carbon sequestration, flood regulation, and landscape connectivity; and the increase in soil erosion, habitat fragmentation, and the emission of CO_2 into the atmosphere [1–3]. Furthermore, climate change effects add to the impacts of competing land uses in ecosystem services, affecting the economic activities on which the affected communities depend and the resilience of the ecosystem to perturbations. The integrated landscape management (ILM) approach has been proposed in this context and as part of climate change mitigation and adaptation efforts.

ILM is a holistic approach focused on dealing with complex challenges associated with simultaneously balancing competing land uses, maintaining ecological integrity, and enhancing the livelihoods of local communities [4,5]. In addition, ILM is considered to lessen some impacts of climate change. For example, ILM promotes sustainable, productive practices (e.g., agroforestry, regenerative cattle ranching) that increase the provision of carbon sequestration and storage, flood regulation, and other ecosystem services. Also, from an ecological standpoint, ILM increases landscape connectivity by encouraging climate-smart practices that are coupled with agriculture and livestock ranching (e.g., live fences, restoration of riparian vegetation, and scattered trees in pastures). From an economic point of view, ILM boosts livelihood diversification with sustainable income-generating activities such as eco-tourism, reducing the vulnerability of rural communities to climate change.

ILM's transition from theory to practice depends on overcoming several challenges, for instance, coordination among stakeholders with conflicting interests and priorities, institutional barriers, limited resources (e.g., funding, technical expertise, and data), and unwillingness to implement the promoted strategies when the costs and benefits (ecological, financial, and economic) are unclear [5]. Besides, a technical challenge is monitoring changes in ILM's impact due to funding constraints, time lags, and confounding effects between interventions [6].

In order to advance in implementing the ILM approach, using reliable economic tools, such as cost-benefit analysis (CBA), is crucial to highlight the private and social outcomes [7,8]. A private cost-benefit analysis (CBA-P) allows producers and investors to quantify the financial benefits of the promoted practices and select the alternative that generates increased yields and reduced costs. In addition to the individual producers' financial gain, social cost-benefit analysis (CBA-S) accounts for social and environmental externalities such as carbon sequestration and other ecosystem services. Also, CBA-S allows decision-makers to make an informed decision about which practices are to be supported, to ensure that the incentives promote socially and economically inclusive efforts, and to develop policies and programs to promote ILM.

Increasing or maintaining carbon sequestration and recovering landscape connectivity are expected ecological and social co-benefits of implementing ILM practices, such as converting monocultures to agroforestry, installing live fences, and planting trees in strategic areas [9]. The increase in vegetation cover associated with these activities should result in higher amounts of carbon stored in the landscape and better-connected habitat patches [10]. Moreover, these practices benefit the organisms living in vegetation remnants in the study area without affecting primary productive activities [11].

Implementing measures to preserve ecosystem services relies on understanding how ecosystem services are translated into economic value [12,13]. In this sense, several spatially explicit tools focused on quantifying and mapping ESs have been developed to provide technical inputs for public policies, green accounting, and natural capital assessment to boost the sustainable use of ecosystems [14], highlighting efforts to reconcile ecosystem conservation, the sustainable use of Ess, and better diversification of economic activities. Thus, we evaluate the viability of selected climate-smart productive practices using a comprehensive approach, integrating environmental, financial, and economic objectives in three pilot watersheds in Mexico. These watersheds represent diverse biophysical and sociocultural contexts, enriching our understanding of the effect of different ILM strategies in specific conditions. Implementing a broader holistic assessment of potential solutions expands the scope of this study beyond conventional approaches to address contemporary challenges, such as aligning conservation and socioeconomic goals.

2. Materials and Methods

In three study cases, biophysical modeling at the watershed scale determined the potential co-benefits regarding carbon sequestration and landscape connectivity. The biophysical analysis was performed in two contrasting scenarios: a scenario with an ILM approach (ILM scenario, hereafter) that included three practices (live fences, isolated trees in pastures, and riparian vegetation recovery) and a reference or business-as-usual scenario (BAU scenario, hereafter), implemented in crops and pastures. Subsequently, we included the biophysical information in a feasibility analysis of those practices. Then, seven additional climate-smart practices with no available biophysical data were evaluated economically and financially. In the 10 cases, the feasibility analysis was performed through a cost-benefit analysis, and the benefits of the ILM and BAU scenarios were assessed in three periods (2022, 2026, and 2041).

2.1. Study Area

We assessed three contrasting watersheds in Mexico: Ameca-Mascota, Del Carmen, and Jamapa (Figure 1). These watersheds are prioritized by the Mexican government for integrated landscape management (ILM) and climate-smart practices associated with agroforestry and cattle ranching due to their significance in food production, vulnerability to climate change, and biodiversity conservation [15,16].

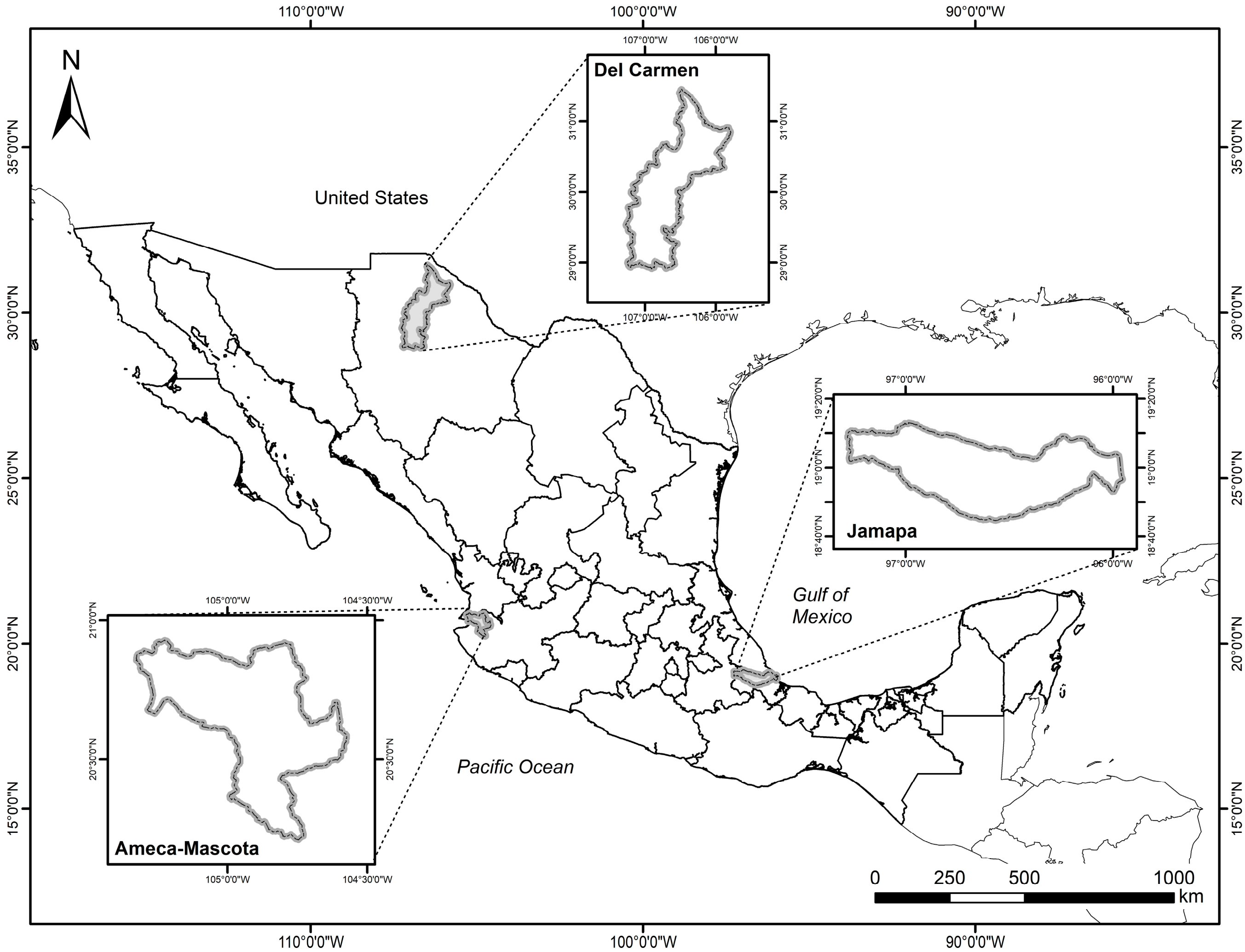

Figure 1. Location of the three watersheds selected as study cases: Ameca-Mascota (Jalisco), Del Carmen (Chihuahua), and Jamapa (Veracruz). The watersheds' delimitation was obtained from the Integrated Watershed Action Plans (IWAP) [15,16].

Ameca-Mascota covers 2745 km^2 in Jalisco state, draining to the Pacific coast. Del Carmen spans 16,008 km^2 in Chihuahua state, near the USA border. Jamapa extends over 3921 km^2 in Veracruz state, draining to the Gulf of Mexico coast.

Natural vegetation cover in Ameca-Mascota and Del Carmen is over 70%, while Jamapa is predominantly used for agriculture and cattle ranching, with over 80% anthropic land use.

There is a range of primary productive activities across the sites based on biophysical conditions. Ameca-Mascota's topography determines the concentration of activities in the upper watershed valleys and the urban areas in the coastal floodplain. Del Carmen experiences an extreme climate and limited water availability, restricting activities to low-density cattle ranching in extensive areas. In turn, Jamapa has favorable conditions for a range of activities, including coffee agroforestry and cattle ranching, with a dispersed human population.

In terms of population, Jamapa is the most populated (779,763 inhabitants, 198.9 per sq. km), followed by Ameca-Mascota (204,044 inhabitants; 74.3 per sq. km), and Del Carmen (39,240 inhabitants, 2.5 per sq. km) [17]. The poverty and food insecurity rates are highest in Jamapa and lowest in Del Carmen [18].

2.2. Selected Climate-Smart Practices

Ten climate-smart practices were selected from a governmental portfolio to enhance ILM, sustainable livestock and agroforestry, women's participation, climate change adaptation, and post-pandemic green recovery (Table 1). Experts in sustainable production and development in the three watersheds from 17 institutions participated in a workshop to validate the practices based on their co-benefits of carbon sequestration and landscape connectivity, implementation feasibility, and site characteristics [19]. Table 1 presents the assessed practices and the evaluation type. Three practices underwent biophysical and economic assessments, while seven were evaluated solely from an economic perspective. In the Ameca-Mascota and Jamapa watersheds, multi-layer live fences, planting isolated trees in pasture parcels, and restoring riparian vegetation were biophysically and economically assessed. However, due to the challenging conditions in the Del Carmen watershed, shrub fences replaced multi-layered tree fences, and soil management with regenerative cattle ranching was assessed instead of riparian vegetation restoration.

Table 1. Climate-smart practices assessed and evaluation type.

Climate-Smart Practices	Biophysical Evaluation	Type of Economic Valuation	Description
Protein fodder banks	No *	Private, social or both	Refers to planting herbs, trees, or shrubs with high protein content, which can be harvested and taken to the animals in a cut-and-carry system.
Silvopastoral production	No *	Private, social or both	Livestock production mixing cattle, pasture, trees, and shrubs (woody perennials) in the same area.
Water distribution systems	No *	Private, social or both	Installing a water delivery system such as a pipeline network to supply the livestock watering troughs on the farms.
Technical assistance on breeding techniques and reproductive technologies	No *	Private, social or both	Implementing a counselling program for cattle breeding improvement.
Technical assistance on livestock water-quality monitoring	No *	Private, social or both	Implementing a technical counselling program for water quality monitoring for livestock drinking.

Table 1. *Cont.*

Climate-Smart Practices	Biophysical Evaluation	Type of Economic Valuation	Description
Traditional subsistence/small-scale farming	No *	Private, social or both	Installing traditional backyard gardens for self-consumption.
Live fences (multi-strata in Ameca-Mascota and Jamapa) and shrubs (Carmen)	Yes	Private, social or both	Live fences are established surrounding the parcels. The main benefits are help in soil conservation, providing shade, windbreak for the compound, and production of mulch, fruit, bee forage, wood, and habitat.
Isolated trees in pastures	Yes	Private, social or both	Increasing the number of arboreal elements within the agricultural matrix at key sites would enhance vegetation recovery and habitat for some species.
Restoration of riparian vegetation (Ameca-Mascota and Jamapa)	Yes	Private, social or both	Active planting to replace any missing riparian vegetation strata.
Improved grazing management to restore soil carbon sequestration (Del Carmen)	Yes	Private, social or both	Decreasing grazing pressure and providing adequate pasture rest time.

* Note: The biophysical evaluation only considered certain practices because spatially explicit information was unavailable.

2.3. Economic Feasibility and Socioecological Co-Benefits of Selected Practices

The co-benefits of the selected practices regarding carbon sequestration and landscape connectivity were first determined with biophysical modeling when possible, and the results were incorporated in the financial and economic analyses. Then, a cost-benefit analysis was conducted to evaluate the implementation feasibility of all of the practices.

2.3.1. Biophysical Analysis: Carbon and Functional Connectivity Co-Benefits

The selected climate-smart practices were assessed for their economic feasibility and socioecological co-benefits. First, a biophysical analysis was conducted to evaluate carbon sequestration and landscape connectivity. Carbon-related co-benefits were determined using the InVEST Carbon Storage and Sequestration model based on carbon values of the four common pools (aboveground biomass, underground biomass, soil carbon, and litter/dead wood) obtained from secondary studies, but developed for the three watersheds (Data source: [20–31]), as well as land use and vegetation maps from 2002 and 2018 [32–35].

Functional landscape connectivity was estimated considering the spatial locations of vegetation patches (2002 and 2018; INEGI series [32,35]) in the three watersheds, and the importance of each patch to the landscape connectivity was calculated using CONEFOR 2.6 software [36]. Two indices were analyzed: the probability of connectivity (PC) and the delta of the probability of connectivity (dPC). The PC index is derived from habitat availability, dispersal probabilities between habitat patches, and the landscape structure. The dPC index estimates the value that each patch contributes to the overall connectivity, recalculating the connectivity index when performing the simulation of removing a given patch from the landscape. For both indices, a threshold for movement between fragments of 500 m was set to estimate the degree of landscape connectivity because species with moderate to intermediate dispersal capabilities are the most affected by connectivity-related landscape changes [37,38] and reflect the dispersal capacities of key species in forest ecosystems, such as small rodents (50–1000 m) and passerine birds (100–1000 m) [39,40]. In the Del Carmen watershed, connectivity was not assessed because no tree recovery practices were considered.

2.3.2. Economic Valuation

The economic valuation involved calculating carbon's social and market costs using different pricing models, and the carbon values obtained from biophysical modeling were input to calculate carbon's costs. In the first case, the present value of the current and future social costs of an extra ton of carbon emitted to the atmosphere was obtained from the literature [41] and set at USD 28.3/ton/2021. In the second case, the Swedish market price (USD 152.3/ton/2021), the California market price (USD 16.4/ton/2021), and the Mexican market price (USD 3.3/ton/2021) were considered, and the inflation was adjusted (Formula (1) in Table 2).

Table 2. Adjustment for inflation, weighting formula based on connectivity, weighting formula based on total production value, willingness to pay per municipality, economic value of scenic beauty, and net present value formula.

Formulas	**Variables**
Formula (1). Adjustment for inflation	
$P_{2021} = P_t\left(\frac{CPI_{2021}}{CPI_t}\right)$	P_{2021} = deflated price 2021. P_t = price in year t that must be adjusted. CPI_t = Consumer Price Index (energy sector and tariffs) for 2021 and the year t.
Formula (2). Weighting based on connectivity importance formula	
$PdPC_i = \left(\frac{dPC_i}{dPC_m}\right)$	$PdPC_i$ = weighting based on the level of importance of connectivity of municipality i. dPC = level of importance of connectivity for the municipality of Puerto Vallarta (m) and for another municipality (i).
Formula (3). Weighting based on total production value	
$PVP_i = \left(\frac{VP_i}{VP_m}\right)$	PVP_i = weighting based on the production value of the municipality i. VP = production value for Puerto Vallarta (m) and another municipality (i).
Formula (4). Willingness to pay per municipality	
$WTP_i = WTP_t * PdPC_i * PVP_i * P_{2021}$	WTP_i = willingness to pay for the scenic beauty of the municipality i. WTP_t = willingness to pay for the scenic beauty of the municipality of Puerto Vallarta. $PdPC_i$ = weighting based on the level of importance of connectivity of the municipality i. PVP_i = weighting based on the production value of the municipality i. P_{2021} = deflated price for the year 2021.
Formula (5). The economic value of scenic beauty	
$EV_c = \sum_{i=1}^{t} WTP_i * NTourists_i$	EV_c = economic value for the scenic beauty of watershed "c" (c = Ameca-Mascota, del Carmen and Jamapa). WTP_i = willingness to pay for the scenic beauty of the municipality i. No. $Tourists_i$ = the number of tourists visiting municipality "i" per year. Data were obtained from the Ministry of Tourism (SECTUR) and the official websites of the municipalities.
Formula (6). Net Present Value	
$NPV = \sum_{t=1}^{n} \frac{V_t}{(1+k)^t} - I_0$	NPV = Net Present Value V_t = the (private) income or (social) benefits minus the (private or social) costs of the different t periods analyzed. Both private income or benefits and private share costs are included. k = interest rate or the opportunity cost of the investment. This rate makes it possible to transform a flow of money to be realized in the future into a flow of money in the present. A rate of 10% is considered based on the Mexican Ministry of Finance and Public Credit (SHCP) stipulations for the economic analysis of projects. Additionally, scenarios with 6 and 9% rates are considered for the sensitivity analysis. I_0 = investment made at the beginning of the first year of implementing the analyzed practice. t = the periods considered for the analyzed practices were 2022 (t = 0), 2026 (t = 4), and 2041 (t = 19). NPV result = NPV > 0 means the practice is feasible for implementation; NPV = 0 means the practice is indifferent to implementation; and NPV < 0 means the practice is not viable for implementation.

Then, two methods were used to estimate the economic value of landscape connectivity: the opportunity cost of replacing the vegetation patches with cattle ranching and tourists' willingness to pay (WTP) for the scenic view of less fragmented landscapes. In the first method, the parcels in each study case were weighted depending on the connectivity index values obtained from the biophysical modeling, ranging from 1 to 100 (no connectivity and maximum connectivity, respectively), and the total annual production value per hectare was calculated using data reported in the literature. Then, the production value was multiplied by the connectivity index value. In the WTP method, connectivity was considered and input into the production function of having more or fewer tourists; consequently, the municipalities were weighted based on the importance of connectivity (Formula (2), Table 2) and the total production value per watershed ([42]; Formula (3), Table 2), which considered an inflation adjustment (Formula (1), Table 2). Then, the WTP was calculated for each municipality (Formula (4), Table 2), and the economic value of the scenic beauty was estimated (Formula (5), Table 2).

2.3.3. Economic Feasibility: Cost-Benefit Analysis

The cost-benefit analysis from private (CBA-P) and social (CB-S) perspectives using the Net Present Value (NPV, Formula (6) in Table 2) was conducted to assess the feasibility of implementing each practice. Costs and revenues generated by each practice were included in the CBA-P, and were provided by specialized companies and from previous experiences reported in national studies [43,44]. Additionally, CB-S included the effect of the practices on carbon sequestration and landscape connectivity as externalities.

2.4. BAU and ILM Scenarios Definition and Assessment

The BAU and ILM scenarios were evaluated for two periods (2026 and 2041), using 2022 as the base year. These periods are linked to the expected outcomes of the CONECTA project (2021–2026), which aims to promote climate-smart practices in 15 watersheds, including Ameca-Mascota, Del Carmen, and Jamapa. The first year (2026) indicates the end of the project-implementation phase, while the second year (2041) represents the expected results 20 years after the project's initiation. In the BAU scenario, the continuation of current trends in productive activities and land degradation is expected, whereas in the ILM scenario, the implementation of the selected climate-smart practices (Table 3) is considered.

Table 3. Modeling characteristics of the climate-smart practices.

Climate-Smart Practice	Definition/Modelling Characteristics
Live fences	• Multi-strata live fences in Ameca-Mascota and Jamapa: 10 m-diameter buffer around selected parcels. • Shrub fences in Del Carmen: 5 m-diameter buffer around selected plots.
Scattered trees in pastures	• All cases: 500 trees randomly placed per priority site with a 5 m buffer per tree to emulate the canopy.
Other practices	• Restoring riparian vegetation in Ameca-Mascota and Jamapa: 20 m buffers (10 m on each side) around permanent and intermittent water currents within the priority sites. • Improving grazing management in Del Carmen: The total area of pastures was considered to evaluate the effects of improved grazing management to restore soil carbon sequestration capacity.

Under these scenarios, the expected co-benefits (landscape connectivity and carbon storage) were determined by considering deforestation trends and the effects of the implemented practices at the watershed scale. Deforestation trends from 2011 and 2018 were analyzed using Markov chains and official LULC maps (Series V and VII, [34,35]). Also, detailed vegetation classification was performed to avoid double-counting existing riparian vegetation, isolated trees, and live fences with 10 m-resolution SENTINEL satellite images from March 2022.

The area and spatial distribution of the selected practices in each study case were defined based on the goals established by the Mexican government in the integrated watershed management action plans (IWAPs) of Ameca-Mascota and Jamapa (280 ha and 400 ha, respectively). In Del Carmen, all induced pasture parcels (1681 ha) were assessed because the corresponding IWAP was unavailable (Table 3). Conservative and optimistic assessment perspectives were explored, considering the practices' total area and strictly implemented areas (Perspectives 1 and 2, respectively).

3. Results

3.1. Carbon and Landscape Connectivity

Ameca-Mascota had the highest average carbon-stored value (205 tC/ha), followed by Jamapa (176.5 tC/ha), while Del Carmen recorded the lowest value (124.8 tC/ha) (Figure 2; Panel A). Variability was observed within each case study, with Jamapa showing the lowest and highest values (29.88 and 298.13 tons/ha, respectively) and Del Carmen ranging from 64.22 to 247.56 tons/ha. Ameca-Mascota exhibited fewer extreme values, ranging from 134.12 to 245.75 tons/ha.

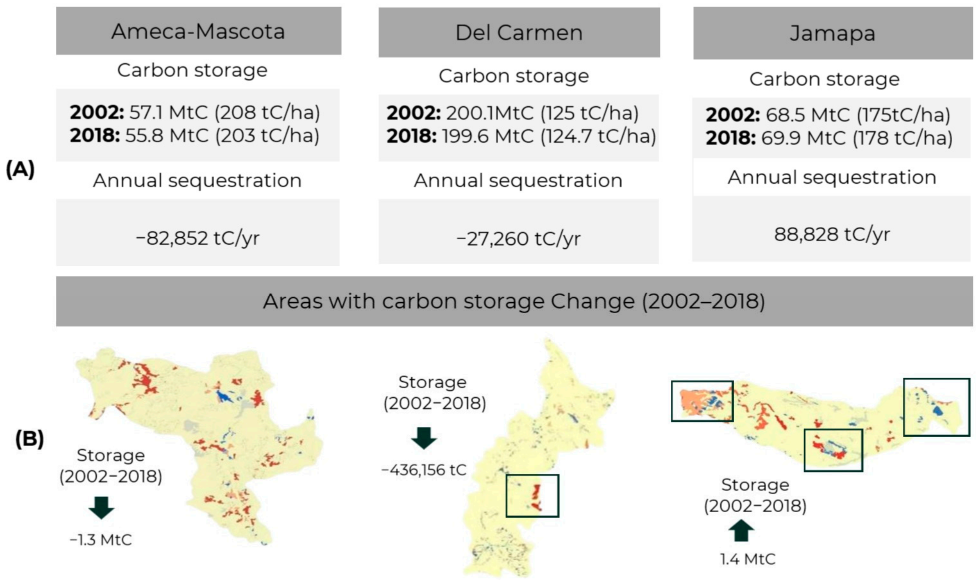

Figure 2. Amount of carbon storage and sequestration in the three watersheds (**A**) and zones with a high increase (blue) or loss (red) between 2002 and 2018 (**B**).

The carbon values decreased in Ameca-Mascota and Del Carmen watersheds but increased in Jamapa between 2002 and 2018. Deforestation scattered in the Ameca-Mascota watershed was the leading cause of carbon loss. In contrast, Del Carmen experienced a significant decrease in carbon due to the deforestation of a patch of pine-oak forest. In Jamapa, the carbon increased due to mangrove and cloud forest restoration efforts and the passive restoration of forests in abandoned crops.

Jamapa had the lowest functional connectivity (4.23), while Del Carmen had the highest mean value (9.85). Over half of the Del Carmen landscape had high connectivity, while less than 10% of Ameca-Mascota and Jamapa each fell into this category (Figure 3). Ameca-Mascota had a higher proportion of medium-level connectivity compared to Jamapa. The above figure highlights that pine-oak forests played a crucial role in connectivity for Ameca-Mascota and Del Carmen, while cloud forests were important for Jamapa.

Vegetation fragments facilitated species mobility between the upper and lower parts of the Ameca-Mascota and Del Carmen watersheds. However, in Jamapa, critical vegetation was confined to the upper part, isolating the middle and lower parts of the watershed. The connectivity probability decreased in all three study cases between 2002 and 2018.

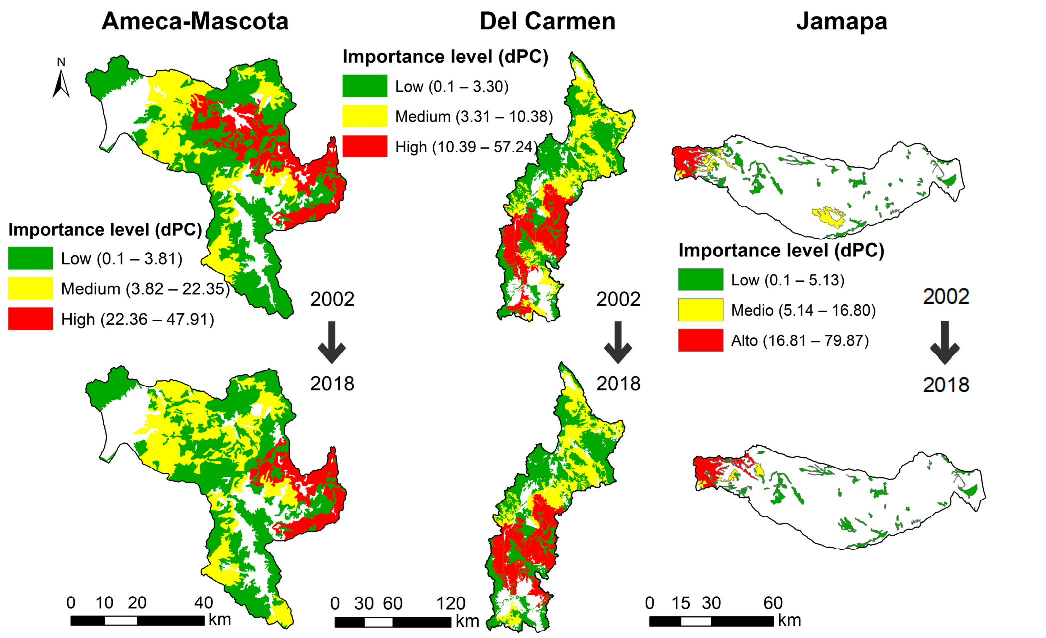

Figure 3. Landscape connectivity values per study case: Ameca-Mascota, Del Carmen, and Jamapa.

3.2. Social and Market Costs of Carbon Sequestration and Landscape Connectivity Value

3.2.1. Carbon Sequestration

The social cost of carbon was USD 77 million in Ameca-Mascota, USD 277 million in Del Carmen, and USD 97 million in Jamapa. In contrast, the market value was USD 45 million in Ameca-Mascota, USD 161 million in Del Carmen, and USD 56 million in Jamapa.

3.2.2. Landscape Connectivity

The willingness to pay (WTP) for conservation indicated a minimum economic value per year of over USD 22 million in Ameca-Mascota, USD 19 million in Del Carmen, and approximately USD 16 million in Jamapa. These values increased with more potential tourists (Table 4). In turn, the opportunity cost of cattle ranching considering the landscape connectivity value was nearly USD 23 million in Ameca-Mascota, USD 19 million in Del Carmen, and around USD 17 million in Jamapa (Table 4).

Table 4. Willingness to pay of potential tourists for a landscape with higher level of connectivity.

	Proportion of Tourists	Ameca-Mascota	Del Carmen	Jamapa
WTP for conservation	10%	USD 22.7	USD19.0	USD 16.5
	40%	USD 90.9	USD 76.1	USD 66.4
	60%	USD 136.4	USD 114.1	USD 99.6
	80%	USD 181.8	USD 152.1	USD 132.8
Opportunity cost of cattle ranching		USD 19.9	USD 19.1	USD 12.8

3.3. BAU and ILM Scenarios

According to the Markov chains analysis, the Ameca-Mascota watershed will experience significant natural vegetation losses of 17% and 19% in 2026 and 2041. In contrast, Jamapa, which had less than 20% natural vegetation cover in 2022, is expected to lose only 0.25% and 0.4% in 2026 and 2046. Similarly, Del Carmen will see 0.17% (2026) and 0.21% (2046) transformations of natural vegetation into different land uses.

The effects of the analyzed practices on carbon sequestration and landscape connectivity were assessed under two perspectives of intervention intensity. Ameca-Mascota required the combination of riparian vegetation restoration, multi-layered live fences, and isolated trees in pastures in fewer parcels than Ameca-Mascota to reach the vegetation recovery goal under both perspectives (Table 5). The number of parcels needed to reach the vegetation goal is six and seven times lower in Perspective 1 than in Perspective 2 for Ameca-Mascota and Jamapa. In comparison, Del Carmen needed fewer parcels with combined shrub live fences and improved grazing management to reach the targeted vegetation goal due to larger average parcel areas.

Table 5. The total area of selected practices per watershed under two assessment perspectives.

Watershed	Practice	Perspectives	
Ameca-Mascota		Perspective 1 (47 parcels)/ha	Perspective 2 (47 parcels)/ha
	Riparian Vegetation	1.66	39.34
	Multi-strata live fences	38.32	235.86
	Scattered trees in pastures	3.93	3.93
Jamapa		Perspective 1 (47 parcels)/ha	Perspective 2 (47 parcels)/ha
	Riparian Vegetation	7.55	18.70
	Multi-strata live fences	83.10	376.68
	Scattered trees in pastures	3.93	3.93
Del Carmen		Perspective 1 (15 parcels)/ha	
	Live fences with shrubs	54.35	
	Grazing management	1670.44	

Effect of the Evaluated Practices on Landscape Connectivity and Carbon Sequestration

Implementing the practices in the ILM scenario increased the landscape connectivity and carbon sequestration in both evaluation perspectives (Table 6). The ILM scenario promoted natural vegetation conservation, reducing the deforestation trends in Ameca-Mascota by 3% and 15%, depending on the assessment perspective, and increasing connectivity to higher values in 2026 than in 2022. In contrast, the ILM scenario decelerated the vegetation loss in Jamapa (1–4%), but the connectivity decreased under both perspectives, decelerating the loss by 2026 and shifting only in the long term. The higher values of connectivity and decelerating effects of Perspective 2 were related to a more extensive and better-distributed network of vegetation parcels in Ameca-Mascota and increased connectivity between the remaining vegetation fragments in Jamapa.

Table 6. Carbon sequestration and landscape connectivity under BAU and ILM scenarios for 2022, 2026, and 2041.

Ameca-Mascota

Benefits	2022	Scenarios	2026		2041	
			Perspective 1	Perspective 2	Perspective 1	Perspective 2
Vegetation cover (ha)	2075.65	BAU	1722.79		1681.28	
		ILM scenario	1767.82	1981.53	1726.30	1940.01
Connectivity	0.07	BAU	0.06		0.06	
		ILM scenario	0.08	0.18	0.08	0.18
Carbon (tC/year)	259,415.16	BAU	215,314.16		210,125.86	
		ILM scenario	220,941.78	247,652.04	215,752.61	242,462.87

Jamapa

Benefits	2022	Scenarios	2026		2041	
			Perspective 1	Perspective 2	Perspective 1	Perspective 2
Vegetation cover (ha)	12,025.74	BAU	9019.30		7215.44	
		ILM scenario	9113.88	9418.61	7215.44	7614.75
Connectivity	0.19	BAU	0.11		0.12	
		ILM scenario	0.12	0.15	0.17	0.19
Carbon (tC/year)	2,141,151.04	BAU	1,608,863.28		1,287,090.62	
		ILM scenario	1,625,734.46	1,680,091.75	1,287,090.62	1,358,319.09

Del Carmen

Benefits	2022	Scenarios	2026	2041
Pasture (ha)	1670.44	BAU/ILM scenarios	1670.44	
Carbon (tC/year)	208,772.18	BAU	208,772.18	
		ILM scenario	273,491.56	

In all cases, natural vegetation loss and permanence in the BAU scenario were directly associated with carbon sequestration values (Table 6). The ILM scenario decelerated the loss of carbon sequestration capacity in Ameca-Mascota and Jamapa. In contrast, the carbon values increased in Del Carmen, reaching higher values in 2026 than in 2022 (Table 6).

3.4. Economic Valuation

The ILM scenario was evaluated from private and social points of view. Regarding the private standpoint, the analysis suggests that most ILM practices positively impact income and costs for livestock and/or agroforestry production in the medium and long term. In addition, the sensitivity analysis showed that having a low interest rate is preferable to having a higher return on investment from the private standpoint. From the social perspective, a low rate implies a higher value of the carbon services and landscape connectivity in the medium and long term. The main results of the private (CBA-P) and social (CBA-S) cost-benefit analyses and the sensitivity analysis of the CBA-P and CBA-S are presented below.

3.4.1. CBA-Private

Financially viable practices in the short term include silvopastoral production, technical assistance in breeding, multi-strata live fences, and planting isolated trees. The feasibility differs among the cases and time horizons. For example, conventional cattle ranching is not viable in the Ameca-Mascota watershed. However, the same type of cattle ranching is viable in Jamapa and Del Carmen in the three time horizons (2022, 2026, and 2041) due to additional practices and local government support. Some practices, such as silvopastoral systems and technical assistance with breeding and reproductive technologies, showed an increased viability over time (Table 7).

Table 7. Net present value—private standpoint for each practice and year in the three study cases.

		Ameca-Mascota			Jamapa			Del Carmen		
Practice	**Unit**	**NPV 2022**	**NPV 2026**	**NPV 2041**	**NPV 2022**	**NPV 2026**	**NPV 2041**	**NPV 2022**	**NPV 2026**	**NPV 2041**
BAU	1 ha	−$95.3	−$381.2	−$1810.9	$400.9	$1603.4	$7616.3	$21.7	$86.6	$411.3
Protein fodder banks	1 ha	−$336.8	−$133.8	$261.4	−$336.9	−$133.8	$261.4	−$336.9	−$133.8	$261.4
Silvopastoral production	1 ha	$12.4	$49.7	$235.9	$740.9	$2963.4	$14,076.3	NA	NA	NA
Water distribution systems (pumping)	1 m	−$0.8	−$0.9	−$1.1	−$0.8	−$0.9	−$1.1	−$0.8	−$0.9	−$1.1
Water distribution systems (gravity)	1 m	−$0.6	−$0.7	−$0.9	−$0.6	−$0.7	−$0.9	−$0.6	−$0.7	−$0.9
Technical assistance on breeding techniques and reproductive technologies	1 ha	$455.4	$2001.8	$6631.7	$616.8	$2711.3	$8982.4	$71.7	$315.1	$1043.9
Technical assistance on livestock water-quality monitoring	Per visit	−$1400.4	−$3476.2	−$11,716.6	−$1400.4	−$3476.2	−$11,716.6	−$1400.4	−$3476.2	−$11,716.6
Traditional subsistence/ small-scale farming	Per farm	−$39.5	$82.3	$302.2	−$39.5	$82.3	$302.2	−$39.5	$82.3	$302.3
Multi-strata live fences	1 m	$2.3	$10.3	$26.0	$2.3	$10.3	$26.0	NA	NA	NA
Isolated trees in pastures	1 ha	$142.9	$961.3	$2565.9	$142.9	$961.3	$2565.9	NA	NA	NA
Restoration of riparian vegetation	1 ha	−$443.9	−$488.1	−$579.0	−$443.9	−$488.1	−$579.0	NA	NA	NA
Live shrub fences	1 ha	NA	NA	NA	NA	NA	NA	−$57.5	$262.4	$888.9
Improved grazing management to restore soil carbon sequestration	1 ha	NA	NA	NA	NA	NA	NA	$17.9	$71.5	$339.5

Note: Due to the biophysical conditions of Del Carmen, silvopastoral production and multi-strata live fences were not assessed (NA) in this watershed and were substituted by improved grazing management to restore soil carbon sequestration and shrub fences, respectively, which in turn were not assessed in Ameca-Mascota and Jamapa.

In contrast, protein fodder banks, traditional subsistence farming, and shrub fences are unviable in the short term but become viable with an expanded time horizon (Table 7). Particular attention should be paid to riparian restoration and water distribution systems; these practices have several social benefits but are financially unviable because the potential incomes were only partially considered due to a lack of high-quality data.

3.4.2. CBA-Social

The ILM scenario reduces losses in carbon sequestration and landscape connectivity compared to the BAU scenario (Table 8). The leading cause of this is the fewer hectares providing ESs under BAU, resulting in a decreased, or even the loss of, the economic value of carbon and connectivity (habitat proxy) services. Despite the ILM scenario preventing significant losses in economic value, the carbon value decreases over time due to the time value of money and deforestation trends. For example, considering the Californian market, the value of carbon in 2026 and 2041 is lower than in 2022. Nonetheless, implementing the

ILM scenario is more profitable than doing nothing, particularly in the Del Carmen case (Table 8).

Table 8. Net present value–social standpoint for each practice and year in the three study cases.

Site	NPV-Year	Carbon (Millions of USD)						Landscape Connectivity					
		Social Value			California Market			WTP (Thousands of USD)			Opportunity Cost (Millions of USD)		
		BAU	ILM Scenario P1	ILM Scenario P2	BAU	ILM Scenario P1	ILM Scenario P2	BAU	ILM Scenario P1	ILM Scenario P2	BAU	ILM Scenario P1	ILM Scenario P2
Ameca-Mascota	NPV 2022	$6.8	NA	NA	$3.9	NA	NA	$13.0	NA	NA	$19.9	NA	NA
	NPV 2026	$5.6	$5.8	$6.5	$3.2	$3.3	$3.7	$9.5	$12.4	$22.3	$17.1	$22.7	$51.1
	NPV 2041	$5.5	$5.6	$6.4	$3.2	$3.3	$3.7	$9.2	$12.1	$21.8	$17.9	$25.6	$59.7
Del Carmen	NPV 2022	$5.5	NA		$3.2	NA		NA	NA	NA	$19.1	NA	NA
	NPV 2026	$5.5	$7.2		$3.2	$4.2		NA	NA	NA	NA	NA	NA
	NPV 2041	$5.5	$7.2		$3.2	$4.2		NA	NA	NA	NA	NA	NA
Jamapa	NPV 2022	$56.5	NA	NA	$32.8	NA	NA	$75.4	NA	NA	$12.8	NA	NA
	NPV 2026	$42.4	$42.8	$44.2	$24.6	$24.8	$25.7	$49.8	$64.1	$101.5	$7.4	$8.1	$10.1
	NPV 2041	$33.4	$33.7	$33.9	$19.1	$19.5	$19.7	$39.8	$50.7	$81.2	$7.3	$10.8	$12.1

NA: not assessed.

For landscape connectivity, higher fragmentation leads to less habitat and hedonic value, reducing the potential income from tourism. The monetary connectivity values are either maintained or increased in all cases in the ILM scenario (Table 8). For example, the value of connectivity associated with tourism in Ameca-Mascota was around USD 13,000 per year in 2022, decreasing to USD 9500 in 2026 under the BAU scenario but increasing to USD 12,500 and USD 22,300 under Perspectives 1 and 2 of the ILM scenarios for the same year (Table 8). In Jamapa, it was around USD 75,000 per year in 2022, decreasing to USD 39,000 in 2024 under the BAU scenario but increasing to USD 50,700 and USD 81,200 under Perspectives 1 and 2.

4. Discussion

The present study explored the feasibility from financial and economic perspectives of 10 climate-smart practices across different time horizons and watersheds. The socioecological co-benefits regarding enhanced landscape connectivity and carbon services were included in the feasibility analysis of three practices (live fences, the restoration of riparian vegetation, and isolated trees in pastures). The main results showed that most of the 10 practices were feasible in the medium and long term from the private and social standpoints. Also, combining the three biophysically modeled practices enhanced carbon services and functional connectivity at the landscape scale, with different performances depending on the case study and the implementation intensity.

The following sections discuss the main findings, considering the socioecological benefits and the utility of CBA in assisting decision-making and supporting the design of grounded policies in priority regions.

4.1. Co-Benefits of Practices with Short-Term Feasibility

Practices with short-term feasibility are suitable as ILM strategies. In addition, live fences and isolated trees in pastures that act as corridors and steppingstones that increase functional connectivity on fragmented landscapes have been broadly recognized as conservation strategies (e.g., [11,45]).

Also, silvopastoral production and technical assistance with breeding and reproductive technologies have been recognized for their socioenvironmental benefits. In the first case, providing shelter, nesting, and food sources for several species increases the landscape connectivity [46,47]. Furthermore, the tree cover associated with these systems increases the provision of carbon sequestration and soil conservation services, while production diversification enhances the resilience of farmers' livelihoods [48,49]. In the second case, technical assistance enables farmers to increase the livestock production systems' efficiency and sustainability, including the reproduction of animals that are better-adapted to local environmental conditions and the synchronization of breeding and calve seasons with favorable foraging availability and climatic conditions, increasing the production resilience and decreasing the pressure on grazing lands [50].

4.2. Co-Benefits Provided by Practices with Medium- and Long-Term Feasibility

Establishing protein fodder banks and implementing traditional subsistence farming systems are viable in the medium- and long-term. Besides the benefit of high-protein forage in animal health and productivity, fodder banks increase the reliability of the feed supply during dry seasons or feed shortages, increasing profitability and minimizing the pressure on pasture lands [51]. ESs such as nutrient cycling and soil fertility are associated with this practice when legumes are incorporated as fodder crops because of their nitrogen-fixation capacity, and an increase in water infiltration and reduction in soil erosion could be promoted when deep-rooted legumes are included [52]. Similarly, traditional subsistence farming systems with a more diverse range of crops than protein banks, and which often incorporate sustainable soil management practices, are recognized for their co-benefits in terms of soil fertility, nutrient cycling, and agrobiodiversity conservation [23,53]. Furthermore, these systems support the preservation of traditional knowledge and cultural heritage [54].

4.3. The Unfeasible Practices

The restoration of riparian vegetation, technical assistance with livestock water-quality monitoring, and the implementation of water distribution systems were found to be financially inviable. The unviability was mainly related to a lack of data about the economic benefits, while data about investments were common. However, these practices offer essential environmental benefits. Riparian vegetation provides water filtration, erosion control, flood regulation, and landscape connectivity [55–57]. Technical assistance and water distribution systems ensure access to safe water for livestock, prevent resource depletion, and minimize pollution associated with nutrient loads [58]. Also, placing water points could help distribute water to the livestock in the landscape, reducing the impacts on soil and vegetation.

4.4. The Importance of the CBA

CBA enabled the identification of mutually beneficial practices that enhance producers' income while simultaneously aiding in the restoration of landscape connectivity and carbon ecosystem services. CBA, preferably supported by biophysical modeling, allows for identifying feasible practices for producers, considering their financial valuation and payback times. Additionally, CBA allows for the economic valuation of the societal benefits of the implemented practices, aiding in decision-making, resource allocation, and policy formulation. Moreover, CBA enables the promotion of conservation efforts by considering ESs recovery, such as the habitat quality measured through landscape connectivity and carbon sequestration and storage. Visualizing the economic feasibility and payback times of various actions is particularly significant when intervention is needed in large areas with limited technical expertise and financial resources.

4.5. Public and Private Feasibility Analysis into Public Policy

Given Mexico's vast biodiversity and cultural richness, therefore having diverse conservation interests, it is critical to include monetary aspects and biophysical data or information to prioritize its investments and design effective conservation and development policies. The incorporation of monetary aspects into ESs conservation and sustainable-use projects requires considering investments, costs, and revenues that directly impact beneficiaries, integrating all social benefits and positive externalities, which can be measured in monetary terms.

Allocating a larger budget to ESs conservation and recovery is of the utmost importance for public policy in the face of climate change, whether at the national, state, or municipal level. In order to accomplish this, authorities responsible for environmental and production matters can utilize the findings of feasibility and co-benefits studies to support their case and advocate for the maintenance of or increasing public funds as well as the design of grounded policies in priority regions. By presenting the results of these studies in monetary terms in addition to the ecological aspects, negotiations with the public financial sector, including finance ministries, can be more effectively conducted. This integrated approach allows for a comprehensive understanding of the economic value associated with ESs, providing a persuasive argument for budgetary allocations that prioritize their conservation and social benefits.

4.6. Methodological Caveats

- Future scenarios: Future scenarios have limitations as they rely on assumptions and past trends, excluding unmanifested trends and unimplemented policies. Despite these limitations, future scenarios provide insights into favorable and unfavorable impacts;
- Data source heterogeneity and lack of field data information: Modeling outcomes depend on the scale of the input data, and this study used a watershed scale to show significant landscape patterns that may directly affect the provision of ESs in priority regions. Further efforts are needed to understand localized effects and improve the accuracy by incorporating field data;
- Carbon sequestration and storage methods: The InVEST carbon model was chosen for estimating carbon storage and sequestration at the watershed scale. The model is widely accepted internationally and is suitable for our purposes. However, there are limitations to the model, such as assumptions about carbon transitions, relying on land-use classification and carbon pool values, and not accounting for carbon movement between pools. Also, climate-smart practices involve using certain plant species exposed to additional factors like pests, wind, and weather, which can affect their growth differently than in a natural ecosystem. Consequently, it is essential to generate detailed and accurate maps and conduct field sampling to better understand the benefits of climate-smart practices in carbon storage and sequestration.

5. Conclusions

From the financial and economic standpoints, we assessed the feasibility of 10 climate-smart practices compatible with the transition to sustainable agricultural practices under integrated landscape management in three priority watersheds in Mexico. The evaluation included the biophysical modeling of potential co-benefits regarding the carbon sequestration and landscape connectivity of three selected practices, which were projected under BAU and ILM scenarios for two periods (2026 and 2041), using 2022 as the base year. The results showed that most climate-smart practices are viable in the medium and long term from a private standpoint. However, more significant benefits in a shorter period are achievable when social and ecological co-benefits are considered. Also, the projected scenarios showed that live fences, isolated trees in pastures, and riparian vegetation would decelerate or compensate for deforestation trends, which is expected to continue in the three evaluated watersheds.

The effect of the biophysically evaluated climate-smart practices on vegetation dynamics improved the provision of carbon services and landscape connectivity in the medium and long term (2026 and 2041). However, the magnitude of these socioecological benefits depends on the case study and the implementation intensity (conservative or ambitious), ranging from decelerating the loss of carbon sequestration capacity and landscape connectivity in the long term to achieving higher values of both services in the medium-term time horizon (2026) than in the base year (2022).

Despite the practices preventing significant losses in connectivity and carbon services, carbon's value decreases over time due to the time value of money and deforestation trends. Nonetheless, implementing the practices is more profitable than doing nothing. Biophysical modeling can support cost-benefit analysis, and the results of the CBA and this integrated valuation approach provide a comprehensive understanding of the ESV, supporting budgetary allocations and prioritizing conservation and social benefits.

Integrating biophysical assessments of ecosystem services provision with financial and economic dimensions is crucial to promoting climate change adaptation and gender-focused green recovery initiatives within resource-constrained contexts. A more holistic assessment of the socioeconomic and environmental costs and benefits aids policymakers, municipal institutions, and companies in internalizing those outcomes into informed policy- and decision-making. For example, these evaluations could guide the design of more effective policies for adopting sustainable cattle ranching and agroforestry, enhance municipal planning processes to optimize resource allocation into more resilient and equitable alternatives, and be integrated into business strategies to improve private companies' long-term sustainability, including environmental risk reduction. Moreover, incorporating traditional knowledge into these strategies can enhance community resilience, emphasizing the importance of multifaceted assessments in fostering sustainable development.

Furthermore, the data generated in this study are a starting point for assessing the feasibility and co-benefits of different climate-smart practices, prioritizing sites for implementation at the watershed scale, and evaluating potential outcomes at the landscape level. However, the results depend on multiple factors such as the species combination, survival rates, climate variability, local preferences, stakeholder involvement, market fluctuations, and policy changes, in which future transdisciplinary research is critical. Additionally, a fine-scale analysis with long-term monitoring, including field data, would improve the understanding of the spatial variations in effectiveness, allowing for adaptive management and guiding future scaling efforts.

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