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Translated from the original in spanish **Original article**

Evaluation of the role of the forest and its ecosystem services in a demonstration polygon in Viñales, Pinar del Río. Cuba

Evaluación del papel del bosque y sus servicios ecosistémicos en un polígono demostrativo en Viñales, Pinar del Río. Cuba

Avaliação do papel da floresta e de seus serviços ecossistêmicos em um polígono de demonstração em Viñales, Pinar del Río. Cuba

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ABSTRACT

It is known that forests, depending on their state of conservation, influence the ecological quality of the water network, especially the waters to maintain soil humidity. If these have quality, the effects of drought are attenuated, also favoring the soil quality. The ecosystem service of biodiversity with the presence of an adequate index of species diversity, both flora and fauna, guarantees the necessary processes related to pollination, natural pest control, and the aesthetic quality of the landscape. For this, the role of forests and some of their ecosystem services were evaluated, within a demonstrative polygon, to present a proposal for measures that favor them, identifying indicators and variables of each ecosystem service studied, taking into account the problems of each one; allowing the operationalization of the variables during the evaluation, in order to improve the state of water, soils and biodiversity in the Los Monsegui demonstration site.

Keywords: forests, ecosystem services, water, soil, biodiversity.

RESUMEN

Es conocido que los bosques, según su estado de conservación, influyen en la calidad ecológica de la red hídrica, en especial las aguas para mantenimiento de la humedad del suelo, si éstas poseen calidad, se atenúan los efectos de la sequía, favoreciendo también la calidad de los suelos; el servicio ecosistémico de biodiversidad con la presencia de un adecuado índice de diversidad de especies, tanto de la flora como de la fauna, garantiza los procesos necesarios relacionados con la polinización, el control natural de plagas, y la calidad estética del paisaje. Para ello se evaluó el papel de bosques y algunos de sus servicios ecosistémicos, dentro de un polígono demostrativo, para presentar a una propuesta de medidas que favorezcan los mismos, identificándose indicadores y variables de cada servicio ecosistémico estudiado, teniendo en cuenta las problemáticas de cada uno; permitiendo la operacionalización de las variables durante la evaluación, con el fin de mejorar el estado del agua, los suelos y la biodiversidad en el polígono demostrativo Los Monsegui.

Palabras clave: bosques, servicios ecosistémicos, agua, suelo, biodiversidad.

RESUMO

Sabe-se que as florestas, dependendo de seu estado de conservação, influenciam a qualidade ecológica da rede hídrica, especialmente a água utilizada para manter a umidade do solo; se forem de boa qualidade, os efeitos da seca são atenuados, favorecendo também a qualidade do solo; o serviço ecossistêmico da biodiversidade, com a presença de um índice adequado de diversidade de espécies, tanto da flora quanto da fauna, garante os processos necessários relacionados à polinização, ao controle natural de pragas e à qualidade estética da paisagem. Para isso, foi avaliado o papel das florestas e de alguns de seus serviços ecossistêmicos em um polígono de demonstração, a fim de apresentar uma proposta de medidas que os favoreçam, identificando indicadores e variáveis para cada serviço ecossistêmico estudado, levando em conta os problemas de cada um; permitindo a operacionalização das variáveis durante a avaliação, com o objetivo de melhorar o estado da água, dos solos e da biodiversidade no polígono de demonstração de Los Monsegui.

Palavras-chave: florestas, serviços ecossistêmicos, água, solo, biodiversidade.

INTRODUCTION

Ecosystem or ecosystem services are the benefits that an ecosystem provides to people. These benefits are the result of natural ecosystem processes (Izurieta *et al.*, 2018). These are provided in complex and interconnected socio-ecological systems, which are characterized by having biophysical and social determining factors that interact with each other.

Although the literature provides different conceptual frameworks and there is still a debate about the scope of the terms processes, functions and ecosystem services that in some cases have been used interchangeably, today it is recognized that the latter constitute a reconceptualization of ecosystem functions, by incorporating the concepts of value and use by human societies. (Sánchez & Maldonado, 2021).

In recent years, there has been an increase in research and publications that refer to ecosystem services, not only in ecological and environmental contexts, but also from other spheres of human endeavor; call it political, economic, cultural, educational, etc. (Correa & Fuentes, 2019).

According to Wildlife Conservation Society with its acronym (WCS), the importance of ecosystem services (ES) lies in the fact that they generate an interface between the generation of scientific knowledge and support for decision making in different contexts. In this sense, the definition of SE according to Fisher *et al.* (2009), corresponds to the elements of ecosystems that are used (actively or passively) to generate human well-being. This implies that ES have to be the result of ecological processes and that they do not necessarily have to be used directly by society (WCS, 2019).

According to him, (Baggethun, 2018) there has not always been a divorce between Economy and Ecology as strong as the one witnessed today. For example, the first unified school of economic thought, that of the French physiocrats, understood land (what today is often called natural capital) to be the source of all wealth. An important thing about this school is that it had a physical notion of the concept of `production. That is, when something was called "economic production" we were talking about production in physical terms, as happens for example in agriculture, forestry or fishing; and in rescuing that union, enhancing the value of ecosystem services plays a fundamental role.

Ecosystem services make human life possible, for example by providing nutritious food and clean water; by regulating disease and climate; by supporting crop pollination and soil formation, and by offering recreational, cultural and spiritual benefits. While these assets are estimated to be worth US$125 trillion, they do not receive adequate attention in economic policies and regulations, meaning that not enough is invested in their protection and management. In the next section, you can learn more about the four types of services provided by global ecosystems (FAO, 2023).

It is important to mention that a healthy, functional forest that conserves a good part of its biotic community is probably the best guarantee of the quality of the service that can be obtained from it.

Forests provide ecosystem services, including pollination, natural pest control, water provision and soil maintenance (Martínez. *et al.,* 2017), which are those studied in this research.

Pollination

Many crops depend on pollinators of certain species, in addition to a certain amount of these organisms for their fruiting. The scarcity of pollinators and the loss of specific pollinators can cause declines in crop yields. For these pollinators to continue providing the service, a wide variety of natural habitats are needed for their feeding, reproduction and shelter (Martínez *et al.,* 2017).

Natural Pest Control

It is estimated that the majority of potential crop pests are controlled by natural enemies such as some birds, insects, parasites, parasitoids, viruses and other types of microorganisms, which are only present in the crop if they have a habitat that sustain them (Martínez *et al.,* 2017).

Some birds can play a fundamental role in regulating pests in a plantation. These birds are associated with forest fragments and biological corridors, which serve as habitat and shelter and provide them with food the rest of the year.

Ecosystem Services of hydrographic basins

Climatic rainfall patterns, as well as the balance of the components of the hydrological cycle, the characteristics of the vegetation, soil and subsoil influence the quantity, quality and temporality of the available water through complex physical, chemical and biological interactions.

Forests provide moisture to the atmosphere that turns into rain in the hydrological cycle. Without forests or wetlands, there would be much less precipitation, since moisture from other sources (e.g. the sea) is not enough to provide rain to terrestrial systems.

Hence the need to reforest the strips of rivers, dams and other bodies of water; these, due to their function, are called hydroregulatory forest strips and contribute to the retention and quality of water (Herrero, 2003).

Soil conservation ecosystem service

A large part of the ecosystem services provided by the soil are due to its relationship with the biotic community, such as the microorganisms, microfauna, microrhizas, that are found in it, which is why soil biodiversity is critical for the service that the soil provides. the soils provide (Rojas *et al*., 2014).

When there are trees, there are many advantages for soil conservation, avoiding erosion through:

- The increase in dead soil cover (litter, branches) and the provision of organic matter, which keep the nutrient cycle active;
- Promotes the natural development of terraces through the accumulation of soil;
- It stabilizes the soil structure through root systems, also increasing infiltration and water retention capacity.
- The reduction of evaporation and therefore the maintenance of humidity in the soil.

Evaluation and valuation of ecosystem services

Evaluation is a process that allows us to demonstrate and express the behavior of ecosystem services for their different beneficiaries. The valuation offers their value, with the aim of integrating them into decision-making processes (Valle, 2022). Both are an important basis for territorial environmental management and the design and implementation of public

policy instruments, as well as for the creation and management of projects focused on appropriation and the generation of environmental awareness (Ruiz, 2018).

Hence, an evaluation of the role of the forest and its ecosystem services is presented, taking as a case study the Los Mosegui Industrial Estate, belonging to the Rubén Martínez Villena Credit and Forest Services Cooperative (CCSF), of the Agricultural Company (EA), Viñales, where difficulties arise with their proper management.

MATERIALS AND METHODS

Brief characterization of the study area

Figure 1 Below shows the location of the study area: Los Mosegui Industrial Estate of the CCSF Rubén Martínez Villena of the EA Viñales, Pinar del Río.

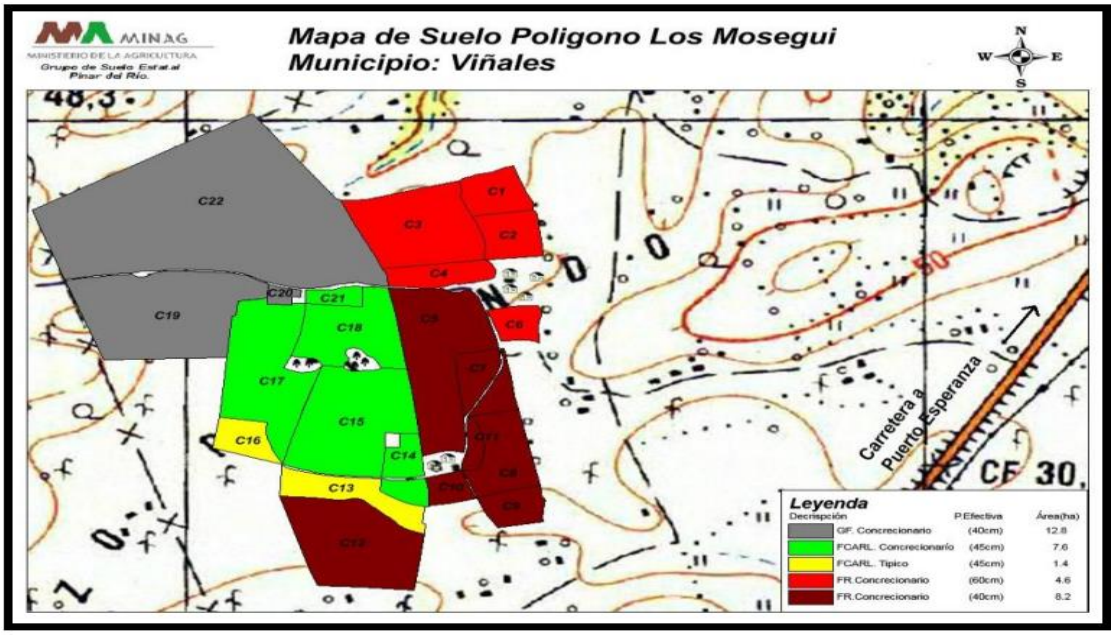

Figure 1. *- Location of the study area. Viñales Municipality*

Source: Planning Plan for the Los Monsegui Demonstration Estate.

Forest Resources

In the area of the farm reserved for forest there are three strata (arboreal, shrubby and herbaceous). Existence of trees used as living fences, taking advantage of the natural regeneration of these native species.

Within the forest resources, 2.34 ha of natural forest predominate; Table 1 lists the plant species present in the study area.

Table 1. *- Inventoried species*

Species Scientific name	*Common name*
***Annona muricata* L.**	soursop
***American Persian* Will.**	avocado
***Citrus aurantifolia* Christm**	lemon
***Annona reticulate* L.**	chirimoya
***Samanea breath* Jacq**	carob
***Bursera does not fly* L.**	almácigo
***Guazuma ulmifolia* Lam.**	guásima
***Cecropia fur coat* L.**	yagruma
***Savant soapy* L.**	jaboncillo
***Tabernacle lemon leaves* L.**	an egg from a rooster
***Gliricide fence* Jack**	Piñón Florido
***Dichrostachys gray* L.**	marabú
***Company cubensis* Masa et Molt**	for the
***Cordia collococci* L.**	common weaving
***Zanthoxylum Martinicense* Lam.**	ayúa
***Cedrela odorata* L.**	cedar
***Roystonea regia* Kunth.**	Royal palm tree
***Swietenia mahagoni* L.**	Antillean mahogany
***Swietenia macrophylla* King.**	honduran mahogany
***Trichilia hirta* L.**	ax head

***Source: Los** Monsegui Demonstrative Polygon Planning Plan (2023).*

Faunistic species that inhabit the area:

The area is characterized by presenting a great variety of plant formations, where secondary forests predominate, which adjoin natural fragments. Furthermore, the presence of bodies of water favors a varied faunal diversity; where most classes of terrestrial vertebrates are represented, with birds predominating. It is noteworthy that there are also migratory species that use the territory for rest, replenishment of fat and then continuation of journeys. Among the most represented species are the following (Table 2).

***Table 2.** - Some species of birds reported in the polygon*

Scientific name	*Common name*
Colinus virginianus (L)	Codorniz
Zenaida asiática (L)	Paloma Aliblanca
Zenaida macroura (L)	Paloma rabiche
Columbina passerina (L)	Tojosa
Chlorostilbon rocordii (Gervais)	Zunzún
Crotophaga ani (L)	Judío
Coccyzus merlini (D'Orbigny)	Arriero
Bubulcus ibis (L)	Garza Ganadera
Jacana spinosa (L)	Gallito de Río.

***Source: Los** Monsegui Demonstration Polygon Planning Plan (2023).*

Table 3 shows the most representative reptiles in the study area.

***Table 3.** - Reptiles of the study area*

Scientific name	**Common name**
***Epicrates angulifer* BIBRON .**	Majá
***Alsophis cantherigerus* Schlegel.**	Jubo sabanero
***Anolis equestris* Merrem.**	Chipojo
Anolis porcatus	Chameleon

***Source:** Los Monsegui Demonstrative Polygon Planning Plan (2023).*

The ecological network is made up of a primary natural matrix in the Sierra de los Órganos and an intermediate protection zone in the heights of Pizarras del Sur, where broadleaf forests are located: typical mesophilic semi-deciduous on acidic soil, natural pine forests of *Pinus caribaea* and *Pinus tropicalis*.

It is considered important to mention that it has two relatively close natural areas that stand out for their high landscape, fauna and floristic value and enable the exchange of different plant and animal species. This area serves as an ecotonal zone, which favors connectivity between natural relics and provides ideal conditions for the development of biological diversity in general, which are found within the polygon.

The Viñales National Park protected area is located in the natural matrix. The area has a high biotic potential and physical-geographic values, high endemism, habitat for endangered species and landscape values, being 5 km from the polygon.

For these reasons and the location of the polygon with respect to the aforementioned areas, it is considered that it plays an important role in the development of life and reproduction of different species of animals and plants, as long as conservation actions, soil improvement, water and forest management are implemented. Also, if there exits the established vegetation in the crop area, as well as the surrounding areas. It also serves as a natural corridor for various species and as a breeding and breeding area for them.

Theoretical methods of documentary research, bibliographic analysis of authors related to the topic, as well as empirical methods of scientific observation were used.

Below are the steps to follow or the methodological outline of the research (Figure 2).

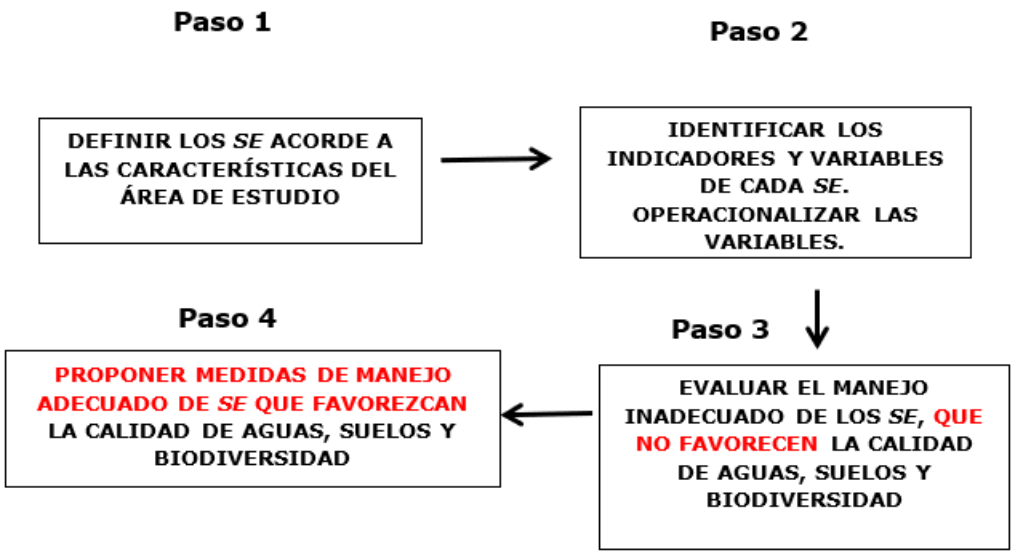

Figure 2. *- Step-by-step scheme for evaluating the role of the forest and its ecosystem services in the study area*

RESULTS AND DISCUSSION

Monsegui Demonstration Estate is of great importance for the area, due to its characteristics as a protector of Soils, Waters and Forests with a view to sustainable land management. Its forests have a high % of native species (71.4), according to the Los Monsegui Demonstrative Polygon Planning Plan (2023).

For step 1 you have:

Identification and characterization of ecosystem services (Table 4)

Table 4. *- Ecosystem services*

Supply services	Regulatory services
The comprehensive assessment of biodiversity and ecosystem services is conceived in the territory as an agroecosystem, where interest in the individual social or ecological components is recorded, as well as the local interactions between them.	**Water control:** The protection of water resources, both in quantity and quality, is key to the success of an ecosystem. Systematic sampling of water supply sources is carried out. **Soil improvement:** Erosion is worked on with control measures and soil conservation and improvement technologies. However, emphasis should be placed on improvement from a forestry point of view (windbreaks, as well as resources for water protection. **Pollination:** Pollination is considered by agricultural producers as an ecosystem service with low management capacity in the polygon, because they consider forest relics necessary as shelter and habitat for pollinators.

Source: *Own elaboration based on the updated opinion of the "Los Mosegui " Industrial Estate, request to opt for recognition of a site initiated in sustainable land management (2022).*

The proposed step 2 is recorded in Table 3, Table 4 and Table 5 referring to the operationalization of variables and indicators of each ecosystem service studied. Tables 5, Table 6 and Table 7 below.

Table 5. *- Biodiversity Conservation ecosystem services*

Indicator	description	Measurement	Elements to evaluate	Criteria
-Natural forest cover	-Amount in Hectares	Dasometric parameters	Restoration/improvement of natural forest cover	Effects of forestry management among others.
Forest composition and structure. **-Diversity indices**	-Forest age class -Forest or ecosystem structure -A set of native species -Forest density -Amount of standing and	Dasometric parameters and floristic study.		Preference for pollinators in the main

	fallen dead wood.			
-Size or connectivity of the network of conservation areas. **-Representativeness of the network of conservation areas**	Network connectivity of conservation areas Connectivity with conservation areas outside the polygon. Connectivity with the habitat outside the network of conservation areas. Presence of natural environmental values Available habitat area Habitat Suitability Habitat connectivity inside and outside the polygon.	Maps of area communication networks.	Maintenance of a network of conservation areas sufficient at an ecological level.	State of biological corridors and relict forests
-Anthropogenic disturbance at the landscape level	-Disturbance level -Road density -Fragmentation level	Landscape study methodology.	Conservation of the characteristics of natural forests.	Action of the communities and actors involved.
-Diversity of native fauna species. **-Availability of habitat within the polygon for focal species that facilitate pollination.**	-Abundance of species suitable for pollination. -Habitat area available -Habitat suitability -Habitat connectivity -Area protected from illegal hunting and illegal logging	Biodiversity Study. Faunistic analysis aimed at the species involved.	Conservation of the diversity of fauna species suitable for pollination.	Pollinators at its core Current laws and regulations

Table 6. *- Ecosystem services of hydrographic basins*

Indicator	description	Measurement	Elements to evaluate	Criteria
-Water quality.	-Water turbidity -Water temperature -Dissolved oxygen -pH of water -Nutrients in water (phosphorus, nitrogen) -Sedimentation level/sediment load of water (grams per liter) -Perceived quality of water (used as drinking water, drinking water for livestock and other purposes)	Analysis of existing bodies of water.	Water quality maintenance	Systematic analyzes
-Condition of watersheds	-Percentage of forest cover in the relevant watershed undisturbed -Percentage of degraded land in relation to total land area -Percentage of the shore of a body of water with forest cover -Percentage of undisturbed water sources -Length of the water bank restored with tree plantations with the purpose of providing shade and reducing the temperature inside the stream -Reforestation/restoration area	Hydrological maps of the study area and *in situ verification.*	Maintaining the capacity of watersheds to purify and regulate water flows.	hydroregulatory forest belts and the water network in general.

Table 7. *- Soil conservation ecosystem services*

Indicator	description	Measurement	Elements to evaluate	Criteria
-Soil properties	-Thickness of the soil organic matter layer -Organic matter content (%) -Soil nutrient content (N, P) -Abundance of macrofauna in the soil -Soil stability -Area and degree of soil compaction (roads and exploitation areas)	Soil analysis.	Soil condition maintenance	Systematic soil analysis
-Soil condition	-Percentage of undisturbed forest cover -Forest area as a proportion of the total land area. -Proportion of degraded land in relation to the total land area. -Percentage of damaged soil -Degree of soil compaction in the areas in which it operates (roads and exploitation areas) -Drained peat bog area -Incidence of landslides -Productivity (forestry and agricultural) per unit. -Volume of production per unit of work by size classes of agricultural/pastoral/forestry enterprise	Soil maps of the study area and *in situ verification.*		Soil quality
-Soil erosion	Area affected by wind and/or water erosion. Amount of erosion (cubic meters, affected area). Soil erosion and sedimentation levels.	Preliminary studies, *on-site verification.*	-Reduction of soil erosion through reforestation/restoration	State of the soils in terms of the type of erosion.

	-Impacts of sediment deposited by wind and/or water erosion on nearby land or bodies of water -Percentage of family units within local communities affected by landslides

Source: *Own elaboration with adjustments from FSC-PRO-30-006 V1-2 ES (2021).*

Step 3. Evaluate the consequences of inadequate management of ES, which do not favor the conservation status of the forests.

Premises

Mosegui " Industrial Estate, application to opt for the recognition of a site initiated in sustainable land management (2022) and the Los Monsegui Demonstrative Industrial Estate Planning Plan of the CCSF Rubén Martínez Villena, Mpio . Viñales, 2023, as well as the diagnosis carried out based on the indicators proposed for each SE studied:

- Pollination is considered by producers as an ecosystem service with low management capacity, because it depends on natural and ecological factors that are difficult to control directly by humans. They consider forest relics necessary as shelter and habitat for pollinators. Key habitats for pollinators are found in forested areas, regenerating vegetation, and other natural areas that provide flowers for pollinators throughout the year.

- The periphery of the reservoir is unprotected, so there is an urgent need to reforest the entire hydroregulatory belt. Among the tree species, the *Cedrela predominates odorata* (375 plants), *Swietenia mahagoni* (185 plants), *Swietenia macrophylla, Trichilia hirta,* among others

- According to previous studies carried out to update the polygon's opinion, there is a low level of knowledge about the protection of natural resources, ecosystem services and the application of technologies with less environmental impact.

- Hydroregulatory strips of the Rosario, El Rosario and El Junco rivers, among others, have an effective management plan that will enable their rehabilitation and conservation; however, it is necessary to direct efforts to their correct execution in order to improve the hydro-ecosystem protection service and water quality.

- The soils of the CCSF are characterized by having low fertility, because their physical characteristics (sandy loam texture) allow the washing of the exchangeable bases, little retention of nutrients, resulting in them being strongly and moderately desaturated with the bases of the absorbent complex, the PH acidic to very acidic and low cation exchange capacity. These characteristics limit the absorption of nutrients by plants, favoring water erosion, making it necessary to resort to organic amendments such as the application of biofertilizers, as well as to develop agroforestry.

Hence, for the maintenance and conservation of forests and their ecosystem services, the following is recommended:

Proposal for adequate management measures for these services, which favors the conservation status of the forests in the study area.

- Develop comprehensive programs for the maintenance, conservation and promotion of forest plantations in the watersheds, as well as in the mountainous areas of the municipality and the Protected Area.

- Carry out soil conservation and improvement programs in areas affected by erosion, salinity and acidity.

- Select the technologies (mixed, polycropping; agroforestry, alternating monocultures; conservation agriculture) to apply in correspondence with the properties of the site.

- Introduce polycultures; silvopastoral systems in the livestock area.

Site preparation alternatives

- Apply soil conservation measures. Among others, reforesting drainage edges, tillage against slope and in contour, use of live fences and windbreaks.

Water management alternatives.

- Protect and reforest surface and underground water bodies.
- Reforest the hydroregulatory strip of surface water bodies.

CONCLUSIONS

The study carried out with the identification of indicators and variables of each ES, as well as the sources of information analyzed, served as a basis for the evaluation of the role of forests and their ecosystem services in the face of their inadequate management.

A proposal is made for adequate management measures for these services, which favor the conservation of forests.

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The authors declare not to have any interest conflicts.

***Contribution of the authors*:**

The authors have participated in the writing of the work and analysis of the documents.