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Partial Economic Valuation of Ecosystem Services in the Yuscarán Biological Reserve

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Abstract– Ecosystem services (ES) provided by protected areas play a critical role in supporting human well-being. This study presents a partial economic valuation of selected ecosystem services in the Yuscarán Biological Reserve (YBR), Honduras, applying a participatory approach for ecosystem service identification and prioritization, followed by economic valuation methods. Semi-structured interviews with the economically active population were conducted to identify and prioritize ecosystem services, followed by a technical characterization of the selected. The economic value of water provision, soil formation, climate regulation, and aggregated non-use services was estimated using a combination of revealed preference, replacement cost, technological substitution, and investment cost approaches. Results indicate that climate regulation represents the highest economic contribution, followed by aggregated non-use ecosystem services, soil formation, and water provision. By quantifying the economic value of selected ecosystem services, this study generates baseline information that can support conservation planning and ecosystem management in protected areas with limited availability of primary data.

Keywords-- Biological reserves; economic valuation; total economic value; participatory identification; Honduras.

I. Introduction

Ecosystem services are the direct and indirect benefits that ecosystems provide to human societies and are fundamental to human well-being and quality of life [1]. These services are generated across diverse ecosystems, including forests, watersheds, grasslands, agricultural landscapes, coastal areas, and wetlands, and their availability depends on ecological conditions, land cover, management frameworks, and their recognition within local economies [2]. However, the provision of ES is increasingly threatened by global and regional drivers such as climate change, air pollution, and growing anthropogenic pressures, particularly in biodiversity-rich regions [3].

To better understand and assess ecosystem services, several classification frameworks have been developed, among which the Common International Classification of Ecosystem Services (CICES) provides a structured approach by grouping services according to their primary ecological functions and contributions to human well-being [4]. Over time, CICES has undergone multiple updates, refining the classification of provisioning, regulating, and cultural services and distinguishing ecosystem functions from the benefits derived by society. Within this context, economic valuation has emerged as a key tool to make ecosystem services more visible in decision-making processes, particularly for benefits that are not captured by conventional markets [5]. Valuation methods vary according to the type of ecosystem service and may include approaches such as direct market valuation, the travel cost method, the hedonic pricing method, and others [6]. The incorporation of participatory approaches during the identification and prioritization of ecosystem services has been shown to enhance the relevance and legitimacy of valuation processes by integrating local knowledge and stakeholder perspectives [7].

Within this framework, forests stand out as one of the ecosystems that provide a wide range of ecosystem services, including carbon sequestration, hydrological regulation, soil nutrient retention, biodiversity conservation, and climate regulation, playing a critical role in maintaining ecological stability at local and global scales [8]. Many forest ecosystems are designated as protected areas, which are recognized as effective mechanisms for conserving forest cover and associated ecosystem services [9]. Despite their importance, protected forests worldwide face increasing threats, particularly in Latin America: land-use change, uncontrolled forest fires, agricultural expansion, livestock production, mining activities, invasive species, and habitat fragmentation, leading to progressive ecosystem degradation [10, 11].

In Honduras, biological reserves play a crucial role in conserving forest ecosystems and supporting ecosystem services that are essential for local communities. The Yuscarán Biological Reserve, located in the eastern region of the country, represents an ecologically significant protected area due to its contribution to water provision, biodiversity conservation, and climate regulation [12]. Despite its socio-environmental importance, there is limited quantitative information regarding the economic value of ecosystem services provided by this reserve. Consequently, the purpose of this study is to estimate the partial economic value of three use-related ecosystem services and an aggregated group of non-use ecosystem services within the YBR. To achieve this purpose, the study pursues the following specific objectives: (i) to conduct a participatory qualitative assessment to identify the ecosystem services present in the Yuscarán Biological Reserve; (ii) to characterize the ecosystem services prioritized by the selected population; and (iii) to estimate the economic value and final economic prioritization of four ecosystem services based on their monetary value and spatial distribution across the total area of the reserve.

II. MATERIALS AND METHODS

A. Study area

The study was conducted in the Yuscarán Biological Reserve, located in the municipality of Yuscarán, El Paraíso Department, eastern Honduras (Fig.1). The reserve covers an area of 6,065.55 ha and was established under Decree 87-87 as part of the national system of protected areas due to its importance for cloud forest conservation, water production,

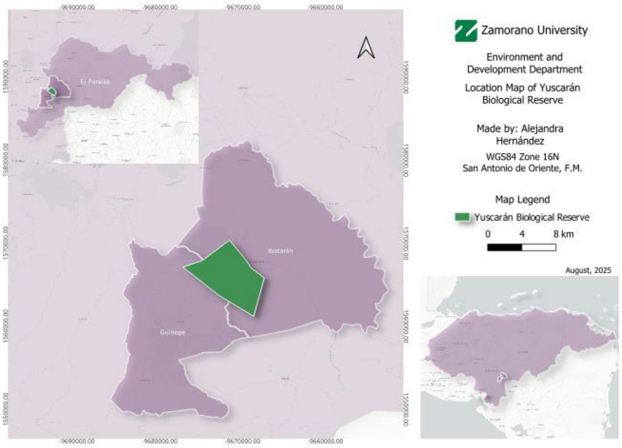

Fig. 1 Location of the study area.

and biodiversity protection [12]. The reserve reaches elevations of up to 1,980 m above sea level at Cerro El Volcán and forms part of a biological corridor recognized as an Area of Importance for Bat Conservation [11]. The surrounding communities depend on ecosystem services provided by the reserve, particularly those related to water provision, climate regulation, and soil conservation.

B. Participatory Identification and Prioritization of Ecosystem Services

A participatory qualitative assessment was applied to identify and prioritize ecosystem services associated with the YBR, following established methodological recommendations for the integration of local knowledge in ecosystem service assessments [13].

The study population was selected using a convenience sampling strategy, based on accessibility and relevance to the research objectives [14]. Participants were drawn from the economically active population (EAP) of the municipality of Yuscarán, defined as individuals older than 15 years [15].The final sample consisted of 27 participants. Selection bias was mitigated through the application of predefined inclusion criteria, including professional status, residence in the study area, or basic knowledge of the biological reserve.

Data collection was conducted through semi-structured interviews, designed based on a review of ecosystem service assessments in protected areas and structured according to the CICES classification, version 4.3 [16]. The interview protocol followed methodological guidelines proposed by Arcos Severo and Ruiz Rosado [17].

Ecosystem service prioritization was conducted through a frequency-based analysis, in which a mode criterion was applied to identify the services most consistently recognized by participants. The prioritized services were subsequently selected for technical characterization and economic valuation.

C. Technical Characterization of Prioritized Ecosystem Services

The technical characterization of the prioritized ecosystem services was conducted to define the biophysical and socioeconomic variables required for subsequent economic valuation. This step bridged the participatory prioritization phase and the subsequent monetary estimation.

Characterization was carried out through a systematic review and organization of information derived from primary and secondary sources (Fig.2). For each ecosystem service, relevant variables were identified based on the nature of the service and data availability, and corresponding data sources were specified.

The characterization outputs were compiled and systematized to ensure consistency across ecosystem services and to provide standardized inputs for the valuation methods described in the consecutive section (Table I).

D. Economic Valuation Methods

All quantitative data were organized into standardized working matrices and converted to comparable units. Monetary values were homogenized and expressed in $USD \cdot year^{-1}$ and $USD \cdot ha^{-1} \cdot year^{-1}$ to allow integration into the partial Total Economic Value (TEV) framework. All calculations were based on an area of 4,187 ha corresponding to the updated delimitation of the YBR.

1) Water: The partial economic value of the water provision ecosystem service was estimated using a revealed preference method based on household water tariffs already established in the community providing an observed preference valuation of willingness to pay.

A total of 14 water intake infrastructures located within the YBR were identified, of which eight were included in the analysis due to the availability of complete information. The remaining six were excluded as the associated communities were unable to provide sufficient data on the status of their water intake systems.

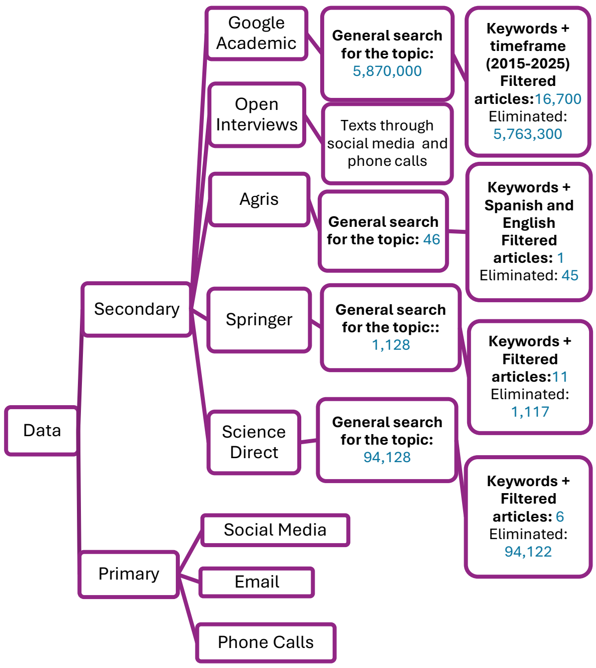

Fig. 2 Methodology to obtain primary and secondary data.

TABLE I
CHARACTERIZATION CRITERIA AND VALUATION METHODS FOR ECOSYSTEM SERVICES

Ecosystem Service	Characterization Criteria	Valuation Method	Source
Water provision	Monthly and annual flow rates for each water intake structure; number of households using the resource per month and per year; and monthly and annual tariffs paid for the service to water user associations or organizations responsible for managing the water resource.	Revealed Preference	Korsgaard and Schou [18]
Soil Formation	Soil formation rate and unit cost of compost.	Replacement Cost	Drechsel *et al.* [19]
Climate Regulation	Evapotranspiration factors: average surface evaporation; steam energy consumption converted per unit volume of water; electricity price; latent heat of vaporization of water; and water density.	Technological Substitution	Zhao *et al.* [9]
Non-Use Services	No variables were used, as the monetary value was directly classified under the TEV approach, complemented by projected investment data from the YBR management plan.	Investment Cost	Bhandari *et al.* [20]

For each intake system, data on measured discharge (flow rates), number of beneficiary households, and monthly water tariffs (HNL) were compiled. Flow data were converted to $m^3 \cdot month^{-1}$ to ensure dimensional consistency. Average household water consumption was then estimated and expressed as $USD \cdot m^{3-1} \cdot household^{-1} \cdot month^{-1}$ and subsequently annualized to obtain $USD \cdot year^{-1}$ per intake system. The total annual economic value of water provision was calculated as the sum of all intake systems and normalized by the effective area of the reserve, yielding an estimate in $USD \cdot ha^{-1} \cdot year^{-1}$.

2) Soil Formation: The partial economic value of the soil formation ecosystem service was estimated using a replacement cost approach, based on the cost of substituting naturally formed soil with an equivalent external input. The estimation required the calculation of key biophysical parameters, including soil formation rate and bulk density.

Due to the absence of site-specific measurements, parameter values were derived from scenarios with comparable environmental and edaphic conditions. These included soil formation rates ($mm \cdot year^{-1}$) reported for Andisols under productive land uses, as well as bulk density values for volcanic dark soils, soils with slopes of approximately 15%, and soil depths of 38 cm. Mean values were calculated to obtain representative parameters for the study area. Soil characteristics were based on the classification of soils in the YBR reported by Simmons [21]. The annual soil formation rate expressed in mass units ($t \cdot ha^{-1} \cdot year^{-1}$) was calculated using (2), adapted from Montgomery [22] and the economic value of soil formation was then estimated using (3), adapted from Drechsel *et al.* [19].

$$FS = T \times DA \times 10 \tag{1}$$

$$VE = FS \times CUC \tag{2}$$

Where in (2), FS represents the soil formation rate expressed in tons per hectare per year ($t\ ha^{-1}\ yr^{-1}$), T denotes the vertical soil formation rate of Andisols ($mm\ yr^{-1}$), and DA corresponds to soil bulk density ($t\ m^{-3}$). The constant factor 10 is a unit conversion coefficient used to transform vertical soil formation rates expressed in millimeters into volumetric and mass-based units per hectare. For (3) VE refers to the economic value of soil formation ($USD\ ha^{-1}\ yr^{-1}$), FS is the estimated soil formation rate, and CUC represents the unit cost of compost ($USD\ t^{-1}$) used as a replacement input to approximate the cost of restoring soil formation functions under a hypothetical degradation scenario.

3) Climate Regulation: The economic valuation of climate regulation as an ecosystem service was conducted using an energy substitution approach, following the methodology proposed by Zhao *et al.* [9]. This approach estimates the climatic regulation function of ecosystems through their role in evapotranspiration processes, which contribute to temperature stabilization and humidity regulation by dissipating latent heat.

The economic value associated with humidity regulation was calculated using (4), which relates surface evaporation to the energy required to replace this natural process through artificial means:

$$V_{r2} = Q_{r2} \times Q_e \times P_{r2} \tag{3}$$

Where $V_{(r2)}$ represents the value of humidity regulation ($USD\ ha^{-1}\ yr^{-1}$), $Q_{(r2)}$ is mean surface evaporation (mm), Q_e denotes the energy consumption required to vaporize a unit volume of water ($kWh\ m^{-3}$), and $P_{(r2)}$ corresponds to the electricity price ($USD\ kWh^{-1}$). Similarly, the economic value of temperature regulation was estimated using (5):

$$V_{r3} = Q_{r3} \times W/Y \times P_{r3} \tag{4}$$

Where $V_{(r3)}$ is the value of temperature regulation ($USD\ ha^{-1}\ yr^{-1}$), $Q_{(r3)}$ represents mean surface evaporation (mm), W is the latent heat of vaporization of water ($kWh\ kg^{-1}$), Y denotes water density ($kg\ m^{-3}$), and $P_{(r3)}$ is the electricity price ($USD\ kWh^{-1}$). A mean potential evapotranspiration value of 1,364.7 mm was used for both $Q_{(r2)}$ and $Q_{(r3)}$. To reduce potential bias, this value was adjusted using crop coefficient ($K_{(c)}$) values to better reflect actual evapotranspiration conditions within the reserve. Crop coefficients were assigned based on land-use and land-cover categories present in each part of the YBR and derived from studies conducted in environmentally and biophysically comparable ecosystems, improving the accuracy of the economic valuation. Spatial data on land-use and land-cover were obtained from the Honduran Forest Sector Geoportal. The resulting values for humidity and temperature regulation were aggregated to obtain the total economic value of climate regulation, expressed in USD yr^{-1} and USD ha^{-1} yr^{-1}.

4) Aggregated Non-use Ecosystem Services: The economic value of non-use ecosystem services in the YBR was estimated using the TEV framework, which enables the systematic identification of both use and non-use benefits generated by ecosystems. This study follows the methodology proposed by Bhandari *et al.* [20], who recommend the TEV framework as an integrative tool for valuing natural forests by distinguishing use values (direct and indirect) from non-use values (option, existence, and bequest) that captures non-market benefits associated with conservation efforts, management activities, and knowledge generation, which reflect existence, legacy, and information values rather than direct or indirect use. Altruistic non-use values were excluded due to the absence of reliable data. The relative contribution of each ecosystem service was calculated as a proportion of the total estimated economic value of the reserve.

Non-use values were approximated using an investment-based approach, whereby annual expenditures allocated to conservation, environmental education, and research programs within the protected area were used as proxies for society's willingness to preserve ecosystem functions independently of direct use. Investment data were obtained from the Instituto Nacional de Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre (ICF) [12]. Identified expenditures were classified according to their corresponding non-use value categories, standardized, and expressed in USD$\cdot$$ha^{-1}\cdot yr^{-1}$.

E. Integration and Final Economic Prioritization of Ecosystem Services

The economic values estimated for individual ecosystem services were integrated into a consolidated valuation matrix presenting total values and unit values, allowing for a comparative assessment of their monetary contributions to the YBR. This integration facilitated the construction of a partial TEV framework described before.

Final prioritization of ecosystem services was based on their estimated economic values expressed in USD yr^{-1} and USD ha^{-1} yr^{-1}. Services were ranked in descending order according to their monetary contribution, enabling the identification of their relative economic importance within the reserve. A matrix was constructed, including the ecosystem service, its total and unit economic values, and its corresponding rank. This ranking represents the final prioritization of both use and non-use ecosystem services in the YBR and provides a transparent basis for comparison and interpretation of valuation results.

II. RESULTS

A. Participatory Identification and Prioritization of Ecosystem Services

Based on semi-structured interviews with the selected population, a total of 22 ecosystem services associated with the YBR were identified and subsequently prioritized, from which five were selected as the most important. These ecosystem services were classified into five groups, among which regulating and maintenance services accounted for the largest share of mentions (36%). This distribution reflects the perceived importance of regulatory functions for environmental stability and ecosystem resilience within the reserve, particularly in the context of a protected area with limited direct resource extraction.

The participatory ranking identified water provision, air quality regulation, tourism, soil formation, and climate regulation as the most important ecosystem services (Table II). This ranking provides a clear rationale for the selection of services subjected to subsequent technical characterization and economic valuation. Although air quality regulation and tourism were initially assigned the same priority position, air quality regulation was ultimately ranked higher because it was mentioned by a greater number of respondents. This outcome highlights a preference for regulating services over cultural services when prioritization involved trade-offs among ecosystem benefits.

Several of the prioritized ES are consistent with those identified in formal management frameworks for protected areas in Honduras, including water provision, climate regulation, air quality improvement through carbon capture, and scenic beauty [23]. Comparable participatory assessments conducted in Latin America report similar patterns. For example, in the El Padmi micro-watershed in Ecuador, local populations prioritized water for human consumption, followed by provisioning services and air quality regulation [24]. In a similar way, a study carried out in a biosphere reserve in central Chile found comparable results through semi-structured interviews, identifying water as the most important ecosystem service perceived by local

TABLE II
PARTICIPATORY PRIORITIZATION, CICES CLASSIFICATION, AND SELECTION CRITERIA FOR ECOSYSTEM SERVICES

Ecosystem services	Justification for the selected population	Priority assigned by the selected population	CICES classification	Adjusted priority β
Water Provison	Primary source of water supply for Yuscarán, Güinope, and Oropolí, and the most widely used resource by the community.	1	Provisioning	1
Air Quality Regulation	Air purification perceived within the municipality.	2	Regulation and Maintenance	2
Tourism	Regular field visits are conducted to the reserve, which also functions as a tourist attraction for the area.	2	Cultural	3
Soil Formation	Service that provides support for all ecosystems present within the reserve.	3	Regulation and Maintenance	4
Climate Regulation	Regulation of microclimates within the reserve and surrounding areas.	4	Regulation and Maintenance	5

β: Prioritization adjusted based on frequency of mention.

communities, followed by fresh air, climate change regulation, and others [25].

In this regard, the predominance of regulating services observed in the YBR may be attributed to its protected status and to local awareness and education of the reserve's role in sustaining ecological functions rather than direct material extraction. Similarly, research conducted in two forest reserves in northern Benin showed that communities located closer to the forest were more capable of identifying regulating and supporting ecosystem services than those located farther away, consistent with the YBR case [26]. The study also found that education level had a significant positive effect on the identification of these services. Overall, the participatory prioritization underscores the centrality of regulating ecosystem services in local decision-making and provides a socially grounded foundation for the economic valuation and final ranking of ecosystem services presented in the following sections.

B). Economic Valuation of Ecosystem Service Use Values

1) Water provision: Water provision was identified as the highest-ranked ecosystem service in the participatory prioritization and represents the most socially relevant use ES provided by the YBR.

The estimated economic value of water provision reached USD 48,727.68 per year, equivalent to USD 11.64 per hectare per year. In relative terms, water provision ranked as the lowest among the economically valued ecosystem services; however, this result reflects the institutional and social context in which water tariffs are designed to ensure affordability rather than to internalize the full economic value of the service.

The economic valuation of this service was based on the water intake systems with complete information, which supply urban and peri-urban households through gravity-fed distribution systems dependent on surface water sources within the reserve. Monthly tariffs ranged from USD 0.48 to USD 4.00 per household, resulting in annual values per intake system between USD 1,248 and USD 13,296, depending on flow availability, number of beneficiary households, and tariff structure. Substantial variability was observed among intake systems.

The lowest unit values were associated with La Cidra, Los Iguanos, and La Aurora, which presented tariffs as low as USD 0.0009 per m^3 per month per household, whereas La Ínsula 2 exhibited the highest unit value (USD 1.59 per m^3 per month per household). These differences may be linked to variations in management arrangements, service quality, accessibility, and socio-economic characteristics of the population served. Despite this heterogeneity, the aggregated valuation highlights the consistent dependence of the municipality on water resources originating within the protected area.

The relatively low economic value estimated for water provision should therefore be interpreted as a conservative approximation, constrained by existing tariff schemes rather than by hydrological scarcity or ecosystem performance. Comparable studies in Latin America report substantially higher willingness-to-pay values for watershed services. For example, households in Loja, Ecuador, have an average willingness to pay USD 5.80 per month for basin protection to improve water quality and reliability, with strong support across income levels [27]. In Costa Rica, the water purification service provided by forests is valued at USD 9.5 per hectare per year, based on a methodology that assesses the effects of forest cover on water quality and treatment costs, thereby reflecting a systematic approach to economic valuation [28]. This contrast underscores the extent to which existing pricing mechanisms shape the monetary expression of ecosystem service values.

From a management perspective, the valuation of water provision underscores the critical role of the YBR in sustaining urban water security.

The reliance of multiple intake systems on forested micro-watersheds within the reserve suggests that ecosystem degradation could directly translate into reduced availability or increased supply costs. A case study in the Ecuadorian Andes also confirms that inadequate water service tariffs can lead to financial unsustainability and suggests that integrating ecosystem conservation into municipal water management can be justified by economic values derived from tariff structures supporting investments in hydrological function maintenance [29].

Consequently, even modest economic values derived from current tariff structures provide a quantitative basis for integrating ecosystem conservation into municipal water management and for supporting investments aimed at maintaining hydrological functions within the protected area.

2) Soil Formation: Soil formation constitutes a key regulating ecosystem service within the Yuscarán Biological Reserve, underpinning forest productivity, hydrological regulation, and long-term ecosystem resilience. The economic valuation of this service reflects the contribution of natural soil-forming processes driven by weathering, organic matter decomposition, and biogeochemical cycling across predominantly forested landscapes.

Based on estimated soil formation rates and apparent density values derived from comparable Andisol-dominated systems, the reserve generates approximately 2,889.5 tons of soil per year. Using a replacement cost approach, the total economic value of soil formation was estimated at USD 2,142,009.95 per year, equivalent to USD 511.59 per hectare per year. In relative terms, soil formation ranked as the third most valuable ecosystem service evaluated, reflecting its substantial contribution to the reserve's overall economic value, despite being perceived as only the fourth most important service by the local community.

The spatial distribution of soil formation reflects the predominance of forest cover within the reserve, particularly dense coniferous forests and humid broadleaf forests, which together account for a large proportion of the total soil production. These land covers exhibited the highest estimated annual soil formation rates, whereas mixed forest systems and areas under pastures or crops showed comparatively lower contributions. The dominance of volcanic-derived soils, particularly Andisols with high porosity and favorable physical properties, plays a central role in sustaining soil formation processes across the reserve.

The estimated economic value of soil formation in the YBR is consistent with, and in some cases exceeds, values reported in global and regional assessments. Costanza *et al.* [30] estimated soil formation values in agricultural systems ranging between USD 100 and 500 per hectare per year, while Pimentel *et al.* [31] reported values between USD 10 and 100 per hectare per year based on replacement cost approaches linked to biological activity. The higher value observed in the present study reflects both the extensive forest cover of the reserve and the application of a valuation framework tailored to local ecological conditions and soil characteristics.

The high economic value associated with soil formation underscores the importance of maintaining forest cover and minimizing land-use changes that could disrupt pedogenic processes. Soil degradation within the reserve would imply not only ecological losses but also substantial economic costs associated with the replacement of soil functions. The importance of maintaining forest cover and minimizing land-use change is further supported by evidence from the central mountains of Honduras, where the high economic value of soil formation is underscored by the substantial costs associated with soil degradation. In particular, nutrient loss emerging from inadequate land management represents a significant economic burden, one that conservation practices have been shown to effectively mitigate [32]. Accordingly, soil formation should be recognized as a critical, though often overlooked, regulating ecosystem service in conservation planning and land management strategies within protected areas.

3) Climate Regulation: Climate regulation was the dominant ecosystem service in economic terms within the YBR, in total annual value and per-hectare contribution. The estimated economic value of this service reached USD 6,414,714.91 per year, equivalent to USD 1,754.82 ha^{-1} $year^{-1}$, positioning climate regulation as the primary contributor to the total economic value of the reserve. This result reflects the strong role of forest cover and land-use composition in regulating local microclimatic conditions through evapotranspiration-driven processes.

In tropical forest ecosystems, evapotranspiration contributes to temperature moderation and atmospheric moisture regulation, reducing thermal extremes and stabilizing local climate conditions. The magnitude of the estimated value highlights the importance of these biophysical processes as indirect ecosystem benefits that are not captured through market transactions but generate substantial avoided costs.

The per-hectare value estimated for climate regulation in the YBR falls within the range reported in global and regional assessments of forest ecosystem services. Costanza *et al.* [33] estimated climate regulation values between USD 1,000 and 3,500 ha^{-1} $year^{-1}$ for forested ecosystems, while empirical studies have shown that forest cover can reduce local air temperatures by up to 4 °C, significantly decreasing energy demand for artificial cooling [34]. Similar patterns have been observed in tropical protected areas, where microclimate regulation often represents one of the largest components of total ecosystem service value [35].

In the context of the YBR, climate regulation accounts for more than half of the total estimated economic value of all assessed ecosystem services. However, despite its high economic contribution, this service was perceived by the community as the least important among the five ecosystem services prioritized from the twenty-two ecosystem services identified. This dominance underscores the role of protected forest ecosystems in delivering large-scale regulating services that extend beyond local resource use, reinforcing their relevance for climate resilience and landscape-scale environmental processes.

4) Aggregated Non-Use Ecosystem Services: The aggregated non-use value reached USD 3,146,257.33 per year, equivalent to USD 751.43 ha^{-1} $year^{-1}$, representing the second-largest contribution to the total economic value of the reserve after climate regulation.

The largest share of this value corresponds to existence values, primarily associated with conservation projects and reserve management activities, which together account for the majority of the non-use valuation. These results highlight the economic relevance of sustained institutional investment in protected area governance, even in the absence of direct resource extraction. A methodologically comparable pattern emerges in a TEV assessment conducted at a Ramsar Site in Nepal, where non-use value similarly accounted for more than half of the total economic value of the reservoir, followed by direct use value [36]. Although the two studies differ in their ecosystem type, a biological reserve and a wetland system, respectively, the convergence of their valuation structures suggests that non-use values, particularly those linked to conservation, consistently represent a dominant and often underestimated component of total economic value across different protected area typologies.

In contrast, non-use values related to information, such as environmental education and scientific research, exhibited comparatively lower monetary contributions, while legacy values associated with long-term social and environmental benefits showed moderate contributions. This distribution reflects a valuation structure strongly driven by conservation-oriented investments, emphasizing the role of protected areas as repositories of ecological integrity whose value extends beyond immediate use.

The magnitude of the aggregated non-use value underscores the importance of recognizing conservation expenditures as proxies for societal willingness to maintain ecosystem integrity. Similar approaches have been applied in data-limited contexts where stated preference methods are not feasible, reinforcing the relevance of investment-based valuation for informing conservation planning and policy design in protected areas [20, 37].

C. Integration of Economic Values and Final Economic Prioritization of Ecosystem Services

Table III summarizes the annual economic valuation of the four main ecosystem services assessed in the Yuscarán Biological Reserve, expressed in both USD per year and USD per hectare per year. The TEV of the reserve was estimated at USD 11,751,709.87 (Fig. 3), with use values accounting for the largest share at USD 8,605,452.54, representing 73.2% of the TEV. Within this category, indirect use values dominate (USD 8,556,724.86), indicating that most economic benefits arise from regulating functions, ecological support processes, and non-extractive services.

TABLE III
ANNUAL ECONOMIC VALUATION OF ECOSYSTEM SERVICES IN THE YUSCARÁN BIOLOGICAL RESERVE

Ecosystem service	Total economic value (USD·year^{-1})	Total economic value (USD·ha^{-1}·year^{-1})
Water Provision	48,727.68	11.64
Soil Formation	2,142,009.95	585..97
Climate Regulation	6,414,714.91	1,754.82
Non-Use ES	3,146,257.33	751.43
Totals	11,751,709.87	3,029.48

This pattern is consistent with valuation studies conducted in protected areas, where regulating services often represent the largest proportion of total value due to their broad spatial influence and the application of replacement or substitution-based valuation approaches [38, 39].

Non-use values amount to USD 3,146,257.33, corresponding to 26.8% of the TEV. Existence value constitutes the majority of this component (USD 3,121,835.28), while legacy and option values contribute comparatively smaller shares, estimated at USD 14,885.50and USD 9,536.55, respectively.

The predominance of existence value is consistent with approaches commonly applied in protected-area assessments, where investments in conservation and management are used as proxies for non-use values in the absence of stated-preference data [40].

In terms of individual ecosystem services, climate regulation exhibits the highest annual economic value, reaching USD 6,414,714.91, followed by aggregated non-use services (USD 3,146,257.33). Soil formation ranks third, with an estimated value of USD 2,142,009.95 per year, while water provision presents the lowest economic value at USD 48,727.68 per year (Fig. 4).

When expressed on a per-hectare basis (Fig. 5), climate regulation remains the dominant service, with a value of USD 1,754.82 ha^{-1} year^{-1}, followed by aggregated non-use services (USD 751.43 ha^{-1} year^{-1}) and soil formation (USD 585.97 ha^{-1} year^{-1}), while water provision exhibits a markedly lower value of USD 11.64 ha^{-1} year^{-1}.

Despite its low monetary valuation, water provision was identified as a fundamental ecosystem service during the participatory assessment. This discrepancy reflects methodological constraints associated with the valuation approach, particularly the influence of low existing tariff structures, rather than a lack of social relevance. Conversely, services such as climate regulation, soil formation, and non-use services yield substantially higher economic values due to valuation methods based on replacement costs, technological substitution, large spatial extents, and investment-based approaches.

III. CONCLUSIONS

Of the 22 ecosystem services identified by the local population, five were considered particularly relevant. However, this prioritization differed from the results obtained through economic valuation, where regulating and non-use services ranked highest, while water provision exhibited the lowest monetary value. This contrast demonstrates that social perception does not always align with estimated economic value, underscoring the importance of integrating both participatory and economic approaches in the planning and management of the reserve.

Through the technical characterization of the ecosystem services prioritized by the selected population, information was obtained for three use services, climate regulation, soil formation, and water provision, as well as for non-use ecosystem services classified into different categories. Notably, although some of these services are not directly perceived or consumed; they continue to generate significant economic contributions to the reserve.

The partial economic valuation of ecosystem services in the Yuscarán Biological Reserve was estimated in U.S. dollars per year and per hectare per year. Although partial, these values reaffirm the importance of ecosystem services for local populations and highlight their relevance for guiding conservation investments and supporting decision-making processes derived from these findings.

These findings highlight the need for conservation strategies that recognize both the ecological and socio-economic dimensions of ecosystem services in protected areas.

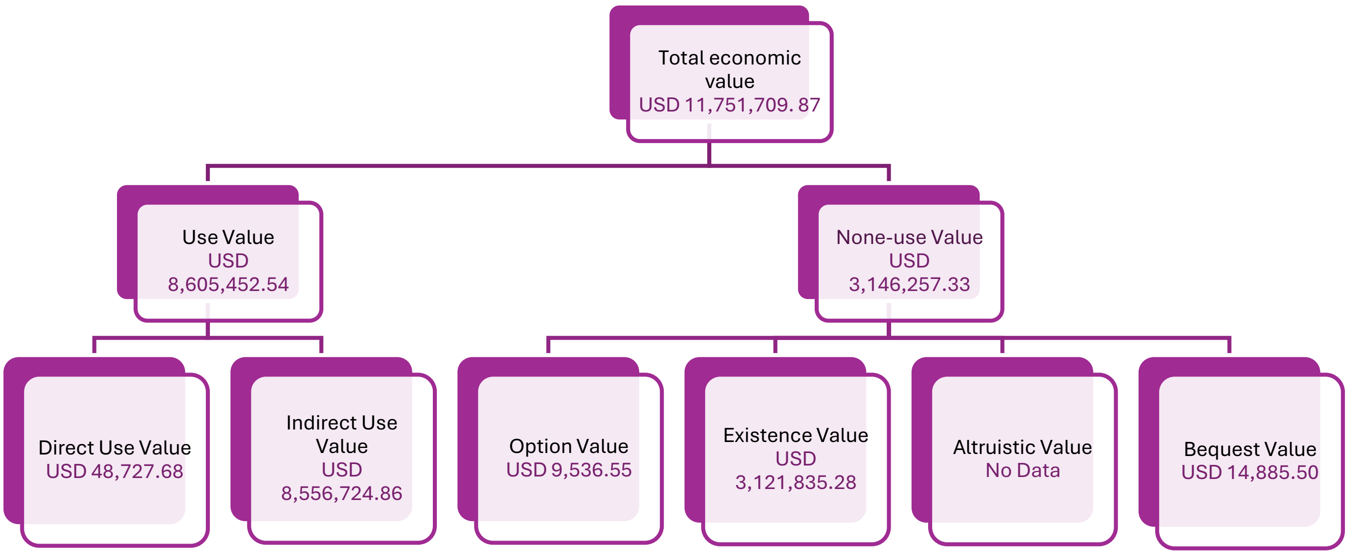

Fig. 3 Distribution of the Total Economic Value of Ecosystem Services in the YBR.

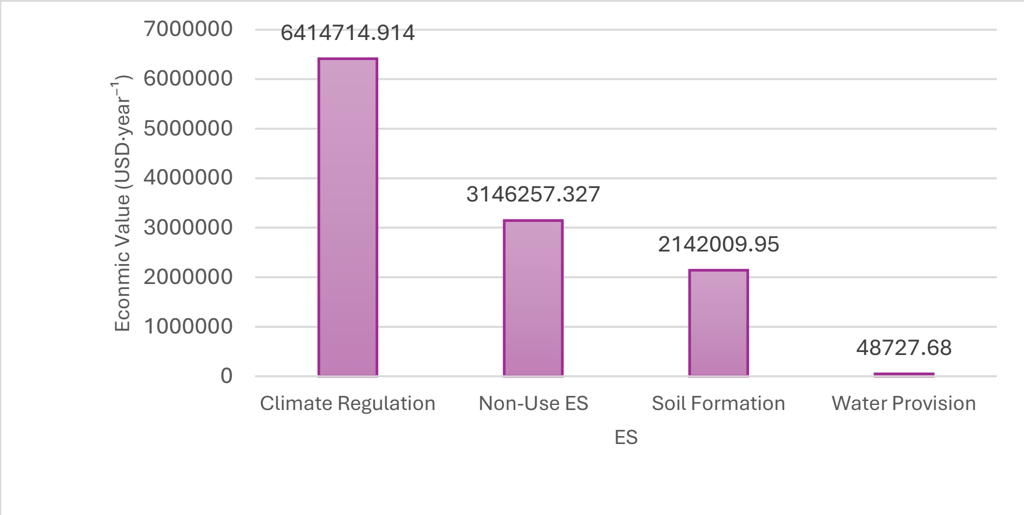

Fig. 4 Prioritization of Ecosystem Services in the YBR Based on Total Annual Value.

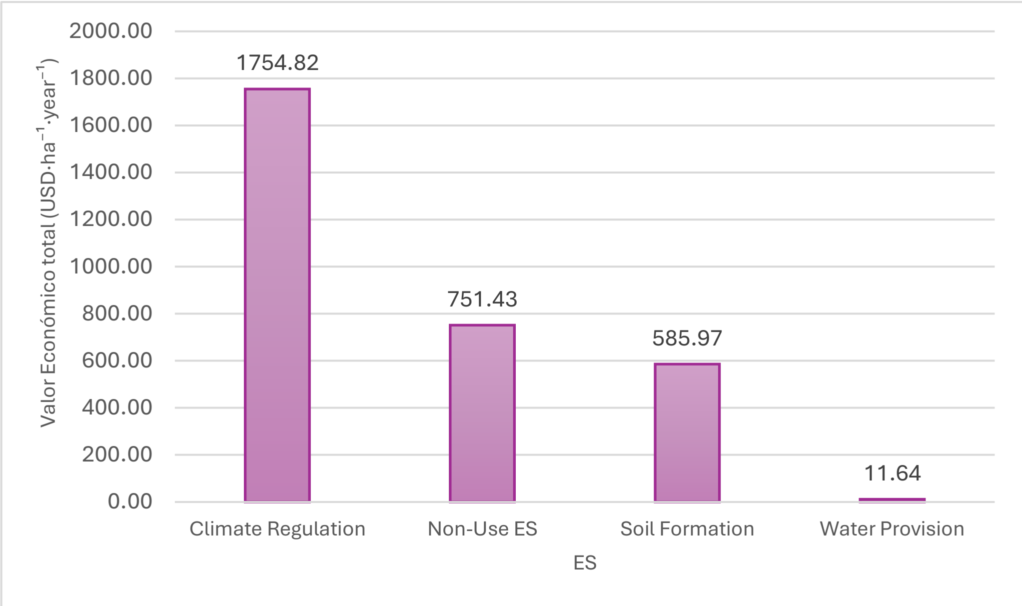

Fig. 5 Prioritization of Ecosystem Services in the YBR Based on Total Annual Value in USD per Hectare.

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