e-ISSN:2316-9834

GeAS

Revista de Gestão Ambiental e Sustentabilidade
Journal of Environmental Management & Sustainability

Received: 19 June 2023 - **Approved:** 16 Jan. 2024
Responsible Editor: Andreza Portella Ribeiro
Evaluation Process: Double Blind Review
https://doi.org/10.5585/2024.24723

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Valuation of ecosystem goods and services of seven Caribbean coastal lagoons: the case of the Sabana-Camagüey Archipelago

María Elena Zequeira Álvarez [1] Roberto González-de Zayas [2] José Miguel Plasencia Fraga[3] and Julio Antonio Lestayo González [4]

[1] Doctor. Faculdade de Ciências Econômicas da Universidade de Camagüey. Camagüey, Camagüey-Cuba. mariaelenazeque@gmail.com

[2] Doctor. Faculdade de Ciências Técnicas da Universidade de Ciego de Ávila. Departamento de Engenharia Hidráulica Ciego de Ávila, Ciego de Ávila -Cuba. roberto.gz710803@gmail.com

[3] Doctor. Centro de Pesquisa Ambiental de Camagüey. Camagüey, Camagüey-Cuba. jmplasencia@cimac.cu

[4] Master. Universidade Nacional Autônoma do México-UNAM. Laboratório de Biogeoquímica Aquática. Instituto de Ciências Marinhas e Limnologia. Cidade do México - México. jalestayo@gmail.com

Authors' notes'

The authors have no conflicts of interest to declare.

Correspondence regarding this article should be addressed to Roberto González-de Zayas.

Acknowledgments. Our special thanks to Vicente O. Rodríguez for revising the manuscript in English and to Idea Wild for supporting with resources such as a laptop and a digital camera. Funding: This research was funded by the Territorial Program “Sustainable Tourism in Cuba”. Project code P211LH005-013.

Cite como - American Psychological Association (APA)

Zequeira Álvarez, M. E., González de Zayas, R., Plasencia Fraga, J. M., & Lestayo González, J. A. (2024). Valuation of ecosystem goods and services of seven Caribbean coastal lagoons: the case of the Sabana-Camagüey Archipelago. *J. Environ. Manag. & Sust.*, *13*(1), 1-32, e24723. https://doi.org/10.5585/2024.24723

Abstract

Objective: This study was to estimate the value of the ecosystem goods and services of seven coastal lagoons in the Sabana – Camagüey Archipelago.

Methodology: Results were obtained using general and empirical methods, as well as different research techniques. Four of the lagoons studied are in Cayo Coco and the rest in Cayo Sabinal.

Relevance: The methodological framework for this research had dynamic, comprehensive and systemic purposes with two steps: comprehensive characterization of the lagoons and their ecosystem goods and services and the calculation of the value (revenues) of these goods and services (real and potential) for each lagoon, for each territory and for the entire study area.

Results: The coastal lagoons from Cayo Coco and Cayo Sabinal offer a wide variety of goods and services (fishing, beekeeping, tourism) still underestimated due to different factors. The direct and indirect use values of these lagoons represented more than 95 % (15 million Cuban pesos) of the total estimated value.

Social / management contributions: the current social and economic context of Cuba and the regulatory and institutional frameworks require the use of methods and techniques for economic valuation of ecosystem goods and services, particularly those of coastal ecosystems, in correspondence with the fast development of tourism in coastal areas. For this reason, the results of this study could be a starting point to expand the valuation of ecosystem goods and service to other Caribbean and Cuban coastal lagoons.

Key words: goods, services, coastal lagoons, tourism, Cuba

Valoración de bienes y servicios ecosistémicos de siete lagunas costeras del Caribe: el caso del Archipiélago Sabana-Camagüey

Resumen

Objetivo: Este estudio fue para estimar el valor de los bienes y servicios ecosistémicos de siete lagunas costeras del Archipiélago Sabana – Camagüey.

Metodología: Los resultados se otuvieron utilizando métodos generales y empíricos, así como diferentes técnicas de investigación. Cuatro de las lagunas estudiadas se encuentran en Cayo Coco y el resto en Cayo Sabinal.

Relevancia: El marco metodológico de esta investigación tuvo propósitos dinámicos, integrales y sistémicos con dos pasos: la caracterización integral de las lagunas y sus bienes y servicios ecosistémicos y el cálculo del valor (ingresos) de estos bienes y servicios (reales y potenciales) para cada laguna, para cada territorio y para toda el área de estudio.

Resultados: Las lagunas costeras de Cayo Coco y Cayo Sabinal ofrecen una amplia variedad de bienes y servicios (pesca, apicultura, turismo) aún subestimados por diferentes factores. Los valores de uso directo e indirecto de estas lagunas representaron más del 95 % (15 millones de pesos cubanos) del valor total estimado.

Aportes sociales/de gestión: el contexto social y económico actual de Cuba y los marcos regulatorios e institucionales requieren el uso de métodos y técnicas para la valoración económica de los bienes y servicios de los ecosistemas, particularmente los de los ecosistemas costeros, en correspondencia con el rápido desarrollo del turismo en áreas costeras. Por esta razón, los resultados de este estudio podrían ser un punto de partida para ampliar la valoración de los bienes y servicios ecosistémicos a otras lagunas costeras del Caribe y Cuba.

Palabras clave: bienes, servicios, lagunas costeras, turismo, Cuba

Valoração de bens e serviços ecossistêmicos de sete lagoas costeiras do Caribe: o caso do arquipélago de Sabana-Camagüey

Resumo

Objetivo: Este estudo teve como objetivo estimar o valor dos bens e serviços ecossistêmicos de sete lagoas costeiras no Arquipélago de Sabana – Camagüey

Metodologia: Os resultados foram obtidos usando métodos gerais e empíricos, bem como diferentes técnicas de pesquisa. Quatro das lagoas estudadas estão em Cayo Coco e o restante em Cayo Sabinal.

Relevância: O quadro metodológico para esta pesquisa teve propósitos dinâmicos, abrangentes e sistêmicos com duas etapas: caracterização abrangente das lagoas e seus bens e serviços ecossistêmicos e o cálculo do valor (receitas) desses bens e serviços (reais e potenciais) para cada lagoa , para cada território e para toda a área de estudo.

Resultados: As lagoas costeiras de Cayo Coco e Cayo Sabinal oferecem uma grande variedade de bens e serviços (pesca, apicultura, turismo) ainda subestimados por diversos fatores. Os valores de uso direto e indireto destas lagoas representam mais de 95% (15 milhões de pesos cubanos) do valor total estimado.

Contribuições sociais/de gestão: o actual contexto social e económico de Cuba e os quadros regulamentares e institucionais exigem a utilização de métodos e técnicas de valorização económica dos bens e serviços ecossistémicos, particularmente os dos ecossistemas costeiros, em correspondência com o rápido desenvolvimento do turismo em áreas costeiras. Por esta razão, os resultados deste estudo poderiam ser um ponto de partida para expandir a valorização dos bens e serviços ecossistêmicos para outras lagoas costeiras caribenhas e cubanas.

Palavras-chave: bens, serviços, lagoas costeiras, turismo, Cuba

Introduction

Cuban coastal lagoons have not been classified using the criteria of Kjerfve (1994). However, González–De Zayas et al. (2022) described -for the first time in Cuba- three coastal lagoons in Cayo Sabinal (Sabana–Camagüey Archipelago) and González-De Zayas et al. (2018) studied trace metals in the sediments of three coastal lagoons in Cayo Sabinal and four lagoons in Cayo Coco and concluded that they were under anthropogenic and natural

pressures.

In Cuba, the Caribbean and around the world, coastal lagoons have been subjected to different natural (Hanley, Bouma, & Mossman, 2020; González- De Zayas et al., 2021) and human pressures (González-De Zayas et al., 2018; Erostate, 2020; Walker, Lee, & Li, 2021) that induce ecological changes in these transitional waters. However, these pressures not only affect the chemical, geological, biological and ecological properties of coastal lagoons, but also the natural goods and services they provided (Basset et al., 2013).

According to Newton et al. (2018), the scientific community knows the importance of these ecosystem goods and services; however, the real value and magnitude of these services are still underrated due to many gaps and limitations such as unified methodologies, different valuation units, variable monetary values, fluctuations in exchange rates, etc. In other cases (such as in Cuba), the absence or limitations to access databases is another problem.

Although in the last decades many new legal and environmental tools to preserve natural resources (including coastal lagoons) have been developed, studies on goods and services of coastal ecosystems are still insufficient in Cuba. Only a few articles regarding the economic value of the mangrove forests of the Sabana – Camagüey archipelago (Gómez, 2002), economic values of some wetlands (Zequeira, 2005; 2006; 2007; Zequeira et al., 2013; 2014) and marine (Figueredo-Martín, Pina-Amargós, & Angulo-Valdés, 2013) and coastal protected areas have been published (Mir Frutos et al., 2022).

The absence of published studies on the goods and services of the Cuban coastal lagoons, and the importance of showing more empirical evidence of the value of transitional waters, led to the two main objectives of this research, 1) to identify the physical indicators of goods and services per categories of the environmental – economic equation for each lagoon, and 2) to obtain the monetary expression of real and potential values of the main goods and services for each lagoon and the total for Cayo Coco and Cayo Sabinal. These objectives will be help to respond how these coastal lagoons impacted or no, by natural and anthropogenic

processes, are important to social and economic development in Cuba

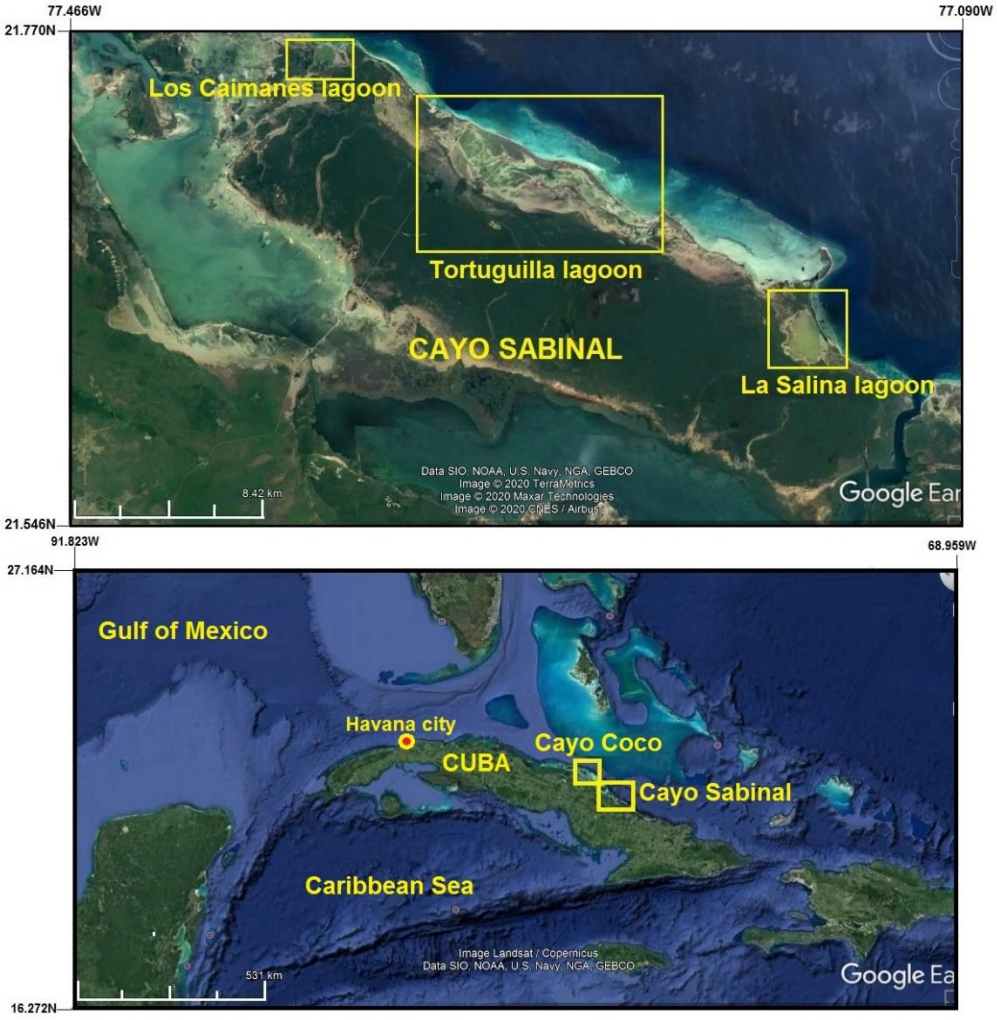
Methodology

Study area

Seven lagoons of the Sabana – Camagüey Archipelago were studied: three (3) in Cayo Sabinal (Figure 1) and four (4) in Cayo Coco (Figure 2). According to González-De Zayas et al. (2022), three lagoons (Los Caimanes, Tortuguilla and La Salina lagoons) in Cayo Sabinal have hypersaline conditions, high nutrient content and low dissolve oxygen and except Tortuguilla Lagoon, the rest have poor marine biodiversity due to their extreme ecological conditions. For more information on lagoons see González-De Zayas et al. (2020) and González-De Zayas et al. (2022).

Figure 1

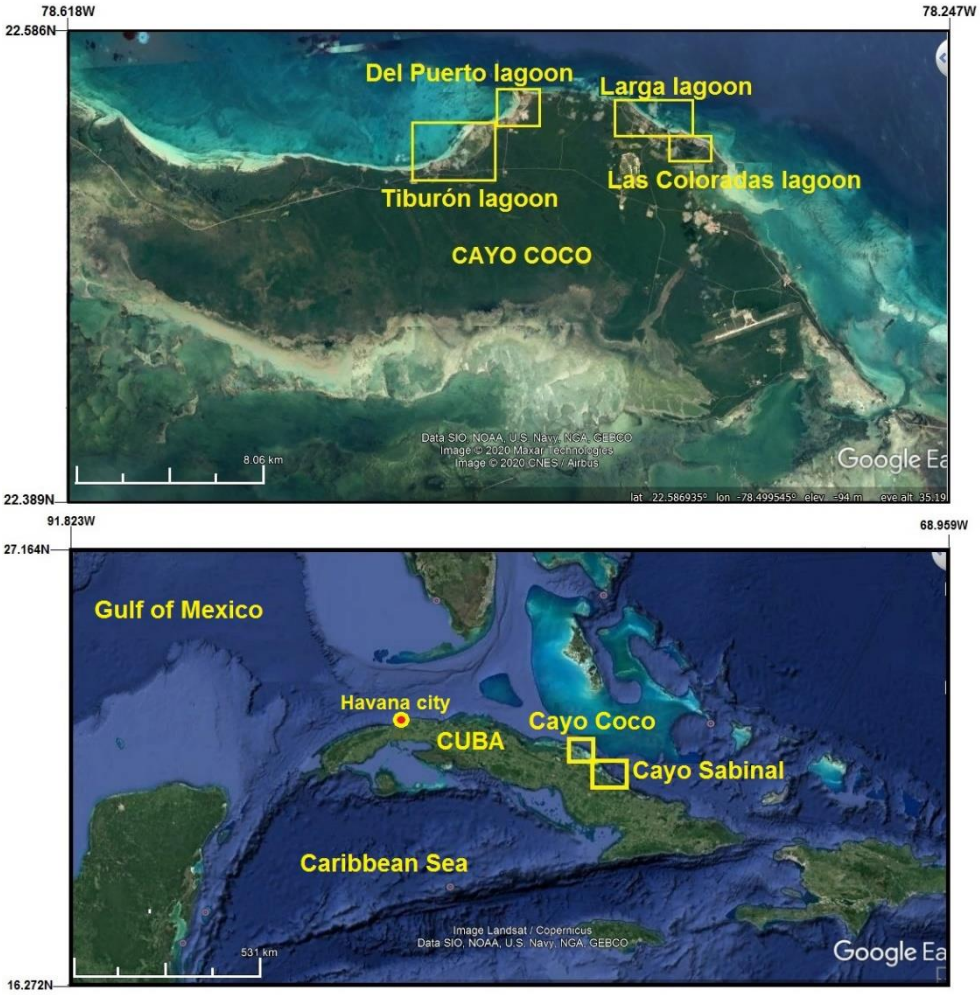
Location of coastal lagoons in Cayo Sabinal (Cuba)



The coastal lagoons of Cayo Coco, (Tiburon, Loma del Puerto, Larga and Las Coloradas) have been less studied (except Larga Lagoon). González-De Zayas et al. (2020) found that Larga and Las Coloradas lagoons were highly impacted (high nutrient and trace metal content, low dissolved oxygen, low water transparency, etc) by tourism activities, and Tiburon and Loma del Puerto lagoons were less impacted. All the lagoons showed high indexes of marine biodiversity and were important in the context of tourism development in Cayo Coco. For more information on lagoons see González-De Zayas et al. (2013; 2018; 2020; 2021)

Figure 2

Location of coastal lagoons in Cayo Coco (Cuba)



General methods

Three general methods were used in this study:

1. Logical-Historical: used to assess the development of the problem and the treatment of the subject in the Cuban context (coastal lagoons).
2. Inductive-Deductive method: used to analyze the behavior of coastal lagoons, potential economic benefits of their products and ecosystem functions, the production of goods and services for the economic activities in the study area.

3. Analysis and synthesis: used to review all previous studies and references on the topic and areas.

Empirical methods

Five empirical methods were used in this study:

1. Documentary and bibliographic study: to know the theories and tendencies related to the research topic based on the study of previous technical reports and references.
2. Observation: for the characterization of the coastal lagoons studied and to document their goods and services.
3. Statistical: for the analysis of information and estimates of ecosystem goods and services.
4. Interviews: to obtain information and/or adaptation of available information from previous studies and databases.
5. Workshops: to obtain criteria about final and partial results.

Research techniques

The research techniques listed below were used:

1. Geographical Information System (GIS): for the characterization of the study area and the transference of economic and environmental benefits of coastal lagoons.
2. Avoided cost (of replacement and alternative/substitute): to estimate the economic value of the benefits from the hypothetical impact of the use of science on ecosystem services.
3. Transference of economic benefits/per hectare: To extrapolate the environmental economic benefits from ecosystems with similar behaviors.
4. Cost of restoration: To calculate the cost of restoration from damage caused by the economic subsystem.
5. Opportunity cost: To calculate the value of goods and services missed when choosing one alternative over another.

The results of this research are presented by stages of the methodological framework designed by the authors, considering the objectives, information required, methodological steps, techniques used and outputs.

Literature review and theoretical framework

Conceptual framework

The authors are affiliated to Environmental Economics, a discipline that began in 1970^{s}, due to the increasing deterioration of the environmental quality of the planet, resulting from the unsustainable economic and technological growth. Environmental Economics is based on the interrelations between economy and the environment, and its main economic functions: supplier of natural resources, waste receptor and assimilator, and direct source of revenues. These functions are, according to Toledo (1998), components of a general life support function. However, these ecosystems, which supply many goods and services need management and conservation actions (Daily, 1997).

The possibility to quantify is given by the fact that in the processes of degradation conservation and mitigation, there are measurable expenses and, the non-existence of ecosystem goods and services would cause damage that could also be estimated.

In this research, the interpretation of categories for the economic valuation of the coastal lagoons studied has considered that the use value is associated to the materiality of goods and services and not particularly from this valuation; for this reason, we defined:

1. Direct use value: price sum of the products obtained from or offered by the coastal lagoon.
2. Indirect use value: estimated value from environmental economic benefits that coastal lagoon functions contribute to society.

3. Option value: sum of the estimated prices of potential products (under conservation) of the coastal lagoon.

Methodological Framework

Many authors agree that the global environment has been increasingly deteriorating due to the unsustainable use of natural resources. Some have shared experiences regarding the use of methodologies that could contribute to a sustainable balance between the economy and the environment (Windevoxhel, 1991; McConnell, 1990; Azqueta, 1994; Dixon & Sherman, 1990; Field, 1995; Barbier, Acreman, & Knowler, 1997; Toledo, 1998; Barsev, 2002).

A complex topic in the Cuban context is the methodological procedures to be used for the economic valuation of goods and services in coastal lagoons. To design this procedure, the environmental economist (head of the research) must work with a multidisciplinary team knowledgeable of the ecosystem in general and of the study area in particular (characterization of the nature and socio-economy subsystems). This team should work on the identification and characterization of the ecosystem geology, geomorphology, climate, ecological processes and critical areas for biodiversity, soil, flora, vegetation, fauna, hydrology and socio-cultural and landscape diversity. The identification of environmental risks and impacts is also an important topic.

An essential aspect of the methodological framework is the selection of techniques, tools and information as well as their reliability, which favors statistical consistency. Finally, a reliable analysis that leads to viable results that inform the decision-making process can be performed. Due to the complexities of the process and data limitations, the use of a partial economic valuation, starting from the selection of products and ecosystem functions, is more frequent at a global scale.

In Cuba, the valuation of economic benefits contributed to human activities by the management of biodiversity is still limited; for this reason, these valuation processes are

included in the National Environmental Strategy. This framework includes previous studies on the valuation of ecosystem goods and services conducted in Cuba, which are important references and tools (Gómez, 2002; Zequeira, 2005; 2006; 2007; Zequeira et al., 2013; 2014; Figueredo-Martín, Pina-Amargós, & Angulo-Valdés, 2013; Mir Frutos et al., 2022).

In this methodological framework, some definitions and statements from the national research project “The Biodiversity of the Sabana- Camagüey Archipelago in the context of Climate Change. Steps for its conservation and management” were included (González –De Zayas et al., 2017). Some examples are given below:

- Coastal lagoons are ecosystems with high fragility and vulnerability to human and natural impacts. There are only a few studies of Cuban coastal lagoons from the holistic point of view.
- The coastal lagoons are aquatic systems bordering continental and insular coastlines. Most of them have limited connections with the adjacent sea, poor water renovation, long residence time, and are ephemeral in the geologic time scale (Kjerfve, 1994).
- In Cuba, coastal lagoons have been subjected to natural and human impacts for the last few decades. Published data of freshwater entries to coastal lagoons is scarce. However, there are many dams in Cuba that could be limiting freshwater fluxes to the lagoons. Some of these lagoons are located near agricultural zones that contribute pollutants such as pesticides and organochlorine compounds (González-Sansón & Aguilar, 1984).
- Waste disposal have impacted some coastal lagoons in Cuba during the last decades.
- During the last decades, the tourist industry has become one of the principal economic activities in Cuba (mainly sun and sand tourism). Many hotels have been built in coastal zones, some of them in or near coastal lagoons. Tourism development has affected water dynamics and the ecological functions of coastal lagoons such as those of Cayo Coco (González-De Zayas et. al, 2013; 2017, 2018; 2020; 2021).

According to Millennium Ecosystem Assessment (2005), ecosystems have dynamic interactions with human populations. Human actions cause ecosystem transformation which brings about changes in aspects of human well – being. The ecosystem – human interactions are measured by the functions and services of these ecosystems and could be classified as:

Provisioning services: consuming goods and services obtained from ecosystems. They are products and tangible support obtained directly from ecosystems.

Regulating services: benefits resulting from regulation of ecosystem processes. They are benefits obtained from the biophysical processes of ecosystems.

Cultural services: Non-materials benefits obtained from ecosystems. These services are closely related to the cultural, moral and ethical features of human groups that interact with the ecosystems, and to the social and cultural development of every person.

Supporting services: they are necessary for providing the rest of ecosystem services.

In this study, we propose an adapt classifications where the word “education” is identified as the importance, scope and dimension of environmental education in Cuba and the term “scientific” is identified as the bacterial structures (stromatolites) reported by Valdespino et al. (2018) at Los Caimanes Lagoon (Cayo Sabinal) that are important in the context of the origin of life on Earth.

The research was conducted following the methodological procedures listed below:

1. Teamwork selection, including previous self-preparation on research background.
2. Workshop to plan the stages of the research.
3. Office work to identify products and functions of coastal lagoons.
4. Selection of variables and indicators per category for the environmental economics equation of coastal lagoons.
5. Classification of selected products and functions per category for environmental economics equation of coastal lagoons.

6. Definition of physical indicators of selected products and functions per category for the environmental economics equation of coastal lagoons.
7. Identification of valuation techniques to be used per category for the environmental economics equation of coastal lagoons.

The methodological procedures for this research followed a dynamic, comprehensive and systemic goal with two stages: Comprehensive characterization of the lagoons and estimate of the real and potential ecosystem goods and services of each lagoon and the total for each zone (Cayo Coco and Cayo Sabinal).

The above-mentioned environmental economics equation is equation 1:

$$Y = \sum_{i=1}^{n} X_i \qquad (1)$$

Where:

Y: goods and services of coastal lagoons (in Cuban pesos)

X_i: categories of valuation (direct use value, indirect use and option) (i=3)

The indicators combined are in equation 2:

$$X_i = \sum_{i=1}^{n} A_{ij} Q_{ij} \qquad (2)$$

Where:

$A_{ij:}$ market price (specific and/or similar) or the cost of the element of the equation (*i*) in the biodiversity or service (*j*)

$Q_{ij:}$ quantities of the elements of the biological diversity and the element of the equation (*i*) in the biodiversity or service (*j*)

Results

In the first stage of this research, all the lagoons studied were evaluated considering the previous characterizations. All the lagoons were euryhaline and hypersaline systems due to the restricted communication with the adjacent sea (Los Caimanes Lagoon is completely closed), scarce precipitation (less than 1200 mm per year), high evaporation rates (more than 1600 mm per year), and the absence of natural freshwater inputs (groundwater and rivers). All the lagoons of Cayo Coco, (particularly Larga and Las Coloradas) receive inputs of sewage fluxes due to occasional discharges from a nearby hotel).

Some ecosystem goods and services associated to the lagoons studied were identified (Table 1).

Table 1

The ecosystem goods and services identified in coastal lagoons of Cayo Coco and Cayo Sabinal

Category of service	Type of service
Provisioning	Food (indirect, it is part of the life cycle)
Regulating	Prevention of erosion
	Control of flooding
	Acumulation of sediments
	Recirculation of nutrients
	Water cycling
	Maintenance of life cycles (migratory species, nursing habitat)
	Habitat for the flora and the fauna
	Maintenance of genetic diversity
Habitat/support	Nesting and feeding areas for marine and migratory bird species.
Cultural	Recreation and tourism
Supporting	Soil formation
	Nutrient cycling
	Primary production
Education	Environmental education
Scientific	Identified microbialite formations at Los Caimanes Lagoon (Cayo Sabinal)

These fragile ecosystems have important potential and current economic activities (Cayo Coco and Cayo Sabinal); however, these activities could have negative effects on the lagoons. For example, all the lagoons of Cayo Coco have been severely impacted by road construction, desiccation and filling with exogenous material for the construction of hotels. In Cayo Sabinal, road construction has impacted the natural water dynamics of lagoon ecosystems, resulting in high salinity levels.

Many fish species (of all stages of their life cycles) were identified in the lagoons studied, including commercial species such as Mutton snapper (*Lutjanus analis)* and Gray snapper (*Lutjanus griseus)*. Invasive species as the Red Lionfish (*Pteroir volitans)* were also identified.

The socioeconomic characterization of every lagoon environment is well defined. In Cayo Coco, tourism (mainly sun and sand tourism) is the principal activity; it is operated by two companies (MINTUR and Gaviota SA). The use of the natural resources of Cayo Sabinal is limited to activities such as honey collection, fishing (near Tortuguilla Lagoon) and occasional tourism.

For the valuation of real and potential ecosystem goods and services for each lagoon and territory studied (Cayo Coco and Cayo Sabinal), each activity was evaluated according to the indicators established in equations 1 and 2 and to independent variables:

Direct use value: revenues from beekeeping, fishing and tourism were calculated by lagoons.

Beekeeping: was only identified in Tortuguilla Lagoon (Cayo Sabinal) with a yield of six tons per year (6000 beehives) (Table 2)

Table 2

Calculated revenues from honey sales (beekeeping activity) in Tortuguilla Lagoon (Cayo Sabinal)

Lagoon	Annual estimated production (in tons)	Unitary price (in thousands of Cuban pesos)	Annual sales (in thousands of Cuban pesos) (revenues from beekeeping farmers)
Tortuguilla	6	16.0	96.0
Total			**96.0**

Fishing: this activity is occasional and local. Catch is only used as food by the personnel that work in Cayo Sabinal (only in Tortuguilla Lagoon). The valuation was made according to the method proposed by Gomez (2002) that uses the Gross Benefit value calculated in USD per ha per year in a mangrove forest area (Table 3).

Table 3

Estimated monetary benefits from fishing in Tortuguilla Lagoon (Cayo Sabinal)

Lagoon	Mangrove area (ha)	Gross benefit (USD/ha/year)	Estimated value (in thousands of Cuban pesos)
Tortuguilla	938	178970.0	151.1

Tourism: In Cayo Coco (mostly sun and sand tourism), all the beaches used are close to coastal lagoons (separated only by the sand dune system). Tourism is operated by two main companies (MINTUR and Gaviota SA). The recorded income for a mean year of the hotels of Cayo Coco was used for the estimated value of this activity (Table 4).

Table 4

Mean annual income from tourism activities

Lagoon	Mean annual income (in thousands of Cuban pesos)
Loma del Puerto	207.9
Tiburón	7.5
Larga	11.1
Las Coloradas	12.5
Total for Cayo Coco	***239.0***

Indirect use value: carbon sequestration, contribution to recirculation of nutrients, maintenance of quality and protection of soil, nesting and feeding areas for marine and migratory birds. These costs were calculated using transfer of benefits, avoided cost and restoration cost methods.

Carbon sequestration: The economic benefit from carbon sequestration was estimated at 103.5 USD per ha; the mangrove forests were the main plant formation associated to coastal lagoons. The USD value was calculated according to the official exchange rate (1 Cuban Convertible Peso approximately 0.90 USD and 1 Cuban Convertible Peso = 24 Cuban Pesos) (Table 5).

Table 5

Value of Carbon sequestration by coastal lagoon. Values given in thousands of Cuban pesos

Territory/Lagoon	Total area (ha).	Mangrove area (ha)	Carbon sequestration (in thousands of Cuban pesos)
		Cayo Coco	
Loma del Puerto	32	16	1.5
Tiburón	113	35	3.3
Larga	39	21	2.0
Las Coloradas	17	7	0.7
Sub total	**201**	**79**	**7.4**
		Cayo Sabinal	
Los Caimanes	108	76	7.1
La Salina	228	179	16.7
Tortuguilla	974	937	87.3
Sub total	**1310**	**1192**	**111.0**
Ecosystem service (total value)			**118.4**

Nutrient circulation: the contribution of coastal lagoons to nutrient recirculation was calculated considering the cost of a sewage treatment plant (in Cuba, 50000 Cuban pesos). In Cayo Sabinal, the cost was estimated as avoided cost (there is no infrastructure in Cayo Sabinal) (Table 6).

Table 6

Calculated value of the contribution to nutrient recirculation of coastal lagoons in Cayo Sabinal

Lagoon	Annual cost of a sewage treatment plant (in thousands of Cuban pesos)
Los Caimanes	50.0
La Salina	50.0
Tortuguilla	50.0
Total ecosystem service value	150.0

Maintenance and protection of soil: Another indirect use of coastal lagoons is the protection and maintenance of soil. For the appraisal of this indirect use some considerations were made; first, the cost of the maintenance of soil quality per hectare was considered and second, it was assumed that soil maintenance was done using an organic fertilizer (*compost*). With these assumptions, to total area of the lagoon was subtracted from the mangrove forest area and the result was multiplied by the unitary cost of compost (17.00 Cuban pesos per ha). All the lagoons studied are located on the coastal zone where soil salinity is very high; for this reason, another cost of soil restoration was added (from 9000 to 27000 Cuban pesos using the maximum value (data from the Soil Institute of the Province of Camagüey) (Table 7).

Table 7

Calculated value of the maintenance of quality and protection of the soil for coastal lagoons

Maintenance of soil quality			
Territory/lagoon	**Soil area (ha)**	**Cost per ha (in Cuban pesos)**	**Economic benefit (in thousands of Cuban pesos)**
	Cayo Coco		
Del Puerto	16	17	0.3
Tiburón	78	17	1.3
Larga	18	17	0.3
Las Coloradas	10	17	0.2
Sub total			***2.1***
	Cayo Sabinal		
Los Caimanes	32	17	0.5
La Salina	49	17	0.8
Tortuguilla	37	17	0.6
Sub total			***2.0***
Total ecosystem service value	***240***		***4.1***
	Protection of soil		
	Cayo Coco		
Del Puerto	16	27000	432.0
Tiburón	78	27000	2106.0
Larga	18	27000	486.0
Las Coloradas	10	27000	270.0
Sub total	***122***		***3294.0***
	Cayo Sabinal		
Los Caimanes	32	27000	864.0
La Salina	49	27000	1323.0
Tortuguilla	37	27000	999.0
Sub total	***118***		***3186.0***
Total ecosystem service value			***6480.0***

Feeding and nesting areas for migratory and aquatic birds: to calculate the value of ecosystem service regarding feeding and nesting areas for migratory and aquatic birds, the cost

per opportunity proposed by Zequeira (2007) for aquatic birds and flamingos in the Río Maximo Fauna Refugee was used. The cost was calculated only for three lagoons in Cayo Sabinal, because the lagoons in Cayo Coco are used by tourism. The cost was calculated as a unitary cost of 3385 Cuban pesos per ha (from Zequeira, 2007) (Table 8).

Table 8

Calculated value of feeding and nesting areas for migratory and aquatic birds for coastal lagoons

Territory/lagoon	Feeding and nesting area (ha)	Unitary cost (thousands of Cuban pesos ha)
Cayo Sabinal		
Los Caimanes	108	365.6
La Salina	228	771.8
Tortuguilla	974	3297.0
Subtotal	***1310***	***4434.4***
Total ecosystem service value		***4434.4***

Option use value: using the cost of opportunity method, the potential income from wood and charcoal extraction from the mangrove forests was calculated. The cost of opportunity could be defined as **the potential forgone profit from a missed opportunity—**the result of choosing one alternative and no other. The benefits lost by discarding the next best alternative are the opportunity costs of the chosen action".

For the valuation of the potential income from wood and charcoal extraction from mangrove forests, a growth rate of 4.2 m^3 per ha was used, value estimated from growing data of Cuban forests. For the appraisal of mangrove forest wood, the estimated value of the potential income per m^3 proposed by Zequeira et al. (2013) for the Sabana – Camagüey archipelago was used. For the valuation of the potential income from charcoal, it was assumed that 20 m^3 of firewood could be converted to 30 sacks of charcoal (18.90 Cuban pesos per bag)

and that 1 ha could yield 1.5 m^3 of firewood. The total potential income from this ecosystem service is shown in table 9; this value is high for Cayo Sabinal (more than 1.6 million of Cuban pesos).

Table 9

Potential income from wood and charcoal from the mangrove forests of Cayo Coco and Cayo Sabinal

Territory/lagoon	Area (ha)	Estimated volume (m^3)		Bag of charcoal	Cost of opportunity or potential income (thousands of Cuban pesos)		
		wood	firewood		wood	charcoal	Total
Cayo Coco							
Del Puerto	16	67	10.4	16	7.7	0.3	8.0
Tiburón	35	147	22.75	34	16.8	0.6	17.5
Larga	21	88	13.65	20	10.1	0.4	10.5
Las Coloradas	7	29	4.55	7	3.3	0.1	3.5
Subtotal	***79***	***332***	***51.35***	***77***	***37.9***	***1.5***	***39.3***
Cayo Sabinal							
Los Caimanes	76	319	49.4	74	36.5	1.4	37.9
La Salina	179	752	116.35	175	86.1	3.3	89.4
Tortuguilla	937	3935	609.05	914	450.4	17.3	467.7
Subtotal	***1192***	***5006***	***774.8***	***1162***	***573.0***	***22.0***	***595.0***
Total ecosystem service value					***610.9***	***23.4***	***634.3***

The total estimated value for ecosystem goods and services was calculated by adding direct, indirect and option values for each lagoon and territory (Cayo Coco and Cayo Sabinal) (Table 10). In the case of Cayo Coco, the estimated value for tourism is underrated due to restrictions on accessing reliable data. The calculated value for Cayo Sabinal shows a high ecosystem service value and where ecosystem services are most important (93 %).

Table 10

Total value of ecosystem goods and services for each lagoon and territory

Territory/lagoon	Value of use		Value of option	Value of ecosystem goods and services (in thousands of Cuban pesos)
	Direct	Indirect		
Cayo Coco				
Del Puerto	207.9	542.1	8.0	758.0
Tiburón	7.5	2110.6	17.5	2135.6
Larga	11.1	488.3	10.5	509.8
Las Coloradas	12.5	270.8	3.5	286.8
Subtotal	***239.0***	***3411.8***	***39.3***	***3690.1***
Cayo Sabinal				
Los Caimanes		1280.1	37.9	1318.0
La Salina		2145.6	89.4	2235.0
Tortuguilla	247.1	4346.6	467.7	5061.4
Subtotal	***247.1***	***11184.1***	***595.0***	***12026.2***
Total Value	***486.1***	***14595.9***	***634.3***	***15716.2***

Discussion

The national and international theoretical contributions of ecosystem goods and services are very important to establish the theoretical and conceptual bases of our research. The theoretical bases for the calculation of ecosystem benefits as the criteria for economic valuation of ecosystem goods and services is supported by monopolist political economy and especially by its subjective school. A first interpretation would be to underestimate the need to value environmental resources. However, some authors (Braat & de Groot, 2012; Newton et al., 2018; recognize some aspects listed below should be considered:

1. Recognizing the importance of natural ecosystem products and functions is not enough to guarantee its rational use.

2. The degradation and loss of natural resources has become an economic problem, which is sometimes irreversible.
3. The contribution of legal and institutional frameworks enhances environmental education and social communication programs, among others.
4. The valuation of ecosystem goods and services favors the availability of income for conservation projects, the enforcement of public policies, and planning of material resources and management of ecosystems.

In Cuba, the economic valuation of ecosystem goods and services is feasible for the decision making process because there are many legislative and governmental tools such as the Law for the System of Natural Resources and Environment, approved by National Assembly (Article 10.1 rules the need to design and promote the implementation of economic tools for the protection of natural resources and to recognize the value of ecosystem goods and services), the National Environmental Strategy for the period 2021 – 2030, the Decree – law 369 of 2018 which enacts (Article 24) that local projects must be related to the protection and sustainable use of natural resources and to the improvement of environmental conditions and finally, the Guidelines for Economic and Social Policy for the period 2021 – 2026, which support the sustainable use and preservation of the natural resources of Cuba.

At studied lagoons a high number or ecosystem services and goods (ESG) were identified, and specifically those that are important for food provisioning and tourism support (Newton et al., 2018). López- Castañeda et al. (2021) identified for coastal lagoons at Caguanes National Park (Cuba), some ESG and these were associated to tourism and recreation, however, only two others ESG (wood production and aesthetic value) identified for coastal lagoons.

The results of this work show that the use (direct and indirect) had the highest values for all the lagoons and territories studied (Velasco et al., 2018; Duijndam et al., 2020). In this

context, the limited direct use of the lagoons of Cayo Sabinal (only beekeeping and occasional fishing) and the scarce data of revenues from tourism in Cayo Coco (related to the beaches near coastal lagoons) contributed to the low benefits (in monetary terms) recorded for this valuation (Basset et al., 2013; Newton et al., 2018).

Other studies around the world have reported higher values (in monetary terms per lagoon) of goods and services than those of our study, which highest value was recorded at Tortuguilla Lagoon (less than 5.0 million Cuban pesos per year), much lower than that of Simpson Bay Lagoon in Saint Martin Island (US$ 12.1 million per year) Duijndam et al. (2020). Velasco et al. (2017) established that the indirect use and non-use value of the lagoon ecosystem conservation was 43.3 million Euros per year in Mar Menor Lagoon (Spain) and Clara et al. (2018) calculated a minimum value of 12.5 million Euros for the Ria de Aveira Lagoon in Portugal. However, these studies used different valuation techniques, contexts, and data and were conducted in a wide range of ecosystem services (Newton et al., 2018).

In Cuba, no previous studies on to the valuation of coastal lagoons goods and services have been published; most studies have focused on the natural and protected areas of Cuba (Zerqueira et al., 2013; 2014; Mir Frutos, 2022); therefore, the findings of this research are the first approach to the valuation of one of the main marine and coastal ecosystems in Cuba (González – De Zayas et al., 2022).

The amount of 15.7 million of Cuban pesos per year for the lagoons studied should increase in the few next years due to tourism development in Cayo Sabinal. Like in Cayo Coco, this tourism development (sun and beach modality) will take place in sites next to coastal lagoons. However, these lagoons (including the lagoons of Cayo Coco) must be protected from the impacts of this activity. González -De Zayas et al. (2013; 2018; 2020; 2021; 2022) documented that most of the lagoons from Cayo Coco and Cayo Sabinal are at risk due to natural (hurricanes) and anthropogenic impacts. Our results support the need to protect these lagoons due to their environmental, social and economic importance.

Finally, this research and the methodology used for the valuation of the goods and services of these lagoons could be extrapolated to other Caribbean and Cuban lagoons, particularly to those in areas affected by tourism development, due to the major role of these ecosystems in the principal modality of Caribbean tourism (sun and beach) and its economic significance for the region.

Conclusions

The coastal lagoons from Cayo Coco and Cayo Sabinal offer a wide number of goods and services, principally associated to food provisioning and tourism support. This study is the first report of ecosystems services and goods for coastal lagoons in Cuba. The direct and indirect use values of these lagoons represent more than 95 % of the total estimated value which informs decision – makers of the importance of protecting these ecosystems.

For this reason, in the current social and economic context of Cuba and the regulatory and institutional frameworks require the use of methods and techniques for economic valuation of ecosystem goods and services, particularly those of coastal ecosystems, in correspondence with the fast development of tourism in coastal areas.

In addition, the results of this study could be a starting point to expand the valuation of ecosystem goods and service to other Caribbean and Cuban coastal lagoons.

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