

Article



# **Environmental Policy and Regulatory Framework for Managing Mangroves as a Carbon Sink in Cuba**

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Abstract: Carbon stored in mangroves is valuable for climate change mitigation. Managing the carbon stored in the mangrove requires an adequate legal framework and an environmental policy. In Cuba, there is little research on the capacity of mangroves to retain carbon and its articulation in environmental policy and management. In the present study, the following research question is raised: Is there a favorable context in the environmental policy to manage the mangrove as a carbon reservoir in Cuba? The aim of this research is to identify aspects of environmental policy, legal and administrative frameworks related to managing mangroves as a carbon sink in Cuba. The qualitative method of social research, the content analysis technique, and the modified Ibero-American Network for Integrated Coastal Management (IBERMAR) decalogue were used to compile, understand, and discuss the potential for effective management of mangroves for carbon storage. One hundred and twenty-one articles published in WOS and Scopus databases between 2019 and 2022, as well as books and material reviewed on the official websites, were checked. Present policy in Cuba manages mangroves for coastal protection and other ecosystem services but lacks a developed plan for considering the role of this marine forest system as a carbon sink. Managing mangroves as a carbon reservoir will require vigorous efforts to measure and monitor the system. It is necessary to build a robust national political agenda and strengthen institutional and regulatory capacities. This research provides a systematization of environmental policy as a baseline for the management of carbon reservoirs in mangroves in Cuba.

Keywords: IBERMAR; decalogue; carbon capture; climate change; coastal policies

## 1. Introduction

The role of mangroves in climate change mitigation through carbon capture is well documented [1–6]. Mangrove ecosystems are important carbon sinks capable of retaining an average of 692.8  $\pm$  23.1 (SE) megagrams (Mg) of organic C ha<sup>-1</sup> [7], more so than any other ecosystem on Earth. This results from a combination of high rates of photosynthetic carbon fixation coupled with very low decomposition rates in the water-saturated anaerobic soils. Mangrove forest loss could contribute to 19% of total global deforestation emissions [8]. Disruption of these coastal forests means loss of the capacity to capture new carbon, and importantly, the release of fixed carbon from the often-deep organic soils. As such,



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**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). international environmental management agendas recognize the importance of mangroves in terms of climate change (CC) both for the ability to sequester carbon and the vulnerability to release it [9,10].

Considering the carbon storage capacity of mangroves, it is important to establish policies addressing the role of these coastal forests in mitigating CC and sustaining biodiversity [11]. The United Nations Framework Convention on Climate Change [12] favors proposals to include mangrove management in policies, actions, and reports at the national level [13,14]. Within this convention, three market-based "flexibility mechanisms" for emission reductions were conceived, including the Clean Development Mechanism (CDM) [15]. The CDM is the only one of the mechanisms of the Kyoto Protocol that involves developing countries to finance afforestation and reforestation projects and among them, mangrove forests are of great interest [15].

Another way to establish policies for the conservation of carbon retained in mangroves is the Reducing Emissions from Deforestation and Forest Degradation (REDD+) program which allows a financial value to be assigned to the carbon stored in forests [16,17]. REDD+ focuses on the important carbon reservoirs within forests, which includes mangroves [16].

However, mangrove management from the carbon sequestration approach is not often considered in national CC mitigation strategies [7]. An enabling legal context, integrated planning, adequate institutional framework and policies, actions and reports at the national level are needed [18]. Yet, most of the existing national legal frameworks commonly relate to the environment and forests in general, rather than to mangroves. The specification of mangroves in the policy framework can contribute to global and national carbon management and increase the resilience of socio-ecological systems [9].

The Sundarbans in Bangladesh constitute the largest continuous extension of mangroves on the planet and do not have a specific agenda or policies as a carbon reservoir, and instead are managed as general forest resources [19]. Similarly, in Vietnam, policies and projects are aimed at the restoration of forests, but with less emphasis on the conservation of existing ones and scarce attention to the use of mangroves for carbon sequestration [20].

Mexico has aligned its policies for the conservation and restoration of blue carbon ecosystems with those outlined in the Paris Agreement for reduction of greenhouse gases. Yet mangroves there still face threats from loopholes in the conservation laws [21]. However, it is one of the 175 countries that have signed the Paris Agreement and has committed to "increase carbon sequestration and coastal protection with the implementation of conservation and recovery schemes for coastal and marine ecosystems, such as coral reefs, mangroves, seagrasses and dunes", through Mexico's Nationally Determined Contribution under the heading Adaptation [22].

In Cuba, mangroves are considered coastal wetlands of high fragility and special relevance [23]. They represent 5.1% of the country's surface and 27% of the total forest cover. Studies on mangroves in Cuba have been approached from different perspectives. These include general ecological aspects [24–26], floristic composition [27], primary production and associated processes [28,29], health status assessments [30–34], relative resilience studies of the ecosystem [35,36], ecological restoration as part of forest management actions within protected areas prevail [37–40], among others. However, there is a gap in the scientific literature about the role of mangroves as a carbon reservoir in Cuba.

For the Cuban government, mangrove conservation is important for the sustainability of coastal communities, as they constitute a natural barrier of protection for the coastal population and a breeding space for numerous marine species [23,41]. The strategic and operational documents in the country recognize the need for "mangrove conservation for coastal protection", as proposed, for example, in the National Program to Confront Climate Change in Cuba, known as "Tarea Vida" (Task Life) [42]. This program prioritizes the development of comprehensive research to protect, conserve and rehabilitate the environment and adapting environmental policy to the new projections of the economic and social environment for confronting CC [42,43]. As evidence of the efforts made to

recover and preserve the ecosystem, Cuba reported an increase of 115,000 hectares of mangroves in the period from 1990 to 2020 [44].

Despite these advances, Cuba lacks specific environmental policy that address the role of mangroves in sequestering carbon. This study aims to analyze the aspects of Cuban environmental policy and the legal and administrative frameworks related to mangroves in Cuba that facilitate management actions from the perspective of carbon capture. The following research question is considered: is there a favorable context in Cuban environmental policy to manage mangrove forests as a carbon reservoir? We present the findings obtained from a documentary review of environmental policy in Cuba that pertain to the mangrove as a carbon reservoir. This analysis made it possible to identify the gaps, the limitations, the state of knowledge on carbon capture by the mangroves and perspectives for the implementation of carbon markets in Cuba.

#### 2. Materials and Methods

We used qualitative method research This method uses a deductive and logical scheme that allows for the development of research questions, to later test them [45] (see Figure 1). This is an exploratory investigation, whose units of analysis are public documents (scientific articles, legal instruments, official documents, official sites of Cuban institutions) about current Cuban policies related to the use of mangroves as carbon sinks and their role in addressing CC. The materials were analyzed objectively and systematically, and valid inferences were made for the Cuban context. The validity and reliability are measured by the methodological coherence assumed by the authors. Starting from a research question valid for the expected results and findings found the validity and reliability are measured by the methodological coherence assumed by the authors.



**Figure 1.** Research methodological framework. (www.gacetaoficial.gob.cu, accessed on 6 February 2022).

The study was not conceived to carry out statistical analysis and inferences, but to obtain descriptive data structured in qualitative variables. The information was analyzed in order to understand the processes of environmental policy in Cuba and generate a baseline on the subject. The aim is not to quantify but to understand the underlying arguments that determine the inclusion of carbon sequestration by the mangrove in the country's mitigation actions. We apply the content analysis technique to structure the information from the decalogue of Ibero-American Network for Integrated Coastal Management (IBERMAR) [46].

The content analysis technique was structured from a set of questions whose internal logic allowed deepening of and arguing around the qualitative variables of the decalogue explained below. It was used for the study of the normative documents of the environmental policy in Cuba [45]. Documents available on the website of the Official Gazette of Cuba (www.gacetaoficial.gob.cu, accessed on 6 February 2022) were consulted. We included studies on mangroves in Cuba published in Google Scholar databases with 75 articles checked, 7 in Scopus, and 37 in the Web of Science (all papers were examined between 2019 and 2022). Furthermore, we analyzed the specialized national publications incorporated into the Revista Forestal Baracoa (http://www.inaf.co.cu/revistas/revista--forestal--baracoa, accessed on 10 December 2021), and the Anuario Ambiental de Cuba (http://www.onei.gob.cu, accessed on 1 December 2021).

The content analysis technique [45] is also applied to the postgraduate academic programs of universities of the Ministry of Higher Education of Cuba (www.mes.gob.cu, accessed on 1 December 2021), leaders in environmental issues, emphasizing those that have master and doctoral programs (Figure 1). Subsequently, the analysis was directed to the search for academic offerings and publications in terms of carbon capture by the mangrove within the web pages of the 20 centers of higher education studies, identifying 12 universities with postgraduate programs on environmental research topics.

The decalogue (methodology for systematic management) of Ibero-American Network for Integrated Coastal Management (IBERMAR) [46] is designed to address the analysis of Integrated Coastal Zone Management. It is a simple and effective instrument that exposes and evaluates in a synthetic way the fundamentals of any public system oriented to comprehensive management through an exercise of abstraction [46]. In addition, it allows for making concrete proposals and suggestions for improvement and cost-effective comparisons between coastal regions relevant to the area studied [46]. The questions place special emphasis on aspects related to the legal and administrative framework and that it is the system through which the relationships between the socioeconomic and physicalnatural systems on the coast are regulated. The decalogue methodology provided ten variables validated in coastal policy studies worldwide. All the above guarantees the search for relevant information for our investigation.

The decalogue was modified to address the state of the environmental policy in Cuba concerning mangrove management as a carbon reservoir. The following variables were analyzed: policy, norms, institutions, competencies, strategic and operational instruments, knowledge and information, education for sustainability, education and training, economic resources, and citizen participation. The modifications made to the decalogue consisted of incorporating questions about the legal and administrative framework related to mangrove management and the perspective of their capacity to capture organic carbon in the Cuban context. This allowed for the analysis of the environmental policy and the ecosystem management in Cuba, identifying key issues, understanding the peculiarities of reality in the country, and observing dysfunctions to be solved.

Table 1 presents the objectives and components resulting from the content analysis for each of the aspects of the decalogue.

 Table 1. Variables and guiding questions of the research.

Decalogue Variable	Guiding Question
1. Policy Objective: To know if there is an institutional policy on mangrove management to support actions for the blue carbon market.	Is there an explicit and public institutional policy for the management of mangroves as a carbon reservoir that is formally adopted? (accessible through institutional documents or publications, for example. Are there any national strategies, with a public policy character, related to the subject? Are you explicitly involved in international efforts related to the implementation of the blue carbon market for mangroves or the management of mangroves as a carbon reservoir? (with the ratification of relevant international agreements).
2. Normative	
Objectives: Specify the regulatory basis for the management of the mangrove. Analyze the normative field situation concerning the integrated nature that the management of the same requires.	Are there currently any initiatives aimed at specific legislation? (Indicate the most important and specific for mangrove management in Cuba giving an approximation for the management as a carbon reservoir)
3. Competencies	Are the responsibilities for mangrove management shared? Could they apply to
Objectives: To have a scheme of the distribution of public responsibilities in the management of mangroves.	carbon management? On which territorial scale of the administration does the greatest responsibility fall: national, regional, or local? Is there transparency on competencies?
Analyze whether this distribution allows for mangrove management as a carbon reservoir.	Is there coordination and cooperation between the different territorial scales of management?
	Are there collegiate bodies for coordination and cooperation between
4. Institutions Objective: To specify those institutions involved in managing mangroves as a carbon reservoir and to conduct a qualitative analysis of them.	institutions? Which institution assumes the leadership of initiatives related to the management and conservation of mangroves as a carbon reservoir? Is the administrative process adapted to address the problems and conflicts of mangrove management as a carbon reservoir?
	Are they cross-cutting, i.e., do they seek to integrate the multiple sectoral initiatives into a coherent whole, or is there a dispersed sectoral strategy?
5. Strategic and operational instruments	Are there effective operational instruments for mangrove management?
To identify and analyze the strategic and operational instruments that allow for	Is the service as a carbon reservoir included in these instruments?
the management and conservation of mangroves and include the management approach as a carbon reservoir.	mangroves as a carbon reservoir?
approach as a carbon reservoir.	Are there evaluation or monitoring instruments for the management of mangroves as a carbon reservoir? (strategic environmental assessment, environmental impact assessment, etc.) and those included within each instrument (plan, program, strategy).
	Is there a university degree that responds to the national/regional needs of this
6. Education and training Objective:	sector? Are there postgraduate courses (master's degrees, for example) that respond to
To approach the possibilities of the country to train managers/administrators in the management of the mangrove as a carbon reservoir and the carbon market.	the specific needs of mangrove management as a carbon reservoir and the carbon market?
	Are there resources available for sustainable mangrove management that are easily known?
7. Economic resources	Are there funds available specifically for mangrove management as a carbon
To know the economic–financial basis that could support proposals for the	Is the financial contribution derived from private initiatives or activities
management of mangroves as a carbon reservoir in Cuba.	Are foreign funds contributing to mangrove management as a carbon reservoir? Are the contributions made through any international cooperation agency(-ies)?
	Knowledge: can it be said that there is an acceptable knowledge of mangroves as a carbon reservoir?
8. Knowledge and information	Air reservoir holding capacity. Retention capacity in the underground reservoir.
Objective: To determine the level of knowledge about mangroves as a carbon reservoir and accessible public information on the subject in Cuba.	Export to adjacent ecosystems (marine grasslands, coral reefs, other coastal wetlands)
	Does the existing knowledge lie mainly in the institutions or universities and research centers or the institutions responsible for the management of the mangrove as a carbon reservoir?
9. Education for sustainability Objective: To know the main education initiatives for citizens and coastal users related to the management of mangroves as a carbon reservoir	Are there formal or non-formal education plans/programs/projects related to mangrove management in the country? Is there any mention of the carbon
	sequestration service by the ecosystem? On which institution do the most important activities that are developed depend: education, environment, others?
10. Citizen participation Objective: To relate decision-making for the management of mangroves as a carbon reservoir with citizen participation.	Are there citizen/community groups interested in managing mangroves as a
	Carbon reservoir? Are these groups involved in the processes that lead to public decisions about
	coastal resource management? Specifically, for mangroves, is citizen representation made possible mainly through conservation groups?

### Area of Study

Cuba is an island nation made up of more than 1600 islands, islets, and cays, with a surface area of 109,884.01 square kilometers and 6073 km of coastline, approximately [47]. It is located at 19°49′ and 23°16′ N latitude and 74°08′ and 84°57′ W longitude of the Greenwich meridian; north of the Caribbean Sea and south of the Tropic of Cancer [47].

Mangroves represent 5.1% of the country's surface and 27% of the total forest cover [25], making Cuba tenth on the list of countries in the world by mangrove extent [23]. Four different species comprise Cuban mangroves: *Rhizophora mangle* L., *Avicennia germinans* [L.] L., *Laguncularia racemosa* [L.] Gaertn. and *Conocarpus erectus* L. [25], and 157 other botanical species, belonging to 100 genera and 64 families; of these species, 36 are trees, 20 shrubs, 44 herbs, 17 lianas, 16 epiphytes and 7 hemiparasites [27]. They are considered coastal wetlands of high fragility and special relevance [25].

Due to their ecological value, mangroves are present in 97 areas in different categories within the National System of Protected Areas in Cuba. These represent 60% of the country's mangroves [48]. From an economic point of view, they are important for the development of mariculture and their contribution to habitat for fisheries [49]. Additionally, they are used for the development of beekeeping [50], traditional medicine [51] and fishing for subsistence [30].

From the social point of view, 122 coastal population settlements are currently considered highly vulnerable to the effects of climate change expected for Cuba by 2100 [52], so adaptation and mitigation measures to CC are vital for Cuba as an island state. It is estimated that mangroves in Cuba protect 22,476 people annually on average, avoiding more than USD 150 million of economic losses and reducing 222 km<sup>2</sup> of flooded area [53].

The climate change scenarios foreseen for the country indicate the increased risk resulting from sea level rise and the increase in intensity and frequency of extreme hydrometeorological phenomena, such as droughts and hurricanes [54], with impacts on mangroves, such as coastal erosion, vegetation degradation, flooding, and loss of emerged territory, among others.

#### 3. Results

The research findings revealed that, in Cuba, the sustainable development model is based on the ecosystem approach [55]. That is, its principles are aimed at achieving the sustainability of development through ecosystems. Ecosystems are selected with a criterion of hierarchy, accounting for the environmental problems they show, as well as the fragility of the system [56]. In addition, emphasis is placed on adaptive management, considering all usable goods and services, and optimizing the mix of their benefits. Finally, sustainable development is oriented to the preservation of the environment and society, adopting a long-term vision [57].

Based on this, the conceptual basis of the ecosystem approach implicit in Cuban environmental policy and the search for synergies with international conventions related to the subject, a set of special programs have been identified that are contemplated in the National Economic and Social Development Plan for 2030 [58]. This plan contains actions that allow for managing and regulating the resources of the ecosystems present in each space. The following is the analysis of legal instruments and strategic and operational instruments in Cuba related to the management of mangroves as a carbon reservoir based on the IBERMAR decalogue [59–61].

#### 3.1. Policy

In Cuba, there is not an explicit and public institutional or sectoral policy regarding the carbon retained in mangroves. No reports on national strategies and integrated proposals on the subject were found. However, there is explicit and public political will in the country for the protection of the environment. As part of international politics, Cuba is a signatory to a set of international agreements and treaties, such as the United Nations Convention on Climate Change (1992) and the Convention on Biological Diversity (2002) where the subject

is mentioned. Important signs of government interest in environmental protection consist of, for example, the inclusion of climate change mitigation and adaptation within national environmental policy and participation in international efforts related to the issue [62,63]. Adaptation is a priority within the country's government measures and is consistent with public policies since it is considered a nation with low greenhouse gas emissions. For example, one adaptation measure is the reforestation of mangroves to counteract the impact of rising sea levels. This way, mangroves are identified as protective barriers for settlements and infrastructure in coastal areas [54]. Regarding mitigation, reference is made to actions to reduce the causes of CC [62,63]. In this case, Cuba assumes activities related to reducing GHG emissions and absorbing these gases (through sinks, such as forests).

In the analysis of national public policy, instruments were observed that link with mangrove conservation and their protective role for coasts in the face of the impacts of climate change (Table 2). This stems from the explicit constitutional article addressing the preservation of the environment and concern for vulnerabilities to climate change [63]. Some progress is shown in the development of ecosystem monitoring systems, community participation and activities, such as reforestation and the integral recovery of mangroves, although without mentioning the issue of carbon reservoirs [43]. Another crucial element is that national policy is explicitly positive about less carbon-intensive economic development, reducing coastal degradation and moving towards establishing environmental accounts [58]. The authors hold that these measures could contribute to making more flexible international collaborative processes for conservation.

National Public Policy Instruments	Link with Mangrove Management and Carbon Sequestration
Constitution of the Republic [64]	Article 16, Subsection f " to promote the protection and conservation of the environment and the fight against climate change, which threatens the survival of the human species, based on the recognition of common but differentiated responsibilities; the establishment of a just and equitable international economic order and the eradication of irrational patterns of production and consumption" [64].
National Economic and Social Development Plan (PANDES 2030) [58] (incorporation of the strategic axis natural resources and environment)	General objective 3. Reduce the country's vulnerability to climate change. Specific objective 11. Develop effective and efficient programs and actions to face climate change. Specific objective 14. Stop degradation of coastal and marine ecosystems, promote sustainable development of activities in the coastal zone and adapt to CC. Specific objective 15. Promote economic incentives to achieve financial sustainability in the use and conservation of natural resources and the environment. As well as progress towards the establishment of environmental accounts. Specific objective 20. Promote international cooperation to face the effects of the CC.
State Plan to Face Climate Change, or "Tarea Vida" (Task Life) [43]	Task 1. To restore beaches, mangroves, and other protective natural ecosystems. Task 5. Reforestation actions. Task 8. Measures of adaptation to the CC. Task 9. Strengthening of monitoring, surveillance, and early warning systems. Task 10. Increased knowledge and degree of participation of communities. Task 11. Search for international financing.
Law of the National System of Natural Resources and Environment [55]	<ul> <li>(a) The National Environmental Strategy and the programs and plans that are adopted under its protection.</li> <li>(b) Environmental planning, as part of territorial planning.</li> <li>(c) The environmental license.</li> <li>(d) Environmental impact assessment.</li> <li>(e) Strategic environmental assessment.</li> <li>(f) The national environmental information system.</li> <li>(g) The state environmental inspection system.</li> <li>(h) The integrated environmental monitoring system.</li> <li>(i) Environmental education for sustainable development.</li> <li>(j) Science, technology, and innovation.</li> <li>(k) Economic instruments.</li> <li>(l) Environmental addit.</li> <li>(m) The system of recognition and environmental awards</li> <li>(n) The angler administrative liability regimes, angler rating, civil and criminal.</li> </ul>

**Table 2.** Synthesis of the links of the instruments of national public policy in Cuba with mangrovemanagement and carbon capture.

It is possible that through the implementation of the instruments of public policy analyzed above, new opportunities will be created to pay greater interest to the carbon retained in Cuban mangroves. The authors agree that the consulted policy instruments can be a basis for mangrove conservation and management proposals from the perspective of the carbon sequestration service. The PANDES (2030) introduces the concept of less intensive development in greenhouse gas emissions in the country's public policies. The main actions aim to use renewable energy sources, energy efficiency, and reforestation. The progress detected in this study is scarce concerning specific policies to take advantage of the carbon stored in mangroves. For example, Cuba participates voluntarily in the context of FAO (United Nations Food and Agricultural Organization) and shows interest in the management of emissions associated with forest degradation as a mitigation measure. An example of the progress is the reduction of emissions of 1618 Kt  $CO_2$  eq in the period of 2010–2018 through the measures applied [54]. However, the report refers to the Cuban forestry sector in general, without differentiating the contribution of mangroves.

Cuba is committed to participating in the Emission Reductions from Deforestation and Forest Degradation (REDD+) mechanism through the Ministry of Agriculture (https:// redd.unfccc.int/submissions.html?country=cub 10 February 2022). In the present study, the reasons why the country has not made progress in the implementation of this mechanism are not clarified. The authors consider that it can be related to the financing policy of the projects and the origin of the funds for them. In addition, the focus of the Cuban strategy on climate change is an adaptation to impacts, rather than on reducing net GHG emissions. Cuba's First Nationally Determined Contribution (NDC) contains the commitment to reduce emissions in the country [54]. We did not find any mention of the implementation of REED+ initiatives. However, when analyzing sectors that contributed to this research, they agree on the lack of an MRV system. Cuba is currently working on these proposals under the coordination of CITMA.

During the review, it was confirmed that the CND contains prioritized actions for adaptation, such as the restoration of mangroves. Regarding mitigation measures, it is proposed to increase forest cover by 33% by 2030. This proposal is still in preparation for implementation by the Cuban Forestry Sector. Coinciding with the findings of this investigation, the safeguards exposed in the CND identify as threats to the fulfillment of the proposed goals the following aspects: (1) the occurrence of extreme natural phenomena, (2) the lack of financing, (3) technology transfer, and (4) capacity building with the consequent negative impact of a tightening of the economic, commercial, and financial blockade by the United States of America against Cuba.

#### 3.2. Normative

The normative Cuban body shows transversality accordingly with the international agreements to which the country is a signatory. In the analysis carried out, it was possible to appreciate that mangrove management is not regulated by specific legislation, nor were proposals or initiatives identified for it. Despite this, there is a legal body that could constitute the basis for establishing competencies and legal responsibility in a management initiative for this purpose (Table 3).

<b>Resources or Regulated Activity</b>	Legal Instrument
All activities in the field of environment (updating process). Environmental protection.	Law on the Natural Resources System and the Environment [55] (New Law approved in May 2022). Decree/Law 200/99 on environmental infringements [65]
Regulation of the protection, use and conservation of forest resources.	Law 85/98 Forestry Law [66]. Decree 268/99 "Contraventions of forestry regulations" [67].
Soil, agricultural activity, coastal forests.	Decree 179/93 "Protection, sustainable use and conservation of soils" [68].
Protected areas, flora and fauna, environment.	Decree-Law 201 National System of Protected Areas [69].
Changes in land use, delimitation of the ecosystem.	Decree-Law 212 Coastal Zone Management [70] (under review and improvement).

Table 3. Current Cuban legislation allows regulating activities in the mangrove as a resource.

The first tool of interest for this study is the Law on the System of Natural Resources and the Environment [55]. It is the framework instrument in Cuba for all activities in the field of the environment and the use of natural resources. In this context, the ecosystem approach is the strategy for the management of natural resources in the country and this explicitly recognizes the complexity of the links between natural resources, ecosystems, and socioeconomic elements as a successful path to sustainable development. The respondents agree that it is an advanced instrument that clarifies clear administrative responsibility over natural resources, lays the foundations for organizing ecosystem monitoring systems, the valorization and management of ecosystem goods and services and promotes the search for economic incentives for the conservation of ecosystems. In addition, it centralizes administrative responsibility for environmental management and training activities at the Ministry of Science Technology and Environment (CITMA) and certain activities shared with other related ministries and the Council of Ministers.

Secondly, the "Forestry Law" [66] aims to regulate the protection, use and conservation of forest resources. In this case, the elements of interest for this research are the framework of responsibilities proposed by the instrument and the conceptual position of the mangrove within the Cuban forest heritage. Administrative responsibility is conferred by the Ministry of Agriculture (MINAGRI) to direct, execute and control the country's policy on the use of forest heritage resources in coordination with CITMA. The National Institute of Hydraulic Resources, for the protection of watersheds, through the conservation, improvement or establishment of forests and the State Forest Service as the authority in charge of exercising control over compliance with the regulations established regarding forest heritage together with MINAGRI participation. In addition, the Ministry of the Interior (MININT) organizes and directs the Forest Rangers, who oversee surveillance and protection in forest heritage areas. This instrument defines mangroves as Coastal Protective Forests and recognizes the importance and functions of these forests for the coastal zone and establishes regulations for the protection of mangroves. It is a clear instrument in terms of the establishment of shared responsibilities and concepts, but it does not contain references to carbon reservoirs in forest heritage in general and neither for the case of mangroves.

Thirdly, Decree-Law 212/00 "Coastal Zone Management" [70] includes provisions that allow the delimitation, protection and sustainable use of the coastal zone based on the MIZC. This legal tool defines the physical limits to guarantee the protection of the mangrove and a buffer zone is established, as well as the regulation of the human activities permissible in each case. Like the previous instrument, the main legal responsibility remains on the CITMA in collaboration with the Ministry of Economy and Planning (MEP), specifically the Institute of Physical Planning and the Ministry of the Interior. No reference was found to carbon reservoirs in coastal ecosystems.

Finally, the existence of ministerial agreements for the implementation of the Clean Development Mechanism (CDM) was identified (Agreement No. 4604 of the Executive Committee of the Council of Ministers, 2002 [71,72]). This is the only process identified during the present study in Cuba where activities related to the absorption capacity of forests in general are recognized, although without specific mention of mangroves. Despite this, no reports were found on projects or actions aimed at managing the carbon retained by forests in the country.

#### 3.3. Competences

Responsibilities for managing the carbon stored in mangroves are not clearly defined. However, based on the current legal framework, it is possible to establish a scheme of competencies related to mangroves that can be used as a baseline for management proposals that address the issue of carbon storage (Figure 2).



Figure 2. Scheme of competencies established in the legal framework in force in Cuba.

According to current environmental legislation, CITMA proposes environmental policy and organizes the country's environmental management. Its role is decisive in perfecting environmental management instruments, programs, and strategies, as well as for identifying sources and mechanisms of international financing for the implementation of projects. This ministry plays a determining role regarding the policy to confront climate change and the formulation of the CRC. More recently, it has overseen the coordination of the Measurement, Registration, and Verification system [55], which places this ministry as the governing body of the activities carried out on the country's natural resources and with the capacity to organize initiatives on carbon capture in the country.

In this regard, the regulations also establish links with other ministries, such as the MINAGRI, the MININT, and the MEP [55,66,70]. The Ministry of Agriculture (MINAGRI) has specific responsibilities regarding the resources of the forest heritage and the quality of reforestation activities [55]. In addition, the coordination between CITMA, the State Forest Service, and the Ranger Corps (Ministry of the Interior) exercises control over compliance with regulations on forest heritage [66]. Another necessary link for the management and implementation of policies is the participation of the Ministry of Economy and Planning (MEP) and specifically the Institute of Physical Planning as responsible for the policy of territorial ordering in correspondence with environmental aspects and development of human activity [70].

#### Competencies for the Implementation of the Clean Development Mechanism in Cuba

Another possible approach is the scheme used for the implementation of the Clean Development Mechanism (CDM) in Cuba (Figure 3). It defines the functions and attributions of the National Determined Authority (NDA), the Center for the Management of Prioritized Projects and Programs and the National Group within the process of attention and implementation of the projects. By the provisions of the regulations, the NDA is responsible for authorizing the participation of specific entities in project activity for the CDM [72]. The approval of the project goes through a series of complex stages and requirements, which require consistent evidence of the contribution and correspondence of the project with the criteria of sustainable development in Cuba.



**Figure 3.** Scheme of competencies for the implementation of the CDM in Cuba according to Ministerial Resolution No. 76 of 2003 [60].

#### 3.4. Institutions

In Cuba, there are no specific institutions or collegiate bodies to manage the mangrove as a carbon reservoir. The leadership of environmental initiatives is the responsibility of CITMA, as indicated in the new law on the Natural Resources System and the Environment [55]. According to current environmental legislation, a set of institutions can also be held responsible (Table 4), which would allow for the establishment of structures and a basis for the management of the mangrove as a carbon reservoir, although the administrative process is not designed to address the problems and conflicts of the mangrove in this case, as shown in Figure 3.

**Table 4.** Probable administrative framework for mangrove management as a carbon reservoir according to current environmental legislation in Cuba.

Resource or Activity (Regulated)	Institution, Administration, Ministry (Responsible)
Mangrove forest Mangrove conservation and management	Ministry of Agriculture Forestry Sector State Forest Service Ranger Corps National Center for Protected Areas State Forestry Company
Watershed management	National Institute of Hydraulic Resources
Price of captured carbon Management of economic resources Project approval	Ministry of Economy and Planning (https://www.mep.gob.cu/es 10 February 2022) Ministry of Finance and Prices (https://www.mfp.gob.cu 10 February 2022) Ministry of Foreign Trade and Foreign Investment (https://www.mincex.gob.cu/es/ 10 February 2022)

The Forestry Sector is the only net carbon sink identified in Cuba [73]. The State Forestry companies are responsible for monitoring and managing this both in plantations

and natural forests. Within natural forests are mangroves. These constitute a smaller portion of carbon sequestration than other forests within the sector.

On the other hand, the Ministry of Agriculture (MINAGRI) represents the country in the REDD+ program context (https://redd.unfccc.int/submissions.html?country=cub accessed on 10 February 2022), although no concrete actions are reported for the implementation of this program in Cuba.

#### 3.5. Operational and Strategic Instruments

The conceptual basis of the ecosystem approach implicit in Cuban environmental policy allows synergies with international conventions on the subject. Thus, in the National Economic and Social Development Plan until 2030, one of its six strategic axes is Natural Resources and the Environment [58]. This plan defines comprehensive programs, such as watershed management, protected areas, coastal zones, marine resources, reforestation, and forest protection. The vision of the mangrove as a carbon reservoir or actions aimed at conservation on this basis are not explicitly stated. However, the objectives it pursues contain an implicit possibility of developing projects, for example for the protection of locals and community, the use of natural resources and the possibility of implementing economic incentives for this purpose is added. Emphasis is placed on continuing to increase the country's forest cover and especially "protective forests" and the care of coastal areas. Finally, modifications are proposed in the current environmental legislation, with the aspiration of considering environmental policies and the legal framework in all forms of economic management.

The Cuban government expresses concern about the effects of rising sea levels and increasing aridity on mangroves and the effects of the loss of their protective role on the coasts in the National Climate Change Strategy [62]. This strategy is one of the first mentions of the need to conserve mangroves as a measure of adaptation to climate change in Cuba. Thus, the country has continuously reaffirmed in international spaces the government's position to restore and protect mangroves for their role in mitigating the impacts of CC [54,62,63].

Existing strategic instruments are useful for the conservation of mangroves as protective elements of the coastline because of sea level rise and the impact of extreme hydrometeorological phenomena. No references were found to the role of mangrove mitigation in the carbon sequestration process (Table 5).

Vision	Strategic Instrument
Mitigation of rising average sea levels, coastal protection	Climate Change Adaptation Strategy [74]
Mitigation of rising average sea levels, coastal protection	Cuban State Plan to Confront Climate Change [43]
Connectivity with other ecosystems, climate change adaptation and mitigation	National Environmental Strategy [75] (https://www.citma.gob.cu/estrategia- ambiental-nacional/ 10 February 2022)
Natural resources (strategic axes), protective forests	National Economic and Social Development Plan until 2030 [54]

**Table 5.** Strategic instruments in Cuba include activities in mangroves and the vision of the ecosystem within them.

Neither strategic nor operational instruments are identified that allow for the management of the mangrove as a carbon reservoir, but there are bases to support this kind of proposal.

#### 3.6. Education and Training

This section analyzed whether the management of the mangrove as a carbon reservoir in Cuba is included in the professional training profile of public administrations. Of the total of 24 universities of the Ministry of Higher Education in Cuba (www.mes.gob.cu, 10 February 2022), 17 of them (70.8%) offer academic programs in environmental issues at the master or doctoral level. The topic of the management of carbon sequestration by the mangrove was not identified within the lines of research, nor were thesis results found (in publicly accessible repositories) on the subject.

#### 3.7. Economic Resources

During the present research, we did not find economic resources for managing the mangrove as a carbon reservoir in Cuba. Nor were intentions identified regarding the implementation of voluntary markets in the country; the applicability of these options is limited by the economic embargo on Cuba that limits Cuba's activities and relations with international banks.

According to the information presented under the headings of regulations and competencies, the economic resources for the management of the mangrove as a carbon reservoir could pass through the CDM and the implementation path in Cuba, as presented in Figure 3. In the Modalities and Procedures for the CDM, the NDA has the responsibility to authorize the participation of specific entities in project activity for the CDM.

Resolution 76 establishes an initial stage of evaluation to assess the correspondence of the project with Cuba's sustainable development criteria. The project developer must present in a simplified format basic information with a description of the potentialities to reduce emissions and additionality. The Cuban state reserves the right to assess the positive performance of the investing country concerning its obligations under the United Nations Framework Convention on Climate Change [12] and to evaluate compliance with the country's internal provisions for foreign investment [72].

Two types of possible CDM projects are considered: those whose proposals are prepared and presented directly by the investor to the DNA, and those that are in the portfolio of opportunities prepared by the Prioritized Projects and Programs Management in conjunction with the Governing Ministries of each related sector. The latter group is guaranteed to correspond with the country's sustainable development priorities, the existence of conditions for its implementation and a pre-feasibility analysis, based on a baseline of opportunities. Thus, in this case, the evaluation of sustainable development is omitted.

The findings of this research suggest that the identification of funds for the development and implementation of possible projects on carbon sequestration by mangroves in Cuba should go through the CDM structure explained in this section.

#### 3.8. Knowledge and Information

The reports on carbon sequestration by forests in Cuba correspond to the studies carried out in the forest heritage managed by the Forestry Enterprise, using the automated system SUMFOR (SUMideros FORestales) to evaluate the carbon retained in natural and planted forests [76]. For Cuban mangroves, it is estimated at 49.9 Mg-C ha<sup>-1</sup> considering aerial biomass only [77]. Several authors agree that the low level of average carbon sequestration of the Cuba mangrove obtained through the implementation of SUMFOR is due to the methodological premise that excludes the belowground sink [78,79].

For the implementation of SUMFOR, the Forest Management Projects of state forestry companies are used as a source of information. Specifically, data refer to the areas and volumes of standing wood existing in plantations and natural forests [77,80]. In the case of mangroves, estimates of aboveground biomass are reported, but the carbon contained in the soil is excluded because it is subject to frequent flooding regimes [77]. This must be corrected in order to develop a more accurate carbon budget for mangrove ecosystems.

Research on general ecological aspects of mangroves in Cuba is not carried out systematically, so it is not enough to assess carbon sinks. We did not detect any monitoring system for this purpose.

#### 3.9. Education for Sustainability

In Cuba, the development of training activities linked to informal education started with the National Environmental Strategy (EAN) in 1997 and continues with a new cycle of the Strategy for the period 2021–2025 (https://www.cubahora.cu/uploads/documento/2019/05/21/estrategia-ambiental-nacional-2016-2020.pdf, accessed on 1 December 2021). National and international collaborative projects have been implemented, for example, with approaches to Integrated Coastal Zone Management and resource management [81].

An approach, in this case, is the Manglar Vivo project [82]. It was approved by CITMA in 2014 as an ecosystem-based adaptation measure (EBA) and received funding from UNDP. The activities were implemented in the coastal area of the provinces of Artemisa and Mayabeque to build capacities in the communities for sustainability and risk reduction in the face of climate change impacts, such as floods, erosion, and saline intrusion. There are references to strengthening local actors for the use of EBA measures, mangrove restoration and valuation of ecosystem goods and services [82], although the elements about the carbon capture service by the mangrove are not explicit.

#### 3.10. Citizen Participation

The Cuban state promotes citizen participation as a constitutional right in the realization of educational and scientific policy [55]. This is as well as the necessary popular consultation for matters of local interest, which is explicitly recognized in the Constitution of the Republic, approved in 2019. In particular, the role of communities in the management of coastal natural resources is recognized.

In the case of MIZC projects, community training aims to provide the populace with tools for active participation in the management of coastal resources [83–85]. These experiences have shown that the participation of coastal communities is indispensable to advancing coastal sustainability [60,61].

The existence of popular consultation mechanisms established through the National Environmental Strategy is considered particularly important for the implementation of coastal area development and conservation projects [75]. This guarantees the existence of ways to channel participation and a tendency toward the participatory approach in social life [81]. Therefore, it is considered that there are positive conditions for citizen participation given the network of social organizations in the communities.

#### 4. Discussion

#### 4.1. Basic Knowledge about the Mangrove for Management as a Carbon Reservoir in Cuba

Cuba has limitations in robustly demonstrating the role of mangroves in CC mitigation through carbon capture. The use of the SUMFOR automated system provides limited data due to the difficulty of estimating carbon in the soil of mangrove forests [76]. In this sense, the respondents agree that, initially, the contribution of Cuban mangroves in the mitigation of CC through carbon capture could be of greater relevance at the national level and a vital component within the Cuban NDC.

Global estimates report that Cuban mangroves can contribute to reducing up to 1.5% of CO<sub>2</sub> emissions of the country [86]. Other research places Cuba among one of the three countries that generate the largest positive net price in terms of income contribution generated by carbon sequestration in coastal ecosystems [87].

A robust tool for estimating carbon capture is the use of allometric equations [88]. In Cuba, there are no precedents for the use of this method in mangrove species, but it is possible to use general models or models developed for specific areas, such as La Florida [89–91]. It is important to consider the characteristics and specific composition of the mangrove species between Cuba and the study areas where the allometric equation was developed.

Remote sensing and Geographic Information Systems (GIS) could be used to locate and quantify carbon stores in mangroves. Linked to other techniques, such as accepted allometric equations, this pairing reduces field data collection and saves time and implementation costs [88]. It is a tool regularly used for monitoring mangroves in the international context [1,88,92–95]. Presently Cuban scientists use only field methods for study and monitoring of mangroves [96,97]. GIS and remote sensing have been used in various investigations [25], and some recent results have allowed a generation of preliminary indicators for monitoring mangrove extension [98].

The Blue Carbon Initiative methodology provides standardized methods for measuring and analyzing blue carbon stocks and flux in mangroves [99], as well as addressing activity data and emission factors following IPCC guidelines. It allows for characterizing the carbon content for each mangrove sink and estimating the total existence of carbon in the studied area. An applicable methodology is considered to address the study of carbon sinks in the mangrove swamp in Cuba.

Despite this, there are methodological and economic limitations to carrying out studies on the carbon reservoir in the soil in Cuba. The methodology used to evaluate carbon sequestration by the Cuban forestry sector does not allow these data to be considered in the case of the mangrove. From an economic point of view, soil analysis is expensive, and it is not always possible to access laboratory techniques and equipment.

#### 4.2. Assessment of the Cuban Environmental Policy and Regulations Context

The effectiveness and efficiency of mangrove conservation policy are influenced by the role of decision-makers and their interests and the integration of actors at different levels [18]. In the case of mangroves as a carbon reservoir and CC mitigation role, it seems to move from the national interest to the international context, but with an important weight of local interests and initiatives [18,100]. It should be in the governmental interest to present mangroves as carbon sinks within its emission reduction commitments under the Paris Agreement [100,101]. In some cases, mangrove conservation is explicit in the policy and references the  $CO_2$  capture service, such as in the Philippines and Mexico [100,102]. This allows them to draw up national policies for conservation, although in some cases they are not effective at the local level due to the lack of integration between the multiple actors [18]. Other authors suggest that carbon policies should consider the criteria of local actors, particularly women and their interests and needs and their socio-cultural relationship with mangroves [103].

The literature is consistent that there is not enough coherence between mangrove management at the local level and international carbon policies [93]. It is necessary to build robust national political agendas and strengthen strong institutional and regulatory capacities for this [104].

According to the First Nationally Determined Contribution of Cuba, the country does not have a Measurement, Reporting, and Verification system to the Enhanced Transparency Framework of the Paris Agreement [54] and contains no mention of the implementation of REED+ initiatives. The CND contains prioritized actions for adaptation, including the restoration of mangroves.

Regarding mitigation measures, a proposal to increase forest cover by 33% by 2030 is being prepared for submission to the Cuban Forestry Sector. Coinciding with the findings of this investigation, the safeguards exposed in the CND identify as threats to the fulfillment of the proposed goals, for example, the occurrence of extreme natural phenomena, the absence of financing, technology transfer, and capacity building, and the consequence of the negative impact of a tightening of the economic, commercial, and financial blockade of the United States of America against Cuba. The present investigation did not clarify the reason, despite the extensive mangrove forests in the country, for the lack of established mechanisms to account for and monitor the carbon retained in these coastal forests. Conducting interviews with specialists and decision-makers at the national level could help identify the causes of this gap. According to international references, scientific knowledge is required for decision-making, such as an extensive mangrove monitoring system [99], since it is necessary to quantify the carbon retained and build a baseline of the carbon sinks [105]. However, it is considered that in Cuba there are conditions and opportunities for the implementation of carbon sequestration practices as a measure to confront the impact of climate change.

Cases examined, such as Bangladesh and Indonesia, with significant mangrove forests do not have specific regulations for this ecosystem [101]. Moreover, in Africa, the regulatory framework is insufficient to manage the mangroves [106,107]. Cuba has not designed a specific tool for this purpose; however, it has a wide spectrum of instruments that allow for regulating mangrove components independently. In general, it is considered that it is exceedingly difficult to achieve an exclusive legal norm for the mangrove, which can be associated with the diversity of areas of environmental protection that regulate the different legal bodies [108].

The findings of this research in the international context allowed us to corroborate the importance of normative legal aspects in the implementation of mangrove conservation policies, and in the valorization of the ecosystem goods and services they offer [106,109]. It also allowed for the reviewing and updating of institutional capacities, the obsolescence of standards and the lack of clarity in the competencies and roles of institutions in this process [108]. In contrast, the legal instruments in Cuba establish a centralized mechanism that allows for identifying the legal responsibility of institutions in terms of the management of different activities in the mangrove. A positive aspect detected is that there are no overlaps or administrative conflicts between these institutions given the participation of CITMA in all procedures as a national environmental authority. Despite this, the evolution of the legal code has not been extended to the service of mitigating climate change through carbon capture.

The environmental policy in Cuba on this issue is incipient. In the evaluated period, it has developed training and preparation actions for the personnel involved to begin a gradual implementation process. Unfortunately, that performance cannot be rated yet.

#### 4.3. Carbon Capture and Economics

In general, countries with tropical forests and mangroves have a high potential for market participation arising from the easing mechanisms under the Kyoto Protocol [14]. The CDM is a scheme established to implement emission reduction projects in Cuba [75]. The authors agree that it could allow for the development of proposals for the management and conservation of mangroves as a carbon reservoir through afforestation/reforestation project types. Cuba, like other Latin American countries, has used this mechanism mostly for the development of projects in the energy sector, followed by the sector of reducing methane emissions and scarce carbon sink projects [103].

Afforestation/reforestation projects are more complex and characterized by reducing and capturing  $CO_2$  for a while [15]. These are characterized by capturing carbon and not by removing it. This means that the captured  $CO_2$  can be released into the atmosphere if the reservoir is disturbed. The minimum accreditation period is 7 years (renewable twice) up to a maximum of 60 years. Implementing this type of project in Cuba can be complex, given the frequency and intensity of extreme hydro-meteorological phenomena that affect the country [76]. For example, despite the existence of models that allow evaluating scenarios and estimating the impact of tropical cyclones, it is not enough information to assess the impact on national forests, including mangroves.

The implementation of the CDM in Latin America is vulnerable in terms of the fragility of financing and the stability of DNAs [103]. However, the CITMA as DNA in Cuba presents high institutional strength and qualified officials, and although no sources of financing were identified for projects of this type within the country, through the mechanism itself it is possible to identify and obtain investment from foreign sources. On the other hand,

for several years there has been a strategic alliance between the government, UNDP, the Global Environment Facility, and other international organizations through which important environmental achievements have been realized [110]. The respondents agree that the greatest challenge for Cuba lies in the identification of sources of financing and the negotiations of carbon credits identified in the context of the economic system and the consequences of the economic embargo that the island suffers.

The REDD+ program is another proposal successfully implemented in the international context outside the Kyoto Protocol. This program contains a rigid structure for elaborating its policy that promotes reforestation in the context of each country [111]. Cuba attended the training activities, but no publications on implementation progress during the present research were found. One of the central international debates on REDD+ between intersectoral policies is the issue of land tenure and forests.

The state is the owner of the land in Cuba. This situation reduced the conflicts of private interests over land use. The use of the land in usufruct is allowed through Decree Law 358, which lets the land be managed and exploited by natural persons [112]. Both instruments form a positive context for the possible management of soil carbon. The country has a committed government and actors articulated by a legal framework. Although it is not specific to the issue of mangroves, Cuba is already moving towards the proposal of mechanisms for monitoring, reporting and verification (MRV). Therefore, the REDD+ methodology could apply to Cuba. It may allow linking and standardizing of the national forest inventories (NFI) with GIS and MRV protocols, revealing the potential of the Cuban mangrove as a carbon reservoir. However, the absence for the MRV system persists and the present study was unable to clarify the causes of the country not advancing in the implementation of REDD+.

Contrary to what has been observed in the international literature [103,106,113–115], no cases of mangrove management by the private sector are identified in Cuba. Therefore, conflicts of interest between private and state sectors do not emerge for the management and conservation of the ecosystem as in Bangladesh and Africa [106,108,113]. In Cuba, the communities do not show high dependence on mangrove resources for subsistence [37]. Despite this, they could become involved and contribute to national targets for CC mitigation through mangrove carbon sequestration in coastal municipalities.

Quantifying and valuing the carbon stored in mangroves at the municipal level could benefit the creation of a new way of conserving these areas and obtaining economic incentives for the communities through the carbon credit market. When the study was concluded, there was no precision regarding the policy's implementation scale. However, integrating the scales from the national to the municipal level would be considered appropriate. In Cuba, the municipality plays an important role in territorial development, and there are articulated actors and institutions with capacities to implement local projects [116]. In this case, it is of interest for possible proposals for community participation in mangrove management.

The estimation of the potential of Cuba in this sense is high, management and conservation activities in the country could considerably increase the carbon reservoir in the mangrove forest [117].

Up to this point of analysis, we found a promising framework for developing mangrove conservation and management actions from the perspective of carbon sequestration. However, there are barriers to moving towards the carbon market for the country, such as the lack of financial and banking infrastructures. Cuba has made efforts to participate in the carbon market through regional initiatives since 2004 without effective inclusion [118]. The longstanding embargo has affected international economic relations for years and has accentuated the economic crisis in the country [119]. In addition, Cuba is included in the list of countries that do not cooperate in the fight against terrorism drawn up by the United States [120]. In this context, it is considered that the credibility of Cuba has been negatively affected by the cooperation with international banks that collaborate in the trade of carbon credits.

## 5. Conclusions

In Cuba, there is a favorable context in environmental policy to manage the mangrove as a carbon reservoir. Our results suggest that the environmental policy in Cuba is propitious, yet it has gaps that could undermine the country's ability to conserve mangroves as a carbon reservoir. Gaps remain in accounting for or estimating the amount of carbon retained, monitoring, and drawing up integrated conservation strategies and policies.

Although there is no specific policy for managing and conserving mangroves as a carbon reservoir, there is a favorable context for initiatives of this type in the country. Therefore, with the participation of civil society, the Cuban government must identify the gaps to enrich the environmental policy that allows new measures or instruments for conserving or managing the mangrove as a carbon reservoir. The Cuban government recognizes the importance of mangroves facing CC, but with greater emphasis on the protective role of the coasts and less mention of the role in mitigation through the absorption of  $CO_2$ . The Cuban environmental policy agenda should explicitly include the role of the mangrove in CC mitigation through carbon capture.

The current legal framework makes it possible to identify the powers and institutions responsible for or that could participate in mangrove management, and CITMA is identified as the leading institution. However, research is needed to identify how to articulate each institution's or ministry's responsibilities to align the vision, objectives, and coordination of activities for managing the mangrove as a carbon reservoir.

Contributing to updating these instruments so that they contain elements related to mangrove carbon sinks constitutes a challenge for future research in Cuba. The existing strategic and operational instruments create a propitious framework for initiating proposals to manage mangrove sinks. However, they are insufficient to address the issue in question; more specific proposals are needed. It is recommended to deepen this sense and conduct interviews with decision-makers and experts at the national level to clarify the steps the country is following in terms of goals and conservation plans for mangroves and if it has been considered to use them as carbon sinks. Considerations for voluntary markets and carbon credits could also be explored; training on these issues and how to implement them in the Cuban context is necessary. It is recommended to evaluate the opportunity for the participation of coastal communities in projects to use carbon captured in the mangrove swamp. It is necessary to consider training communities on these issues.

The contribution of carbon sequestration by Cuban mangroves has greater relevance at the national level and will be a valuable fact to be included in the CND, but research must be carried out at the municipal or provincial level. Estimating carbon action in mangrove ecosystems can support strategies for climate change mitigation and adaptation and can also improve understanding of the ecosystem's response in the current context of changing climate. Thus, it is necessary to build robust national political agendas and strengthen institutional and regulatory capacities for this purpose.

Some pending questions about the elements analyzed are: at what scale of work will it be more feasible to start proposals for carbon capture studies? How to develop data valid for carbon reporting in the Cuban context? In this case, it will be necessary to advance in the estimation of aerial biomass and in carrying out basic research, such as the carbon content in the soil, carbon fluxes, and the particularities of Cuban mangrove species. The authors consider that capacity building is required in the country to develop specific competencies and skills on the conservation of mangrove forests and the management of carbon sinks.

Considering the existing limitations in the country fundamentally associated with the embargo is necessary. That prevents, as we mentioned before, Cuba's access to international financing and the acquisition of technologies to determine carbon stocks. Further investigation is required involving national experts and the implementation of other techniques, such as surveys and interviews. The analysis presented should contribute to improving scientific research agendas and is expected to help, in the medium and long term, to improve Cuba's national environmental policy. Methodology developed in this research can be applied in other countries for evaluating environmental policy. As part of the next stage

of research, we recommended conducting some interviews with other experts to obtain relevant information that can help effectively identify critical issues related to different coastal ecosystems or other relevant integrated coastal zone management problems.

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