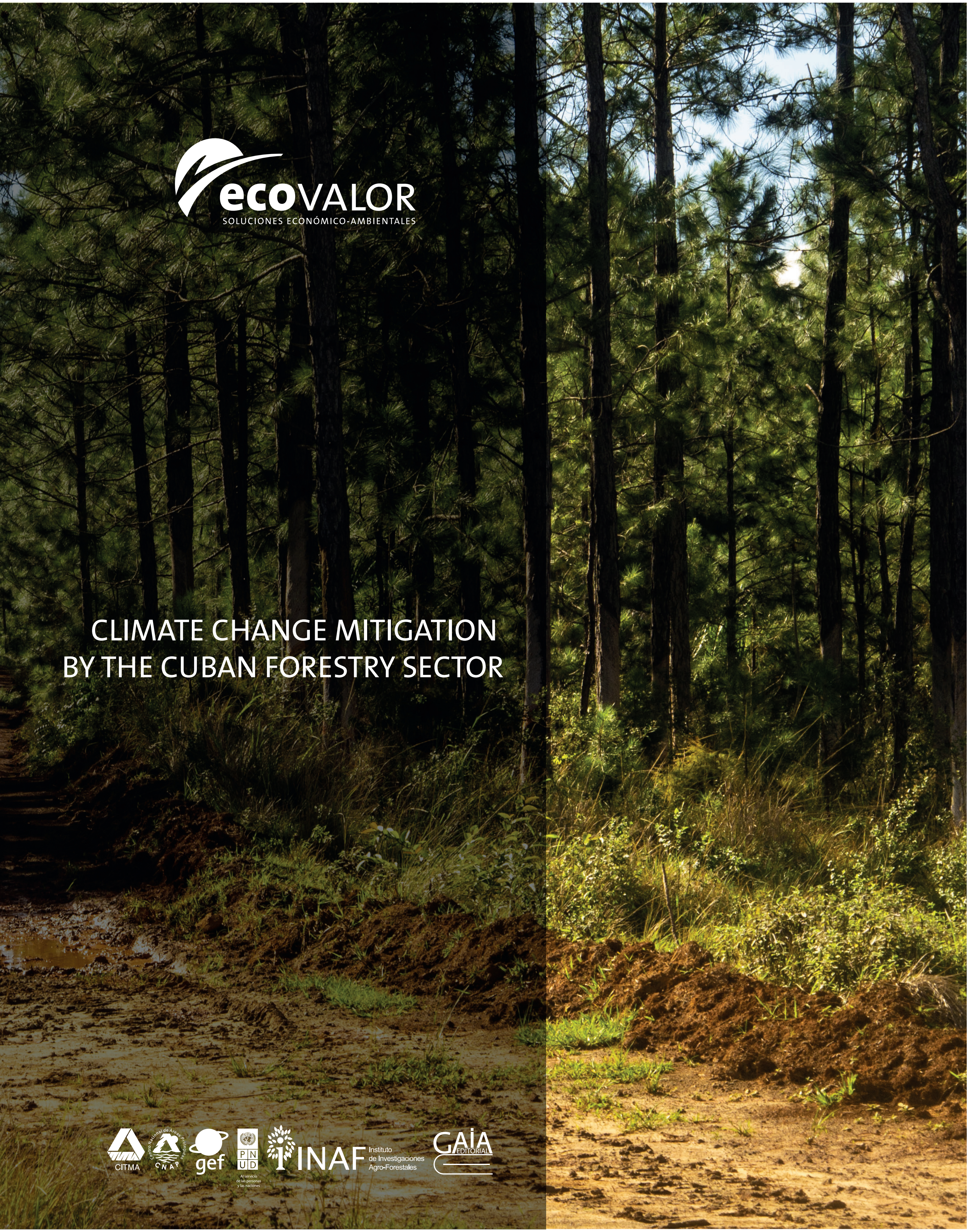

CLIMATE CHANGE MITIGATION BY THE CUBAN FORESTRY SECTOR

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ECOVALOR is a project aimed at supporting the economic evaluation of ecosystem services, led by the National Center for Protected Areas of the Environment Agency of the Ministry of Science, Technology & the Environment, with the cooperation of the Ministry of Agriculture, the Ministry of Tourism and the Ministry of Energy and Mines; it is implemented by the United Nations Programme in Cuba, with the financial support of the Global Environment Facility (GEF).

The printing of this publication has been financed by the project "Incorporation of Diverse Environmental Considerations and their Economic Consequences in The Management of Landscapes, Forests, and Production Sectors in Cuba" (ECOVALOR).

In memory of José Somoza, PhD,"Pepe",
a member of the National Mitigation Team,
a dedicated researcher, and a dear colleague

The Authors
Havana, December 2020

ACKNOWLEDGEMENTS

Determining the balance of greenhouse gas emissions in the forestry sector, the amount of carbon sequestered by the forests, the alternatives for mitigating emissions available to forest tenants, and the scope for insertion into the international carbon market involves a long period of work that started at the beginning of the first decade of this century, extending until 2020, and includes results obtained even during the year of its conclusion.

In this endeavor, the Forestry, Flora, and Wildlife Authority of the Ministry of Agriculture ("MINAG"), most of the companies that make up the Agroforestry Group and its Industry Division, the Tropical Fruit-Growing Research Institute, the National Center for Protected Areas and various protected areas of the Flora and Fauna Business Group provided decisive political support, furnished essential information for the assessments carried out, offered their views on methodological aspects and actively participated in the validation of the results obtained.

However, during this time, many of the authors were also engaged in the preparation of Cuba's First, Second and Third National Communications the UN Framework Convention on Climate Change (UNFCCC), and many of the results presented were obtained in the course of their preparation. Accordingly, we would also like to express our gratitude to the international organizations engaged in the drafting of these reports, including the UN Convention on Climate Change (UNFCCC), the Global Environment Facility (GEF), which acted as international financier, and the UN Development Programme (UNDP), which acted as implementing agency in Cuba. We are also grateful for the support to the research by the University of Alicante, Spain, whose cooperation was crucial to launching the forays involved in obtaining national emission factors that helped reduce the uncertainties associated with the determinations regarding carbon.

Decisive support in achieving the results presented was provided by the group of technicians and workers of the Agroforestry Research Institute, among whom the authors would like to express special thanks to technicians Bárbara Aguirre, Manuel Valle, and Roberto Ramos, who are no longer with us.

To all of them and to all those who were directly or indirectly engaged in obtaining, implementing, evaluating, validating and publishing all these results, both in Cuba and abroad, the authors express their sincerest gratitude.

ALICIA J. MERCADET PORTILLO

Graduated as a forest engineer at the University of Havana in 1974; in 2003 obtained her PhD in Forestry Sciences at the University of Pinar del Río, Cuba. She has been a member of the scientific team of the Agroforestry Research Institute (INAF in Spanish), where she worked as a senior researcher for more than 20 years. Her scientific activity has mainly related to two topics: forestry genetics (introduction of species and origins) and climate change (net emission balances in the forestry sector and climate change mitigation by forests), on which she ran several research projects, while her managerial activity included heading up the Genetics-Protection (1996-1999) and Forestry-Environment (1999-2002) departments and the National Group on Climate Change in the forestry sector (since 2014); she was also a member of the technical team set to complile the national greenhouse gas inventory and of the National Committee on Biological Diversity. She is the author of more than fifty scientific articles, several books, has tutored eight master's theses, two doctoral theses, and has been a member of the group of authors of the three national communications submitted by Cuba to the UN Framework Convention on Climate Change. She provided technical consultancy services in forest genetics in the People's Republic of Angola for one year. For the results of her work, she has received several annual awards from the Ministry of Agriculture; she received the Commemorative Coin for the 30th anniversary of the Academy of Sciences of Cuba (1992); on two occasions she was awarded the national prize of the Academy of Sciences of Cuba and the special environmental prize of the Ministry of Science, Technology & the Environment (2014 and 2015); The National Association of Agricultural and Forestry Technicians awarded her the ACTAF lifetime achievement award (2017), and in recognition of her scientific career, the Council of State of the Republic of Cuba conferred on her the Carlos J. Finlay Order (2016). In 2019 she retired from work, keeping active her scientific production and her relationship with INAF as the senior specialist of the Environment group, while paying special attention to the training of new generations of forestry researchers.

PREFACE

'Climate change mitigation' basically relates to iniatives, measures, programs, and policies that contribute to reducing net greenhouse gas emissions; mitigation encompasses both the reduction of emissions at their sources and emission removal by sinks. Forests, in addition to many other ecosystem functions and services, act as important CO_2 sinks, this gas being the principal of the greenhouse gases. Consequently, climate change science has paid particular attention to the role of forests in the strategies responding to this global challenge, both in terms of adaptation - which aims to reduce vulnerability to climate change-and mitigation.

Each assessment cycle of the Intergovernmental Panel on Climate Change (IPCC) has examined this issue and [its reports] on mitigation- usually those of Working Group III (WG3)-have included a chapter on mitigation, assessing the role of forests. The WG3's contribution to the IPCC Fifth Assessment Report (2014), Chapter 11 (Agriculture, Forestry and Other Land Uses) highlights, among the mitigation options for forestry, the reduction of deforestation, forest management, forestation, and agroforestry[1]. The IPCC Special Report on Climate Change and Land also highlights sustainable forest management as "the management and use of forests and forest lands in a manner and at an intensity that maintains their biodiversity, productivity, regeneration capacity, vitality, and their potential to fulfill, now and in the future, relevant ecological, economic and social functions at local, national and global scales, and that does not cause damage to other ecosystems."

Despite advances in scientific knowledge regarding the contribution of the forest sector to climate change mitigation, uncertainty and knowledge gaps persist in this field, such as those identified by the IPCC Fifth Assessment Report (2014), referring to: the paucity of globally standardized and homogenized data on forest degradation; the need for a better understanding of the degradation effects on carbon balances, for more knowledge of the mitigation potential, interrelationships and costs, the environmental and socioeconomic consequences of mitigation

1. IPCC Special Report on Climate Change, Desertification, Land Management, Food Security and Greenhouse Gas Flows in Terrestrial Ecosystems (IPCC, 2019)

options such as forest conservation, bioenergy production and forestation on national, regional and global scales; the need also for a better understanding of the effects of changing climate parameters for carbon pools and, consequently, for the mitigation potential.

Similarly, these issues have occupied a key focus in multilateral policy negotiations on climate change, particularly in the context of the UN Framework Convention on Climate Change (UNFCCC, 1992), the Kyoto Protocol (1997), and the Paris Agreement (2015).

All of the foregoing confirms the relevance of this work, dedicated to "Climate Change Mitigation by The Cuban Forestry Sector", by the lead authors Alicia Mercadet, Arlety Ajete, and Arnaldo Álvarez. The authors of this book summarize in these pages their work on these issues over the last two decades, as part of the national team on climate change in the forestry sector based at the Agroforestry Research Institute, attached to the Agroforestry Business Group ("GAF"). The results of this scientific research also represent valuable contributions to the national and international debate and to decision-making in Cuba.

The book consists of four chapters in which the authors examine key topics such as:

- the greenhouse gas (GHG) emissions balance of the forestry sector, trends, and prospects (Chapter 1);
- forest carbon sequestration, describing the extended forest carbon cycle, carbon categories, components and pools, the method used for carbon and baseline determination, the proposed measurement, reporting, monitoring, and verification system for the Agroforestry Business Group, and the results of the carbon reports for 2013, 2017, and 2019 (Chapter 2);
- climate change mitigation through afforestaion, the results of assessments, the status of actions proposed in the national communications, nationally determined contributions (NDCs), the capacity building for transparency initiative, mechanism for reducing emissions from deforestation and forest degradation and its sustainable management (REDD+) and the role of the project ECOVALOR (Chapter 3); and
- payment for environmental services (PES) for atmospheric CO_2 removal by forests (Chapter 3).

These results represent a contribution to national decision-making, to the fulfillment of Cuba's international commitments on these issues, and to the training of officials and technicians in related areas. It is worth highlighting the relevance of these results to the objectives of the guiding documents of Cuba's socio-economic and environmental priorities, in particular, the Tarea Vida ('Life Task') national program; and the bases of the National Economic and Social Development Plan up to 2030- in particular, its strategic pillar relating to "natural resources and environment."

As the authors demonstrate, a characteristic of the Cuban forestry sector, in terms of climate change mitigation, is a sustained increase of carbon removal due to sustained growth of Cuba's tree cover, the downward trend in emissions as a result of the reduction in forest harvesting levels and the absence of deforestation. Consequently, since 1994 net emissions from agriculture have been offset by the forestry sector; and since 2010 the agrarian [sic] sector has become an atmospheric carbon sink.

However, the authors warn that by 2025 the annual level of GHG removal by the forestry sector is expected to stabilize at a maximum level, i.e. from that point onward its sink capacity would remain relatively constant, and therefore its potential to offset emissions growth in the agribusiness, energy and other sectors, would be limited.

One of the scientific contributions shown in this work is the application of a method for calculating the carbon sequestered in biomass, necromass, and the soil of the national heritage, using an automated system called SUMFOR (Forest Sinks), in which the national emission factors account for 80% of all the emission factors used. This method has been widely used by Agroforestry Group Companies in 2013, 2017, and 2019.

In addition, various mitigation alternatives proposed at the company level to increase carbon removal are presented. These proposals are supported by an economic and environmental analysis which identifies their minimum and maximum scope in terms of targeted carbon removal from a baseline, and also includes information on costs, payback period, subsequent net revenues and financial viability of the investment, among other parameters.

As indicated above, this team's work has been essential in the preparation of the information on climate change mitigation reported in Cuba's national communications to the UNFCCC secretariat; of Cuba's nationally determined contributions (NDCs) as part of the implementation of the Paris Agreement, among other purposes. Also, the experience gained by the authors has enabled them to follow up on important international projects that have operated in Cuba and whose objectives have included contributing to emissions removal from the forestry sector, such as the ECOVALOR project of the National Center for Protected Areas of Cuba, funded by the Global Environment Facility (GEF), managed by the UNDP.

Another of the contributions of this book is identification of the main challenges faced by the Ministry of Agriculture concerning mitigation by the forestry sector, including the capacity building needed for: preparation of all the information on this issue that Cuba requires to meet its commitments to the UNFCCC; implementation of a national payment system for the environmental service of atmospheric carbon removal; the possible international marketing of forest carbon; implementation of a forestry program to combat climate change; and securing international financing.

In general, the contents of this volume are very useful for those interested in the initiatives undertaken by Cuba in dealing with climate change, especially in terms of mitigation, and in reconciling these measures with Cuba's socio-economic and environmental priorities.

Ramón Pichs Madruga, PhD.
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Vice-Chair of IPCC Working Group III.

EXECUTIVE SUMMARY

On the theme of climate change mitigation, various aspects have been dealt with, including:

- The net balance of greenhouse gas emissions by the forestry sector, its seasonal and future trends;
- The extended forest carbon cycle, categories, components and carbon pools in the heritage, the method used for carbon and baseline determination, a proposed measurement, reporting, monitoring, and verification system for the Agroforestry Business Group and the results of the 2013, 2017 and 2019 carbon reports;
- Forest mitigation, results of the assessments carried out, status of the alternatives proposed in the national communications, the nationally determined contribution (NDC), the Capacity Building Initiative for Transparency (CBIT),the mechanism for reducing emissions from deforestation and forest degradation and sustainable forest management (REDD+) and the role of the ECOVALOR project;
- The status of payment for forest environmental services (PES) and the proposal formulated in this respect, the issues awaiting decision and an analysis of the international carbon market.

This broad set of aspects offers the reader an overview of the scientific-technical activity undertaken by the climate change team of the Cuban forestry sector, headquartered at the Agroforestry Research Institute, in this century to date, as well as a perspective on the direction of its future actions.

The balances between emissions and removals reflect sustained growth in the latter due to a constant increase in Cuba's forest cover. But this increase is not only due to growth in the wooded areas but also to a sustained downward trend in emissions as a result of reduced levels of forestry harvesting and the absence of deforestation. Hence, while in 1990 the balance was -12.6 million tCO_2e, by the end of 2016 it had reached -26.7 million, an increase of 14.1 million tCO_2e, implying that the net emissions from agriculture since 1994 were offset by the forestry sector, and that consequently Cuba's agrarian sector can be considered, from that year on, an economic activity without net GHG emissions and even, since 2010, as an atmospheric carbon sink.

Adopting the calculation methods currently applied to inventories (proposed by the Intergovernmental Panel on Climate Change), from around 2025 the annual level of greenhouse gas (GHG) removals by the forestry sector will have reached a maximum level that will stabilize from that point (due to the full coverage of the heritage), which means that if emissions from or from other sectors (such as energy) continue to grow, Cuba's net emission levels will also increase, because the sink capacity of sector that currently fully or partially offsets them would be constant.

Unlike the 'inventories' gain-loss method used to calculate the carbon balance, the calculation of the carbon sequestered in biomass, necromass and soil of the wooded areas employs the stock-difference method using an automated system supported in Excel: SUMFOR (Forest Sinks), which utilizes mostly national emission factors (around 80%).

On three occasions (2013, 2017, and 2019), this system has been used to assess a group of companies in the Agroforestry Group that together managed 25% of the national forestry heritage, which at the end of 2018 was around 4.0 million hectares.

Based on data as of end-2016 and end -2018 provided by 13 agroforestry companies, the 2019 report's results indicated that between those two years, the managed forest heritage increased by 36,700 hectares, but the timber yield decreased by 1.37 cubic meters per hectare, while carbon sequestration also declined, by 3.57 tC/ha, with 21% of carbon accumulated in biomass, 3% in necromass and 76% in soil. Only two of the 16 natural wooded formations accumulated more than 100.0 ktC: the semi-deciduous on limestone soils and mangrove, while of the seven forestry categories only production and coastal protection forests achieved sequestrations of more than 200 tC/ha.

The three reports to the GAF companies have enabled us, given the UN-REDD Programme, to propose a carbon measurement, reporting, monitoring, and verification system for this group, which with some modifications can be extended to more than 11 entities that currently manage the national forestry heritage.

A set of 10 mitigation alternatives to be implemented at the company level have been included in the SUMFOR system, treating these as environmental investments based on changes to the technical management habitually performed in each company, which increase carbon removal in relation to the baseline calculated from the base year.

In a preliminary study, based on specific interests expressed by six agroforestry companies, a total of 31 mitigation alternatives were evaluated; the results showed that, including all the components and carbon pools in the forestry heritage and assuming a project life (implementation + capitalization) of 10 years:

- At a price of \$2.00/tCO_2, they can remove at least 1.52 million tCO_2 from the atmosphere above the baseline, with an expenditure of 1.18 million pesos, which would be recouped in 4.9 years or less, generating net income of 1.87 million pesos over the following 5.1 years, implying average mitigation of 25.8 kt CO_2 /m and a net economic benefit from the investment of \$0.77/ tCO_2 (atmospheric) mitigated.
- At a price of \$3.00/tCO_2, they can remove at least 11.02 million tCO_2 from the atmosphere above the baseline, with an expenditure of 10.78 million pesos that would be recouped in a maximum 9.0 years or less, generating in the remaining year net income of 22.29 million pesos, implying average mitigation of 102.08 kt CO_2 /m and a net economic benefit from the investment of \$0.98/tCO_2 (atmospheric) mitigated.

The total amount of funding required for mitigation would range from 1.85 and 33.07 million pesos, depending on the price per ton of CO_2 mitigated.

Given that the GAF includes 26 companies that manage forestry heritage, it is clear how important it would be to approve, recognize and officially record the implementation of mitigation alternatives established at the company level.

In Cuba's three national communications submitted to the Climate Change Convention, mitigation alternatives by the forestry sector were addressed, with varying levels of success. Also, as part of the nationally determined contributions (updated) submitted by Cuba in 2020 for the Paris Agreement, a mitigation alternative aimed at increasing Cuba's forest cover to 33% by 2030, requiring, in addition to the self-funded investment, additional financial support of US $2,291 million; this variant that would increase the area covered by artificial forest established between 2019 and 2030, removing 169.9 million tons of atmospheric CO_2.

Interaction between the Cuban Forestry Sector and the REDD+ mechanism was initiated in July 2009, at a regional workshop held before the Copenhagen COP, and was subsequently expanded in 2011 and 2013 at other, similar workshops. In January 2015, following the agriculture ministry's decision to take on the coordination of REDD+ in Cuba, it was informed by the Ministry of Science, Technology & the Environment that the latter had taken note of this decision and that the UN Framework Convention on Climate Change would be notified accordingly. Between 2016 and 2018, three other workshops were held in an attempt to implement the decision mentioned, but to date, no REDD+ funded projects have been undertaken in Cuba.

In late 2018, Cuba's National Center for Protected Areas initiated a project funded by the Global Environment Facility (GEF) and managed by the UN Development Programme (UNDP) entitled "Incorporating multiple environmental considerations and their economic implications in landscape management" (ECOVALOR), in which one of the goals is the removal of 2.8 million tCO_2e over 20 years (a 6-year invrstment phase and a 14-year capitalization/post-investment phase) by 17 forestry intervention sites. Five of these are located in agroforestry companies ("EAFs") and the rest in protected areas (PAs). The initial project appraisal and the periodic monitoring of its results in terms of meeting this goal were performed using the Ex-Act system, prepared by the UN's Food and Agriculture Organization (FAO), with the cooperation of the French Development Research Institute and the World Bank.

Consequently, with a view to improving the reporting of the results of mitigation alternatives through forestry, the ECOVALOR project envisaged the following steps:

a. Make a comparison between the methods and results obtained by Ex-Act and SUMFOR to determine the levels of conservation of carbon pools in forests;
b. Conduct an initial assessment of the potential effects of the project on carbon balances, based on a hypothetical estimate of the initial and final levels of forest degradation; and
c. Develop a methodology to determine the actual levels of degradation in the forest at the beginning, during, and after the completion of the project.

Comparison of the two tools showed that they provide users with different benefits such that neither can be regarded as preferable, but rather that they are complementary. SUMFOR can feed Ex-Act with its Tier 2 values in the forestry management part, while Ex-Act can calculate the carbon balance impact of forest management in conjunction with other activities in the AFOLU sector.

ECOVALOR has carried out three initial assessments on different bases, always relying on the empirical knowledge accumulated by the staff of each operating site regarding the existing conditions at their respective work sites. In the last evaluation, carried out in early 2020 with Ex-Act version 8.5.4c[1], the final result of the project was the forecast removal of 1.5 million tCO_2e in 20 years.

Since 2019, preparation of a methodology to determine the level of forestry degradation at the start, during, and after the completion of ECOVALOR has been under way. Consensus has been reached for defining degraded forest as an established area of natural or artificial forest, where causes of natural and human origin, or resulting from their interaction, limit or prevent the qualitative and/or quantitative fulfillment of the functions proper to forest, whether associated with its main function (determined by its category) or with its complementary functions (determined by functions other than its prinicipal function, while to establish the level of existing degradation, two different types of criteria will be evaluated:

- General, applicable to any forest category, whether natural or artificial.
- Specific, applicable to forestry areas according to their category.

In the field, data will be collected using a model with at least two sheets per sample plot; the plot data are then transferred to an Excel workbook, set up to contain up to 20 plots, and programmed to automatically determine the level of degradation of each plot, using the same scale of values used by Ex-Act so that the data can then be used directly in that system.

A project was launched in early 2020 with international financial support, which aims to strengthen the institutional and technical capacities of the agriculture, forestry, and other land use sub-sectors in response to the enhanced transparency requirements under the Paris Agreement and in line with the State Program for Addressing Climate Change ('Tarea Vida' Project). In essence, the project aims to create the capacities and information systems required for the formulation of their respective measurement, reporting and verification (MRV) Systems at the central state levels of the agriculture ministry (Arable Division, Livestock Division, Forestry Division, and Soils Department). Based on these, each division, with the support of the research institutes of each branch, will take on preparation of the relevant reports relating to net emission balances, mitigation, impact assessment and adaptation measures; subsequently the Ministry's Science, Innovation and Environment Division will act as the consolidating unit for these subsectoral reports, to form the AFOLU sector report (Figure 3.3)., enabling the agriculture ministry, as a central government agency, to submit the information required for the GHG emission inventories, the national communications, the biennial update reports (BURs), the update of the nationally determined emission contributions (NDC) and, later, for the biennial transparency reports (BTRs).

In the coming years, the agriculture ministry's Forestry, Flora, and Wildlife Division will face several important and complex challenges, which include:

- Creating the capacities and mechanisms for data capture that will enable it to take on the preparation and presentation of forestry sector documentation on climate change, in such a way as to honor the commitments assumed by Cuba under the UN Framework Convention.
- Implementing on a national scale the payment for environmental services for the removal of atmospheric carbon to all forestry managers.
- Putting into effect, monitoring, and requiring implementation of a forestry program to combat climate change.
- Taking full advantage of international financing mechanisms created to address climate change.
- Advancing, as far as possible, towards the international marketing of forest carbon as a new source of hard currency for Cuba.

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I. GREENHOUSE GAS (GHG) EMISSIONS BALANCE OF THE FORESTRY SECTOR

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1.1 General aspects

The estimation of carbon emissions and removals in forests, and land use and land use change, are complex questions and often a source of controversy due to biological factors, lack of data (or lack of reliable data), and the adverse human impacts on forestry resources which need to be assessed.

In nature, there is enormous variability even within a clearly defined forest type on a specific plot, and different results may be recorded due to (among other causes) variation in growth between different years, climatic variability, the occurrence of storms and other adverse weather events, genetic differences between and within species, characteristics of the landscape in which the forest is located, and also fires and pests. In addition, there is variation in basic wood density, carbon content of dry matter, biomass density and decomposition rates of organic matter in forest debris.

These aspects introduce fundamental differences compared to other inventory modules, in which emission factors and other coefficients can be obtained with greater accuracy for a given entity, even if they are entity-specific and vary from one entity to another (they are highly dependent on technological or other factors). However, in the area of land use, land use change and forestry (LULUCF), there is a strong influence of natural factors, rather than only current conditions such as humidity, temperature, slope, soil, age, etc., but also the legacy of previous years, which affects, among other things, biomass density.

1. Agroforestry Research Institute
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In the 1996 IPCC Revised Guidelines for National Greenhouse Gas Inventories (IPCC, 1997), priority is given to calculations of emissions from land use, land-use change, and forestry (LULUCF) in three main activities that are CO_2 sources or CO_2 sinks and constitute categories within inventory reporting (biomass changes in forests and other woody vegetation; conversion of forests and grasslands; and, abandonment of cultivated land).

Globally, the most important changes in land use and management practices that result in CO_2 emissions and removals occur in these activities, calculations that are inherently associated with high uncertainties or errors.

In 2003 the IPCC published the Good Practice Guidelines for Land Use, Land Use Change, and Forestry (IPCC, 2003). These guidelines provide good practice for this sector and address some of the problems and limitations of the 1996 IPCC.

These 2003 guidelines do not replace the 1996 IPCC guidelines but incorporate updates and improvements to these. They also include a different approach to estimation of GHG emissions and removals, based on land use categories (forestry land, crops, grassland, wetlands, human settlements, etc.) and also make a distinction based on the following land use status and recent history: (a) land starting and ending an inventory period with the same land use and (b) land conversions to other land uses. In addition, they provide the association of above- and below-ground carbon pools. The application of these guidelines requires information that is not fully available in Cuba, especially data on land use and land-use change for periods of at least 20 years before the inventory year in question. The change in methodology also implies recalculation of emissions and removals for all previous inventory reports already prepared, which poses additional difficulties, as this information, in the new format, must be available for years that are already relatively distant in time.

The most recent IPCC guidelines (2006 IPCC Guidelines for National Greenhouse Gas Inventories) (IPCC, 2006) introduce further changes into the inventory reporting structure (ratio between above-ground and below-ground biomass).

1.2. Characteristics of the Cuban forest emission balance

This subcategory includes CO_2 emissions and removals generated as a result of changes in biomass on forest land remaining as such, thus covering the entire national forest heritage because data on changes in non-forestry land becoming forestry land and/or vice versa are not available. Similarly, changes in CO_2 emissions and removals from dead organic matter, soil, and biomass burning are not accounted for, as no data are available.

In the national context, the sources of removals and emissions included in the net balance of emissions (NBE) of the forestry sector are:

a. Removal by an increase of forestry biomass (above and below ground) of:

- Established artificial forest (older than 3 years), which are grouped into:
    - Species: acacia (*Acacia spp.*), eucalyptus (*Eucalyptus spp.*), teak (*Tectona grandis*), pine (a group including *Pinus tropicalis*, *P. cubensis*, and *P. maestrensis*), and male pine (*P. caribaea var. caribaea*).
    - Species groups[1]: species mix with slow-growing hardwoods (75 species; $0.52 \geq DB^{2} \geq 1.34$ g*cm^{-3}), species mix with fast-growing hardwoods (52 species; $0.50 \geq DB \geq 1.07$ g/cm^3), and species mix with softwoods (32 species; $0.19 \geq DB \geq 0.49$ g*cm^{-3}).
- Natural forests, composed of 16 forestry formations (Bisse, 1988) which are grouped into five categories:
    - Moist forest: cumulative area of the formations cool temperate forest, cloud forest, mountain rainforest, and rainforest.
    - Seasonal forest (less than 20 years): 20% of the accumulated area occupied by the formations of tendrils shrublands, cuabal (Leucocroton flavicans), forests of oak trees, coastal mangrove, pinewoods,

1. To classify softwood, slow-growing hardwood, species, the basic density-BD (Source: Eng. Alberto Ibáñez, Head of Wood Technology Laboratory, Forestry Research Institute) and the growth database per species created by the Forestry Research Institute were used.

2. BD–Basic Density.

semi-deciduous on limestone soil, semi-deciduous on acid soil, semi-deciduous on poorly drained soil, scrubland and xerophytic scrubland (Source: Group of Experts).
  - Seasonal forest (older than 20 years): 80% of the accumulated area occupied by the same formations of the previous group (Source: Expert Group).
  - Dry forest: Typical xerophilous formation.
  - Mangrove forest: Mangrove formation [3].

- Fruit trees within the forest.
- Non-forest trees, broken down into two groups:

  - Citrus plantations.
  - Other arboreal fruit-tree plantations.

b. Timber harvesting emission from the following assortments:

- Bole (saw timber), broken down as follows:

  - Coniferous species. Four species, all of the genus Pinus.
  - Precious species. 14 species with qualities and special economic value (Gómez, ***et al***., 1973).
  - Broadleaved species. Broken down into hard, semi-hard, and soft (Gómez, ***et al***., 1973).

- Poles (wood for street lighting and telephony). Species of the genus Pinus only.

- Railway sleepers. Broken down into:

  - Hardwood species (Gómez, ***et al***., 1973).
  - Eucalyptus.

- Roundwood (wood for direct use). Broken down into:

  - Coniferous species (genus Pinus).
  - Hard species (Gómez, *et al*., 1973).
  - Semi-hard species (Gómez, *et al*., 1973).

- Support poles for tobacco curing. Broken down into:

  - Coniferous species (genus Pinus).
  - Eucalyptus.

- Firewood and charcoal. To avoid duplication of estimates, these assortments are not accounted for in the forest land sub-category, but in the energy category.

Data for determining the net emissions between 1990 and 1996 (even years only) were collected by the Institute of Meteorology ("INSMET"), while from 1998 to 2016 they were recorded by the Agroforestry Research Institute ("INAF"), with the collaboration of the Tropical Fruit-Growing Research Institute ("IIFT").

1.3. Results for forestry net emissions between 1990 and 2016

The national inventories of greenhouse gas emissions (NIGEI) were initiated in Cuba in 1992 and subsequently that for 1990 was calculated, repeating its quantification every two years until 2016, the last completed. However, INAF (at that time the Forestry Research Institute-IIF) began to participate in the inventories exercise in 2000, and since then has been in charge of preparing the net emissions balance of the national forestry sector.

During the period 2000-2014, all the balances determined by INAF were based methodologically on the revised 1996 IPCC Guidelines, specifically on the provisions of Module 5: Land use change and forestry (IPCC, 1997), which defines the balance as the difference between the atmospheric carbon removed by the forest in a year due to its growth and the carbon extracted from the forest in that year as a consequence of its use. However, GHG emissions from other factors, such as fires, which were analyzed by other institutions and then incorporated into the results of the energy module, were not taken into account, to avoid duplication of data.

The balances determined between 2000 and 2004 used the default emission factors provided by the guidelines; however, as from the 2006 balance calculation, these began to be progressively replaced by national emission factors (Valdés, *et al*., 2013), recalculating the previous balances, while in arriving at the 2014 balance, of the 79

3. Included as of 2000 by Forestry Research Institute due to its national relevance.

emission factors used, 50 were national (63.3%). However, for the calculation of the 2016 balance, it was decided to replace the use of the revised 1996 IPCC guidelines with those of 2006 (IPCC, 2006); to recalculate on this basis all the balances determined biannually (for even years) between 1998 and 2014 and also to complete the 1998-2016 series with the calculation of the balances for the odd years. However, it was not possible to recalculate the balances for the years 1990-1996 due to insufficient data.

From the year 2000, when INAF started to perform the balance calculations, until the 2016 (the last completed), the area covered by the forests of the national forestry heritage rose from 2.06 to 4.09 million hectares (Division of Forestry, Flora, and Wildlife, "DFFFS", 2017).

The achieved results of emissions and removals in each balance sheet are shown in Figure 1.1 (Mercadet, Álvarez and Rodríguez, 2016), where it can be seen sustained growth presented by removals due to the constant increase in the area covered by forests in Cuba, which is proposed to eventually reach a coverage rate slightly above 34% and at the end of 2016 it already reached 31.15% (DFFFS, 2017).

However, the increase in removals of atmospheric carbon shown by the balances is not only due to growth in the area covered by forests, but also to a sustained downward trend in emissions as a consequence of the reduction in the levels of forest harvesting carried out in the period (Fig. 1.2), and to the fact that Cuba does not record deforestation and this has been recognized by the Food and Agriculture Organization of the United Nations (FAO) in its State of the World's Forests reports.

Regarding GHG emissions and removals in absolute terms by forest land components (Table 1.1 and Figure 1.3), in 2016 biomass increment in natural forests was the most important with 53.9%, followed by 38.5% for biomass increment in artificial forests; 3.2% for biomass increment in unforested trees; 1.6% for roundwood production; 1.3% for biomass increment of fruit trees in forests; 1.2% for roundwood production and less than 1.0% for the rest of the components.

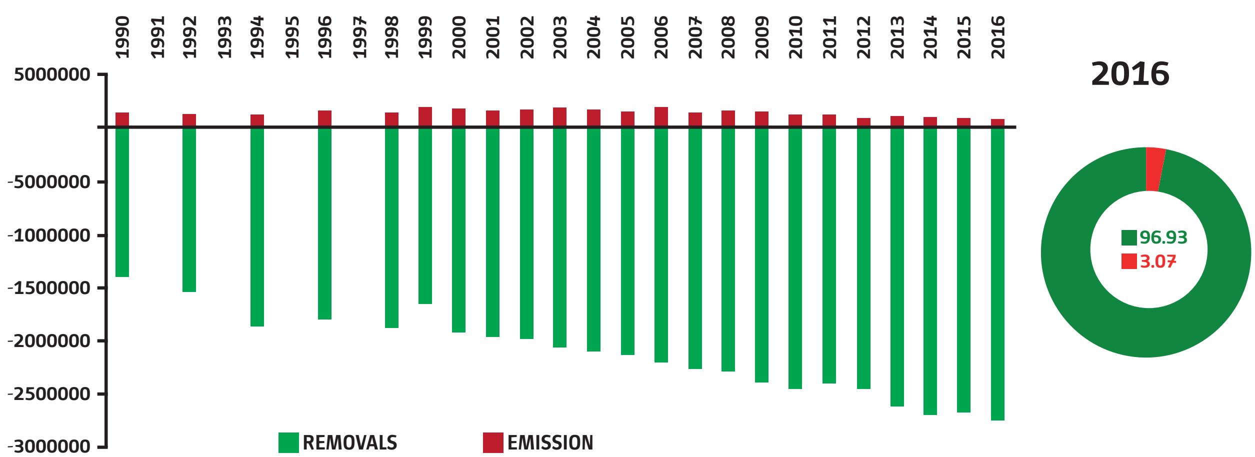


Figure 1.1. Forest land: annual CO_2 emissions and removals (t CO_2 eq). 1990-2016 series. (Mercadet, Álvarez and Rodríguez, 2016).

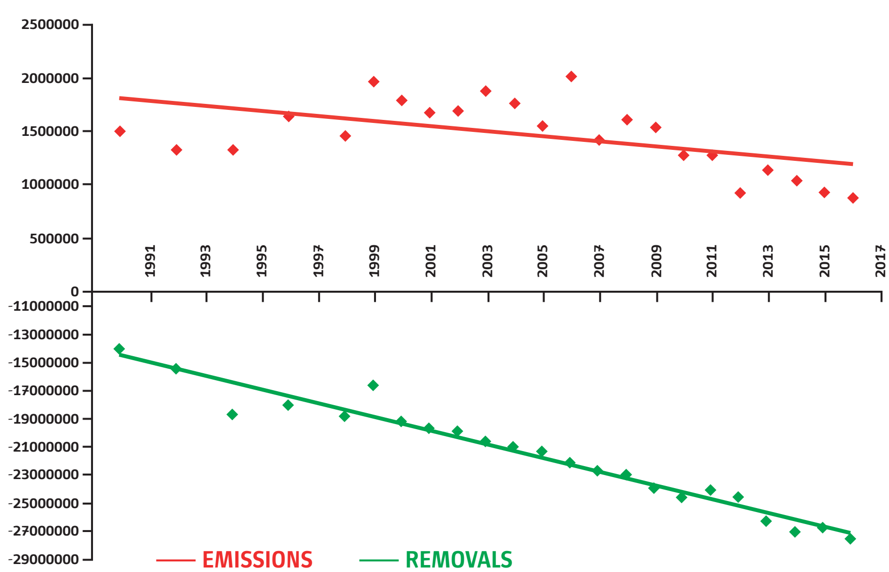


Figure 1.2. Forest land: the hyper-annual trend of CO_2 emissions and removals (t CO_2 eq.). emissions and removals (t CO_2 eq). 1990-2016 series. (Mercadet, Álvarez and Rodríguez, 2016).

Table 1.1. Forest land: CO_2 emissions and removals (t CO_2 eq) by component.

Indicator	Component	1990	2000	2010	2016
Emissions	Bole	473,100.16	669,856.50	634,647.86	464,122.23
	Poles	14,161.70	12,223.78	47,502.81	1,958.79
	Railroad sleepers	71,118.14	43,514.50	78,101.48	697.95
	Roundwood	883,866.48	909,134.98	483 636,65	346,793.66
	Horizontal beams	54,879.47	149,894.66	29,778.92	60,824.19
Removals	Artificial forests	-3,920, 063.07	-7,291,459.69	-10,321,445.68	-10,971 110.01
	Natural forests	-9,446,607.56	-11,131 498.12	-13,123,113.59	-15,346 264,57
	Fruit trees in the forests	No data	No data	-248,949.36	-374,327.74
	Unforested trees	-706,325.40	-816,481.04	-935,526.56	-907,393.29
Balance		-12,575,870.10	-17,454,814.42	-23,355,367.45	-26,724,698.80

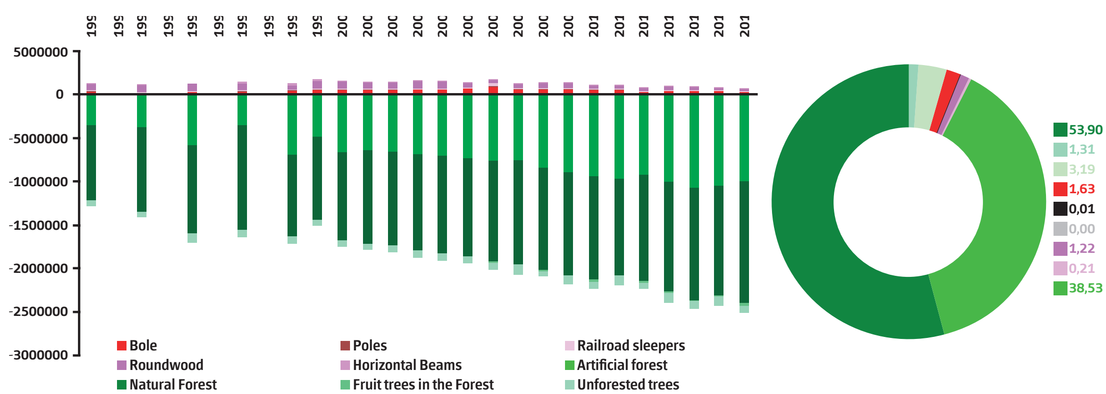


Figure 1.3. Forest land: CO_2 emissions and removals (t CO_2 eq) by sources and sinks. 1990-2016 series. (Mercadet, Álvarez and Rodríguez, 2016).

GHG removal trend

In 2016 CO_2 removal accounted for -27,597,079.62 t CO_2 eq, increasing 96.1% since 1990 and 12.6% since 2010 (Table 1.2 and Figure 1.4).

Table 1.2. Increase in biomass: CO_2 removals (t CO_2 eq) by sinks. 1990-2016 series. (Mercadet, Álvarez and Rodríguez, 2016).

Table 1.2. Increase in biomass: CO_2 removals (t CO_2 eq) by sinks. 1990-2016 series. (Mercadet, Álvarez and Rodríguez, 2016).

Sink	1990	2000	2010	2016
Artificial forests	-3,920,063.07	-7,291,459.69	-10,321,445.68	-10,97,110.01
Natural forests	-9,446,607.56	-11,131,498.12	-13,123,113.59	-15,346,264.57
Fruit trees in the forests	No data	No data	-248,949.36	-374,327.74
Unforested trees	-706 325,40	-816,481.04	-935,526.56	-907,393.29
Total	-14,071,006.04	-19,237,438.84	-24,627,025.18	-27,597,079.62

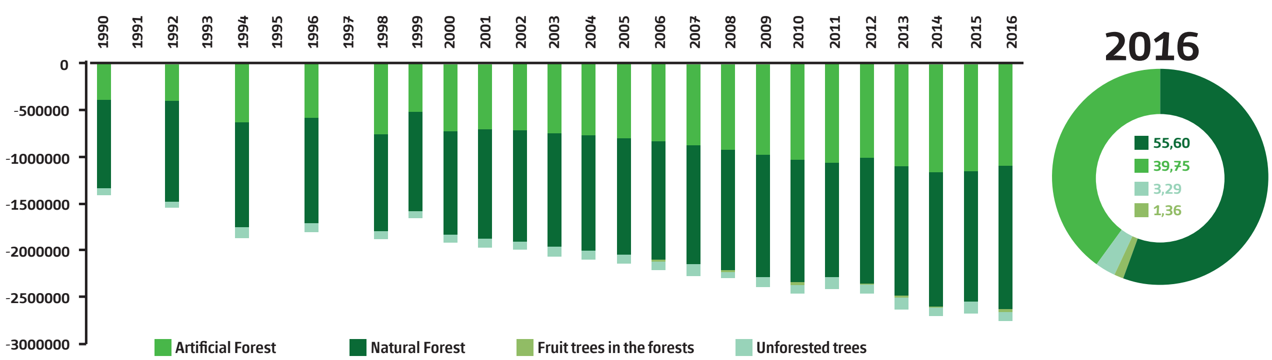


Figure 1.4. Increase in biomass: CO_2 removals (t CO_2 eq) per sink. 1990-2016 series. (Mercadet, Álvarez and Rodríguez, 2016).

Regarding GHG removals in absolute terms by sinks (Figure 1.4), in 2016 natural forests (whose area is approximately 75% of total forests), were the most important with 55.60%, followed by artificial forests with 39.75%, while fruit trees, both inside and outside the forest, together accounted for less than 5.00%.

Concerning GHG removals by natural forests, seasonal forests older than 20 years were the most important in 2016, increasing 58.0% since 1990 and 1.2% since 2010 (Table 1.3 and Figure 1.5).

Table 1.3. Increase in biomass: CO_2 removals (t CO_2 eq) by natural forests. 1990-2016 series. (Mercadet, Álvarez and Rodríguez, 2016).

Natural forest	1990	2000	2010	2016
Moist	-839,091.17	-1,399,912.31	-2,020,414.43	-3,643,947.57
Seasonal (<20 years)	-1,829,483.53	-2,290,789.49	-2,857,420.29	-2,890,985.02
Seasonal (>20 years)	-3,658,967.07	-4,874,455.40	-5,714,840.58	-5,781,970.03
Dry	-918,713.80	-705,140.92	-498,131.56	-414,214.94
Mangroves	-2,200,352.00	-1,861,200.00	-2,032,306.73	-2,615,147.01
Total	-9,446,607.56	-11,131,498.12	-13,123,113.59	-15,346,264.57

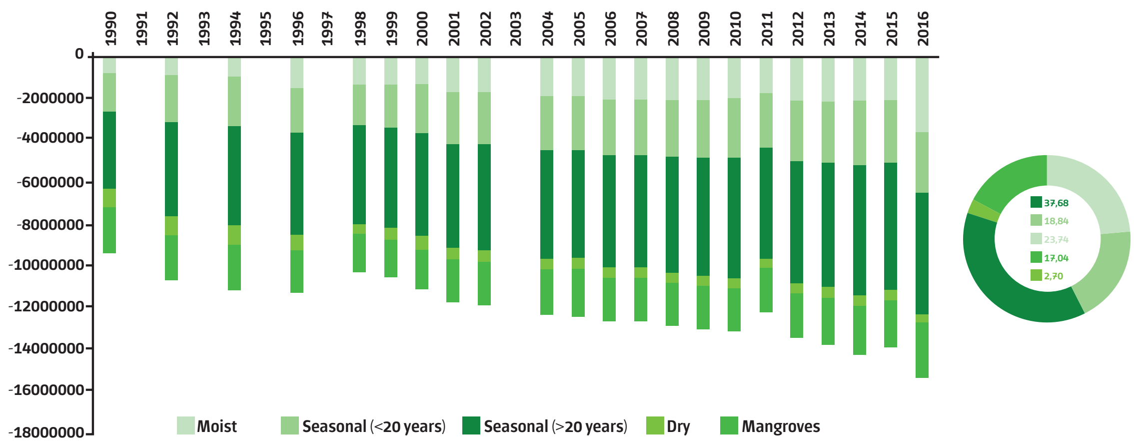


Figure 1.5. Comparison between the expected results of the Net Carbon Balance of the Forestry Sector using the IPCC 1996 Guidelines (in black), and also taking into account forest biomass changes (in green) (Source: Álvarez, Mercadet, and Rodríguez, in press).

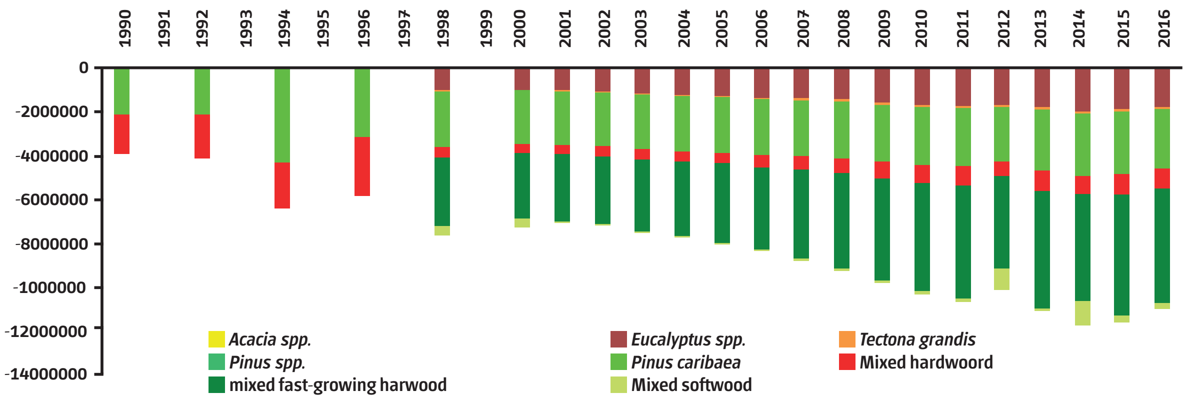
In absolute terms, seasonal forests older than 20 years accounted for 37.6% of total removals in 2016 (Figure 1.5.), followed by moist forests with 23.7%, seasonal forests younger than 20 years, and mangroves, which accounted for 18.8% and 17.4% respectively, while dry forests accounted for only 2.7%.

Regarding GHG removals by artificial forests, in the period 1990-1996 of the series, data were only recorded for even years in two categories and it was not possible to update and/or complete them.

In the period 1998-2016 of the series the group fast-growing hardwood species was the most important, increasing 73.6% since 2000 and 5.9% since 2010 (Table 1.4 and Figure 1.6).

Table 1.4. Increase in biomass: CO_2 removals (t CO_2 eq) by Artificial Forests. 1990-2016 series. (Mercadet, Álvarez and Rodríguez, 2016).

Artificial forest	2000	2010	2016
Acacia spp.	-22,425.48	-165,599.36	-361,468.94
Eucalyptus spp.	-970,398.00	-1,519,021.22	-1,431,209.84
Tectona grandis	-25,773.40	-107,207.12	-107,088.16
Pinus spp.	-378,312.64	-622,271.60	-690,704.57
Pinus caribaea	-2,059,128.31	-2,018,258.97	-2,008,127.07
Mixed hardwoord	-402,981.23	-806,195.30	-885,148.34
Mixed fast-growing hardwood	-3,020 ,11.16	-4,950,525.27	-5,244,004.94
Mixed softwood	-411,729.47	-132,366.84	-243,358.15
Total	-7,291,459.69	-10,321,445.68	-10,971,110.01



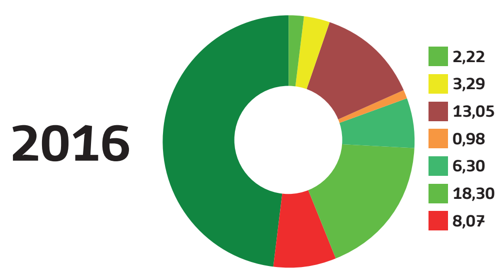


Figure 1.6. Increase in biomass: CO_2 removals (t CO_2 eq) by type of artificial forest. 1990-2016 series. (Mercadet, Álvarez and Rodríguez, 2016).

In absolute terms, in 2016 the group of fast-growing hardwood species accounted for 47.8% of total removals (Figure 1.6.), followed by *Pinus caribaea var. caribaea* with 18.3%, *Eucalyptus spp*. which accounted for 13.1%, slow-growing hardwood species with 8.1% and *Pinus spp.* with 6.3%, while the remaining categories as a whole reached6.5%.

GHG emission trend

In 2016, emissions amounted to 874,396.82 t CO_2 eq, decreasing by 58.4% compared to 1990 and by 68.7% compared to 2010 (Table 1.5. and Figure 1.7).

Regarding GHG emissions in absolute terms by assortment (Figure 1.7.), in 2016 the production of roundwood (for sawmilling) was the most important with 53.1%, followed by roundwood (for direct use) with 40.0%, while the rest of the sources together accounted for 7.3%.

Table 1.5. Timber harvesting: CO_2 emissions (t CO_2 eq) by assortment. 1990-2016 series. (Mercadet, Álvarez and Rodríguez, 2016).

Sink	1990	2000	2010	2016
Bole	473,100.16	669,856.50	634,647.86	464,122.23
Poles	14,161.70	12,223.78	47,502.81	1,958.79
Railroad sleepers	71,118.14	43,514.50	78,101.48	697.95
Roundwood	883,866.48	909,134.98	483,636.65	346,793.66
Horizontal beams	54,879.47	149,894.66	29,778.92	60,824.19
Total	1,497,125.93	1,784,624.42	1,273,667.73	874,96.82

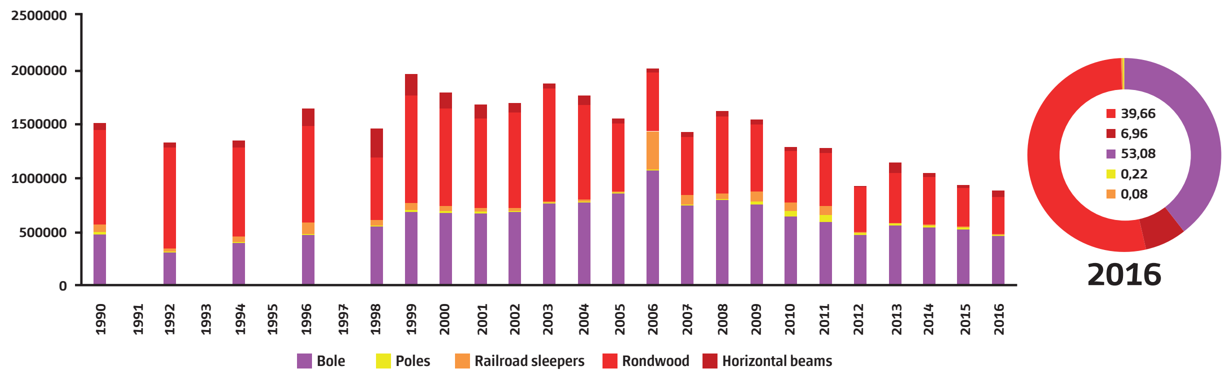


Figure 1.7. Timber harvesting: CO_2 emissions (t CO_2 eq) by assortment. 1990-2016 series. (Mercadet, Álvarez and Rodríguez, 2016).

Over the period 1990-2016, 49.5% of cumulative annual emissions were caused by the harvesting of coniferous trees for the production of wood products, while the remaining 50.5% were caused by the harvesting of broad-leaved species.

The comparison between the results of the balances using both Guidelines for the period 1998-2016 is shown in Fig. 1.8.

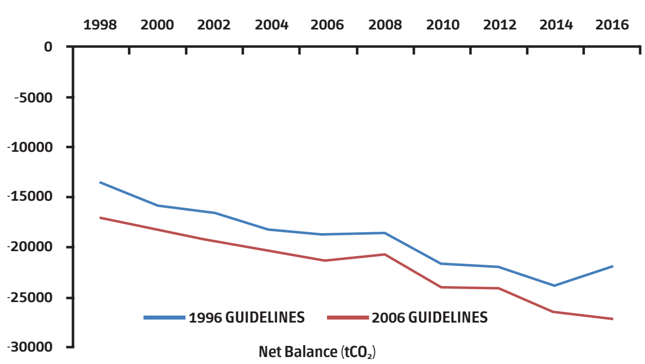


Figure 1.8. Comparison of the results of the Net balances calculated using different Guidelines calculated using different IPCC Guidelines. (Mercadet, Alvarez, and Rodriguez, 2016).

1.4. Forest balance of emissions vs. agricultural balance of emissions

Figure 1.9 shows the final results of all GHG Inventories carried out by Cuba during the period 1990-2014, by sector (CITMA, 2018).

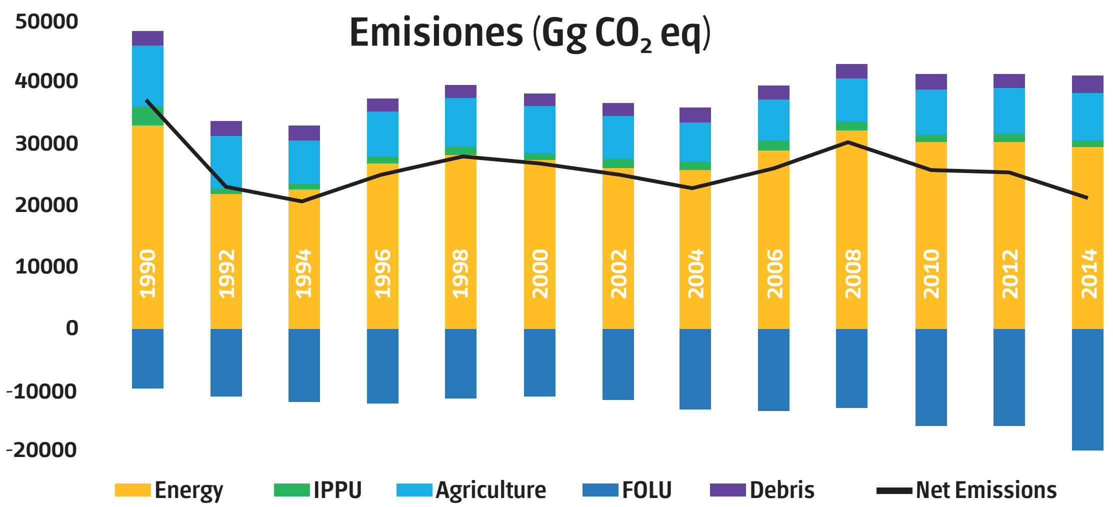


Figure 1.9. Results of National GHG Inventories per sector. Period 1990-2014 (CITMA, 2018).

This shows that the net emissions levels recorded for the Agriculture Sector (agricultural and livestock activities) from 1994 onward have been offset by the Forestry Sector and Other Land Uses (FOLU), which means that the Cuban Agricultural Sector can be considered from that year onward as an economic activity with no net GHG emissions and even from 2010 onward, as an atmospheric carbon sink.

1.5. National emission factors used in the net carbon balance of the Forestry Sector

The carbon balance for the Forest Sector in the sub-module Changes in forests and other woody biomass of the Land Use, Land-Use Change and Forests (LULUCF) module of the National Inventories (1990-2014) is divided into three parts:

- The first is dedicated to the annual carbon increment recorded by forests.
- The second is dedicated to the annual consumption of biomass extracted from forests.
- The third part calculates the difference between the total of the first and second parts to determine the balance.

Eight categories of artificial forests, four of natural forests and two of other forests are used to calculate the annual increment of carbon recorded by forests, while three categories are used for trees outside forests; two emission factors are used for each of them: the average annual increment of dry biomass (IMA_{BS}) and the carbon fraction (CF).

In Cuba, research to obtain national emission factors for these categories was initiated in 2006 and the factors currently used are shown in Table 1.6.

The first AMI for pine trees were initially reported by Álvarez, Mercadet, *et al*. (2011), with values lower than those shown in Table 1.6; however, the extension of the assessments to other areas of the forest heritage allowed them to be modified and those reported by Mercadet, *et al*. (2012) are now in use. For the cases of *Acacia sp*, *Eucalyptus* sp. and *Tectona grandis*, research has progressed to IMA_{BS} values of 6.49 t/ha/a, 16.84 t/ha/a, and 15.55 t/ha/a, respectively (Mercadet, *et al*., 2017), while for the mangrove formation values of 0.32 t/ha/a (Mestril, 2017) and 2.91 t/ha/a (O'Farrill, 2019) have been obtained; however, until the 2016 Emissions Balance these values had not been put to use because the assessments were being extended to other environments. Values for citrus and other fruit plantations were provided by Betancourt (2010 and 2016).

The values of the mean annual increment of dry biomass were obtained from the mean annual increment of volume and basic wood density (Table 1.7.), while the carbon fraction was determined under laboratory conditions using a LECO Tru-Spec CN analyzer, using an EDTA standard with 40.94% carbon concentration.

Table 1.6. Emission factors are used per category for the calculation of the annual carbon increment by forests in the net carbon balances. (Mercadet, Álvarez y Rodríguez, 2016).

Type	Category	IMABS	CF
Artificial forests	*Acacia spp.*	15.00	0.4854
	Eucalyptus spp.	14.50	0.4875
	Tectona grandis	8.00	0.4849
	Pinus spp.	6.32	0.4702
	Pinus caribaea	8.51	0.4753
	Mixed hardwood	6.80	0.4688
	Mixed fast-growing hardwood	12.50	0.4697
	Mixed softwood	14.50	0.4690
Natural forests	Moist	6.25	0.4745
	Seasonal (<20 years)	4.00	0.4658
	Seasonal (>20 years)	2.00	0.4658
	Dry	3.40	0.4620
Other forests	Mangroves	2.00	0.4700
	Fruit trees in the forests	6.80	0.4500
Trees outside the forest	Citrus plantations	2.53	0.4500
	Plantations. Other fruit trees.	4.72	0.4500

National emission factors are shown in red.

Table 1.7. Wood basic density values are used for IMA_{BS} determinations (Henry, 2017; Mercadet, 2020), and wood carbon is used for carbon factor determinations (Alvarez, Mercadet, *et al.*, 2011).

Species		Average Basic Density (g/cm³)	Carbon (%)
Scientific name	Common name		
Acacia auriculiformis A. Cunn. ex Benth.	Acacia auriculiformis	0.412	
Acacia mangium Willd.	Acacia mangium	0.521	48.54
Albizzia cubana Britt.	Bacona		49.40
Albizzia falcataria (L.) Fosberg.	Albizia		47.17
Albizzia procera Benth.	White siris	0.477	
Albizzia saman (Jacq.) F. Muell.	Raintree		46.37
Alvarodoa amorphoides Liebm. subsp. psilophylla (Urb.) Cronquist	Mexican alvarodoa	0.860	
Amyris elemitera L.	Sea Torchwood	0.913	
Andira inermis (Sw.) HBK	Cabbage tree		47.64
Antirrhea radiata (Griseb) Urb.	Vera	0.610	
Ateleia apetala Griseb.	Mierda de gallina	0.545	
Auerodendron northropianum (Urb.) Urb.	Sangre de toro	0.766	
Azadirachta indica A. Juss.	Neem tree	0.611	49.74
Bambusa vulgaris Schrad ex Wendland var. vulgaris Hort.	Common bamboo		48.15
Bauhinia monandra Kurz.	Pink Bauhinia	0.531	
Brya microphylla Bisse	Granadillo		46.64
Buchenavia tetraphylla (Aubl.) How.	Fourleaf buchenavia	0.652	
Bursera simaruba (L.) Sargent	West Indian birch		45.53
Callycophyllum candidissimum (Vahl.) DC.	Degame	0.577	
Calophyllum antillanum Britt. y Walls.	Ocuje	0.587	48.75
Canella winteriana (L.) Gaertn.	Cinammon bark	0.750	
Carapa guianensis Aubl.	Royal mahogany		47.28
Casuarina equisetifolia Forst.	Beach casuarina	0.804	47.59
Catalpa punctata Griseb.	Cigar tree	0.424	
Cecropia peltata L.	Trumpet tree		46.50
Cedrela odorata L.	Cedar	0.416	47.43
Chrysophyllum argenteum Jacq.	Manacabo	0.637	
Chrysophyllum oliviforme L.	Satin leaf		46.40
Coccoloba uvifera L.	Seagrape		44.66
Colubrina elliptica (Sw.) Brizicki et Stern.	Soldierwood		47.15
Colubrina ferruginosa Brongn.	Snakewood		46,39
Cupania americana L.	Wild acke		45.37
Diospyros crassinervis (Krug. et Urb.) Standl.	Feather bed	0.665	
Dipholis salicifolia (L.) A. DC.	Willow bustic	0.725	
Ehretia tinifolia L.	Black oak		47.42
Enterolobium cyclocarpum (Jacq.) Griseb.	Earpod tree		46.88
Erythrina berteroana Urb.	Piñón de pito	0.226	
Erythroxylum areolatum L.	Swamp redwood	0.767	

Species		Average Basic Density (g/cm³)	Carbon (%)
Scientific name	Common name		
Erythroxylum confusum Britt.	Barberry bullet		45.41
Eucalyptus grandis W. Hill ex Maiden	Flooded gum	0.578	
Eucalyptus pellita F. V. M.	Red mahogany		48.75
Eucalyptus saligna Sm.	Blue gum		42.34
Eugenia buxifolia (Sw.) Willd.	White wattling		45.62
Ficus religiosa L.	Peepal tree		49.09
Gerascanthus gerascanthoides (Hbk) Borh.	Varía	0.616	46.02
Gliricidia sepium (Jacq.) Steud.	Quickstick	0.383	46.88
Gmelina arborea Roxb.	Beechwood	0.424	46.98
Gossypiospermum praecox (Griseb.) P. Wils.	Barberry	0.700	
Guaiacum officinale L.	Roughbark		48.26
Guarea guara (Jacq.) P. Wils.	Yamagua		47.88
Guazuma ulmifolia HBK.	Bastard cedar	0.409	46.42
Guibourtia hymenifolia (Moric.) J. Leonard	Caguairán		46.27
Gymnanthes lucida Sw.	Oysterwood		45.53
Juglans insularis Griseb.	Walnut tree		45.94
Hibiscus elatus Sw.	Rose-mallow	0.453	46.60
Khaya nyasica Stapf.	African mahogany	0.473	
Laurocerasus occidentalis (Sw.) Roem.	Cherry laurel	0.637	
Leucaena leucocephala (Lam.) De Wit	Ipil-Ipil	0.516	46.46
Lonchocarpus blanii C.Wr.	Lancepod	0.663	
Lysiloma latisiliqua (L.) Benth.	False tamarind		45.21
Lysiloma sabicu A. Rich.	Horseflesh mahogany		46.78
Mastichodendron foetidissimum (Jacq.) Cronquist	Mast wood	0.633	46.83
Melia azadirachta L.	Pride of India	0.461	45.91
Mycrocarpus frondosus Fr. All.	Sassafras	0.565	
Nectandra coriacea (Sw.) Gris.	Buckroot	0.604	46.08
Ochroma pyramidale (Cab.) Urb.	Balsa		47.90
Oxandra lanceolata (Sw.) Bail.	Black lancewood	0.726	46.10
Parmentiera cerífera Seem.	Candle tree	0.578	
Peltophorum ferrugineum (Decne) Benth.	Yellow flamboyant		
0.427			
Pinus caribaea Morelet var. *caribaea* Barret y Golfari	Caribbean pine	0.518	47.53
Pinus cubensis Griseb.	Cuban pine		47.15
Pinus maestrensis Bisse	Pino de la Maestra		46.78
Pinus tropicalis Morelet	Tropical pine	0.566	47.14
Piscidia piscipula (L.) Sargent.	Florida fishpoison tree		46.20
Poeppigia procera Presl.	Tengue		46.66
Protium cubense (Rose) Urb.	Copal	0.660	
Pterocarpus macrocarpus Kurz.	Rosewood	0.274	
Quercus oleoides C.&S. var. *sagreana* C.H. Mull.	Live oak grove	0.741	
Rheedia aristata Griseb.	Espuela de caballero	0.855	
Sterculia apetala (Jacq.) Karst.	Anacahuita	0.230	

Species		Average Basic Density (g/cm³)	Carbon (%)
Scientific name	Common name		
Swietenia macrophylla King.	Caoba	0.420	46.79
Swietenia mahagoni (L.) Jacq.	Caoba	0.542	47.99
Sysigium jambos (L.) Alston	Pomarrosa	0.595	
Tabebuia angustata Britt.	Roble blanco		49.07
Tabebuia brooksiana Britt.	Roble		47.16
Tabebuia chrysantha	Roble de Venezuela	0.696	
Tectona grandis L.	Teca	0.534	48.49
Terminalia catappa L.	Almendro de la India	0.442	47.38
Theobroma cacao L.	Cacao		46,91
Trichilia hirta L.	Cabo de hacha		46.50
Zanthoxylum elephantiasis Macfd.	Bayúa		50.47
Zanthoxylum martinicense (Lam.) DC.	Ayúa	0.406	46.16
Zuelania guidonia (Sw.) Britt. et Millsp.	Guaguasí		45.10

In the case of carbon fractions, the estimates of Mercadet, *et al*. (2010) and the procedures reported by Álvarez, Mercadet, *et al*. (2011) for calculating the fractions corresponding to species mixtures in artificial forests and natural forests have been maintained to date.

Fifteen harvest categories are used in the calculation of annual biomass consumption from forests, distributed in seven assortments: roundwood, poles, railroad sleepers, roundwood, fuelwood, charcoal, and horizontal log beams for hanging tobacco's dry leaves; three emission factors are used for each of them:

- The factor for the conversion of the final volume of each harvest category to the initial dry biomass before processing (FCV, kt ms).
- The expansion factor of the pre-processing biomass to the biomass originally extracted from the forest (EFB, s/u).
- The carbon fraction corresponding to each harvesting category, according to the species involved, taking into account the values reported by Mercadet, *et al*. (2010) (CF, s/u).

The factors currently used for the calculation of the annual consumption of biomass extracted from forests are shown in Table 1.8.

Table 1.8. Emission factors are used by category for the calculation of annual biomass consumption (Mercadet, 2000).

Categories/ Assortment	**FCV**	**EFB**	**CF**
Bole:			
Coniferous	**0.565**	**1.19**	**0.4715**
Precious	**0.618**		**0.4700**
- Hard	**0.811**		**0.4741**
- Semi-hard	**0.652**	**1.19**	**0.4633**
- Soft	**0.482**		**0.4671**
Poles:			
Broad-leaved (semi-hard)	**0.652**	**1.19**	**0.4734**
Railroad sleepers:			
Hard	**0.811**	**1.19**	**0.7170**
Semi-hard (eucalyptus)	**0.717**		**0.4555**
Roundwood:			
Coniferous	**0.565**	**1.19**	**0.4715**
Broadleaved (semi-hard)	**0.652**		**0.4633**
Fuelwood:			
Broad-leaved (semi-hard)	**0.652**	**1.19**	**0.4633**
Carbon:			
Hard (myrobalan)	**0.645**	**1.19**	**0.4741**
Semi-hard (eucalyptus)	**0.717**		**0.4555**
Cujes:			
Coniferous	**0.510**	**1.19**	**0.4715**
Semi-hard (eucalyptus)	**0.717**		**0.4555**

National emission factors are shown in red.

1.6. Forest balance forecast of net emissions up to 2030

The forecast of the emissions balance was made by combining, on the one hand, the historical trend of variation of the balance recorded between 1990 and 2015 for five-year periods and, on the other hand, the part of the forest heritage that remains to be reforested and the annual rate of establishment of artificial forests, which led to the results shown in Fig. 1.9.

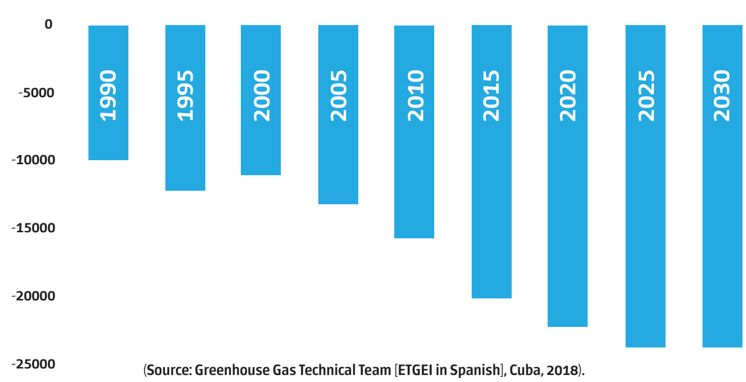


Figure 1.9. Emission balance forecast for the forestry sector until 2030.

The above results indicate that from approximately 2025 onward, the annual level of GHG removals from the Forestry Sector will have reached a maximum value that will stabilize from that date onward, which means that if emissions from the Agriculture Sector (agriculture and livestock) or other sectors such as the Energy Sector increase from 2025 onward, Cuba's net emission levels would increase because the sector that currently offsets them would maintain its sink capacity constant.

Such a result is a direct consequence of the method established by the 1996 and 2006 IPCC Guidelines for the calculation of the Emission Balance in the AFOLU Sector forest subcategory, where carbon removals are calculated as the product of the forest area times the average annual increase in dry biomass per hectare times the carbon coefficient and, given that the latter two values are constant when the first value is also constant due to the full coverage of the forest heritage, the annual removals would present a constant value.

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However, this is not what happens in reality because although the entire forest area of the heritage will be covered by forests, the volume of forest will continue to increase as a consequence of growth and for this to be achieved, the levels of atmospheric CO_2 removed by tree photosynthesis will continue to increase and with it, the sink capacity of the Forest Sector, which has been demonstrated by Alvarez, Mercadet and Rodríguez (in press) (Fig. 1.5).

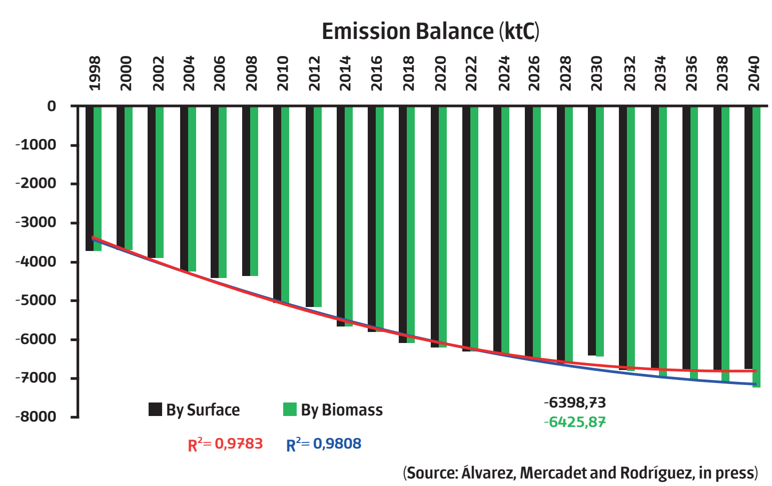

Figure 1.5. Comparison between the expected results of the Net Carbon Balance of the Forestry Sector using the 1996 IPCC Guidelines (in black) and also considering forest biomass changes (in green).

The use of the 2006 IPCC Guidelines in these calculations would introduce increases in the results of below-ground biomass (roots) of forests; however, the general basis of the removals determinations is also based on the areas covered by forests and not on their biomass increments, so that a comparison of the two methods would perhaps reduce the magnitude of the differences, but would ratify the reporting according to the IPCC Guidelines of a nearly constant net balance (only altered if the value of wood removals changed), starting from the early 1930s.

This situation, derived from the peculiarities of Cuba concerning the situation and management of its forest heritage on the one hand, and the calculation methodology established to carry out the Emission balances in the AFOLU Sector on the other, will soon have to be the subject of a joint assessment between the Cuban GHG Technical Team, the Intergovernmental Panel on Climate Change (author of the calculation methods for the Inventories) and the United Nations Framework Convention on Climate Change (UNFCCC), to which the Inventories are submitted.

II. FOREST CARBON SEQUESTRATION

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2.1. Extended forest carbon cycle: removal, sequestration, emission, and carbon sequestration

The extended forest carbon cycle is composed of two stages: the first, which occurs during forest establishment and growth, where atmospheric forest carbon removal occurs along with forest emissions to the atmosphere, forming a cyclical system, and the second, which occurs during forest harvesting and production of goods, where carbon is sequestered during the useful life of the final product and then returns to natural systems, including the atmosphere.

Figure 2.1 shows the set of processes inherent to the first stage of the extended forest carbon cycle (Álvarez, Mercadet, and Ajete, 2018), in which the definition of three concepts is important due to their reiterated use in this book: carbon removal, sequestration, and emission.

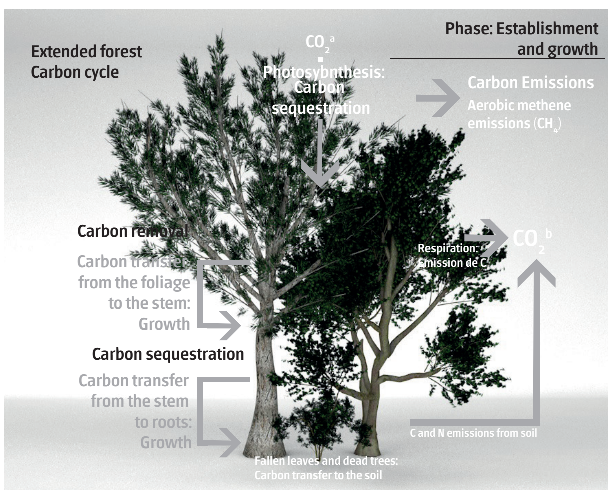

Figure 2.1. Component processes of the first stage of the extended forest carbon cycle.

Throughout this material, atmospheric carbon removal will be understood as the process by which trees take carbon dioxide (CO_2) from the atmosphere through the stomatic system, generally present in their leaves, for photosynthesis, whereby organic compounds of varying complexity are formed and converted into inputs for plant growth, protection, and development. The magnitude of the removal is influenced by the forestry investment made for forest management (spacing, pruning, sanitary felling, thinning, etc.) which translates fundamentally into changes in tree growth rates.

The transfer of organic compounds formed as a result of photosynthesis to the different parts of the tree, integrating into its structures (foliage, flowers, fruit, branches, stem, bark, and roots), results in the carbon removed from the atmosphere becoming carbon sequestered in the biomass (both on the ground or above-ground biomass) and below ground or below ground biomass).

During the growth and development processes of trees, their structures (leaves, flowers, fruits, branches, bark, and even the whole tree) have a limited life span, in some cases due to natural causes and in others due to anthropic actions, which when reached results in the death of these structures, thus giving rise to the carbon sequestered in the necromass, where it is maintained for a while and then, through the aerobic and anaerobic decomposition processes that take place on and in the soil, it is incorporated into the organic carbon existing in the shallower layers, giving rise to the carbon sequestered in the soil.

However, the action of the soil microbiota on the organic compounds in the soil produces carbon (CO_2) emissions to the atmosphere (also nitrogen in the form of NO, NO_2, which constitute GHG), to which CO_2 emissions from plant respiration are added, emissions of methane (CH_4), which under aerobic conditions is generated by the foliage of some species, the biomass extractions derived from the management and use of forests for timber production and the subsequent decomposition of the residues of these last two actions that remain in the field.

This set of terms (removal-Rm, sequestration-Rt, and emission-Em) is the conceptual basis for the calculation of net GHG emissions (E) in forests, which can be calculated using two different methods:

- The gain-loss method, which compares emissions and removals occurring during a given period (E=Em-Rm) in the same area, used in the National GHG Inventories for the forestry component of the Agriculture, Forestry, and Land Use Change sector.
- The stock-difference method, which compares the existing removals at two different points in time (E=Rt1-Rt2) in the same area.

Both are applications of warehouse control methods, the former based on the inputs and outputs of a product during some working time, reflected in the stowage cards, and the latter on the total stock of the product at the beginning and end of the working time.

In the case of forests, for both methods, a positive value of net emissions (E) is equivalent to the presence of a carbon-emitting source (because emissions exceeded removals in the first method, or because carbon sequestered decreased overtime in the second method), while a negative value means the existence of a carbon sink (because removals exceeded emissions, or because carbon sequestered increased over time, depending on the method used).

This explains why deforestation (understood as the change of land use of the forest heritage to uses other than forestry) is a process that, by decreasing the extent of the heritage and its area covered by forests, generates GHG emissions and can change its character from a carbon sink to a carbon-emitting source.

Figure 2.2 shows the set of component processes of the second phase of the extended forest carbon cycle (Álvarez, Mercadet, and Ajete, 2018), where the definition of the concept of carbon sequestration is important.

Under domestic conditions during industrial wood harvesting and processing, more than 50% of the original biomass in the forest remains unused and is converted into residues which, whether in the forest or industrial facilities, are generally discarded, with the carbon contained in them passing either into the soil as organic carbon or into the atmosphere as carbon emissions.

However, the part of the wood that was used for timber use with limited processing (railway sleepers, piles, poles, posts, wood for formwork, etc.) or the production of goods (parts for structures, pallets, furniture, floor, and/or wall coverings, paper, cardboard, etc.) keeps the carbon contained in it sequestered for the lifetime of each final product.

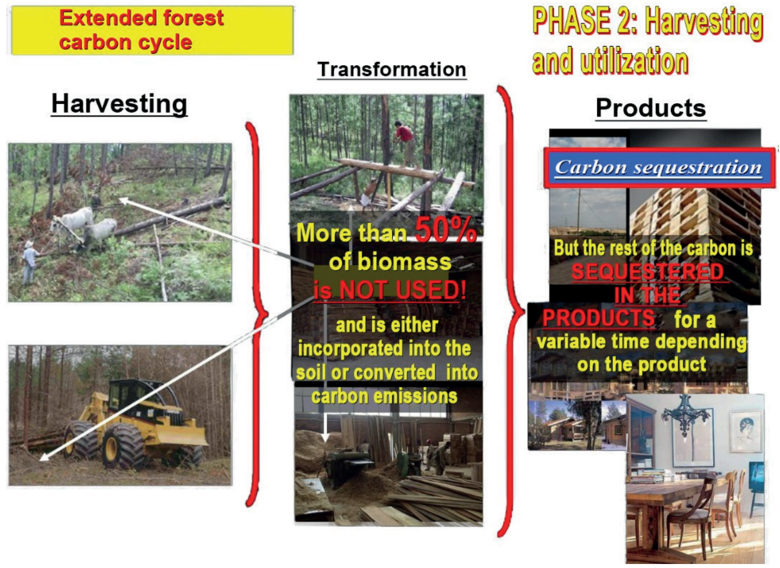

Figure 2.2. Component processes of the second phase of the extended forest carbon cycle.

2.2. Categories, components, and carbon pools of the forest heritage

When undertaking calculations to establish the magnitude of forest carbon sequestration, it is essential to define the meaning of the terms forest category, forest heritage components, and what carbon pools exist in each component.

The forest categories constitute the legal establishment of the use that can be made of them in Cuba; they were initially defined in a general way by Law 81/97 (Environmental Law), Article 113 (Republic of Cuba, 1997) and were later specified by Law 85 (Forestry Law), Article 15 (Republic of Cuba, 1998), which established a total of seven forest categories:

- (timber) production forest.
- Protection forests: Water and soil protection forests; Coastal protection forests.
- Conservation forests: Special Management Forests, Forests for the Protection and Conservation of Fauna, Recreational Forests, and Educational and Scientific Forests.

In turn, the heritage components are established based on the situation in which their cover is found, and comprise five components:

- unforested area. That which, due to its characteristics or functions, will never be covered by forest, despite being part of the heritage. (E.g. marshes, nurseries, roads, industrial facilities, etc).

- Area to be reforested. Commonly called "deforested", even though this does not correspond to the concept of deforestation expressed above because it is part of the heritage.

- Area under development. Covered by artificial forests that have not yet met the age requirement to be certified as established artificial forests.

- Established artificial forests. Man-made forests that have already been certified.

- Natural forests. Existing forests in which man did not intervene in their creation.

At the end of 2017, the national forest heritage reached 4,207.13 Kha and in it, the interrelationships between components and categories reached the values presented in Table 2.1. (DFFFS, 2018).

Table 2.1. Composition of forest heritage at the end of 2017 (Kha).

Component	Category							TOTAL
	Production forest	Protection forest		Conservation				
		Water and Soil	Coastal	Flora and Fauna	Special management	Recreational	Educational and Scientific	
Unforested area	79.23	102.47	121.54	124.56	80.68	8.59	0.09	517.17
Area to be reforested	130.88	64.95	15.60	19.25	3.69	1.56	0.20	236.13
Artificial forests under development	42.59	34.19	6.41	3.29	1.01	0.68	0.13	88.30
Established artificial forests	317.01	162.15	25.48	136.96	8.03	5.34	1.23	656.20
Natural forests	676.30	838.48	475.75	556.74	154.62	7.35	0.10	2,709.34
TOTAL	1,246.01	1,202.24	644.78	840.80	248.03	23.52	1.75	4,207.13

(Source: DFFFS, 2018)

Finally, carbon pools are the places in the heritage where carbon removed from the atmosphere is sequestered, corresponding to the component types as shown in Table 2.2.

Table 2.2. Carbon pools present in each heritage component.

Carbon pool	Component				
	Unforested area	Area to be reforested	Artificial forests under development	Established artificial forests	Natural forests
Above-ground biomass	X	X	X	X	X
Underground biomass				X	X
Necromass				X	X
Soil	X	X	X	X	X

Once all the above elements have been defined, it is possible to undertake calculations to determine the amount of carbon sequestered in the forest heritage of any of its managers, whether they are specialized forestry companies, protected areas, agricultural companies, livestock companies, entities of the agricultural cooperative system or any other.

2.3. Determination of carbon sequestered in the base year. The sumfor system

Taking into consideration the peculiarities of the national forestry sector, since the last years of the last century, the preparation of an automated calculation system was initiated to determine the carbon sequestered by the forest heritage managed by different managers, and as a result of this effort, in mid-2006 Mercadet and Álvarez (2006) reported the methodological aspects considered for this purpose, which were the basis for the development of the SUMFOR system.

SUMFOR (an acronym for the term Forest Sink) has progressed from version 1.00 to the currently used version 4.00 (Álvarez, Mercadet, and Peña, 2019), whose detailed calculation methodology is presented in Annex 1, and over time has been subject to constant improvement, both in terms of methodology, the emission factors used, and the system scope.

The first option of its current design allows determining the carbon sequestered in the forest heritage for a base year, considering all carbon pools and components shown in Table 2.2.

To determine the carbon contained in artificial forests, 125 different species are taken into account; in the case of developing forests the calculations are based on the existing area per species, while for established forests both area and wood volume is used, as shown in Table 2.3.

Table 2.3. An example of the starting data used for artificial forests.

No.	Common name	ARTIFICIAL FORESTS		
		ESTABLISHED		UNDER DEVELOPMENT
		Area (ha)	Volume (m^3)	Area (ha)
1	Acacia	10.0	345.0	0.0
2	Bullytree	0.0	0.0	10.0
3	Poplar	0.0	0.0	0.0
...				
125	White oak	0.0	0.0	0.0
126	Other species	0.0	0.0	0.0

In the case of natural forests, the 16 natural formations recognized by the Forestry, Flora, and Wildlife Division of MINAG are taken into account, each of them broken down into the seven forest categories established by the Forestry Law (Table 2.4.) and the calculations are based on the surface area and volume of wood of each combination.

Table 2.4. An example of the starting data used for natural forests.

No.	Formation	Category	Area (ha)	Volume (m^3)
1	Tendrils shrubland	Production forest	0.0	0.0
		Water and soil protection	120.0	520.0
		Coastal protection forest	0.0	0.0
		Conservation of Flora/Fauna	0.0	0.0
		Special management	3,250.0	322,500.0
		Recreational	0.0	0.0
		Educational/Scientific	0.0	0.0

In general, the following steps are used to calculate the carbon sequestered by forests:

- Conversion of stem volume into biomass, using basic wood density (70 species have their values; the remaining species have estimates obtained from air-dry density. For natural formations, average values are used, according to the species composition reported for each formation, per geographical region of Cuba).

- Calculation of the expansion factor (EBF) from stem biomass (SB) to above-ground biomass (AB).

- Estimation of below-ground biomass (BB) from above-ground biomass.

- Calculation of carbon content in biomass. For established artificial forests, 64 species have their own nationally derived carbon fractions (Alvarez, Mercadet, *et al*., 2011); for the rest, the value 0.4701 (average of 60 national broad-leaved species) is used. In the case of the four existing pine species in Cuba, the carbon content in wood and bark are calculated separately, due to their different carbon fractions (between 0.4678 and 0.4753 for wood; between 0.5027 and 0.5268 for bark) and the magnitude of the bark biomass in the total volume of the tree (up to 25%). For natural formations, mean values are used, according to the species composition reported for each formation by geographical region of the country, varying between 0.4584 in the grapevine formation and 0.4750 in the Mountain Rainforest.

- Calculation of the carbon content in the necromass.

- Calculation of soil carbon up to 30 cm depth, generally based on the area and type of existing forest, using the fractions provided by different authors (Adger and Brown, 1994; Bolin and Sukamar, 2000; ICRAF-ASB, 2001 and Nabuurs and Mohren, 1993) and in the case of mangroves, the value reported by the Blue Carbon database (Sifleet, Pendleton, and Murray, 2011) of the Nicholas Institute for Environmental Policy Solutions is used, adjusted for 30 cm depth, because the mangroves in Florida have the same species composition as those in Cuba. In the case of pine forests (Renda, Rodriguez, and Mercadet, 2011 and Rodriguez, Renda and Mercadet, 2013), carbon values determined in Cuba for forest soils of these species up to 30 cm depth (between 288.32 tC/ha and 967.87 tC/ha) are used.

The use of the SUMFOR system makes it possible to obtain information such as that shown in Tables 2.5-2.8, derived from the evaluation of the Mayabeque Agroforestry Company based on data corresponding to the end of 2016 (Álvarez and González, 2018).

Table 2.5. Artificial forest carbon sequestration (ktC).
Mayabeque Agroforestry Company (2016).

No.	Species	Biomass	Necromass	Soil	Total	Average (tC/ha)
1	Rain tree	0.4	0.1	1.2	1.7	173.78
2	White siris	100.4	8.8	125.9	235.0	229.61
3	Carob tree	1.9	0.3	3.9	6.1	191.54
4	Copperwood	0.0	0.0	0.1	0.2	164.33
5	Almond	1.9	0.2	2.2	4.3	236.81
34	Yana	31.2	4.8	69.4	105.5	186.81
35	Brasiletto	6.3	0.8	11.3	18.4	201.31
36	Other species	1.1	0,2	3,0	4.3	176.79
Established artificial forests		467.3	51.9	1,683.8	2,203.0	277.25
Artificial forests under development		30.0		285.7	30.0	12.87
TOTAL		497.3	51.9	1,969.5	2,233.0	

Table 2.6. Natural forest carbon sequestration (ktC).
Mayabeque Agroforestry Company (2016).

No.	Formation	Biomass	Necromass	Soil	Total	Average (tC/ha)
1	Cuabal	3.3	1.7	24.5	29.5	147.96
2	Mangrove	498.0	42.3	2,524.4	3,064.8	619.17
3	Semi-deciduous on limestone soil	1,132.4	137.8	1,981.2	3,251.3	201.85
4	Semi-deciduous on poorly drained soil	1,471.4	111.6	1 601,8	3 184.8	244.56
5	Grapevine	2.1	0.5	6.9	9.4	168.01
6	Xerophilous scrub	7.0	1.6	23.2	31.9	168.93
TOTAL		3,114.1	295.5	6,162.0	9,571.6	27.25

Table 2.7. Natural forest carbon accumulation per category (ktC)
Mayabeque Agroforestry Company (2016).

No.	Category	Biomass	Necromass	Soil	Total	Average (tC/ha)
1	Production forest	1,769.9	139.5	2,396.1	4,305.5	264.33
2	Agroforestry protection/soils	604.2	72.9	1,086.1	1,763.3	206.76
3	Coastal protection	485.0	42.6	2,069.7	2,597.3	521.84
4	Special management	178.7	28.5	410.3	617.5	185.13
5	Recreational	76.4	11.9	199.8	288.1	206.55
TOTAL		3,114.1	295.5	6,162.0	9,571.6	277.25

Table 2.8. Carbon sequestration by component and pool (ktC)
Mayabeque Agroforestry Company (2016).

	Carbon pool				Average (t/ha)
Component	Biomass	Necromass	Soil	Total	
Established artificial forests	467.3	51.9	1,683.8	2,203.0	363.9
Artificial forests under development	30.0		285.7	30.0	12.9
Natural forests	3,114.1	295.5	6,162.0	9,571.6	277.3
Area to be reforested	50.4		78.7	129.1	
Unforested area	384.3		5,747.2	6 131,5	
Total	4,046.2	347.4	13,957.4	18,350.9	
Average (tC/ha)	83.1	8.6	253.5	333.2	

2.4. Differences between methods for carbon sequestration in the base year

The calculation system followed by SUMFOR is based on the application of the stock-difference method described above; however, by adapting the calculation system that is used to calculate the net emission balance of the Forestry Sector for National Inventories using the 1996 IPCC Guidelines, it is possible to apply the gain-loss method and develop a comparative analysis between the results of both.

a. Adequacy of the gain-loss method.

Carbon removals.

In the Inventories reported by Cuba, the method proposed by IPCC (1996) to calculate carbon removals (based on gains and losses) takes into account artificial forests established in eight groups, while natural forests are divided into five groups and for each group values of average annual increment of dry biomass (IMA_{BS}) and default carbon ratio (CP) are proposed, to facilitate calculations in case these factors are not available in Cuba (Table 2.10).

This method assumes that the annual carbon removal (CAR, in tC) is defined by the expression:

- $RAC = S * IMA_{BS} * PC$ [1]

where: S-Surface (ha)

- IMA_{BS}-Average annual increase in dry biomass (t/ha)
- PC-Carbon ratio in dry biomass (s/u)

regarding as a pool only the existing above-ground biomass and as components, the area covered by established artificial forests and natural forests.

Table 2.10. Format of carbon removal calculation (IPCC, 1996)

INDICATORS		A	B	C	D	E
		Area	IMA_{BS}	Annual increase in biomass	Carbon ratio (CR)	Annual carbon increment
		(ha)	(t ms/ha/año)	(t ms)	(s/u)	(t C)
				C=(A x B)		E=(C x D)
Artificial forests	*Acacia spp.*		15.00		0.45	
	Eucalyptus spp.		14.50		0.45	
	Tectona grandis		8.00		0.45	
	Pinus spp.		11.50		0.50	
	Pinus caribaea		10.00		0.50	
	Mixed hardwood		6.80		0.45	
	Mixed fast-growing hardwood		12.50		0.45	
	Mixed soft wood		14.50		0.45	
Natural forests	Moist		6.25		0.45	
	Seasonal (<20 years)		4.00		0.45	
	Seasonal (>20 years)		2.00		0.45	
	Dry		3.40		0.45	
	Mangroves		2.00		0.45	
TOTAL FORESTS						

The adjustments made to the method (for comparison with the stock-difference method) consisted of substituting the eight groups of established mixed artificial forests for the 125 species reported in Cuba by the Forestry Dynamics and the five groups of natural forests for the 16 natural formations described in Law 85 (Republic of Cuba, 1998), using for each species and formation carbon fractions determined in Cuba (Álvarez and Mercadet, 2017), while the IMA_{BS} (tms/ha/a) determined in Cuba were only used for the first five categories of artificial forests (*Acacia sp.* -6.49; *Eucalyptus sp.* -16.84; *Tectona grandis* -15.55; *Pinus caribaea* -7.49 and *Pinus sp.* -11.50), maintaining for the rest of the species and formations the IPCC default values.

The species differentiation between the mixed hardwood and mixed softwood groups was made using the value of their basic densities, establishing 700 kg/m^3 as the limit between them (A. Ibáñez, personal communication), while the division between the mixed hardwood and mixed fast-growing hardwood groups was made taking into account the growth database created as part of the forest genetics research carried out by the INAF.

Carbon emissions.

The method proposed by the IPCC for calculating carbon emissions requires the division of volumes by harvest groups so that seven groups are used nationally, and for all of them, the volume to biomass conversion factors and the carbon ratios in wood determined in Cuba are applied, while in all cases the biomass expansion factor used is that proposed by default by the IPCC (Table 2.11).

This method proposes that the annual carbon emissions (AUC, in tC) are defined by the expression:

- EAC=V * FC * FEB * CC [2]

where: V- Volume(m^3)

- FC- Volume conversion factor to dry biomass (s/u)
- FEB- Biomass expansion factor used to total biomass extracted (s/u)
- PC- Carbon ratio in dry biomass (s/u)

The adjustments made consisted of replacing the seven harvest groups with three intervention groups: treatment/thinning, clear-felling, and other fellings, breaking down within each of them into four harvest groups: fuelwood, horizontal beams, roundwood, and bole, according to the ratios indicated for each of them. For all categories, nationally determined biomass volume conversion factors and carbon fractions are applied, while in all cases the biomass expansion factor used is the default one proposed by the IPCC (1.90) (Table 2.12).

Net emission balance

The net carbon removals or emissions are obtained by subtracting the Total Annual Carbon Emission (Table 2.12., col. O) from the Total Annual Carbon Increase (Table 2.10, col. E) and converting the result to tons of CO_2 by multiplying the carbon value by the factor 44/12. If the balance is positive, it is equivalent to a source of emissions and if negative, to a carbon sink.

Table 2.11. Calculation format for carbon emission (IPCC, 1996)

(The factors shown in red were obtained nationally)

Harvest Categories	F	G	H	N	O
	Commercial harvest	Biomass Conversion/ Expansion Ratio	Total Biomass Removed per Commercial Harvest	Carbon Ratio	Annual Carbon Emission
	(m^3 in bole)	(t ms)	(t ms)	(s/u)	(t C)
			H = (F x G)		O = (H x N)
Bole:					
Coniferous		0.565/1.90		0.4715	
Precious		0.618/1.90		0.4700	
Hard broad-leaves		0.811/1.90		0.4741	
Semi-hard broad-leaves		0.652/1.90		0.4633	
Soft broad-leaves		0.482/1.90		0.4671	
Poles: (Coniferous)		0.565/1.90		0.4734	
Railroad sleepers:					
Hard broad-leaves		0.811/1.90		0.4741	
Semi-hard broad-leaves (eucalyptus)		0.717/1.90		0.4555	
Roundwood:					
Coniferous		0.565/1.90		0.4715	
Hard broad-leaves		0.645/1.90		0.4741	
Semi-hard broad-leaves		0.652/1.90		0.4633	
Fuelwood:					
Coniferous		0.565/1.90		0.4715	
Hard broad-leaves		0.645/1.90		0.4741	
Semi-hard broad-leaves		0.652/1.90		0.4555	
Carbon:					
Hard broad-leaves (Olive bark-tree)		0.645/1.90		0.4741	
Semi-hard broad-leaves (eucalyptus)		0.717/1.90		0.4555	
Horizontal beams:					
Coniferous		0.510/1.90		0.4715	
Semi-hard broad-leaves (eucalyptus)		0.717/1.90		0.4555	
TOTAL					

Table 2.12. Modified calculation format that was used for carbon emissions. (The factors shown in red were obtained nationally)

Harvest Categories	F	G	H	N	O
	Commercial harvest	Biomass Conversion/ Expansion Ratio	Total Biomass Removed per Commercial Harvest	Carbon Ratio	Annual Carbon Emission
	(m^3 in bole)	(t ms)	(t ms)	(s/u)	(t C)
			H = (F x G)		O = (H x N)
Treatment/Thinning					
Fuelwood (70%)		**0.628/1.90**		**0.4633**	
Horizontal beams (20%)		**0.686/1.90**		**0.4579**	
Roundwood (10%)		**0.599/1.90**		**0.4688**	
Clearcutting					
Fuelwood (30%)		**0.628/1.90**		**0.4633**	
Horizontal beams (20%)		**0.686/1.90**		**0.4579**	
Roundwood (30%)		**0.599/1.90**		**0.4688**	
Bole (20%)		**0.578/1.90**		**0.4708**	
Other felling					
Round wood (30%)		**0.599/1,90**		**0.4688**	
Bole (70%)		**0.578/1.90**		**0.4708**	
TOTAL					

b. Adaptation of the stock difference method.

It consisted of establishing, using the SUMFOR v-3.03 system, the carbon sequestered at the end of two different years and for each year, the Unit Sequestration (tC/ha of forest) was calculated; the difference of unit sequestration between both years, multiplied by the area of forest (artificial or natural) of the last year, resulted in the C Stock Difference for that type of forest, as reported by Álvarez *et al*. (2017).

Although the system calculates the carbon sequestered in each component pool, to maintain a level playing field in the comparison with the gain-loss method, only above-ground biomass was regarded as a carbon pool, and as components, the area covered by established artificial forests and natural forests.

Finally, the conversion of the result to tons of CO_2 was done by multiplying the carbon value by the factor 44/12.

c. Comparison of the results of both methods.

For the development of the case studies, the reports presented on the management of the forest heritage administered each year by three agroforestry companies were taken into account: Ciego de Avila (years 2011, 2014 and 2016), Mayabeque (years 2002, 2007, and 2016) and Matanzas (years 2013, 2014 and 2015), and the results of each company in each period were obtained using both methods.

The results of the comparison of both methods are shown in Table 2.13.

Table 2.13. Results achieved per company for the comparison of the methods

Company	Method*	INDICATOR	Year		
			First	Second	Third
C. Ávila	G/P	Net C balance (t)	-105,522.7	-915,376.4	-103,519.3
		CO_2 balance (t)	-386,916.5	-3,356,380.2	-379,570.9
	DE	Net C balance (t)	-----	65,956.2	22,021.4
		CO_2 balance (t)	-----	241,694.3	80,7451
Mayabeque	G/P	Net C balance (t)	-118,120.4	-131,900.9	-120,722.2
		CO_2 balance (t)	-433,108.2	-483,636.5	-442,648.1
	DE	Net C balance (t)	-----	604,83.5	-778,207.6
			-----	2,217,726.5	-2,853,427.7
Matanzas	G/P	Net C balance (t)	-70,176.4	-61,707.6	-62,403.5
		CO_2 balance (t)	-257,313.3	-226,261.0	-228,812.8
	DE	Net C balance (t)	-----	-5,446.4	-120,822.9
			-----	-19,970.1	-443,017.3

* G/P - Gain/Loss; DE - Stock Difference

Using the gain-loss method, the three companies presented net balances that showed evidence of atmospheric CO_2 removals for all the years evaluated, with a marked difference between the second year (2014) and the other two (2011 and 2016) in the case of C. Avila; however, the stock difference method characterized C. Avila as a source of emissions in both assessments (higher in the 2011-2014 period) and Mayabeque in the first assessment, while Matanzas was classified as a carbon sink for both assessments, with much higher results in the 2014-2015 period.

The differences between the results of the two methods are caused by the way they operate.

The gain-loss method bases the calculation of CO_2 removals on the area of forest cover and whenever this increases, atmospheric CO_2 removals will also increase, whereas the calculation of emissions is based on the levels of wood removals that have occurred; so whenever removals are less than the annual increase in the volume of the area covered (which is a basic principle of forestry), the net balance will be negative, indicating the existence of a carbon sink.

On the other hand, the stock difference method calculates the carbon sequestration per hectare for both years, taking into account not only the area covered by forest but also the stock of wood present in it, so that two years with equal areas covered but a lower stock of wood in the second year will result in a decrease in the removal of atmospheric CO_2, indicating the existence of a source of emissions.

As for C. Avila AFC, the 2014 results of the Gain-Loss method were mainly caused by a sharp increase in the area of established artificial forests (116,746.2 ha in 2014, compared to 4,689.3 ha in 2011 and 2,366.6 ha in 2016), while in the case of the Matanzas AFC, the 2014-2015 results of the Stocking Difference method were mainly due to the reported increase in the volume of natural forests (69,126.8 m^3 in 2013-2014, compared to 94,975.8 m^3 in 2014-2015).

In summary, the stock difference method was more accurate in detecting behaviors in the net emissions balance that the gain-loss method could not recognize, results that corroborate what was stated in section 1.6 when both methods were used to estimate the projected net emissions balance for Cuba until 2030.

2.5. Temporary forecast of change from the base year: The carbon baseline

In addition to the information obtained for a given base year, it is important to know how carbon sequestration will behave in future years as a result of the technical management to which the heritage under evaluation is currently subjected, because there is a possibility that some of the technical elements involved in this management are reducing the level of atmospheric carbon removal or increasing GHG emissions, and although this may not be evident today, in subsequent years it will be reflected in the environmental results of the area under evaluation.

This forecast of the behavior of carbon sequestration as a result of the technical management of the heritage under management is called the carbon baseline, and the dynamics of land-use change within the forest heritage, shown in Fig. 2.3, is used to estimate it.

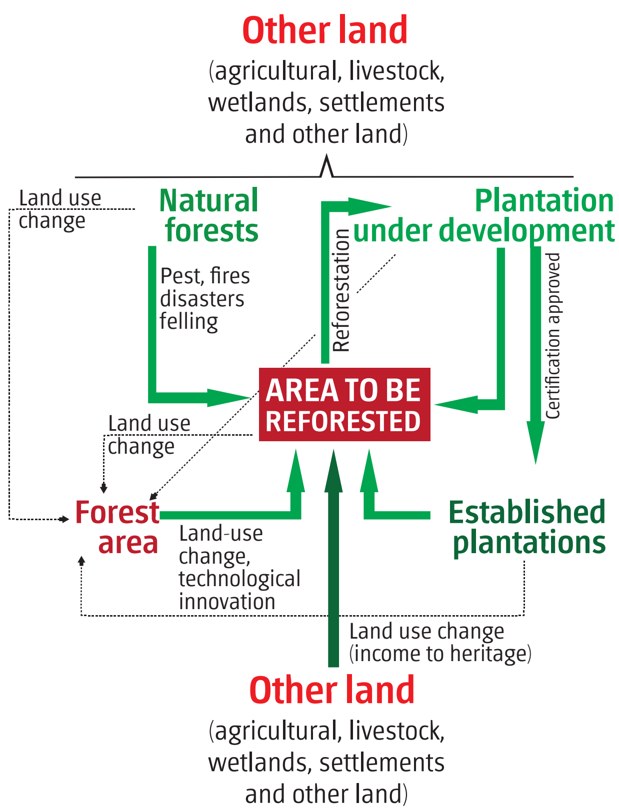

Figure 2.3. Dynamics of land-use change within the forest heritage.

The heritage managed by an manager may present various changes in land use as a direct consequence of the management itself (reforestation, certification, harvesting, development of technical actions such as nurseries, trails, roads, etc.), as well as the action of natural factors (pests, fires, hurricanes, etc.) and all this creates a change dynamics that must be considered because it will affect the future modification of the carbon currently sequestered in the base year.

For this reason, the current design of SUMFOR allows us, as a second option, to determine the baseline carbon sequestration, starting firstly from the results achieved for the base year itself, and secondly, taking into consideration the characteristics of the technical management of the heritage carried out by the manager, for which the data presented in Table 2.9 are requested, made up of four groups of elements: the surface area of the heritage components, forestry management, timber extractions, and annual increments.

The use of the SUMFOR system allows us to obtain information such as that shown in Table 2.10 and Fig. 2.4, derived from the evaluation of the Mayabeque Agroforestry Company based on data corresponding to the end of 2016.

Table 2.9. Data required by SUMFOR for the carbon baseline estimation.

Date:		Prepared by:	
Province:			
1	Name of Manager:		
2	Base year of data:		
3	Area of natural forests (ha):		
4	Area of established artificial forests (ha):		
	• Of these, categorized as Production forests (ha):		
5	Area of artificial forests under development (ha):		
6	Area to be reforested (ha):		
	• Without sickle bush (<50%) (%):		
	• With sickle bush (≥50%) (%):		
7	Area of swamps (ha):		
8	Area of grassland (ha):		
9	Area of agricultural land (ha):		
10	Area of semi-deserts (ha):		
11	Area of other unforested areas (ha):		
12	Average annual development plan (ha):		
13	Average survival of artificial forests (%):		
14	Average reforestation achievement (%):		
15	Average annual area of burned areas (ha):		
	• Burned areas in unforested areas (%):		
	• Burned areas in areas to be reforested (ha): Burned areas in reforested areas (%)		
	• Burned areas in areas to be reforested (%):		
	• Areas burnt in developing artificial forests (%)		
	• Areas burned in established artificial forests (%)		
15	Average annual volume harvested per treatment/thinning (m^3):		
	• Treatment/thinning in artificial forests (%)		
	• Treatment/thinning in natural forests (%)		
16	Average annual area of clear-cutting (ha):		
	• Clear-cutting in established artificial forests (%)		
	• Clear-cutting in natural forests (%)		
17	Average annual volume harvested by other fellings (m^3):		
	• In established artificial forests (%)		
	• In natural forests (%)		
18	Annual average increment of natural forests (m^3/ha/year):		
19	Average annual increment of artificial forests (m^3/ha/year):		

Table 2.10. Results of the carbon baseline calculation (ktC) Mayabeque AFC (2016). SUMFOR v-3.03.

Components	Year										
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Unforested areas	6131.5	6131.5	6131.5	6131.5	6131.5	6131.5	6131.5	6131.5	6131.5	6131.5	6131.5
Areas to be reforested	129.i	119.5	109.2	98.2	86.6	75.0	63.4	51.7	40.1	28.5	16.9
Artificial forests under development	315.7	268.0	220.3	172.6	172.6	172.6	172.6	172.6	172.6	172.6	151.8
Established artificial forests	2203.0	2617.4	3,067.7	3,553.9	3,923.2	4,310.0	4,714.5	5,136.6	5,576.3	6,033.7	6,508.7
Natural forests	9571.6	10,032.6	10,491.5	10,947.0	11,399.0	11,847.6	12,292.7	12,734.4	13,172.5	13,607.3	14,038.5
Baseline	18,350.9	19,169.0	20,020.2	20.903.3	21,713.0	22,536.8	23,374.7	24,226.8	25,093.1	25,973.6	26,847.5

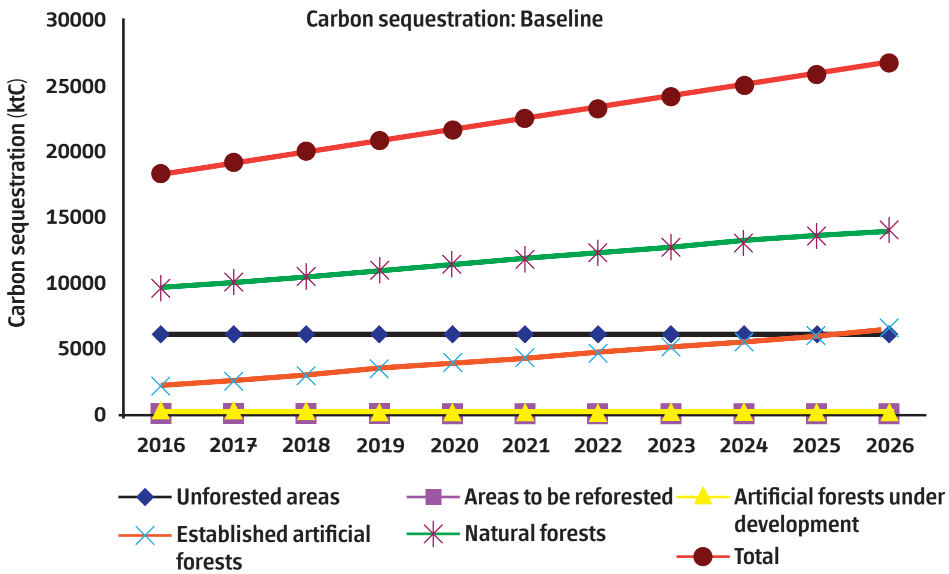

Figure 2.3. Graphical representation of the carbon baseline and the contributions made to it by each component. Mayabeque AFC (2016).

The results in Figure 2.3. indicate that the current management of the forest heritage managed by the Company will allow the carbon sequestered in 2016 to continue increasing over the next 10 years, both in its total value and in that sequestered by the natural and artificial forests established.

At the end of the period, natural forests will show a slight increase (2.2%) over established artificial forests, compared to the values presented by both in 2016, while the carbon sequestered in the areas to be reforested and in the artificial forests under development will progressively decrease, as a result of the progress in reforestation and certification of the reforested areas.

Baseline analyses carried out on a set of 12 agroforestry companies with data corresponding to the end of 2018 demonstrated (INAF, 2019) the existence of three different patterns of behavior among the main components of the heritage (natural forests and established artificial forests):

1. Companies in which the contribution of natural forests always exceeded that of artificial forests, but the two lines are roughly parallel and rising (Fig. 2.4.).

2. Companies where the two lines diverge and although the contribution of natural forests generally exceeds that of artificial forests, both are on the rise (Fig. 2.5.).

3. Companies where the two lines intersect or tend to do so that although initially, the contribution of natural forests is higher, after some time artificial forests outnumber them, both are on the rise (Fig. 2.6.).

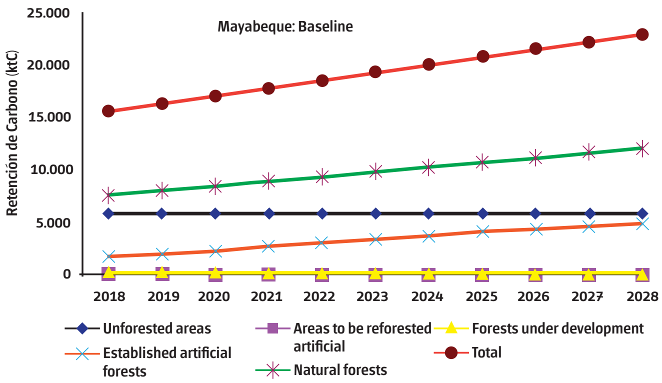

Figure 2.4. An example of ascending but parallel carbon inputs.

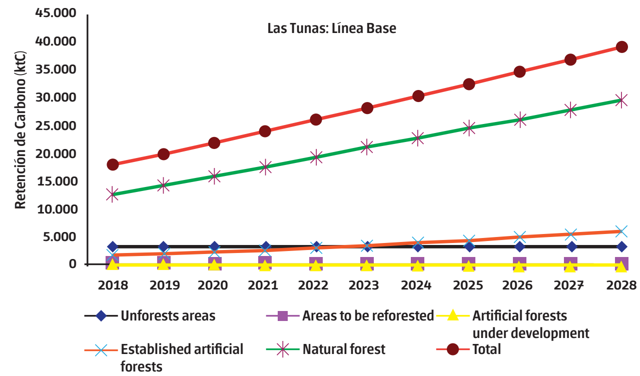

Figure 2.5. An example of ascending but diverging carbon inputs

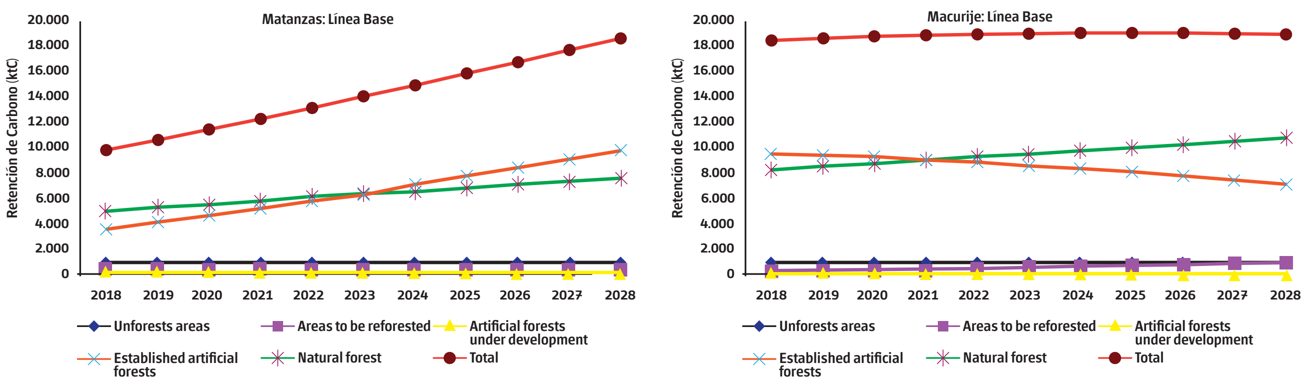

Figure 2.6. Examples of cross carbon inputs.

On the other hand, recent evaluations (Álvarez and González, 2018; Miñoso, 2018; Ajete *et al*., 2019; Mercadet *et al*., 2019; Frómeta, Conde and Torres, 2019; Martínez *et al*., 2019; Álvarez, Barrios and Mojena, 2019; Catanares *et al*, 2019 and Catanares, Debrot and Esparraquera, 2020) have shown how different the expected baseline results can be when compared between agroforestry companies using relative values (Fig. 2.7.).

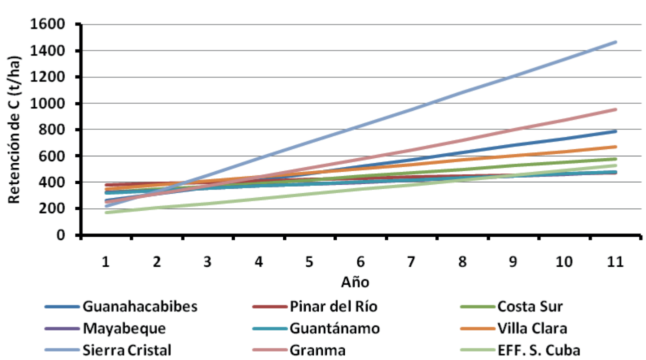

Figura 2.7. Comportamiento de la línea base de carbono entre diferentes empresas agroforestales.

While the set of companies starts from a range of common values in the evaluation year (year 1), their different technical management of the forest heritage they administer plans, 10 years later, a growing differentiation between them, which reaches maximum values in the EAF Sierra Cristal and Granma, Agroforestry Companies both of which exceed 900 tC/ha.

In the case of these two companies, these exceptionally high values were obtained as a consequence of both having a very high carbon ratio per cubic meter of wood (over 24 tC/m^3), while the S. Cristal AFC had more than 20% of its established artificial forests and more than 30% of its natural forests formed by *Pinus maestrensis* B., the species to which the forest soils with the highest levels of carbon correspond.

2.6. Proposed MRMV system for the Agroforestry Business Group

Versions 1.xx and 2. xx of the SUMOR system were used between 2001 and 2011 for validations in real conditions of both the methodology proposed by Mercadet and Álvarez (2009) and the automated system, evaluating a total of 12 integrated forestry companies whose results were used to prepare the 2013 Carbon Registry (INAF, 2014), a document that constituted the first official report on the carbon sequestration capacity of Cuba's forest heritage managers, technically endorsed by the Agroforestry Research Institute and approved by the Mountain Agriculture Business Group (GEAM) and the Forestry Division of MINAG.

The experiences gained in the preparation of the register and the need to expand the scope of the methodology and the system to determine not only the carbon sequestered after one year and the carbon baseline, but also the net carbon balance between two successive assessments, and even the simulation of the effects of different mitigation alternatives based on modifications to the reported technical management of the heritage (business as usual), led to the preparation of versions 3.xx.

However, in 2013, in conjunction with the development of the register, the UN-REDD Programme published methodological guidelines for national forest monitoring systems called the M-MRV system (UN-REDD, 2013), so to validate the new aspects included in the methodology and the automated system, it was decided to adapt the M-MRV system to the conditions of the Agroforestry Business Group (GAF) by preparing the MRMV (Measurement, Reporting, Monitoring, and Verification) system.

The validation process was undertaken between 2015 and 2016 using the MRMV system with 15 agroforestry companies, resulting in the presentation of the 2017 Carbon Report, which, in GAF's interest, included information not only on carbon but also on timber yields.

The main objective of the MRMV system is to establish an official, stable and functional mechanism through which any GAF company (or its Base Enterprise Units-UEB) that manages forest assets, can periodically have a certified and scientifically supported assessment of the following aspects:

- Carbon sequestered in the forest heritage it manages (base year).
- Status of Sustainable Forest Management Indicator 3.5, specifically linked to climate change (Herrero *et al*., 2005).
- Net carbon balance results between successive assessments.
- 10-year forecast of the results of carbon sequestration (baseline), assuming that its stock and technical management are kept the same as in the baseline year.

Such aspects can be used, among others, for the following purposes:

- To make informed decisions for the improvement of the management of the managed estate, increasing the efficiency of the forestry investment.
- To provide information to municipal and provincial government bodies for decision-making.
- To have a certification that shows the amount of atmospheric CO_2 removed between successive assessments, in a way that allows access to a national system of payment for environmental services (PES).

Four different actors are involved in the MRMV-GAF system:

- GAF's companies or UEBs, managers of forest heritage.
- GAF's Forestry and Natural Fibers Division (DFFN).
- The Agroforestry Research Institute (INAF).
- The Division of Forestry, Flora, and Wildlife (DFFFS) of the Ministry of Agriculture (MINAG).

The roles of each of the parties in the MRMV system are as follows:

- Companies and/or UEBs.

  They apply for certification and provide the DFFN with the data required for the planned assessments, and are responsible for the data's veracity.
  They receive the certification results from the DFFN, accompanied by the technical assessments and indications issued by the DFFN.
  They carry out the relevant assessments and establish the procedures for the implementation of their decisions.

- GAF's Forestry and Natural Fiber Division:

  Establishes the periodicity with which companies/UEBs have to certify their carbon performance.

  Receives requests for certification from co-businesses/UEBs.

  Contracts with INAF the carbon certification service for all the companies/UEBs, delivering the applications.

  Receives from INAF the certification applications in which errors have been detected.

  Receives from INAF the results of certification and the Carbon Reports periodically issued.

  Analyzes the results of the certifications and defines the actions to be implemented.

  Delivers the certifications to the companies/UEBs, together with their indications.

  Establishes the monitoring system to control compliance with the indications.

- The Agroforestry Research Institute:

  Ensures continuous improvement of the methodology and automated system used for carbon certifications.

  Receives applications for certification from the DFFN and checks the quality of the data for possible errors; if detected, returns the application to the DFFN.

  It processes the applications and issues the corresponding certificates, delivering them to the DFFN.

  Periodically and based on the results of the certifications, prepares and submits GAF Carbon Reports to the DFFN and DFFFS.

  It archives and safeguards for 10 years the applications received and the certifications issued.

- The Forestry, Flora, and Wildlife Division of MINAG.

  On behalf of the State, the State Forest Service verifies the veracity, functioning, and transparency of the MRMV system, from the delivery of the data by the managers and the INAF certification service to the implementation of the actions by the companies/UEBs and their monitoring by the DFFN.

  It receives from INAF the periodically issued Carbon Reports.

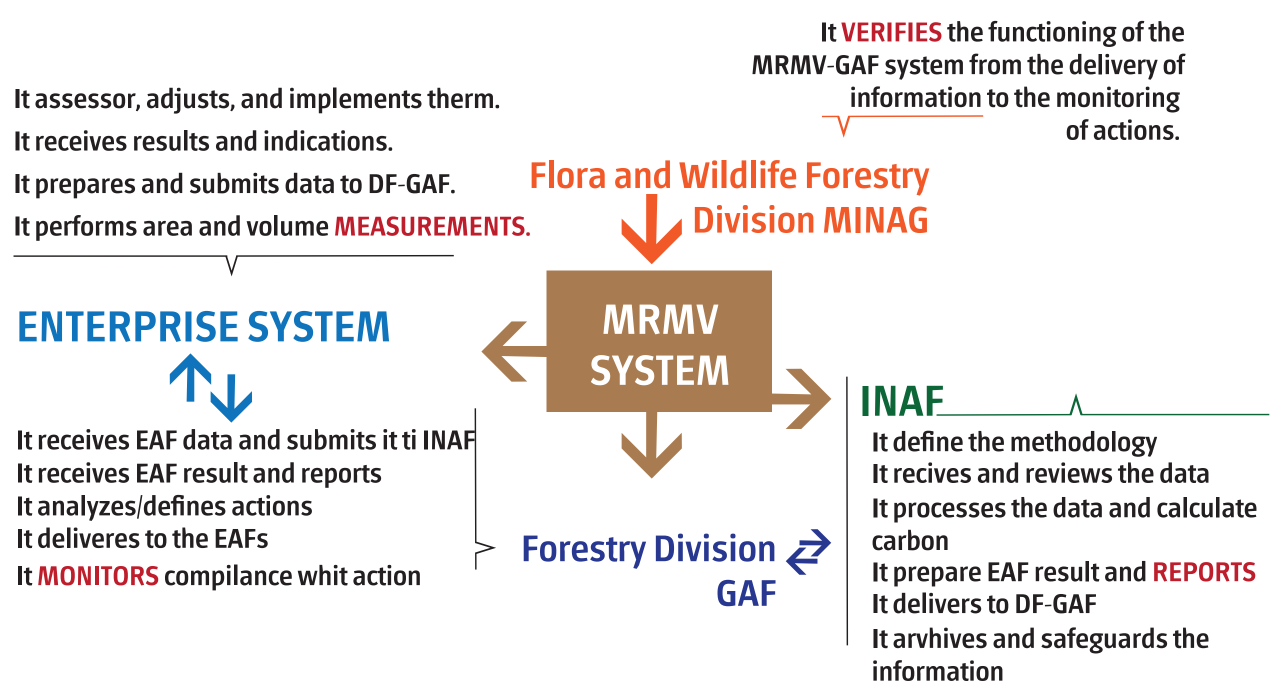

Figure 2.8. Diagram of operation of GAF's MRMV system.

2.7. 2013, 2017 and 2019 carbon reports of the Agroforestry Business Group

Research carried out between 2001 and 2011 by the Forestry Research Institute to determine the carbon sequestration corresponding to different companies of the Agroforestry Group - GAF (Suárez, 2010 (5); Ortiz, 2008 (7); Caballero *et al*, 2012 (8); Caballero, 2012 (9); Álvarez and Rivera, 2012 (10); Mogena, 2013 (12); Yero, 2010 (13) and A. Álvarez and I. Zulueta(4) (6) (11) (14) (15)), using the first two versions of the SUMFOR system, allowed the presentation in 2013 of the first Carbon Report (INAF, 2013) prepared for the Forestry Sector in Cuba (Table 2.14).

Table 2.14. 2013 Report results for each company.

No.	Company	Base Year	Surface[1] (ha)	Base Year[2]		Base Year+10[3]	
				RMC (tC/ha)	RTC (MtC)	RMC (tC/ha)	RTC (MtC)
1	Viñales[4]	2007	40,645.2	190.5	7,741.1	144.3	5,863.9
2	La Palma[5]	2007	27,602.6	169.7	4,685.3	144.1	3,150.0
3	Mayabeque[6]	2007	66,841.6	265.0	17,709.8	376.6	25,170.7
4	Victoria de Girón[7]	2006	437,151.2	380.1	166,172.2	432.9	189,231.6
5	Villa Clara [8]	2011	59,281.7	147.1	8,717.4	312.5	18,526.3
6	Sancti Spiritus[9]	2011	79,916.7	200.8	16,051.1	283.4	22,645.3
7	Ciego de Avila[10]	2011	66,206.2	207.7	13,747.9	335.6	22,220.5
8	Las Tunas[11]	2004	94,965.8	123.5	11,725.0	246.3	23,389.6
9	Granma[12]	2011	61,786.4	119.6	7,389.2	384.7	23,770.3
10	Gran Piedra[13]	2001	14,545.0	171.7	2,497.7	347.7	5,057.7
11	Imías[14]	2007	41,279.0	129.4	5,340.6	467.1	19,283.4
12	Baracoa[15]	2002	54,877.9	284.0	15,583.0	358.8	19,688.1
TOTAL			1,045,099.3	265.4	277,360.1	344.0	359,471.1

[1] It includes all areas of heritage.
[2] It includes all carbon pools: RMC - average sequestration; RTC - total sequestration.
[3] RMC and RTC values expected 10 years after the base year.

Subsequently, with the data submitted at the end of 2016 and 2018 by different GAF companies, the 2017 (INAF, 2017) and 2019 (INAF, 2019; Tables 2.15. and 2.16.) Reports were prepared.

Table 2.15. Results for each company in the 2017 Report.[1]

No.	Company	Base Year	Surface (ha)			Timber yield (m^3/ha)			Carbon sequestration (tC/ha) (*)				IMFS 3.5 (Best value 4)
			Company	Artificial forests	Natural forests	Covered area	Artificial forests	Natural forests.	Company	Artificial forests	Natural forests	10 years later	
1	Macurije[2]	2016	88,577.2	39,819.0	35,935.2	95.95	111.08	79.19	354.33	369.18	437.65	478.65	4
2	M. Matahambre[3]	2016	59,514.6	20,106.2	34,388.9	88.30	112.50	74.15	413.21	382.78	483.32	521.70	4
3	Pinar del Río[4]	2016	43,755.9	8,552.6	21,652.8	127.53	137.01	123.78	376.58	412.19	538.30	468.78	4
4	Costa Sur[5]	2016	52,161.4	6,546.4	31,385.7	58.74	41.26	62.39	323.06	316.08	332.13	590.39	4
5	Mayabeque[6]	2016	55,068.1	6,054.5	34,523.7	96.79	78.21	100.04	333.24	363.85	277.25	487.54	4
6	Matanzas[7]	2016	49,120.9	12,043.1	22,340.6	60.46	51.53	65.27	255.41	279.48	343.95	560.07	4
7	Villa Clara[8]	2016	51,106.2	12,801.7	24,188.1	72.45	69.61	73.95	340.65	269.00	486.27	635.56	4
8	Sancti Spiritus[9]	2016	81,115.7	5,441.1	56,968.6	38.30	43.89	37.76	253.25	195.79	256.85	457.49	4
9	Ciego de Ávila[10]	2016	122,631.2	2,320.6	39,661.3	66.86	33.42	68.82	195.91	193.06	314.00	255.45	2
10	Las Tunas[11]	2015	104,786.4	7,648.4	72,377.2	39.58	34.35	40.14	272.98	175.34	308.69	512.05	4
11	Mayarí[12]	2016	60,219.0	13,844.0	32,675.5	15.90	7.02	19.90	243.29	285.20	300.36	1,158.95	2
12	Granmma[13]	2015	58,558.0	21,546.3	27,008.3	48.66	9.96	79.53	246.02	333.83	241.38	910.93	4
13	Cafet. R. Ayub.[14]	2016	4,620.3	4,018.2	139.0	10.08	10.10	9.35	138.31	141.82	142.28	1,464.92	4
14	Guantánamo[15]	2016	39,692.5	9,851.4	26,784.0	570.45	591.65	562.66	478.15	591.60	479.38	602.62	4
15	Imías[16]	2016	52,118.7	12,283.2	28,971.0	58.47	74.17	51.81	188.69	276.80	199.40	340.15	4
	Agroforestry Group		**923,046.0**	**182,876.7**	**488,999.9**	**96.57**	**93.72**	**96.58**	**294.21**	**305.73**	**342.75**	**629.70**	**3.80**

(*) It includes all carbon pools and all heritage components.

1. Analyses carried out by A. Álvarez using SUMFOR v-3.02, with the collaboration of: E. Castro (GAF); (2)M. Puente; (3)J. M. Torres; (4)J. L. Guelmez; (5)J. L. López; (6)G. González; (7)M. Pí; (8)E. Orama; (9)J. R. Toledo; (10)Y. Rivera; (11)I. Domínguez; (12)A. Magaña; (13)O. Mojena; (14)T. Rodríguez; (15)F. Conde and (16)W. Moreira.

Table 2.16. Results for each company in the 2019 Report[2].

No	Company	Base Year	Surface (ha)			Timber yield (m³/ha			Carbon sequestration (tC/ha) (*)				IMFS 3.5 (Best value 4)
			Total	Artificial forests	Natural forests	Covered area	Artificial forests	Natural forests	Company	Artificial forests	Natural forests	10 years later	
1	Macurije[2]	2016	88,577.2	39,819.0	35,935.2	95.95	111.08	79.19	314.20	364.57	343.85	468.13	4
		2018	88,529.5	39,530.2	35,994.8	95.86	111.16	79.06	311.34	359.08	344.16	319.38	3
2	Pinar del Río[3]	2016	43,755.9	8,552.6	21,652.8	127.53	137.01	123.78	280.66	407.50	346.32	386.86	4
		2018	43,684.8	8,535.1	21,873.7	132.98	144.68	128.41	285.15	411.62	350.09	408.66	4
3	Costa Sur[4]	2016	52,161.6	6,546.4	31,385.7	58.74	41.26	62.39	240.38	259.04	206.75	431.47	4
		2018	52,746.4	7,236.4	31,739.4	63.84	55.13	65.82	218.29	282.22	209.83	395.54	4
5	Matanzas[6]	2016	55,068.1	6,054.5	34,523.7	96.79	78.21	100.04	288.99	253.39	226.06	402.41	4
		2018	54,746.0	6,938.4	34,427.7	84.03	73.52	86.15	284.10	254.82	219.76	416.36	4
6	Villa Clara[7]	2017	57,763.3	20,424.1	28,056.1	70.10	83.99	59.99	231.32	278.42	213.96	455.82	4
		2018	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	Cienfuegos[8]	2016	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
		2018	42,560.9	4,519.6	30,914.2	80.08	67.27	81.95	192.17	206.64	213.68	294.26	4
8	Sancti Spiritus[9]	2016	81,115.7	5,441.1	56,968.6	38.30	43.89	37.76	197.29	189.06	177.81	351.16	4
		2018	76,827.7	5,673.8	54,065.2	58.81	42.65	60.51	199.47	186.65	198.64	309.17	4
9	Ciego de Ávila[10]	2016	122,631.2	2,320.6	39,661.3	66.86	33.38	68.82	161.76	178.41	209.26	201.84	2
		2018	122,892.8	2,426.9	39,994.3	70.66	40.03	72.52	162.57	187.50	213.80	205.82	2
10	Las Tunas[11]	2015	104,786.4	7,648.4	72,377.2	39.59	34.42	40.14	184.43	165.21	181.56	254.39	4
		2018	986,78.8	9,281.5	71,839.2	32.72	32.73	32.72	181.01	164.63	173.87	394.71	4
11	Mayarí[12]	2016	60,219.0	14,737.3	32,675.5	15.90	7.02	19.90	220.57	284.93	258.60	1,178.94	3
		2018	61,886.2	14,158.4	37,862.6	23.43	16.60	25.99	233.89	299.8	253.83	975.12	4
12	Granma[13]	2015	58,557.6	21,546.3	27,008.3	48.66	9.96	79.53	239.24	333.42	224.90	990.13	4
		2018	59,051.1	23,297.5	27,326.3	47.54	9.85	79.67	241.29	322.16	224.77	931.64	4
13	Imías[14]	2016	47,637.2	12,283.2	28,971.0	58.47	74.17	51.81	201.48	275.69	198.51	373.63	4
		2018	47,226.6	13,772.3	28,398.0	56.26	65.34	51.85	202.48	257.77	198.76	376.46	4
	Agroforestry Group	2016	761,175.0	142,679.3	398,880.5	62.22	60.63	66.59	229.30	271.38	233.11	505.13	3,67
		2018	797,830.5	147,405.9	436,858.0	60.75	60.90	60.32	225.73	268.13	234.97	449.17	3,67
		2018-2016	36,655.5	4,726.5	37,977.4	-1.47	0.27	-6.27	-3.57	-3.25	1.86	-55.96	

* It includes all carbon pools and all heritage components.

2. Analyses carried out by A. Álvarez using SUMFOR v-4.00, with the collaboration of: E. Castro (GAF); (2) M. Puente; (3) J. L. Guelmez; (4) J. L. López; (5) G. González; (6) M. Pi and U. Ortiz; (7) M. Martínez; (8) I. Pino; (9) M. Lozano; (10) O. García; (11) J. Figueras; (12) A. Magaña; (13) O. Mojena; (14) W. Moreira.

In addition, and at GAF's request, the 2017 and 2019 Reports included information on timber yields and on compliance with Sustainable Forest Management Indicator 3.5, which is directly related to climate change.

Another new aspect of the 2017 and 2019 Reports was information on the distribution of carbon pool sequestration (Table 2.17.).

The results of the net emissions balance for the companies that matched in the 2017 and 2019 Reports are shown in Table 2.18.

Table 2.17. Distribution of carbon pool sequestration.

No.	Company	Base Year	Distribution (%/ha)		
			Biomass	Necromass	Soil
1	Macurije	2016 (1)	22.69	2.34	74.97
		2018 (2)	22.05	2.33	75.62
2	Pinar del Río	2016	28.34	2.11	69.55
		2018	28.63	2.09	69.28
3	Costa Sur	2016	20.56	2.59	76.85
		2018	23.98	2.90	73.12
4	Mayabeque	2016	25.42	2.18	72.40
		2018	24.45	2.28	73.27
5	Matanzas	2016	23.31	3.14	73.54
		2018	27.23	3.07	69.70
6	Villa Clara	2017	25.29	3.12	71.59
		2018	-----	-----	-----
7	Cienfuegos	2016	-----	-----	-----
		2018	34.27	3.72	62.00
8	Sancti Spíritus	2016	18.69	3.34	77.97
		2018	26.03	3.34	70.63
9	Ciego de Ávila	2016	18.47	1.81	79.72
		2018	19.36	1.82	78.83
10	Las Tunas	2015	18.52	3.54	77.94
		2018	16.67	3.88	79.45
11	Mayarí	2016	6.59	3.06	90.36
		2016	9.27	3.08	87.65
12	Granma	2018	17.03	2.96	80.01
		2016	17.01	3.04	79.95
13	Imías	2018	24.23	3.69	72.08
		2016	23.70	3.78	72.52
Agroforestry Group		2018	20.28	2.83	76.90
		2016	21.83	2.83	75.33

(1) 2017 Report; (2) 2019 Report

Between these two balances, there is a marked difference in the number of companies that were sources of GHG emissions: only one out of seven in 2017, while in 2019 there were six out of a total of 11.

Table 2.18. Result of the net emission balance for each company.

Company	2017 Report				
	Base Year	Surface (ha)	Sequestration (tC/ha)	Emission Balance	
				ktC	kt CO_2
Mayabeque	2007	66,841.6	265.0	-7,912.4	-29,012.1
	2016	88,577.2	354.3		
Villa Clara	2011	59,281.7	147.1	-9,891.4	-36,268.6
	2016	51,106.2	340.6		
Sancti Spíritus	2011	79,916.7	200.8	-4,254.9	-15,601.4
	2016	81,115.7	253.3		
Ciego de Ávila	2011	66,206.2	207.7	+1,447.0	+5,305.8
	2016	122,631.2	195.9		
Las Tunas	2004	94,965.8	123.5	-15,663.8	-57,434.1
	2015	104,786.4	273.0		
Granma	2011	61,786.4	119.6	-7,403.2	-27,144.9
	2015	58,558.0	246.0		
Imías	2007	41,279.0	129.4	-3,090.3	-11,331.2
	2016	52,118.7	188.7		

2019 Report					
Company	Base Year	Surface (ha)	Sequestration (tC/ha)	Emission Balance	
				ktC	kt CO_2
Mayabeque	2016	55,068.1	240.4	+360.8	+1,323.0
	2018	54,746.0	218.3		
Villa Clara	2016				
	2018				
Sancti Spíritus	2016	81,115.7	197.3	+678.4	+2,487.6
	2018	76,827.7	199.5		
Ciego de Ávila	2016	122,631.2	161.8	-118.6	-521.7
	2018	122,892.8	162.6		
Las Tunas	2015	104,786.4	184.4	+1,463.4	+5,365.9
	2018	98,678.8	181.0		
Granma	2015	58,557.6	239.2	-238.9	-875.9
	2018	59,051.1	241.3		
Imías	2016	47,637.2	201.5	+35.7	+131.0
	2018	47,226.6	202.5		
Macurije	2016	88,577.2	314.2	+267.7	+981.6
	2018	88,529.5	311.3		
Pinar del Río	2016	43,755.9	280.7	-176.1	-645.7
	2018	43,684.8	285.2		
Costa Sur	2016	52,161.6	240.4	+1,024.4	+3,756.1
	2018	52,746.4	218.3		
Matanzas	2016	49,120.9	191.3	-297.3	-959.3
	2018	49,051.1	196.9		
Mayarí	2016	60,219.0	220.6	-1 192,2	-4 371,4
	2018	61,886.2	233.9		
Agroforestry Group	2016	761,175.0	229.3	+1,819.5	+6,671.4

This was because in 2017 the balance calculation was performed as the difference between the sequestrations reported in 2013 and 2017, multiplied by the area reported in 2017, in such a way as to avoid surface area differences over the period evaluated, which varied between 4 and 11 years; however, in 2019, when taking into account two years common for most of the companies, this calculation method was modified to allow reflecting the incidence of surface area changes in the carbon calculation, because such changes of the managed heritage constitute a major cause in the final results; an element that indicates the convenience of adequately assessing in the future the consequences, before deciding such changes.

A clear example of these situations was provided by EAF Las Tunas and Costa Sur.

The EAF Las Tunas, which turned out to be the one with the highest positive balance between 2015 and 2018, presented a decrease of more than six thousand hectares in the managed heritage mainly due to a similar reduction in the artificial forests under development, which was neither reflected in a similar increase in the established artificial forests, nor in the areas to be reforested, so they must have been transferred to the control of another manager and such thing means that the carbon contained in them, even when the Company lost it, was not converted into emissions to the atmosphere, but changed manager.

However, the EAF Costa Sur, which had the second-highest positive balance between 2016 and 2018, presented an increase of only slightly more than 500 ha in the managed heritage (a very different situation from that of the EAF Las Tunas), but between the two years, the unforested swamp area (a very important carbon reservoir) decreased by more than two thousand hectares (change of manager). In addition, there was an increase of 5.5 thousand cubic meters in volume extracted by other fellings, including more than 3.5 thousand cubic meters in natural forests (selective felling), which adds a significant carbon reduction to the previous cause and which in this case did constitute emissions to the atmosphere.

Other common aspects in the three Reports were the information on carbon sequestration by species in the established artificial forests (90 species in the first Report and 87 in the other two; see Annex 3); per natural formation for 15 of the 16 existing ones (Table 2.19.) and per forest category for six of the seven existing ones (Table 2.20).

Table 2.19. Distribution of carbon sequestered per natural formation in the three Reports.

No.	FORMATION	2013 Report		2017 Report				2019 Report			
		Carbon in aerial biomass (t/ha)	Carbon in total Biomass (t/ha)	Company with the species	Total surface area (ha)	Timber yield (m^3/ha)	Carbon sequestration (tC/ha)	Company with the species	Total surface area (ha)	Timber yield (m^3/ha)	Carbon sequestration (tC/ha)
1	Tendrils shrubland	0.00	0.00	3	10,484.60	20.97	199.76	3	10,484.60	20.97	199.75
2	Cuabal	23.2	30.1	5	2,511.55	11.3	159.94	5	2,511.55	11.30	159.94
3	Oak grove	58.1	75.6	3	1,931.20	68.33	187.98	3	1,931.20	68.33	187.98
4	Mangrove	103.3	134.3	14	135, 900.66	64.23	596.31	14	135,900.66	64.23	596.31
5	Coastal shrubland	31.7	41.2	5	2,545.51	48.37	187.49	5	2,545.51	48.37	187.49
6	Cool temperate forest										
7	Cloud forest	10.3	13.4	1	389.7	120	248.6	1	389.70	120.00	248.60
8	Pine tree	117.0	152.1	8	41,174.90	114.38	732.04	8	41,174.90	114.38	732.04
9	Rainforest	107.7	140	4	530.41	81.94	198.63	4	530.41	81.94	198.63
10	Mountain rainforest	101.4	131.8	4	16,485.14	73.76	347.51	4	16,485.14	73.76	347.51
11	Semi-deciduous on acid soil	38.8	50.4	11	64,202.91	45.9	189.26	11	64,202.91	45.90	189.26
12	Semi-deciduous in limestone soil	73.5	95.6	13	152,492.42	131.61	208.86	13	152,492.97	131.61	208.86
13	Poorly drained semi-deciduous	84.4	109.8	12	76,902.97	82.4	199	12	76,902.97	82.40	199.00
14	Grapevines	27.5	35.7	4	543.2	23.13	160.02	4	543.20	23.13	160.02
15	Xerófilo de mogote	10.4	13.5	5	8,959.26	76.01	196.14	5	8,959.26	76.01	196.14
16	Xerófilo típico	8.1	10.6	3	13,606.80	88.9	209.65	3	13,606.80	88.90	209.65

Table 2.20. Distribution of carbon sequestration per forest category in the three Reports*

No.	Category	2013		2017				2019			
		Carbon in aerial biomass (t/ha)	Carbon in total biomass (t/ha)	No. of companies	Surface area (ha)	Timber yield (m^3/ha)	Carbon sequestration (tC/ha)	No. of companies	Surface area (ha)	Timber yield (m^3/ha)	Carbon sequestration (tC/ha)
1	Production forest	92.7	120.5	15	214,192.21	123.87	298.64	13	148, 179.60	63.85	231.01
2	Water/soil protection	60.1	78.1	15	149,169.04	59.52	253.89	13	147, 430.65	65.16	186.85
3	Coastal protection	79.0	102.8	14	139,090.21	59.12	498.65	13	115, 416.13	60.16	205.31
4	Flora/fauna protection	91.9	119.4	5	18,848.54	135.99	152.49	3	18,573.54	59.04	194.62
5	Special management	103.7	134.8	5	5,073.70	56.05	350.93	4	4,969.00	46.13	169.32
6	Recreational	58.3	75.8	5	2,287.53	60.97	0.00	6	2,289.03	63.55	194.51
7	Educational/Scientific	0.0	0.0	0	0.00	0.00	0.00	0	0.00	0.00	0.00

*It only includes natural forests.

After the general results presented above, the Reports contain the specific results of each of the companies evaluated, for use at that level of forest heritage management.

In addition to what is included in the reports, other evaluations have been carried out to entities of the enterprise system, among which can be cited the Mayabeque Agroforestry Company (Álvarez and González, 2018), the Pinar del Río Agroforestry Company (Miñoso, 2018), the Macurije Agroforestry Company (Ajete, Ramos and Puentes, 2019), the Guanahacabibes Agroforestry Company (Ajete *et al*., 2019), the Villa Clara Agroforestry Company (Martínez *et al*., 2019), the Granma Agroforestry Company (Álvarez, Barrios and Mojena, 2019), the Guantánamo Agroforestry Company (Frómeta, Conde and Torres, 2019), the Costa Sur Agroforestry Company (Mercadet *et al*., 2019), the Sierra Cristal Agroforestry Company (Catanares *et al*., 2019); the Santiago de Cuba Agroforestry Company (Catanares, Debrot and Esparraguera, 2020) and two UEBs of the Imías Agroforestry Company (Frómeta, Romero and Moreira, 2020), the results of which are summarized in Table 2.21.

This company, with almost 23,000 hectares of managed heritage, 90.1% of which is covered by forests, mainly natural (80.5%), achieved average carbon sequestration of only 173.9 tC/ha at the end of 2019, a value below which five GAF companies were 10 or more years ago (Table 2.14.); at the end of 2016 only the R. Ayub Coffee Company (Table 2.15.) and more recently, at the end of 2018, only the Ciego de Ávila Agroforestry Company (Table 2.16.).

Considering that this company reports no fire damage, that given its function it does not harvest timber and that it also covers more than eight thousand hectares of semi-deciduous forest on limestone soil, more than six thousand hectares of mountain rainforest, and a little more than one thousand hectares of pine forests, one would expect higher amounts of carbon per hectare, but when one notes that the area covered registers only 18 m^3/ha and that in its natural forests this indicator decreases to 11.5 m^3/ha, one can understand its low carbon results and assume that, despite its status dedicated to the conservation of biodiversity, a reanalysis of the management plan currently applied to its forests should be considered.

Table 2.21. Summary of results achieved with other evaluations (Mercadet, 2020).

Company	Base year	Carbon sequestration (t/ha)			Carbon per pool (%)		
		The entire company	Artificial forests	Natural forests	Biomass	Necromass	Soil
EAF Mayabeque	2016	333.24	182.83	209.98	22,05	1.89	76.06
EAF Macurije	2017	354.38	369.79	344.31	20.10	2.07	20.10
EAF Guanahacabibes	2017	262.47	205.35	245.76	8.68	2.91	88.42
EAF Pinar del Río	2017	380.56	408.82	348.58	21.16	1.57	77.28
EAF Costa Sur	2017	326.20	346.18	330.43	16.18	1.93	81.89
EAF Guantánamo	2017	318.00	377.18	317.94	43.85	2.50	53.365
EAF Villa Clara	2017	352.78	312.19	439.45	16.57	2.04	81.38
EAF Sierra Cristal	2017	220.60	176.68	297.35	4.59	3.46	91.95
EAF Granma	2017	240.55	324.98	224.70	16.51	2.92	80.56
EAF Imías	2018	172.97	173.06	183.87	27.41	4.61	67.99
EFF Stgo. Cuba	2019	173.88	264.87	176.75	9.27	4.45	86.28

Among these companies, the evaluation results of the EPFF (Company for the Protection of Flora and Fauna) in Santiago de Cuba by Catanares (2020) are striking, as it is the first one carried out by INAF in a protected area.

The Guantánamo Agroforestry Company is also notable for having the highest proportion of carbon in biomass among all the values reported since 78% of the species in its artificial forests and 86% of the formations present in its natural forests achieve timber yields of over 200 m^3/ha, values much higher than those contained in the 2017 and 2019 reports.

2.8. Perspectives on carbon reporting in the forestry sector

The carbon reporting system prepared for the forest heritage management companies of the Agroforestry Business Group was, in the first instance, a step forward in the search for more information for decision-making on the management of forest resources through forest management projects; however, with the publication in 2013 by the UN-REDD Programme of the document on national forest monitoring systems, including monitoring and measurement, as well as reporting and verification (M and MRV) in the context of REDD+ activities, it then became clear that the extension of reporting to the entire forestry sector could contribute to at least three of the five activities put into force by Decision 1/CP. 16, paragraph 70, of the 16th Conference of the Parties (COP) to the UNFCCC in Cancun, Mexico:

- Conservation of forest carbon stocks.
- Sustainable management of forests.
- Enhancement of forest carbon stocks.

However, to achieve the generalization to the forestry sector of what has already been done to GAF, it would be necessary to introduce modifications to the scheme presented in Figure 2. 8, in such a way that what is identified there as the business system would be replaced by Heritage Management Entities, while what is identified as the GAF Forestry Division would become Heritage Management Agencies, and a change as apparently simple as this entails a substantial modification of the scope of the reports, because according to the Forestry, Flora, and Wildlife Division (DFFFS) of MINAG, at the end of 2016 the composition of agencies involved in the administration of the heritage was as shown in Figure 2.9, which shows that although three of them managed more than 80% of the total, 10 others were involved in these activities.

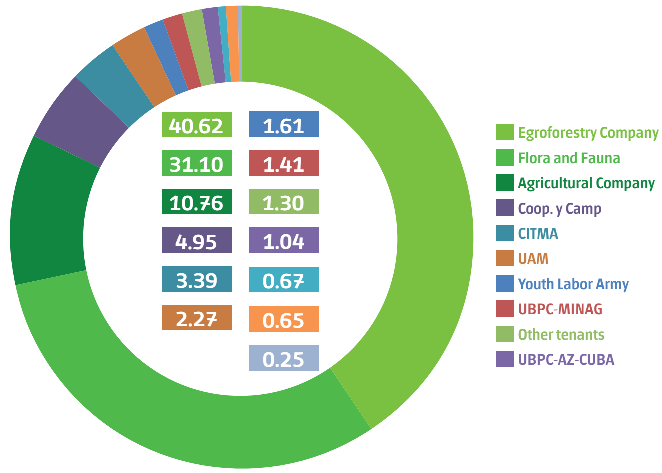

Figure 2.9. Relative participation (%) of entities involved in the management of the national forest heritage (DFFFS, 2016).

III. CLIMATE CHANGE MITIGATION THROUGH FORESTRY

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3.1. Concept of mitigation by forestry and its assessment from the baseline

Increases in wooded area and/or the volumre of growing stock lead to increases in atmospheric carbon removal; however, the reasons for these changes are not always the same.

Usually, implementation of the management plans of tenants who manage more than 500 ha of forestry heritage or the management plan for those who control less than 500 ha of forest heritage is associated with the certain technical management of the forest, which requires an economic investment known as forestry investment.

Forestry investment aims to manage the forest heritage in such a way as to maximize the main function for which it is intended, depending on its category: to produce timber; to protect the soil, water, and/or coastline; or to conserve biodiversity, recreation and/or develop educational/scientific activities. However, this does not prevent the effects of such management from also favoring and increasing, as a co-benefit, the provision of other environmental services by the forest, such as the removal of atmospheric carbon.

Though, this does not prevent the effects of such management from also favoring and increasing, as a co-benefit, the provision of other environmental services by the forest, such as the removal of atmospheric carbon.

Therefore, forestry investment generates a set of technical activities that characterize the heritage management in each forest category, which in turn gives rise to a set of expected results known as a baseline or, in terms of scenarios, as a business as usual (BAU) scenario, which can be applied both to products such as timber production and to environmental services such as the removal of atmospheric carbon.

Applying these concepts, Table 3.1- shows the composition of the heritage managed by the Mayabeque Agroforestry Company during 2016, composed of production, protection, and conservation forests, as well as the set of technical activities to which it dedicated forestry investment during 2016 for the management of this heritage (Peña, Álvarez and González, in press).

Assuming that the total area of the heritage managed by the company and the technical management of the heritage remain constant over the next 10 years, then two sets of expected outcomes or baselines would be generated (Figure 3.1.): one for the volume of standing timber and the other for the amount of carbon sequestered in the heritage (as a co-benefit).

Based on the results shown in Figure 3.1, it is possible to define a forestry mitigation action as one in which, through a modification of some of the aspects that are part of the technical management of the base year, an alternative carbon sequestration line is achieved that exceeds the results of the baseline for time evaluated, resulting in the mitigation magnitude of the difference between the values of the two lines (Figure 3.2).

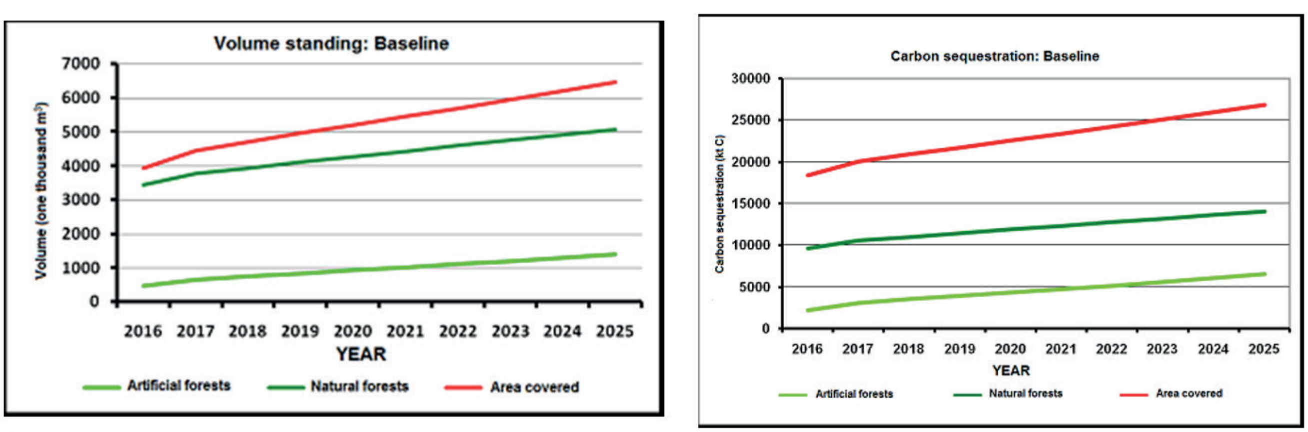


Figure 3.1. Baselines of standing volume and carbon sequestered, resulting from the timeline of the technical management carried out by the Mayabeque Forestry Company during 2016.

Table 3.1. Characterization of the technical management of the heritage during 2016.
Mayabeque Agroforestry Company.

INDICATOR	VALUE
Natural forests (ha):	34,523.70
• Production forests (ha):	16,288.30
• Protection forests (ha):	13,505.40
• Conservation forests (ha):	4,730.00
Established artificial forests (ha):	6,054.50
Artificial forests under development (ha):	2,332.00
Area to be reforested (ha):	2,070.10
• Without sickle bush (< 50 %) (%):	35.00
• With sickle bush (≥ 50 %) (%):	65.00
Swamp area (ha):	8,936.90
Grassland area (ha):	0.00
Area of agricultural land (ha):	10.20
Area of semi-deserts (ha):	0.00
Area of other unforested areas (ha):	1,140.70
Average annual development plan (ha):	425.00
Average survival of artificial forests (%):	84.00
Average reforestation achievement (%):	91.00
Average annual surface of burned areas (ha):	135.00
• Burned areas in unforested areas (%):	0
• Burned areas in areas to be reforested (%)	0
• Areas burned in developing artificial forests (%)	0
• Burned areas in established artificial forests (%)	45
• Burned areas in natural forests (%)	55
Average annual volume extracted per treatment/thinning (m^3):	2,044.50
• Treatment/thinning in artificial forests (%)	100
• Treatments/thinning in natural forests (%)	0
Average annual area of clear-cutting (ha):	65.50
• Clear-cutting in established artificial forests (%)	30
• Clear-cutting in natural forests (%)	70
Average annual volume harvested by other logging (m^3):	544.00
• In established artificial forests (%)	0
• In natural forests (%)	100
Current annual increment of natural forests (m^3/ha/year):	5.20
Average annual increment of artificial forests (m^3/ha/yr):	6.30

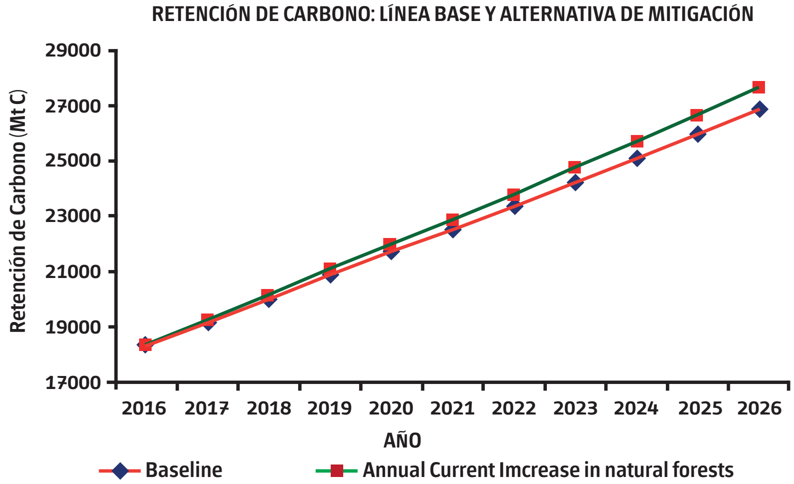


Figure 3.2. Carbon baseline and mitigation alternative, resulting from the temporal projection of the technical management carried out by the Mayabeque Forestry Company during 2016.

However, unlike forestry investment whose main objective is to manage the forest heritage in such a way as to improve the function of the forest according to its category, the implementation of a mitigation action will require that, in addition to the forestry investment, an environmental investment be made and in this case, while in the forestry investment the increase in carbon removal is a co-benefit, in the environmental investment the associated increase in standing volume would be the one that would constitute a co-benefit.

The calculation of the expected effects of a mitigation action requires, in general, establishing the magnitude of the modification of the technical management component of the base year to be taken into account and the time required to implement this modification. However, in cases where the modification covers a large part of the heritage and requires a long time for its full implementation, it will also be necessary to establish the annual area to be modified.

In addition to the above, considering that any mitigation action is an environmental investment, the selection of which option to implement requires not only an analysis of its environmental effects but also the typical economic analysis of any investment, including the magnitude of the costs to be incurred and revenues to be received (assuming that the carbon is paid for), economic efficiency, the cost/income ratio, the net present value (NPV), the internal rate of return (IRR) and the payback time.

SUMFOR version 4.00 provides heritage tenants with the ability to environmentally and economically assess up to 10 different mitigation alternatives, consisting of:

1. Increase the annual development plan;
2. Increase the achievement of (re)afforestation;
3. Decrease the area of established burned artificial forests;
4. Decrease the area of burned natural forests;
5. Decrease the annual area of clear-cutting in established artificial forests;
6. Decrease the annual area of clear-cutting in natural forests;
7. Decrease the annual volume harvested by other clear-cutting in established artificial forests;
8. Decrease the annual volume harvested by other fellings in natural forests;
9. To increase the average annual increment in established artificial forests; and
10. Increase the current annual increment in natural forests.

Of these, the last two require a definition of the area managed annually to increase the increment, because agroforestry companies usually manage heritages composed of thousands of hectares of both types of forest, which is 10 years cannot be managed with such objectives.

In the case of the Mayabeque Forestry Company, in 2018 the company requested the assessment of four of the above alternatives, establishing for each of them the following conditions (Table 3.2.), assuming as price per ton of CO_2 mitigated $2.00 (Peña, Álvarez and González, in press).

Table 3.2. Mitigation alternatives selected by the Mayabeque Forestry Company to be assessed.

Alternatives	Initial Value		Variation	Covered area (ha/y)	Unit cost		Implementation period (yr)	Capitalization period (yr)
	Value	Unit			Cost	Unit		
Increase the promotion plan	510.0	ha	20		6,500.00	$/ha	2	8
Decrease burned artificial forests	30.0	ha	90		400.00	$/ha protected	2	8
Increase the average annual increment of artificial forests.	6.4	M3/ ha/a	10	90.00	970.00	$/ha	2	8
Increase current annual increment	5.2	M3/ ha/a	10	225.00	1,000.00	$/ha	2	8

Concerning the data shown in Table 3.2, the implementation of these alternatives would mean:

- Increase the promotion plan from 510 ha/a to 612.0 ha/a, within two years.
- Decrease the area of established burned artificial forests from 30.0 ha/year to 3.0 ha/year within two years.
- Decrease the area of natural forests burned from 6.4 ha/year to 5.8 ha/year within two years.
- Increase the average annual increment (AIA) of artificial forests from 6.40 m^3/ha/year to 7.04 m^3/ha/year, in two years, but only in 90 ha of the 6,938.4 ha of artificial forests managed by the Company.
- Increase the annual current increment (ACI) of natural forests from 5.20 m^3/ha/year to 5.72m^3/ha/year, in two years, but only in 225 ha of the 34,427.70 ha of natural forests managed by the Company.

The assessment results achieved of the five alternatives are shown in Table 3.3.

Table 3.3. Assessment results of the mitigation alternatives.

Alternatives	Mitigation in 10 years (tC)	Total expenditure (TE - $)	Economic efficiency (CP - $/ tCO_2)	Gross income (GI - $)	Net income (NI - $)	TE/GI ratio (G/P-$/$)	NPV ($)	IRR (%)	IRR	
									Years	Months
Increase development plan	2,248,194.46	663,000.00	0.08	16,486,759.36	15,823,759.36	0.040	9,657,604.95	2.04	0	5
Decrease burned artificial forests	2,265,908.34	10,800.00	0.00	16,616,661.18	16,605,861.18	0.001	10,274,358.14	147.31	0	1
Increase average annual increase of artificial forests	2,654,143.58	174,600.00	0.02	19,463,719.55	19,289,119.55	0.009	11,740,905.36	9.82	0	2
Increase the current annual increment of natural forests	3,010,948.16	450,000.00	0.04	22,080,550.48	21,630,550.48	0.020	13,068,605.90	4.04	0	3

Based on the above results, it is up to the heritage tenant to decide which of the alternatives would be preferable to carry out, taking into consideration the following aspects:

- The availability of own financial capital, not committed to other objectives, which allows covering the demand required by the investment.
- If not, define if there is the possibility of resorting to some external financial source that in credit terms supports the development of this environmental investment.
- If such is the case, establish what would be the consequences of such an option on the expected revenues of the investment and in what terms of time its conditions would have to be complied with.
- If the initial conditions of the external financing are not satisfactory for the Company, define what possibilities would exist for negotiation of its terms, in such a way that they would be acceptable.
- Finally, if the option of resorting to external financing is not convenient for the Company, assess whether any of the other mitigation alternatives would be within the range of the Company's financial capabilities and not compromised with other objectives.

3.2. Results of mitigation evaluations in the Agroforestry Group.

As of the end of 2019, a total of six companies in the GAF had requested an environmental and economic assessment of 31 mitigation alternatives, as shown in Table 3.4.

Alternative 6 was not of interest because, except for the Mayabeque Forestry Company which reported 46 ha, no other company performs clear-cutting in natural forests, while in the case of alternative 7, except the Matanzas Forestry Company which reported 15.9 thousand cubic meters, no other company performs selective felling in established artificial forests. The remaining alternatives were selected by each company based on their particular conditions.

Table 3.4. Mitigation alternatives whose assessment was requested*

No.	Alternative	Pinar del Río 2017		C. del Su 2017r		Mayabeque 2017		Matanzas 2017		Villa Clara 2017		Gtnmo 2017	
		current	change	current	change	current	change	current	change	current	change	current	change
1	Increase the annual development plan (ha)	270.0	5			425.0	20	267.0	10	516.7	10		
2	Increase reforestation achievement (%)	92.2	5	87.0	2			69.7	87.0	66.0	10		
3	Decrease annual area of established artificial forests burned (ha)	38.6	10			60.8	55	12.0	50				
4	Decrease annual area of burned natural forests (ha)	192.8	20	146.9	10	74.3	90						
5	Decrease annual area of clear-cutting in established artificial forests (ha)	271.0	10					26.3	3	131.5	3		
6	Decrease annual area of clear-cutting in natural forests (ha)												
7	Decrease annual volume harvested by other fellings in established artificial forests (m3)												
8	Decrease annual volume harvested by other fellings in natural forests (m3)	20,634.0	50	4,722.1	20								
9	Increase average annual increment of artificial forests (m3/ha/year)	5.5	5	4.6	2	6.3	10	13.0	20	7.8	20	13.0	23
10	Increase current annual increment of natural forests (m3/ha/year)	4.3	2	7.8	3	5.2	10	3.9	10	5.6	10	11.0	18

*For all companies, the units in the first column are those indicated in each alternative, while the second column is always expressed as a percentage.

All alternatives had their mitigation achieved calculated, while their economic evaluations were carried out using three different hypothetical prices per ton of CO_2 mitigated: $1.00, $2.00 and $3.00, which are extremely low values compared to international prices.

The mitigation achieved by each alternative in each company is shown in Table 3.5.

Table 3.5. Mitigation by increased atmospheric carbon removal (kt CO_2), 10 years after implementation.

No.	Alternative	P. Río	C Sur	Mayabeque	Matanzas	V. Clara	Gtnmo
		2017	2017	2016	2018	2017	2017
1	Increase the annual development plan	**147.87**		**394.47**	**305.13**	**139.39**	
2	Increase reforestation achievement	**314.02**	**106.00**		**494.98**	**433.93**	
3	Decrease annual area of established artificial forests burned	**65.98**		**341.60**	**132.10**		
4	Decrease annual area of burned natural forests	**624.43**	**182.41**	**799.61**			
5	Decrease annual area of clear-cutting in established artificial forests	**1,687.19**			**96.03**	**21.77**	
8	Decrease annual volume harvested by other fellings in natural forests	**41.30**	**22.97**				
9	Increase average annual increment of artificial forests	**5,236.63**	**131.53**	**1,036.18**	**183.68**	**138.28**	**1,219.22**
10	Increase current annual increment of natural forests	**144.95**	**101.32**	**2,349.36**	**104.03**	**102.38**	**2,327.01**

Minimum values are shown in **red** and maximum values in **blue**.

The results achieved with the economic evaluations of each alternative, in each company and for each payment price per ton of CO_2 were consolidated, discarding the alternatives that were not economically profitable and identifying among all the remaining alternatives those that reached the minimum and maximum mitigation value, resulting in Table 3.6.

Table 3.6. Overall results of the mitigation assessments for six companies.

Indicators	Minimum results			Maximum results		
Total mitigation (kt CO_2)	1,061.43			7,864.43		
Mitigation by biomass (kt CO_2)	222.90			1,651.53		
Average total mitigation (kt CO_2/m)	8.85			65.54		
Indicators	tCO_2 Price			tCO_2 Price		
	$ 1.00	$ 2.00	$ 3.00	$ 1.00	$ 2.00	$ 3.00
Feasible economic alternatives (%)	61.29	80,65	90.32	61.29	80.65	90.32
Total expenditure (thousands $)	701.71	700.24	700.24	3,579.82	3,627.13	4,640.97
Mitigation cost ($/$tCO_2$)	0.6611	0.6597	0.6597	0.4552	0.4612	0.5901
Total net revenue (thousands $)	1,460.72	1,696.87	1,748.21	19,824.35	21,201.72	22,165.20
Maximum payback period (m)	59	59	59	108	108	108

As can be seen, over a period of 10 years the six companies can increase their atmospheric CO_2 removals between 1.1 and 7.9 million tons, depending on which mitigation alternative is implemented, and as the price per ton of CO_2 increases, the number of economically profitable mitigation alternatives also increases, until it reaches almost the maximum amount possible when $3.00 was used as the price, making further increases meaningless (Figure 3.3).

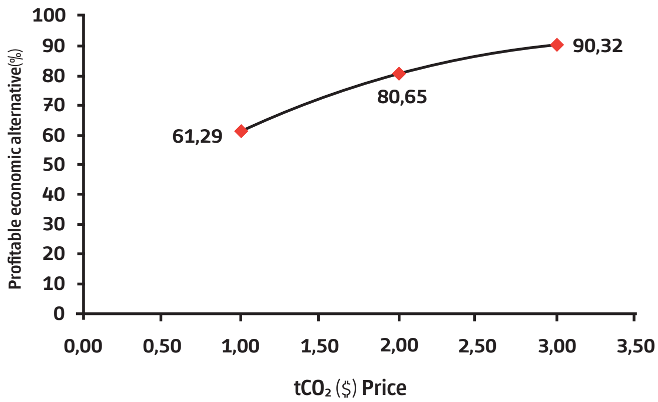


Figure 3.3. Variation of the number of economically profitable mitigation alternatives as a function of the price per ton of CO_2

Including all components and carbon pools of the heritage and considering an implementation period (implementation+capitalization) of 10 years, among the six GAF companies:

- as a minimum, with an expenditure of 0.7 million pesos to be recovered in a maximum time of 4.9 years, they would obtain a minimum net income of 1.5 million pesos, with average mitigation of 8.85 kt CO_2 /m and economic efficiency of the investment of $0.66/ tCO_2 atmospheric mitigation.
- as a maximum, with an expenditure of 4.6 million pesos to be recovered in a maximum time of 9.0 years, they would obtain a maximum net income of 22.2 million pesos, with average mitigation of 16.54 kt CO_2 /m and economic efficiency of the investment of $0.59/ tCO_2 atmospheric mitigation.

The total amount of funding required to pay for the mitigation would vary between a minimum of 1.85 and a maximum of 33.07 million pesos, depending on the price per ton of CO_2 mitigated.

After the six assessments shown above, the Granma Agroforestry Company (Álvarez, Barrios and Mojena, 2019), the EAF Sierra Cristal (Catanares *et al.*, 2019), two of the Imías Agroforestry Company units (Frómeta, Romero, and Moreira, 2019), and the Santiago de Cuba Agroforestry Company (Catanares, Debrot and Esparraguera, 2020) were also analyzed using the same method, thus expanding the available information.

Taking into account that only 28 companies with forest heritage are included in the GAF (without considering the remaining heritage tenants), it is possible to consider how important it would be to implement mitigation alternatives carried out at the company level, based on modifications to the technical management reported in the base year according to the particular interest of each company, which would also have a positive impact on the fulfillment of forest functions as a complementary co-benefit, thereby creating the conditions required for access to existing international financing mechanisms (REDD+, GCF, etc.).

3.3. Status of proposed mitigation actions for the forestry sector in the National Communications

The possibility of undertaking actions with forests that would result in the reduction of Cuba's total net GHG emissions was taken into consideration from the process of preparing the First National Communication (Republic of Cuba, 2001) during the period 1998-2001, resulting in the inclusion of three alternatives:

- Increasing the removal of atmospheric CO_2 by forests, increasing the forest area.
- Increasing carbon sequestration by increasing the time of use of durable wood products.
- Substitution of fossil fuels by using forest biomass as a renewable fuel.

Concerning the first alternative, at the end of 2000, the forest cover in Cuba was 22.2% (2,435.0 Kha) (Álvarez, Mercadet, *et al*., 2011), a figure that by the end of 2017 had changed to a value of 31.3% (3,242.3 Kha) (DFFFS, 2017), which accounts for an increase in forest area covered by forests at the national level of 9.1% (807.3 Kha).

Based on estimates of annual carbon removal by forests for 2002 (López *et al*., 2005), the above-ground biomass of the Cuban forest removed an average of 1.74 MgC*ha^{-1}*year^{-1} from the atmosphere, which means that the increase in forest area recorded between 2000 and 2017 accounts for a cumulative increase in national removals of 22.5 TgC compared to 2000.

As for the second alternative, the use of artificial drying of wood as a way of prolonging its useful life has not shown the desired progress, even though in 2011 there was a potential capacity per drying cycle of more than 1,300 m^3 in Cuba (Álvarez, Mercadet, *et al*, 2011), while in terms of wood preservation, the only plant currently in operation is located in Guane borough, Pinar del Río province, with a potential installed capacity of approximately 15,000 m^3 per year (Álvarez, Mercadet, *et al*., 2011), mainly dedicated to the chemical pressure treatment of pine poles (*P. caribaea var. caribaea* and *P. tropicalis*) for electrical and telephone service.

This plant, after eight and a half years of operation (2009-2018), has treated 82,752.9 m^3 of wood, thus extending its useful life by at least three times and consequently sequestering the carbon contained in it, estimated at 19,975 tC.

The third alternative has two options: the use of charcoal for heat generation and the use of forest biomass for electricity production.

Charcoal production in 2010 was around one million 400 thousand bags (56,000 t), with an upward trend that in 2018 reached 32,875 t in GAF alone (Forestry Division, 2019), to which must be added what other business groups also carry out (e.g. Flora and Fauna Business Group; Agricultural Business Group, etc.), and in this sense, the existence of thousands of hectares of the sickle bush (Dichrostachys cinerea L.) is an important alternative for this option, as its wood offers good heat potential (4,654 kcal*kg^{-1}; Manzanares, *et al*., 2008).

On the other hand, the project "Generation and distribution of renewable energy based on modern energy services. The case of the Isle of Youth" (GP/CUB/05/001), whose main objective was to reduce greenhouse gas (GHG) emissions in Cuba through the promotion of renewable energy technologies, did not achieve the expected final results for various reasons.

For the preparation of the Second National Communication (Republic of Cuba, 2015), the alternative of increasing the removal of atmospheric CO_2 by forests by increasing the forest area was considered again, and a new one was added, based on the change of category from productive to conservative forest in some heritage areas.

In the first case, it was proposed to reach 35% forest cover in Cuba by 2050, which according to Somoza *et al*. (2016) would represent removals amounting to 21,123.05 kt CO_2 , an amount that in the light of the preparation of the 2030 projection for all economic sectors of Cuba would be adjusted to 17,913.34 kt CO_2.

However, on the one hand, since 2010, when this alternative was evaluated, until the end of 2018, the area covered by forests in Cuba has increased to 31.49%, without any clear perspective on the possible incorporation of new lands into the national forest heritage that would allow reaching 35% of the area covered in 2050, and on the other hand, when preparing the net emissions balance of the forestry sector as part of the GHG Inventory-2016, the use of the 1996 IPCC Guidelines was changed to the 2006 Guidelines, a change which, by including the carbon contained in the sub-terrestrial biomass of the forests in the calculations, raised the removals achieved by the area covered to 27,147.20 kt CO_2, a value that is 6,024.15 kt CO_2 higher than that estimated by the alternative analyzed by 2050. This justifies the rejection of this alternative from 2019 onward.

In the second case, it was considered that changing part of the production forests to conservation forests would increase the carbon sequestered in those areas because felling would be reduced to only those established by the management plan for that category, which would improve the forest's performance and reduce its degradation. In this sense, the Empresa Forestal Integral (EFI) Victoria de Girón would be recategorized in its functions and would change from a GAF production entity to a protected area of the Flora and Fauna Company, so that the change from 115.4 Kha of productive forest to conserving forest would make possible the mitigation of some 23.5 $ktCO_2eq$ annually, at 29.3 USD/tCO_2e avoided.

The forest heritage managed by the EFI Victoria de Girón, the largest company-managed forest in Cuba, was transferred to the administration of the Grupo Empresarial para la Conservación de la Flora y la Fauna, changing its management objectives completely, becoming a Managed Resource Protected Area.

However, given the category of protected area that was assigned to it, instead of changing the categorization of the producer forests to protective forests, it was decided to reduce the annual harvesting levels of the existing producer forests by more than 80% compared to those reported by the previous tenant, a modification that has had similar results to those expected in terms of mitigation, but probably at a lower net cost than initially calculated, by maintaining a certain level of marketable timber production in force.

Considering that there is no immediate prospect of recategorization of these forests, the implementation of this mitigation alternative is concluded.

3.4. Cuba's Nationally Determined Contribution, the Paris Agreement, and the Forestry Sector

At the end of 2015 and prior to the Paris Conference of the Parties (COP-21), Cuba provisionally showed a Nationally Determined Contribution (NDC) that included a reduction in emissions that was subsequently ratified, in which, among other aspects, it included the construction by 2030 (depending on compliance with the international obligations established under the Convention) of 19 bioelectric plants with 755 MW, using sugarcane and forest biomass as fuel.

At the end of 2016, COP-21 was held, which resulted in the Paris Agreement, which established that Parties shall report on the progress of GHG emissions and removals included in their Nationally Determined Contributions and, in doing so, promote environmental integrity, transparency, accuracy, and consistency to avoid double counting, with the objective of enabling a clear assessment of progress and results achieved.

Of the bioelectric plants committed, several are already under construction and the first one in early 2020, located in the municipality of Ciro Redondo, Ciego de Avila province, began generating electricity with a potential annual capacity of 89 GWh.

At the end of 2019, the update of the NDC submitted by Cuba in 2015 to the Paris Agreement for the period 2020-2030 was initiated (Republic of Cuba, 2020), which for new mitigation contributions states that, "Considering the sectoral contribution to the national GHG inventory, the sectors prioritized for emission reductions, at the current stage, are energy and agriculture. These sectors are the focus of Cuba's efforts to identify and implement mitigation measures."

Among the new mitigation contributions by sector proposed in Cuba's NDC update, there is one referring to the forestry sector shown in Table 3.7.

In addition, according to paragraph 85 of the COP Decision adopting the Paris Agreement, the Capacity Building Initiative for Transparency (CBIT) was established, which aims to: (a) strengthen national institutions for transparency-related activities, in line with national priorities; (b) provide relevant tools, training and assistance to comply with the provisions stipulated in Article 13 of the Agreement; and, (c) help improve transparency over time.

Table 3.7. Proposed new forest mitigation action for Cuba's NDC update.

Name of the contribution: Increasing Cuba's forest cover to 33% by 2030.					
Objective	**Monitoring indicator (magnitude)**	**Executing Entity**	**Status**	**Base year / Target year**	**Base value / Target value**
Non-GHG contribution. Objective: To increase Cuba's forest cover.	Covered area by established forest (ha).	Agroforestry Business Group; Flora and Fauna Business Group; other national heritage managers.	Preparation for implementation.	2019/2030	3,260.940 ha/ 3,434.400 ha
Brief description of the contribution.	Cuba's forest area (area susceptible to forest cover) at the end of 2018 was 3,573.400 ha, of which 3,269.400 ha were already covered by forests and 304,000 ha remained to be covered (DFFFS, 2019). The contribution envisages increasing the area covered by forests by 165,000 ha in the period 2019 - 2030, reaching coverage of 33% in Cuba. With its own effort, Cuba can increase the area covered by 80 thousand hectares by 2030 (with a reforestation rate equal to that of the 2010-2018 period), which would constitute its unconditional contribution. This would cost USD 1.96 billion and remove 115.7 million tCO_2 of atmospheric CO_2 in that period. With additional support, Cuba can increase the pace of reforestation and achieve the proposed increase of 165,000 hectares by 2030. To do so, it requires, in addition to investment with its own resources, additional financial support of USD 2,291 million. This variant would increase the area covered by established artificial forests between 2019 and 2030, removing 169.9 million tCO_2 of atmospheric CO_2 in that period.				
Results to be achieved.	Increase forest cover by 165 thousand ha in the period 2019 - 2030. Remove 169.9 million atmospheric tCO_2 in the period 2019 - 2030.				
Conditions for the contribution's implementation.	Long-term credit support of USD 2,291 million is required for the implementation of the conditional contribution.				
Methodologies and/ or methods expected to be monitored.	The activity level data (forest cover) is obtained from the complementary statistical system of MINAG. The forest carbon sequestration factor is calculated according to the methodologies of the IPCC, Guidelines 2006, Vol. 4; Chapter 4. Forest Land.				
Actions required to comply with the Paris Agreement	The MRV system needs to be formally established for the measures that make up the contribution.				

Therefore, based on national needs and priorities and following the CBIT programming instructions, paragraphs 18 and 19, MINAG decided to propose the implementation of the project "Strengthening institutional and technical capacities in the agriculture, forestry and other land uses (AFOLU) sector in Cuba to improve transparency under the Paris Agreement" to the Global Environment Facility (GEF), managed by the Food and Agriculture Organization of the United Nations (FAO) and coordinated by the Research Institute in Pastures and Forages (IIPF), whose main objective would be: In line with the State Plan for Addressing Climate Change (Tarea Vida Project), strengthen the institutional and technical capacities of the agriculture, forestry and other land use sub-sectors to respond to the enhanced transparency requirements under the Paris Agreement.

This project aims, in essence, to create in the central state levels of MINAG (Agricultural Division, Livestock Division, Forestry Division and Soils Department) the capacities and information systems required for the formulation of their respective Measurement, Reporting and Verification (MRV) systems, and that, based on these, each directorate, with the support of the branch's research institutes, assumes the preparation of the corresponding reports related to net emission balances, This should take place between 2019 and 2022, so that from 2023 onward the Ministry's Division for Science, Innovation and Environment will act as a consolidating unit for these sub-sectoral reports to make up the AFOLU sector report (Figure 3. 4.), in order for MINAG, as a Central State Administration Body, to show the information required for the GHG Emission Inventories, for the National Communications, for the Biennial Update Reports (BUR), for the update of the Nationally Determined Emission Contributions (NDC) and later on, for the Biennial Transparency Reports (BTR), according to the schedule shown in Figure 3.5., all of which are government reports to the UNFCCC.

The implementation of this project would entail an additional modification to the scheme set out in Figure 2.4, in which the bodies holding the forest heritage would not show their information to INAF for the preparation of reports, but to the Forestry, Flora, and Wildlife Division, which would establish the appropriate working mechanisms with INAF to carry out the evaluations and prepare the reports, which would return to the Division for approval and from there, would pass to the Division of Science, Innovation and the Environment.

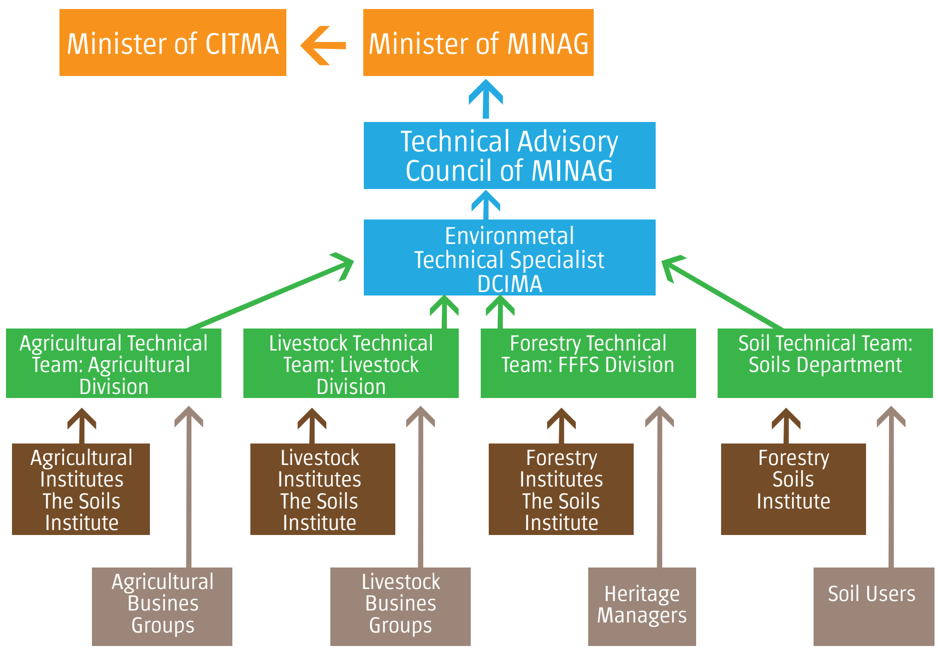
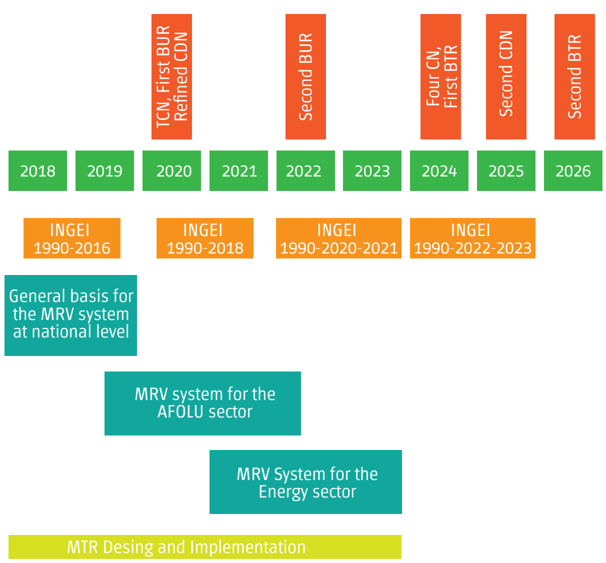


Figure 3.4. Organizational system to be created for MINAG to take over the preparation and show all reports related to the AFOLU sector (Blanco, 2019).



- INGEI-National GHG Inventory
- TCN-Third National Communication.
- MVR- Measurement, Reporting and Verification System.
- BTR-Biennial Transparency Report.
- BUR- Biennial Updated Emissions Report.
- AFOLU- Agriculture, Forestry and Other Land Use Sector.
- NDC- Nationally Determined Emission Reduction Commitment.

Figure 3.5. Schedule of actions to be implemented by Cuba in compliance with the Paris Agreement (Carrera, 2019).

3.5. The Forestry Sector and the REDD+ mechanism

As stated by Akong, *et al*. (2009), the definition of REDD+ was not clearly defined at that time and was, therefore, a contentious issue in the negotiations, considering that the concept could include the following options:

- RED=Reducing emissions due to deforestation: Only changes in the area from "forest" to "unforested" area are included and the details depend very much on the operational definition of "forest".

- REDD=add to the above (forest) degradation or changes towards smaller carbon pools within the forest; details are highly dependent on the operational definition of "forest".

- REDD+=adds to the above the enhancement of stocks within and towards the "forest"; in some versions, REDD+ also includes lowlands irrespective of their forest status; details still depend very much on the operational definition of "forest".

- REDD++=adds to the above land cover transitions that affect carbon pools, whether lowland or mineral soils, trees outside forests, agroforestry, artificial or natural forests. It does not depend on the operational definition of "forest".

However, nine years later, Soto (2018) defined REDD+ as a mechanism accepted in 2007 by the United Nations Framework Convention on Climate Change (UNFCCC) and established by successive Conference of the Parties (COP) agreements to encourage developing countries to contribute to climate change mitigation efforts through:

- reducing Greenhouse Gas (GHG) emissions by slowing, halting, and reversing forest loss and degradation.
- increasing GHG removals from the earth's atmosphere through the conservation, management, and expansion of forests.

Interaction between the Cuban forestry sector and the REDD+ mechanism began in July 2009, before the COP in Copenhagen, when an INAF delegation attended a regional training workshop held in Cali, Colombia, to disseminate the characteristics and possibilities of the mechanism, as a result of which an initial analysis was made of Cuba's compliance with the requirements for the presentation of REDD+ projects, which indicated that (Mercadet and Ajete, 2009):

- The country showed its First National Communication to the UNFCCC in 2001 and started the preparation of the Second Communication at the end of 2008.
- National indicators for the assessment of sustainable forest management are effective.
- Land tenure is legally supported at the national level.
- There should be no objection to formulating an institutional commitment to implement REDD+ activities (after the entry into this funding mechanism is assessed and approved).
- All that remains to be done is to prepare the national definition of degraded forest, identify its distribution in Cuba, as well as the causes and drivers of degradation.

Based on the above, the necessary continuity tasks were proposed to:

1. The formulation, presentation, and access to REDD+ projects.
2. Access to the training course that would be held later in Argentina, on the use of satellite images and systems for forest inventories.
3. The preparation of national capacities on REDD+ projects.

Including a proposal to request the advice of Mr. Erich Mies, Programme Manager of the German NGO International Training and Development (InWEnt), to identify which NGO or donor would be the most appropriate to show him the type of project to be implemented in Cuba, according to the specific format to be used, taking into account that Cuba's forest cover was systematically increasing annually and therefore there was no rate of deforestation, there was no reported rate of deforestation, which had been internationally recognized by the FAO in its reports on the Status of the World's Forests, and therefore, Cuba would participate in projects aimed at reducing emissions by solving forest degradation and achieving sustainable forest management.

Two years later, in July 2011, the same delegation attended a second regional training workshop in Quito, Ecuador, on biodiversity-related safeguards in the framework of the REDD+ mechanism. In this case, a report related to the objectives of the workshop was shown on behalf of Cuba (Annex 4).

In 2013, a third regional training workshop on REDD+ was held in Cali, Colombia, which was attended by a delegation from the National Forestry Division of MINAG, where the opportunities offered by REDD+ for the countries of the region were discussed. In the case of Cuba, the report shown detailed Cuba's situation for insertion into the mechanism summarized in the following aspects (Russó and Palenzuela†, 2013):

- The decision to establish the engagement commitment with the UN has not yet been taken.
- The First National Communication was shown in 2001; the Second in 2015 and the Third in 2020. The Forestry Sector has been involved in the preparation of all of them.
- There is a legal framework for safeguarding biodiversity, including the Environment Law, the Forestry Law, the National Environmental Strategy and that of the MINAG, the National Biodiversity Commission, among other instruments.
- From 1990 to 2006, in even years, the net balance of greenhouse gas emissions from Cuban forests has been systematically reported, using internationally accepted methodologies. Balances for 2008 and 2010 will be prepared next year. The net CO_2 removals (Gg) from biomass changes in Cuban forests in the even years of the period 1990-2002 were as shown in Table 3.7.

Table 3.7. Results of the net carbon balance of the Cuban forestry sector.
Even years of the period 1990 - 2002.

Indicator	Año						
	1990	1992	1994	1996	1998	2000	2002
CO2 removals	-13,731.82	-15,306.18	-15,950.59	-16,420.55	-15,666.29	-15,967.89	-16,653.66
CO2 emissions	1,559.87	1,508.10	1,447.52	1,621.18	1,420.36	1,988.65	1,828.82
Net CO2 removals	-12,171.95	-13,798.08	-14,513.07	-14,799.37	-14,245.94	-13,979.24	-14,824.84

- Work has been underway since 1998 to adapt these methodologies to Cuba's own conditions, and the 2012 and 2013 Carbon Registers have already been shown, and preparations for 2014 have begun.
- The 2013 Register already includes 12 Forestry Companies that manage 1,045,099.3 ha of the heritage, more than a quarter of the 2012 national total (3,913,062.3 ha), with average sequestration of 265.4 tC/ha and total sequestration of 277,360.1 ktC.
- All of Cuba's forest heritage is state-owned, so there are no ownership conflicts.
- There is no reported deforestation, which has been internationally recognized by the FAO in its reports on the State of the World's Forests, and for this reason, Cuba would participate in projects aimed at reducing emissions by reducing forest degradation and sustainable management.
- In both 2009 and 2011, staff from the Agroforestry Research Institute have participated in regional workshops on REDD+, to facilitate the start of Cuba's adoption of this mechanism.

At the end of 2013, the 19th COP of the United Nations Framework Convention on Climate Change was held in Warsaw, Poland, which was attended by a Cuban government delegation. As a result of the negotiations and the decisions adopted, the delegation drafted a document alerting the Cuban forestry sector to the opportunities that were opening up within the framework of the REDD+ mechanism (Annex 5; Rey, 2014).

On 23 December 2014, the Minister of Agriculture informed the Minister of Science, Technology and Environment, Cuba's Focal Point to the United Nations Framework Convention on Climate Change, that the Ministry of Agriculture was willing to assume national coordination of Cuba's REDD+ Programme, On 27 January 2015, the Minister of Science, Technology and Environment informed the Minister of Agriculture that she had taken note of the decision and that, consequently, the corresponding notification would be made to the United Nations Framework Convention on Climate Change.

One year later, between late November and early December 2016, a delegation from MINAG attended the capacity building workshop for the project entitled National Forest Monitoring Systems for REDD+ Reporting, organized at FAO headquarters in Rome, Italy, with the following objectives:

1. To show an overview of the different automated systems already available for the capture, processing, and analysis of satellite images as far as forest areas are concerned.
2. To promote the exchange of experience gained in the use of these systems by the countries participating in the project.
3. To create a space for critical evaluation by the 18 participating countries on the performance of the project, both in technical and organizational aspects.
4. To show a perspective on the future of the project.

At a meeting held by the project coordinators with the Cuban delegation, it was made clear that the opening at INAF of a computer center technically prepared for the use of the automated systems already created and for the capture, processing, and analysis of satellite images was a decision of the project currently underway and that such equipment would be delivered to Cuba as a donation. However, due to the unavailability of technically appropriate offers in Cuba, their acquisition was being managed by FAO abroad, which had encountered difficulties due to the US blockade (Álvarez, 2016).

Nevertheless, even though the unavailability of funding for the further development of a second phase of the project canceled the insertion of Cuba in the REDD+ Reports, considering the exchanges and experiences gained during the workshop, at the end of 2016 the INAF prepared and later submitted for the consideration of the Forestry, Flora, and Wildlife Division, a first version of the document entitled Conceptualization and classification of degraded forests in Cuba in the context of the REDD+ mechanism (Álvarez, 2017).

In mid-2018, the first local action related to the mechanism was carried out in Cuba, consisting of an informative workshop on the REDD+ readiness process, whose general objective was to "Provide information to representatives of national institutions on the requirements for accessing positive incentives through the implementation of mitigation actions in the forestry sector (REDD+)", organized by the Forestry, Flora, and Wildlife Directorate of MINAG, with technical support from FAO and INAF (Santos and Soto, 2018).

Six technical topics were addressed at the workshop: (1) Background and generalities of the REDD+ process; (2) REDD+ readiness; (3) REDD+ implementation; (4) Payment for results; (5) Institutional arrangements; and (6) Next steps and timeline, while the main outputs achieved were (Santos and Soto, 2018):

a. (a) participants deepened their knowledge on the REDD+ mechanism and the requirements for its implementation in Cuba;
b. (b) it was decided, in the first instance, to initiate the national REDD+ readiness process.
c. (c) It was proposed to form the Group to establish the climate action plan for the forestry sector, the subgroups that would integrate it, the main role of each of them, and the participating institutions:
    - Political Instance: Inter-ministerial Group on Climate Change.
    - Technical body: Consulting Council for Sustainable Forestry Development (Forestry Consulting Council for short).
    - Working group: the bodies that would make up the group were established.
    - Technical Group: the bodies that would integrate it were established.
d. The next steps for advancing the REDD+ readiness process were set out:
    - Collect background information. It is the responsibility of the National Forestry Division.
    - Update the climate action plan for the forestry sector. It is the responsibility of INAF.
    - Proposal for a workshop to initiate REDD+ strategy. It is the responsibility of FAO.

Next workshop: week 24-28 September 2018. Agenda items:
- Submit and adjust the workshop proposal to initiate the development of the national REDD+ strategy and establish links with the development of the CBIT project.
- Show and adjust the constitution, objectives, roles, and tasks of the established groups.
- Show the first versions of the compilation of the background information and the climate action plan for the forestry sector.
- Establish a timetable of activities.
- Tasks and pathways for the establishment of the Safeguards Information System (SIS).

Options of participating countries to transfer experiences and support the process: In REDD+ strategy: Argentina, Ecuador or Mexico; in Safeguards Information System (SIS): Colombia or Mexico.

e. other ongoing processes were mobilized in collaboration with FAO; specifically, with the Global Forest Resources Assessment (FRA) and the Forest Monitoring Toolkit (SEPAL).

In compliance with the action for which INAF was responsible as part of the next steps to advance the REDD+ readiness process, in the month of July 2018, the update of the Forestry Program to Address Climate Change for the period 2019-2025 was drafted, and later delivered to the Forestry, Wildlife, and Forest Division for its consideration (Annex 6).

The next meeting was held in November 2018, two months later than initially planned, under the title Workshop to initiate actions for Cuba's participation in REDD+, with the participation of representatives from Ecuador and Colombia, pursuing the following objectives:

General objective: To advance mitigation actions in the forestry sector for Cuba's participation in the REDD+ mechanism.

Specific objectives:

- Adjust objectives, roles, and tasks for the established working groups.
- To learn about experiences and lessons learned from countries in the region that are advanced in the preparation and implementation of REDD+.
- Establish a roadmap for the formulation of the national REDD+ strategy or action plan.
- Initiate reflection on the development of the Cancun safeguards approach.

Finally, a meeting of the Forestry Consulting Council, a consulting body of the Forestry, Flora, and Wildlife Division, was convened in June 2019 to approve the working groups proposed for the REDD+ mechanism at the November 2018 workshop, as well as their working functions.

To date, no projects funded by the REDD+ mechanism of the United Nations Framework Convention on Climate Change are being carried out in Cuba.

3.6. Mitigation actions in the context of the ECOVALOR project

In late 2018, Cuba's National Center for Protected Areas initiated a project funded by the Global Environment Facility (GEF) and administered by the United Nations Development Programme (UNDP) entitled "Incorporating Multiple Environmental Considerations and their Economic Implications in the Management of Landscapes, Forests and Productive Sectors in Cuba" (ECOVALOR), in which one of its goals is the removal of 2.8 million tons of CO_2 over a period of 20 years (6 years of implementation and 14 years of capitalization) by 17 forest intervention sites, five of which are located in agroforestry companies (EAF) and the rest in protected areas (PA); however, as a condition for carrying out the Ex-ACT evaluation of the project, as well as the periodic monitoring evaluations of its results in relation to the fulfillment of this goal, the GEF established the use of the EX-ACT system prepared by the Food and Agriculture Organization of the United Nations (FAO), with the collaboration of the French Development Research Institute and the World Bank (Figure 3. 6).

This system, based on the comparison of the expected effects on atmospheric CO_2 removals without and with a project, in the cases of land-use change evaluates three mitigation alternatives:

- Reduction of deforestation (not included in the project because it does not exist in Cuba).
- Reforestation (the project includes 2,650 ha).
- Other changes in land use (not included in the project because it is not foreseen).

While for the mitigation alternatives through soil and forest management, it is based on the changes produced by the project on the initial level of forest degradation (the project includes 2,750 ha of artificial forests and 8,200 ha of natural forests), using a scale of six levels (Table 3.8).

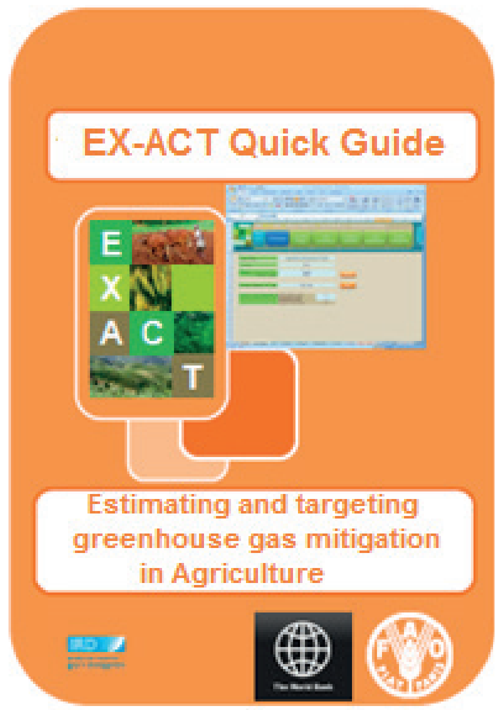


Figure 3.6. Presentation of the introductory material on the use of the EX-ACT system

Table 3.8. Degradation levels and associated biomass losses used by Ex-Act.

Tier	Qualification	Biomass loss due to degradation (%)	
		By default	Adjusted for Cuba[1]
1	No degradation	0	0
2	Very low degradation	10	10
3	Low degradation	20	19
4	Moderate degradation	40	29
5	Severe degradation	60	39
6	Extreme degradation	80	48

1Calculated from results obtained with SUMFOR.
(Audeberg, personal communication).

This implies that to improve future reporting on the results of mitigation alternatives with forests, it was envisaged that the ECOVALOR project would:

a. Undertake a comparison between the methods and results obtained by EX-ACT and SUMFOR to determine the levels of conservation of carbon stocks in forests.

b. To undertake an ex-act assessment of the potential effects of the project on carbon balances, based on a hypothetical estimate of initial and final levels of forest degradation.

c. Prepare a methodology to determine the actual levels of forest degradation at the beginning, during, and after completing the project.

a. Comparison of the Ex-Act and SUMFOR systems.

In this regard, in November 2019, ECOVALOR organized a 10-day consultancy with Mr. Philip Benedikt Audebert, an independent consultant and one of the authors of the EX-ACT system, which included among its objectives the comparison between the analysis methods and results of the EX-ACT tool (FAO) and the SUMFOR tool (INAF, Cuba), to improve the experiences of carbon balance analysis (ECOVALOR, 2019).

The comparison results between the two tools considered: (1) the description and analysis of the scope of each one and, (2) the differences and synergies between them, and the considerations made are shown below (Hernández, *et al*., 2019):

Ex-Act: A tool developed by the Food and Agriculture Organization of the United Nations (FAO), which aims to "provide ex-act estimates of the mitigation potential of agricultural and forestry development projects by estimating the net carbon balance from greenhouse gas (GHG) emissions and carbon sequestration" (Bernoux, *et al*., 2016). EX-ACT is a "soil-based accounting system, which measures soil carbon stocks, stock changes per unit of land, CH_4 and N_2O emissions expressed in tCO_2eq per hectare and year" (Bernoux, *et al*., 20162). The main output of the tool is an estimate of the carbon balance, which is associated with the adoption of sustainable land management practices compared to a BAU (business as usual) scenario. The tool has been developed using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, complemented by other existing methodologies.

SUMFOR: It is an Excel-based automated system that reanalyzes climate change mitigation alternatives for agroforestry companies already assessed and formulates mitigation alternatives for new companies in the sector. Mercadet and Alvarez (2009) published the methodology from which version 1.0 of the automated SUMFOR (Forest Sinks) system, designed to calculate carbon sequestration in the base year, was prepared. Both authors later addressed the "system extension by adding the baseline calculation for 10 years, the deepening of aspects related to the validation and evaluation of Indicator 3.5 for Sustainable Forest Management - Contribution of forest ecosystems to the reduction of the greenhouse effect and the stabilization of climate change-as part of Criterion III -Contribution of forest ecosystems to environmental services-, until reaching version 2.13 (Álvarez, A., Alicia Mercadet, *et al*., 2011), assuming that the forest recourse management reported in the base year would remain constant" (Mercadet and Álvarez, 2019).

Differences and Synergies[1]:

Although both tools aim to assess carbon impacts in the AFOLU sector, the tools differ significantly in their scope and purpose.

Ex-Act offers the advantage of a broad scope of greenhouse gas analysis, through its inclusion of a wide spectrum of agricultural, forestry, and other land-use activities (AFOLU), including, among others, forest and unforested land-use changes, management of annually flooded rice cropland, perennial, grassland, livestock, degradation, coastal wetlands, input use, and infrastructure investments, fisheries and aquaculture management. In addition, it considers five different carbon stocks (above-ground biomass, below-ground biomass, deadwood, litter, and soil carbon). The tool considers the three main gases produced by the AFOLU sector, namely carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4).

Ex-Act was specifically designed for broad application in all possible continents, climates, and soils and for different project time horizons. The tool uses a Tier 1-Tier 2 approach, i.e. it provides IPCC default values for emission factors and can be refined with national or sub-national data, given their availability. Although Ex-Act does not directly provide economic analysis, most of its results and considerations can be used for economic and financial analysis. In particular, Ex-Act's main output, the carbon balance in tCO_2-e, can be multiplied with a market price or the social cost of a ton of CO_2-e to provide an estimate of the environmental benefit generated through a project. Other considerations are the use of increased or sequestered soil carbon as an indicator of increased soil fertility, replacing fertilizer use and increasing productivity and ultimately also improving water quality. Carbon increment or sequestration in biomass can be used to calculate the commercial value of forests (Audebert, *et al*. 2019).

SUMFOR was initially designed as a forest inventory for Cuba. This explains why it only covers forestry activities, including afforestation/reforestation. It was done specifically for the Cuban context and has very specific carbon storage factors for the various boroughs and regions of Cuba. SUMFOR also breaks down the forest types into the species growing in Cuba. This allows the assessment to be very accurate. In addition, it reversed the Tier 1-Tier 2 logic used by the Ex-Act tool. In line with the IPCC recommendation to use specific emission and carbon sequestration factors where data are available, SUMFOR first asks the user to provide specific information on the forest species, the area where the forest species are planted, their yield and their carbon sequestration. Only when this data or information is not available locally, the tool will use national averages as default data. In its fourth version, SUMFOR also offers a carbon balance analysis and an economic analysis. The carbon balance allows a comparison of mitigation alternatives for forestry activities. The approximate economic analysis links the carbon balance to a price paid per tCO_2 mitigated. SUMFOR will provide the basis for a large-scale payment for environmental services scheme in the adoption process by the Cuban government from 2019.

Both tools provide users with different advantages. For the reasons explained above, it cannot be concluded that one tool can be preferred over the other. Rather, the tools are highly complementary. SUMFOR can feed Ex-Act with its Tier 2 values in the forest management part. Ex-Act can calculate the carbon balance impact of forest management in conjunction with other activities in the AFOLU sector.

A recommendation for the future would be to always report carbon balance values from both systems to identify a range of variability in the results.

An important consideration in carbon balance analyses is the uncertainty of the estimate, as large uncertainties in carbon balance estimates are very common. Ex-Act already has an appreciation of the analysis uncertainty of the analysis. This uncertainty is due, in the case of default or tier one values, to regional emission factors. In the case of using Tier 2 values, the analysis uncertainty of the analysis drops significantly, as they are more representative of the reality in a specific country and/or site. A recommendation for SUMFOR would be to establish an uncertainty estimation methodology (although the uncertainty can be expected to be relatively low for carbon balance analysis with SUMFOR, due to the use of Tier 2 values, it is important to inform the user about the variability in the assessment).

1. This section sets out the criteria provided by consultant Philip Audebert based on his experience with the EX-ACT tool and input on SUMFOR from INAF experts on such a tool.

In the estimation of the carbon balance by the consultant, the Ex-Act tool was used with the help of specific Tier 2 values provided by SUMFOR and forestry reports prepared with their results.

b. Ex-Act evaluation of the expected results of ECOVALOR.

The most immediate use of the Ex-Act system is the ex-act assessment of the expected results of proposed mitigation projects so that funders can have a first level of information for decision-making on possible project approval.

ECOVALOR has fulfilled this requirement at three different times and in three different ways, always relying on the empirical knowledge accumulated by the staff of each intervention site about the existing conditions at their respective worksites:

- The first in 2014, when the initial version of the project was shown and accompanied by two very preliminary analyses using version 7.1.5. of Ex-Act, considering as unique areas those dedicated to reforestation on the one hand and those of artificial and natural forest management on the other, always employing default emission factors (Republic of Cuba, 2014).
- The second in 2019, following the Ex-Act training workshop, when a separate analysis was conducted for each intervention site using Ex-Act version 8.5.4, using mostly country-specific emission factors (Alvarez, 2019).
- The third in 2020, similar to the previous one but using Ex-Act version 8.5.4c-1. (Álvarez, 2020).

As expected, the results achieved in each case were different, with increasing levels of accuracy and decreasing uncertainty, and the results of the third assessment are shown in Tables 3.9 and 3.10, as well as the ex-act carbon baseline derived from these results (Figure 3.7).

Table 3.9. Results of the third ex-act evaluation of the intervention sites.

Intervention site	.-Degradation			General results (tCO_2e)			Uncertainty (%)
	Initial	Final		Not covered by the project	Covered by the project	Balance	
		Not covered by the project	Covered by the project				
Guanahacabibes AFC				**12,206**	**-115,151**	**-138,874**	**21.16**
• Reforestation				-3 150	-89,825	-86,675	22.31
• Artificial forest management	4	5	3	11,517	-11,505	-23,022	21.16
• Natural forest management	3	4	2	15,356	-13,820	-29,176	20.00
Macurije AFC				**39,840**	**-130,292**	**-170,132**	**20.77**
• Reforestation				-3,150	-89,825	-86,675	22.31
• Artificial forest management	4	5	3	17,950	-17,932	-35,882	20.00
• Natural forest management	3	4	2	25,039	-22,535	-47,575	20.00
La Palma AFC				**39,840**	**-130,292**	**-170,132**	**20.77**
• Reforestation				-3,150	-89,825	-86,675	22.31
• Artificial forest management	4	5	3	17,950	-17,932	-35,882	20.00
• Natural forest management	3	4	2	25,039	-22,535	-47,575	20.00
Matanzas AFC				**47,271**	**-78,010**	**-125,280**	**20.76**
• Reforestation				-945	-27,494	-26,549	22.27
• Artificial forest management	5	6	4	27,775	-27,804	-55,580	20.00
• Natural forest management	5	6	4	20,440	-22,712	-43,152	20.00
Las Tunas AFC				**8,104**	**-114,086**	**-122,191**	**20.38**
• Reforestation				-1,485	-89,841	-88,356	21.13
• Artificial forest management	5	6	4	9,589	-9,599	-19,189	20.00
• Natural forest management	6	6	5	0	-14,646	-14,646	20.00
APRM C. Zapata				**30,066**	**-80,994**	**-111,060**	**21.13**
• Reforestation				-3,150	-91,646	-88,496	22.27
• Natural forest management	5	6	4	33,216	10,652	-22,564	20.00
APRM Mil Cumbres				**46,763**	**-134,747**	**-181,511**	**21.16**
• Reforestation				-3,150	-89,825	-86,675	22.31
• Natural forest management	3	4	2	49,913	-44,922	-94,835	20.00
PA Bahía N. Grandes-La Isleta				**10,898**	**-9,808**	**-20,707**	**20.00**
• Natural forest management	3	4	2	10,898	-9,808	-20,707	20.00
PA Caletones				**14,719**	**-13,247**	**-27,967**	**20.00**
• Natural forest management	3	4	2	14,719	-13,247	-27,967	20.00

Intervention site	.-Degradation			General results (tCO_2e)			Uncertainty (%)
	Initial	Final		Not covered by the project	Covered by the project	Balance	
		Not covered by the project	Covered by the project				
PA Cayo Sta. María				**44,993**	**-22,496**	**-67,489**	**29.21**
• Natural forest management	3	4	2	44,993	-22,496	-67,489	29.21
PA Guanahacabibes				**47,991**	**-23,995**	**-71.86**	**20.00**
• Natural forest management	3	4	2	47,991	-23,995	-71,986	20.00
PA Lanzanillo-Pajonal-Fragoso				**31 ,72**	**-15,636**	**-46,908**	**38.42**
• Natural forest management	3	4	2	31,272	-15,636	-46,908	38.42
PA Las Picuas-Cayos del Cristo				**31,272**	**-15,636**	**-46,908**	**38.42**
• Natural forest management	3	4	2	31,272	-15,636	-46,908	38.42
PA Los Pretiles				**39,235**	**-19,617**	**-58,852**	**28.44**
• Natural forest management	3	4	2	39,235	-19,617	-58,852	28.44
PA Río Canímar				**40,344**	**-20,172**	**-60,517**	**29.05**
• Natural forest management	3	4	2	40,344	-20,172	-60,517	29.05
PA Varahicacos				**7,292**	**-3,646**	**-10,937**	**29.,05**
• Natural forest management	3	4	2	7,292	-3,646	-10,937	29.05
PA Viñales				**47,991**	**-23,995**	**-71,986**	**20.00**
• Natural forest management	3	4	2	47,991	-23,995	-71,986	20.00

Table 3.10. Overall results of the third ex-act evaluation.

No.	ECOVALOR PROJECT	General Results (tCO_2e)			Average Uncertainty (%)
		Not covered by the project	Covered by the project	Balance	
1	Reforestation	-18,180	-568,282	-550,102	22.13
2	Artificial forest management	84,782	-84,772	-169,555	20.23
3	Natural forest management	485,011	-298,770	-783,781	24.27
TOTAL		551,614	-951,824	-1,503,437	22.21

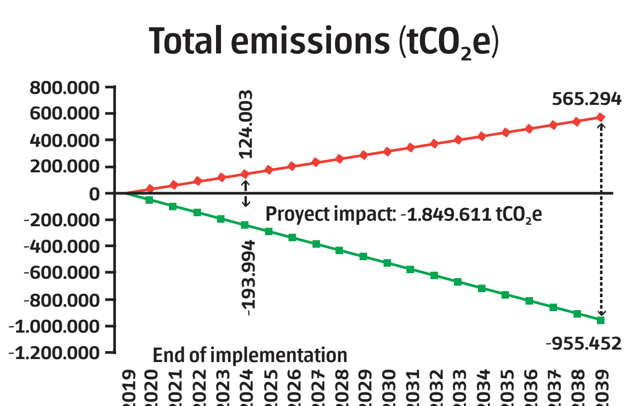


Figure 3.7 Ex-ACT carbon baseline of the ECOVALOR project (3rd assessment).

c. Methodology to determine the level of forest degradation at the beginning, during, and after the completion of ECOVALOR.

In addition to the ex-act assessment already carried out by the project as a preliminary stage at the beginning of its implementation, based on the empirical knowledge of those who will participate in each intervention site, the beginning of the activities consists of: (1) the establishment of a small group of permanent sampling plots in each work area to establish the corresponding sample size and, (2) the establishment of the total number of plots required by each work area.

In both groups of plots, the measurement of forest and tree variables will be undertaken and evaluations carried out, for which it was necessary to previously prepare a methodological document in which the concept of forest degradation to be used was defined, as well as how the existing level of degradation would be determined.

After several exchanges and discussions, a consensus was reached to define a degraded forest as the area established of natural or artificial forest, where causes of natural origin, anthropic or resulting from their interaction, limit or prevent the qualitative and/or quantitative fulfillment of the functions that correspond to the forest, whether associated with its main function (determined by its category), or those associated with its complementary functions (determined by other functions other than the main one).

To establish the level of existing degradation, two different types of criteria will be evaluated:

- General criteria, applicable to any category of a forest, whether natural or artificial.

- Specific criteria applicable to forests according to their category.

Table 3.11 shows a general summary of the set of criteria used, and Annex 7 provides a detailed description of the methodology and an example of its use.

Table 3.11. Set of criteria used to determine degradation.

Type	Criteria	Forest category (natural or artificial)					
			Protection Forest		Conservation Forest		
		Productive Forest	Water and/or Soil	Coastal	Special Management	Flora and fauna	Recreational
General	1. Phytosanitary impact	X	X	X	X	X	X
	2. Mechanical damage	X	X	X	X	X	X
	3. Presence of thorny species	X	X	X	X	X	X
	4. Soil erosion	X	X	X	X	X	X
	5. Fire damage	X	X	X	X	X	X
Specific	6. Density <0,3 or >0,7	X					
	7. Economically important trees*	X					
	8. Density >0,6 or >0,8		X	X			
	9. Presence of exotic species		X	X	X	X	
	10. Harvesting fellings				X	X	X
	11. Species harmful to human beings						X

In the field, data are collected using a template (Annex 7) with at least two sheets per sample plot; the plot data are then transferred to an Excel workbook (Figure 3.8), prepared to contain a maximum of 20 plots and suitably programmed to automatically determine the level of degradation of each plot, using the same scale of values used by Ex-Act, so that it can then be used directly in that system.

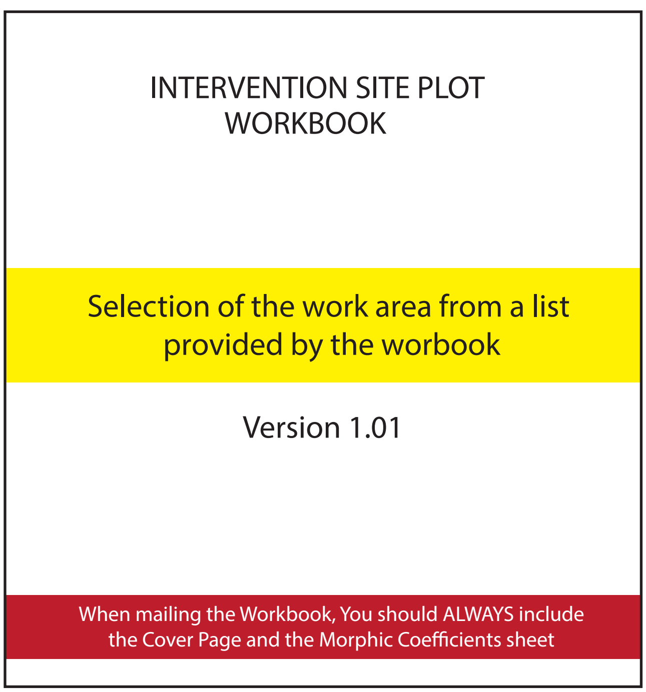


Figure 3.8. Cover page of the Excel workbook for processing the data from the permanent sample plots.

IV. PAYMENT FOR ENVIRONMENTAL SERVICES (PES) FOR ATMOSPHERIC CO_2 REMOVAL BY FORESTS

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4.1.Current status of forest PES

To date, payment for environmental services provided by forests, including the atmospheric carbon removal, has not been implemented in Cuba, even though the intention to start doing so shortly has been made clear in different ways.

Several aspects influence the fact that PES has not been implemented, among which the following can be mentioned in general:

- Its nomination, definition, and recognition are not included in any of the effective regulatory instruments: Environmental Law, Forestry Law, Water Law, etc.

- Consequently, there are no established mechanisms for the measurement, certification, reporting, verification, and payment of environmental services, an activity that is not taken into account among the aspects to be covered by the different national sources of financing that attend to actions carried out on the environment.

- Even though there is a certain degree of awareness of their importance for different dimensions and although for some there are methods that allow their quantification in tangible physical units, they are referred to in qualitative terms that generate an image of intangibility (water quality, regulation of climate or soil fertility, conservation of scenic beauty, spiritual satisfaction, etc.).

- Although there are arguments to identify who produces them, it is not established who should pay for them, which financial source to use, what their price would be, or what can be done with the economic benefits they generate.

- Some sectors that use or benefit from these services are not convinced that it is appropriate to pay for them.

The situation of the various environmental services provided by forests concerning the reasons for non-payment varies. For example, the atmospheric carbon removal has a technically approved and validated assessment methodology under real conditions, which has allowed a mechanism for measurement, certification, reporting, and verification to be proposed, as well as substantiation for prices per ton of CO_2 removed; however, other services are much less advanced.

For these reasons, the remainder of this chapter will be solely devoted to forest carbon.

4.2. What carbon to pay for?

As explained in previous chapters, atmospheric carbon removal can be the result of two different actions: one related to the implementation of the management project or management plan through a forestry investment, where the carbon is a co-benefit of the direct objective of the forest intervention and the other related to the implementation of a mitigation action through an environmental investment, where the carbon is the direct objective of the forest management and the timber increment derived from it is a co-benefit (for ease of differentiation only, hereinafter the first action will be referred to as carbon removed and the second as carbon mitigated).

International mechanisms created by the Climate Change Convention such as the CDM, REDD+, and GCF, as well as various national mechanisms such as the New Zealand Emissions Trading Scheme (NZ ETS), the New South Wales GHG Abatement Scheme (NSW GGAS), the Chicago Climate Exchange (CCX) or the Voluntary Over-The-Counter (OTC) market, favor the payment of mitigated carbon (Diaz, Hamilton, and Johnson, 2011); however, the national experiences accumulated during the preparation of the 2013, 2017 and 2019 Carbon Reports showed that the mere fact of managing forest heritage does not per se lead to an annual increase in atmospheric carbon removal, as sometimes the levels achieved in one assessment were lower than those achieved in the previous one due to various causes and this generates a positive balance, although this does not always mean the GHG emissions into the atmosphere.

These results, in addition to the lack of national culture for assessing and undertaking mitigation actions, are the reasons why it has been proposed to undertake the first stage of PES for carbon removed, aimed at encouraging a sustained increase in the removal or penalizing decreases in removal, provided that these are the responsibility of those who manage the heritage, to carry out at a later stage, as a complement to this mechanism and in addition to it, carbon payment mitigated.

On the other hand, when paying for forest carbon, whether removed or mitigated, it will also be necessary to consider which components of the heritage and which carbon pools will be taken into consideration, because, as has already been explained, there are five components and five differentiable pools in the forest heritage:

- among the components, the unforested area, the area to be reforested, the developing artificial forests, established artificial forests, and the natural forests.
- among the pools, the stem biomass (i.e. standing volume), above-ground biomass (i.e. stem+crown); total biomass (i.e. above-ground biomass+below-ground biomass); necromass (i.e. dead trees, unharvested residues, litter, etc.), and soil.

The international trend on this issue has been toward taking into account the area covered by forest (artificial and natural) and including more and more pools in carbon calculations.

Thus, for example, the 1996 Guidelines for National Emission Inventories (IPCC, 1997) only considered in the Land Use, Land-Use Change and Forests (LULUCF) module the carbon removals from forests due to above-ground biomass increment, whereas the 2006 IPCC Guidelines (IPCC, 2006) considered in the Agriculture, Forestry and Land Use (AFOLU) module all above-ground and below-ground forest biomass and in addition to that, in both Guidelines the calculation of changes in soil carbon content was included.

In Cuba, the issue of components and pools has not been addressed in depth for decision-making purposes, and as is typical of any activity that is just beginning, the case study carried out preferred to be conservative rather than excessively comprehensive in terms of results.

4.3. A case study: the Matanzas Agroforestry Company

The progress made by the Agroforestry Research Institute (INAF) on the evaluation of atmospheric carbon removal by forests was shown at the end of the first half of 2018 for the consideration of the MINAG Working Group for the Attention to the Tarea Vida Project, with representatives of the Division of Science, Innovation, and Environment and the Forestry, Flora, and Wildlife Division, both of the MINAG; the Ministries of Planning and Economy, Finance and Prices, and Science, Technology and Environment, as well as the Agroforestry Business Group.

The Working Group considered that in principle all the necessary technical conditions were met to undertake, in the context of the Biodiversity Finance Initiative (BIOFIN-1, 2019), the development of a case study that would demonstrate, under real conditions, the feasibility of establishing a mechanism for measuring, certifying and paying for the forest carbon removal, selecting the Matanzas Agroforestry Company for this purpose, and the following conditions were established:

1. Two evaluations would be carried out: a general evaluation of the company and another for each of the Base Business Units (UEB) that made up the company, to compare the results.
2. Carbon removal would be carried out using the Stock Difference method, using the SUMFOR system and the Company's data corresponding to the end of 2016 and 2017.
3. The assessments would only consider above-ground biomass as a carbon pool, differentiating the results between carbon removals from productive forests on the one hand and protection or conservation forests on the other.
4. Hypothetically, a payment of $1.00/tCO_2$ removed by productive forests and $2.00/tCO_2$ removed by protection or conservation forests would be assumed.
5. Payment would only be appropriate when, in addition to proving CO_2 removal, the assessed unit achieves an assessment of 3 or higher for Sustainable Forest Management Indicator 3.5, directly related to GHG removals and emissions by forests.
6. It would be necessary to estimate how much would be paid to the Company for the carbon removal and to INAF for the certification service (based on the tariff proposed by the institution).
7. It would be necessary to estimate the total amounts of funding that would be required for PES for atmospheric CO_2 removal by forests, at the national level.

Taking into consideration the SUMFOR system's demand for data for a modified version according to the calculation conditions established to make the assessments, the Matanzas Agroforestry Company provided the information corresponding to 2016 and 2017, which after processing generated the results shown in Table 4.1 (BIOFIN-1, 2020).

Table 4.1. Summary of the results of the pilot test in the Matanzas Agroforestry Company.

Company	Forest surface area 2017 (ha)	IMSB 3.5		Balance 2016/ 2017 (Mt CO_2)	Participation of forests per category				Total Bonus ($)	$/t$CO_2$	$/ha Forest
		2016	2017		Productive forests		Forests (Protection + Conservation)				
					Rate (%)	Bonus ($)	Rate (%)	Bonus ($)			
EAF Matanzas	34,346.0	4	4	-1,147.9	49.00	562,431.18	51.00	1,170,958.04	1,733,389.22	1.51	50.47
UEB Colón	991.7	4	4	-14.9	100.0	14,907.23	0.00	0.00	14,907.23	1.00	15.03
UEB Jovellanos	3,314.5	4	3	-89.7	97.82	87,772.38	2.18	3,918.67	91,691.05	1.02	27.66
UEB Los Arabos	7,079.9	2	0	-417.3	99.91	--------	0.09	--------	--------	--------	--------
UEB Martí	13,266.7	4	4	-464.3	9.76	45,335.91	90.24	838,019.59	883,355.51	1.90	66.58
UEB Matanzas	9,685.3	4	4	-199.0	53.51	106,499.39	46.49	185,072.66	291,572.05	1.47	30.10
EAF Matanzas	34,346.0	3.6	3.0	-1,185.2	49.00	254,514.91	51.00	1,027,010.92	1,281,525.83	1.08	37.31

The results achieved showed that irrespective of the units assessed, both the company and its UEBs were carbon sinks. However, the results for Indicator 3.5 were unfavorable for UEB Los Arabos, indicating that the analysis at this scale was able to detect situations that were uncovered at the company level.

The company would receive 35.26% more funding when the analysis was done at the company level than when it was done by UEB; even if the incentive were not conditional on the result of Indicator 3.5, Los Arabos UEB would have received $417,624.08 for CO_2 removal and this would increase the company's total to $1,699,149.91, but the total amount of funding would still be $34,239.31 less than that obtained through the company analysis.

To estimate how much the payment to INAF for the certification service would be, the following considerations were made:

1. The first certification of any tenant only allows determining the reference value of the carbon sequestered by the forest biomass and therefore never originates the PES.
2. From the second certification onward, a comparison is made between the results of the last certification and the previous one; if removal of atmospheric CO_2 is verified and Indicator 3.5 is met, the PES is triggered.
3. However, if in the last certification the results do not show that CO_2 removal has occurred or does not comply with Indicator 3.5, the applicant will not receive the PES either.

Consequently, the price of the certification must be set at a value that avoids being extremely low to the detriment of the fee-charger and at the same time does not conspire against the essential objective of the PES, which is to generate an incentive for the tenant; furthermore, it must take into account that the real benefits for the certifier will come more from the number of tenants requesting the service than from the value attributable to each particular service.

Taking all these elements into account, the proposed payment system is as follows:

1. Once the applicant's data has been processed and the certificate prepared, the certifier will verbally communicate the price of the service to the applicant so that he/she can proceed to pay it; only after the payment is made, the certificate will be delivered to the applicant and to the Forestry Division, Flora and Wildlife of MINAG.
2. When for any reason the certification does not give rise to the PES (be it the first or any subsequent certification), the certifier will charge a fixed price of \$3,000 for each service, which will be paid by the applicant.
3. Where the PES is less than \$100,000, the applicant shall pay \$3,000 to the certifier.
4. Where the certification results in PES for a value equal to or greater than \$100,000, the certification fee shall be equivalent to 3% of the total amount to be charged by the applicant, who shall pay the amount to the certifier.

Thus, taking into account what has been proposed, the economic results of the certification carried out for the case study are shown in Table 4.2, which shows that when the certification is carried out for the whole company, it would receive 96.83% of the total incentive, while when it is carried out by UEB, it would receive 94.21% of the total, ensuring in both cases that most of the incentive would go to the tenant.

To estimate the total funding levels that would be required to pay an incentive for atmospheric CO_2 removed by forests, it was taken into account that the maximum difference in payment per ton of CO_2 removed by the company's assessment or that of its UEBs is 0.39 cents; however, the CO_2 payment per hectare of forest cover would vary between \$50.47/ha and \$15.03/ha, which equals a difference of \$35.44/ha between the two assessment methods.

Table 4.2. Summary of carbon certification payments.

Company	Base Year of Certification	Total Incentive (\$)	For the Tenant (\$)	For the Certifier (\$)
Matanzas AFC	**2016**	**0.00**	**0.00**	**3,000.00**
	2017	**1,733,389.22**	**1,681,387.54**	**52,001.68**
Colón UEB	2016	0.00	0.00	3,000.00
	2017	14,907.23	11,907.23	3,000.00
Jovellanos UEB	2016	0.00	0.00	3,000.00
	2017	91,691.05	88,691.32	3,000.00
Los Arabos UEB	2016	0.00	0.00	3,000.00
	2017	0.00	0.00	3,000.00
Martí UEB	2016	0.00	0.00	3,000.00
	2017	883,355.51	856,854.84	26,500.67
Matanzas UEB	2016	0.00	0.00	3,000.00
	2017	291,572.05	282,884.90	8,747.15
Matanzas AFC	**2016**	**0.00**	**0.00**	**15,000.00**
	2017	**1,281,525.83**	**1,229,621.29**	**59,247.82**

4.4. Proposed system for PES for atmospheric CO_2 removal

Different actors are involved in the process of PES for atmospheric CO_2 removal:

- the tenant, who manages the heritage;
- the State Forest Service (SEF), which has the power to veto the certification requested by the tenant;
- INAF, which, as the certifying body, continuously improves the methodology, processes the tenant's data, issues and delivers the certificates to the tenant and the Forestry, Flora, and Fauna and Wildlife Division (DFFFS), periodically prepares the forest carbon reports and archives and keeps custody of all the information;
- the DFFFS, which organizes payment as appropriate;
- the financial source making the payment, considering the use of the National Forestry Development Fund-FONADEF;
- the state bodies in charge of verifying and/or auditing the functioning of the whole system, which include the Ministry of Finance and Prices (MFP), the Ministry of Science, Technology, and Environment (CITMA), and the Office of the Comptroller General of the Republic (CG), among others, which has been schematically shown in Figure 4.1.

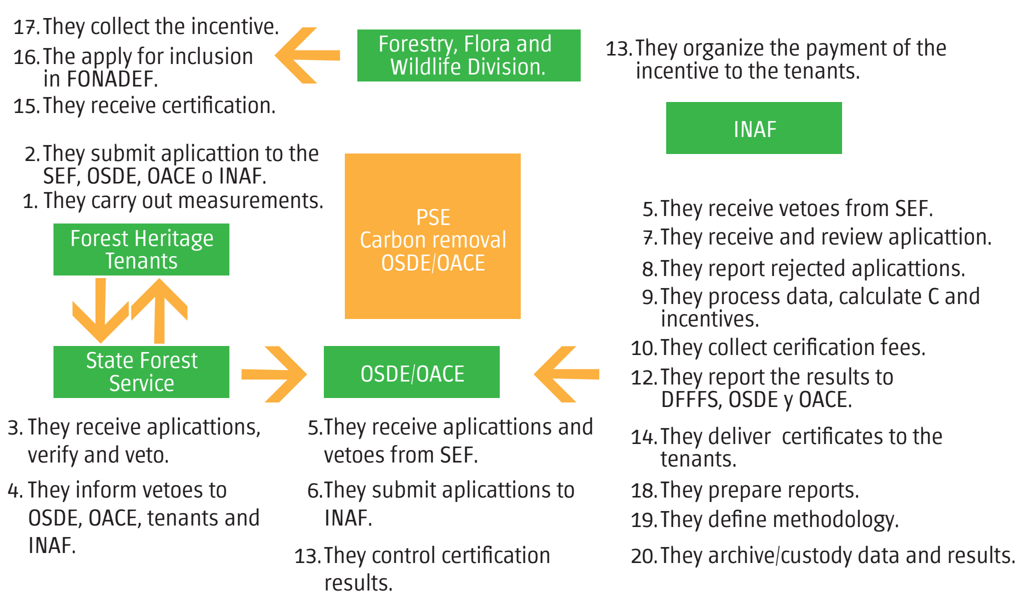

Figure 4.1. General diagram of the proposed system for PES by carbon removal. (The numbers indicate the order in which the events occur).

4.5. The role of the Indicator 3.5. of Sustainable Forest Management (IMFS 3.5.). Proposal for its modification

The criteria and indicators for assessing the extent to which Cuban forests are managed sustainably were presented by Herrero (2005) as one of the results of the Institutional Strengthening of the Forestry Sector in Cuba project, implemented with funds from the Canadian Institutional Development Agency (CIDA).

Five criteria were established for this purpose: I-The forest cover, II-The health and vitality of forest ecosystems, III-The contribution of forest ecosystems to environmental services, IV-The productive functions of forest ecosystems, and V-The multiple socio-economic benefits to cover the needs of society. Their maintenance and enhancement.

Within Criterion III, Indicator 3.5 was included. Contribution of forest ecosystems to the reduction of the greenhouse effect and the stabilization of climate change, which is based on the relationship between two components: on the one hand, the sink capacity of the managed heritage and, on the other hand, the importance of its greenhouse gas emissions.

In the light of the results achieved in the case study of the Matanzas AFC, an analysis of this Indicator was undertaken, which indicated that:

- the forest cover index used relates the area covered to the total area of the heritage, which also includes areas under development, to be reforested and non-forested; however, unforested areas will never be forested, so considering them distorts the assessment of sustainable forest management.
- the area affected by fire relates that area to the whole heritage, thus giving equal importance to the effects of the area covered and those of the rest of the heritage areas, including non-forest areas; furthermore, it does not consider the degree of damage caused by fire, on which the amount of GHG emissions produced depends, all of which limits the precision of the indicator.

In addition to the above elements, the Indicator was prepared 15 years ago and during the period since its implementation to date:

- the available information increased considerably in quantity and quality, even making it possible to differentiate between the behavior of natural and artificial forests;
- initially, the determination of the Indicator was simplified as much as possible;
- it is now possible to fully automate its determination.

For all these reasons it was considered appropriate to propose a readjustment of the IMFS 3.5, to increase its quality and usefulness and to make it consistent with the conditions to be established for carrying out the assessments leading to the payment of the environmental service, and therefore the following changes were proposed:

In the sink capacity of the assessed area.

- Forestry index.

Replace it with the ratio between the area covered (according to the type of forest: natural or artificial) and the forest area of the managed heritage (area covered+area under development+area to be reforested).

- Carbon sequestered.

– Consider only the area covered as a component and only the biomass (above-ground + below-ground) as a pool, differentiating these elements by forest type (natural or artificial).
– Modify the range of values currently in use, which varies from less than 115 tC/ha to more than 285 tC/ha, by the corresponding value for each type of forest (natural or artificial).
– To determine the new range of values to be used per forest type, use the results presented in the 2017 C Report.

On the importance of emissions.

- Fire-affected area.
    - Replace the value used by the value corresponding to the specific damage reported for natural and artificial forests.
    - Add an assessment of the degree of damage caused by the fire to the forest.

- Consider that while fire damage in artificial forests is mostly recoverable, fire damage in natural forests is generally not.

Based on the above elements, the overall assessment of Indicator 3.5. is proposed to be carried out differentiating first between artificial and natural forests so that the overall assessment results from a compromise between the results of both components of the area covered and is carried out using the elements shown in Table 4.3.

Table 4.3. Assessment elements to be used to determine the IMFS 3.5.

Established artificial forests

Sink capacity:

Use of forest area(%)	Carbon sequestration (t/ha)				
	>80.0	61.0 to 80.0	43.0 to 60.9	24.0 to 42.9	<24.0
>46	4	4	3	3	2
36-45	4	3	3	2	2
21-35	3	3	2	2	1
10-20	3	2	2	1	1
<10	2	2	1	1	0

Importance of emissions:

Suface area affected (%)	Extent of forest impact				
	Slight	Fair	Serious	Very serious	Total
< 2,0	4	3	2	1	0
2,0 - 2,5	3	2	2	1	0
2,6 - 3,0	2	2	1	1	0
3,1 - 3,5	1	1	1	0	0
> 3,5	0	0	0	0	0

Contribution to IMFS 3.5.

Magnitude of sequestrations	Magnitude of emissions				
	4	3	2	1	0
4	4	4	3	3	2
3	4	3	3	2	2
2	3	3	2	2	1
1	2	2	2	1	1
0	2	2	1	1	0

Natural forests

Sink capacity:

Use of forest area (%)	Carbon sequestration (t/ha)				
	>95.0	75.0 to 95.0	55.0 to 74.9	24.0 to 54.9	<24.0
> 85	4	4	3	3	2
76 - 85	4	3	3	2	2
66 - 75	3	3	2	2	1
50 - 65	3	2	2	1	1
< 50	2	2	1	1	0

Importance of emissions:

Suface area affected (%)	Extent of forest impact				
	Slight	Fair	Serious	Very serious	Total
< 2,0	3	3	2	1	0
2,0 - 2,5	3	2	2	1	0
2,6 - 3,0	2	2	1	1	0
3,1 - 3,5	1	1	1	0	0
> 3,5	0	0	0	0	0

Contribution to IMFS 3.5.

Magnitude of sequestrations	Magnitude of emissions				
	4	3	2	1	0
4	4	3	2	1	4
3	3	3	2	1	3
2	3	2	2	1	3
1	2	2	1	1	2
0	2	1	1	0	2

Contribution to artificial forests	Contribution to natural forests				
	4	3	2	1	0
4	4	3	2	1	1
3	4	3	2	1	1
2	3	3	2	1	1
1	2	2	2	1	0
0	1	1	1	0	0

Although at first sight, the proposed readjustment of the Indicator gives the impression of being very complex and difficult to determine, it must be remembered that in both the current Indicator and the proposed modification, the first variable to be used is carbon sequestration (tC/ha) and this data can only be obtained from the carbon assessment carried out with the SUMFOR system, which in turn is responsible for calculating the Indicator from the same input data used until now, providing the results as part of the Forest Carbon Certificate that is issued.

The only difference between the current and proposed Indicator is that the Certificate currently includes an overall value for the Indicator, whereas under the proposed alternative it would include the final results of two values: that of artificial forests and that of natural forests.

However, it is up to the FDA to take the final decision on the readjustment of the Indicator.

4.6. Pending aspects to implement the payment of the forest carbon incentive

As explained earlier in this Chapter, the aspects related to the methodology and the automated system for the determination of the amount of carbon removed from the atmosphere by the forest heritage is already available and its use was validated through a case study carried out in real conditions, monitored by various agencies of the Central State Administration.

Based on the results of this experience and taking into consideration the provisions of paragraph (r), article 2. 1 of Joint Resolution No. 1/2012 (MEP/MFP, 2012), the Ministry of Agriculture proposed to the Ministry of Finance and Prices to include among the purposes for which funding from the National Forestry Development Fund (FONADEF) can be used, the payment for environmental services provided by forests (among which is included the PES removal of atmospheric carbon by forests), to which the Ministry of Finance and Prices responded affirmatively at the end of 2019.

Despite the undoubted progress that the above actions represent with a view to the payment of the forest carbon incentive, an important set of propositions remain to be officially approved on the roadmap towards the achievement of this objective:

1. Which component(s) of the forest heritage will be considered for the determination of carbon sequestration: unforested area, area to be reforested, artificial forest development, established artificial forests, and natural forests? The last two have been proposed.
2. In that (those) component(s), which carbon pools will be taken into account for calculating carbon sequestration: stem biomass, above-ground biomass, total biomass, necromass, and soil? Total biomass has been proposed.
3. Which company will be designated as the official forest carbon certification company in Cuba? The Agroforestry Research Institute has been proposed.
4. What maximum validity period will be established for the carbon certificate issued? It has been proposed for 3 years.
5. What will be the price per ton of atmospheric CO_2 removed by the forest? Will a single price be used or will there be a price differentiation based on the fulfillment of some condition(s) to be met? Three prices have been proposed: the lowest price for natural production forests, an intermediate price for natural protection or conservation forests, and the highest price for all types of artificial forests.
6. Will the forest carbon incentive initially comprise only removed carbon, leaving mitigated carbon for a second stage, or will both carbon credits be incentivized from the outset? It has been proposed to start by considering only the carbon removed.
7. Will the forest carbon incentive include all forest heritage holders from the outset, or will an annual certification cycle be established, consisting of groups of holders comprising similar total areas of forest heritage? It has been proposed to start with GAF agroforestry enterprises, but this need not necessarily be limited to them.
8. Will the use of the incentive received be at the discretion of the asset holder or will regulations be established? It has been proposed to leave it to the holder's decision.

9. The increase of the removal of atmospheric CO_2 within a maximum time period will result in the payment of an incentive to the holder, but if the amount of atmospheric CO_2 removed decreases compared to a previous assessment, how will this be done? There is still no proposed answer to this question.

All decisions taken are in the first instance the responsibility of the Forestry, Flora and Wildlife Division of the Ministry of Agriculture, irrespective of whether or not they require further approval and/or the manner in which such regulations are established.

4.7. The international carbon market

As has been pointed out, the forest carbon removal constitutes a social benefit per se, since it is one of the two major sinks in the global carbon cycle (IPCC, 2001 and 2007; Fig. 4.2), thus forming part of the existing mechanisms to mitigate climate change, a process that has been recognized as the main environmental factor threatening life on the planet.

In this regard, at the presentation in Nairobi of the third edition of the Global Biodiversity Outlook (GBO-3), the United Nations warned that the basic conditions for human life in nature are seriously threatened by the loss of the planet's biodiversity (one of the main impacts of climate change): "The provision of food, fibers, medicines, freshwater, pollination of crops, filtration of pollutants and protection against natural disasters are some of the natural resources potentially threatened by the deterioration and changes in biodiversity" (Diaria, 2010).

However, this environmental contribution of forests is global and inadequate to provide local, tangible, and short-term socio-economic benefits, which is why it is necessary to identify additional ways to add other values to those already mentioned, and for this, it is necessary to take into consideration the possibilities offered by existing mechanisms for trading carbon emissions, to make use of those that facilitate the sale in convertible currency of the carbon certificates issued, based on the evaluation of the management carried out by the holders of the forest heritage.

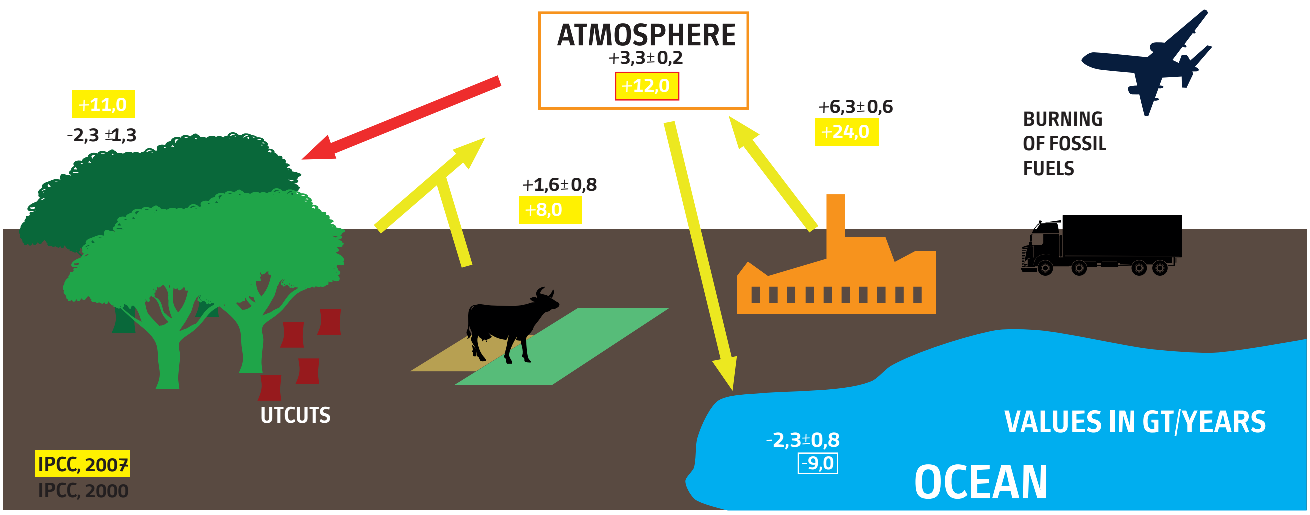

Figure 4.2. Diagram of the main components of the global carbon cycle and their annual contributions to atmospheric carbon concentration, with data for the years 2000 and 2007 (values on yellow background). (IPCC, 2001 and 2007).

Walker et al. (2008) note that: "...There are several types of market mechanisms, each of which plays a different role. Regulatory mechanisms are used by companies subject to regulated, legally binding carbon emissions. Voluntary mechanisms operate for use by companies that are not legally regulated. The rules and regulations required for carbon credits to be registered differ markedly between regulatory and voluntary registries. As a consequence, some mechanisms are better suited to certain activities or project locations than others..."

At the end of 2008, the main existing regulatory mechanisms included (Walker *et al.*, 2008):

- The Clean Development Mechanism (CDM) of the Kyoto Protocol, for Annex 1 and Non-Annex 1 countries.
- The Joint Implementation Mechanism (JIM) of the Kyoto Protocol, for Annex 1 countries only.
- The Kyoto Protocol's Emissions Trading Mechanism, for Annex 1 Countries only.
- The U.S. Climate Registry, a common GHG emissions reporting system, which in 2007-2008 registered the addition of 39 U.S. states, three Native American tribes, four Canadian provinces, and two Mexican states.
- The New South Wales GHG Abatement Scheme, created only for this Australian state.

However, of all of them, the only one available to the Cuban forestry sector was the CDM of the Kyoto Protocol, which also only certified the carbon sequestered by forestry projects dedicated to reforestation, with other significant conditions, which substantially limited its use for the objectives pursued, as in practice it applied fundamentally to part of the sugarcane areas transferred to the forest heritage.

The second type of mechanism is called REDD+ (Reducing Emissions from Deforestation and Forest Degradation and their Sustainable Management), which according to Parker, *et al*. (2008), has as its basic idea that countries willing and able to reduce emissions caused by these causes and/or forms of management can be financially compensated for doing so, and given that previous attempts to reverse global deforestation have not been successful, REDD+ would then provide a new framework to enable deforesting countries to break this historical trend.

The Bali Action Plan, adopted at the 13th Conference of the Parties, stated that action consistent with climate change mitigation could include: Policy actions and positive incentives on aspects related to reducing emissions from deforestation and forest degradation in developing countries, which is why REDD+ was then primarily linked to reducing emissions. However, REDD+ has the potential to go much further, because it could simultaneously address climate change and rural poverty while conserving biodiversity and sustaining vital ecosystem services.

While these benefits are real and important considerations, the crucial question is, to what extent will the inclusion of conservation and development objectives achieve the development and overall success of a future REDD framework, or instead complicate and then possibly undermine the subsequent REDD+ negotiations process? (Parker, *et al*., 2008).

The prospects for REDD+ as an alternative to the Kyoto Protocol's forest CDM were to be discussed at the 2009 Copenhagen COP, but events there prevented such an analysis from taking place. Subsequently, the First World People's Conference on Climate Change and the Rights of Mother Earth, held in Bolivia in 2010, raised among its conclusions the need to replace the REDD+ mechanism with another mechanism that was not based on the development of the carbon market, that respects the sovereignty of states and the right of peoples to free, prior and informed consent, and that directly transfers economic and technological resources from developed countries to pay for the restoration and maintenance of forests and jungles (Morales, 2010), elements that could significantly prolong its practical application.

Regarding emerging markets other than Kyoto, Neef, *et al*. (2007) classified the demand for carbon credits from various users as shown in Figure 4.3.

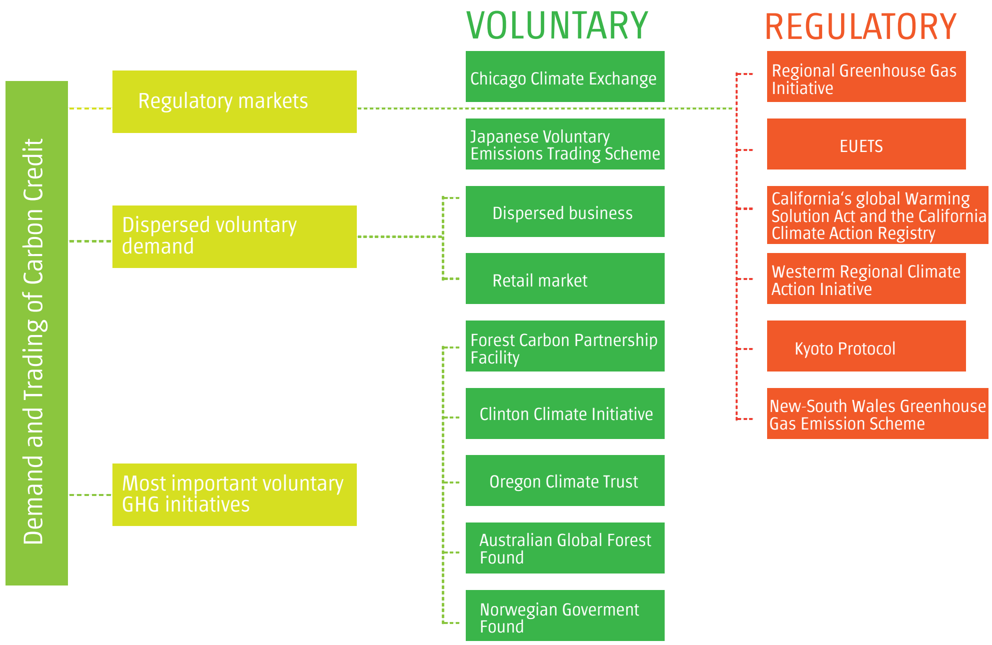

Figure 4.3. Classification of demand for carbon credits into various types of markets and various types of buyers (Neef, et al., 2007).

These authors point out that markets can be distinguished as regulatory markets when emission reduction targets are imposed by law and as voluntary markets when the demand for carbon credits comes from businesses and individuals who voluntarily decide to partially or fully offset their emissions footprints.

Another distinction is between allowance-based and project-based systems. In allowance- and transaction-based systems, market participants have obtained emission rights (allowances) that they can trade with any other participant. Many of these markets allow for the import of project-based credits. In addition, individuals and businesses that choose to voluntarily offset their emissions can do so by purchasing credits from projects. Most participants in the voluntary offset market are dispersed and trade mostly in very small volumes, although there are also some larger voluntary carbon offset purchasing initiatives.

Concerning voluntary mechanisms, Walker, *et al.* (2008) note that: *"...The voluntary market is composed of reductions that are not linked to regulations. These can take many forms, including the purchase or trade of carbon credits by companies or individuals to reduce their GHG emissions, the purchase of reductions directly from the development of an emission abatement project or their resale, and donations from companies for abatement projects in exchange for obtaining the credits. Currently, the voluntary market can be grouped into two types: legally binding cap-and-trade markets, such as the Chicago Climate Exchange (CCX) and non-binding markets, called OTC (Over The Counter) abatement markets..."*.

The CCX was established in 2003 and was the predominant GHG emissions trading system in North America, characterized as a voluntary but legally binding system, which is why it is not relevant for the purposes intended.

In the OTC market, reductions are project-based and the credits produced are called Voluntary or Verified Emission Reductions (VERs). Buyers in this market are not driven by regulations, but for various reasons such as public relations, philanthropy, desire to reduce climate change impacts, to prepare for future regulations or resale (brokers), while sellers of VERs are generally projects that believe they will benefit more by selling credits in the voluntary market, or that for some reason do not meet the conditions required by the CDM or the MIJ (Walker et al., 2008), which makes it suitable for achieving short-term, tangible, local socio-economic benefits, provided it successfully captures the attention of buyers in this market sector.

According to the World Bank (World Bank, 2007, cited by Walker, *et al.*, 2008), at the end of 2007 the reported prices for VER credits by source forestry project type were as follows:

- Single-species reforestation 10.00-13.00 USD/ tCO_2e
- Mixed reforestation with native species 0.50-45.00
- Avoided deforestation 10.00-18.00

Neef, *et al.* (2007) surveyed the preferences of potential buyers of carbon credits from forestry projects, finding that the majority of respondents indicated reforestation projects as one of their preferences, and approximately half of the participants were interested in forest conservation projects (prevention of deforestation), and less than a third preferred management project.

In addition, other relevant aspects that will need to be taken into consideration if the sale of forest carbon credits is undertaken are (Walker, *et al.*, 2008):

- In the voluntary market there is no common set of regulations to comply with, although several organizations have created various guidelines and standards (Figure 4.4). The formation of such mechanisms builds confidence in the market and helps ensure that credits are actual, measurable, and additional. Most standards require a third party to verify the project and the credits earned.
- Another necessary component of trade transparency is registration. The registry creates an inventory of credit creation and owners to prevent credits from being sold to multiple buyers. Most registries consider both the credits verified in a given year by a project and the credit transactions. Many registries have been formed over the last few years, and it is unknown whether one or more of them will dominate the market.

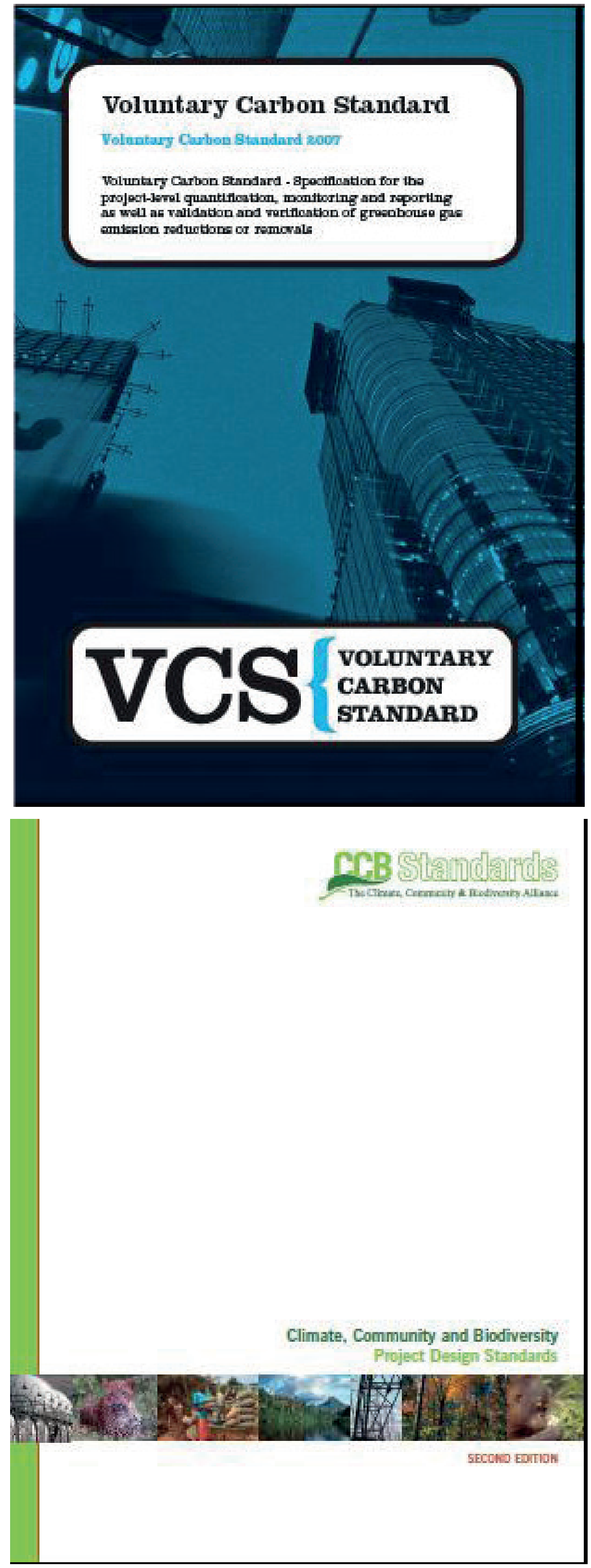

Figure 4.4. Examples of existing voluntary carbon market standards (Olander, 2009).

In this respect, Neef, *et al*. (2007) have pointed out that in most cases, a buyer will make a selection concerning trade-offs and origin. Therefore, a set of project characteristics has a strong influence on the competitiveness of the project. The offsets of voluntary markets have a less well-defined quality standard, so standards are in this case even more important to distinguish projects (Bayon *et al*., 2006).

Although standards have not yet fully penetrated the market, users are very well informed about the quality trade-offs (ultimately reflected by these standards). Standards are important for the following reasons:

- Quality of compensation. The quality of an offset is determined by the criteria that have been applied in its generation.
- Quality control and auditing. Most offsets are audited in one form or another, implying that the offset has been made and that it has met the expected quality criteria.
- Use of standards. Using a standard for carbon offsets assures the potential buyer that the quality criteria applied are indeed good enough.

Several universal quality criteria have emerged over time in some project-based carbon markets. These can be summarized as:

- Additionality. An additional offset project must demonstrate that it is the result of incentives associated with the existence of carbon markets. There are now standardized tests that allow the additionality of specific projects to be proven.
- Accounting methodologies, baseline setting and leakage determination. Projects can claim carbon credits for the amount of carbon removals obtained under the project scenario over the no project scenario (business-as-usual) scenario, also called the baseline scenario. The baseline scenario quantifies how many emissions (or removals) would have occurred in the absence of the project activity. How the baseline and project scenarios are quantified therefore has a major impact on the number of offsets that can be sold by the activity in question.
- Permanence of carbon removals. For reforestation projects (and more generally for sink projects, but not to the same extent for conservation and avoided deforestation projects) it is crucially important to demonstrate that the carbon removals obtained are permanent. When carbon credits are generated by growing forests, the carbon storage in trees is used to offset emissions. Consequently, if a carbon reversal occurs, the re-emission of carbon from, for example, fires or harvesting would eliminate the offset. Several accounting methods and mechanisms (such as liability provisions, reserves and legally enforceable remedial measures) have been carried out to manage the risk of carbon reversal and to assure users of the permanence of offsets.
- Double counting and ownership of offsets. Project records are designed to ensure that an offset cannot be sold more than once. In addition, it is important to ensure that project-based offsets are not double-counted in any allocation-based scheme. To prevent double counting, it is necessary to ensure legal ownership of carbon credits on a contractual basis before offsets are sold. In the forest sector, the initial owner of carbon removals is usually linked to the ownership of the land where the trees are located.
- Harvesting of carbon credits: This is the point at which removals and emission reductions occur. To what extent current emissions can be offset by offsets that will only be carried out in the future is open to question. Accordingly, the ownership of carbon credits includes the time over which carbon removals and emission reductions from forestry projects are performed. The 'harvests' of carbon credits describe the time at which emissions reductions or traded carbon removals occur. When offsets are traded on the spot market, the relevant carbon removals from tree growth have already occurred, so the user can use the carbon credits to offset emissions that occurred in the same year. In the future markets, however, future carbon credits are traded and will be delivered a couple of years later. To achieve environmental integrity, the harvesting of carbon credits should take place as close as possible, in terms of time, to the point in time at which the emissions to be offset occur.
- Verified carbon credits or support for tree planting. Sponsorship of tree planting has also been sold as an emissions offset. Some companies offer to plant trees to offset their customers' emissions and then sell the carbon that those trees will remove in long-term frameworks, in the future, when the trees grow. This type of plantation sponsorship

markets EX-ACT projected future carbon removals, rather than their already verified ex-post carbon removals. This is different from the usual forward transaction, which trades ex-post verified carbon removals and where it is simply agreed that the timing of the transaction will take place in the future. In some cases, the offset buyer is not informed about the discrepancy between the timing of offset payment (which is instantaneous) and the realization of the carbon offset (which will only occur after decades of tree growth). In addition, guaranteeing uninterrupted plantation growth for very long periods seems difficult. This is exacerbated by the fact that, typically, the developers and marketers of the project in question do not put in place mechanisms to manage the risk of forestry problems. Indeed, sponsoring tree plantations does not deliver verified carbon credits in the same way that other forestry activities do.
- Environmental and socio-economic impacts. A high-quality offset will incorporate criteria such as co-benefits and potential externalities of the project. The audit and registration process will seek external statements that a project's impacts are positive, or at least negligible if negative.
- Third-party auditing and certification. Offsets are more credible if they are verifiable. To do this requires monitoring offset activities and verifying how many of the offsets quantified on paper have taken place in the field. The design and rigor of the monitoring methodology can again have an impact on the number of offsets that are awarded.

Taking all of the above into account, everything suggests that the most promising alternative for Cuba to convert the carbon sequestration certificates issued as a result of the technical management of the holders of the national forest heritage into income in freely convertible currency for Cuba would be to sell them on the Voluntary Carbon Market, whose buyers, unlike what generally occurs, would not come to negotiate the purchase of VERs in the future, but rather to negotiate the purchase of credits that have already been achieved and that are backed by a whole system of credits that are already in Cuba's possession, and that are backed by a system of credits that are already in Cuba's possession, unlike what generally happens, would not come to negotiate the purchase of VERs in the future, but to negotiate the purchase of credits that have already been achieved and that are backed by a whole system of evaluation and certification, appropriate to the conditions, species and forests existing in Cuba, which would lend credibility and confidence to the product on offer.

Of the aspects mentioned above for this market, the one concerning additionality deserves special comment. After all, it means that when a buyer in the Voluntary Market claims compliance with this requirement in the carbon certificates it acquires, this will mean that it will only be able to sell credits generated by holders whose plan is adjusted to the mitigation line, because this is the one that generates additionality of carbon sequestered, concerning the baseline.

In 2015, Ludeña, De Miguel, and Schuschny simulated and analyzed different carbon emission reduction scenarios and structures for emissions trading (with their respective CO_2 tax equivalents), and their impacts on the economies and welfare of developed and developing countries, particularly those in Latin America and the Caribbean.

These authors concluded that: "the participation of developing countries is crucial for lowering the costs of reducing CO_2 emissions. This effect is magnified when some of these developing countries also undertake mitigation commitments (mitigation initiatives were simulated for Brazil, China, India, Mexico, and South Africa), thereby further lowering mitigation costs. The economic impact on developing countries, which is always very small, varies between energy-exporting and energy-importing countries. The results are also influenced by the participation of the United States in emission reduction efforts. In energy-exporting countries, welfare losses are mainly caused by a deterioration in the terms of trade, as Annex I countries reduce their emissions by reducing their consumption of energy sector products such as coal, gas, crude oil, and petroleum products. This affects the terms of trade of energy exporting countries, as the prices of their products fall relative to import prices. The largest terms-of-trade impact is seen in Latin American energy-exporting countries such as Argentina, Colombia, Mexico, and the Bolivarian Republic of Venezuela, under their close relationship with the United States of America as a trading partner. However, welfare changes due to participation in an ETS are generally positive for Latin American countries (unless the United States does not participate), even when they are committed to reducing their emissions. The Bolivarian Republic of Venezuela is the only country that could suffer from a global emissions trading system with commitments for all major polluters (Annex I countries of the Kyoto Protocol and the G5)".

On the other hand, more recently Di Bella (2020), Programme Manager of the Climate Change and Sustainability Programme of the Parliamentary Network on Climate Change, has argued: "Carbon pricing instruments are mechanisms designed to internalize the costs of environmental damage by putting a price on GHG emissions in different sectors of the economy. Carbon pricing consists of a tariff on GHG emissions to incentivize the reduction of carbon emissions. These mechanisms contribute to a transition away from fossil fuel consumption and shift investment patterns to renewable energy for sustainable development. Currently, almost 40 countries and more than 20 cities, states, and provinces (World Bank, 2016) have already done or are preparing for a carbon price and have started to link their markets. These countries have started to implement carbon pricing mechanisms as an approach to meet their nationally determined commitments adopted under the Paris Agreement, which explicitly recognizes the important role of carbon pricing mechanisms in mitigating GHG emissions. The global carbon market is estimated to be worth USD 52 billion (Climate Markets and Investment Association, 2017)".

"There are four carbon pricing instruments (Globe Advisors, 2016). These four mechanisms aim to reduce GHG emissions, which are the main catalysts of climate change. Carbon pricing instruments can potentially decarbonize economies and promote technological innovation. These mechanisms can become an important revenue-generating activity for the private sector and national governments (Climate Reality Project, 2016), by creating resources to invest in renewable energy alternatives, the instruments mainly include:

1. Emissions taxes: A carbon tax imposes a direct tax on GHG emitters, regardless of the source. This is regarded by many as a direct public policy approach to reducing carbon emissions. Taxes are usually set by simulating the cost of reducing emissions to a specific target. This mechanism has met with political opposition from business and conservative groups.
2. Cap-and-trade systems: This approach uses free-market principles to achieve reducing emissions of specific GHGs. A government agency or regulator sets a limit on the total amount of emissions allowed in a sector of the economy and issues or auctions permits (carbon credits) for that amount.

   Companies or organizations included in the cap must only emit according to the allowances they have. If companies exceed their emission allowances, they must either obtain credits from other companies with surplus credits or invest in projects that offset their emissions (offset projects). As a result, emissions are capped and emitters can trade credits until their emissions match the number of allowances they hold. A cap-and-trade system, to the extent that emission allowances are auctioned, can also generate similar amounts of revenue (https://www.c2es.org/document/cap-and-trade-vs-taxes/).
3. Fuel or input taxes: This applies direct taxes on fuels (in this case fossil fuels) that aim to discourage their purchase and promote the transition to cleaner fuels. These taxes differ from emissions taxes by focusing progressive tax categories on different fuel inputs (paraffin, gas, propane, diesel, crude oil) rather than emissions. These can encourage private sector companies and industries to transition to cleaner fuels or renewable energy sources.
4. Hybrid instruments: These consist of a combination of emission taxes and cap-and-trade instruments. Most current market pricing mechanisms are hybrid systems that are used as transitional mechanisms for emissions trading or in cap-and-trade markets providing temporary measures to create new sources of revenue to reinvest in markets. These can help create the institutional framework necessary to make a sustainable and efficient carbon market.

The steps outlined by Di Bella to establish a carbon market include:

1. Establish the scope of the market (geographic area, sectors, sources of emissions and GHGs to be regulated).
2. Collect robust data on emissions; determine the level of the cap for the sectors.
3. Distribute emission allowances to regulated entities while ensuring adequate oversight to address potential leakage issues that prevent carbon emission sources from moving to different jurisdictions, to improve distributional impacts and create opportunities for governments to raise revenue.
4. Address potential volatility and price uncertainty through market stability design features such as a price floor, price cap, or allowance reserves.
5. Define a rigorous approach for participants' compliance obligations and government oversight of the system.
6. Ongoing engagement with stakeholders to understand and address respective perspectives and concerns to avoid public policy misalignment and ensure political and public support, as well as foster collaboration between government and market actors.
7. Seek to link domestic carbon markets with international markets. This expands flexibility as to how far emission reductions can occur and can also improve market liquidity and competitiveness and facilitate international cooperation.
8. Allow for periodic reviews of market functioning, backed by rigorous and independent evaluation, to enable continuous improvement and adaptation to changing circumstances

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ANNEX 1

Calculation methodology used by SUMFOR v-4.00

1. Carbon calculations for the Carbon Base Year.

    a. In the unforested area.

The total carbon is stored in the two pools (biomass and soil) of each component: swamps, grasslands, and agricultural land. It is assumed that the other unforested areas do not store carbon, as roads, facilities, etc. are reported in them.

The carbon coefficients per hectare used for these calculations are shown in Table 2.

Table 2. Calculation of carbon in the unforested area.

Component	Carbon coefficients ($tC*ha^{-1}$ [1])	
	Biomass	Soil
Swamps	43	643
Grasslands	5	33
Agricultural land	2	80
Semideserts	2	42

Source: Mercadet and Alvarez (2010)

b. In the surface to be reforested.

In this component of the heritage, the total carbon is stored in the above-mentioned reservoirs (biomass and soil), varying the carbon coefficient used for the biomass according to the presence of sickle bush reported by the manager as shown in Table 3.

Table 3. Calculation of carbon in the surface area to be reforested.

Presence of sickle bush	Carbon coefficients ($tC*ha^{-1}$)	
	Soil	Soil
Without sickle bush (< 50 %)	15.0	38
With sikcle bush (≥ 50 %)	29.4	38

Source: Mercadet and Alvarez (2010)

1. The basic density used per species is shown in Annex 2.

c. In plantations established.

- For broad-leaved species.

The following calculations are made for each species:

- BF: Biomass of stem (t)=Volume (m³) x Basic Density (kg/m³) x 10^{-3}
- BF/ha: Biomass of stem/hectare (t/ha) = Biomass of stem (t) / Area (ha)
- FEB: Biomass Expansion Factor (s/u) = $e^{[3.213-0.506 \ln (BF/ha)]}$ (3.00≥FEB≥1.74) (Source: Mercadet and Álvarez, 2010)
- BA: Aerial biomass (t)=BF (t) x FEB (s/u)
- BS: Below-ground biomass (t)=$e^{[-1.0587 + 0,8836 \ln (BA)]}$ (t) (IPCC, 2003; quoted by Andrade, 2006)
- BT: Total biomass (t)=BA (t)+BS (t)
- NM: Necromass (t)=18,2 (t/ha) x Area (ha) (Mercadet and Álvarez, 2010)
- MT: Total Mass (t)=BT (t)+NM (t)
- CBA: Carbon Biomass above ground (t) = BA (t)[2]x Wood Carbon Coefficient (s/u)
- CBT: Total Biomass Carbon (t)=BT (t) x Wood Carbon Coefficient (s/u)
- CNM: Necromass Carbon (t)=NM (t) x Wood Carbon Coefficient (s/u)
- CS: Soil Carbon (t)[3]=123 (t/ha) x Area (ha) (Mercadet and Álvarez, 2011); except for the species shown in Table 4, for which specific data are used:

For each species the following calculations are made:

- BF: Biomass of stem (t)=Volume (m³) x Basic Density (kg/m³) x 10^{-3}
- BF/ha: Biomass of stem/hectare (t/ha)=Biomass of stem (t) / Area (ha)
- FEB: Biomass Expansion Factor (s/u)=$e^{[3.213 - 0.506 \ln (BF/ha)]}$ (3.00≥FEB ≥ 1.74)
- (Mercadet and Alvarez, 2013)
- BA: Above-ground biomass (t)=BF (t) x FEB (s/u)
- BS: Below-ground biomass (t)=$e^{[-1.0587 + 0,8836 \ln (BA)]}$ (t) (IPCC, 2003; quoted by Andrade, 2006)
- BT: Total biomass (t)=BA (t)+BS (t)
- NM: Necromass (t)=18,2 (t/ha) x Area (ha) (Mercadet and Álvarez, 2010)
- MT: Total mass (t)=T (t)+NM (t)
- $V_{cc/ha}$: Volume with bark per hectare (m³/ha) = Total volume (m³) / Surface area (ha)
- $V_{ct/ha}$: Volume with bark per hectare (m³/ha)=42.875+0.1885 Vcc/ha (m³/ha) (Álvarez, Mercadet and Aguirre, unpublished).
- $V_{sc/ha}$: Volume without bark per hectare (m³/ha)=Vcc/ha (m³/ha)-Vct/ha (m³/ha).
- V_{mad}: Total volume of timber (m³)=Vsc/ha (m³/ha) x Area (ha)
- V_{cort}: Total volume of bark (m³)=Vct/ha (m³/ha) x Area (ha)
- B_{mad}: Wood biomass (t=Vmad (m³) x Basic Density (kg/m³) x 10^{-3}

Table 4. Soil carbon values used for mangrove plantations.

Species	Average carbon content (t/ha)	Source
Red mangrove	153*	Blue Carbon Database Nicholas Institute for Environmental Policy Solutions (2011). (Depth: 1 m; 510 tC/ha)
Black mangrove		
Yana		

* Adjustment to 30 cm depth from the value reported for one meter.

- TC: Total Carbon (t) = CBT (t) + CNM (t) + CS (t)
- **For pine species.**

- B_{cort}: Bark biomass (t)=Vcort (m³) x 0.0941[4] Basic Density (kg/m³) x 10^{-3}
- $B_{branches}$: Biomass of foliage (t)=BA (t)-BF (t)
- C_{wood}: Carbon in wood (t)=Bmad (t) x Wood Carbon Coefficient (s/u)
- C_{bark}: Carbon in bark (t)=Bcort (t) x Bark Carbon Coefficient (s/u)
- C_{stem}: Carbon in the shaft (t)=Cwood (t)+ Cbark (t)

2. The carbon coefficient used per species is shown in Annex 3.

3. Soil carbon calculations are made for a standard depth of 30 cm for all species

4. Ratio representing basic density of bark vs. basic density of wood in P. caribaea var. caribaea.

- Cbranches: Carbon in the foliage (t)=Branches x Wood Carbon Coefficient (s/u)
- CBA: Carbon in above-ground biomass (t).

If: CBA>0, CBA=Cstem+Cbranches;
If: CBA≤0, CBA=BA x Wood Carbon Coefficient (s/u)

- CBS: Carbon in belowground biomass (t)=BS (t) x Coefficient of Carbon in Wood (s/u)
- CBT: Total carbon in biomass (t).

If: (CBA+CBS)>0, CBT=CBA (t)+CBS (t)
If: (CBA+CBS)≤0, CBT=BT x Wood Carbon Coefficient (s/u)

- CNM: Necromass Carbon (t)=NM (t) x Wood Carbon Coefficient (s/u)
- CS: Soil Carbon (t)=(Value Table 5) x Area (ha)

In natural forests.

The following calculations are made for each formation:

- BF: Stem Biomass (t)=Volume (m^3) x Basic Density (kg/m^3) x 10^{-3}

  The value of the Basic Density of a formation is the average of the Basic Density of the species that compose it, grouped in three regions of natural distribution (Annex 2):

- West (P. Rio, Artemisa, Mayabeque, Matanzas and I. Juventud).
- Center (V. Clara, Cienfuegos, S. Spiritus, C. Avila and Camagüey)
- East (Las Tunas, Holguín, Granma, S. Cuba and Guantánamo).

Table 5. Soil carbon values used for pine plantations.

Species	Average carbon content (t/ha)	Source
Male pine	288.32	Renda, Rodríguez and Mercadet (unpublished)
Mayarí Pine	350.78	
Female pine	671.32	
Sierra Pine	967.87	

- TC: Total Carbon (t)=CBT (t)+CNM (t)+CS (t)

d. In plantation development.

The following calculations are made for each species:

- AACI: Average Annual Carbon Increase (tC/ha/year).
  - Where the species has areas recorded in plantations established, the total carbon calculated there for the species (TC) is divided by the area reported for it and by 20 (20 years of development is assumed).
  - Where the species has no areas recorded in plantations established, the sum of the total carbon of all reported species is divided by the sum of their areas and divided by 20.
- CBA: Above-ground Biomass Carbon (t)=Area (ha) x IMAC (t/ha/a)
- CS: Soil Carbon (t)=123 (t/ha) x Area (ha); except for pine forests, where the value is 80 t/ha (Mercadet and Álvarez, 2011).
- TC: Total Carbon (t)=CBA (t)+CS (t)

In this way, according to the province in which the manager being evaluated is located, the corresponding value of Basic Density for each forest formation is used in the calculation of the Stem Biomass.

In case a company reports the existence of a natural formation in a region for which no average Basic Density value was determined (e.g. the oak formation in the Central and Eastern regions), the system will use the national average value for the calculation.

- BF/ha: Stem Biomass/hectare (t/ha)=Stem Biomass (t) / Area (ha)
- FEB: Biomass Expansion Factor (s/u)=$e^{[3.213 - 0.506 \ln (BF/ha)]}$ (3.00≥FEB≥1.74) (Mercadet and Álvarez, 2010)
- BA: Above-ground biomass (t)=BF (t) x FEB (s/u)
- BS: Below-ground biomass (t)=$e^{[-1.0587 + 0,8836 \ln (BA)]}$ (t) (IPCC, 2003; quoted by Andrade, 2006)
- BT: Total biomass (t)=BA (t)+BS (t)
- NM: Necromass (t)=18,2 (t/ha) x Area (ha) (Mercadet and Álvarez, 2010)
- MT: Total Mass (t)=BT (t)+NM (t)
- CBA: Above-ground Carbon Biomass (t)=BA (t) x Wood Carbon Coefficient (s/u)

The value of the Carbon Coefficient of a formation is the average of the Carbon Coefficient of its component species, as shown in Table 6.

Table 6. Average values of the Carbon Coefficient per natural formation.

Nº	FORMATION	C Coefficient	No.	FORMATION	C Coefficient
1	Scrub	0.4701	9	Dry forest	0.4670
2	Cuabal	0.4701	10	Semi-dry forest on acid soil	0.4696
3	Oak forest	0.4701	11	Semi-dry forest on limestone soil	0.4699
4	Mangrove	0.4701	12	Semi-deciduous poorly drained forest	0.4708
5	Coastal mangrove	0.4701	13	Pine forest	0.4710
6	Xerófilo de mogotes	0.4701	14	Rainforest	0.4729
7	Cool forest	0.4701	15	Mountain rainforest	0.4750
8	Cloud forest	0.4701	16	Grapevine	0.4584

- CBT: Total Biomass Carbon (t)=BT (t) x Carbon Coefficient (s/u)
- CNM: Carbon Necromass (t)=NM (t) x Carbon Coefficient (s/u)
- CS: Soil Carbon (t)=123 (t/ha) x Area (ha) (Mercadet and Álvarez, 2010); except for the Formations shown in Table 7, for which specific data are used.

Table 7. Soil carbon values used for the Pine and Mangrove Formations.

Formation	Average Carbon Content (t/ha)	Source
Pinegrove	570	Álvarez, Mercadet et al. (2011) Rodríguez, Renda and Mercadet (2013) Renda, Rodríguez and Mercadet (2014) (Depth: 30 cm)
Mangrove	153*	Nicholas Institute for Environmental Policy Solutions Institute for Environmental Policy Solutions (2011). (Depth: 1 m)

* Adjustment to 30 cm depth from the value reported for one meter.

3. Determination of Sustainable Management Indicator 3.5

The indicator is calculated based on the following elements of the heritage under management:

- Coverage achieved (%):

$$\frac{\text{(Area of natural forests + Area of plantations established)*100}}{\text{(Area of natural forests + Area of plantations established + Area to be reforested)}}$$

- Average carbon sequestration (tC/ha): Derived from Base Year results.
- Weighing of sink capacity: Derived from Table 8.

Table 8. Weighing of the Company's sink capacity.

Coverage Reached (%)	Carbon Sequestration (tC/ha)				
	> 285	231 – 285	171 – 230	115 – 170	< 115
>90	4	4	3	3	2
86–90	4	3	3	2	2
81–85	3	3	2	2	1
75–80	3	2	2	1	1
<75	2	2	1	1	0

- Fire damage (%):

$$\frac{\text{Average annual area burned} * 100}{\text{(Area of natural forests + Area of plantations established)}}$$

- Weighting of the level of GHG emissions: Derived from Table 9.

Table 9. Weighting of the Company's GHG emissions.

Range	Weighing
Relative fire area of less than 1.0%.	4
Relative fire area between 1.1% and 1.5%.	3
Relative fire area between 1.6% and 2.0%	2
Relative fire area between 2.1% and 3.0	1
Relative fire area greater than 3%.	0

- Assessment of Indicator 3.5: Results from the joint analysis of the weighing of the Company's sink capacity and emission level, obtained from Table 10.

Table 10. Weighing of Sustainable Management Indicator 3.5.

Sink Capacity Weighting	Emission Level Weighing				
	4	3	2	1	0
4	4	4	3	3	2
3	4	3	3	2	2
2	3	3	2	2	1
1	2	2	2	1	1
0	2	2	1	1	0

The final results of the weighing of Indicator 3.5 would be as follows:

- Outstanding contribution to mitigation: 4.
- Favorable contribution to mitigation: 3.
- Weak contribution to mitigation: 2.
- Very weak contribution to mitigation: 1-0.

4. Determination of the Emission Balance (EB)

This is an option provided by the system for the manager to know if there has been an increasing evolution of atmospheric carbon removals between two successive assessments of the heritage under management.

To do this, the year of the previous assessment and the total sequestration achieved in the previous assessment (RT0, tC/ha) are requested for comparison with the total sequestration of the current assessment (RTA, tC/ha), according to the expression:

$$BE = RT0 - RTA$$

If the previous assessment exceeds the current assessment by three years, the message <u>Exceeds the allowed time limit</u> will be issued and the calculations will not be performed. Otherwise, the years whose results are compared and the emission balance in thousands of tons of carbon and CO^2 are presented.

If the balance is positive (RT0>RTA), the message <u>**emission source Entity**</u> will be displayed below, but if it is negative (RT0<RTA), the message <u>**carbon sink Entity**</u> will be displayed.

II. Calculation of the Baseline and Mitigation Alternatives

1. Calculation of the Carbon Baseline.

The calculation of the Carbon Baseline takes into consideration, on the one hand, the characterization of the technical management of the forest heritage provided by the manager and, on the other hand, the algorithm that explains the temporal dynamics of land use and land-use change within the forest heritage (Fig. 1).

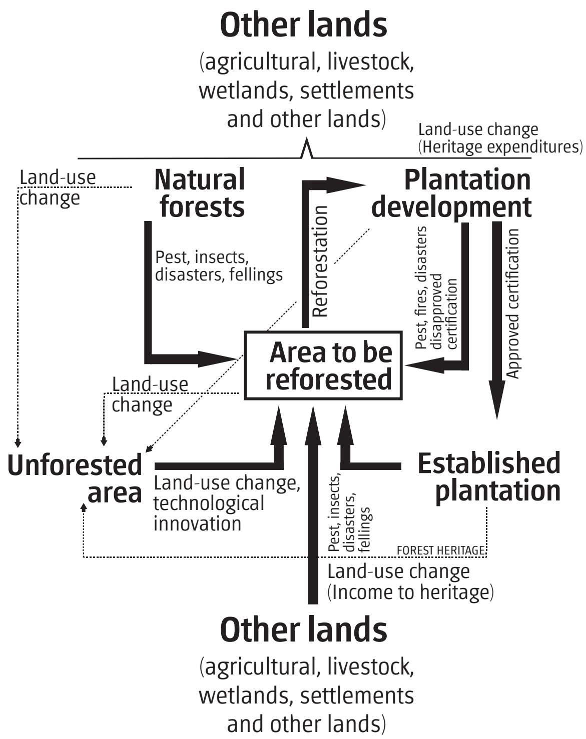

Figure 1. Algorithm of temporal dynamics of land use and land-use change within the forest heritage.

a. Calculation of the variation of unforested areas and the carbon they sequester.

- Its surface area remains constant throughout time and what varies is the carbon it sequesters, depending on whether or not it was affected by fires.
- In the case of unforested areas, only the above-ground area of the swamps (686 tC/ha) is considered to be affected by fire, with a recovery period of 3 years for its above-ground biomass (43 tC/ha) (Mercadet and Álvarez, 2010).
- For the remaining unforested areas (grasslands, agricultural lands, and semi-deserts), the carbon values shown in Table 2 are used annually.

b. Calculation of the change in surface area of the areas to be reforested and the carbon they sequester.

- Check whether the area to be reforested is greater than the annual reforestation plan.
- If it is, the plan is deducted; if it is not, the plan is adjusted to the available area.
- We calculate how much of the clear-cut area corresponds to plantations.
- We calculate the area of fires that affected areas to be reforested, plantations under development, certified plantations, and natural forests.
- We calculate how much of the plantations under development do not reach certification.
- The area to be reforested for the following year is calculated: the area that remains to be planted, plus the area of clear-cutting, plus the area burnt (except for the unforested area and the area that was to be reforested), plus the plantations under development that were not established.
- Carbon sequestration is calculated using the coefficients shown in Table 3.

c. Calculation of the change in the area of plantations under development and carbon sequestration.

- This is based on two values for the area of plantations under development: those already existing in the heritage in the base year and the area planted annually from that year onward.
- During the first 3 years, each year one-third of the plantations existing in the base year is incorporated annually into the certified plantations, minus the areas burnt and the level of attainment.
- From the fourth year onward, each year the value of the annual planting plan carried out 3 years earlier is incorporated into the certified plantations, minus the areas burnt and the level of attainment.
- To calculate the carbon sequestered, the average value of tC/ha obtained for the areas under development in the base year (total amount of carbon sequestered / total area of plantations under development) shall be used.

d. Calculation of the change in the area of plantations established, their volume, and carbon sequestration.

- Existing plantations established are reduced by the area of annual clear-cutting and annual area burnt.
- To the remaining area of plantations established, the area of plantations under development that has reached 3 years of age is added each year (minus the area of fire and attainment).
- From the newly calculated total area, the average volume per hectare in the base year, and the AMI volume, the increase in the total volume of plantations is calculated.

- From the relationship between volume/ha and C/ha, the change in carbon sequestered is calculated.
- From the carbon sequestered by the plantations, the carbon extracted by non-clear cutting is deducted, based on the ratio calculated in the base year between the carbon sequestered by the above-ground biomass and the existing volume.

e. Calculation of the change in the area of natural forests, their volume, and carbon sequestration.

- Existing natural forests are reduced by the area of annual clear-cutting and annual area burned.
- From the newly calculated total area, the average volume per hectare in the base year, and the volume AMI, the increase in the total volume of natural forests is calculated.
- From the relationship between volume/ha and C/ha, the change in carbon sequestered is calculated.
- From the carbon sequestered by natural forests, the carbon removed by clear-cutting is deducted, based on the ratio calculated in the base year between the carbon sequestered by above-ground biomass and the existing volume.

f. Overall change in carbon sequestered (Mt C) for each component of the Baseline.

The overall carbon sequestered per year is the annual sum of carbon sequestered by unforested areas, areas to be reforested, plantations under development, plantations established, and natural forests.

2. Simulation of mitigation alternatives.

The system evaluates the effects generated on the behavior of the Baseline for a total of 10 mitigation alternatives, for a maximum period of 10 years, as shown in Table 11.

Table 11. Mitigation alternatives included in the system.

No.	Alternative	Variation (%)	Time (years)	
1	Increase the annual development plan:			
2	Increase reforestation achievement:			
3	Decrease annual area of burned forests:			
4	Decrease annual area of burned natural forests:			
5	Decrease annual area of clear-cutting in established artificial forests:			
6	Decrease annual area of clear felling in natural forests:			
7	Decrease annual volume harvested by other felling in established artificial forests:			
8	Decrease annual volume harvested by other felling in natural forests:			Covered area/year (ha)
9	Increase the average annual increment of artificial forests:			
10	Increase the current annual increment of natural forests.			

Calculation and comparison of sequestration by mitigation alternatives

If the requested mitigation alternatives are error-free, the system calculates the new value to be used concerning the value initially provided in the Data Entry Pages, reprocesses the Base Year data, and obtains the requested Mitigation Alternative Lines.

For the calculation of the Alternative Mitigation Lines the system:

1. divides the percentage of variation indicated for the simulation, by the execution time estimated necessary for its realization, resulting in a percentage of annual variation (PAV [%/year]).
2. modifies the results of the original Baseline by progressively adding PAV to each year, for the years indicated, until the percentage indicated for the simulation is reached.

For alternatives 9 and 10, the system calculates the usual carbon sequestration achieved and adds to it the sequestration corresponding to the area that the manager can manage annually, applying the established increase so that the maximum indicated is reached in the estimated time. Finally, to obtain the alternative results, the system adds both sequestrations and compares them with the Baseline.

The process of alternative simulation can be repeated several times with different values from the initial ones, including new alternatives in the selection or excluding some of those already evaluated but does not allow the automatic calculation of the effects of two or more alternatives in a single result.

III. Economic analysis of mitigation

This analysis process is only made by the system when the manager provides the unit costs corresponding to each selected mitigation alternative (Table 12) and the price at which the ton of CO_2 mitigated will be paid is indicated.

Table 12. Cost data per mitigation alternative to be provided by the manager.

EXECUTION COST OF EACH ACTIVITY		(CUP+CUC)	UNITS
1	Increase the annual development area:		$/ha
2	Increase the reforestation achievement:		$/ha established
3	Reduce the annual area of burned established artificial forests:		$/ha protected
4	Reduce the annual area of burned natural forests:		$/ha protected
5	Reduce the annual area of clear felling in established artificial forests:		$/m³ timber
6	Reduce the annual area of clear felling in natural forests:		$/m³ timber
7	Decrease annual volume harvested by other fellings in established artificial forests:		$/m³ timber
8	Decrease annual volume extracted by other fellings in natural forests:		$/m³ timber
9	Increase the average annual increase of artificial forests:		$/ha
10	Increase the annual current increase of natural forests:		$/ha

1. Annual and total expenditure to achieve mitigation (TG-$).

For each mitigation alternative and based on the value obtained as the difference between the result of the mitigation line and the baseline for each year, as well as the unit cost provided by the user, the system calculates the expenditure that the manager must incur annually to achieve that mitigation and, in the end, the total expenditure to be executed during 10 years to implement the mitigation alternative.

2. Annual and average cost to achieve mitigation (AC-$).

For each mitigation alternative and based on the annual expenditure that the manager must incur to achieve the mitigation and on the magnitude of mitigation achieved, the system calculates the annual cost for the alternative and the average cost at the end of the 10 years of implementation.

3. Gross income (GI-$).

Result of the product of the price per ton of CO_2 mitigated, by the total mitigation achieved at the end of the 10 years of implementation.

4. Net income (NI-$).

Result of the difference between the gross revenue and the total expenditure for each mitigation alternative.

If in an alternative the gross income obtained is less than the total expenditure incurred, the net income will be marked as Not available.

5. Expenditure per peso in revenue (E/P-$).

Result of the quotient between total expenditure and gross income; it is an indicator of the cost-effectiveness of the mitigation alternative evaluated.

1. Net present value (NPV-$).

It is calculated from the 10-year cash flow (an annual difference between income and expenses, including fixed and variable costs) corresponding to each mitigation alternative. Once the cash flows have been calculated, the Net Present Value (NPV) is calculated to estimate the present value of a certain number of future cash flows, originated by the environmental investment represented by the implementation of the mitigation alternative, determined by the expression (Gómez, 2015):

$$\mathrm{VAN}=\left(\sum_{(t=1)}^{n}((B_t - C_t)/(1-\mathrm{r})^{t})\right)-I_0$$

where:
Bt-Profits in year t.
Ct-Costs in year t.
r=discount rate (10%).
I0=initial investment.

Considering the results as follows:

- NPV>0 Profits: c> Present value of income> Present value of expenditure.
- NPV=0 Indifferences: No profit or loss.
- NPV<0 Losses: Present value of income< Present value of expenditure.

7. Internal rate of return (IRR-%).

It is based on the NPV formula, defined as the value of the discount rate (r) at which the net value would become zero, i.e. the discounted net benefits are equal to the initial investment (Gómez, 2015):

$$VAN=\left(\sum_{(t=1)}^{n}((B_t-C_t)/(1-r)^{t})\right)-I_0=0$$

Considering the results as follows:

- IRR>k positive NPV.
- IRR=k NPV=0
- IRR<0 negative NPV.

If the NPV is negative, the IRR will display the warning Not applicable.

8. Payback period (IRR - years and months).

To calculate the payback period of the investment, taking into account different cash flows between years, the expression (Gómez, 2015) is applied:

$$VAN=\left(\sum_{(t=1)}^{TR}((I_t-C_t)/(1-r)^{t})\right)-I_0=0$$

where:

It-Investment in year t.
Ct-Cash flow in year t.
r-Discount rate (10%).
I0-Initial investment.

If the NPV is negative, the IRR will display the warning Not applicable.

REPORT OF RESULTS

The results are presented in the REPORT sheet, divided into four parts:

1. Base year results.
2. Emission balance.
3. Baseline carbon sequestration results.
4. Results of mitigation alternatives.

1. Base year

The base year results include the definition of the year corresponding to the data analyzed, the overall values obtained for the forest heritage assessed and the relative distribution (%) of carbon content per pool and component; those corresponding to established forests per species, natural forests per formation and forest categories, as shown in Table 13.

Table 13 Results of the assessed heritage for the base year.

BASE YEAR RESULTS:

General results of the manager:

MANAGER	REPORT										IMSB 3.5
	Surface area (ha)			Timber yield (TY: m³/ha)			Carbon sequestration (CS: tC/ha)				
	TOTAL	Artificial forests	Natural forests	Covered area	Artificial forests	Natural forests	TOTAL	Artificial forests	Natural forests	10 years later	Best value: 4

Carbon distribution per pool (%):

POOL	TOTAL	Artificial Forests	Natural Forests
In biomass	0.00	0.00	0.00
In necromass	0.00	0.00	0.00
In the soil	0.00	0.00	0.00

Table 13 (cont)

1. Established artificial forests

No.	SPECIES	Surface area (ha)	RM (m^3/ha)	RC (tC/ha)
1	Acacia			
2	Acana			
3	Poplar tree			
4	Falcate albizzia			
5	Albizzia procera			
120	Yaba			
121	Yagruma			
122	Yamagua			
123	Yana			
124	Yarúa			
125	Yaya			
126	Other species			

2. Natural forests

Nº	FORMATION	Surface area (ha)	RM (m^3/ha)	RC (tC/ha)
1	Tendrils shrubland			
2	Cuabal			
3	Holm oak forest			
4	Mangrove			
5	Coastal mangrove			
6	Cool forest			
7	Cloud forest			
8	Pine forest			
9	Rainforest			
10	Mountain rainforest			
11	Semi-caducous/acid			
12	Semi-deciduous/poorly drained			
13	Semi-ducted / limestone			
14	Grapevine			
15	Xerófilo de mogote			
16	Typical xerophile			

W	FOREST CATEGORY	Surface area (ha)	RM (m^3/ha)	RC (tC/ha)
1	Producing			
2	Water and Soil Protector			
3	Coastal Protector			
4	Flora and Fauna Protection			
5	Special Management			
6	Recreational			
7	Educational and Scientific			

2. Emission balance

The calculation of the emission balance provides the manager with an assessment of the effect caused by the forest heritage management on the removal of atmospheric carbon, specifying the magnitude of the results and whether the company has been a source of emissions or a carbon sink during the time between two successive assessments, as shown in Table 14.

Table 14. Carbon balance results.

EMISSION BALANCE:		
Thousands of tC	Thousands of tCO_2	

3. Carbon sequestration baseline

The baseline carbon sequestration forecast for a 10-year period appears in two forms in the results: in tabular form and, alongside it, in chart form as shown in Table 15.

Table 15. Baseline carbon sequestration results.

VARIABLES	YEARS										
	0	1	2	3	4	5	6	7	8	9	10
Unforested areas											
Areas to be reforested											
Plantations under development											
Established plantations											
Natural forests											
TOTAL											

When processing, the system replaces the year numbers with the corresponding values, both in the table and in the chart, by assigning values to the Y-axis on the chart.

4. Results of the mitigation alternatives.

The results of the mitigation alternatives are shown in two tables. The first contains the data summary of the initial input data for the calculations, as shown in Table 16, while the second contains the mitigation results of each alternative (amount by which it exceeds the baseline CO_2 removal value at 10 years) and all the economic indicators required to enable the manager to make an informed decision on what is best to do, as shown in Table 17.

Alternativas	Initial value		Variation (%)	Covered area (ha/a)	Unit cost		Implementation period (a)	Capitalization period (a)
	Value	Units of meas.			Cost	Unit		
Increase in the development plan		ha				\$/ha		
Increased achievement		%				\$/ha established		
Decrease of burnt artificial forests		ha				\$/ha protected		
Decrease in natural forests burnt		ha				\$/ha protected		
Decrease in clear-cutting of artificial forests		ha				\$/m³ timber		
Decrease in clear-cutting of natural forests		ha				\$/m³ timber		
Decrease in other clear-cutting of artificial forests		m³				\$/m³ timber		
Decrease in other clear-cutting of natural forests		m³				\$/m³ timber		
Increase in AMI artificial forests		m³/ha/a				\$/ha		
Increase in ACI of natural forests		m³/ha/a				\$/ha		

The implementation and capitalization periods refer to the time needed to carry out the mitigation actions (implementation) and the total time during which their effects will be evaluated (capitalization, which for all alternatives will be 10 years from their start). Consequently, if implementation takes 3 years, capitalization will take 7 years, totaling 10 years.

Below the first table is the price that was used for the payment per ton of atmospheric CO_2 mitigated.

Table 17. Results of the evaluated mitigation alternatives.

Alternatives	Mitigation (tC)	Total expenditure (TE - $)	Economic efficiency ($/tCO2)	Gross income (GI - $)	Net income ($)	TE/GI Ratio ($/$)	NPV ($)	IRR (%)	Payback period	
									Years	Years
Increase in the promotion plan										
Increased achievement										
Decrease of burnt artificial forests										
Decrease in burnt natural forests										
Decrease in clear-cutting of artificial forests										
Decrease in clear-cutting of natural forests										
Decrease in other artificial forest clear-cutting										
Decrease in other fellings of natural forests										
Increase in AMI of artificial forests										
Increase in ACI of natural forests										

If the economic evaluation of mitigation was not requested, the columns with economic indicators in Table 17 will be blank.

Usually, the best mitigation alternative is the one that achieves the highest mitigation, with the highest net income, in the shortest payback period; however, the selection of the alternative to be implemented may be conditioned by other technological and/or economic aspects, depending on the particular conditions of the manager. For this reason, instead of comparing, selecting, and proposing a specific alternative, the system offers the results of all alternatives to the manager, so that he/she can decide which one to choose.

ANNEX 2

Emission factors: basic density and carbon fraction per species used by SUMFOR v-4.00 (Álvarez, Mercadet and Peña, 2019).

No.	COMMON NAME	SCIENTIFIC NAME	BASIC DENSITY[1] (kg/m³)	CARBON FRACTION[2] (%)
1	Acacia mangium	*Acacia mangium Willd.*	520	48,54
2	Acana	*Manilkara albescens* (Gris.) Cronq.	**917**	47,01
3	Alamo	*1atif religiosa* L.	403	49,09
4	Albizzia falcata	*Albizia falcataria* (L.) Fosberg.	250	47,17
5	Albizzia procera	*Albizia procera* Benth.	**493**	47,01
6	Albizzia sp.	*Albizia spp.*	485	47,01
7	Mesquite	*Prosopis juliflora* (Sw.) P. DC.	578	47,01
8	Rain tree	*Albizia saman* (Jacq.) F. Muell.	**437**	46,37
9	White siris	*Albizia procera* Benth.	**493**	47,01
10	Silk tree	*Albizia spp.*	568	47,01
11	Turpentine tree	*Bursera simaruba* (L.) Sargent.	293	45,53
12	Almendro	*atifí occidentalis* (Sw.)	830	47,01
13	Indiana almond	*Terminalia catappa* L.	440	47,38
14	Panama tree	*Sterculia apetala* (Jacq.) Karst.	378	47,01
15	Clammy Cherry	*Cordia colloccoca* L.	425	47,01
16	White pricklyash	*Zanthoxylum martinicense* (Lam.) D.C.	500	46,16
17	Magnolia minor	*Talauma minor* Urb.	**645**	47,01
18	Bacona	*Albizia cubana* Britt. Et Wilson	**773**	49,40
19	Balsa tree	*Ochroma pyramidale*	250	47,90
20	Common bamboo	*Bambusa vulgaris* Schrad.	**565**	48,15
21	Spanish elm	*Gerascanthus gerascanthoide* L.	740	46,02
22	Bayúa	*Zanthoxylum elephanthiasis* Macfd.	**525**	50,47
23	Rosewood	*Pterocarpus macrocarpus* Kurz.	**701**	47,01
24	Greenheart	*Colubrina arborescens* (Mill.) Sarg.	**677**	46,39
25	Brasilletto	*Caesalpinia vesicaria* L.	**1013**	47,01
26	Mountain Immortelle	*Erythrina poeppigiana* (Walp.) O.F. Cook.	**266**	47,01
27	Red Cedar	*Trichilia hirta* L.	610	46,50
28	Giant cane	*Arundo donax* L.	**614**	47,01
29	Horsebush	*Peltophorum dubium*	**717**	47,01
30	Horse Cassia	*Cassia grandis* L.	**645**	47,01
31	African Mahogany	*Khaya ivorensis* A. ati.	445	47,01
32	West Indian Mahogany	*Swietenia mahagoni* (L.) Jacq.	**653**	47,99
33	Honduras Mahogany	*Swietenia machrophylla* King.	470	46,79
34	Big-leaf mahogany	*Swietenia macrophilla x* S, mahagoni	**605**	47,01
35	Soldierwood	*Colubrina elliptica* (Sw.) Brizicki et Stern	**843**	47,15
36	Malabar Chestnut	*Pachira insignis* Sarg.	**614**	47,01
37	Casco de vaca	¿?	**614**	47,01
38	Beach pine	*Casuarina equisetifolia* Forst.	820	47,59
39	Cajeput	*Melaleuca leucodendron* L.	**589**	47,57

1. Values in bold and black are estimates of basic density from air dry density values (BD = 0.0134 + 0.800 DD); values in bold and red are average values obtained from the species set.

No.	NOMBRE COMÚN	NOMBRE CIENTÍFICO	BASIC DENSITY[2] (kg/m³)	CARBON FRACTION[2] (%)
40	Cedar	*Cedrela odorata* L.	**525**	47,43
41	Ceiba	*Ceiba pentandra* (L.) Gaert.	251	47,01
42	Black mastic	*Terminalia eriostachya* Rich.	**893**	47,01
43	Coconut tree	*Cocos nucifera* L.	500	47,01
44	Copal	*Protium cubense* (Rose) Urb.	**621**	47,01
45	Autograph Tree	*Clusia rosea* (L.) Jaq.	670	47,01
46	Western cherry laurel	*Laurocerasus occidentalis* (Sw.) Roem.	840	47,01
47	Willow Bustic	*Bumelia salicifolia*	**813**	47,01
48	Degame	*Callycophyllum candidissimum* (Vahl.) DC.	760	47,58
49	Feather Bed	*Diospyros crassinervis* (Krug. Et Urb.) Standl.	670	47,01
50	Coast live oak	*Quercus oleoides C.&S. var. sagreana* C.H. Mull.	480	47,01
51	Lemon-Scented Gum	*Eucalyptus citriodora* Hook f.	640	47,01
52	Blue gum	*Eucalyptus saligna* Sm.	590	42,34
53	Red Mahogany	*Eucalyptus pellita* F. Muell.	920	48,75
54	Flowering Gum	*Eucalyptus spp.*	790	47,01
55	Yellow flamboyant	*Baryxylum inerme* (Roxb.) Pierre	**573**	47,01
56	Red flamboyant	*Delonix regia* (Coger) Raf.	713	47,01
57	Frijolillo	*Hebestigma cubensis* (H.B.K.) Urb.	**909**	47,01
58	Paradise Tree	*Simaruba glauca* D.C.	390	47,01
59	Gmelina	*Gmelina arborea* Roxb.	400	46,98
60	Pigeon berry	*Eugenia axillaris* (Sw.) Willd.	760	45,62
61	Jamaican-dogwood	*Piscidia piscipula* (L.) Sargent.	800	46,20
62	Guana	*Sterculia cubensis* Urb.	**213**	47,01
63	Guanima	¿?	**614**	47,01
64	American Toadwood	*Cupania glabra* Sw.	**614**	47,01
65	Guásima	*Guazuma tomentosa* H.B.K.	**517**	46,42
66	Roughbark	*Guaiacum officinale* L.	**1085**	48,26
67	Calabash tree	*Crescentia cujete* L.	**605**	47,01
68	Hicaquillo	*Coccoloba retusa* (Gris.) Cat.	**764**	47,01
69	Manila tamarind	*Pithecellobium dulce* (Roxb.) Bent.	**549**	47,01
70	White leadtree	*Leucaena leucocephala* (Lam.) De Wit	640	46,46
71	Jaboncillo	*Sapindus saponaria* L.	580	47,01
72	Jagűey	atif spp.	390	47,01
73	Pau Branco	*Phyllostylon brasiliensis* Capanema.	770	47,01
74	Jiquí	*Pera bumeliaefolia* Gris.	**973**	47,01
75	Jobo	*Spondias atifí* L.	372	47,01
76	False mastic	*Mastichodendron foetidissimum* (Jacq.) Cronquist.	**853**	46,83
77	Fourleaf buchenavia	*Buchenavia tetraphylla* (Aubl.) How.	510	47,01
78	Fleaf buchenavia	*Buchenavia capitata* (Vahl.) Eichl.	645	47,01
79	Ipil-Ipil	*Leucaena leucocephala* (Lam.) De Wit	640	47,01
80	Negra lora	*Matayba domingensis* (DC.) Radlk.	**613**	47,01
81	Maguey	¿?	**614**	47,01

2. Values in bold and black are estimates of basic density from air dry density values (BD = 0.0134 + 0.800 DD); values in bold and red are average values obtained from the species set.

No.	NOMBRE COMÚN	NOMBRE CIENTÍFICO	BASIC DENSITY[3] (kg/m³)	CARBON FRACTION[2] (%)
82	Rose-mallow	*Hibiscus elatus* Sw.	455	46,60
83	Manajú	*Rheedia aristata* atifí.	**766**	47,01
84	Black mangrove	*Avicennia germinans* (L.) L.	680	47,01
85	Red mangrove	*Rhizophora mangle* L.	840	47,01
86	Cuban magnolia	*Magnolia cubensis* Urb.	530	47,01
87	Cashew nut	*Anacardium occidentale* L.	790	47,01
88	Royal mahogany	*Carapa guianensis* Aubl.	523	47,28
89	Neem tree	*Azadirachta indica* A. Juss.	**613**	49,74
90	Nogal	*Juglans atifícal* Gris.	**533**	45,94
91	Beach calophyllum	*Calophyllum pinetorum* Bisse	610	48,75
92	Devil's ear	*Enterolobium cyclocarpum* (Jacq.) Gris.	350	46,88
93	Bull Thatch Palm	*Sabal maritima*	900	47,01
94	Cuban royal palm	*Roystonea regia* O.F. Cook.	**781**	47,01
95	Palma sp.		930	47,01
96	Blackwood	*Haematoxylum campechianum* L.	**805**	47,01
97	False mamery	*Calophyllum brasiliense* Camb.	530	47,01
98	Chinaberry tree	*Melia azadirachta* L.	460	45,91
99	White mangrove	*Laguncularia racemosa* (L.) Gaertn.	620	47,01
104	Barbados nut	*Jatropha curcas* L.	**253**	47,01
105	Quick stick	*Gliricidia sepium* (Jacq.) Steud.	520	46,88
106	Piñón	*atifíca* spp.	612	47,01
107	Roble blanco	*Tabebuia angustata* atif.	612	49,07
108	Roble guayo	*Vitex atifícale* Sw.	**581**	47,01
109	Savannah oak	*Tabebuia spp.*	693	47,16
110	Sabicu wood	*Lysiloma sabicu* (L.) Benth.	**629**	46,78
111	Salsafrá	¿?	**614**	47,01
112	Sandbox tree	*Hura crepitans* L.	400	47,01
113	Water wood	*Hyeronima crassistipula* Urb.	**783**	47,01
114	Kakanga Root	*Nectandra coriacea* (Sw.) Gris.	**597**	46,08
115	False tamarind	*Lysiloma latisiliquum* (L.) Benth.	**605**	45,21
116	Teca	*atifíc grandis* L.	515	48,49
117	sore-mouth bush	*Poeppigia procera* Presl.	**673**	46,66
118	Seagrape	*Coccoloba uvifera* Jacq.	**765**	44,66
119	Uva gomosa	*Cordia atifíc* Willd.	**445**	47,01
120	Yaba	*Andira atifíc* (Sw.) H.B.K.	640	47,64
121	Trumpet tree	*Cecropia peltata* L.	**309**	46,50
122	Yamagua	*Guarea guara* (Jacq.) P. Wills.	**605**	47,88
123	Buttonwood	*Conocarpus erecta* L.	**893**	47,01
124	Brasiletto	*Caesalpinea violacea* (Mill.) Standl.	**749**	50,10
125	Yaya	*Oxandra atifícale* (Sw.) Bail.	**773**	46,10
126	Other species		**614**	47,01
		AVERAGE DENSITY	**614**	
		AVERAGE CARBON COEFFICIENT		47,01

3. Values in bold and black are estimates of basic density from air dry density values (BD = 0.0134 + 0.800 DD); values in bold and red are average values obtained from the species set.

No.	COMMON NAME	SCIENTIFIC NAME	BASIC DENSITY (kg/m³)	CARBON FRACTION (%)	
				Timber	Bark
100	Cuban pine	*Pinus maestrensis* Bisse	**605**	46,78	52,55
101	Pino de Mayarí	*Pinus cubensis* 4atifí.	**629**	47,15	51,91
102	Tropical pine	*Pinus tropicalis* Morelet	**525**	47,14	50,27
103	Caribbean pine	*Pinus caribaea* Morelet var. *caribaea* Barret y Golfari	495	47,53	52,68
		AVERAGE DENSITY	**564**		
		AVERAGE CARBON COEFFICIENT		**47,15**	**51,85**

Emission factors: basic density and carbon fraction density per natural formation used by SUMFOR v-4.00

Nº	FORMATION	Average Basic Density (kg/m³)				Carbon Fraction (%)
		NATIONAL	WESTERN	CENTRAL	EASTERN	
1	Tendrils shrubland	740,0	670,0	670,0	740,0	47,01
2	Cuabal	821,8	821,8	823,0	852,9	47,01
3	Oak grove	480,0	480,0	480,0	480,0	47,01
4	Mangrove	753,3	753,3	753,3	753,3	47,17
5	Coastal shrubland	636,7	636,7	636,7	636,7	47,01
6	Cool temperate forest	740,0	740,0	740,0	740,0	47,01
7	Cloud forest	690,0	710,0	570,0	690,0	47,01
8	Pine tree	627,1	630,0	627,1	636,7	46,90
9	Rainforest	583,5	523,3	591,1	638,7	47,29
10	Mountain rainforest	638,8	604,2	591,1	638,7	47,50
11	Semi-deciduous on acid soil	593,0	633,8	665,7	593,0	47,08
12	Semi-deciduous in limestone soil	662,3	653,9	652,0	656,3	46,99
13	Poorly drained semi-deciduous	637,9	637,0	646,3	645,6	46,96
14	Grapevines	720,0	720,0	720,0	720,0	45,84
15	Xerófilo de mogote	770,0	755,7	830,0	770,0	47,01
16	Xerófilo típico	799,1	809,0	805,6	800,3	46,70

ANNEX 3

Agroforestry Business Group Carbon Reports. Timber and carbon results by species

Nº	SPECIES	2013 Report		2017 Report				2019 Report			
		Carbon in above-ground biomass (tC/ha)	Carbon in total biomass (tC/ha)	No. of Cos. having the sp.	Total surface area (ha)	Timber Yield (m^3/ha)	Carbon sequest(tC/ha)	Number of Cos. having the species	Total surface area (ha)	Timber Yield (m^3/ha)	Carbon sequestr. (tC/ha)
1	Acacia	29,40	38,20	10	2 815,66	45,39	170,23	10	2 815,66	45,39	170,23
2	Albizzia falcata			2	3,00	8,00	135,17	2	3,00	8,00	135,17
3	Albizzia procera	12,50	16,20	2	464,40	35,89	159,31	2	464,40	35,89	159,31
4	Albizzia sp.	32,50	42,30	2	10,00	57,55	177,46	2	10,00	57,55	177,46
5	West-Indian locust	13,60	17,70	12	1 088,72	44,37	151,35	12	1 088,72	44,37	151,35
6	Indian locust	45,80	59,50	9	6 489,70	53,66	173,59	9	6 489,70	53,66	173,59
7	Spanish locust	56,40	73,30	3	97,30	33,17	117,76	3	97,30	33,17	117,76
8	Turpentine tree	27,60	35,90	3	13,29	19,27	140,53	3	13,29	19,27	140,53
9	Almond tree	82,60	107,30	4	120,60	38,25	180,89	4	120,60	38,25	180,89
10	Indian almond			1	7,00	120,63	218,63	1	7,00	120,63	218,63
11	Panama tree	3,10	4,00	1	26,80	6,00	135,36	1	26,80	6,00	135,36
12	Spoon tree	3,00	3,90	2	10,80	19,50	145,80	2	10,80	19,50	145,80
13	Yellow prickle			1	0,80	42,25	167,08	1	0,80	42,25	167,08
14	Dove wood	55,10	71,70								
15	Balsa	41,60	54,00	1	0,10	8,00	135,65	1	0,10	8,00	135,65
16	Bamboo	5,60	7,30	9	825,20	22,53	138,51	9	825,20	22,53	138,51
17	Santa-maria	15,70	20,50	8	1 088,27	26,90	146,12	8	1 088,27	26,90	146,12
18	Wild coffee	13,20	17,20	9	1 780,67	29,37	163,48	9	1 780,67	29,37	163,48
19	Brazilwood			1	3,92	5,00	140,24	1	3,92	5,00	140,24
20	Bois immortelle	3,60	4,60	2	2,20	2,00	66,74	2	2,20	2,00	66,74
21	Golden shower	18,60	24,10	1	9,90	4,00	136,44	1	9,90	4,00	136,44
22	Pink shower	14,10	18,30	1	0,00	0,00	0,00	1	0,00	0,00	0,00
23	African mahogany	84,10	109,40	7	62,46	43,76	163,95	7	62,46	43,76	163,95
24	West Indies mahogany	23,40	30,40	11	1 575,87	29,85	151,60	11	1 575,87	29,85	151,60
25	Honduras mahogany	26,60	34,50	13	2 694,43	32,74	145,78	13	2 694,43	32,74	145,78
26	Hybrid mahogany	20,70	26,90	3	244,68	20,33	151,73	3	244,68	20,33	151,73
27	Zebrawood	3,30	4,30	2	51,90	18,56	156,81	2	51,90	18,56	156,81
28	Horse-tail tree	52,10	67,70	11	6 621,11	42,62	173,39	11	6 621,11	42,62	173,39

Nº	SPECIES	2013 Report		2017 Report				2019 Report			
		Carbon in above-ground biomass (tC/ha)	Carbon in total biomass (tC/ha)	No. of Cos. having the sp.	Total surface area (ha)	Timber Yield (m^3/ha)	Carbon sequest(tC/ha)	Number of Cos. having the species	Total surface area (ha)	Timber Yield (m^3/ha)	Carbon sequestr. (tC/ha)
29	Cayeput	54,70	71,10								
30	Cedar	7,50	9,70	13	1 019,03	32,03	149,32	13	1 019,03	32,03	149,32
31	Silk-cotton tree	1,30	1,70	1	0,20	4,00	133,49	1	0,20	4,00	133,49
29	Coconut tree	54,70	71,10								
30	Caribbean princewood	7,50	9,70	13	1 019,03	32,03	149,32	13	1 019,03	32,03	149,32
31	Monkey apple	1,30	1,70	1	0,20	4,00	133,49	1	0,20	4,00	133,49
32	Cuyá	27,60	35,80	3	24,70	61,67	182,17	3	24,70	61,67	182,17
33	Lemonwood tree	5,30	6,90	1	0,40	4,00	136,13	1	0,40	4,00	136,13
34	Ebony	128,30	166,80								
35	Encino	31,10	40,40	2	35,80	10,32	145,38	2	35,80	10,32	145,38
36	Eucalypto saligna	113,40	147,40								
37	Eucalypto sp.	16,20	21,00								
38	Yellow flamboyant	71,50	92,90								
39	Eucalypto saligna	115,70	150,40	4	8 707,20	85,63	198,85	4	8 707,20	85,63	198,85
40	Eucalypto sp.	46,10	60,00	11	6 983,63	44,04	168,84	11	6 983,63	44,04	168,84
41	Yellow flamboyant	6,20	8,10	1	8,30	3,00	134,53	1	8,30	3,00	134,53
42	Red flamboyant	19,80	25,80	2	2,90	43,39	183,55	2	2,90	43,39	183,55
43	Lancewood	6,30	8,20	2	46,20	21,50	162,91	2	46,20	21,50	162,91
44	Mountain trumpet	18,00	23,40	2	12,20	5,92	135,54	2	12,20	5,92	135,54
45	Gmelina	53,30	69,30	7	272,69	51,23	165,03	7	272,69	51,23	165,03
46	Red stopper	37,90	49,30	1	4,00	10,00	143,84	1	4,00	10,00	143,84
47	Spanish oak	3,50	4,50	1	39,60	8,00	141,70	1	39,60	8,00	141,70
48	Guanima			1	2,00	37,50	170,36	1	2,00	37,50	170,36
49	Candlewood tree	61,20	79,50	1	10,60	63,02	194,38	1	10,60	63,02	194,38
50	West-Indian sumac	16,50	21,40	4	83,10	39,78	165,65	4	83,10	39,78	165,65
51	Cabbage bark	22,90	29,70	2	220,00	10,50	84,26	2	220,00	10,50	84,26
52	Calabash tree	3,10	4,10								
53	Apes earring	7,20	9,40	3	445,10	12,67	98,86	3	445,10	12,67	98,86
54	Ipil-ipil	8,40	10,90	8	3 701,00	34,60	149,87	8	3 701,00	34,60	149,87

Nº	SPECIES	2013 Report		2017 Report				2019 Report			
		Carbon in above-ground biomass (tC/ha)	Carbon in total biomass (tC/ha)	No. of Cos. having the sp.	Total surface area (ha)	Timber Yield (m^3/ha)	Carbon sequest(tC/ha)	Number of Cos. having the species	Total surface area (ha)	Timber Yield (m^3/ha)	Carbon sequestr. (tC/ha)
55	Wild fig			1	2,70	55,00	167,56	1	2,70	55,00	167,56
56	Jatía	3,90	5,10	1	1,60	23,00	161,70	1	1,60	23,00	161,70
57	Wild olive	4,60	6,00	1	7,90	6,00	140,14	1	7,90	6,00	140,14
58	Bully tree	65,40	85,00	3	155,00	47,72	170,21	3	155,00	47,72	170,21
59	Spanish bully tree	10,70	13,90	3	334,80	38,96	171,56	3	334,80	38,96	171,56
60	Giant leadtree	64,00	83,20	4	141,49	96,58	215,95	4	141,49	96,58	215,95
61	Maguey	1,00	1,30	2	258,80	80,50	208,99	2	258,80	80,50	208,99
62	West Indies trema	49,80	64,70	12	5 329,24	46,26	153,97	12	5 329,24	46,26	153,97
63	Manajú	33,10	43,00								
64	Black mangrove	37,80	49,10	6	597,40	29,92	193,77	6	597,40	29,92	193,77
65	Red mangrove	56,70	73,70	12	4 716,05	33,61	192,23	12	4 716,05	33,61	192,23
66	Cashew	5,10	6,60	5	128,70	37,80	148,25	5	128,70	37,80	148,25
67	Najesí	37,00	48,10	1	2,10	121,00	236,94	1	2,10	121,00	236,94
68	Nim	19,20	22,40	5	216,40	16,40	122,73	5	216,40	16,40	122,73
69	Walnut tree	33,10	43,00								
70	Santa maria	56,90	74,00	13	4 786,22	48,82	168,99	13	4 786,22	48,82	168,99
71	Oreja de judío	4,90	6,40	1	17,60	8,00	136,23	1	17,60	8,00	136,23
72	Palma cana			2	29,00	50,60	194,59	2	29,00	50,60	194,59
73	Royalpalm	12,20	15,80	8	79,18	23,13	144,06	8	79,18	23,13	144,06
74	Spanish palm tree	1,00	2,50	1	2,50	36,92	188,78	1	2,50	36,92	188,78
75	Paraíso de la India	96,60	125,50	3	194,80	56,33	171,85	3	194,80	56,33	171,85
76	White buttonwood	76,40	99,40	3	1 787,70	86,62	601,30	3	1 787,70	86,62	601,30
77	Sierra Maestra pine tree	69,80	90,70	1	4 998,20	10,00	985,66	1	4 998,20	10,00	985,66
78	Mayarí pine tree	114,40	148,80	3	13 589,20	36,77	269,18	3	13 589,20	36,77	269,18
79	Female pine tree	109,30	142,10	2	4 040,90	127,85	761,21	2	4 040,90	127,85	761,21
80	Male pine tree	94,60	123,00	9	42 659,31	111,44	361,27	9	42 659,31	111,44	361,27
81	Piñón botija	1,10	1,40	1	8,20	6,00	134,19	1	8,20	6,00	134,19
82	Quick stick	25,00	32,50	6	734,40	31,44	135,76	6	734,40	31,44	135,76

Nº	SPECIES	2013 Report		2017 Report				2019 Report			
		Carbon in above-ground biomass (tC/ha)	Carbon in total biomass (tC/ha)	No. of Cos. having the sp.	Total surface area (ha)	Timber Yield (m^3/ha)	Carbon sequest(tC/ha)	Number of Cos. having the species	Total surface area (ha)	Timber Yield (m^3/ha)	Carbon sequestr. (tC/ha)
83	White oak	20,00	26,00	6	700,10	29,73	162,70	6	700,10	29,73	162,70
84	Spanish oak	44,40	57,80	7	125,56	43,14	180,16	7	125,56	43,14	180,16
85	Wild tamarind	4,40	129,20	2	126,00	29,00	162,90	2	126,00	29,00	162,90
86	Black torch	1,00	1,80	1	1,80	51,67	182,22	1	1,80	51,67	182,22
87	Soplillo	19,60	25,50	11	5 436,51	36,14	152,47	11	5 436,51	36,14	152,47
88	Teak	38,60	50,20	11	1638,70	47,51	171,99	11	1638,70	47,51	171,99
89	Tengue	1,20	1,50	1	1,50	3,00	135,08	1	1,50	3,00	135,08
90	Seagrape	38,70	50,40	4	41,58	11,16	144,65	4	41,58	11,16	144,65
91	Uva gomosa	3,00	3,90	1	134,40	5,00	135,19	1	134,40	5,00	135,19
92	Cabbage angelin	30,10	39,10	6	123,70	20,42	131,41	6	123,70	20,42	131,41
93	American muskwood	2,00	2,60	1	12,40	4,00	133,57	1	12,40	4,00	133,57
94	Yamagua	3,50	4,60	3	19,90	46,33	176,76	3	19,90	46,33	176,76
95	Button-mangrove	71,90	93,50	4	2 206,82	42,48	220,20	4	2 206,82	42,48	220,20
96	Yarúa	30,90	40,10	9	1 952,40	20,39	143,31	9	1 952,40	20,39	143,31
97	Other species	40,70	52,90	12	2 337,69	22,86	143,36	12	2 337,69	22,86	143,36

ANNEX 4

Combined safeguards and REDD+ capacity building workshop

Quito, Ecuador, 5-8 July 2011

Report of the Ministry of Agriculture of the Republic of Cuba

C. Alicia Mercadet Portillo, PhD
Eng. Arlety Ajete Hernández
National experience on REDD+.

- National structure. There is no national structure created for the implementation of REDD+, but it is in the interest of MINAG to create this structure immediately.

- Readiness for REDD+. The areas of interest for REDD+ implementation are:

    - The recovery of natural forests (Holguín [267.8 Mha]; Guantánamo [201.4 Mha]; Pinar del Río [51.5 Mha]; Havana [8.9 Mha of coastal forests]).
    - The reduction of the area to be reforested with native species (Camagüey: 88.1 Mha; 31.5%).
    - Recultivation of open-cast mining areas (Holguín: 2,768.2 ha) and 152,700 ha in other provinces.
    - The updating and improvement of forest management and forest dynamics (incorporation of satellite images), with a view to more precise monitoring of the carbon sequestered by forests, using the methodology and system created by INAF to determine the baseline and evaluate mitigation alternatives for 10-year periods in the companies, such as greater survival and increase of the IMA (requiring forestry treatment) - insufficient resources.
- How are biodiversity experts involved, including traditional knowledge stakeholders and local communities?
    - What is being done? Research-development projects (conservation, NTFP, and analog forestry), including species conservation, ethnobotanical studies to determine and extend potential use of flora and reconstruction of original forests.

- Where is it done? They are carried out in rural communities or in areas of the city where inhabitants have large backyards or plots of land.
- How is it done? Surveys and interviews in which mostly women participate; communities are involved in the making of action plans and their implementation.

National experience in safeguarding biodiversity

- Level of political support and capacity to safeguard biodiversity.

    - There is a legal framework (Environment Law, Forestry Law; National Environmental Strategy; MINAG's Environmental Strategy).
    - The National Center for Protected Areas and the National Company for the Protection of Flora and Fauna together manage 263 areas, of which 80 are of national significance; they generally cover 29.5% of Cuba, of which 17.6% is terrestrial, with more than 1.9 million hectares. In addition, the Biodiversity Center (CenBIO, IES-CITMA) and the National Forestry Division (DNF in Spanish).
    - National Biodiversity Commission that includes a working group on forest biodiversity (National Action Plan-CBD) and the National Commission on Genetic Resources, which has a forestry working group.

- Main obstacles to including the safeguarding of biodiversity.

    - Lack of a law on access, use, and conservation of genetic resources.
    - Insufficient knowledge of the economic value of biodiversity by managers and specialists at all levels.
    - Financial and material limitations to guarantee the implementation of regulations.
    - Insufficient control of existing invasive species in Cuba.
    - Natural disasters

- Specific training needs at different levels:

    - Convention on Biological Diversity (national, national NGOs).
    - Expanded Work Program on Forestry (forestry sector).
    - Reconstruction of degraded forests (forestry sector).
    - Rescue of threatened or endangered species (forestry companies and communities).
    - Ecosystem approach to forests (forestry sector).
    - Introduced species. Management. (forestry sector).
    - Role of forests as a carbon sink (forestry sector).

- Lessons learned on safeguarding biodiversity.

    - Importance for mitigating climate change and dealing with its impacts (sea level rise and temperature impact studies have been carried out).
    - Use of NTFPs as livelihoods for small communities and even at provincial and national levels (yagua from royal palm [tobacco]; bejuco guaniquiqui [furniture]; oleoresin from pine [extracts]; plant parts [green medicine]).
    - Use of inappropriate species in reforestation.

National experience on assessment and monitoring of REED+ impacts

- Are tools being created to assess/monitor REDD+ impacts on biodiversity and livelihoods of indigenous and local communities? If so, how, and have you identified or designed any criteria or indicators for REDD+ impacts on biodiversity?

As REDD+ has not been implemented in Cuba, no work has been done in this regard; however, criteria and indicators for sustainable forest management have been defined at the national level, including the following:

Criterion II: Health and vitality of forest ecosystems, with 12 indicators.

Criterion III: Contribution of forest ecosystems to environmental services, with 11 indicators (including one on climate change mitigation).

These tools could be used, adapted or expanded to monitor and assess the impacts of REDD+ on biodiversity.

- Has your country completed the National Ecological Gap analysis under the CBD? No.
- Is the National Gap Analysis considered in REDD planning? No.
- Are you creating or applying multi-benefit tools at the national level (i.e. biodiversity and carbon pool mapping, such as www.carbonbiodiversity.net/OtherScales)? No.

REDD+: Seeking synergies between the CBD and UNFCCC

- How do you seek synergies between the two conventions through their respective forestry work programs?

Cuba seeks synergies with both conventions through the National Forestry Development Programme, whose general objective is: "To achieve a forest cover index of 29.3% by 2015, increasingly guaranteeing the main needs of the economy and society, under the principles of Sustainable Forestry Development", highlighting among some of its strategic objectives:

- To have the entire forest heritage under management plans and to establish systematic monitoring of its dynamics.
- To manage and rehabilitate 493.0 Mha of natural forests and plantations.
- Complete monitoring of Criteria and Indicators at the baseline level.
- Develop a strategy to diversify forest production, the use of biomass for energy, non-timber products, and nature tourism, with actions to include:
- Intensify the promotion of protection and conservation plantations, emphasizing the use of fruit trees, combined with indigenous species, species of high melliferous value, and threatened or endangered species.
- Strengthen infrastructure and preventive and control measures for the protection of forest heritage resources.
- Strengthen infrastructure for inventory and sustainable management of forest heritage resources and systematic monitoring of their management.
- Prioritize the reconstruction of degraded natural forests.
- Enhance the development and utilization of non-timber forest products.
- Enhance the use of forest heritage to provide for environmental services, especially ecotourism and carbon sequestration.

- **How can synergies be achieved through the design and implementation of the REDD+ mechanism?**

The REDD+ mechanism would make it easier for Cuba to implement the actions and achieve the objectives set out in its National Forestry Development Programme, thereby enhancing the synergy effect between the two conventions that this instrument seeks to achieve.

Development Programme, thereby enhancing the synergy effect between the two conventions that this instrument seeks to achieve.

- **To what extent have you found a mechanism to achieve the objectives of both conventions?**

That mechanism is the forestry-related actions within the National Forestry Development Programme.

- **What are the threats and opportunities for finding synergies between the forestry objectives related to both conventions?**

The main threat is Cuba's status as a small island developing state, which implies significant financial and resource constraints, making it necessary to place food security and social care at the first level of attention, while at the same time presenting a high vulnerability to the impacts of climate change, especially rising sea levels and reduced rainfall, which have a very negative influence on national food production.

The main opportunity is determined by the sustained and growing global concern about the reduction of biodiversity and the strengthening of climate change, aspects that have determined the emergence of various international mechanisms, including financial ones, aimed at supporting national actions to address these problems.

- **Cuba's strengths in dealing with threats and taking advantage of opportunities to establish synergies between the two Conventions**

  The country has a demonstrated political will to support any initiative linked to actions aimed at protecting biodiversity, mitigating climate change and adapting to its impacts.

  Over the past half century, Cuba has built up a significant knowledge potential related to Cuba's biodiversity, which over the past 20 years has been complemented by the development of scientific capacities related to climate change, providing an important starting point for creating national capacity building at all levels and establishing mechanisms to facilitate its use.

ANNEX 5

Opportunities for Cuba in forestry activities (REDD+) under the Warsaw Decisions: The need for early action

I. Progress of the Forestry Decisions in the climate negotiations

The 19th Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (hereafter referred to as the Convention), which took place in Warsaw in December 2013, culminated a long and complex political and technical process to further integrate forestry activities in developing countries, as an important form of mitigation, into the international climate architecture under the concept commonly known as REDD+, an acronym used to refer to reducing emissions from deforestation, forest degradation, and sustainable forest management.

To date, only reforestation and deforestation projects have been considered under the Clean Development Mechanism (CDM) and with serious limitations.

The Warsaw decisions close a cycle in which it is clearly defined what constitutes REDD+ activities (see box below) and what methodological and information requirements are necessary to benefit from financial support to undertake these activities.

It also defined practical aspects of cooperation and financing for REDD+ activities, and the monitoring, reporting, and verification (MRV) requirements and activities for accessing payments for these activities.

The Decisions referred to in Part 1 of this document are interlinked and should be seen as a whole.

REDD+ activities

a. Reducing emissions from deforestation;
b. Reducing emissions from forest degradation;
c. Conservation of forest carbon stocks;
d. Sustainable management of forests
e. Enhancement of forest carbon stocks;

(**As per decision 1/Ch.17, paragraph 70**)

II. Cuba and forestry activities[1]

Twenty years of research on this topic have shown that the forestry sector:

- It is a net carbon sink for Cuba[2].
- It has several significant alternatives to increase carbon sequestration and further reduce greenhouse gas emissions.
- It is exposed to various climate change impacts, some of which have already been recorded.
- Coastal forests are Cuba's only terrestrial defense against the impacts of sea-level rise and saline intrusion in groundwater aquifers on food production areas and can be an important source of carbon sequestration.

This has been reflected in the Forestry Programme for Dealing with Climate Change, proposed by the Forestry Research Institute (INAF) and not yet approved by the Forestry Directorate of the Ministry of Agriculture.

The forestry sector also recognizes that the REDD+ mechanism is advancing internationally, especially aimed at strengthening the forestry sector to increase its capacity as a carbon sink and reduce emissions of other greenhouse gases but despite four years of efforts, Cuba has not yet joined the REDD+ process.

Although there is an annual increase in forest cover in Cuba as a result of the National Reforestation Programme[3], there are various problems that affect the pace and quality of this process, many associated with limited financial and material resources, including:

- Organizational deficiencies and limited resources for seed and nursery activities.
- Insufficient and/or inadequate preparation of the areas to be reforested.
- Low compliance with key indicators in the progress of reforestation processes (species selection, survival, and planting success).
- Only 59% of forest areas have approved their Management Plans.

Concerning climate change, the Forestry Sector's evaluations indicate the following deficiencies:

- Slow progress in approving and implementing the Forestry Programme for Dealing with Climate Change.
- Failure to take advantage of international alternatives for strengthening the sector to combat climate change.

III. Proposals to accelerate Cuba's participation in REDD+.

Due to its potential importance for Cuba, early and active participation in the development of REDD+ activities is required, following all the methodological and informational requirements agreed in the Convention, as well as requesting the necessary financial and technological support from the Green Climate Fund (GCF) and bilateral cooperation, seeking an adequate positioning of Cuba to access these resources.

There are options for this at present, as there is sufficient bilateral funding[4] for REDD+ activities and the GCF is due to start funding readiness activities in the middle of this year, which can also be used for REDD+.

As was the case with the CDM, it is expected that those countries that submit funding proposals first will benefit the most.

These early actions would also facilitate the submission of other proposals to specialized bodies, such as UN-REDD.[5] At the same time, environmental and/or social co-benefits could be achieved, including those that occur when ensuring the necessary compliance with the safeguards established by Decision 1/Ch.16 for REDD+ activities (see Part 2 of this document), and abundant resources to create a robust national forest monitoring system, which in addition to monitoring and verification of REDD+ activities, could also serve many other forestry functions. The proposed actions to be undertaken are as follows:

1. Data were taken from the Ministry of Agriculture: Overview of the Forestry Sector, October 2013.

2. This excludes the sea and coastal marine ecosystems (e.g. turtle grass), which do not count for Greenhouse Gas inventories.

3. 2012 closed with a forest cover index of 28.6%. Source State Forest Service, 2013.

4. Estimated at over $2 billion. See http://www.forestsclimatechange.org/redd-map/ and http://reddplusdatabase.org/. In addition, the Norwegian government announced in Warsaw an additional USD 280 million in funding for REDD+ activities.

5. The United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation (or UN- REDD Programme) is composed of FAO, UNDP, and UNEP.

1. Designate as soon as possible a national entity or focal point to liaise with the UNFCCC Secretariat and its competent bodies on the coordination of support for the full implementation of REDD+ activities. In this regard, the Forestry Division of MINAG has submitted the relevant proposals. In addition, this national entity may nominate other entities to obtain and receive results-based payments, in line with the specific operational modalities of the financial entities providing support to them.

    - In this regard, it was agreed that these national entities or focal points from all Parties should meet at least once a year to consider the development of REDD+ activities at the global level, which can be extremely useful for national work.
    - Without this designation, it would be impossible for Cuba to access financial and technical support for REDD+ activities from the Convention and its bodies, including its financial mechanism.

2. Designate as soon as possible a national authority, in this case, to recommend to the GCF Board funding proposals in the context of national climate strategies and plans, as invited by decision 3/Ch.17. This is not specific to REDD+ activities, but to all mitigation and adaptation activities for which support from the Green Climate Fund is sought, but is a requirement for the Green Climate Fund to support REDD+ activities. Without this designation, it would be impossible to access financial support from the GCF, which will start in 2014, and whose mandate includes support for REDD+ activities.

    Of particular importance is that the GCF will already start to financially support readiness activities in various parts of the world in the second half of 2014, which could benefit multiple REDD+ activities in Cuba such as the establishment and strengthening of national forest heritage monitoring systems.

3. Develop as soon as possible a national action plan or strategy for those REDD+ activities that Cuba considers appropriate to request financial, technical, and technological support for their implementation, and that includes the necessary organizational actions regulated by the REDD mechanism itself. The basis could be the Forest Programme for Dealing with Climate Change proposed by INAF.

4. Declare as national reference level of forest emissions, based on which the results of REDD+ activities will be measured, those corresponding to the GHG Inventories in Cuba, of which the 2010 estimate will be prepared in 2014, maintaining a constant improvement of the estimation methods, taking into account that the Convention itself recognizes that this is an iterative task, which will be improved as experience is gained and adequate support is obtained, as agreed by the COP on Climate Change, and as can be seen in Part 3, where a series of elements to be taken into account are set out, based on the Decisions of the COP.

    Additionally, and to undertake national payment for ecosystem services provided by forests, adopt the certification of carbon sequestered by forests at the administrator scale, which includes the annual issuance of the forest sector carbon register.

5. Consolidate a robust and transparent national forest monitoring system1, under national[6] circumstances and capacities. This system, following decision 4/Ch.15, should use a combination of remote sensing and ground-based forest carbon inventory methods to estimate forest-related greenhouse gas (GHG) emissions and removals, forest carbon stocks and forest area changes.

    It should also provide estimates that are transparent, consistent over time, as accurate as possible and that reduce uncertainties, taking into account national means and capabilities, and that can be reviewed by the Conference of the Parties, if it so decides.

    The relevant CoP 19 decision agreed that these systems should be adequate for the measurement, reporting and verification (MRV) of GHG emissions and removals by forests, forest carbon stocks, and forest area changes resulting from the implementation of REDD+ activities. It was also decided that they should:

    a. Build on existing systems, as appropriate.
    b. Allow for the assessment of different types of forests in Cuba, including
    c. Be flexible and allow for improvement.

6. Noting, as appropriate, the guidance on consistent representation of land areas contained in the Intergovernmental Panel on Climate Change's Good Practice Guidance for Land Use, Land Use Change and Forestry.

This system would be based on the current "forest dynamics", an automated system of the Forestry Division of MINAG, which annually updates how and by how much the area of forest heritage has changed, from the administrators to the nation, both in natural forests and in established and developing plantations, and which includes various output alternatives for different objectives.

At the same time, areas for improvement of this system would be identified, so that, through international mechanisms, funding can be requested to improve it and make it more robust, transparent and prepared to take MRV actions, necessary to evaluate the results of REDD+ activities and also to guarantee other forest functions not linked to carbon, but required for sustainable forest management.

6. Develop a system to provide information on how the safeguards outlined in Appendix I of decision 1/Ch.16 (Part 2) are being addressed and respected throughout the process of implementing REDD+ activities, while respecting country sovereignty.

   In undertaking this task, consideration should be given to what is agreed in Decision 5/Ch.17 on these systems, whereby national circumstances and respective capacities should be taken into account, recognizing national sovereignty and legislation and relevant international obligations and agreements, and respecting gender considerations. This implies:

   a. Being consistent with the guidance set out in Decision 1/Ch.16, Appendix I, paragraph 1.
   b. Providing transparent and consistent information that is accessible to all stakeholders and regularly updated.
   c. Be transparent and flexible to allow for improvements over time.
   d. Provide information on how all safeguards set out in appendix I to decision 1/Ch.16 are being addressed and respected.
   e. Be country-driven and implemented at the national level.
   f. Build on existing systems, if any.

The relevant CoP 19 decision stated that this information will be included in national communications and could also be provided, voluntarily, through the platform located on the Convention's website.

It was also recognized that Parties' national forest monitoring systems may be in charge of providing information on how the safeguards contained in decision 1/Ch.16 are addressed and respected. It is up to Cuba to decide whether the two systems are carried out and work together or independently.

As inputs for this system, the existing strategic and legal basis in Cuba will be usable, although it needs to be complemented concerning forest genetic resources and flora and fauna in general. These elements would facilitate the preparation of a system in line with Decision 5/Ch.17.

IV. Specific actions to manage funding

(A) Preparatory. Develop, as soon as possible, a set of funding requests for readiness activities to increase Cuba's potential to use REDD+ activities. Recipients of such requests could include the GCF, the Global Environment Facility (GEF), bilateral collaboration, UN-REDD, etc.

These requests may cover institutional strengthening for undertaking REDD+ activities; for the forest heritage control and monitoring system (designed to support other forest activities); for the system to provide information on how safeguards are being addressed and respected; and for other forest activities, including the extension of forest cover with REDD+ activities, as well as for the development and refinement of the national forest reference emission level and/or the national forest reference level, among others.

(B) Future payment for results activities. Consider which REDD+ activities could benefit from payments for results and, once the requirements for inclusion in the REDD+ mechanism are met, start making relevant funding proposals for project development. Recipients of such requests may include the GCF, GEF, bilateral collaboration and other financial institutions that can be accessed.

Part 1. CoP Decisions on REDD+

Decision	Year	Title
-/Ch.19.	2013	Work program for financing to advance the full implementation of activities referred to in decision 1/Ch.16, paragraph 70.
-/Ch.19.	2013	Coordination of support for the implementation of activities relating to mitigation actions in the forest sector by developing countries, including institutional arrangements.
-/Ch.19.	2013	Modalities for the National Forest Monitoring System.
-/Ch.19.	2013	Modalities for measurement, reporting and verification.
-/Ch.19.	2013	Timing and frequency of submission of summary information on how all safeguards referred to in decision 1/Ch.16, Part I, are being addressed and respected.
- Ch.19.	2013	Addressing drivers of deforestation and forest degradation.
-/Ch.19.	2013	Guidelines and procedures for the technical assessment of Parties' submissions on their proposed forest reference levels.
1/Ch.18	2012	Agreed outcome in accordance with the Bali Action Plan (paragraphs 25-40).
12/Ch.17	2011	Guidance on systems for providing information on how safeguards are being addressed and respected and on modalities for forest reference emission levels and forest reference levels referred to in decision 1/Ch.16.
1/Ch.16		Cancun Agreements: outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention (paragraphs 68-79).
4/Ch.15		Methodological guidance for activities relating to reducing emissions from deforestation and forest degradation and the role of conservation, sustainable forest management and enhancement of forest carbon stocks in developing countries.
2/Ch.13		Reducing emissions from deforestation in developing countries: approaches to stimulate action.

Part 2. Appendix I to Decision 1/Ch.16

Guidance and safeguards for policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.

1. Actions referred to in paragraph 70 of the present decision should:

. Contribute to the achievement of the objective set out in Article 2 of the Convention.
. Contribute to the implementation of commitments under Article 4, paragraph 3, of the Convention.
. Be country-driven and considered as options available to Parties.
. Be consistent with the objective of environmental integrity and take into account the multiple functions of forests and other ecosystems.
. Be undertaken under the circumstances, development objectives and priorities and capacities of countries, and respect their sovereignty; (f) Be consistent with the national sustainable development needs and objectives of Parties

b. Be implemented in the context of sustainable development and poverty reduction, while responding to climate change.
c. Be consistent with the adaptation needs of Cuba.
d. Be adequately and predictably supported financially and technologically, including support for capacity-building.
e. Be results-based.
f. Promote sustainable forest management;

2. In implementing the actions referred to in paragraph 70 of the present decision, the following safeguards should be promoted and supported:

a. The complementarity or compatibility of measures with the objectives of national forest programs and relevant international conventions and agreements.
b. The transparency and effectiveness of national forest governance structures, taking into account national legislation and sovereignty.
c. The respect for the knowledge and rights of indigenous peoples and members of local communities, taking into consideration relevant international obligations and national circumstances and legislation, and bearing in mind that the United Nations General Assembly

has adopted the United Nations Declaration on the Rights of Indigenous Peoples.

d. The full and effective participation of stakeholders, in particular, indigenous peoples and local communities, in the actions referred to in paragraphs 70 and 72 of the present decision.
e. Compatibility of measures with the conservation of natural forests and biological diversity, ensuring that those measures identified in paragraph 70 of the present decision are not used for the conversion of natural forests, but instead serve to incentivize the protection and conservation of natural forests and their ecosystem services and to enhance other social and environmental benefits.
f. The adoption of measures to address risks of reversal;
g. Measures to reduce displacement of emissions.

Part 3. Elements of Decision 12/Ch.17

a. it was agreed that a tiered approach to the development of national forest reference emission levels and/or national forest reference levels would be useful, allowing Parties to improve these levels by incorporating better data, improved methodologies, and, where appropriate, additional pools, taking into account the importance of adequate and predictable support referred to in decision 1/Ch.16;

b. it was recognized3 that sub-national forest reference emission levels and/or sub-national forest reference emission levels may be carried out as an interim measure until national levels are created and that interim reference levels may cover an area of forest smaller than the forest area of their entire national territory;

c. it was also agreed that forest reference emission reference levels and/or their forest reference levels should be updated periodically, as appropriate, taking into account new knowledge, emerging trends, and changes in scope and methodologies.

The development of interim levels should ensure that they are prepared to take into account paragraph 7 of Decision 4/Ch.15[7], and maintaining consistency with forest-related emissions in national greenhouse gas inventories. Guidelines for reporting reference levels are contained in the Part of Decision 12/Ch.7.

Given their similarity, a valuable source of practical information for the development of national forest reference levels was the process of creating forest management reference levels by 38 developed countries that are members of the Kyoto Protocol as required by decision 2 CMP/6. It contains guidelines on how to make these levels and how to assess them technically. The Convention's[8] website contains the reports of these tiers submitted by Parties and their corresponding technical assessments conducted by five international teams of experts. Document FCCC/KP/AWG/2011/INF.2 summarizes the technical assessment process, including a description of the problems faced by these countries in creating their national forest management reference levels and the recommendations of the technical assessment to overcome these problems.

Part 4. Impact of the Warsaw decisions on the financing of REDD+ activities

The COP 19 Decision on financing for advancing the full implementation of REDD+ activities:

It recalled that in developing countries to receive this funding for their REDD+ activities the results of these activities must be monitored, reported, and verified (MRV) following the methodological decisions on REDD+ adopted by the COP. It also called on countries undertaking REDD+ activities to provide information on how they have complied with established safeguards before receiving any payments.

It encouraged all entities providing results-based finance for REDD+, including the GCF, to collectively channel adequate and predictable payments in an impartial and balanced manner when working with many countries in a position to obtain these payments.

7. It considers that developing countries, in setting forest reference emission levels and forest reference levels, should do so in a transparent manner, taking into account historical data and national circumstances, following relevant decisions of the Conference of the Parties.

8. See http://unfccc.int/bodies/awg-kp/items/5896.php

It also encouraged all institutions outside the Convention that already provide payments for REDD+ and required the GCF, when providing results-based finance, to do so in compliance with the methodological decisions on REDD+ adopted by the COP. In the same vein, it required the Standing Committee on Finance to work towards coherence in financial support to Parties by all donors.

It was agreed to create an information hub on the secretariat's website, as a means of publishing all information on results and payments received for them. In this hub, countries that have had or are seeking results-based finance must provide information on the results of REDD+ activities for each payment received, reference levels, compliance with safeguards, description of the linkage of the REDD+ action to the national strategy or action plan, as well as information on the national forest monitoring system.

This decision has three readings: (1) REDD+ as part of the climate architecture will be able to receive considerable financial support based on results; (2) countries that can meet all the requirements for results-based payments in a short time will benefit; (3) the aim is to put in order the existing differences in the requirements for financial support for REDD+ activities so that the payment for results responds to real results.

The secretariat's new information hub will be important for this and countries must therefore be prepared to provide quality information to it to attract funding under new and more demanding conditions.

ANNEX 6

FORESTRY PROGRAM TO COMBAT CLIMATE CHANGE PHASE: 2020-2025

INTRODUCTION

Since 1988, the international community has become increasingly concerned about the temporal evolution of climate and the effects of greenhouse gas emissions on it.

In response to this concern, the Intergovernmental Panel on Climate Change (IPCC) has published five assessment reports on the subject in 1990, 1995, 2001, 2007, and 2013-2014, with the preparation of the sixth report beginning in 2017.

Likewise, the United Nations Organization prepared and presented for international consideration at the Rio de Janeiro Summit (1992), the United Nations Framework Convention on Climate Change (UNFCCC), an instrument to which Cuba is a Party.

Both in the IPCC assessment reports and the Conferences of the Parties to the UNFCCC, it has been demonstrated that climate change is an environmental process caused by the growing anthropogenic emissions of greenhouse gases, and that of all the countries that make up the international community, Small Island Developing States (such as Cuba) is the sector most vulnerable to the impacts generated by this process.

For these reasons, in 2007 the Council of Ministers included among the issues under its attention the analysis of the Cuban climate situation and its possible future effects on the economic, environmental and social sectors, resulting in the indication to undertake the preparation of the Programme for Dealing with Climate Change in all the Agencies of the Central State Administration.

In this regard, since 2008, the Ministry of Agriculture has undertaken the implementation of actions to combat climate change, which in addition to having a general component, also included actions for the preparation of sectoral programs.

BACKGROUND

The forestry sector established its first contact with the issue of climate change in 1992, when the preparation of the Second Assessment Report of the IPCC began, a process that concluded in 1995 and in which several Cuban specialists participated, including one from the Forestry Research Institute (IIF). Three years later, in 1998, when the preparation of Cuba's First National Communication to the UNFCCC began, the forestry sector again participated in the process, which concluded in 2001. From then on, a permanent research team was established at the IIF (currently the Forestry Research Institute - INAF) to address the issue in its five dimensions:

1. Greenhouse gas inventory.
2. Climate change mitigation.
3. Impact assessment, adaptation, and reduction of vulnerabilities.
4. Transfer of technologies for mitigation and adaptation.
5. Capacity building.

Between then and 2020, six research projects on forests and climate change were carried out and concluded, including participation in the preparation of the Second and Third National Communication of Cuba to the UNFCCC. In addition, a few years ago, the University of Pinar del Río also initiated research aimed at assessing the impacts of climate change on the natural distribution of native pine forests. Based on these premises and the background on the subject that existed in the forestry sector of the Ministry of Agriculture, in 2013 the first version of the Forestry Program to Confront Climate Change (PFECC) for the period 2013-2020 was presented, which established the objectives that the sector intended to achieve at that stage of implementation. However, for various reasons, this programmatic document was never put into effect. On 25 April 2017, the Council of Ministers approved the launch of the State Program for Dealing with Climate Change (Task Life); A month later, the Third Plenary Session of the Central Committee and the National Assembly approved Guideline 107, specifically dedicated to climate change as part of the Science, Technology, and Environment Policy to be implemented in Cuba. In July, the Minister of Science, Technology, and Environment presented Tarea Vida Project to the National Assembly, with an investment program for the short (2020), medium (2030), long (2050), and very long (2100) terms.

The results derived from all the research carried out include, in one way or another, the heritage managed by a group of companies of the Agroforestry Business Group and two protected areas, as well as the natural distribution of the two species of pine in the west of Cuba, which together represent more than half of the national forest heritage, and based on all these results, and from what was contributed to the First, Second and Third National Communication, the provisions of Guideline 107 and Task Vida, an updated version of the Forest Program to Combat Climate Change (PFECC) has been formulated, within the framework of the forestry development projection until 2025.

PREMISES

For the preparation, implementation, and progressive adjustment of the Forestry Program to Combat Climate Change (PFECC), the following premises have been considered:

1. The international recognition that climate change, although it originates from socio-economic aspects, has a relevant environmental impact and is capable of aggravating other existing environmental problems.
2. The certainty that climate change is a process whose impacts can negatively and significantly affect Cuba's agricultural sector and, in particular, the forestry sector.
3. The fact that country's forest heritage, managed by entities linked to the agricultural sector, comprised more than 40% of Cuba in 2017, and natural forests make up 75% of this heritage, which generates a high vulnerability to various impacts of climate change.
4. The fact that Cuba's forest heritage is, since 1990, the nation's only net carbon sink and therefore the only element available to offset its greenhouse gas emissions, while since 2010 it has offset all the emissions generated by Cuba's agricultural sector.
5. The fact that coastal forests (which include the natural formations: Mangrove, Seagrapes, coastal shrubs, and a large part of the semi-deciduous forests on poorly drained and limestone soils) constitute the only physical land barrier Cuba has to temporarily mitigate the impacts on agricultural areas that follow them inland, derived from the rise in average sea level and the surge caused by tropical cyclones, which establishes a relevant link

between the forestry sector, food security, and national security.

6. The identification of the issue of climate change as a relevant element within the Guidelines of the Economic and Social Policy of the Party and the Revolution (Guideline 107).
7. The organization by CITMA, at the request of the Government, of a Scientific Program of State Interest dedicated to climate change.
8. The results of the First, Second, and Third National Communication to the UNFCCC described the forestry sector as highly vulnerable to the impacts of climate change.
9. The implementation of a State Program to Combat Climate Change.
10. The scientific demonstration that in Cuba, during the 20th century, the minimum temperature increased by 2.9ºC (INSMET), rainfall decreased by 200 mm (INRH), and the average sea level increased at a rate of 1.43 mm/year (Institute of Oceanology). In addition, during the first dozen years of the 21st century, Cuba has experienced an unprecedented number of Category 3 or higher hurricanes (Safir-Simpson scale).
11. Cuba's submission in 2016 of its Nationally Determined Commitment for the reduction of GHG emissions to the Paris Agreement, which was updated in 2020 for the period 2020-2030, and which establishes the development of the following actions:
    - Direct reforestation towards the maximum protection of soil and water in terms of quantity and quality, as well as the recovery of the most affected mangroves. Prioritize reservoirs, canals, and hydro-regulating strips in the tributary basins of the main bays and the coasts of the island platform.
    - Implement and control adaptation measures derived from sectoral policies in programs, plans, and projects linked to food security, territorial and urban planning, fisheries, agriculture, health, tourism, construction, transport, industry, and integrated forest management. (This is a broad program that covers 12 sectors and the actions to be applied should be examined under the respective sectoral programs).
    - Strengthen monitoring, surveillance, and early warning systems to systematically assess the state and quality of the coastal zone, water, drought, forest, human, animal, and plant health.
    - Increase Cuba's forest cover to 33% (of land area, excluding watercourses and reservoirs) by 2030, removing 169.9 million atmospheric tCO_2 in the period 2019 - 2030.
12. The process of preparing Cuba's Forest Policy, which in its October 2019 version included:
    - Guideline No. 2: Direct forest development towards solving key problems related to the production of goods, environmental protection, and adaptation to climate change; take into account the multiplicity of functions of forests and their need for creation and management based on the state of forest areas.
    - Guideline No. 3: Improve financial mechanisms by establishing variants that lead to better use of the state budget while recognizing payment for environmental services and applying new incentives towards sustainable forest development.
13. The approval in 2020 of the international project Strengthening institutional and technical capacities in the agricultural, forestry, and another land-use sector (AFOLU) in Cuba to improve transparency under the Paris Agreement, which aims to progressively transfer to the Ministry of Agriculture the control and preparation of all information from the sector that contributes to the GHG Emissions Inventory, the Biennial Update of the Inventory, the National Communication and the Paris Agreement.
14. The development since 2018 of the international project Incorporation of diverse environmental considerations and their economic consequences in the management of landscapes, forests, and productive sectors in Cuba (ECOVALOR), financed by the Global Environment Facility (GEF) and coordinated by the National Center for Protected Areas (CNAP); the recent approval of the international project Improving resilience and adaptation to climate change in Guantánamo, with Italian funding and the project Contribution of the Forestry Sector to the Fourth National Communication on Climate Change with national funding, both coordinated by INAF, as well as the international project Increasing the resilience of vulnerable rural households and communities through the rehabilitation of productive agroforestry landscapes in selected localities of the Republic of Cuba (IRES), funded by the Green Climate Fund and coordinated by the Agroforestry Business Group.
15. The definition among the organic functions of the Forestry Research Institute of the attention to environmental issues in Cuba's forest heritage, as well as technical advice and

assistance on these issues to the Forestry, Flora, and Wildlife Division DFFFS) of MINAG and the Agroforestry Business Group (GAF).

FORESTRY PROGRAM TO COMBAT CLIMATE CHANGE

Ex-Act Assessment

In compliance with the agreements adopted in 2007 by the Council of Ministers on the subject of climate change, at the end of 2012 the Forestry Research Institute carried out a diagnosis of the state of knowledge of the subject in the forestry branch and its results indicated that:

1. The scientific system in charge of responding to the productive and environmental demands posed by the forestry sector was adequately trained on the issue of climate change.
2. The productive system of the forestry sector was predominantly unaware of the issue of climate change and its impacts on the forest heritage, which were not taken into consideration when preparing medium and long-term development programs, making forestry and industrial investments in the sector extremely vulnerable.
3. The Forestry Division of MINAG was aware of the issue of climate change and was beginning to include it in policies and branch programs, in the control of their implementation, and the interaction with international mechanisms such as REDD+, favoring the reduction of the vulnerability of the sector.

As a consequence of these results, the Forestry Division asked the Forestry Research Institute to cooperate in designing a first version of the Forestry Programme for Dealing with Climate Change (PFECC), which was completed and delivered in 2013, then updated in 2019, without becoming an official document of the Forestry Division.

At the beginning of 2016, at the initiative of MINAG, Cuba asked the UN to include it in the UNFCCC's REDD+ initiative (Reducing Emissions from Deforestation and Forest Degradation; enhancing removals through conservation, sustainable management, and mitigation) and as part of this process, in July 2018 the first national REDD+ workshop was held in Havana, with the support of FAO, whereas part of its agreements, it was decided to reactivate and update the PEFCC for its presentation at the second national workshop held at the end of that year.

The general objective of the program

To protect the Cuban forestry sector from the expected negative impacts of climate change; to maintain and increase the role of the forest heritage as the only element available to offset Cuba's greenhouse gas emissions and as the only natural terrestrial barrier to mitigate the negative effects of sea-level rise, saline intrusion and hurricane surge on agricultural areas.

Specific objectives of the program

1. Maintain and improve the inventory of greenhouse gas emissions from the forestry sector, systematically defining its net emissions balance.
2. Identify and propose mitigation strategies to improve the net emissions balance of the forestry sector.
3. Identify and assess the negative impacts of climate change expected in the forestry sector, proposing the relevant adaptation strategies.
4. Identify, evaluate and propose the transfer of technologies that will enable the forestry sector to strengthen its climate change mitigation and adaptation strategies.
5. Create in the sector the capacities required to assume the activities related to its contribution to the National GHG Inventory, to the National Communication and the fulfillment of the commitments to the Paris Agreement, successfully undertaking the PFECC.

1ST PROGRAM IMPLEMENTATION PHASE (2020-2025)

Objective 1: Inventory of greenhouse gas emissions

Actions:

a. Build the required capacities in the DFFFS to take over the National GHG Inventories and for Biennial Updates.
b. Carry out the net balances of the forestry sector for the National GHG Inventories (INGEI) and the Biennial Updates during the period 2020 - 2025, in coordination with the National INGEI Team of the Institute of Meteorology.
c. Replace no less than 80% of the international emission factors used in the National GHG Inventories of the sector with national factors.
d. Establish a laboratory for the refinement of emission factors used in the net balances of the forest sector (average annual increments of dry biomass and carbon coefficients in wood, bark, soils and necromass).
e. Break down the results of the National Inventory of the forest sector to the provincial level, for the years 2020-2025.

Objective 2: Climate change mitigation

Actions:

a. Build the required capacities in the DFFFS to take on mitigation assessments and actions.
b. Completion of the mitigation actions set out in Cuba's First, Second and Third National Communications to the UNFCCC.
c. Fulfilling the commitments made by Cuba before the Paris Agreement that are related to the forestry sector.
d. Establish the system of measurement, reporting, monitoring and verification (MRMV) of the forestry sector as complementary information to the GHG Inventories.
e. Formulate, analyze, implement, monitor and evaluate local mitigation strategies for forest heritage tenants.
f. Coordinate mitigation actions under development and those newly created with Cubaenergía, in the Environment Agency.
g. Establish, as of 2021, payment for the environmental service of forest carbon for all tenants of forest heritage.
h. Implement actions to participate in international systems that finance climate change mitigation.

Objective 3: Assessment of impacts, adaptation and reduction of vulnerabilities

Actions:

a. Build the required capacities in the DFFFS to take over the monitoring and reporting of impact assessments and adaptation actions.
b. Implement local adaptation strategies with the already assessed forest heritage holders and include the actions in management projects and management plans.
c. Determine impacts and formulate local adaptation strategies for those whose forest heritage is to be assessed.
d. Implement the actions linked to the macro project and the Tarea Vida.
e. Intensively monitor the coastal zone, with emphasis on the mangrove formation.
f. Conclude the management projects of all the protected areas with coastal zones.
g. Evaluate and protect the existing ecosystems in the main mountain systems of Cuba, from the watershed to the coast.
h. Recover the coastal ecosystems in the south of Mayabeque and Artemisa provinces.
i. Implement an information and capacity building program on the protection of coastal areas.
j. Strengthen the public's perception of the importance of the protection and recovery of the coastal system.

Objective 4: Technology transfer

Actions:

a. Identify technologies whose transfer would strengthen the implementation of mitigation actions in the forestry sector and undertake their adoption.
b. Identify technologies whose transfer would strengthen the implementation of adaptation actions in the forestry sector and undertake their adoption.

Objective 5: Capacity building

Actions:

a. Form and train the climate change team of the Forestry Division, Flora and Wildlife; define its functions and working system.
b. Train the State Forest Service on climate change.
c. Train the business component of GAF, GEFF, GAG and GEGAN on climate change mitigation and adaptation to its impacts in the forestry sector.
d. Train the non-business component of the forestry sector on climate change mitigation and adaptation to its impacts.

Program implementation

Once the Program is approved, it will be necessary to:

a. Define the person in charge and the implementation schedule for each of the actions foreseen in each specific objective.
b. Define the control system to be applied to monitor the implementation of the Programme.
c. Define the aspects that should be part of the functions of the DFFFS climate change team.
d. Establish the work coordination between the DFFFS team, INAF, UPR and CNAP.

ANNEX 7

METHODOLOGICAL ASPECTS FOR CARBON ASSESSMENTS IN THE ECOVALOR PROJECT

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Methodology document

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INTRODUCTION

To facilitate the preparation and submission of forestry projects to the Reducing Emissions from Deforestation, Degradation and Sustainable Management of Forests (REDD+) Mechanism, in February 2016 the Forestry Division of MINAG requested the Forestry Research Institute (INAF) to carry out some work that would allow:

1. Define the term Degraded Forest.
2. Identify the Criteria for assessing forest degradation and the scales for their use.
3. Identify the method by which, using the Degradation Criteria, the level of forest degradation is established.

The definition, Criteria, and methodology to be proposed had to apply to all combinations of forest categories (Producer, Soil and Water Protection, Coastal Protection, Special Management, Wildlife Protection, and Conservation, Recreational and Educational/Scientific) and forest types (natural and artificial) existing in Cuba.

Later, during the preparation process of the international project Incorporating multiple environmental considerations and their economic implications in the management of landscapes, forests and productive sectors in Cuba (ECOVALOR) coordinated by the National Centre for Protected Areas (CNAP), the Global Environment Facility (GEF) established among the goals to be achieved by the project the removal of 2, 9 million tons of atmospheric CO_2 in 20 years (6 years of implementation and 14 years of capitalization), establishing that the ex-ante evaluation, monitoring during and ex-post evaluation of the fulfillment of this goal had to be carried out using the Ex-Act tool, an automated system for calculating carbon in the sectors served by the Food and Agriculture Organization of the United Nations (FAO): land-use change, agriculture, livestock, forestry, fisheries/aquaculture and agricultural infrastructure.

For the particular case of established forests (natural or artificial), Ex-Act calculates carbon emissions or removals based on a scale of forest degradation, ranging from no degradation to extreme degradation (Table 1), but without establishing a definition of forest degradation, nor Criteria that would allow its assessment, which made ECOVALOR's needs for forest degradation assessments coincide with those formulated two years earlier by the Forestry Division.

Table 1. Assessment scale used by Ex-Act.

Value	Degradation	Biomass Loss (%)
0	No degradation	0
1	Very low degradation	10
2	Low degradation	20
3	Medium degradation	40
4	High degradation	60
5	Extreme degradation	80

In response to the request of the Forestry Division, between 2016 and 2018 INAF prepared and substantiated the definition of Degraded Forest and the methodology to be used to assess degradation, while in 2019 the ECOVALOR project facilitated the conditions required to define the Degradation Criteria to be used, with the participation of a technical team of more than 30 specialists among which the Forestry Division and the Soil Department of MINAG, CNAP, the Agroforestry Business Group (GAF), INAF, the Institute of Ecology and Systematics (IES), the Soil Institute, technicians from 10 protected areas and five agroforestry companies were represented, a result that completed all the required elements.

In the framework of the EVOVALOR project, from 2020 until 2023, everything established on forest degradation will be applied in real conditions, a process in which five agroforestry companies and 12 protected areas will participate, which together will evaluate more than 10,000 hectares of natural and artificial forests with this methodology, including two moments to critically analyze all aspects (the definition, the Criteria, and the evaluation method), to improve them based on accumulated practical experience, to finally present the results achieved to the consideration of the Forestry, Flora and Wildlife Division of MINAG, so that it can assess the convenience of establishing the application of the methodology on a national scale.

CONCEPT OF DEGRADED FOREST

Established area of natural or artificial forest, where causes of natural origin, anthropic or resulting from their interaction, limit or prevent the qualitative and/or quantitative fulfillment of the functions that correspond to the forest, whether associated with its main function (determined by its forest category) or those associated with its complementary functions (determined by other functions other than the main one).

CRITERIA FOR ASSESSING FOREST DEGRADATION

The criteria are divided into two groups:

- General criteria applicable to any forest category, natural or artificial (Table 2).
- Specific criteria applicable to forests according to their category (Table 3).

Table 2. General degradation criteria for forests of any category.

No.	Criteria	Variable to be measured
1	Phytosanitary damage (insects and diseases)	Affected trees (%)
2	Presence of mechanical damage	Affected trees (%)
3	Invasion of thorny species (sickle bush, aroma, weller, maya, etc.)	Encroached area (%)
4	Soil erosion	Affected area (%)
5	Affected by fire	Affected area (%) and degree of impact

Table 3. Specific degradation criteria per forest category.

No.	Criteria	Variable to be measured
Production forests		
6	Density less than 0.3 or greater than 0.7	Table of densities
7	Trees of economic value (only applicable in natural forests)	Number of trees (u)
Water and soil protection forests - Coastal protection forests		
8	Density less than 0.6 or greater than 0.8	Density Table
9	Presence of exotic species (other than those in Criterion 7)	Area occupied (%)
Special Management Forests - Wildlife Protection/Conservation Forests		
9	Presence of exotic species (other than those in Criterion 7)	Area occupied (%)
10	Evidence of felling of trees felled	Trees felled (%)
Recreational forests		
10	Evidence of clear-cutting	Trees felled (%)
11	Plant species detrimental to human health	Area occupied (%)

Forests categorized as Educational and Scientific will not be assessed, as they only include botanical gardens and arboreta. The summary of general and specific criteria identified by forest category are shown in Table 4.

Table 4. Summary of degradation criteria per forest category.

Criteria	Forest category					
	Production	Water/soil portection	Coastal protection	Special Management	Fauna	Recreation
1. Phytosanitary damage	X	X	X	X	X	X
2. Mechanical damage	X	X	X	X	X	X
3. Thorny species	X	X	X	X	X	X
4. Erosion	X	X	X	X	X	X
5. Fires	X	X	X	X	X	X
6. Density <0.3 o >0.7	X					
7. Economically important trees*	X					
8. Density <0.6 o >0.8		X	X			
9. Exotic tree species		X	X	X	X	
10. Harvesting logging				X	X	X
11. Species harmful to man						X

SCALES FOR ASSESSING CRITERIA

Table 6. Scales for assessing the criteria 1, 2, 3, 4, 9, 10 and 11.

Value	Degradation	Scale (%)
0	No degradation	0
1	Very low degradation	1-10
2	Low degradation	11-20
3	Medium degradation	21-50
4	High degradation	51-79
5	Extreme degradation	80-100

Table 7. Scale for assessing Criterion 5.

Affected area (%)	Extent to which trees are affected				
	Slight	Fair	Serious	Very Serious	Total
0.1 – 0.9	1	2	3	4	5
1.6 – 2.5	2	2	3	4	5
2.6 – 3.0	3	3	4	4	5
3.1 – 3.5	4	4	4	5	5
>3.5	5	5	5	5	5

Value	Degradation
0	No degradation
1	Very low degradation
2	Low degradation
3	Medium degradation
4	High degradation
5	Extreme degradation

Table 8. Density determination scale (Criteria 6 and 8).

Density table											
Average height (m)						Sum of basal areas in m2					
Lsp	Pn	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
		16	14	13	11	10	8	6	5	3	1
5		17	15	14	12	10	8	7	5	3	1
6		18	16	14	13	11	8	7	5	4	2
7		19	17	15	13	11	10	8	6	5	3
8		20	18	16	14	12	10	8	6	5	3
9		21	19	17	15	13	10	8	6	5	4
10		22	20	18	15	13	11	9	7	6	4
11	5	23	21	18	16	14	12	9	7	6	4
12	6	24	22	19	17	14	12	10	7	6	5
13	7	25	22	20	17	15	12	10	8	7	5
14	8	26	23	21	18	16	13	10	8	7	6
15	9	27	24	22	19	16	14	11	8	7	6
16	10	28	25	22	20	17	14	11	8	7	6
17	11	29	26	23	20	17	14	12	9	8	7
18	12	30	27	24	21	18	15	12	9	8	7
19	13	31	28	25	22	19	16	12	9	8	7
20	14	32	29	26	22	19	16	13	10	9	7
21	15	33	30	26	23	20	16	13	10	9	8
22	16	34	31	27	24	20	17	14	10	9	8
23	17	35	32	28	24	21	18	14	11	10	8
24	18-19	36	32	29	25	22	18	14	11	10	9
25	20-22	37	33	30	26	22	18	15	11	10	9
26	23-25	38	34	30	27	23	19	15	11	10	9
27-28	26-28	39	35	31	27	23	20	16	12	11	9
29-30	29-30	40	36	32	28	24	20	16	12	11	10

Lsp – Broadlea27f Pn- Pines

Table 9. Scale for assessing Criteria 6 and 8.

Criterion 6		Criterion 8	
Degradation	Density	Degradation	Density
0 – No degradation	0.3 -0.7	0 – No degradation	0.6 - 0,8
3 – Moderate degradation	0.2 – 0.8	3 – Moderate degradation	0.4 or 0.5
5 – Extreme degradation	0.1 or 0.9-1.0	5 – Extreme degradation	0.1 a 0.3 or 0.9 - 1.0

Table 10. Scale for assessing Criterion 7.

Value	Degradation	Trees /plot
0	No degradation	> 4
1	Very low degradation	4
2	Low degradation	6
3	Medium degradation	2
4	High degradation	1
5	Extreme degradation	0

DEGRADATION DETERMINATION OF A SAMPLE PLOT

The degradation assessment of a temporary (PMT) or permanent (PMP) sample plot is carried out by assessing its specific and general Criteria.

The detailed description of the assessment methodology, including the general and specific Criteria, the variables to be considered and the assessment scales to be used, may give the impression that the field determination of degradation will be extremely burdensome for the teams working with the sample plots.

However, the methodology is endorsed by an automated system supported by an Excel spreadsheet, which reduces the complexity of its application in the field to just ticking the corresponding boxes in the tables contained in the measurement model.

Example:
One of the five permanent sample plots established in a natural broad-leaf forest located in the Cayo Santa María protected area, categorized as a Special Management Area, is evaluated. Then, using Table 11, the evaluation of degradation by Specific Criteria for the plot is carried out:

Table 11. Specific degradation criteria.

Variable	Assessment (%)					
	0	1-10	11-20	21-50	51-79	80-100
Special management forests						
9. Encroached area by exotic species (%)	X					
10. Trees felled (%)		X				

While in Table 12 the assessment of all General Criteria is made for that plot:

Table 12. General degradation criteria.

Variable	Assessment (%)					
	0	1-10	11-20	21-50	51-79	80-100
1. Trees attacked by pests (%)	X					
2. Mechanical damage to trees (%)	X					
3. Area occupied by thorny species (%)				X		
4. Affected area by erosion		X				

Criterion 5. Burnt forests: Not affected (X)

Surface area affected (%)	Extent to which trees are affected				
	Slight	Fair	Serious	Very serious	Total
0.1-1.5					
1.6-2.5					
2.6-3.0					
3.1-3.5					
>3.5					

Based on this data, the automated evaluation system would then define the following results:

Natural broad-leaved forest Special Management	Degradation criteria											Máximum degradation
	1	2	3	4	5	6	7	8	9	10	11	
	0	0	3	1	0	0	0	0	0	1	0	3

Value	Degradation
0	No degradation
1	Very low degradation
2	Low degradation
3	Moderate degradation
4	High degradation
5	Extreme degradación

The degradation value of the natural broad-leaf forest located in the Cayo Santa María protected area, categorized as a Special Management Area, will be the average of the highest degradation values reached by each of the five permanent sample plots established in that work area.

In the case of Production and Protected Forests, the determination of Specific Criteria 6 and 8 is made based on the Density Table, which establishes a relationship between the average total height of the plot and the accumulated basal area per hectare to define the density of wood in the plot, and with it, its level of degradation.

The entire process for the determination of these Specific Criteria is carried out by the calculation system made in Excel, from the data of diameter at 1.30 m from the ground and total height corresponding to all the trees measured in the plot.

Attached to this methodology are the models that will be used for the evaluations and field measurements in the sampling plots,which will be established in the ECOVALOR project intervention sites.

PERMANENT PLOT NO. ____________________________

Intervention site		Coniferous trees		Broad-leaf trees	
Work area		Team members			
Artificial forest: Species					
Natural forest: Formation					
Date:					

Work area (Ha)

Coordinates					
North			West		

Forest category					
P	PAS	PL	CME	CFF	CR

P- Production; **PAS**-Water/soil protection; **PL**-Coastal protection; **CME**-Special Management; **CFF**-Conservation of Flora/Fauna; **CR**-Recreational

CAUSE OF DEGRADATION: ____

ASSESSMENT OF DEGRADATION INDICATORS: GENERAL CRITERIA.

No. of indicator and variable	Assessment (%)					
1. % of trees attacked by pests	0	1-10	11-20	21-50	51-79	80-100
2. % of mechanically damaged trees						
3. % area occupied by thorny species						
4. % area affected by soil erosion						

5. Burned, unaffected forests ( )

Affected area (%)	Degree of tree damage				
	Slight	Fair	Serious	Very Serious	total
0.1-1.5					
1.6-2.5					
2.6-3.0					
3.1-3.5					
>3.5					

ASSESSMENT OF DEGRADATION INDICATORS. SPECIFIC CRITERIA.

No. of indicator and variable	Assessment (%)					
	0	1	2	3	4	> 4
- Production (natural) forest						
7. Number of economically important trees/plot						
No. of indicator and variable	Assessment (%)					
	0	1-10	11-20	21-50	51-79	80-100
- Water, soil and coastal protection forest						
9. % Encroached area by exotic species						
- Conservation forest: Special Management and Fauna Protection/Conservation						
9. % Encroached area by exotic species						
10. % of trees felled						
- Conservation forest: recreational						
10. % of trees felled						
11. % area with species detrimental to health						

PERMANENT PLOT NO.______________ SHEET NO.________________________

Intervention site:		Work area:		Date:	

TREE NO.	SPECIES	BARK (mm)	DIAMETER (6 cm)	TOTAL HEIGHT (m)

TREE NO.	SPECIES	BARK (mm)	DIAMETER (6 cm)	TOTAL HEIGHT (m)

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