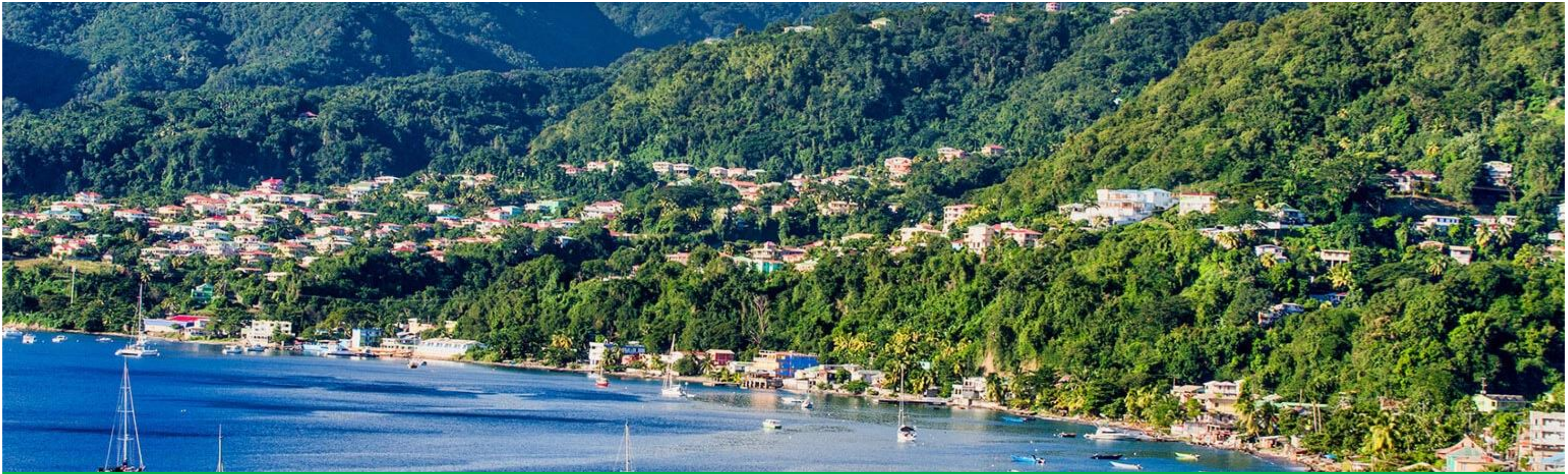
DOMINICA SECOND FOREST REFERENCE LEVEL / FOREST REFERENCE EMISSIONS LEVEL 2018 -2025

2024



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Cover Photo: credit Forestry, Wildlife & Parks, Dominica

[1] Photo 1: https://immigrantinvest.com/en/insider/dominica-sustainable-development-goals-2021/

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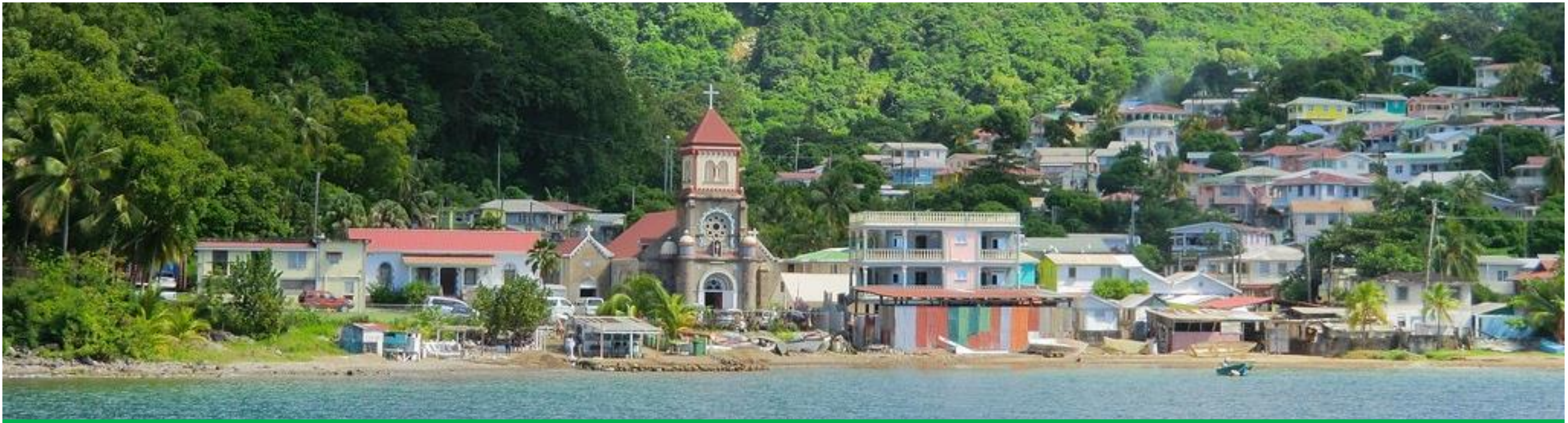
[2] https://www.state.gov/countries-areas/dominica/

LIST OF ABBREVIATIONS AND ACRONYMS

AFOLU	Agriculture, Forestry, and Other Land Use
BUR	Biennial Update Report
BTR	Biennial Transparency Report
CfRN	Coalition for Rainforest Nations
CH_4	Methane
CO_2	Carbon dioxide
COP	Conference of the Parties
ETF	Enhanced Transparency Framework
FAO	Food and Agriculture Organization (of the United Nations)
FOLU	Forest and Other Land Use
Gg	Gigagrams
GHG	Greenhouse Gas
GHGI	Greenhouse Gas Inventory
GPG	Good Practice(s) Guidance
GWP	Global Warming Potential
Ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
INDC	Intended National Determined Contributions
LULUCF	Land Use, Land Use Change and Forestry
LDC	Least Developed Countries
m^3	Cubic meter
MPG	Modalities Procedures and Gridlines
MRV	Monitoring, reporting, and Verification
N_2O	Nitrous oxide
NFI	National Forest Inventory
NIR	National Inventory Report
NAP	National Adaptation Plan
NDC	National Determined Contributions

[4] Photo: https://www.uncommoncaribbean.com/dominica/having-it-made-in-the-mero-beach-shade-dominica/

NDVI	Normalized Difference Vegetation Index
PA	Paris Agreement
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RRR+	Reporting for Results-based REDD+
SBSTA	Subsidiary Body for Scientific and Technological Advice
SIDS	Small Island Developing States
TNC	Third National Communication
TOA	Top of Atmosphere
UNFCCC	United Nations Framework Convention on Climate Change



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[5] Photo: https://thecommonwealth.org/our-member-countries/dominica

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1. CONTEXT

In 1994, the Commonwealth of Dominica ratified the *United Nations Framework Convention on Climate Change* (UNFCCC)[7], hereinafter referred to as "the Convention", whose ultimate objective is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system; and within a sufficient timeframe to facilitate natural adaptation of ecosystems, ensure food security and sustainable economic development.

At the 21st Conference of Parties (COP21)[8], a landmark agreement was reached to combat climate change and to accelerate and intensify actions and investments needed for a low carbon future. The Paris Agreement, which builds upon the Convention, has an overall objective to strengthen the global response to the threat of climate change by limiting global temperature rise this century to well below 2°C above pre-industrial levels and to pursue efforts to further limit the temperature increase to 1.5°C through ambitious mitigation actions. In addition, the Agreement establishes measures to increase the ability of nations to adapt to the adverse impacts of climate change and foster climate resilient development through consistent finance flows.

In 2015, in accordance with relevant paragraphs of Decisions 1/CP19[9] and 1/CP20[10] towards achieving the ultimate objective of Article 2 of the Convention, the Government of Dominica committed through its Intended Nationally Determined Contribution (INDC)[11], to a progressive reduction of total greenhouse gas emissions below 2014.

Consistent/in accordance with Decision 18/CMA.1[12] and its annex (the Katowice Climate Package), as well as Article 13 under the Agreement, Dominica provides information under the *Enhanced Transparency Framework*[13] (ETF), which details a set of Modalities, Procedures and Guidelines (MPGs) to build trust and confidence; and strengthen

[6] Photo: https://discoverdominica.com/en/places/68/trafalgar-falls
[7] https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf
[8] https://unfccc.int/documents/184656
[9] https://unfccc.int/documents/8106
[10] https://unfccc.int/documents/8611
[11] https://www4.unfccc.int/sites/ndcstaging/Pages/LatestSubmissions.aspx
[12] https://unfccc.int/documents/193408
[13] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-paris-agreement

the global response to the threat of climate change. Regarding the forest sector, Dominica also intends to provide information as indicated in Article 5 of the Paris Agreement for REDD+ (Reducing Emissions from Deforestation and Forest Degradation) following the guidance developed since COP13 ensured transparency in the implementation of REDD+ activities. It is important to recall that REDD+ Conference of the Parties (COP) guidance emphasizes the importance of accurate and robust national GHG inventories and puts in place a unique verification process compared to all other sectors responsible for GHG emissions.

Small Island Developing states (SIDS) like Dominica, are on the frontlines of the climate crisis and are among the most vulnerable to its adverse impacts, but at the same time are at the forefront of climate actions. Dominica has taken national, sub-national and sectoral approaches towards its transition to a carbon-neutral, green, climate-smart and climate-resilient nation, with a cross-cutting emphasis on accessing climate change finance. Dominica has established a strong track record for the continual development, implementation and communication of policies and strategies to support climate change adaptation, mitigation, and resilience, with a focus on nature-based solutions.

The Government of Dominica considers it to be an important part of its mission to lead a process of collaboration with others with a view of preserving the nation's forests, rivers, and eco-tourism product, preserving the marine environment and the country's biodiversity; and popularizing even as preserve the nature island concept and brand. It is Government's intention to make an active and deliberate contribution to sustainable development of the natural and built-in environment, giving special attention to the larger environmental issues such as biodiversity, land degradation, climate change and the emission of GHG gases that cause global warming. We will give high priority to pursuing policies and programs that are consistent with well-researched proposals and programs developed by the international community and are consistent with our countries' needs and capacities.

The Government will contribute to ensure that in his or her personal behavior, a consciousness and pride in our Nature Isle is manifested by every Dominican. It is Government's policy that the Nature Isle will take the lead in enshrining green principles as the guide to our national planning, and to inform initiatives in all sectors.

Pursuant the commitments set by the Government; Dominica has the honor to present to you the Second Forest Reference Level/Forest Reference Emissions Level (FREL/FRL) for the years 2018-2025 of the country at the national level to be evaluated during the period of 2024.


[14]

2. FREL/FRL KEY ELEMENTS

Modalities for FREL/FRL according to 12/CP.17

- **Paragraph 7**. The FREL/FRL presented by Dominica is expressed in **tons of CO_2 equivalent per year**, to serve as a benchmark for assessing the country's performance in implementing the REDD+ activities, in particular the restoration and regeneration of Dominican forests after the impact of Hurricane Maria in 2017.

- **Paragraph 8.** Dominica developed a **single database for the National GHG Inventory, the FREL/FRL and the NDC**. This grants full consistency. All calculations are explicit to maximize transparency. This database also allows to easily check which emissions and removals from the National GHG Inventory are selected for the FREL/FRL.

- **Paragraph 9**. In this submission, Dominica includes information and rationale on the development of the FREL/FRL and how the national circumstances were considered. A key national circumstance is that Dominica is a net carbon remover (removals are higher than emissions) across all sectors and when considering forest-related sources and sinks; this circumstance is the basis for the current FREL/FRL .

- **Paragraph 10**. In this submission, Dominica presents an improvement plan, which considers the gradual improvement of methods.

- **Paragraph 11**. Dominica's FREL/FRL is presented at the national level.

- **Annex, chapeau**. the information provided by Dominica is guided by the IPCC guidance and guidelines, specifically the **2006 IPCC guidelines for National GHG Inventories**.

[14] Photo: https://www.experience-dominica.com/post/the-kalinago-people

- **Annex, paragraphs (a), (b)**. A comprehensive database is attached to this report[15]. Also, extensive descriptions of the methods and data used are provided below, as well as in technical annexes to facilitate understanding by the readers and the UNFCCC reviewers.

- **Annex, paragraph (c)**. Those carbon pools included, and the reasons for those excluded are provided. The FREL/FRL covers the historical emissions and removals associated to Forest land remaining Forest lands, and conversions to and from Forest land. In essence, this is equivalent to measuring and monitoring all possible REDD+ activities in the FREL/FRL .

- **Annex paragraph (d)**. The forest definition used for the FREL/FRL is the same as for the National GHG Inventory to be included in the 1 Biennial Update Report.

[15]

3. REDD+ ACTIVITIES

As indicated in the Decision 1/CP.16, paragraph 71, Dominica has decided to develop a **national** forest reference level (FRL)/ forest reference emission level (FREL) in accordance with national circumstances and as a *benchmark* to assess the country's performance in implementing all five REDD+ activities referred to in decision 1/CP.16, paragraph 70:

Included REDD+ Activities

1. Deforestation
2. Forest degradation
3. Conservation of forest carbon stocks
4. Enhancement of forest carbon stock
5. Sustainable management of forest

Definition of Forest

Forest is defined as lands with a tree canopy cover equal or higher than 60%, with a minimum area extension of 1 ha and woody vegetation of minimum 3m height or higher, including temporary unstocked areas with the potential to reach the forest definition. There are seven (7) forest types on the island: Elfin Forest, Montane Cloud Forest, Montane Rainforest, Semi-evergreen Forest, Semi-deciduous Forest, Dry Scrub Forest and Littoral Forests which vary depending on altitude and location. Characteristics of each forest type are described in section 7.1.

Under the REDD+ Framework for Dominica, the Forest Definition was agreed upon within various consultations held among Forestry, Physical Planning & Agriculture Officers. To fulfil two (2) main objectives:

- To be operational for the Monitoring Reporting Verification (MRV) process, with Monitoring done through Remote Sensing Images.

[16] Photo: https://www.experience-dominica.com/post/the-kalinago-people

- In Dominica there is a policy statement of dedicating to increase forest cover as part of climate resilience strategies; thus, we concluded that a high canopy cover threshold is representative of those objectives.

Table 1. Depicting land use categories and the associated REDD+ activities.

IPCC land category	Associated REDD+ activity(ies)
Forest land remaining forest land	Forest degradation
	Enhancement of forest carbon stocks
	Conservation of forest carbon stocks
	Sustainable management of forests
Land converted to Forest land	Cropland converted to Forest Land
	Grasslands converted to Forest Land
	Wetlands converted to Forest Land
	Settlements converted to Forest Land
	Other lands converted to Forest Land
Forest land conversion to other land uses	Deforestation to Croplands
	Deforestation to Grasslands
	Deforestation to Wetlands
	Deforestation to Settlements
	Deforestation converted to Other lands

Note on treatment of hurricane-affected forests

In 2017, Dominica lost about 85%-90% of their forest cover in the forest lands[17] due to Hurricane Maria, and the remaining 10%-15% was also heavily affected leaving mostly the understory. Since then, Dominica's efforts have focused on restoring and rehabilitating the forest lands in order to recover mostly tree cover and soils, and ensuring temporary unstocked forest lands are not converted to other land uses to allow the expected natural and assisted regeneration of the forest.

Based on expert consultation and their observations after the hurricane, four (4) different categories were used in Dominica to classify the forest.

1) No significant damage, which are patches of forest that because of their location and characteristics were not significantly affected by the hurricane.
2) Damage I, the stem remained standing but had broken branches or heavy defoliation,
3) Damage II: the steam and branches were broken, full defoliation, but trees were not uprooted.
4) Damage III: trees were totally uprooted.

These assumptions are based on the facts that the fallen branches, twigs and tree stumps initially hindered any major movement of persons into the forested areas. Few months after the hurricane, access to forest areas became more complicated due to an exposed undergrowth. Razor grass and other fast-growing shrubs, vines and ground ferns covered the forest floor soon forming a web as tall as 10 feet or more in some areas. In isolated instances, where farmlands, which are adjacent to Protected Areas and unallocated state lands were converted initially to grasslands eventually converted back to forest lands due to fast growing pioneer species.

[17] Post-Disaster Needs Assessment Hurricane Maria September 18, 2017.https://www.gfdrr.org/sites/default/files/publication/Dominica_mp_012418_web.pdf

This new farming in remaining forest has been mostly on private lands and represent about 5% in the country. However, worth mentioning is the fact that in those private (forested) land areas firewood, charcoal and lumber production did occur, whether during the process of utilizing the exposed patches of forest for new farm plots or simply salvaging the fallen timber that was accessible. It was observed, in early 2018, that Forest tree species fruiting patterns have changed from locality to locality, especially in the Middleham area (Southern Range), it has also been observed that Gommier (*Dacryodes excelsa*) tree species were fruiting but not as heavy as in Pond Casse, Central Range. Those changes would have been caused by the hurricane wind stress and defoliation, where, the Pond Casse area is more sheltered from the wind so fruiting is more prominent.

A lot of local knowledge was received and considered from many chainsaw operators, from all Forest Ranges, on what they have seen and experienced regarding some of those canopies disturbed of mature trees within Dominica's forests. The majority of the forests are recovering - the upcoming undergrowth, the mature class (the bulk of Dominica's forest with restored canopy cover), the pioneer species, the forested areas located in the COLS or GAPS (protected valleys) and all other forested areas which are rejuvenating after such massive defoliation. It should be noted that a slow mortality rate had already been observed among those mature hardwood species.

Currently, it is observed that the mortality rates may be levelling off or even declining (as most of the trees which were badly affected have already died and will soon deteriorate or break off), as opposed to those which died soon after the hurricane leading up to present (e.g. softer timber species). However, it must be said here that on the elevated windward slopes in the Eastern Range, some of the mature, copising hard wood species have stabilized their recovery growth curve. The tall, defoliated trees can be easily distinguished among the rest of the recovering/thriving undergrowth forming secondary forest (in certain areas) and pioneer species which have joined together to give back our lush forest appearance.

Therefore, it is considered that for the damage classes I, II, and III, the forest land did maintain the carbon stocks pre-hurricane, and hence, if emissions from deforestation and degradation of theses affected areas were to be included in the FREL/FRL , it would have to be based on the remaining biomass carbon stock, for which no data is available, and not the pre-hurricane biomass. Hence, despite degradation continued to happen after the hurricane observed through tree mortally, it is unlikely that emissions from deforestation and forest degradation in the period 2018 – 2025 would be high in these 3 classes zones and, in addition would be highly uncertain. As a result, the deforestation and degradation rates (hectares of the historical period (2001-2017)) were not considered for the FREL/FRL period (2018-2025) for the whole country; only 25% is being used as a reference for deforestation for the "No significant Damage Class", and no more degradation is assumed.

Accounting method

For the development of the FREL/FRL, Dominica selected a **Land Based Approach**, which means that all forest-related sources and sinks were considered (where all possible REDD+ activities may occur), as depicted in Table 1. Further, the FREL/FRL is a single benchmark and, therefore, no specific FREL/FRL were developed by activity, aiming at environmental integrity (by taking responsibility for the performance of all activities together). Therefore, REDD+

results will be evaluated as an integral outcome of national activities. Nonetheless, the estimations and results are disaggregated and can be evaluated individually if needed.


[18]

4. CONSISTENCY WITH THE NATIONAL GHG INVENTORY

In march 2020, Dominica submitted its Third National Communication which reports on the period from 2005 until the end of 2017, and includes an assessment of greenhouse gas (GHG) emissions during this time, together with an update concerning activities that have been undertaken to reduce Dominica's carbon footprint while building climate resilience, in part though measures to implement Dominica's Low Carbon Climate Resilient Development Strategy including though building the legal and institutional capacity to manage impacts from climate change.

For the forest and land use sector, applicable data for Dominica's forest was not available, with no recent census or forest inventory having been undertaken since 1987. This resulted in basing the GHG inventory on default values from to the FAO Global Forest Resource Assessment data (FAO STAT). The values from FAOSTAT 2000, could not be utilized to calculate the changes in area for the six IPCC land use categories because FAO's categories were different from that described in the IPCC guidelines. Given this information was the only complete land use data source information available for Dominica, Approach 1 was chosen as the best suited methodology for the analysis, because it does not require detailed information on land use changes. For the Emission Factors, Dominica fell into the category of having little or no country specific data available and thus Tier 1 was followed, using 2006 IPCC defaults values.

Based on these needs, during 2020-2021, the Forestry Division took the lead and developed a national FOLU-GHG Inventory including GHG emissions and removals for all Intergovernmental Panel on Climate Change categories and subcategories at national level, which includes land remaining in same category and conversions to other land uses, considering all lands as managed (2006, 2019 IPCC). It includes the pools above-ground biomass, below-ground biomass, dead wood, and soil organic Carbon. Harvested wood products were excluded due to lack of information.

Updated information on Activity Data used was obtained from new land use and land-use change assessments, which were conducted on the basis of a systematic, sampling approach (2006 IPCC, V4, Ch3 approach 3), in which

[18] Photo: https://inaturalist.ca/taxa/204112-Gecarcinus-quadratus

the land-use was determined for each year of the time series 2000 – 2017, derived using the FAO Collect Earth tool. The information on Emission Factors (EFs) was obtained from regional research, scientific literature, and default values of the 2006 IPCC Guidelines and 2019 Refinements to the 2006 IPCC Guidelines. The FOLU-GHG Inventory was developed using the Foundational Platform calculation tool developed by the Coalition for Rainforest Nations and adjusted to Dominican national circumstances and methodological approaches. This tool allows extracting the forest-related information from the GHG inventory to construct the FREL/FRL and update the National Determined Contributions update report, using the same data, methods, and assumptions, which ensures full consistency among the reports. This FOLU-GHG Inventory will be included in the next report to the UNFCCC (1st Biennial Update Report). This FOLU-GHG Inventory was submitted as part of the first FREL/FRL , through the Foundational Platform (calculation spreadsheet), that includes the estimation of the historical emissions and removals that are used for both purposes[19]. This approach meets the requirements of Decision 12/CP.17, paragraph 8 and decision 4/CP.15, paragraph 7. The information of the previous FOLU-GHG Inventory (2021) has been already used for the estimations included in the Updated National Determined Contributions report (2021).

This current FREL/FRL will also be consistent with the upcoming BTR, as the GHG inventory for the BTR will include the improvements captured in this document.

[19] Attach Link to FP


[20]

5. FOREST REFERENCE LEVEL OF DOMINICA

5.1Outline of Forest Reference Level (2018-2025)

The current national FREL/FRL proposed by Dominica is based on the net balance of greenhouse gas (GHG) emissions and removals including all forest-related sources, sinks, carbon pools and GHGs. **The selected FREL/FRL has a value of zero**, meaning that Dominica would only seek results-based payments for net removals that occur as part of the regeneration and recovery of the national forest area after considering all forest-related emissions and removals in the country. Dominica has annual net removals which the country intends to maintain and increase as a result of this recovery process. This is the basis for REDD+ at the national level which guides the current efforts by the government and local stakeholders.

Zero FREL/FRL

Dominica's zero FREL/FRL proposal aims to recognize the country's special circumstance of being a net carbon remover (it presents more removals than emissions, even when considering all sectors – energy, IPPU, waste, agriculture, forestry and other land uses). According to Dominica's third national communication (latest submission to the UNFCCC), the country has a national net balance of -2,816 Gg CO2eq for the year 2017 (latest reporting year). This means that Dominica has already achieved the balance in emission and removals that the Paris Agreement requests of countries by the second half of the century (Article 4, paragraph 1 of the Paris Agreement).

This places Dominica in a unique position to lead climate action, especially through strengthened governance and financial resources to allow hurricane affected forests to recover, thereby increasing net removals at the national level, which in turn increases the contribution of Dominica to the global CO_2 atmospheric concentrations.

Key principles of Dominica's zero FRL/FRL:

1. Dominica, as a net carbon remover country, provides an invaluable contribution by removing CO_2 from the atmosphere directly impacting the global CO_2 concentrations;
2. Dominica seeks to maintain the current balance between emissions and removals by seeking result-based payments for net removals against a zero FREL/FRL , effectively recognizing the country's full extent of CO_2 removals from forests;

[20] Photo: https://associatestimes.com/dominica-pm-roosevelt-skerrit-recalls-torrential-impacts-of-hurricane-maria-at-5th-anniversary/

3. Dominica's FREL/FRL includes all activities, meaning that any deforestation or forest degradation would impact the country's REDD+ performance. The zero FREL/FRL has environmental integrity because it considers all possible sources of emissions.
4. By defining the FREL/FRL as zero, Dominica seeks recognition and results-based payments for net removals, meaning increased forest carbon stocks, following IPCC guidelines: "increases in total C stocks over time are equated with a net removal of CO2 form the atmosphere" (IPCC 2006, volume 4, chapter 1, page 1.6).

The table below explains how the zero FRL/FRL approach fully aligns with COP decisions for REDD+ reference levels, particularly decision 12/CP.17:

Modalities for submission of FREL/FRL (12/CP.17)	Rationale and justification
7. Agrees that, in accordance with decision 1/CP.16, paragraph 71(b), forest reference emission levels and/or forest reference levels expressed in tonnes of carbon dioxide equivalent per year are benchmarks for assessing each country's performance in implementing the activities referred to in decision 1/CP.16, paragraph 70;	• Dominica's Zero FREL/FRL is expressed in tons of CO_2 equivalent per year. • It is a special benchmark designed for assessing Dominica's efforts in maintaining yearly net removals (*when considering all forest-related emissions by sources and removals by sinks*). • By setting the FREL/FRL at zero, Dominica expresses its intention to get recognition for all net removals.
8. Decides that forest reference emission levels and/or forest reference levels, in accordance with decision 1/CP.16, paragraph 71(b), shall be established taking into account decision 4/CP.15, paragraph 7, and maintaining consistency with anthropogenic forest- related greenhouse gas emissions by sources and removals by sinks as contained in each country's greenhouse gas inventories;	• The updated time-series underlying the zero FRL/FRL will be the basis for the upcoming national GHG inventory to be included as part of Dominica's first BTR. • Updated methods, data, assumptions, and results will be consistent with (and will serve as the basis for) the upcoming in the national GHG inventory.
9. Invites Parties to submit information and rationale on the development of their forest reference emission levels and/or forest reference levels, including details of national circumstances and if adjusted include details on how the national circumstances were considered, in accordance with the guidelines contained in the annex to this decision and any future decision by the Conference of the Parties;	• When applying the Zero FRL approach, Dominica is considering their national circumstance of being a net carbon remover, *i.e*. having net removals rather than net emissions. • This circumstance is the main reason behind the application of the approach, *i.e.* to recognize all removals. • As a net carbon remover country, Dominica contributes to reducing CO_2 from the global CO_2 concentrations and thus have a direct impact in the stabilization of the climate. • Net removals are additional every year. Consequently, the best FREL/FRL approach is to set it at zero to get full recognition of Dominica's contribution to climate change mitigation.

Modalities for submission of FREL/FRL (12/CP.17)	Rationale and justification
	• This approach does not require adjustments.
10. Agrees that a step-wise approach to national forest reference emission level and/or forest reference level development may be useful, enabling Parties to improve the forest reference emission level and/or forest reference level by incorporating better data, improved methodologies and, where appropriate, additional pools, noting the importance of adequate and predictable support as referenced by decision 1/CP.16, paragraph 71;	• The Zero FREL/FRL approach applies at a national scale in Dominica. • Dominica may use the step-wise approach to improve the estimation of emissions and removals that underlie the Zero FREL/FRL approach, following IPCC guidance and guidelines, and as methods, data and knowledge improves.
11. Acknowledges that subnational forest reference emission levels and/or forest reference levels may be elaborated as an interim measure, while transitioning to a national forest reference emission level and/or forest reference level, and that interim forest reference emission levels and/or forest reference levels of a Party may cover less than its entire national territory of forest area;	• The Zero FREL/FRL approach applies to national scale, as it attempts to recognize national-level efforts in conserving national-level net removals.
12. Agrees that a developing country Party should update a forest reference emission level and/or forest reference level periodically as appropriate, taking into account new knowledge, new trends and any modification of scope and methodologies;	• See above, related to paragraph 10.
(a) Information that was used by Parties in constructing a forest reference emission level and/or forest reference level, including historical data, in a comprehensive and transparent way;	• Before applying the Zero FREL/FRL approach, Dominica first estimated emissions and removals following IPCC guidance and guidelines for the period 2001-2017 to understand the trends in emissions and removals. • Through this process Dominica confirmed the occurrence of net removals every year, and thus opted to apply the zero FREL/FRL approach. **Note on the use of historical data**: the estimation of historical emissions and removals, and the understanding that Dominica has yearly net removals, is what enabled it to apply this approach, and as such, it is based on historical data.
(b) Transparent, complete, consistent and accurate information, including methodological information, used at the time of construction of forest reference emission levels and/or forest reference levels, including, inter alia, as appropriate, a description of data sets, approaches, methods, models, if	• The zero FREL/FRL approach is be based on transparent, complete, consistent, and accurate information, just as any other FREL/FRL should. • All descriptions of methods, data and assumptions are provided below in this report, including a description of changes versus previously submitted information.

Modalities for submission of FREL/FRL (12/CP.17)	Rationale and justification
applicable and assumptions used, descriptions of relevant policies and plans, and descriptions of changes from previously submitted information;	
(c) Pools and gases, and activities listed in decision 1/CP.16, paragraph 70, which have been included in forest reference emission levels and/or forest reference levels and the reasons for omitting a pool and/or activity from the construction of forest reference emission levels and/or forest reference levels, noting that significant pools and/or activities should not be excluded;	• The Zero FRL approach complies with the same decisions on the inclusion of carbon pools, gases and activities. • The Zero FRL ensures that the IPCC category forest land remaining forest land is included, often a key category in the forest sector.
(d) The definition of forest used in the construction of forest reference emission levels and/or forest reference levels and, if appropriate, in case there is a difference with the definition of forest used in the national greenhouse gas inventory or in reporting to other international organizations, an explanation of why and how the definition used in the construction of forest reference emission levels and/or forest reference levels was chosen.	• The forest definition used for the Zero FRL will be consistent with the national GHG inventory; any differences between definitions and with other definitions used in reporting to other international organizations would be explained.

Main features of the estimation approach

The estimation of emissions and removals is done at national level, following the Gain-Loss method proposed in the 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines for National GHG inventories, and implementing a country-specific excel calculation tool[21]. All lands were considered as managed. It includes the pools above-ground biomass, below-ground biomass, dead organic matter, and soil organic carbon. Dominica acknowledges Decision 4 CP/15, paragraph 7. where "*developing country Parties in establishing forest reference emission levels and forest reference levels should do so transparently taking into account historic data*"; thus, an annual historical analysis from 2000 to 2017 of GHG emissions and removals for Forest land remaining Forest lands undisturbed, Forest land remaining Forest lands disturbed by human (fires, shifting cultivation and logging) and natural events (hurricanes), and conversions to and from Forest Lands is included; however, only as complementary information, because as mentioned previously, historical data does not represent the future expected conditions; therefore, Dominica is applying the zero FREL/FRL approach as described above.

The information on Activity Data (AD) used was obtained from land use and land-use change assessment, which was conducted on the basis of a sampling approach (IPCC approach 3) using Collect Earth, in which the land-use

[21] This country specific tool is similar to the IPCC working sheets but adapted to capture country specific circumstances.

condition, including natural and/or human disturbance, was determined for each year of the time series 2000 - 2017. Forest land was stratified by forest type (Montane Forest -Elfin, Cloud montane, Montane Rainforest-, Seasonal Forest -Semi-Evergreen, Semi-Deciduous-, Littoral Evergreen, Dry Scrub). Croplands are reported as annual and perennial crops. Grasslands and Settlements are reported as Woody and Non-Woody. Wetlands do not have further sub-classification and Other lands divided in Other Lands and Mining (see section 7.1).

The information on wood removals was derived from the Collect Earth assessment, observed through the loss of tree cover, instead of volume loss, with the purpose of increasing the accuracy of the estimation of carbon losses in forest land. Losses due to Disturbances were also identified including Hurricanes, Fires, Logging and Shifting Cultivation.

Methodological assumptions

In order to apply the gain-loss method equations (IPCC 2006, V4, Ch2), the specific country circumstances had to be taken into account. The application of the equations and the emission/removal factors vary depending on the time, specifically before or after the hurricane Maria in 2017, based on the following considerations:

- Hurricanes are a major disturbance and have major effects on tropical forests (Zhang, 2021[22], Lugo 2008[23]; Flynn et al. 2010[24]; Shiels et al. 2015[25]; Uriarte et al. 2019[26]). Hurricane Intense and force winds snap stems and defoliates surrounding vegetation, which compounded and aided by persistent heavy precipitation saturate soils which leads to landslides, loosen roots destroy the landscape of the forest and alter forest structure and composition (Uriarte et al. 2019; Hall et al. 2020[27]; Heartsill Scalley et al. 2010[28]; Arnone et al. 2011[29], 2015[30]; Lepore et al. 2012[31], 2013[32]; Heartsill Scalley 2017[33]).
- The forest structure and composition are affected by the immediate damages and mortality caused by the disturbance and altered by the subsequent recovery via species succession and competition (Zhang 2021). Forest damage depends on the intensity of the hurricane: stronger hurricanes with intense winds and heavy precipitation generally cause stem damage and death in tropical forests at a higher rate than weaker hurricanes (Uriarte et al. 2019). Forest damage depends also on the initial condition of the forest, which is constantly modified by previous hurricane disturbances (Boose et al. 2004[34]).
- The damages are usually classified as Damage I if a stem has light defoliation (< 50%), Damage II if a stem has broken branches or heavy defoliation (≥ 50%), Damage III if the trunk or roots are broken (Zhang, 2021).

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[22] https://smartech.gatech.edu/bitstream/handle/1853/66085/ZHANG-DISSERTATION-2021.pdf?sequence=1
[23]https://www.academia.edu/68096783/Visible_and_invisible_effects_of_hurricanes_on_forest_ecosystems_an_international_review
[24] http://www.columbia.edu/~mu2126/publications_files/Flynn%20et%20al.%202010.pdf
[25] https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=2745&context=icwdm_usdanwrc
[26] https://www.nature.com/articles/s41467-019-09319-2
[27] https://www.nature.com/articles/s41598-020-61164-2
[28] https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1744-7429.2009.00609.x
[29] https://www.researchgate.net/publication/258787948_Physically_based_modeling_of_rainfall-triggered_landslides_a_case_study_in_the_Luquillo_Forest_Puerto_Rico
[30] https://onlinelibrary.wiley.com/doi/abs/10.1002/hyp.10609
[31] https://www.researchgate.net/publication/252395455_Rainfall_Induced_Landslides_in_Puerto_Rico_Invited
[32] https://hess.copernicus.org/articles/17/3371/2013/hess-17-3371-2013.pdf
[33] https://www.researchgate.net/publication/317556438_Insights_on_Forest_Structure_and_Composition_from_Long-Term_Research_in_the_Luquillo_Mountains
[34] https://www.researchgate.net/publication/228865153_Landscape_and_Regional_Impacts_of_Hurricanes_in_Puerto_Rico

- Based on expert consultation and their observations after the hurricane, four different categories were used in Dominica to classify the forest. 1) No significant damage, which are patches of forest that because of their location and characteristic where not significantly affected by the hurricane. 2) Damage I, the stem remained standing but has broken branches or heavy defoliation, 3) Damage II: the steam and branches are broken, heavy defoliation, and tree was not uprooted. 4) Damage IV: trees are uprooted.
- Zhang (2021) found that hurricane-induced mortality varied with species/plant functional types (PFTs) and stem sizes. Early successional trees had the highest mortality. Small stems were protected and had the lowest mortality compared to medium and large stems in a large-stem dominant forest, but they were exposed and had the highest mortality in a small-stem dominated forest. Palms, as they are wind-resistant, had the lowest mortality, followed by mid and late successional trees.
- Hurricane Hugo in 1989 caused extensive damages to the forest vegetation, uprooted and snapped 20% of the trees at El Verde in the Luquillo Experimental Forest (LEF), Puerto Rico (Walker 1991[35]; Walker et al.1992[36]; Zimmerman et al. 1994[37], Scatena & Larsen 1991[38], Heartsill Scalley et al. 2010) and reduced the aboveground biomass by 50% at Bisley in the LEF (Scatena et al. 1993[39]; Heartsill Scalley et al. 2010). Storm Lothar in 1999 reduced approximately 30% of the net biome production in Europe (Lindroth et al. 2009[40]). A squall line (a band of storms) across Amazonia in 2005 destroyed 542±121 million trees, which is equivalent to 23% of the annual biomass accumulated for the forests in that area (Negrón-Juárez et al. 2010[41]). Hurricane Katrina in 2005 damaged about 320 million large trees on U.S. Gulf Coast forests, and the damaged trees are equivalent to 50-140% of the net annual U.S. carbon sink (Chambers et al. 2007[42]).
- Forests recover from disturbances, but the process of recovery varies with the severity of the disturbance. Both the disturbance effects and growth effects will affect the recovery speed and the final state of recovery. The recovery state includes, but is not limited to, the community population, size structure, species composition, biomass accumulation. The recovery time is the time the forest takes to reach the pre-disturbance state (Walker 1991; Everham & Brokaw 1996[43]; Cole et al. 2014[44]; Heartsill Scalley 2017).
- Early successional (pioneer) species establish and recruit in open gaps formed after hurricane disturbances, growing rapidly in the high light environment. Mid successional species, which have intermediate growth rate and are somewhat shade tolerant, gradually substitute early successional species in the canopy as the gaps close. Late successional species, which have low growth rates and are shade tolerant, reach the canopy and become dominant in the plant community as the forest matures until the next disturbance.

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[35] Walker, L. R. Tree damage and recovery from hurricane Hugo in Luquillo Experimental Forest, Puerto Rico. Part A. special issue: ecosystem, plant, and animal responses to hurricanes in the Caribbean. Biotropica 23, 379–385 (1991). Cited in: Zhang (2021)

[36] Walker, L. R., Voltzow, J., Ackerman, J. D., Fernandez, D. S. & Fetcher, N. Immediate impact of hurricane Hugo on a Puerto Rico rain forest. Ecology 73, 691–694 (1992). Cited in: Zhang (2021)

[37] Zimmerman, J, K. et al. Responses of tree species to hurricane winds in subtropical wet forest in Puerto Rico: Implications for tropical tree life histories. Journal of Ecology 82, 911–922 (1994).

[38] https://typeset.io/pdf/physical-aspects-of-hurricane-hugo-in-puerto-rico-3s8352v05d.pdf

[39] https://www.jstor.org/stable/2388975

[40] https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2486.2008.01719.x

[41] https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2010GL043733

[42] https://www.science.org/doi/10.1126/science.1148913

[43] http://ruby.fgcu.edu/courses/everham/Disturbance/EverhamBrokaw1996.pdf

[44] https://www.nature.com/articles/ncomms4906

- In Puerto Rico, after hurricane Hugo (1998), the forest took 20 weeks to recover from defoliation (Walker 1991) and five years to increase the aboveground biomass to 86% of the pre-hurricane level (Scatena et al. 1996[45]). In the succession recovery of the forest after hurricane Hugo, palms had the lowest background mortality and the highest recruitment rate, which make them superior competitors in the forest. Zhang (2021) calibrated a model to represent the stem density, aboveground biomass, plant functional type composition and size structure of the forest in the 25 years of recovery from hurricane Hugo. The simulated results show that a single hurricane disturbance on a forest with wind-resistant initial state will result in a higher aboveground biomass level after 100 years of recovery compared to a less wind-resistant initial state.
- Observations on a tropical forest canopy in western Mexico after two hurricanes—category 2 Jova and category 4 Patricia—showed that hurricane Jova destroyed 11% of the aboveground biomass while hurricane Patricia destroyed 23%; the recovery was more rapid after the less intense hurricane Jova (Parker et al. 2018[46]).
- Zhang (2021), mentions that plant functional types composition and size structure at recovery are not as dependent on initial state. However, frequent and intense hurricane disturbances in the future will decrease the aboveground biomass accumulation and alter the plant functional types composition. He concluded that frequent and intense hurricane disturbances will increase the abundance of palms and early successional trees but decrease the abundance of late successional trees.
- Changes in intensity and frequency of hurricane disturbances, possibly caused by climate change (Bender et al. 2010[47]), could then potentially lead to different forest structure and composition (Wang & Eltahir 2000[48]), which become a different initial condition to further disturbances. Zhang (2021) also studied and scenario under warmer and higher CO_2 concentration climate, and concluded that these conditions will enhance the aboveground biomass accumulation but will have smaller effects on the composition and structure of the forest in comparison to hurricane disturbances. However, the biomass accumulation cannot compensate for the biomass loss due to hurricane disturbances.
- Zhang (2021) concluded that:
    - 1) the state of the forest at the time of disturbance has effects on the recovery of the forest, especially on the biomass accumulation, but less effect on the composition and structure;
    - 2) The severity of the hurricane disturbance has significant impacts on the biomass accumulation, composition and structure of the forest;
    - 3) Climate change with higher temperature, humidity, and CO_2 concentration will promote biomass, but not sufficiently to counteract biomass reduction from hurricane disturbances;
    - 4) Palms will become more and more abundant in forests that are subject to frequent hurricane disturbances.

[45] https://www.fs.usda.gov/research/treesearch/30470
[46] https://www.washingtonpost.com/archive/politics/1989/09/22/hurricane-hugo-rips-through-south-carolina/598c0c54-2225-4fa0-ab22-e6f6daa91982/
[47] https://www.researchgate.net/publication/41111577_Modeled_Impact_of_Anthropogenic_Warming_on_the_Frequency_of_Intense_Atlantic_Hurricanes
[48] https://eltahir.mit.edu/wp-content/uploads/2014/05/2000-Wang-Eltahir-bio_2a.pdf

- Walker (1991), Frangi & Lugo (1991)[49] indicate that defoliation recovers in weeks to months, but forest structure and composition shift over decades following three stages of species succession (Weaver 1989[50]; Vandermeer and de la Cerda 2004[51]; Bonan 2016[52]).

In Dominica's context before Hurricane Maria in 2017, forests cover had a large share of the island and was very ecologically diverse, with more than half being primary forests. Forest ecosystems in Dominica developed under wind-driven severe disturbances, which give a high recovery and adaptation capacity[53]. During Hurricane Maria, in September 2017, mainly massive (extensive) defoliation occurred and not total forest destruction. The proportion of fallen trees in the forest was much less as opposed to the extent of canopy loss occurred. Fallen trees and damaged to understory was mainly caused by trees with heavy crowns compounded/overgrown with huge lianas, vines, bromeliads, ferns, and orchids, other epiphytes increasing the weight, so when they were toppled by the wind the damage was extensive. Twigs/branches were broken off most of which remained on the forest floor (about 3/4 or 75%). The remaining 25%, especially lighter twigs, ended up in the fresh-waterways due to heavy flooding and high velocity of rushing water, transported those debris, especially those along the many Riparian zones, either;

(1) Exited along the seacoast, estuaries, in the city or within villages, or stuck under bridges.

Figure 1 Mero Beach Forest debris 2017 (Source: Dominica Forestry Division)

Figure 2 Forest tree transported to lower levels 2017 (Source: Dominica Forestry Division)

[49] https://www.jstor.org/stable/2388248
[50] https://www.redalyc.org/pdf/339/33906807.pdf
[51] http://www.bio-nica.info/Biblioteca/Vandermeer2004PostHurricaneForest.pdf
[52] https://www.scribd.com/document/384574742/Gordon-Bonan-Ecological-Climatology
[53] Dominica's Forest Note 2020

(2) Formed mini, temporary dams due to the break-down of the velocity of the rushing water, and remained within the boundaries of the forests and along the river bed/s.

Figure 3 River damming by Forest debris, 2017 (Source: Dominica Forestry Division)

The assessmet of distaster post hurricane estimated that 80–90% of environmental resources were significantly affected, particularly forests. Only a few trees in small and very protected pockets retained their leaves. An estimated 20 trees per acre were blown over or destroyed (ACAPs, 2018[54]; PDNA, 2017[55]).

Photograph Scenario Presented by Dominica Forestry Experts, Post Hurricane Maria:

Figure 4 Northern Range, Morne Diablotin National Park, Sept. 2017

Figure 5 Southern Range, Woody Settlement destruction, Sept. 2017

[54] https://www.acaps.org/sites/acaps/files/products/files/20180131_acaps_disaster_profile_dominica_v2.pdf
[55] https://www.gfdrr.org/en/publication/post-disaster-needs-assessment-dominica

Figure 6 Northern Range damage, Nov. 2017

Figure 7 Northern Range damage, Nov. 2017

Figure 8 Central Range-Emerald Pool damage, Dec. 2017

Figure 9 Northern Range-Coconut farm damage, Dec. 2017

Figure 10 North Range-Cabrits National Park, Nov. 2017

Figure 11 Central Forest Range damage-Emerald pool, Jan. 2017

Figure 12 Central Range -Emerald Pool Nature Trail, Jan. 2018

Figure 13 Defoliated Forest North Range-Morne Turner, April 2018

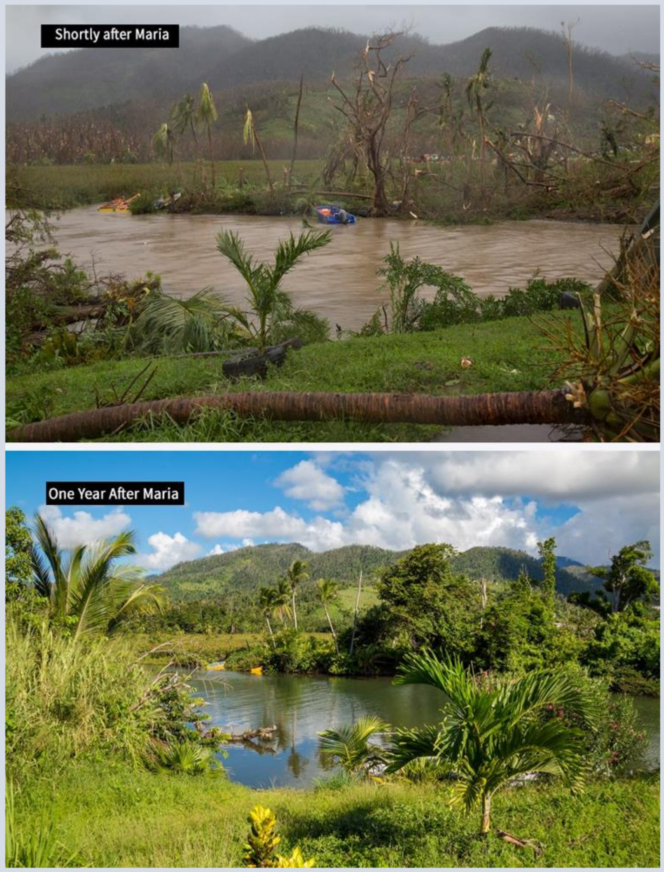


Figure 14 North Range-Indian River (veg. recovery 2017-2018);

Figure 15 Cabrits Eco-trail recovery, April 2018

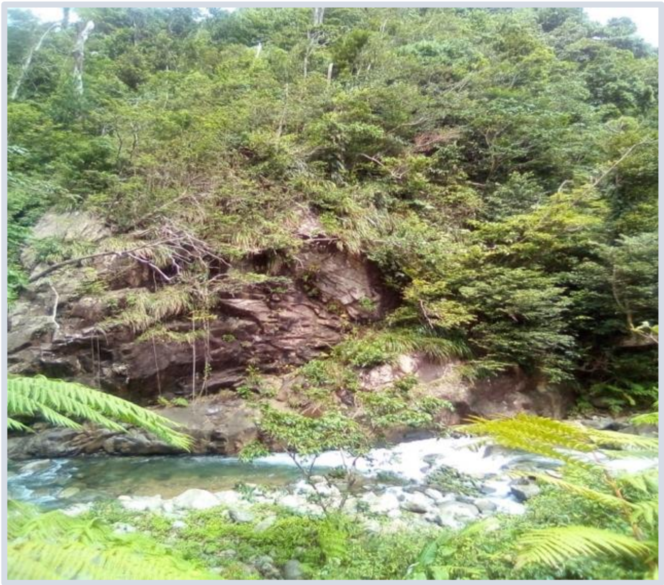


Figure 16 Central Range-Concord May 2021

Figure 17 Central Range-Concord May 2021

Figure 18 South Range damage-Scott's Head Peninsula, Sept. 2021

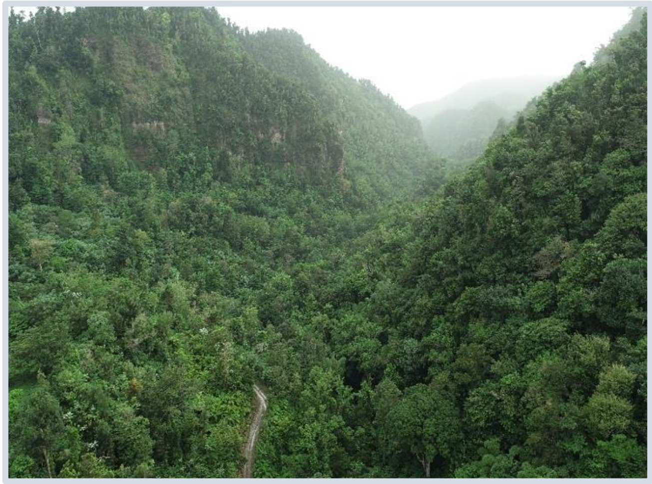


Figure 19 Central Range, July 2022

With regards to the leaf litter, it was observed that some leaves were lost through heavy flooding and blown out of the forest structure, but the majority ended up on the forest floor, evident during forest access route restoration immediately after Hurricane Maria.

Figure 20 Northern Range-Syndicate Eco-trail (leaf litter, wood debris), Jan. 2018

Figure 21 Southern Range debris, April 2018

Figure 22 Southern Range, Middleham, 2018

During and immediately after hurricane Maria, some dead wood was lost due to land erosion, although some remained trapped because of the nature of the destruction. Some rivers changed their courses due to the volume of water or damming along the streams due to landslides. Mainly dead wood on steep slopes was lost to waterways rather than areas of flat land. Approximately 10-20% of dead wood may have reached the ocean. From the remaining 80-90%, about 10% was used for lumber, charcoal, fuelwood, composting, or burnt in heaps, while some sank in the ocean and returned as driftwood. The rest remained in the forest floor and river sides.

Figure 23 African Baobab tree stump recovery from Hurricane David in 1979, Dominica Botanic Gardens

Rotting of trapped dead tree species on the forest floor has provided condition for mushroom growth, worms and beetles, lady bugs and in some areas breeding ground for mosquitoes. Some of the harder dead forest species, like the *Bwa diable (Licania ternatensis)*, *Chataingnier/s (Sloanea spp)*, others are falling unto the forest floor so as to help build back the rich topsoil of the environment.

A large-scale landslide inventory was carried out by a team from the University of Twente, using satellite imagery with resolution of 0.5m which were obtained in September 23rd and October 5th, 2017 right after the Hurricane Maria. Apart from these, also a series of Digital Globe Images were used that were collected for the Google Crisis Response through a KML layer. The images were visually interpreted by image interpretation experts, and landslides were mapped as polygons, separating scarp, transport and accumulation areas, and classifying the landslides in types (Figure 24).

A total of 9,960 landslides were identified, which include 8,576 debris slides; 1,010 debris flows; and 374 rock falls, with area of 7.30 km^2, 2.50 km^2, and 0.50 km^2 respectively. The whole area of landslide is 10.30 km2, which covers 1.37% of the island. The source of landslides is 3.30 km^2, and the other 7.0 km^2 is transportation and deposition area. Almost all the rivers flooded due to intensive precipitation. The flooded area is 13.03 km^2, which covers 1.74% of the island[56].

The figure 24 below shows the location of landslides and floods triggered by Hurricane Maria.

[56] In Dominica: Landslides and floods triggered by Hurricane Maria (18 September 2017). https://reliefweb.int/map/dominica/dominica-landslides-and-floods-triggered-huricane-maria-18-september-2017)

Figure 24 Landslides assessment after hurricane Maria (2017)

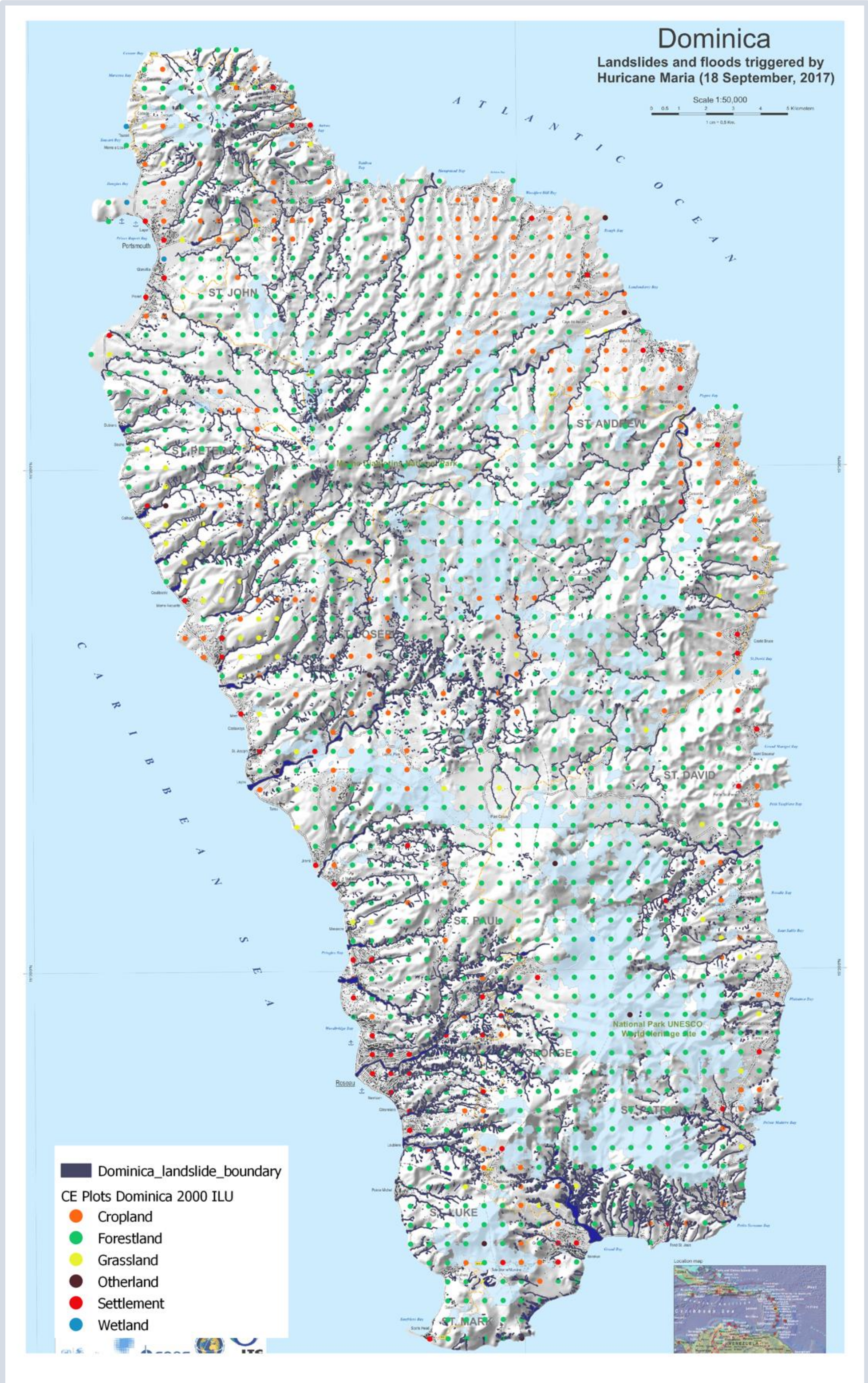


Figure 25 Landslides assessment after hurricane Maria (2017) overlapped with land use assessment sampling grid

National forestry experts indicated that most of the soil was lost along the riparian forests, steep forested lands and already exposed areas. Dominica team tried merging the shapefile of the landslides with the land use sampling plots (Figure 25), but it was identified that most of the landslides did not fall within those plots, so the distribution within the various land classifications was estimated based on the expert judgment, resulting approximately as: Forest lands 50%, Croplands 20%, Grasslands 10%, Settlements 10%, Wetlands 5%, Other lands 5%.

Based on this classification and expert judgment, about 5.3 Km^2 or 530 ha of soil was lost in Forest lands, with a desegregation by forest type as follows: Elfin and Cloud: 40% (212 ha), Montane Rainforest: 30% (159 Ha), Semi-evergreen forest: 20% (106 ha), Deciduous-Coastal Forest: 10% (53 ha).

Dominica does not have data that preceded the hurricane on forest growth (for the different types of forest physiognomies) that could be used to compare with the dynamics of the forest (including growth) after the hurricane event. Long-term research that studies the effect of hurricanes on tree mortality and growth is very scarce, and hence, there are high uncertainties in this respect (Tanner, 2014)[57]. To understand the effect of the soil condition on forest growth, it would be necessary to understand the impact of the hurricane in the soil.

It has been noticed that scars on the landscape are being recolonized by pioneer tree species and areas appear to be of a light yellowish color due to lack of fertile top-soil conditions in some areas. A new generation of trees are positioning themselves to take advantage of the natural thinning created by the hurricane, example: Bwa blanc (*Simarouba amara*), Maurisif (*Byrsonima martinicensis*), Bwa riviere (*Chimarrhis cymosa*), Ti citon/s (*Ilex spp*), to name a few.

The forest recovered faster before (sooner after the hurricane) than at present and the only significant change in species would probably simply be to a higher prevalence of pioneer species. Even though some of those hard wood species eventually die out, within the undergrowth and mid layer of the forest strata, saplings/wildings/small trees of those hard wood and other mature species will thrive due to increased sunlight thru the canopy loss.

Trying to apply approximate percentages, sooner after the hurricane, mortality rate could have been 5% (5-10% would be rather high considering the nature of Dominica's terrain a lot of trees were protected from the wind); so, naturally at present this would be lower = 1% or 2%.

Dominica's' national experts also searched the literature available on landslides in the country to better understand their effect on carbon pools, particularly the soil organic carbon (SOC) pool.

Literature indicates that the total landslide area is characterized by variable physical, chemical and biochemical properties. The upper part of the landslide is strongly eroded and characterized by the least advanced soil cover recovery. Soil organic matter plays a crucial role in the early stages of the formation of soil cover and vegetation.

[57] Tanner, Edmund V. J., et al. "Long-Term Hurricane Damage Effects on Tropical Forest Tree Growth and Mortality." Ecology, vol. 95, no. 10, 2014, pp. 2974–83. JSTOR, http://www.jstor.org/stable/43493923. Accessed 3 Jun. 2022.

The changes in the amount of soil organic matter, nutrients and physical properties have different intensification within the range of landslides and strongly influence the processes of soil cover and vegetation restoration.

Landslides, both natural and human induced, can contribute to either carbon export or sequestration in a watershed. If landslides from upper hillslopes bury soils farther downslope, they can protect that soil carbon from entering the atmosphere. On the other hand, in steep terrains, landslides can strip soil and vegetation off a hillslope and deliver that carbon directly to streams and coastline.

In addition, post-disturbance erosion can affect tropical landslides, even after the initial disturbance. When this occurs, landslides represent a net loss of C from the landscape. Soil type, rates of soil output and plant colonization dynamics are the principal factors determining recovery rates for C lost through landslides. Landslides therefore provide a long-lasting horizontal and vertical alteration of C.

One publication (Blonska et al., 2018[58]) highlights that biochemical parameters (dehydrogenase activity and microbial biomass C and N) turned out to be useful tools for the evaluation of changes taking place in the soil after a landslide.

The landslides that take place in forest areas cause the destruction of trees, and they break the continuity of soil cover which results in different physical, chemical and biological properties (Shiels et al. 2006[59]; Shiels & Walker 2013[60]). Deposits of landslides are characterized by high variability of properties, especially the distribution and the amount of soil organic matter.

From these considerations, Dominica finds it highly uncertain and strongly dependent on several assumptions to provide an estimate of the changes in carbon stock in SOC, considering the different types of soil affected, the geomorphology of the region, erosion processes and, more importantly, the loss (or gain) in SOC from landslide. Few estimates have been found of the soil carbon content in soils, and none addressed the most relevant soil types in Dominica (*Smectoid soils; Kandoid soils; Allophane latosolics; and Allophane podzolic*).

[58] https://www.researchgate.net/publication/318317031_The_effect_of_landslide_on_soil_organic_carbon_stock_and_biochemical_properties_of_soil
[59] https://www.researchgate.net/publication/225796536_Organic_matter_inputs_create_variable_resource_patches_on_Puerto_Rican_landslides
[60] https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=2572&context=icwdm_usdanwrc

Figure 26 Forest devastation scenario depicting loss of soil and trees at riparian zones, Castle Bruce 2022

#Forest damage classification

Therefore, taking all this information into account from local knowledge and local and regional studies, Dominica did the estimations based on the 4 classifications given to forest lands:

1) No significant damage, which are patches of forest that because of their location and characteristics were not significantly affected by the hurricane.
2) Damage I, the stem remained standing but had broken branches or heavy defoliation,
3) Damage II: the steam and branches were broken, full defoliation, but trees were not uprooted.
4) Damage III: trees were totally uprooted.

These classifications were given in order to estimate the carbon dynamics in the different carbon pools: above-ground biomass, below-ground biomass, dead organic matter (litter and dead wood) and soil organic carbon; and specifically understand recovery dynamics, losses and transfers among carbon pools.

Tier 1 methods were applied for the "No significant damage' class 1, applying the same emission and removal factors as before the hurricane and Tier 2 methods were applied to estimate losses due to the hurricane, gains after disturbance and transfers of C among pools (AGB + BGB pool > DOM pool > SOC pool) as follows:

Damage I class, the stem remained standing but has broken branches or heavy defoliation: it is estimated to cover about 60% of the forest. Assumptions include that 5% of the canopy flew away and the other 95% remained on the forest floor. The recovery growth rate is only applied to branches and leaves, and it assumes no changes in the below-ground biomass. The 95% of the canopy on the forest floor is expected to decompose within 5+ years and be transferred annually to the DOM pool. DOM will start transferring to the SOC pool after 5 years.

Damage II class, the steam and branches were broken, full defoliation, and trees were not uprooted: it is estimated to cover about 25% of the forest. Assumptions include that 10 % was used for logs, charcoal, firewood, and a small percentage burnt, while 15% was lost in the waterways. The recovery growth rate will be applied to the whole tree for early successional (pioneer) species established and new recruits in open gaps formed after Hurricane Maria disturbances, growing rapidly in the high light exposed environment. It assumes there were no losses of the below-ground biomass of affected trees while maintaining new establishment of roots for the new trees. The 75% of the canopy that remained on the forest floor is expected to decompose within 100 years and be transferred annually to the DOM pool after 5 years. DOM will start transferring to the SOC pool after 10 years.

Damage III class, the trees were totally uprooted: it is estimated to cover about 15% of the forest. Assumptions include that 10 % was used for logs, charcoal, firewood, while a small percentage was burnt for clearing, and 15% was lost in the waterways. The recovery growth rate is applied to the whole tree for early successional (pioneer) species establish and new recruits in open gaps formed after Hurricane Maria disturbances, growing rapidly in the high light exposed environment. It accounts for the losses of the below-ground biomass of affected trees and the new establishment of roots of the new trees. The 75% of the canopy that remained on the forest floor is expected to decompose within 100 years and be transferred annually to the DOM pool after 5 years. DOM will start transferring to the SOC pool after 10 years.

Bearing in mind all of these specific country circumstances, Dominica did an effort to apply methods that allowed to fulfill the IPCC TACCC principles:

- Transparent, as data sources, definitions, methodologies, and assumptions are clearly described.
- Accurate, as it represents land-use categories, conversions between land-use categories, and conditions before and after disturbances as needed to estimate carbon stock changes and GHG emissions and removals.
- Consistent, as it allows to represent land-use categories consistently over time, without being unduly affected by artificial discontinuities in time-series data.
- Complete, as all land within the country was included.
- Comparable, as it allowed a full time series analysis using same definitions, methodologies, and assumptions.

5.2 Carbon pools

GHG historical analysis (2001 – 2017) and FREL/FRL (2018 – 2025) include the carbon pools: **above-ground biomass**, **below-ground biomass**, **dead organic matter, and soil organic carbon.**

Above-ground biomass was obtained from the National Forest Inventory from Saint Lucia (2009), as both islands share the same forest types and there is no recent Forest inventory has taken place in Dominica. Below-ground biomass and dead organic matter were obtained from default values of the 2006 IPCC Guidelines, 2019 Refinement to the 2006 IPCC Guidelines. Soil organic carbon reference values were obtained from the FAO Global Soil Organic Carbon Map -GSOCmap-, from FAO (2019)[61].

5.3 Gases Included

Carbon dioxide (CO_2), **methane (CH_4)** and **nitrous oxide (N_2O)** emissions from biomass burning in forest land categories are included. Emissions in carbon dioxide equivalents (CO_2e) are reported using the **100-year global warming potentials** (GWPs) contained in **IPCC's fifth Assessment Report (AR 5).**

5.4 Scale

The scale is National. The total land area is 750 square kilometers (km^2) (75000 Ha). The country is divided into 10 parishes. A systematic sampling grid of 1605 plots located 750m distance apart was used to allow a national coverage analysis of the island.

5.5 Reference Period

Dominica analyzed the historical period 2001-2017 as the basis for the application of the zero FREL/FRL for 2018-2025.

5.6 Definition of the FREL/FRL

Historical net GHG emissions and removals average –258.504 tCO2e from 2001 to 2016 including all carbon pools (AGB, BGB, DW, LIT, SOC), and for CO2 and non-CO2 gases (CH4, N2O). This average does not represent future expected Dominica GHG emissions and removals dynamics, hence the application of the zero FREL/FRL as justified above. Because of the hurricane Maria in 2017, the emissions in the AGB and BGB pool were much higher than the historical average that year, losing approximated 2.8 million tCO2e. However, most of the losses in the AGB+BGB pool were transferred to the DOM pool, estimated about -2.3 million tCO2e, increasing drastically the C stocks in the DOM pool. In addition, as these historical emissions and removals were based on a forest that does not exist anymore as it was known, the post-hurricane conditions are different, and therefore, the historical average cannot be used to represent the expected future emissions or removals (table 2). As a result, Dominica is proposing the zero FREL/FRL taking into consideration post-hurricane conditions, mostly based on forest recovery, through natural and assisted regeneration.

[61] https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/global-soil-organic-carbon-map-gsocmap/en/

Table 2 Forest related net balance of GHG emissions and removals 2001-2017 [tCO2e/yr]

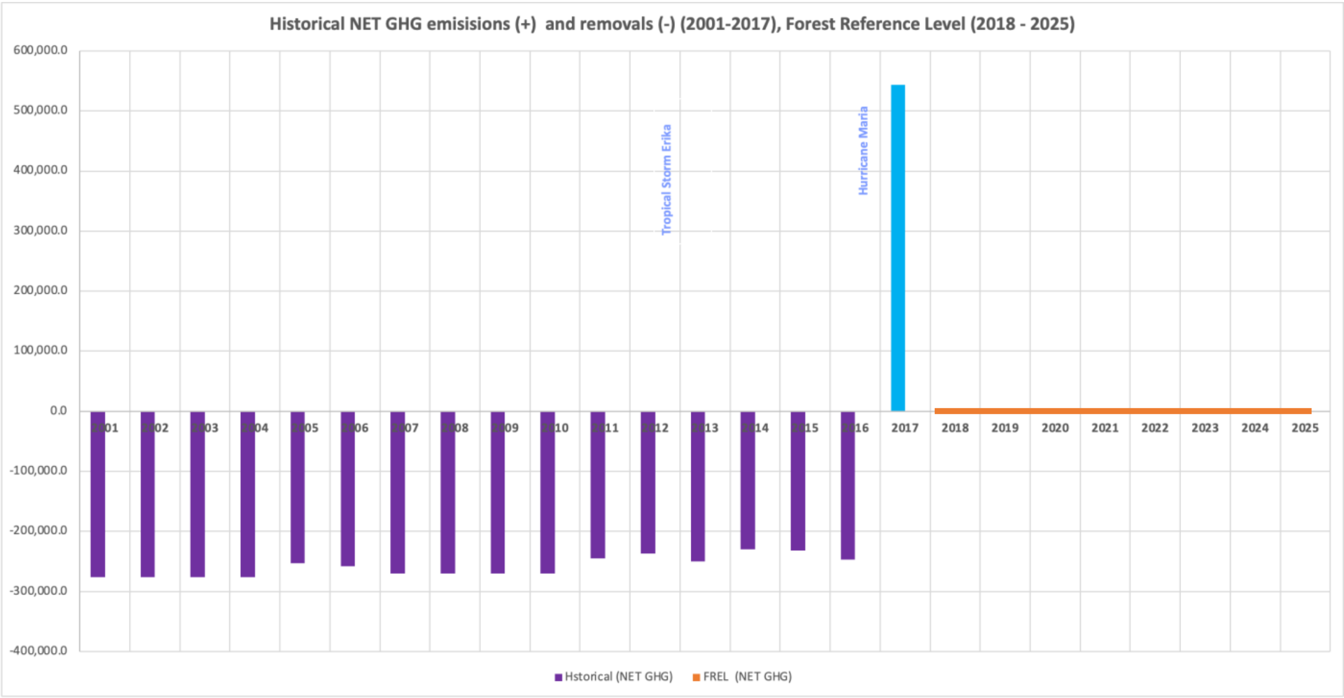
Year	[A+B+C+D] Net balance emissions and removals [tCO2e]	[A] Net balance emissions and removals in F>F (undisturbed*) [tCO2e]	[B] Net balance emissions and removals in F>F (disturbed) [tCO2e]	[C] Net balance emissions and removals in land converted to F [tCO2e]	[D] Net balance emissions and removals in F converted to other land uses [tCO2e]
2001	-276,107	-276,107	0	0	0
2002	-276,107	-276,107	0	0	0
2003	-276,107	-276,107	0	0	0
2004	-276,107	-276,107	0	0	0
2005	-253,044	-275,271	0	0	22,227
2006	-257,533	-274,667	0	0	17,134
2007	-270,177	-274,667	0	0	4,490
2008	-270,177	-274,667	0	0	4,490
2009	-270,177	-274,667	0	0	4,490
2010	-270,177	-274,667	0	0	4,490
2011	-244,557	-273,755	0	0	29,197
2012	-236,362	-272,570	0	0	36,208
2013	-250,148	-271,966	0	-4,251	26,069
2014	-229,814	-270,805	0	-1,243	42,234
2015	-232,295	-269,066	0	-1,243	38,014
2016	-247,182	-269,620	0	-3,936	26,375
*2017	435,173	-67,804	568,402	-1,669	44,335
Average	-211,342	-261,683	33,435	-726	17,632

** Hurricane Maria 2017*

Table 3 Forest reference level/Forest Reference Emissions Level (tCO2e/yr) for Dominica.

Year	ZERO FREL/FRL [tCO2e / yr]
2018	0
2019	0
2020	0
2021	0
2022	0
2023	0
2024	0
2025	0

Figure 27 Historical net GHG emissions(+) and removals (-) (2001-2017) and Forest Reference Level FREL/FRL (2018 - 2025). All units in tons of CO2 equivalent per year.


Historical NET GHG emisisions (+) and removals (-) (2001-2017), Forest Reference Level (2018 - 2025)
600,000.0
500,000.0
400,000.0
300,000.0
200,000.0
100,000.0
0.0
-100,000.0
-200,000.0
-300,000.0
-400,000.0
Tropical Storm Erika
Hurricane Maria
2017
2018
2019
2020
2021
2022
2023
2024
2025
Hstorical (NET GHG)
FREL (NET GHG)


[62]

6. FOREST SECTOR BACKGROUND

6.1 Forest sector Background

Dominica is considered one of the wettest islands in the Caribbean with its inland receiving on average more than 10,000mm of rainfall annually. The islands rugged and steep terrain gives rise to plenty of perennial streams, rivers, lakes and waterfalls. These coupled with its high rainfall, results in extremely lush vegetation resulting in sixty-five percent of the island area covered by natural vegetation. This lushness together with the island's terrain, provides for areas of high biodiversity and relatively intact ecosystems giving Dominica its reputation as the "Nature Island of the Caribbean".

Dominica's island geography and complex geology have created unique habitats and high species diversity. More than 60% of the island is covered with lush forest and its fauna includes: 179 species of birds, 55 species of butterflies, 20 species of crabs, 11 species of crayfish and shrimp, 3 species of amphibians, 17 species of reptiles (4 snakes), 18 mammal species, 11 stick insect species, and around 45 species of inland fish. It is home to a number of global important species, housing a critically endangered toad and an endangered frog, bird, freshwater fish, and grass species. In addition, it comprises two island endemic bird species, 5 endemic reptiles, one endemic frog species and one endemic butterfly as well as a number of lesser Antilles and regional endemics.

Based on the last land use and land use change assessment (2020) done by the Forestry, wildlife and parks Division, Dominica in 2017 had 57.804 Ha of remaining Forest, mostly montane rainforest 28.131 Ha followed by semi-evergreen forest 10.607 Ha and Deciduous Forest 6,262 Ha (table 4).

[62] Photo: https://www.lonelyplanet.com/articles/dominica-hiking-passport

Table 4 Forest area from 2000-2017 [Ha]

	AREA [HA]				
	2000	2005	2010	2015	2017
Elfin forest	2,009	2,009	2,009	2,009	2,009
Cloud forest	4,907	4,907	4,907	4,907	4,860
Montane Rainforest	28,271	28,271	28,224	28,131	28,131
Semi-evergreen Forest	10,841	10,841	10,841	10,701	10,607
Deciduous Forest	6,355	6,308	6,308	6,262	6,262
Dry Scrub Forest	2,103	2,009	2,009	1,822	1,822
Litoral Forest	4,065	4,065	4,065	4,019	4,019
Total	**58,551**	**58,410**	**58,363**	**57,851**	**57,710**
% of Forest based on total country area	**78.1%**	**77.88%**	**77.82%**	**77.13%**	**76.95%**

Only 841 ha of forest were lost in 17 years, which represents 1.45% of the total forest by 2017 and an annual deforestation rate of 49 ha. In an effort to protect these important ecosystems and their biodiversity, Dominica has established seven protected areas over the years, with a further three areas proposed (figure 29).

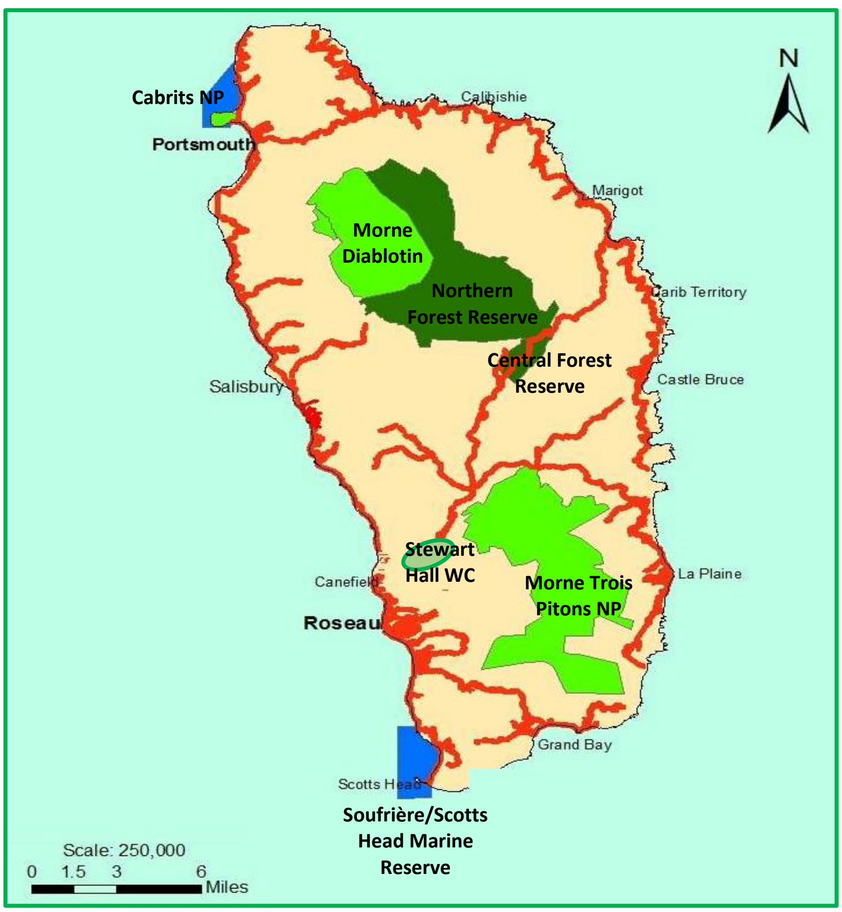


Figure 28 Map of Dominica's Protected Areas System (Adapted from Dominica's Biodiversity Strategy and Action plan 2014-2020)

The management of these protected areas are shared over a number of different Institutions (table 5).

Table 5 Area of Protected Areas System [Km2]

Protected Area	Area km2	Year established	IUCN Category	Management Authority	Key feature(s)
Central Forest Reserve	4.1	1952	VI	Ministry of Environment, Rural Modernisation and Kalinago Upliftment (MoE) – Division of Forestry, Wildlife and Parks Division (DFWP)	• Oldest Forest reserve • Abundance of gommier
Morne Trois Pitons National Park	68.75	1975	II	MoE-DFWP -National Parks Unit (NPU)	• Dominica's first National Park and a World Heritage Site • Valley of Desolation • Boiling lake • Emerald pool • Boeri lake
Stewart Hall + all Water Catchment	3.18	1975 1995	VI	Dominica Water and Sewerage Company (DOWASCO)	• Water catchment areas providing water to island
Northern Forest Reserve	88.14	1977	VI	MoE-DFWP	• Watershed conservation area
Cabrits National Park	1.1 (terrestrial) 4.21 (Marine)	1987	II	MoE-DFWP -National Parks Unit (NPU) Ministry of Blue and Green Economy, Agriculture and National Food security (MoAF)-Fisheries Division	• Twin peaks of extinct volcanoes • Extensive swamp area • Important wetland
Soufrière/Scotts Head Marine Reserve	5.35	1998	V	MoAF- Fisheries Division SSHMR LAMA	• The largest and deepest near shore submarine volcanic crater in the Caribbean.
Morne Diablotin National Park	34.5	2000	II	MoE-DFWP -National Parks Unit (NPU)	• Morne Diablotin-highest mountain in Dominica • Picard Gorge
Total Terrestrial Area	**199.77**				
Total Marine Area	**96.56**				

The island is characterized by a very youthful and fragile forest landscape, which makes it very susceptible to the effects of land degradation. However, historically Dominica has a strong tradition of conserving its land resource base. In the post-World War II period, the banana industry developed, leading to the introduction of heavy machinery to build infrastructure (e.g. roads) together with increased housing needs related to the expanding economy. Thus, significant pressures were brought to bear on the fragile resource base with increasing levels of land degradation and desertification that is now being compounded by impacts from climate change [63].

The general pattern of land use in Dominica has been dictated by topographic limitations. The highest, most rugged elevations in the interior have remained inaccessible and therefore forest cover - which constituted Dominica's

[63] 3.4. Land Use, Protecting Carbon Sinks, and Enhancing the Resilience of Natural Ecosystems: https://unfccc.int/files/cooperation_support/nama/application/pdf/dominica_low_carbon_climate_resilient_strategy__%28finale%29.pdf

largest carbon sink. The narrow flat floodplains of the major rivers in the country have seen the most intensive land utilization, predominantly agriculture, with hillside cultivation extending into the mid-elevation areas along road access routes. Banana and temporary (vegetable and root) crops, coconut and citrus dominate commercial agricultural production in Dominica. Urbanization has been largely confined to the narrow coastal fringe, although newer settlements have been expanding into the interior along the rural road network.

Historically, the majority of the land area in Dominica was parceled into large estates owned by the Crown (mainly unutilized lands in the interior) and private owners (major agricultural estates). As agricultural output from these large estates declined over time the land was subdivided and sold as smaller agricultural parcels and housing lots. By extension, the transition from larger-scale agriculture to small farms has also had implications for implementation of land conservation measures and efforts to enhance the resilience of natural ecosystems to address climate change concerns. As holdings become smaller, farmers tend to cultivate the full acreage within the holding in short-term crops to maximize financial returns.

Dominica's agriculture sector has declined due to weather-related events and fluctuations in world market conditions, but it is still vitally important for rural livelihoods and an important contributor to employment. Tourism is growing, largely based on ecotourism and government support. The Government of the Commonwealth of Dominica (GoCD) is promoting Dominica as a "nature island" destination. Presently, Dominica lacks a timber industry, and the use of non-timber forest products (NTFPs) is not significant. However, the indirect contribution of forestry is very important. Forest resources, especially in its national parks and ecosites, are a key source of the island's high biodiversity and play an important role in attracting tourists. There are close cross-sectoral connections with other sectors as well. Forests in Dominica also have important social dimensions: they have always been connected to the Kalinago (a unique population of pre-Columbian indigenous people) and are considered very important from a history/cultural perspective. Furthermore, an estimated 20 percent of jobs in Dominica are indirectly linked to forestry

Dominica's economy reflects many of the traditional features of a small open economy. This includes a high level of dependence on external trade as a proportion of gross domestic product (GDP), dependence on single sector export products (agriculture) and tourism revenue, high levels of underemployment and unemployment, and dependence on foreign capital (both public and private sector) for investment into productive sectors and for infrastructural development.[64] The Dominican economy has been dependent on agriculture - primarily bananas - in years past, but increasingly has been driven by tourism as the government seeks to promote Dominica as an "ecotourism" destination mainly because Dominica is recognized to be *"The Nature Island of Caribbean*".

Climate change has both on-site and off-site effects on land. On-site effects include the lowering of the productive capacity of the land, causing either reduced outputs (crop yields, livestock yields) and/or the need for increased inputs. Off-site effects include changes in water regime, such as decline in water quality and sedimentation of riverbeds and reservoirs, with increased sedimentation rates in rivers being expected in Dominica due to climate change. Moreover, Dominica is located in the hurricane belt and is highly susceptible to hurricanes. On average the

[64] Information from Dominica´s INDC.

island is impacted directly or indirectly approximately once every four years by hurricanes, with on average one hurricane every 15 years hitting it. Dominica has had two Category 5 hurricanes Hurricane David in 1979 and more recently Hurricane Maria in 2017, which was preceded by Tropical storm Erika in 2015. All brought devastation to the island, causing significant damage to the environment, with trees stripped of leaves, damaged, and even uprooted, destroyed housing and infrastructure, led to water shortages and disease and even in some instances death. Many coastal and marine and eco-tourism sites were damaged and high winds, flooding, and sea swells impacted businesses along coastal areas, along rivers, and in the forest reserve.

6.2 National legislation related to Forest sector

Legislation

The **National Parks and Protected Areas Act No. 16 of 1975** amended by Acts 54 of 1986, Act 12 of 1990, Act 8 of 2001 and Act 1 of 2015, is currently the overarching legislation providing for the declaration and management of terrestrial Protected Areas. The Act provides for the declaration of both national parks and PAs (excluding MPA's with the exception of Cabrits NP), leasing of land for PAs and the establishment of a System of National Parks. However only three of the current seven PA's, which are all considered national parks, were established under this legislation (MTPNP, MDNP and CNP) and whose administration, management and control falls under the remit of the MoE. The Act outlines the purposes for which PAs may be declared, and authorizes the MoE, by order, to set aside state lands for PAs in the form of national parks, historic sites, and recreational areas and to develop regulations. The Act also provides for the establishment of a National Parks Service, led by a Director of National Parks (DNP) and an advisory council whose role is to advise Minister on all matters related to the System of National Parks. However, while a National Parks Unit has been set up, there is currently no DNP or park advisory council. The Act authorizes the DNP to prepare management plans for its National Parks which will be open for public review, although to date no plans have been approved. The roles and powers of park wardens is also provided in under this Act. The Act does not however provide for matters related to a protected areas system such as system plan development. Since its enactment a number of Statutory Rules and Orders and regulations related to the PA system have been developed under the National Parks and Protected Areas Act.

- A User Fee Regulation **SRO No. 27 of 1997** amended, **SRO No. 22 of 2008, SRO No. 7 2013.** authorizes the National Park to generate revenue from user fee ticket sales, License fees from tour operators, vendors and tour guides. Permits for researchers, media personnel and impounding fees from animals in the Parks as well as Park fines for illegal activities in the Park.
- **The National Parks Regulations, No. 54 of 2003,** outlines the code of conduct in protected areas (hours of operation for visitors, prohibited activities, products permitted to be sold in the park, fees on impounding of animals, offences, fines etc.).
- Amended boundaries for parks established under the Act. **SRO 3 of 2000**, **SRO 24 of 2001** and **SRO 36** provide a description the Morne Diablotin National Park boundary and **SRO 54 of 1986** provides a description of the Cabrits National Park amended boundary.

In order to strengthen the management of all categories of PAs and not just National Parks, Dominica has drafted a new **Protected Areas Bill** to replace the existing National Parks and Protected Areas Act. This Bill provides the legislative framework for the establishment, development and effective management of protected areas which will supersede existing laws that contradict the Bill. It further repeals National Parks and Protected Areas Act regulations except those that are consistent with the Bill. This bill provides for the for the establishment of a protected areas system and the preparation and implementation of a plan for the system of protected areas as well as individual PA management plans. Under this bill a Protected Areas Authority, whose function will be to coordinate an integrated approach to the management of protected areas will be established to function as a management authority in respect of national parks and any other protected area for which it has management responsibility. The Bill also provides for the establishment of a Scientific Committee providing advice of a scientific nature to the Authority in the discharge of its functions under the Bill. This draft Bill is still under revision and has not yet been approved.

The **Forest Act, 1958** provides for forest management and the establishment of Forest Reserves on Crown Lands and protected forests on private lands. Currently this is the primary legislation for the Central and Northern Forest Reserves. The **Forest Ordinance Cap. 80, 1959** specifically, covers the designation of forest reserves and includes the designation of private lands as protected forest for water or soil conservation or other public purposes. It is under this Ordinance that the **Forest Rules SRO 17, 1972** were established which specifies prohibited activities in forest reserves and gives details on the issuing of licenses and permits for harvesting forest produce, and the declaration of Stewart Hall Water Catchment as protected forest, **Stewart Hall Water Catchment Rules SRO No. 11, 1975**.

The Forestry and Wildlife Act No. 12 of 1976, amendments **No. 35 of 1982** and **No. 12 of 1990** provides for the protection and management of wild fauna and the management of their forest habits and provides for the creation of wildlife reserves. Under this Act, a wildlife reserve could be declared within the boundaries of an existing PA and the address PA management through various prohibited activities such the introduction of alien species without a permit and hunting in national monuments. This Act however, is not currently linked to other legislation addressing species protection or to the national obligations under conventions such as CITES or CBD.

Relevant regulations further established under this Act are:

Forestry and Wildlife (Fees) Regulations No. 19 of 2014, under section 53 of the Forestry and Wildlife Act, prescribes fees to be paid for seasonal hunting and fishing licenses as provided in Table 5.

Water Catchment Rules of 1995, under the Forestry and Wildlife Act, declare all water catchment areas as protected forests and managed by the Dominica Water and Sewerage Company Ltd. (DOWASCO). Water Catchment Rules include all regulations on prohibited acts, control of dwelling houses and other.

The **Physical Planning Act (2002)** mandates that persons or agencies must apply to develop land and construction practices and includes provisions for prohibitions on land use activities that causing environmental damage. It was established to ensure all development is carried out in an environmentally sustainable manner and requires the preparation of environmental impact assessments for development projects. This Act considers national parks and protected areas as a land for conservation purposes through the preparation of land use/development plans and is likely the most relevant for the establishment and management of any buffer zones surrounding PA’s.

Tourism (Regulations and Standards) Act, 2001. This Act recognizes that the PAs form the base of the ecotourism product, and as such, ensures that all services offered at all national parks and marine management areas will focus primarily on tourists.

Other relevant legislation indirectly related to PA's and their management

- Land Acquisition Act, 1953.
- Crown Lands Ordinance and the Crown Lands Regulations, 1961
- Maritime Areas Act, 1981
- Beach Control Act, 1966, 1990
- Environmental Health Services Act, 1997
- Protection of New Varieties of Plants Act, 1999
- Pesticide Control Act, Pesticides Control (Prohibition) Regulations 2020

National Policies

National Resilience Development Strategy 2030- is the overarching framework which provides the road map and guidelines for taking the country to where it ought to be by 2030. Its vision is for Dominica to be the "*First Climate Resilient Country in the World*". One of the main objectives of the Strategy is to promote sustainable tourism development through the protection, conservation and development of the natural environment within its carrying capacity. It highlights several ways in which it will implement this which include collaborating with relevant agencies to promote the designation of specific areas, including conservation areas, for the development of tourism and coordinating the maintenance, development and management of the national parks, nature sites and trails. Thus, the Protected Areas System will play an important role in the country achieving its resilience development goals.

National Biodiversity Strategy and Action Plan (NBSAP) 2014-2022-As part of its UNCBD agreement the Government of the Commonwealth of Dominica along with the other signatories developed a NBSAP. The national biodiversity strategy sets out Dominica's vision for biodiversity and defines the broad policy and institutional measures that they will take to fulfil the objectives of the Convention. It also provides an action plan to achieve the strategy taking the 20 Aichi targets into account. This is the primary national policy as it relates to PA's. One of its four main objectives is "*To ensure that the basis for development is through the sustainable use of terrestrial and marine biological resources*" with a target for this objective being *"By 2020, at least 15% of terrestrial, inland water and 15% of coastal and marine areas especially areas of particular importance for biodiversity and ecosystem service, are conserved through comprehensive ecologically representative and well-connected systems of effectively managed protected areas and other means and integrated into the wider land and seascape"*

National Land Use Policy, 2014- provides direction for all land use decisions and describes how best to manage development to improve quality of life for Dominicans, through economic and social development, protecting human health and safety, and conserving the natural environment. The National Land Use Policy, enabled under the Physical Planning Act, 2002, represents the overarching policy that guides the development of the National Physical Development Plan. The National Land Use Policy is highly supportive of the protection of the national parks and recognizes the importance Protected Areas to Dominica's Nature Island brand. Protected Areas are incorporated under the national polies specifically by enhancing the vitality of forest reserves and national parks, **ensuring** National Parks are highly valued by citizens and tourists, and to protect and strengthen public access National Parks.

Physical Development Plan, 2016 -acts together with the National Land Use Policy guide planning for future land use and development in Dominica. Overall, its vision is for well managed settlements, agricultural lands, rivers, forests, coastal zones, and biodiversity. It recognizes the importance of National Parks and Forest Reserves to the natural environment, towards climate change mitigation and adaptation and to Dominica's identity. It prescribes the area adjacent to National Parks and Forest Reserves and marine zones as a transition zone and sets out considerations for development within these zones. It proposes the establishment of a third Marine reserve, Salisbury Marine Reserve and considers key species' nesting sites into its plan for land, development areas specifically turtles and parrots nesting sites.

The **National Tourism Policy –** defines the vision and direction of the Dominica's tourism sector. Its vision is for sustainable tourism which includes the national tourism policy is essential to define the vision for tourism and the direction protecting the natural resources and scenic, heritage and cultural features of the country. It states the importance of environment-based natural attractions, facilities, amenities, services and supporting infrastructure and maintaining and enhancing Dominica's pristine environment is one its guiding principles. It has objectives directly related to the system of Protected Areas, specifically to work in partnership with parks management to manage and plan for the sustainable use of the national parks, nature sites and the other protected areas while at the same time maintain the integrity of the resources as it offers quality experiences to visitors.

The Tourism Master Plan 2012-2022 -provides a framework for the development of the tourism sector in Dominica, identifying priority areas for tourism development, related tourism facilities and supporting infrastructure. The potential and opportunities across Dominica's Protected Areas System in growing the country's tourism sector are well recognized in this Master Plan. The plan identifies several areas and plans for tourism development across the country. Specific plans for tourism development within the system of Protected Areas have been highlighted in the previous section 2.1.3.

The **Forest Policy Statement for the Commonwealth of Dominica (2010) -** was developed in order to guide the sustainable management of Dominica's forest resources, while maintaining or improving the present area of forest cover. The Policy covers all of Dominica's forested areas, including Forest Reserves, National Parks, Unallocated State Lands, Carib Territory, and Privately Owned Land. The Policy addresses natural forests, plantations, as well as deforested, degraded forests and agro-forests.

International Commitments[65]

The multilateral environmental agreements (MEAs) directly or indirectly relevant to protected areas that have been signed by the Government of Dominica are-:

65 National Environmental Summary Commonwealth of Dominica 2010.

- UNESCO Convention concerning the Protection of the World Cultural and Natural Heritage, 1972, ratified 1994
- United Nations Convention on Biological Diversity (CBD), ratified 1994
- Cartagena Protocol on Biosafety to the Convention on Biological Diversity, 2000, ratified 2004
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 1973, ratified 1995
- United Nations Framework Convention on Climate Change (UNFCC), 1992, ratified 1994;
- United Nations Convention to Combat Desertification (UNFCC),1994, ratified1997
- United Nations Convention on the Law of the Sea (UNCLOS),1982, ratified 1991
- International Convention for the Prevention of Pollution from Ships (MARPOL), 1973, ratified 1978
- Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region (Cartagena Convention), 1982, ratified 1990
- International Convention on Civil Liability for Oil Pollution Damage, acceded 2001

6.3 Institutional Overview

The management of Dominica's Protected Areas is shared across two Ministries, two local management authorities and a public utility, with no overarching or co-ordination mechanism, making the overall management of the Protected Areas System complex and fragmented (figure 30).

Under the National Protected Areas Act 1976, and the Forestry Act, 1958 the **Ministry of Environment, Rural Modernization and Kalinago Upliftment (MoE)** is responsible for establishing and managing national parks, protected land and forest reserves. It is the Forestry, Wildlife and Parks Division (DFWP) under this Ministry that is responsible for the management and/or administration of the three National Parks, (MTPNP, MDNP and Cabrits NP) and the Central and Northern Forest reserves. The SHWC is managed by the Dominica Water and Sewerage Company Ltd. (DOWASCO) under the Memorandum of understanding "*To undertake a Joint Management Approach for all the Lands Forming Part of the Stewart Hall Water Catchment Protected Forest*" signed with the MoE-DFWP in 2013. However, currently all water catchments fall under the responsibility of DOWASCO (SRO.11,1995).

Several smaller units fall under the DFWP with the largest National Park's Unit responsible for the three National Parks. The administration and management of the two forest reserves falls under the Conservation, Protection &

Maintenance Unit. There is also the Forest Administration Unit and includes the Research and Monitoring Unit, the Environmental Monitoring and Research Unit and Clerical Staff. Lastly, the Forest Management Unit is responsible for all forest resource use as well as the establishment of forest plantation, reforestation programmes and agro-forestry.

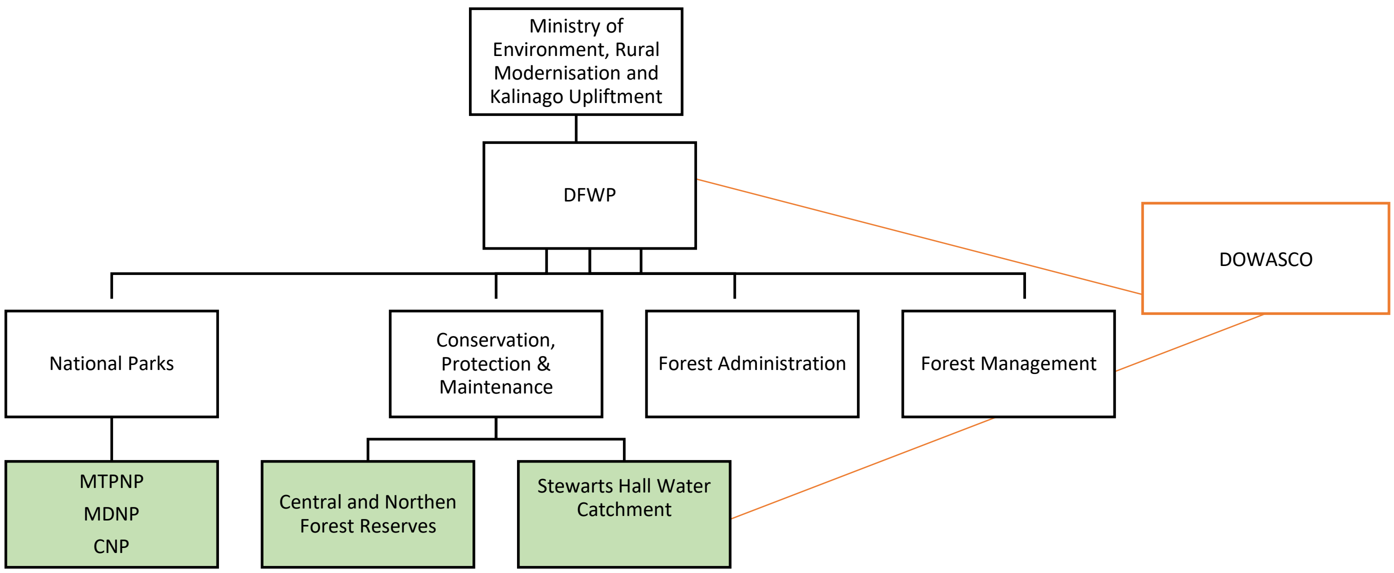


Figure 29 Diagram showing the current institutional set up for managing the PA system. Green boxes represent the PA's that constitute the current PA system. Black lines indicate the legally mandated management structure and orange lines indicate formal agreements

6.4 Procedures and arrangements for the preparation of the FRL

A brief description of procedures and arrangements undertaken to collect and archive data for the preparation of the FREL is included, with information on the role of the institutions involved (Table 6).

Schedule of FREL/FRL tasks

The process started with review of reports and datasets, data collection, selection, processing and analysis, QC/QA procedures, and finalized with a compilation of the FREL/FRL . The process was completed by internal and external independent review.

Table 6 FRL tasks

Stages	Responsible
Identification and formation of the team	DFWP
Allocation of tasks	DFWP
Technical training	CfRN
Data collection	DFWP/ Ministry of Agriculture, Food and Fisheries / CFRN
QC/QA procedures	DFWP/ CFRN
Data analysis	DFWP/ CFRN
Compilation of the FREL	DFWP/ CFRN
QC/QA procedures	DFWP/ CFRN
Independent review	CfRN RRR+IP
Improvement plan	DFWP

DFWP: Forestry, Wildlife and Parks Division CfRN: Coalition for Rainforest Nations. CfRN RRR+ IP: Coalition for Rainforest Nations Independent Panel of Review.

Means of data acquisition and management

Data acquisition

Activity Data:

- On August 29th – 230th 2019, 12 Dominican national experts from the Forestry, Wildlife and Parks Division and Division of Agriculture (Ministry of Agriculture, Food and Fisheries) attended a training by CfRN aimed at increasing knowledge about standardized tools to be used for AFOLU GHGI preparation. Specifically, focus was given at collecting Activity Data through a Collect Earth Campaign, where key steps were discussed such as the protocol for standardizing interpretation and Land Use and Land Use Change Transition Matrix structure for quality control purposes. Furthermore, best practices and lessons learnt with other RRR+ countries were shared with the view to enhance south-south knowledge. Forest definition was discussed and agreed by all participants as well as the sub-divisions for all 6 IPCC categories of land use.

- On November 11th-15th 2019, 3 national experts from the Forest DFWP, and 1 from Agriculture, attended a joint-training with St.Lucia, Belize and Panama, led by CfRN, aimed at increasing knowledge about GHG tools and IPCC guidelines to be used for AFOLU-GHG inventory preparation. Specifically, focus was given to collecting Activity Data through a Collect Earth Campaign, where experts from Belize and Panama led a South-South exchange for the assessment of Land Use and Land Use Changes following the IPCC methods, resulting in a consistent time series as the main input for the GHG Inventory. The information collected is to be used in the preparation and submission of AFOLU-GHG Inventories to the UNFCCC via National Communications (NCs), Biennial Update Reports (BURs), Biennial Transparency Reports (BTRs); also, as a basis for a potential REDD+ Forest Reference Emission Levels/Forest Reference Levels (FREL/FRL).

List of data providers, roles, and responsibilities

Table 7 List of data providers, roles and responsibilities

Institution	Division / Department	Name	E-mail	Role (Data Provider/Data Archiving/ QA/AC/Inventory Prep)
Ministry of Environment, Rural Modernisation and Kalinago Upliftment	Forestry, Wildlife and Parks Division	Minchinton Burton	directorforestry@dominica.gov.dm	Director Forestry, Wildlife and Parks Division - Coordinator
Ministry of Environment, Rural Modernisation and Kalinago Upliftment	Forestry, Wildlife and Parks Division	Bradley Guye	guyeb@dominica.gov.dm	Technical Lead, Activity Data Collection for LULUC 2000-2018, GHGi Preparation, Documentation, QC, Archives.
Ministry of Environment, Rural Modernisation and Kalinago Upliftment	Forestry, Wildlife and Parks Division	Machel Sulton	machelsulton@hotmail.com	Activity Data Collection for LULUC 2000-2018, GHGi Preparation, Documentation, QC, Archives.
Ministry of Environment, Rural Modernisation and Kalinago Upliftment	Forestry, Wildlife and Parks Division	Ricardo Dominique	ricardom13@gmail.com	Activity Data Collection for LULUC 2000-2018, GHGi Preparation, Documentation, QC, Archives.
Ministry of Blue and Green Economy	Agriculture	Nekelia Gregoire	gregoirenekelia@gmail.com	Activity Data Collection for LULUC 2000-2018.
Ministry of Environment, Rural Modernisation and Kalinago Upliftment	Forestry, Wildlife and Parks Division	Felix Eugene	felixeugene09@gmail.com	Technical Support
Ministry of Environment, Rural Modernisation and Kalinago Upliftment	Forestry, Wildlife and Parks Division	Sheldon Simmon	sheldonsimmon@gmail.com	Technical Support
Ministry of Environment, Rural Modernisation and Kalinago Upliftment	Forestry, Wildlife and Parks Division	Cyrille John	johnca63@hotmail.com	Technical Support

Ministry of Environment, Rural Modernisation and Kalinago Upliftment	Forestry, Wildlife and Parks Division	Francisco Maffei	maffeif@dominica.gov.dm	Technical Support
Ministry of Environment, Rural Modernisation and Kalinago Upliftment	Forestry, Wildlife and Parks Division	Richie Laville	richieville2@gmail.com	Technical Support
Ministry of Environment, Rural Modernisation and Kalinago Upliftment	Forestry, Wildlife and Parks Division	Nigel Harve	nigelharve@gmail.com	Technical Support

Data management

All the relevant datasets that have been used during the analysis have been documented. The archives database contains; (a) all inputs datasets and datasheets; (b) country-specific excel calculation tool, including GHG emission and removals estimates (c) manuals and protocols, (d) literature reviewed, (e) completed QA/QC templates and protocols, and (f) all reports and documentation. Archives are held by the Forestry Division.

[66]

7. Methodologies for estimating GHG emission and removals

7.1 Activity Data

The information on Activity Data (AD) used was obtained from land use and land-use change assessment, which was conducted on the basis of a sampling approach (IPCC approach 3) using Collect Earth, in which the land-use condition, including natural and/or human disturbance, was determined for each year of the time series 2000 - 2017. Forest land was stratified by forest type (Montane Forest -Elfin, Cloud montane, Montane Rainforest-, Seasonal Forest -Semi-Evergreen, Semi-Deciduous-, Littoral Evergreen, Dry Scrub). Croplands are reported as annual and perennial crops. Grasslands and Settlements are reported as Woody and Non-Woody. Wetlands do not have further sub-classification and Other lands divided in Other Lands and Mining.

The information on wood removals was derived from the Collect Earth assessment as tree cover loss instead of volume loss, to increase the accuracy of the estimation. ~~as the tool does not allow that estimation~~. Losses due to Disturbances were also identified including Hurricanes, Fires, Logging and Shifting Cultivation, specifically on Forest lands.

7.1.1 Land Representation Approach

According to the 2006 IPCC guidelines, Dominica implemented the Land Representation Approach 3, as it is characterized by spatially-explicit observations of land-use categories and land-use conversions, tracking patterns at specific point location. It is a sampling approach, different to wall-to wall approach (maps), using the Collect Earth tool.

In order to use the sampling approach, clear definitions of land uses were needed. Thus, a workshop took place on August 29-31, 2019. 12 national experts from forestry,

Figure 30 Preparation workshop with Dominica national experts

[66] Photo: https://www.kempinski.com/en/dominica/cabrits-resort-kempinski-dominica/local-information/nature-playground/

agriculture and statistics participated. During this workshop the following land uses were agreed (figure 31).

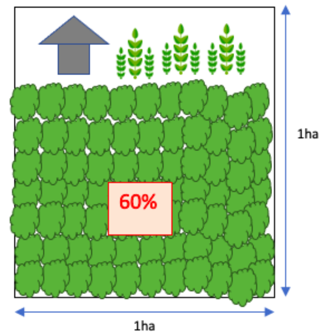
7.1.2 Land Use Classes

Dominica followed 2006/2019 IPCC guidelines structure for the FOLU sector, including the six main land uses proposed: Forest lands, Cropland, Grassland, Wetlands, Settlement, and other lands (Table 8).

Table 8 Land Use classes and sub-categories for Forest land

IPCC categories		sub-categories			Location
Level 1		Level 2	Level 3	Code	m.a.s.l
Forest land	F	Elfin and Cloud Forest	Elfin forest	FELF	>900 (Concentric rings around the island)
			Cloud montane	FCLOUD	701-900
		Montane Rainforest	Montane Rainforest	FRAIN	301-700
		Semi-Evergreen Forest	Semi-Evergreen Forest	FEVER	201-300
		Coastal Forest	Semi-Deciduous Forest	FDEC	101-200
			Dry Scrub	FDRYS	0-100 (west)
			Littoral Evergreen	FLIT	0-100 (east)
Croplands	C	Perennial crop		CPER	
		Annual crop		CANNUAL	
Grassland	G	Grasslands		GGRASS	
Wetland	W	Wetlands		WWET	
Settlement	S	Urban areas		SSET	
		Woody settlements		SWOODS	
Other land	O	Other land		OOTHER	
		Mining		OMIN	

7.1.3 Land Use Classes Definitions



Level 1: Forest (F)

Forest is defined as lands with a tree canopy cover equal or higher than 60% (aprox 1.5 acres), with a minimum area extension of 1 ha and woody vegetation of minimum 3m height or higher, including temporary unstocked areas with the potential to reach the forest definition.

Level 1: Croplands (C)

Crop lands and agroforestry systems where the vegetation structure falls below the thresholds used for the Forest Land category. 1 ha area with more than 20% cover of any type of planted crop, but less than 60% cover of forest or 20% cover of infrastructure.

Level 1: Grasslands (G)

Open areas covered mostly by grasses or sedges, but other herbs and low shrubs are also present. Individual trees or small clumps of trees and taller shrubs may also be present. This vegetation class is most common near areas of Deciduous Seasonal Forest and is usually a result of extreme disturbance to that forest class. Abandoned gardens in wetter areas can temporarily take on this form, but quickly develop into secondary forest. This forest class is defined as a 1 ha area with more than 20% cover of any type of grassland, but less than 60% cover of forest or 20% cover of infrastructure.

Level 1: Wetlands (W)

Land that is covered or saturated by water for all or part of the year and does not fall into the Forest Land, Cropland, Grassland or Settlements categories. It includes reservoirs as a managed subdivision and natural rivers and lakes, reservoir of water, freshwater swamp seasonal (permanently depending on rainfall) and permanently muddy areas fall into this class. This class is defined as a 1 ha area with more than 20% cover, but less than 60% cover of forest or 20% cover of infrastructure.

Level 1: Settlements (S)

1 ha area with at least 20% cover of infrastructure (houses, roads, etc.), but less than 60% forest canopy cover.

Level 1: Other Lands (O)

Bare area with less than 20% cover of grasses, shrubs, trees, wetland, crops or infrastructure and all land areas that do not fall into any of the other five categories. Mining is classified as other land category.

7.1.4 Land sub-classes Definitions

Level 1: Forest lands (F)

Due to the lack of a recent National Forest Inventory, Dominica has used Saint Lucia's forest classification and definitions as described in Gravenson (2009) and complemented with country specific circumstances, as both Islands share the same conditions and forest types[67]. It is important to note that Dominica is already initiating a new national forest inventory, expected to be finalized by 2024. Once the information is available, descriptions and characteristics will be updated.

Level 2: Elfin and Cloud Forest

Level 3: Elfin forest

Slopes are extremely steep, rainfall is very heavy, there is little wind and landslides are very common. The steepest areas are covered with tree ferns and palms, with canopy height of about 4-6m, with some scattered taller trees on slightly less steep areas. Canopy cover is often quite complete on gentler slopes, but broken on steep slopes; ferns, mosses, ground anthuriums, vines, and epiphytes vary from absent to abundant; trees with buttresses and prop roots are present in some areas and absent in others. At ground level, it varies from humid, quite dark, and still, to rather breezy and bright. This variation results from natural factors, especially slope gradient, exposure to the prevailing wind, altitude (and therefore rainfall), and recent climatic disturbances. 3m high. Tropical or subtropical broad-leaved evergreen shrubland (includes bamboos and tuft-trees). In the windiest spots, at an elevation above 900 meters, a shrubland vegetation class dominates. Relatively few species are found in this vegetation type: mainly a mixture of bromeliads, sedges and grasses and shrubs, with many Lesser Antillean endemics.

Level 3: Cloud montane

This vegetation class is found on at an elevation of 700m or higher. The canopy is about 8m high with occasional much taller trees. Terrestrial ferns, anthuriums, bromeliads, and epiphytes are very common; moss cover is often several centimeters thick. Cloud and mist cover, with heavy rainfall, is predominant, with only occasional and short periods of sunshine. Some species found in Montane and Lower Montane Rainforest are also found here.

[67] Graveson R. (2009). National Forest Demarcation And Bio-Physical Resource Inventory Project Caribbean – Saint Lucia: The Classification Of The Vegetation Of Saint Lucia. FCG International Ltd in association with AFC Consultants International GmbH

Level 2: Montane Rainforest

Lower Montane Rainforest merges with Semi-evergreen Seasonal Forest at lower elevations and with Montane/ Cloud Montane Rainforest at higher elevations. Trees are evergreen because there is no water deficit most years in any month. In general, trees of all heights are found, without clear divisions into separate canopy layers. Although there may be a shrub, fern and herbaceous (mainly Anthurium) ground cover, this forest class is easy to walk through (if one ignores the incline) except where the canopy has been destroyed and ferns, vines and shrubs colonize the clearing.

Away from the edge of the forest, on comparatively gentle slopes without much wind, occasional very tall trees, reaching 45m, are found among the main 30-m canopy. This distinctive forest is often called the *Dacryodes-Sloanea* alliance and is often over-emphasized as being the „typical" rainforest. Exposed ridges often have a dwarfed vegetation because of high winds. Landslides are a natural phenomenon in Lower Montane Rainforest and can be seen at various stages of recovery.

In comparison to Semi-evergreen Seasonal Forest, the mean canopy height, wind, and incline are greater and there is a greater abundance of vines, epiphytes, ferns and mosses. The trees are more tightly packed, and the trees can be much wider in girth. This forest class has been recorded from 100- 680m above sea level.

Slopes are extremely steep, rainfall is very heavy, there is little wind and landslides are very common. The steepest areas are covered with tree ferns and palms, with canopy height of about 4-6m, with some scattered taller trees on slightly less steep areas. This class is poorly differentiated from Lower Montane Rainforest in terms of species, but it has a very characteristic appearance. It is found only on very steep slopes at high elevation: where the slope is gentler Lower Montane Rainforest replaces it.

Level 2: Semi-Evergreen Forest

Occupies the zone between Deciduous Seasonal Forest and Lower Montane Rainforest. It is characterized by upper canopy trees with rather thin, often broad, and quite often compound leaves, which may lose some, but not all, of their leaves during a dry spell. There are no, or very few, epiphytes, ground ferns and mosses. Rare forest, all secondary. Upper canopy trees with thin, broad and compound leaves. Might lose some leaves during dry season. This forest class is found in agriculture areas, river valleys below Lower Montane. In comparison with Deciduous Seasonal Forest, this forest class has a higher canopy and greater canopy cover and trunks with a greater girth. It occurs in less windy areas, and generally at a higher elevation.

Level 2: Coastal Forest

Level 3: Semi-Deciduous Forest

It merges inland with the Semi-evergreen Seasonal Forest: the upper slopes of high hills are often covered by Deciduous Seasonal Forest and their lower slopes, leading to ravines, covered by Semi-evergreen Seasonal Forest. This class is defined as deciduous because the taller trees tend to lose all their leaves in most dry seasons, although the smaller trees and shrubs are evergreen. Its overall appearance during a normal dry season is of a more or less leafless canopy. Lowland or sub-montane drought deciduous. It is characterized by patchwork with small gardens, recently coppiced areas, shrub, small and large trees. They are also found in some hills as natural with smaller trees and this forest class reaches an elevation up to 700m. In Dominica, the Deciduous Forest is usually a dense canopy cover with mature forest species reaching approximately 35-40ft (10-12m) in height.

Level 3: Littoral Evergreen

Behind sandy beaches, rocky cliffs and pavements, an evergreen forest or shrubland is found, especially on the Atlantic coast. The harsh conditions caused by wind, salt-spray, often a thin soil and a water deficit even during most of the wet season, favour an evergreen arborescent flora with thick leathery leaves. *Coccoloba uvifera* (wézen, siwiz, sea grape) is commonly present in this vegetation class.[68]

Level 3: Dry Scrub

This type of vegetation is found on the west coast of the island in a narrow zone between littoral rock and cliff vegetation and Deciduous Seasonal Forest or Littoral Evergreen Forest. It consists of forest trees, shrubs, cacti and sometimes grassy spaces influence by human activity (invasives, cleared zones, for animal grazing).

Level 1: Croplands (C)

Level 2: Perennial Crop

Land under permanent or medium-term crops. It is the land that during the reference year was mainly planted with crops which occupy it for a long period of time, and which do not have to be planted after each harvest. It includes all tree crops (bearing or not) banana, plantains, coconut, etc. In case of permanent crops inter-planted with temporary crops that land was reported here.

Level 2: Annual Crop

Land under temporary crops only. It is the land used exclusively for crops with a growing cycle of under one year, which needs to be newly sown or planted for further production after the harvest. It also includes some

[68] For Dominica, the same classification as the National Forest demarcation and bio-physical resource inventory Project Caribbean – Saint Lucia. The classification of the vegetation of Saint Lucia (2010), was used

crops which remain in the field for more than one year and their harvest destroys the plant like cassava. Most common crops according to 2007 Agriculture Census [69] were: tannia, dasheen, christophene, sweet potatoes, yam, cassava, tomato, peas, sweet pepper, cucumber, ginger, chives.

Level 1: Settlements (S)

Level 2: Urban areas

Development in relation to any land carrying out of building, engineering, mining or other operations in, on, over or under any land, the making of any material change in the use of any land or buildings, or the subdivision of any land, and "develops" and "developer" shall be construed accordingly.

Level 2: Woody Settlements

A woody settlement is defined as a rural community with woody trees where both forest types and perennial crops are interspersed. 1 ha area with more than 20% cover mixed with woody trees but with less than 60% cover of forest.

7.1.5 Disturbances:

In general forests in Dominica have suffered physical damage as a result of hurricanes over the past few decades. A number of factors reduce the natural resilience of Dominica's forests ecosystems and increase their vulnerability to climate change and climate variability. Many natural hazards periodically affect or threaten Dominica, among them hurricanes, earthquakes, volcanic eruptions, storm, surges, and landslides. These natural disasters can be attributed as one of the root causes of biodiversity loss in Dominica.

Hurricane David in 1979 caused significant impacts on the island's forest resources, causing damage to in excess of 50% of the trees in the southern half of the island. Hurricanes cause loss of habitat and food supplies for wildlife species and result in wildlife mortality. An indirect resultant effect Hurricane David was the conversion of wildlife habitat to agriculture. In accessible areas the toppled trees provide an opportunity to more easily clear land for farming, resulting in a further fragmentation of wildlife habitat[70].

Hurricane Dean in 2007 caused extensive defoliation resulting in loss of up to 35 percent of the forest cover over the eastern forest range (FAO, 2007)[71].

In August 2015, tropical Storm Erika triggered catastrophic floods and mudslides. Hundreds of homes were left uninhabitable and thousands of people were displaced; the entire town of Petite Savanne was evacuated and subsequently abandoned as a result of the storm. Flooding and landslides severely damaged transport

[69] http://www.malff.com/images/stories/Census%20Data/2007%20Census%20of%20Agriculture%20Summary%20Report.pdf
[70] Dominica Low-Carbon Climate-Resilient Development Strategy 2012-2020
[71] https://reliefweb.int/report/dominica/fao-agricultural-damage-assessment-mission-dominica-following-hurricane-dean

infrastructure and substantially diminished the productive capacity of agriculture and tourism. The main airport was badly damaged.

In September 2017, Hurricane Maria made landfall in Dominica as a Category 5 hurricane with maximum sustained winds of 165 mph (265 km/h). These winds, the most extreme to ever impact the island, battered the roof of practically every home, with half the city flooded, cars stranded, and stretches of residential areas "flattened" it was indicated "total devastation". Its ferocious winds defoliated nearly all vegetation, splintering or uprooting thousands of trees and decimating the island's lush rainforests. The agricultural sector, a vital source of income for the country, was completely wiped out: with 100% of banana and tuber plantations was lost, as well as vast amounts of livestock and farm equipment (figure 32).

Figure 31 Trees stripped by Hurricane Maria in the interior of Dominica, October, 2017[72]

As a result of climate change, it is expected that the intensity of hurricanes will also increase, causing more severe damage, with potentially longer-term consequences for the integrity of the forest structure and canopy. Forest destruction from hurricanes recovers slowly with ecological implications such as landslides and soil loss and consequent socio-economic impacts such as impact on water quality and availability, and possible short to medium term tourism impacts.

7.1.6 Planning the land use assessment

After the experts decided on the land use categories that would be used to estimate the land use change over the years, clear classification criteria were needed to standardize the interpretation. Three main characteristics were selected.

[72] Source: https://www.nybooks.com/daily/2017/12/28/dominica-after-the-storm/

a) **Forest type by elevation.**

As described in the previous section, forest types in Dominica are directly linked to elevation and location; therefore, the following figure was used to standardize the criteria of selection of a forest type (figure 33):

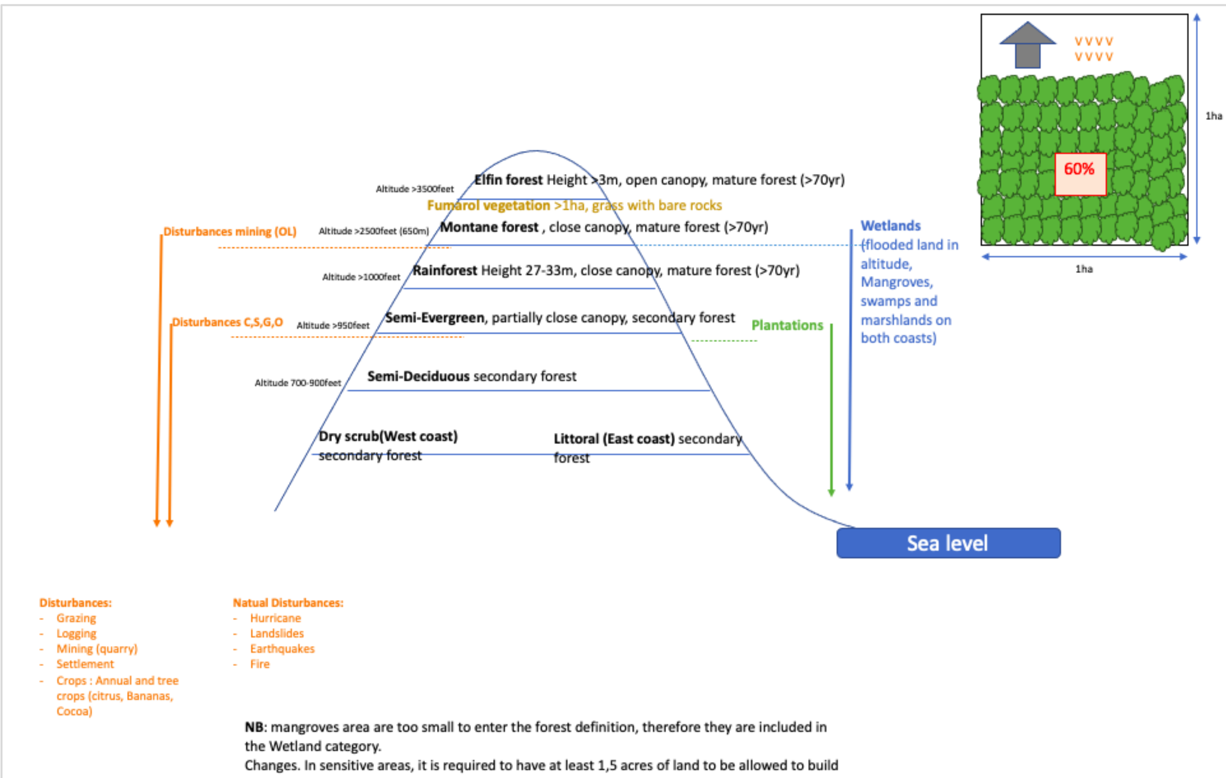


Figure 32 Land uses by elevation and location developed during preparation workshop

Then, clear and unified elevations were assigned (table 9), including transition zones among forest, to allow a harmonized interpretation. Despite the clear criteria, it was acknowledged that because of the topography, some of these might not apply and the expert observation was given relevance at the moment of the interpretation; for instance, in the case of forests in valleys or cliff areas.

Table 9 Dominica's forest types and elevation ranges [m,(feet)]

	Predominantly m.a.s.l	Predominantly f.a.s.l	Transision m (feet)	Location
Dry Scrub	0-100	0-328		West
Littoral Evergreen Forest	0-100	0-328		East
Transition			70-130 (229-427)	
Seasonal Deciduous	101-200	329-656		all over
Transition			170-230 (557-755)	
Seasonal Semi Evergreen	201-300	657-984		all over

Transition			270-330 (856-1082)	
Montane – Rainforest	301-700	985-2297		all over
Transition			650-730 (2133-2395)	
Montane – Cloud Forest	701-900	2298-2952		all over
Transition			870-930 (2854-3051)	
Montane – Elfin forest	>900	>2953		Concentric rings around the island

m.a.s.l: meters above sea level, f.a.s.l: feet above sea level

b) Possible and Impossible land use changes

The next step in the discussion was agreeing what type of land use changes can and cannot happen. This included understanding which forest types can be affected by; for example, which type of crops, or which ones are more subject to conversion to settlements or any other land use that is different from Forest lands. The main goal was to standardize what the disturbance factors are and where Forests are more subject to conversion to Croplands, Grasslands, Wetlands, Settlements and Other Lands. Moreover, which disturbances, both natural and anthropogenic, have affected the islands such as hurricanes, fires in croplands for slash and burn, fire in grasslands for clearing the land for pasture, natural wildfires, pests etc. The result of the discussion can be seen in figure 34:

Vertical: Land Use, Horizontal: Land Use Change		Forest Lands								Croplands		Grasslands	Wetlands	Settlements	Other Lands	Disturbances			
		Elfin	Montane Forest	Rainforest	Semi-evergreen	Semi-Deciduous	Dry Scrub	Littoral	Plantation	Tree Crops	Annual Crops	Grasslands	Wetlands	Settlements	Mining?	Hurricane/Storm	Fires	?	?
Forestlands	Elfin		x	x	x	x	x	x	x	x	x	x	x	x	x				
	Montane Forest	x		x	x	x	x	x	x	x	x	x	ok	x	ok				
	Rainforest	x	x		ok	ok	x	x	x	x	x	x	ok	x					
	Semi-evergreen	x	x	ok		ok	ok	x	ok	ok	ok	ok	ok	ok	ok				
	Semi-Deciduous	x	x	x	ok		ok	x	ok	ok	ok	ok	ok	ok	ok				
	Dry Scrub	x	x	x	x	x		x	ok	ok	ok	ok	ok	ok	ok				
	Littoral	x	x	x	x	x	x		ok	ok	ok	ok	ok	ok	ok				
	Plantation	x	x	x	ok	ok	ok	ok		ok	ok	ok	x	ok	x				
Croplans	Tree Crops	x	x	ok	ok	ok	ok	ok	ok		ok	ok	x	ok	ok				
	Annual Crops	x	x	ok	ok	ok	ok	ok	ok	ok		ok	x	ok	ok				
Grasslands	Grasslands(grazing)	x	x	x	ok	ok	ok	ok	ok	ok	ok								
	Fumarol Veg (?)																		
	Abandoned lands	x	x	ok	ok	ok	ok	ok	ok	ok	ok								
Wetlands	Wetlands	x	x	x	x	x	ok	ok	ok	ok	ok	ok							
Settlements	Settlements	x	x	x	ok	ok	ok	ok	x	x	x	ok	ok						
Other Lands	Mining?	x	x	x	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok					

Legend :

x	Transition not possible in 1 year
ok	Transition seen in 1 year
in color the land remaining in the same category	

Figure 33 Land use and land use change matrix indicating possible and impossible land use changes developed during preparation workshop

c) Hierarchy for land use classification

A hierarchy for the land use categories was established for the visual interpretation during the CE/OF Assessment. This will allow determining the land used depending on the percentage of land use cover (table 10).

Table 10 Hierarchy of land use classification for Dominica for the visual interpretation in the 2019 CE Assessment

Land Use	% Minimum

Forest Lands	60%
Croplands	20%
Grasslands	20%
Wetlands	20%
Settlements	20%
Other Lands	20%

According to the ‘hierarchy of land use classification’, if a sample plot had 60% or more forest canopy, its land use was be classified as "forest". If a sample plot has less than 60% of forest cover, a determination was made to classify the sample plot according to the hierarchy. For example, if a plot only has 10 % forest, 20 % of grassland, 20 % of cropland, and 50 % of other lands, according to the hierarchy, the classification was cropland (figure 35).

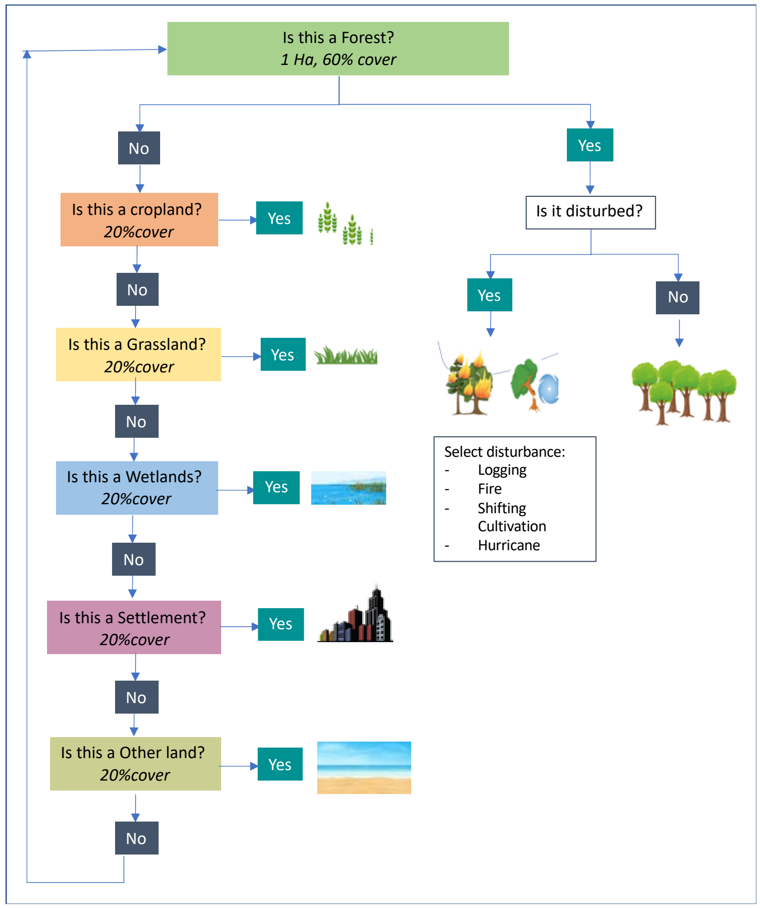


Figure 34 Diagram flow of land use classification hierarchy

7.1.7 Project Design

Based on the information collected during the workshop, the plot size, sampling grid and survey were designed.

Plot Size: The size of the plot was decided to be 1Ha, to allow consistency with the Forest definition. This, along with the samples, 49 of them, facilitated counting the percentage of land use cover, as indicated in the hierarchy diagram (figure 36).

Figure 35 Sampling plot size of 1Ha

Distance among plots: Based on the experience and lessons learnt of Panama and Belize who have recently done their Collect Earth assessment, using grids of 3km by 3km and 1.5 km by 1.5 km (Panama) and Belize (1km by 1 km), Dominica planned to use a high sampling intensity, balancing country size, representatives of the samples, time and interpreters availability. As a result, a sampling of 750m by 750 m was selected (figure 37).

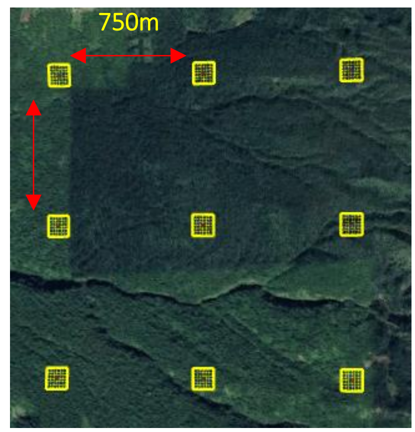


Figure 36. Plot size and distance among plots

National grid: Based on the previous analysis and criteria, a 750m by 750m national systematic grid consisted of 1605 sampling plots of 1Ha was selected. These sampling points were visually evaluated (figure 38).

Figure 37 Dominica's grid (collect earth)

Design of the Survey. For collecting the land use, land use changes, year of land use conversion, disturbance and year of disturbance, a country specific survey was designed that could capture all the information required. This survey included the six IPCCC land uses (Forest lands, Croplands, Grasslands, Wetlands, Settlements and other lands). It also included the sub-categories of land use as previously described (e.g Elfin forest, annual crop), and disturbances (hurricanes, logging, fires, shifting cultivation). This survey was displayed in each of the sampling plots and interpreters must fill it with the information of each plot on an annual basis. If no land use change or disturbance was recorded, the same information as the previous year was included. Figure 39 shows how the survey was seen when selecting a plot for assessment.

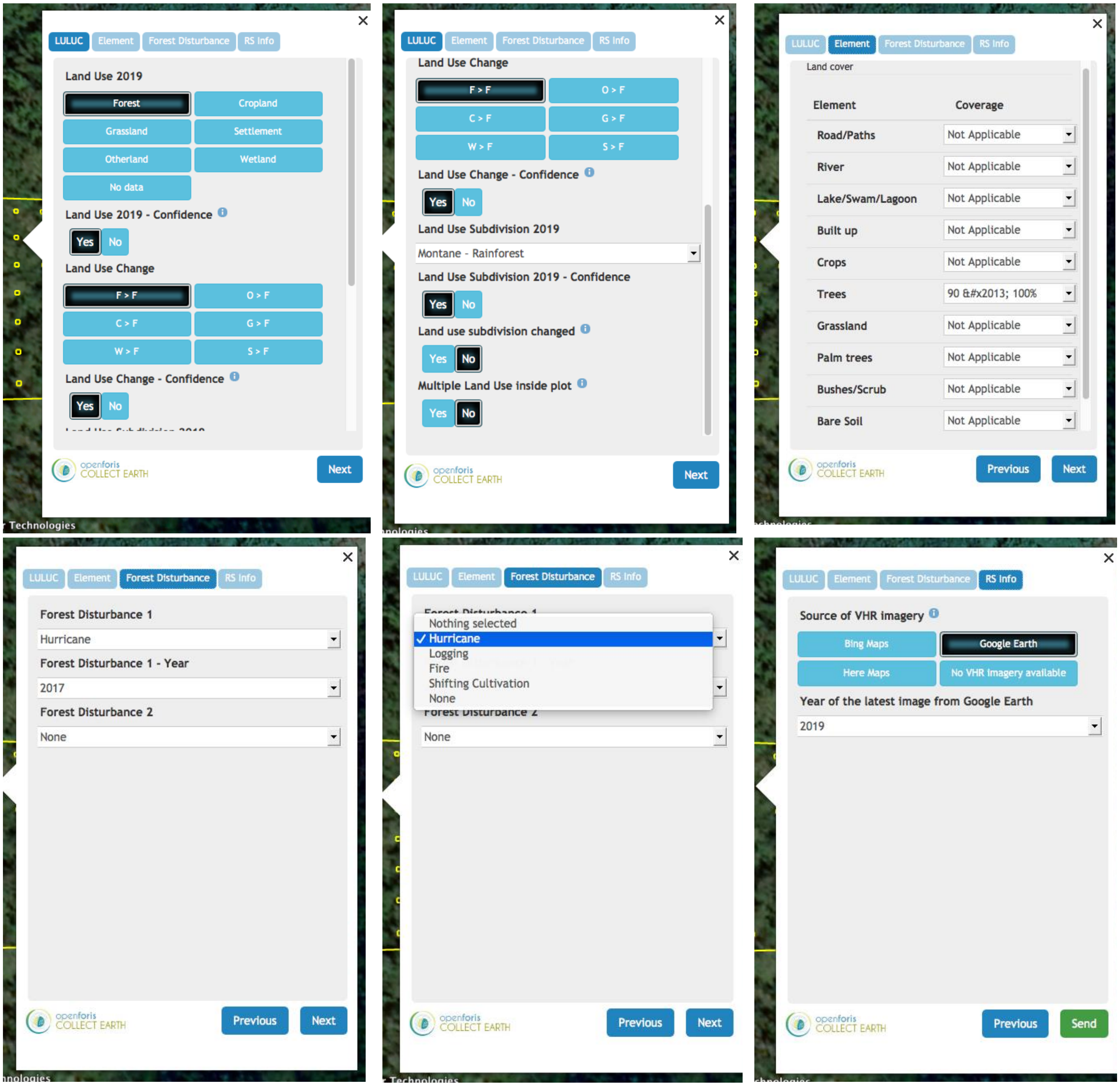


Figure 38. Collect earth survey

7.1.8 Open Foris Collect Earth Desktop

Training on how to use Collect Earth Desktop: On November 11th-12th 2019, 3 national experts from the Forest DFWP, and 1 from Agriculture, attended a join-training with St.Lucia, Belize and Panama, led by the Coalition for

Figure 39 Training of Dominica team on Collect Earth online

Rainforest Nations, on Collect Earth Desktop (figure 40). Collect Earth is a user-friendly, Java-based tool that draws upon a selection of other software to facilitate data collection. Collect Earth uses a Google Earth interface in conjunction with an HTML-based data entry form. Forms can be customized to suite country-specific classification schemes in a manner consistent with guidelines of the Intergovernmental Panel on Climate Change (IPCC).

Collect Earth facilitates the interpretation of high and medium spatial resolution imagery in Google Earth, Bing Maps and Google Earth Engine. Google Earth's virtual globe is largely comprised of 15-meter resolution Landsat imagery, 2.5m SPOT imagery and high-resolution imagery from several other providers (CNES, Digital Global, EarthSat, First Base Solutions, GeoEye-1, GlobeXplorer, IKONOS, Pictometry International, Spot Image, Aerometrex and Sinclair Knight Merz). Collect Earth synchronizes the view of each sampling point across all three platforms. The tool enables users to enter data regarding current land use and historical land use changes. Users can determine the reference period most appropriate for their land use monitoring objectives.

Standardization of the interpretation

An important aspect regarding interpretation, is that all interpreters have the same criteria for selecting a land use or a disturbance. In addition of the previous criteria (elevation, location, possible and impossible transition matrix and hierarchy), different images were visualizing all together to ensure coherent classification among interpreters. Some examples of the plots used for training are included below (figures 41 to 60):

Level 1: FOREST LAND (F)

Level 2: Elfin and Cloud Forest

Level 3: Elfin forest

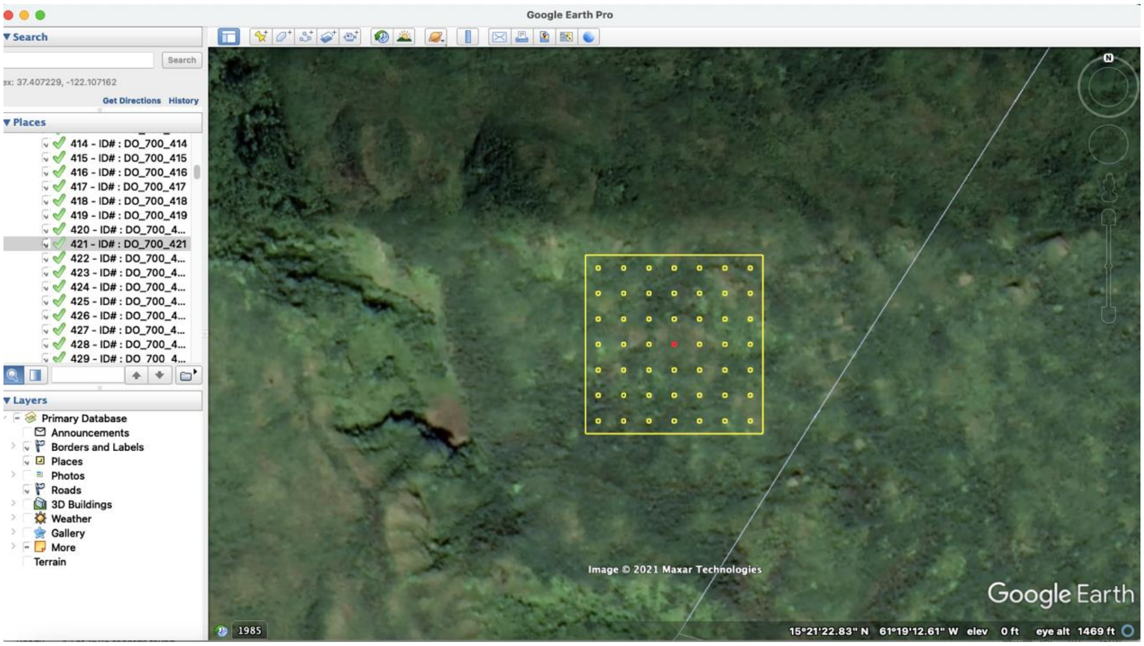


Figure 40 Visualization of Elfin forest in a high resolution image before disturbance

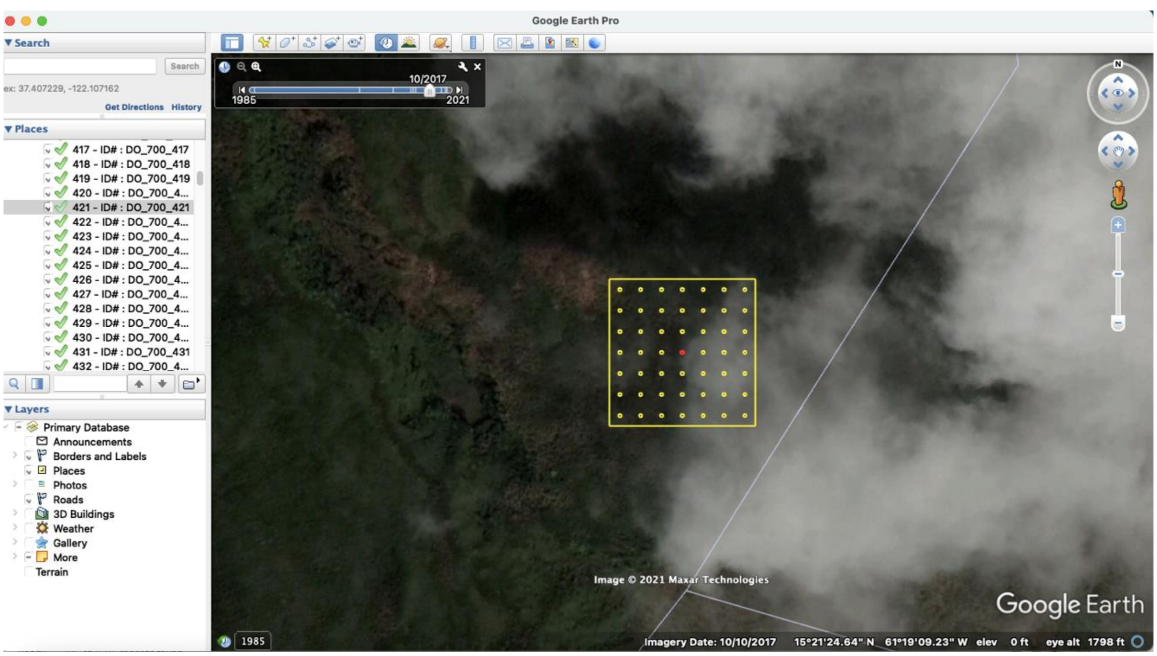


Figure 41 Visualization of Elfin forest (same plot) in a high resolution image after hurricane disturbance

Level 3: Cloud montane

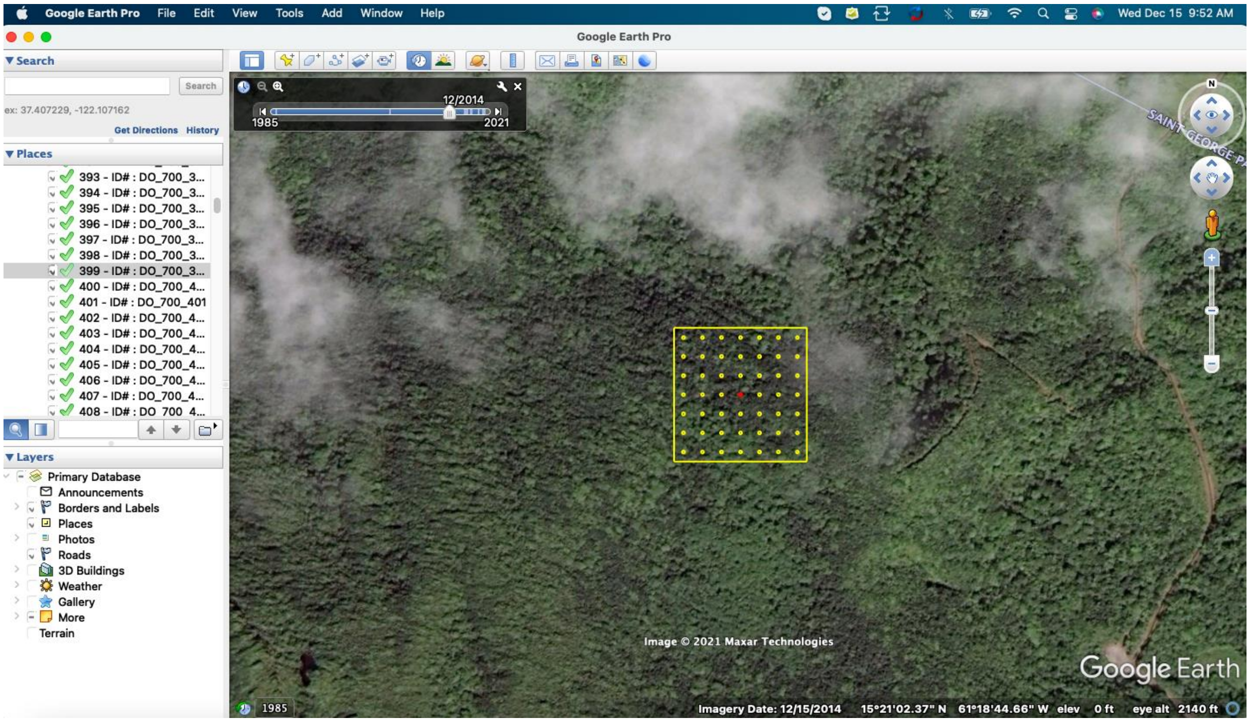


Figure 42 Visualization of Cloud montane forest in a high-resolution image before disturbance

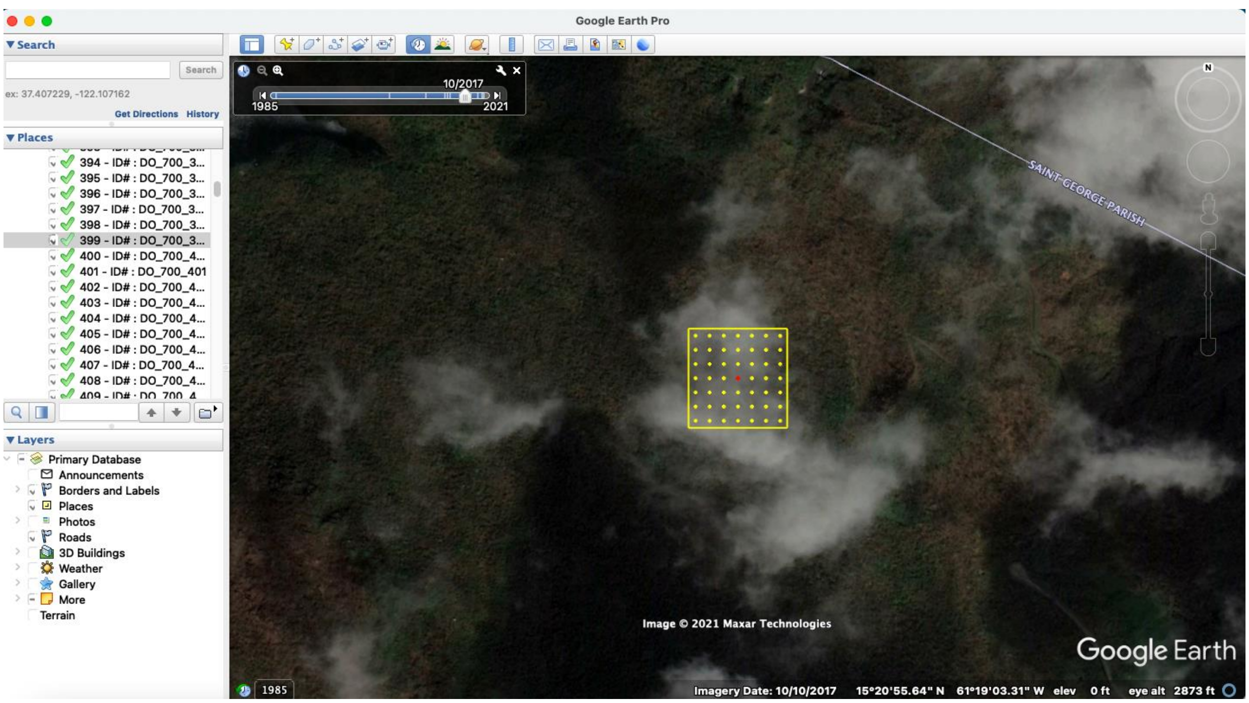


Figure 43 Visualization of Cloud montane forest (same plot) in a high-resolution image after hurricane disturbance

Level 2: Montane Rainforest

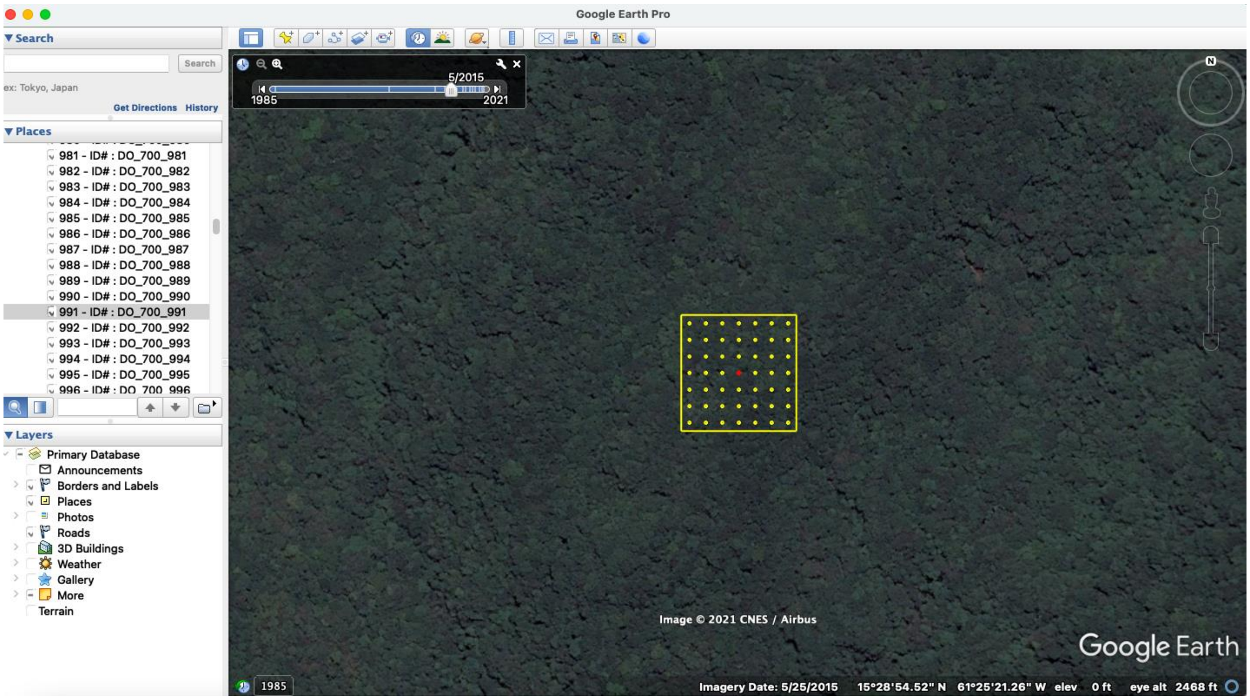


Figure 44 Visualization of Montane rainforest in a high-resolution image before disturbance

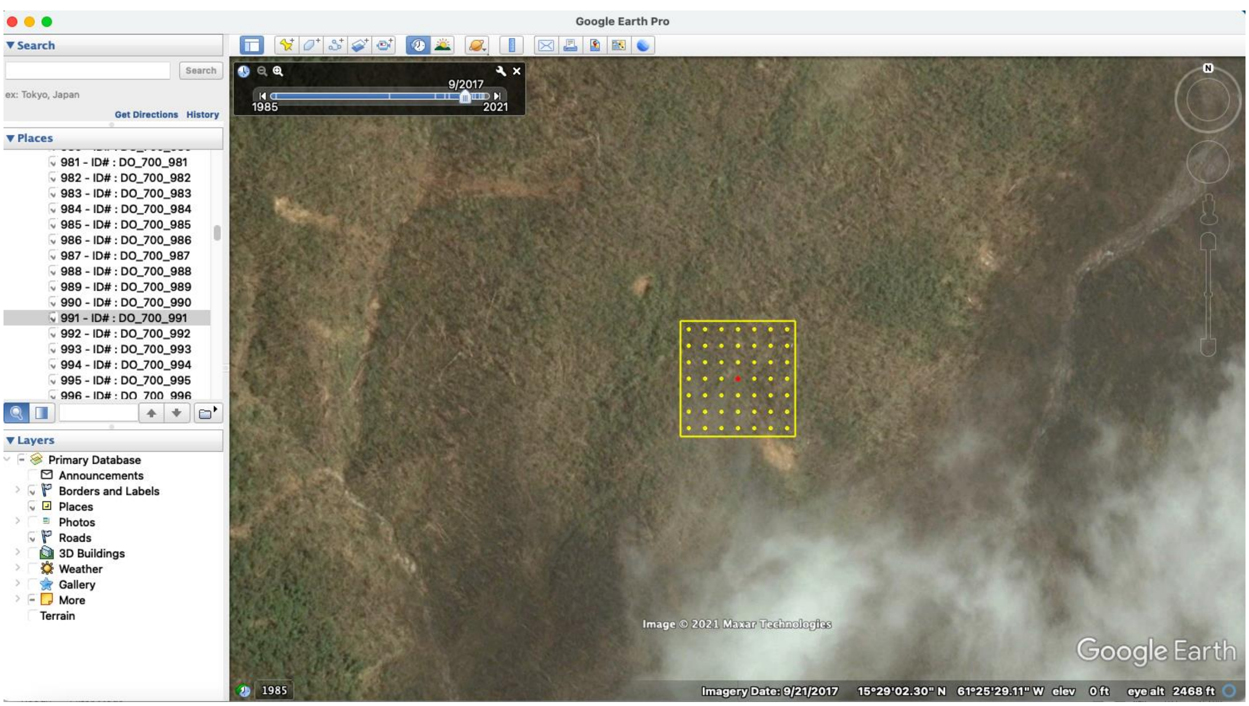


Figure 45 Visualization of Cloud montane forest (same plot) in a high-resolution image after hurricane disturbance

Level 2: Semi-Evergreen Forest

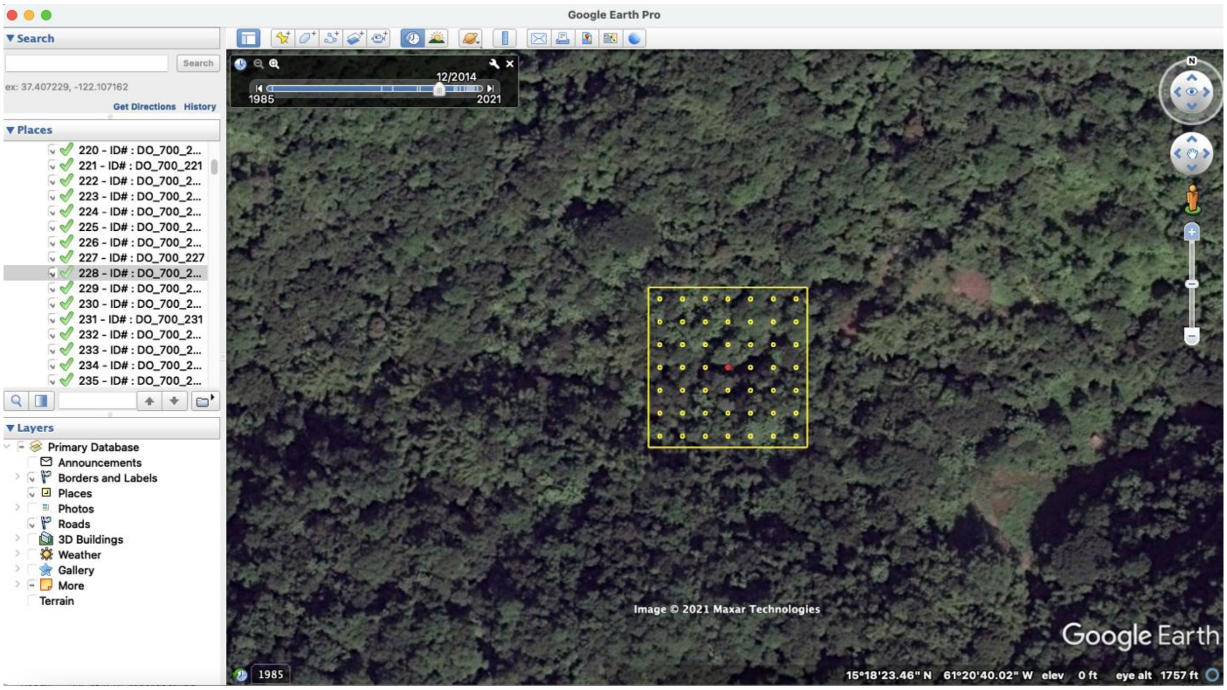


Figure 46 Figure 18 Visualization of Semi-evergreen forest in a high-resolution image before disturbance

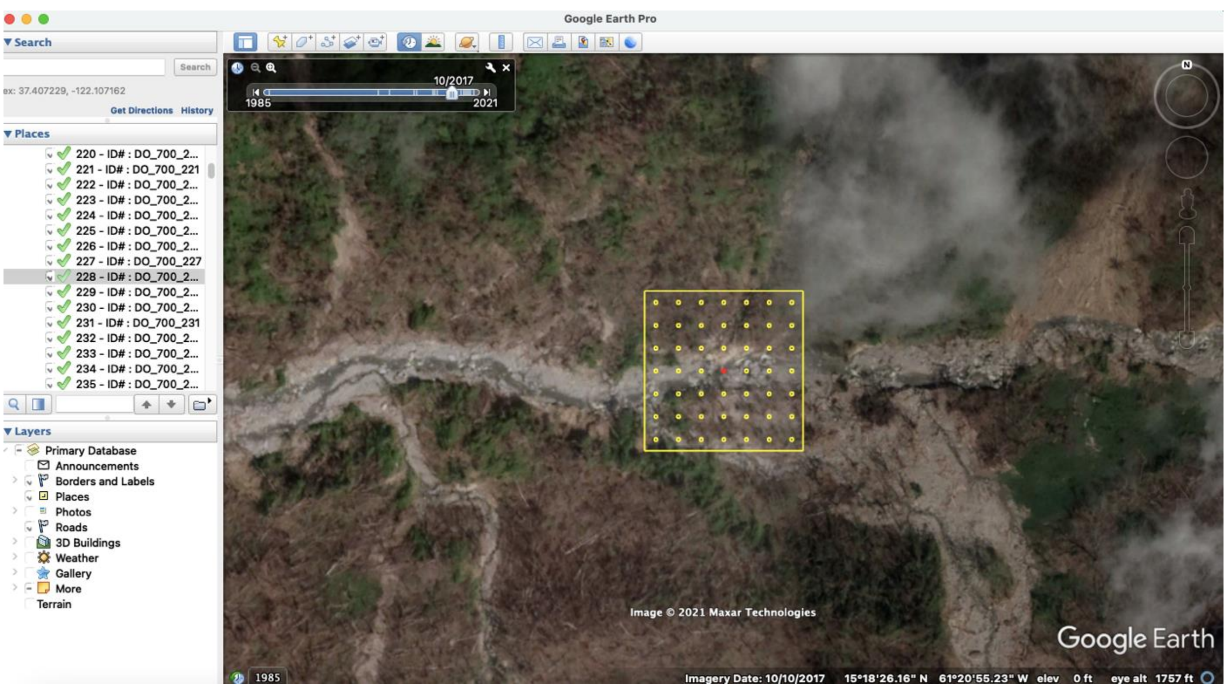


Figure 47 Visualization of Semi-evergreen forest in a high-resolution image after hurricane disturbance

Level 2: Coastal Forest

Level 3: Semi-Deciduous Forest

Figure 48 Visualization of Semi-deciduous forest in a high-resolution image before disturbance

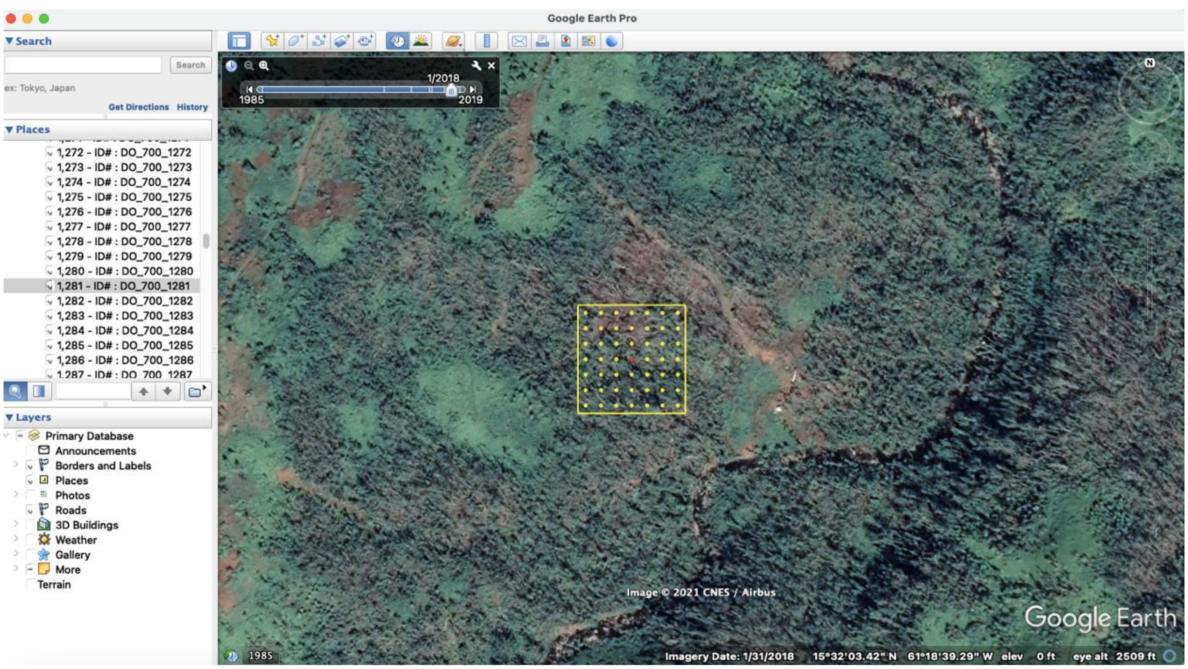


Figure 49 Visualization of Semi-deciduous forest (same plot) in a high-resolution image after hurricane disturbance

Level 3: Littoral Evergreen

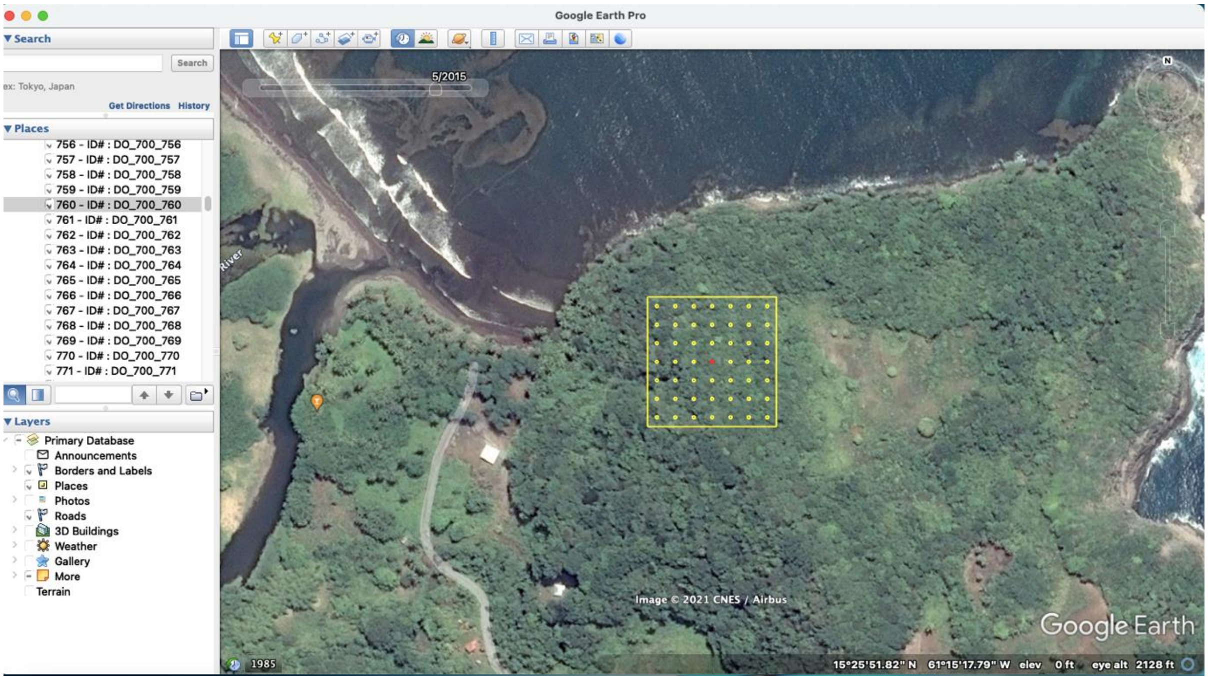


Figure 50 Visualization of Littoral evergreen forest in a high-resolution image before disturbance

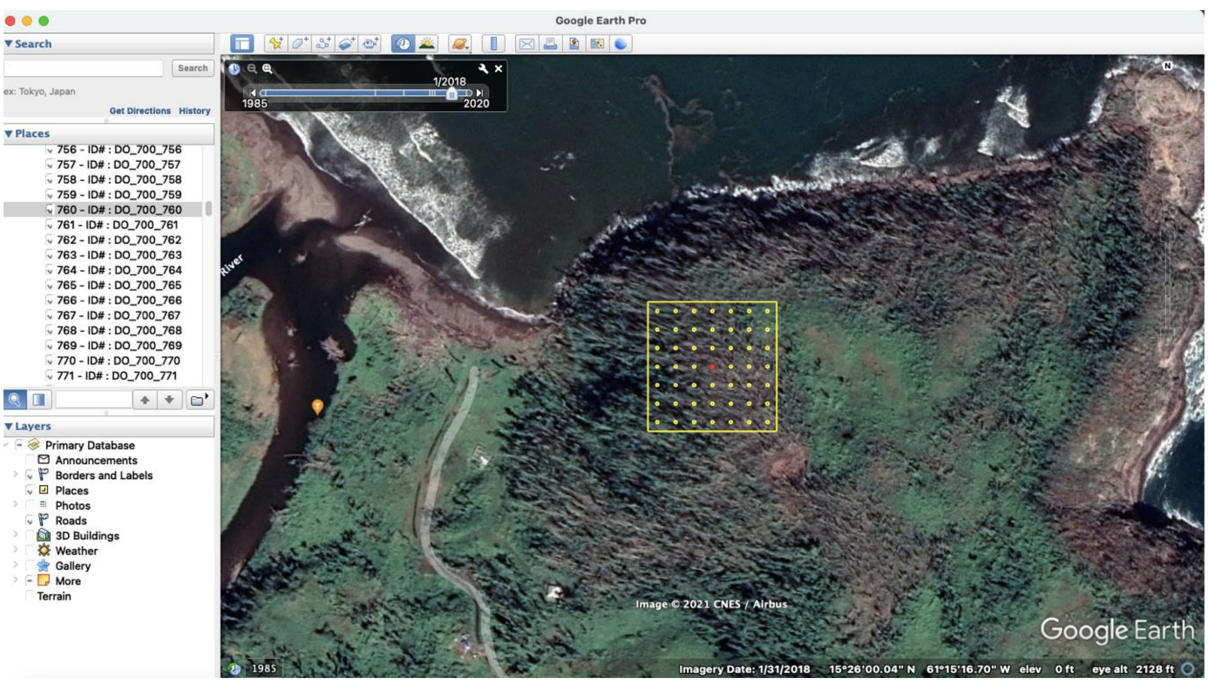


Figure 51 Visualization of Littoral evergreen forest in a high-resolution image after hurricane disturbance

Level 3: Dry Scrub

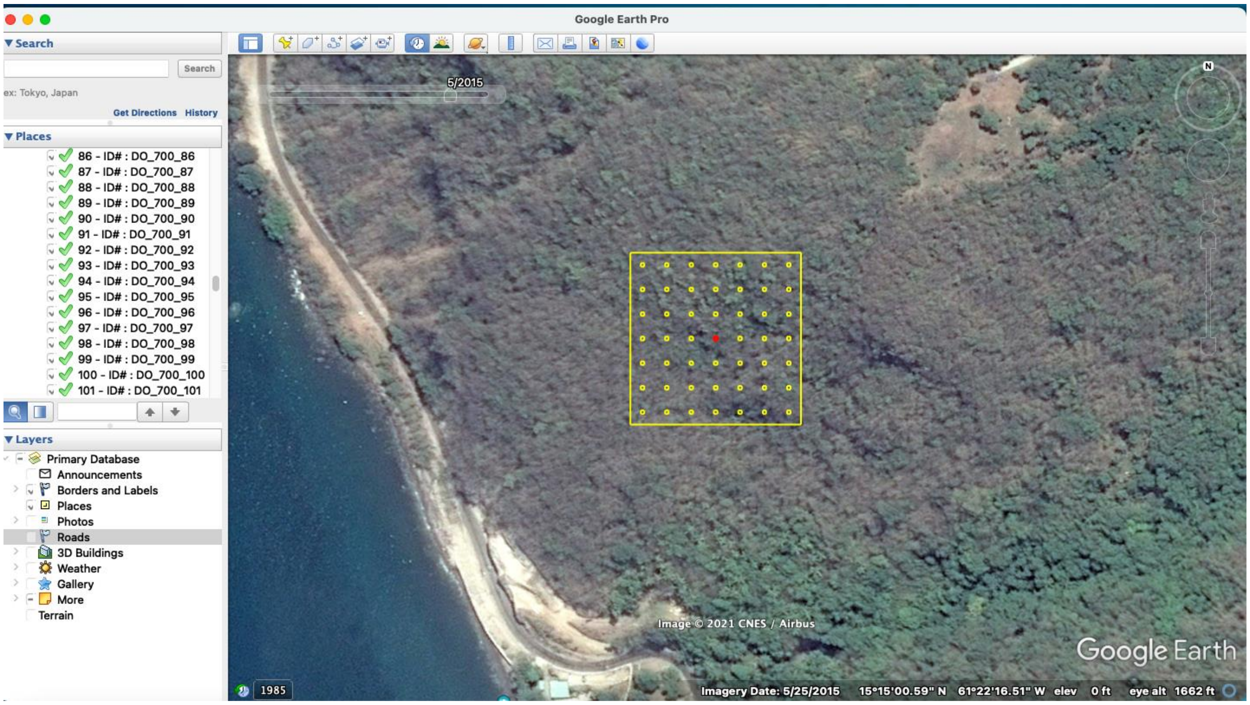


Figure 52 Visualization of Dry Scrub forest in a high-resolution image after before disturbance

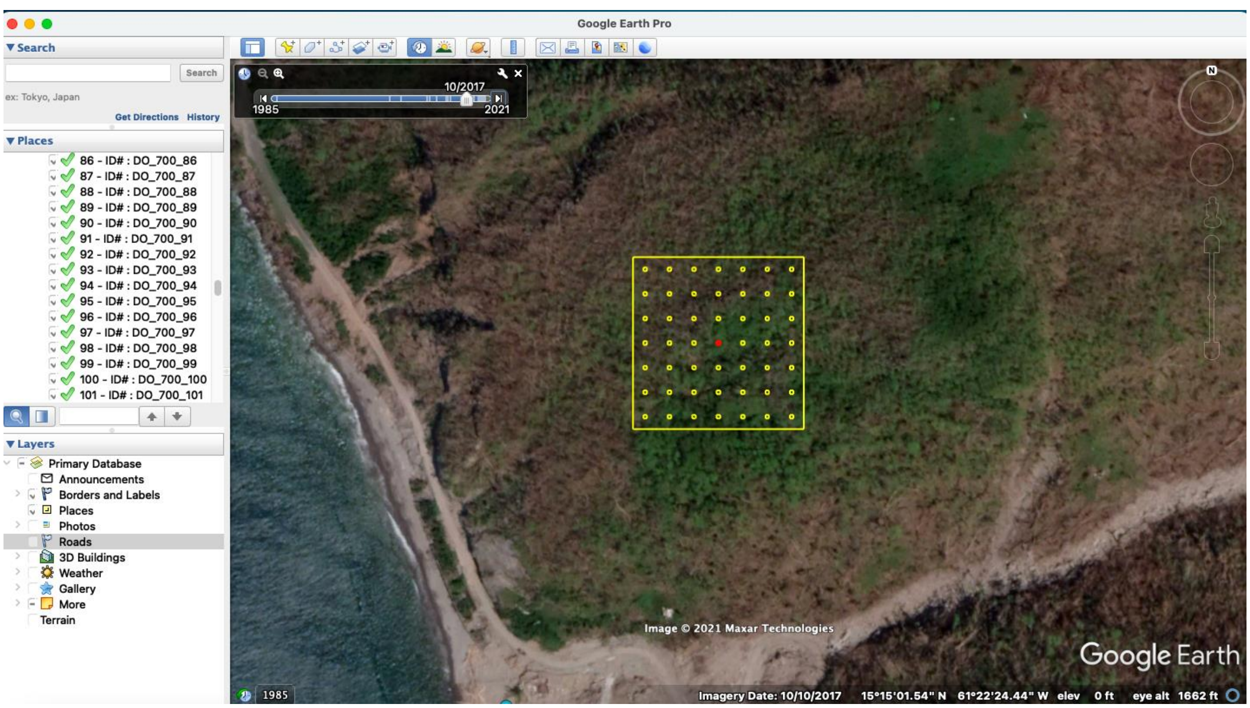


Figure 53 Visualization of Dry Scrub forest (same plot) in a high-resolution image after hurricane disturbance

Level 1: CROPLANDS (C)

Level 2: Perennial Crop

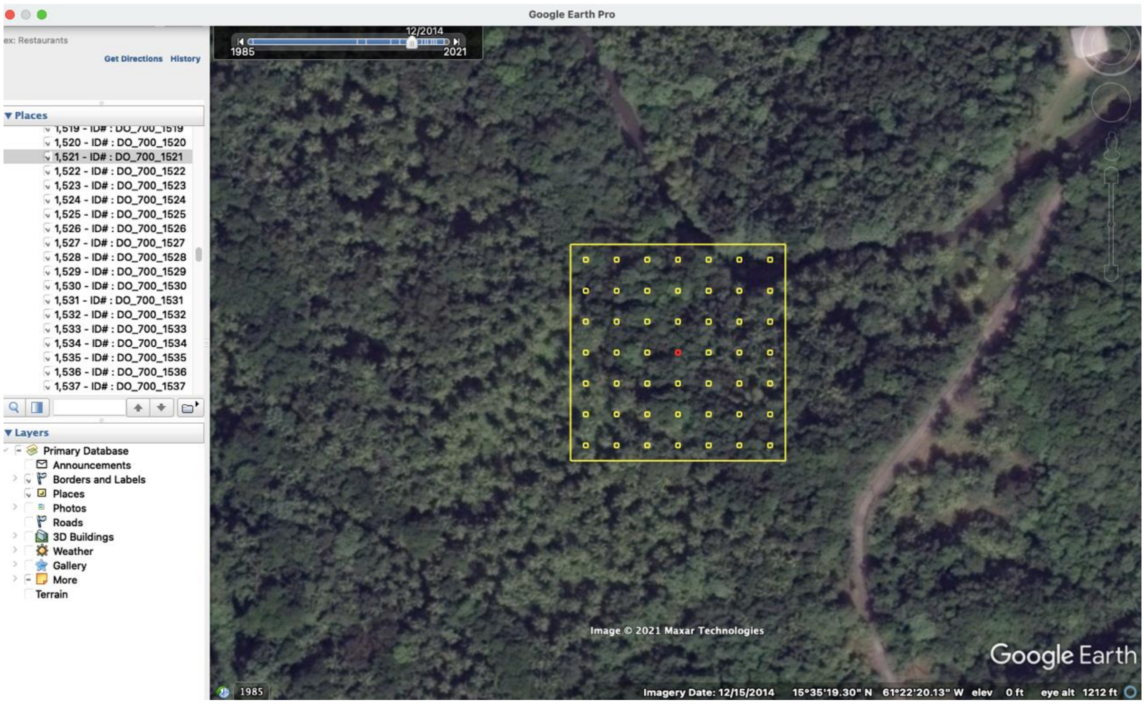


Figure 54 Visualization of perennial crop in a high-resolution image

Level 2: Annual Crop

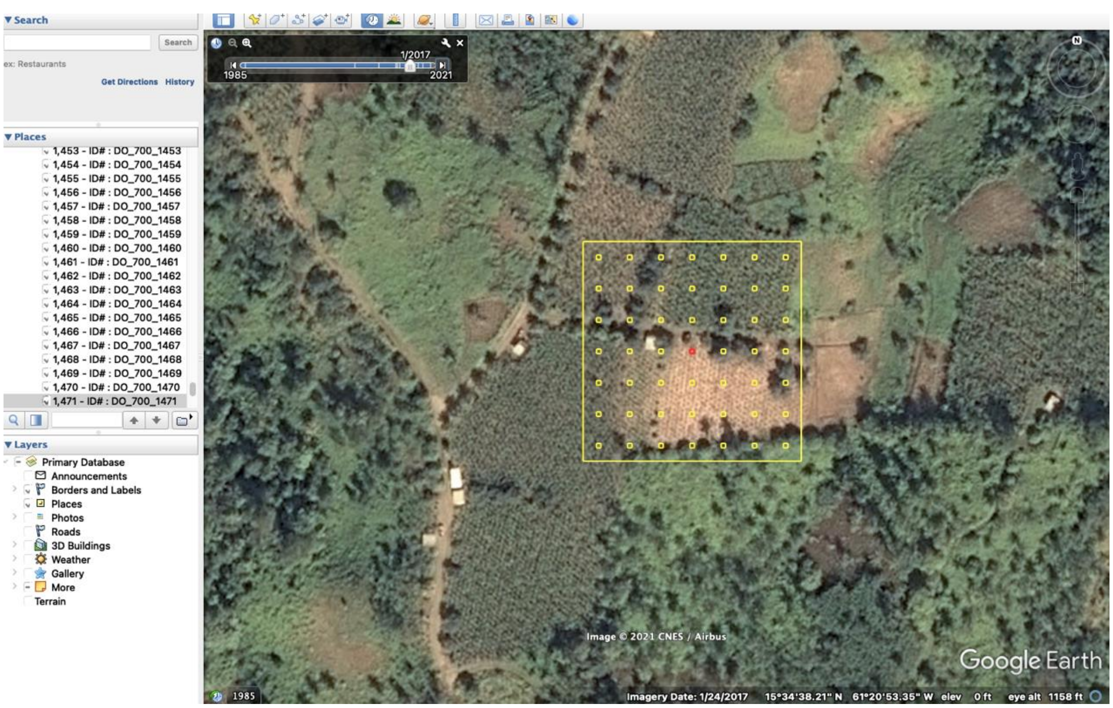


Figure 55 Visualization of annual crop in a high-resolution image

LEVEL 1: GRASSLANDS (G)

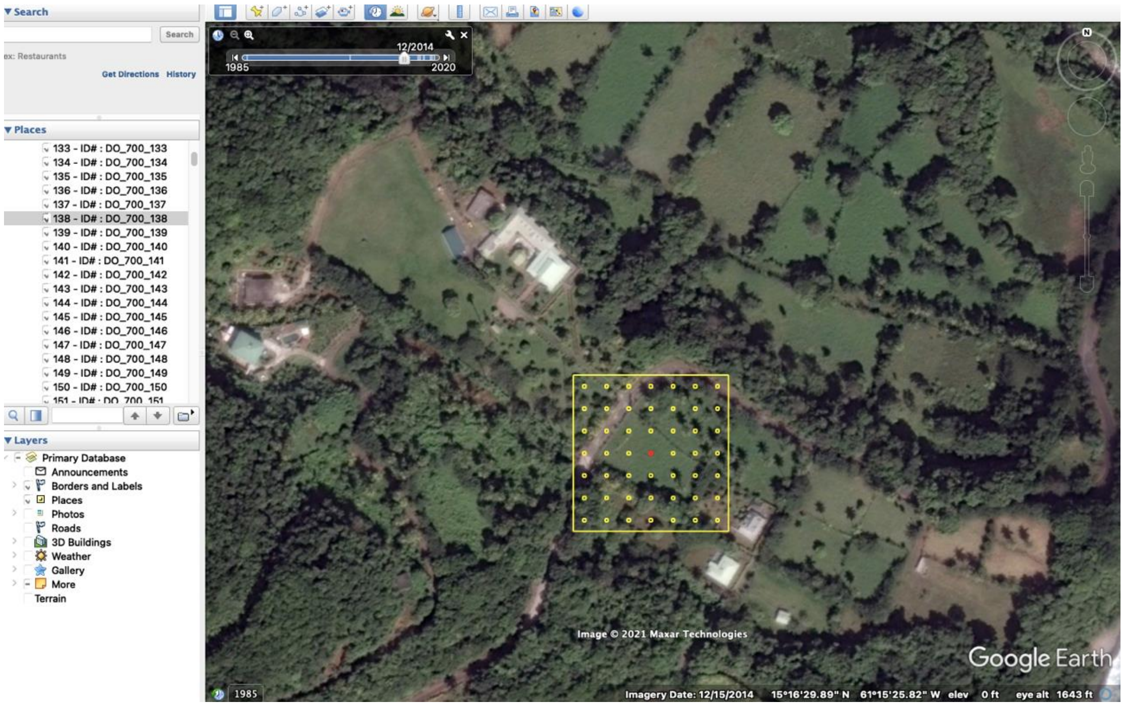


Figure 56 Visualization of grasslands in a high-resolution image

LEVEL 1: SETTLEMENTS (S)

Level 2: Urban areas

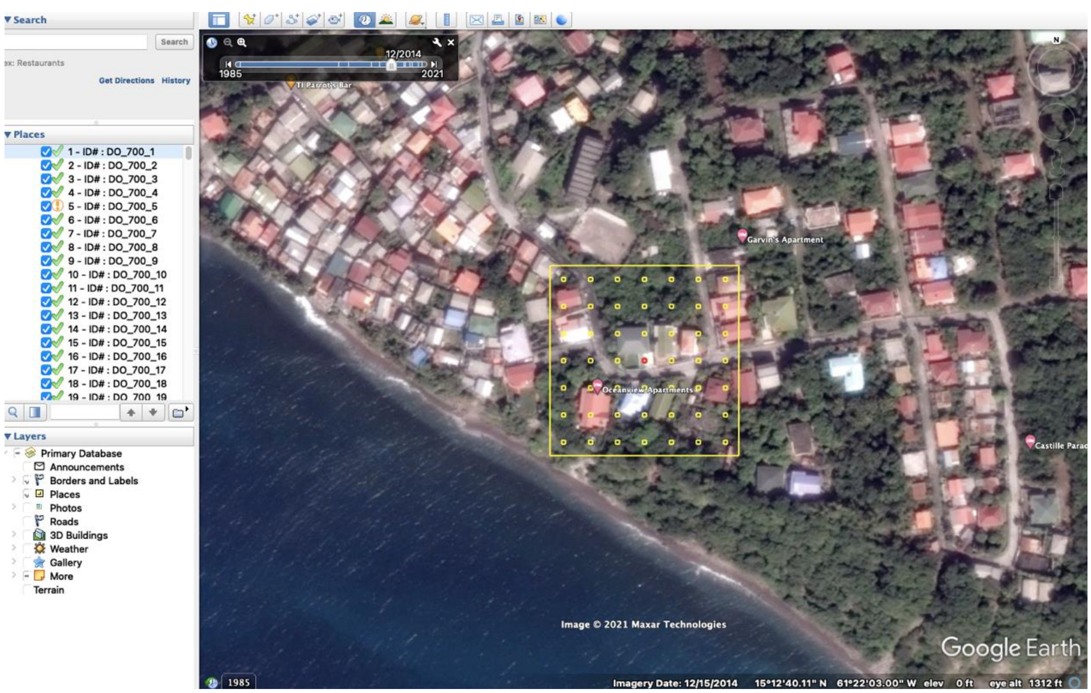


Figure 57 Visualization of settlements in a high-resolution image

Level 2: Woody Settlements

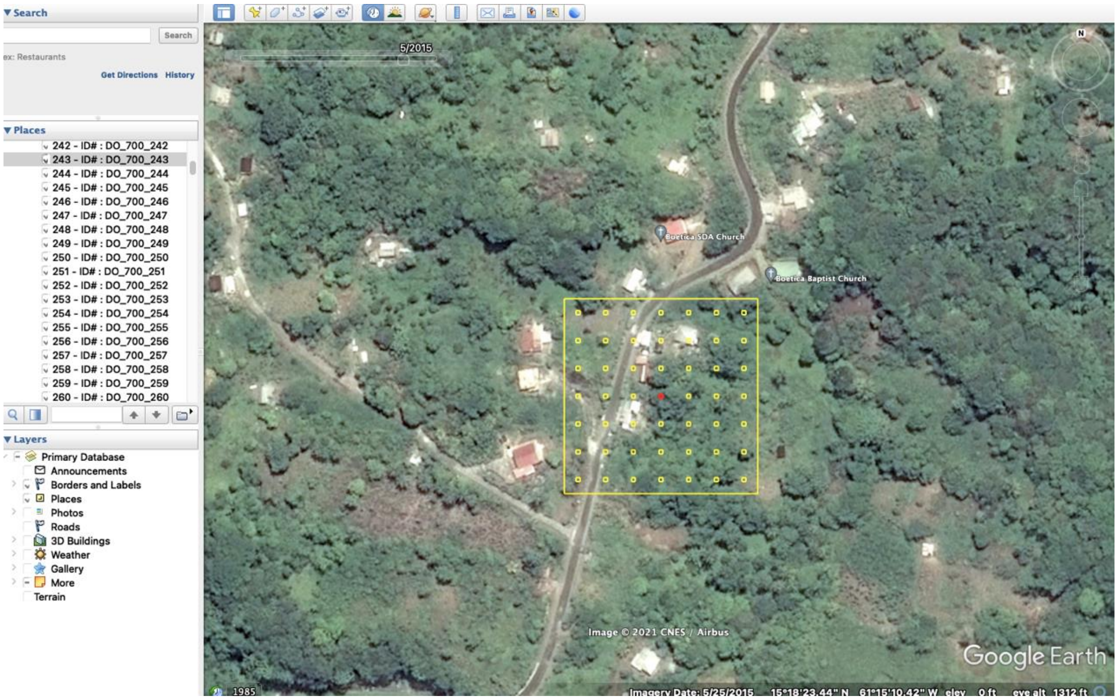


Figure 58 Visualization of woody settlements in a high-resolution image

LEVEL 1: OTHER LANDS (O)

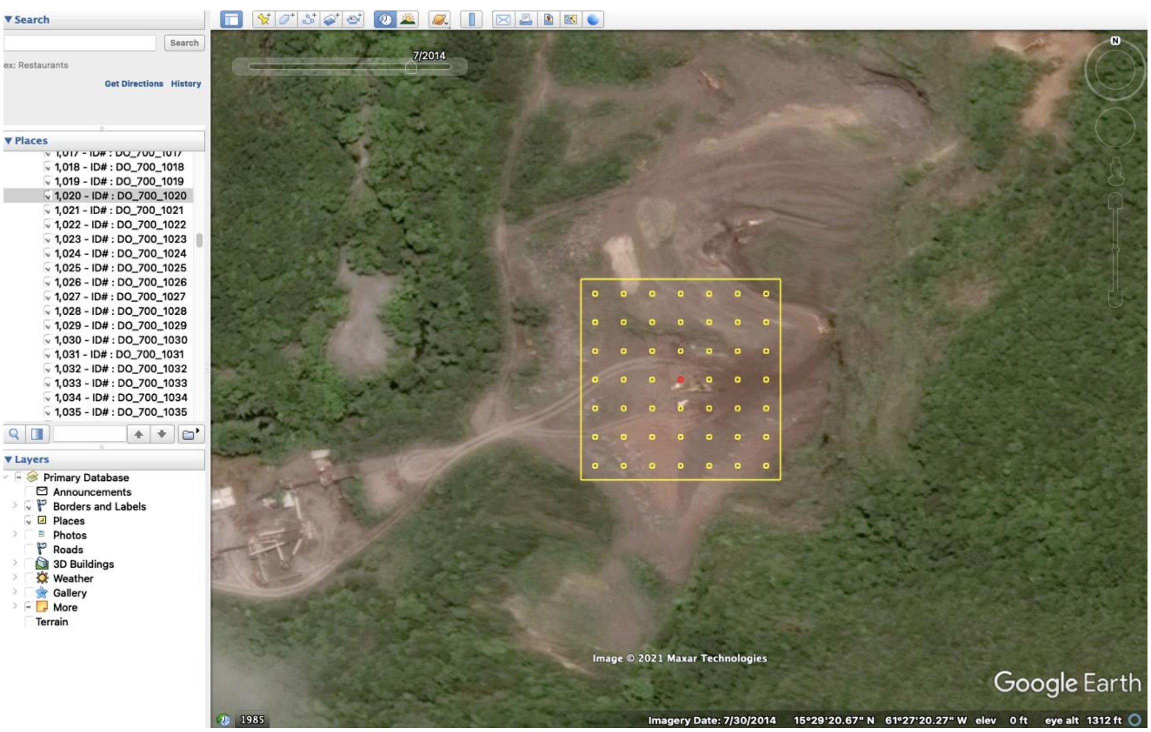


Figure 59 Visualization of other lands (mining) in a high-resolution image

7.1.9 Plot analysis with support images (Sentinel, Landsat 8, Landsat 7, Vegetation Indices)

The 1605 plots were divided into 4 groups. Each interpreter analyzed its assigned plots following the steps indicated in the diagram below (figure 61), which provides an overview of the key steps for assessing land use with Collect Earth and its supporting software:

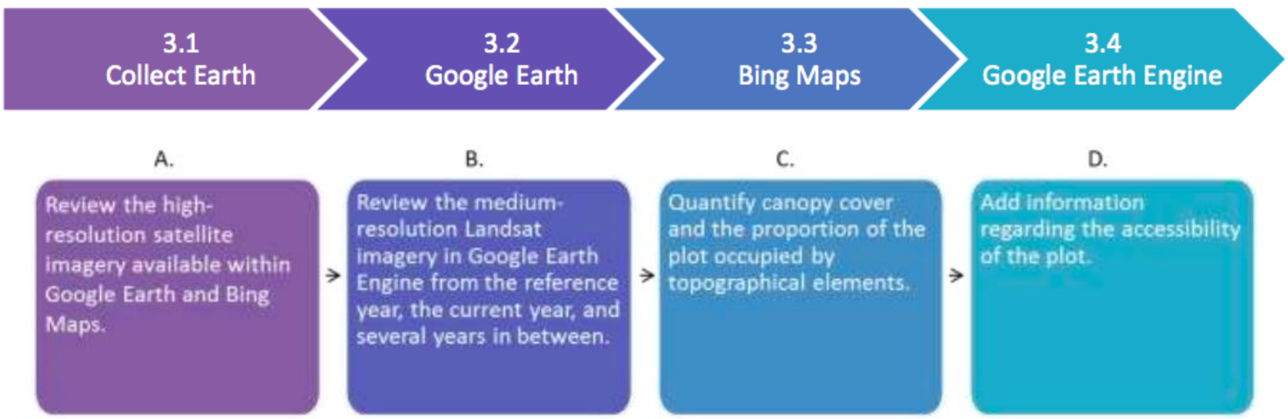


Figure 60. Support images used in CE

Microsoft's Bing Maps presents imagery provided by Digital Globe ranging from 3m to 30cm resolution. Google Earth Engine's web-based platform facilitates access to United States Geological Survey 30m resolution Landsat imagery. Through Bing Map, high spatial resolution satellite imagery from Digital Globe can be viewed and used for land use assessments. Collect Earth plot locations have been linked with Bing Maps because the latter web mapping service has a slightly different geographic coverage. Through Google Earth Engine is the Landsat Greenest-Pixel top of atmosphere (TOA) reflectance composite. These composites, which are available for Landsat 4, 5, 7 and 8, are created by drawing upon all images of a site for a full calendar year. The greenest pixels, with the highest NDVI (normalized difference vegetation index) value, are compiled to create a new image. These composites are particularly useful in tropical forest areas that may be prone to frequent cloud cover. This infrared color composite presents forest with a reddish-brown color and agriculture, grass, and shrubs in lighter shades of orange. Water appears purple and urban areas are shades of blue and green. This composite, pools information from bands that are sensitive to different types of reflectance.

The vegetation indices are indicators that describe the greenness — the relative density and health of vegetation — for each picture element, or pixel, in a satellite image. Collect Earth displays through Google Earth Engine Playground a set of time-frame charts with different vegetation indices to help the user identify possible trends and seasonality for the area of interest.

Historically Imagery

For the annual analysis, interpreters used the historical tool, which allows seeing images from different years, which could be visualizing either high-resolution images (figure 62), or images from Landsat 7, Landsat 8, and Sentinel 2 (figure 63).

Figure 61. Historical imagery

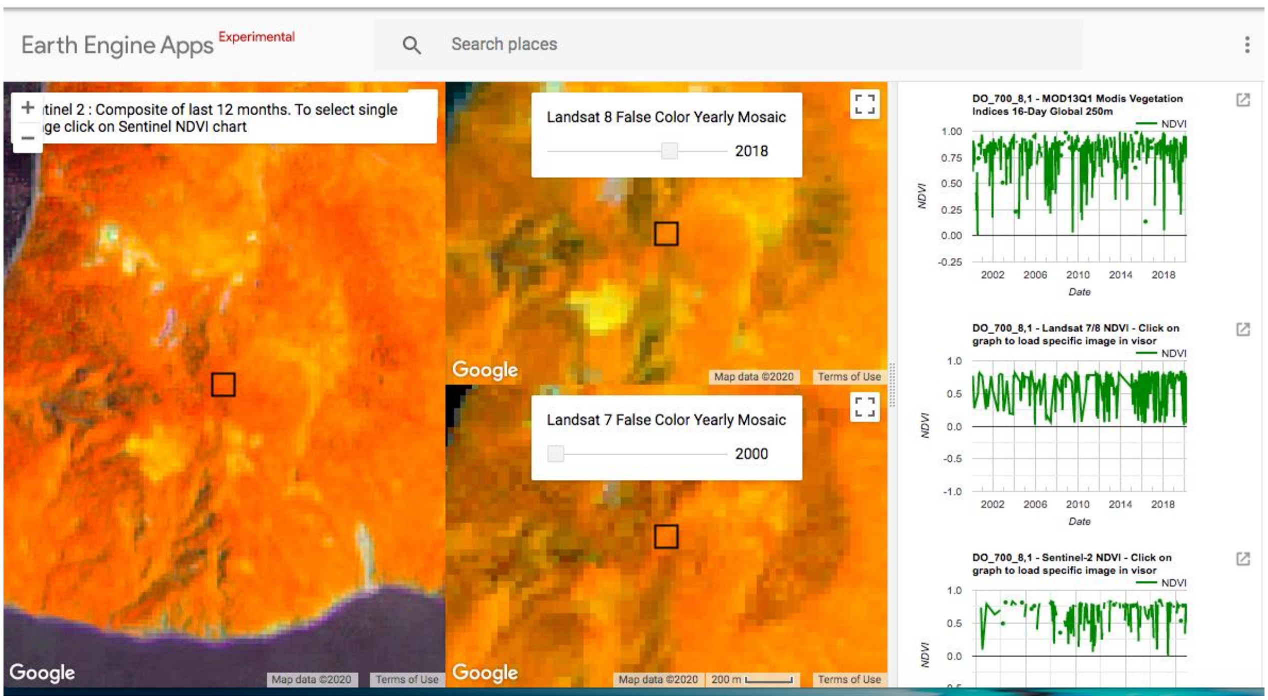


Figure 62. Examples of the use of Google Earth Engine

7.1.10 Collect Earth database with results of the interpretation

After the assessment was finished, a CVS database from the Collect Earth assessment with all information recorded for each of the 1605 plots from 2000 to 2017 was extracted. Each of the plots includes the time series indicating the land use (figure 64), whether the plot remained in the same land use category or if there was a land use conversion, and year of conversion, and if there was a disturbance and year of the event.

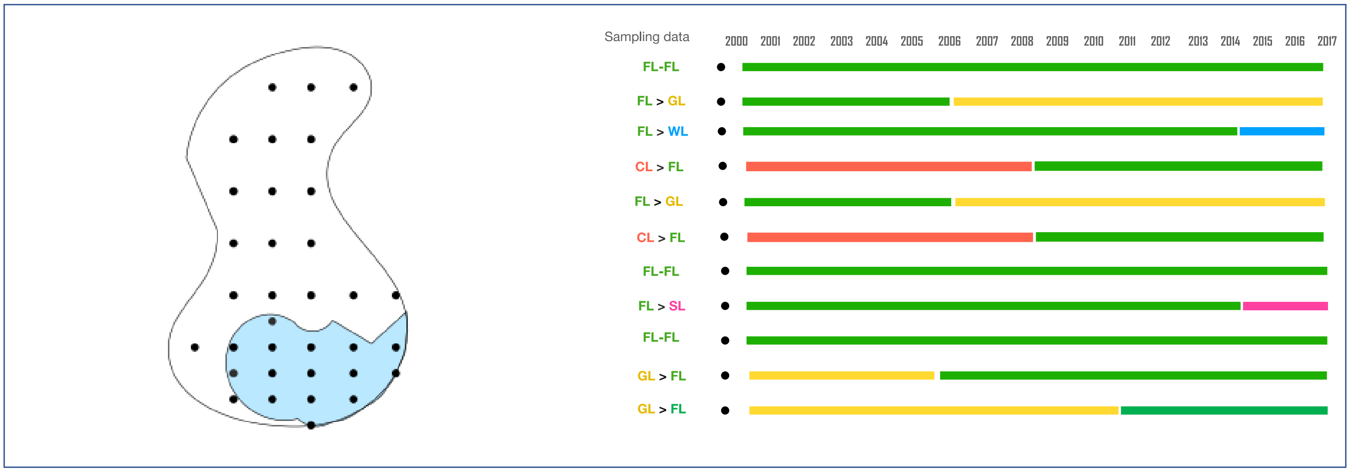


Figure 63 Plot by plot analysis of land use and land use change

7.1.11 Quality Control of the Activity Data

Several rounds of Quality Control took place while developing the Collect Earth Assessment. Plots misidentified were corrected by the National Interpreters (4) and two experts leads from Panama and Belize. The Matrix of impossible transitions of Land Use and Disturbances developed before the assessment was used to identify the errors during the assessment. Elevation ranges previously agreed as well as influence of location in forest types was also used to identify errors (for example, a coastal forest in >1000 m.a.s.l). Posterior to the assessment that took place in Saint Lucia, the technical lead did a full reassessment of all plots, and it was compared to the information previously collected. Different plots were revised and corrected if necessary.[73]

7.1.12 Data processing _ Area estimation

For data analysis of the 1605 plots, a coding system was created to aggregate plots with the same land use or land use change (figure 65).

[73] As part of the uncertainty analysis, a percentage of error interpretation will be given.

Figure 64 Grouping plots with the same land use dynamic.

Codes depict a single trajectory or dynamic of each plot informing land use, land use change (if any) and disturbances (if any). These trajectories in the form of a code were created to simplify the analysis as it sums up all plots with the same trajectory, represented in the same code, reducing considerably the number of plots for which IPCC equations were applied (figure 66).

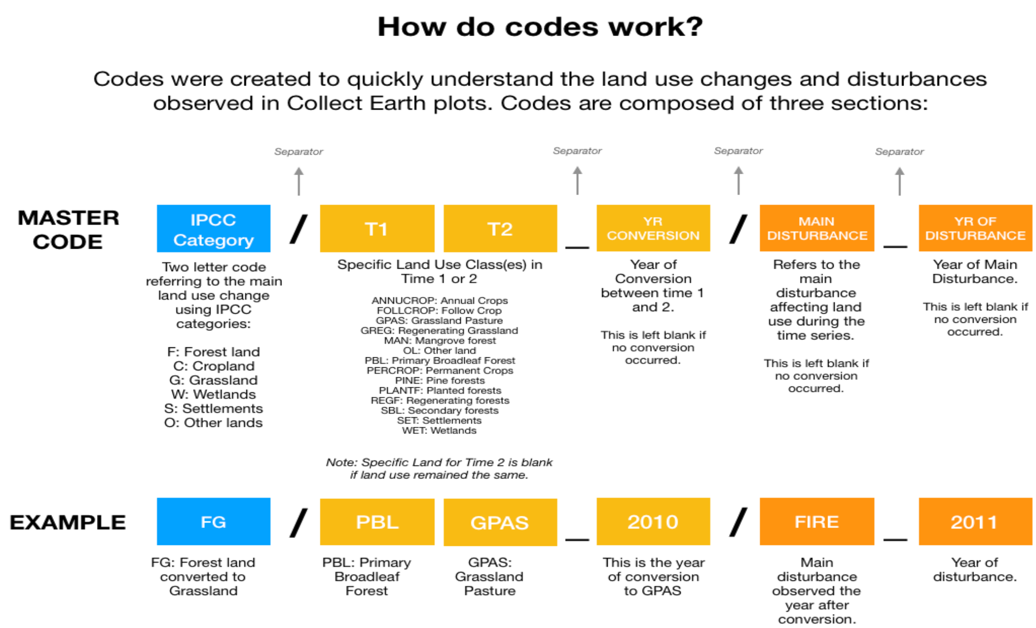


Figure 65 Coding system of land use dynamics

Once the code was applied to each of the 1605 assessed plots, information was summarized on the form of a pivot table (table 11). Then, area that each trajectory was calculated by multiplying the number of plots of each trajectory by the expansion factor, which was calculated diving the total surface of the country (75000 Ha) by the total number of plots of the grid (1605 plots), equal to 43.76 Ha, meaning that each 1Ha plot represents an area of 43.76 ha, area that is distributed surrounding the plot.

Table 11 pivot table summarizing all land use dynamics and area estimation.

STEP 2 - AREA ESTIMATION (Plot count * Exp. Factor)		
	1605	75000
Row Labels	Count of Transition Coding	Area [Ha]
CC/CANNUAL	130	6074.8
CC/CPER	84	3925.2
CF/CANNUAL>FRAIN_2013/Hurricane_2017	1	46.7
CG/CANNUAL>GGRASS_2014/_	1	46.7
CG/CPER>GGRASS_2014/_	1	46.7
CG/CPER>GGRASS_2018/_	1	46.7
CG/CPER>GWGRASS_2017/_	1	46.7
CS/CANNUAL>SSET_2016/_	1	46.7
CS/CPER>SSET_2014/_	1	46.7
FC/FCLOUD>CANNUAL_2011/_	1	46.7
FC/FDEC>CANNUAL_2005/_	1	46.7
FC/FDSCRUB>CANNUAL_2011/_	1	46.7
FC/FEVER>CANNUAL_2017/_	1	46.7
FC/FEVER>CANNUAL_2018/_	1	46.7
FC/FRAIN>CANNUAL_2013/_	1	46.7
FF/FELF/Hurricane_2017	43	2009.3
FF/FCLOUD/Hurricane_2017	104	4859.8
FF/FRAIN/Hurricane_2017	600	28037.4
FF/FEVER/Hurricane_2017	225	10514.0
FF/FEVER/Shifting Cultivation_2015	1	46.7
FF/FDEC/Hurricane_2017	134	6261.7
FF/FDSCRUB/Hurricane_2017	39	1822.4
FF/FLIT/Hurricane_2015	1	46.7
FF/FLIT/Hurricane_2017	85	3972.0
FG/FDEC>GWGRASS_2012/_	1	46.7
FG/DSCRUB>GWGRASS_2005/_	1	46.7
FG/FEVER>GWGRASS_2015/_	2	93.5
FG/FEVER>GWGRASS_2016/_	1	46.7
FG/FLIT>GGRASS_2015/_	1	46.7
FG/FRAIN>GGRASS_2014/_	1	46.7
FO/DSCRUB>Mining_2014/_	1	46.7
FO/FRAIN>OOTHER_2017/_	1	46.7
FS/DSCRUB>SSET_2011/_	1	46.7
FS/DSCRUB>SWSET_2005/_	1	46.7
FS/DSCRUB>SWSET_2014/_	1	46.7

FS/FEVER>SWSET_2012/_	1	46.7
FS/FRAIN>SWSET_2006/_	1	46.7
FS/FRAIN>SWSET_2012/_	1	46.7
GF/GGRASS>FRAIN_2016/Hurricane_2017	1	46.7
GG/GGRASS	26	1215.0
GG/GWGRASS	29	1355.1
OO/IMIN	2	93.5
OO/OOTHER	7	327.1
SS/SSET	27	1261.7
SS/SWSET	34	1588.8
WW/WWET	5	233.6
Sum	1605.0	75000.0

For facilitating the understanding of the data, the information of the pivot table was reorganized in land use and land use change matrices and disturbance matrices (figure 67).

Figure 66. Land use change matrices (area in ha)

2016-2017

Land Use and Land Use Change (LULUC) Vertical: Final Use Horizontal: Initial Use	Montane – Elfin forest	Montane – Cloud Forest	Montane – Rainforest	Seasonal Semi Evergreen	Seasonal Deciduous	Dry Scrub	Littoral Evergreen Forest	Annual Crops	Perennial Crops	Pastures	Shurblands	Natural Water Bodies	Urban Areas	Woody Settlement	Mining	Beaches, rocky areas	Grand Total
Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4860															4860
Montane – Rainforest			28131													47	28178
Seasonal Semi Evergreen				10607				47									10654
Seasonal Decidious					6262												6262
Dry Scrub						1822											1822
Littoral Evergreen Forest							4019										4019
Annual Crops								6262									6262
Perennial Crops									3972		47						4019
Pastures										1402							1402
Shurblands											1589						1589
Natural Water Bodies												234					234
Urban Areas													1402				1402
Woody Settlement														1822			1822
Mining															140		140
Beaches, rocky areas																327	327
Grand Total	2009	4860	28131	10607	6262	1822	4019	6308	3972	1402	1636	234	1402	1822	140	374	75000

2015-2016

	Montane – Elfin forest	Montane – Cloud Forest	Montane – Rainforest	Seasonal Semi Evergreen	Seasonal Deciduous	Dry Scrub	Littoral Evergreen Forest	Annual Crops	Perennial Crops	Pastures	Shurblands	Natural Water Bodies	Urban Areas	Woody Settlement	Mining	Beaches, rocky areas	Grand Total
Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4860															4860
Montane – Rainforest			28131														28131
Seasonal Semi Evergreen				10654							47						10701
Seasonal Decidious					6262												6262
Dry Scrub						1822											1822
Littoral Evergreen Forest							4019										4019
Annual Crops								6262					47				6308
Perennial Crops									4019								4019
Pastures										1402							1402
Shurblands			47								1542						1589
Natural Water Bodies												234					234
Urban Areas													1355				1355
Woody Settlement														1822			1822
Mining															140		140
Beaches, rocky areas																327	327
Grand Total	2009	4860	28178	10654	6262	1822	4019	6262	4019	1402	1589	234	1402	1822	140	327	75000

2014-2015

	Montane – Elfin forest	Montane – Cloud Forest	Montane – Rainforest	Seasonal Semi Evergreen	Seasonal Deciduous	Dry Scrub	Littoral Evergreen Forest	Annual Crops	Perennial Crops	Pastures	Shurblands	Natural Water Bodies	Urban Areas	Woody Settlement	Mining	Beaches, rocky areas	Grand Total
Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4860															4860
Montane – Rainforest			28131														28131
Seasonal Semi Evergreen				10701							93						10794
Seasonal Decidious					6262												6262
Dry Scrub						1822											1822
Littoral Evergreen Forest							4019			47							4065
Annual Crops								6308									6308
Perennial Crops									4019								4019
Pastures										1355							1355
Shurblands											1495						1495
Natural Water Bodies												234					234
Urban Areas													1355				1355
Woody Settlement														1822			1822
Mining															140		140
Beaches, rocky areas																327	327
Grand Total	2009	4860	28131	10701	6262	1822	4019	6308	4019	1402	1589	234	1355	1822	140	327	75000

2013-2014

Land Use and Land Use Change (LULUC) Vertical: Final Use Horizontal: Initial Use	Montane – Elfin forest	Montane – Cloud Forest	Montane – Rainforest	Seasonal Semi Evergreen	Seasonal Deciduous	Dry Scrub	Littoral Evergreen Forest	Annual Crops	Perennial Crops	Pastures	Shurblands	Natural Water Bodies	Urban Areas	Woody Settlement	Mining	Beaches, rocky areas	Grand Total
Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4860															4860
Montane – Rainforest			28131							47							28178
Seasonal Semi Evergreen				10794													10794
Seasonal Decidious					6262												6262
Dry Scrub						1822								47	47		1916
Littoral Evergreen Forest							4065										4065
Annual Crops								6308		47							6355
Perennial Crops									4019	47			47				4112
Pastures										1215							1215
Shurblands											1495						1495
Natural Water Bodies												234					234
Urban Areas													1308				1308
Woody Settlement														1776			1776
Mining															93		93
Beaches, rocky areas																327	327
Grand Total	2009	4860	28131	10794	6262	1822	4065	6308	4019	1355	1495	234	1355	1822	140	327	75000

2012-2013

Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4860															4860
Montane – Rainforest			28131					47									28178
Seasonal Semi Evergreen				10794													10794
Seasonal Decidious					6262												6262
Dry Scrub						1916											1916
Littoral Evergreen Forest							4065										4065
Annual Crops			47					6308									6355
Perennial Crops									4112								4112
Pastures										1215							1215
Shurblands											1495						1495
Natural Water Bodies												234					234
Urban Areas													1308				1308
Woody Settlement														1776			1776
Mining															93		93
Beaches, rocky areas																327	327
Grand Total	2009	4860	28178	10794	6262	1916	4065	6355	4112	1215	1495	234	1308	1776	93	327	75000

2011-2012

Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4860															4860
Montane – Rainforest			28178											47			28224
Seasonal Semi Evergreen				10794										47			10841
Seasonal Decidious					6262						47						6308
Dry Scrub						1916											1916
Littoral Evergreen Forest							4065										4065
Annual Crops								6355									6355
Perennial Crops									4112								4112
Pastures										1215							1215
Shurblands											1449						1449
Natural Water Bodies												234					234
Urban Areas													1308				1308
Woody Settlement														1682			1682
Mining															93		93
Beaches, rocky areas																327	327
Grand Total	2009	4860	28178	10794	6262	1916	4065	6355	4112	1215	1495	234	1308	1776	93	327	75000

2010-2011

Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4860						47									4907
Montane – Rainforest			28224														28224
Seasonal Semi Evergreen				10841													10841
Seasonal Decidious					6308												6308
Dry Scrub						1916		47					47				2009
Littoral Evergreen Forest							4065										4065
Annual Crops								6262									6262
Perennial Crops									4112								4112
Pastures										1215							1215
Shurblands											1449						1449
Natural Water Bodies												234					234
Urban Areas													1262				1262
Woody Settlement														1682			1682
Mining															93		93
Beaches, rocky areas																327	327
Grand Total	2009	4860	28224	10841	6308	1916	4065	6355	4112	1215	1449	234	1308	1682	93	327	75000

2009-2010

Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4907															4907
Montane – Rainforest			28224														28224
Seasonal Semi Evergreen				10841													10841
Seasonal Decidious					6308												6308
Dry Scrub						2009											2009
Littoral Evergreen Forest							4065										4065
Annual Crops								6262									6262
Perennial Crops									4112								4112
Pastures										1215							1215
Shurblands											1449						1449
Natural Water Bodies												234					234
Urban Areas													1262				1262
Woody Settlement														1682			1682
Mining															93		93
Beaches, rocky areas																327	327
Grand Total	2009	4907	28224	10841	6308	2009	4065	6262	4112	1215	1449	234	1262	1682	93	327	75000

2008-2009

Land Use and Land Use Change (LULUC) Vertical: Final Use Horizontal: Initial Use	Montane – Elfin forest	Montane – Cloud Forest	Montane – Rainforest	Seasonal Semi Evergreen	Seasonal Decidious	Dry Scrub	Littoral Evergreen Forest	Annual Crops	Perennial Crops	Pastures	Shurblands	Natural Water Bodies	Urban Areas	Woody Settlement	Mining	Beaches, rocky areas	Grand Total
Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4907															4907
Montane – Rainforest			28224														28224
Seasonal Semi Evergreen				10841													10841
Seasonal Decidious					6308												6308
Dry Scrub						2009											2009
Littoral Evergreen Forest							4065										4065
Annual Crops								6262									6262
Perennial Crops									4112								4112
Pastures										1215							1215
Shurblands											1449						1449
Natural Water Bodies												234					234
Urban Areas													1262				1262
Woody Settlement														1682			1682
Mining															93		93
Beaches, rocky areas																327	327
Grand Total	2009	4907	28224	10841	6308	2009	4065	6262	4112	1215	1449	234	1262	1682	93	327	75000

2007-2008

Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4907															4907
Montane – Rainforest			28224														28224
Seasonal Semi Evergreen				10841													10841
Seasonal Decidious					6308												6308
Dry Scrub						2009											2009
Littoral Evergreen Forest							4065										4065
Annual Crops								6262									6262
Perennial Crops									4112								4112
Pastures										1215							1215
Shurblands											1449						1449
Natural Water Bodies												234					234
Urban Areas													1262				1262
Woody Settlement														1682			1682
Mining															93		93
Beaches, rocky areas																327	327
Grand Total	2009	4907	28224	10841	6308	2009	4065	6262	4112	1215	1449	234	1262	1682	93	327	75000

2006-2007

Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4907															4907
Montane – Rainforest			28224														28224
Seasonal Semi Evergreen				10841													10841
Seasonal Decidious					6308												6308
Dry Scrub						2009											2009
Littoral Evergreen Forest							4065										4065
Annual Crops								6262									6262
Perennial Crops									4112								4112
Pastures										1215							1215
Shurblands											1449						1449
Natural Water Bodies												234					234
Urban Areas													1262				1262
Woody Settlement														1682			1682
Mining															93		93
Beaches, rocky areas																327	327
Grand Total	2009	4907	28224	10841	6308	2009	4065	6262	4112	1215	1449	234	1262	1682	93	327	75000

2005-2006

Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4907															4907
Montane – Rainforest			28224											47			28271
Seasonal Semi Evergreen				10841													10841
Seasonal Decidious					6308												6308
Dry Scrub						2009											2009
Littoral Evergreen Forest							4065										4065
Annual Crops								6262									6262
Perennial Crops									4112								4112
Pastures										1215							1215
Shurblands											1449						1449
Natural Water Bodies												234					234
Urban Areas													1262				1262
Woody Settlement														1636			1636
Mining															93		93
Beaches, rocky areas																327	327
Grand Total	2009	4907	28224	10841	6308	2009	4065	6262	4112	1215	1449	234	1262	1682	93	327	75000

2004-2005

Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4907															4907
Montane – Rainforest			28271														28271
Seasonal Semi Evergreen				10841													10841
Seasonal Decidious					6308			47									6355
Dry Scrub						2009					47			47			2103
Littoral Evergreen Forest							4065										4065
Annual Crops								6215									6215
Perennial Crops									4112								4112
Pastures										1215							1215
Shurblands											1402						1402
Natural Water Bodies												234					234
Urban Areas													1262				1262
Woody Settlement														1589			1589
Mining															93		93
Beaches, rocky areas																327	327
Grand Total	2009	4907	28271	10841	6308	2009	4065	6262	4112	1215	1449	234	1262	1636	93	327	75000

Land Use and Land Use Change (LULUC) Vertical: Final Use Horizontal: Initial Use	Montane – Elfin forest	Montane – Cloud Forest	Montane – Rainforest	Seasonal Semi Evergreen	Seasonal Deciduous	Dry Scrub	Littoral Evergreen Forest	Annual Crops	Perennial Crops	Pastures	Shurblands	Natural Water Bodies	Urban Areas	Woody Settlement	Mining	Beaches, rocky areas	Grand Total
2003-2004																	
Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4907															4907
Montane – Rainforest			28271														28271
Seasonal Semi Evergreen				10841													10841
Seasonal Decidious					6355												6355
Dry Scrub						2103											2103
Littoral Evergreen Forest							4065										4065
Annual Crops								6215									6215
Perennial Crops									4112								4112
Pastures										1215							1215
Shurblands											1402						1402
Natural Water Bodies												234					234
Urban Areas													1262				1262
Woody Settlement														1589			1589
Mining															93		93
Beaches, rocky areas																327	327
Grand Total	2009	4907	28271	10841	6355	2103	4065	6215	4112	1215	1402	234	1262	1589	93	327	75000
2002-2003																	
Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4907															4907
Montane – Rainforest			28271														28271
Seasonal Semi Evergreen				10841													10841
Seasonal Decidious					6355												6355
Dry Scrub						2103											2103
Littoral Evergreen Forest							4065										4065
Annual Crops								6215									6215
Perennial Crops									4112								4112
Pastures										1215							1215
Shurblands											1402						1402
Natural Water Bodies												234					234
Urban Areas													1262				1262
Woody Settlement														1589			1589
Mining															93		93
Beaches, rocky areas																327	327
Grand Total	2009	4907	28271	10841	6355	2103	4065	6215	4112	1215	1402	234	1262	1589	93	327	75000
2001-2002																	
Montane – Cloud Forest		4907															4907
Montane – Rainforest			28271														28271
Seasonal Semi Evergreen				10841													10841
Seasonal Decidious					6355												6355
Dry Scrub						2103											2103
Littoral Evergreen Forest							4065										4065
Annual Crops								6215									6215
Perennial Crops									4112								4112
Pastures										1215							1215
Shurblands											1402						1402
Natural Water Bodies												234					234
Urban Areas													1262				1262
Woody Settlement														1589			1589
Mining															93		93
Beaches, rocky areas																327	327
(blank)																	
Grand Total	2009	4907	28271	10841	6355	2103	4065	6215	4112	1215	1402	234	1262	1589	93	327	75000
2000-2001																	
Montane – Elfin forest	2009																2009
Montane – Cloud Forest		4907															4907
Montane – Rainforest			28271														28271
Seasonal Semi Evergreen				10841													10841
Seasonal Decidious					6355												6355
Dry Scrub						2103											2103
Littoral Evergreen Forest							4065										4065
Annual Crops								6215									6215
Perennial Crops									4112								4112
Pastures										1215							1215
Shurblands											1402						1402
Natural Water Bodies												234					234
Urban Areas													1262				1262
Woody Settlement														1589			1589
Mining															93		93
Beaches, rocky areas																327	327
Grand Total	2009	4907	28271	10841	6355	2103	4065	6215	4112	1215	1402	234	1262	1589	93	327	75000

7.2 Emission Factors

The information on Emission Factors (EFs) was obtained from default values of the 2006 IPCC Guidelines, 2019 Refinement to the 2006 IPCC Guidelines, and from the National Forest Inventory from Saint Lucia (2009), as both islands share the same forest types, and no recent Forest inventory has taken place in Dominica.

For forest land,

- Dominica used the default values from the 2006 IPCC Guidelines for the carbon fraction of wood for all forest classes.
- Literature review for average annual above-ground biomass growth Elfin and Cloud Forest, Montane Rainforest and Semi-evergreen Forest
- The default values from the 2019 Refinement to the 2006 IPCC Guidelines for the ratio of below-ground to above-ground biomass, litter and deadwood stocks for all forest classes, and CH_4 and N_2O EFs
- Regional values estimated from Chave et al. (2005) and data from the Saint Lucia's NFI for the above-ground biomass of all forest classes.
- Local expert judgment for the fraction of biomass loss due to disturbance for all forest classes and transfers from AGB C pool to DOM pool.

For cropland,

- Dominica used the default EFs from the 2006 IPCC Guidelines for the carbon fraction, biomass accumulation rate, above-ground biomass, litter and deadwood stocks for all cropland classes; and the default values from the 2019 Refinement to the 2006 IPCC Guidelines for the ratio of below-ground to above-ground biomass for perennial cropland.

For grassland,

- Dominica used the EFs from the 2006 IPCC Guidelines for all carbon pools covered by the FREL/FRL .

For settlements,

- Dominica used the default EFs from the 2006 IPCC Guidelines for the carbon fraction of woody settlements; and the default values from the 2019 Refinement to the 2006 IPCC Guidelines were used for the ratio of below-ground to above-ground biomass for woody settlements.

Dominica has decided to use emission and removal factor from different scientific papers and IPCC guidelines, selecting the most updated values available and considered most appropriate to the national circumstances.

National Forest Inventory [from Saint Lucia] (Tier 2)

In 2009, two hundred plots were surveyed, each 20 meters in radius, covering a wide range of elevations in all parts of the country. Both floristic and biophysical data were recorded within every plot (table 12). To guide the selection of field sites, a simple starter map was produced, dividing Saint Lucia into 24 cells and showing approximate elevational zones and known areas of botanical interest (Graveson, 2009).[74] The floristic data were analyzed using Two-way Indicator Species Analysis (TWINSPAN), supported with a manual floristic analysis, to assign the plots to distinct vegetation classes. Each vegetation class is described and illustrated in some detail in the report.

A simple method to sample quite rapidly the vegetation, the physiognomy and the habitats throughout the cells and vegetation zones on the starting map was developed. A standardized method that could be applied to all types

[74] Graveson (2009). National Forest Demarcation and Bio-Physical Resource Inventory Project Caribbean – Saint Lucia: The Classification Of The Vegetation Of Saint Lucia. FCG International Ltd in association with AFC Consultants International GmbH

of forest was required, from secondary xeric woodland with small tightly packed trees, to rainforest where some tree trunks are extremely wide. After preliminary trials in contrasting xeric and wet forest types, a 20-metre radius circular plot with a 7m radius subplot in the center was chosen. The prime focus of the standardized survey was the 7m subplot.

Table 12 The biophysical and floristic information recorded from every plot

Plot measurements	Description
Plot	Plot number.
Date	Date of survey.
Location	Name of area plot is located in.
Tea m	Initials of surveyors present on this plot survey.
Description	Simple habitat type: e.g. river valley, degraded dry woodland, rainforest.
GPS N	Northing (UTM) of plot center point as read from GPS.
GPS E	Easting (UTM) of plot center point as read from GPS.
Rockiness	1=1-10% of ground covered by rocks; 2=10-30% of ground covered by rocks; 3=>30% of ground covered by rocks
Canopy (m)	Measured using a clinometer.
Canopy (%)	Estimated visually, using a mirror to reflect the canopy.
Number of stumps ≥5cm	0=no stumps of ≥5cm diameter found in plot; 1=1-4 stumps of ≥5cm diameter found in plot; 2=more than 4 stumps of ≥5cm diameter in plot.
Number of logs ≥5cm	0=no logs of ≥5cm diameter on ground; 1=1-4 logs ≥5cm diameter on ground; 2=more than 4 logs of ≥5cm diameter on ground.
Wind	Assessment based on canopy wind noise and sculpturing of vegetation. 0=no wind noise; 1=slight wind noise; 2=moderate wind noise; 3=full exposure - sculptured vegetation.
Slope (%)	Measured using a clinometer.
Direction (°)	Slope aspect. Measured using a compass.
Elevation (m)	As read from GPS, occasionally with later corrections from map. 1=1-30% of trees in plot have vines; 2=31-70% of trees in plot have vines; 3>70% of trees in plot have vines.
Epiphytes, including ferns	1=1-30% of tree have epiphytes; 2=31-70% of tree have epiphytes; 3>70% of trees have epiphytes.
Herbs (%)	% ground cover, visually estimated to nearest 5%
Ferns terrestrial (%)	% ground cover of non-arborescent ferns, visually estimated to nearest 5%.
Mosses/filmy ferns	0 = absent from trees; 1=surface cover present on most trees; 2=cover with depth on some trees; 3=surface cover with depth on most trees; 4=depths of 2cm present.
DBH1 (cm)	Measurement of the diameter at breast height of the widest trunk in the 7m subplot.
DBH2 (cm)	Measurement of the diameter at breast height of the second widest trunk in the 7m subplot.

Plot measurements	Description
Notes	Notes possibly useful for analysis, including details if the plot survey was not standard.
Species names of all trees DBH ≥5cm	Genus and species name for woody species with stem DBH≥5cm.
Number of trees	Number of individuals of every species with stem DBH≥5 cm (including arborescent herbs with trunks ≥5cm).
Species names of all saplings, herbs, vines and terrestrial ferns	Genus and species names.
Species names of all epiphytes	Genus and species names (dry forest areas only).
Other tree species	Additional tree species in the area, within the 20m plot radius.

All of the plot measurements shown in Table 11 were made in the 7m subplot, with the exception of the "other tree species", which were recorded throughout the 20m plot.

A stratified sampling approach was selected to decide where to conduct the plots, guided by the zones shown on the starter map to ensure not to miss any rare vegetation types. Plots were not chosen randomly but selected to illustrate the variety within each destination. Thus, in rainforest area, a steep slope, a gentle slope, a ridge top, a gulley, exposed positions, and/or sheltered positions might be chosen.

For major forest classes analysis Stehle's (1945) method was followed. For example, some species are typically found in the Deciduous Seasonal Forest where the upper canopy tends to lose its leaves in the dry season; these species were assigned a value of 1. Other species are typically found in moister environments, e.g. by rivers, and the trees lose some leaves during the dry season in proportion to the severity of the drought; these Semi-evergreen Seasonal Forest species were assigned a value of 2. Some species are typically found in the forest reserve and rarely outside, and do not have a seasonal leaf fall; these Lower Montane Rainforest trees were assigned a value of 3. Plants typically only found in Cloud Montane Rainforest were assigned a value of 4. Thus, following this method every plot was placed in a specific vegetation class (table 12).

Table 13 Attributed recorded by Forest Class

Attribute (Average by Forest Class)	Cloud Montane Rainforest (n=4)	Lower Montane and Montane Rainforest (rainforest) (n=75)	Semi-evergreen Seasonal Forest (n=22)	Deciduous Seasonal Forest (n=72)
Mean Forest Class Average (FCV)	3.5	2.9	1.9	1.1
Mean Number of Trees DBH≥5cm	25.0	30.0	17.0	19.0
Mean Rocks Score (0-3)	0.3	0.5	1.3	1.3
Mean Canopy Height (m)	5.3	27.6	22.8	11.2
Mean Canopy (%)	72.0	63.5	64.3	46.5
Mean Stumps Score (O-2)	0.3	1.1	1.1	0.8

Mean Logs Score (0-2)	1.0	1.4	1.5	1.0
Mean Wind Score (0-3)	2.0	1.2	0.6	1.2
Mean Slope (%)	28.0	26.0	20.0	16.0
Mean Elevation (m)	851	445	155	103
Highest Elevation (m)	869	680	390	413
Lowest Elevation (m)	824	102	15	4
Mean Vines Score (0-3)	1.3	1.4	1.0	0.8
Mean Epiphytes Score (0-3)	3.0	0.9	0.2	0.4
Mean Herbaceous (non-fern) ground cover (%)	10.0	4.1	5.9	13.4
Mean Ferns Ground Cover (%)	22.0	15.9	0.6	0.0
Mean Moss Score (0-4)	4.0	0.8	0.1	0.0

7.3 IPCC Methodologies applied

Following paragraphs 10[75] and 21[76] of annex to decision 17/CP.8, information on the specific category-level methodologies employed, including a description of the data and assumptions used to estimate GHG emissions and absorptions are provided in this section.

For the estimation of GHG emissions and removals for the Forest and Land Use Change Sector, Dominica has followed the methodologies proposed in the 2006 IPCC guidelines, Volume 4, Chapter 2 "*Generic Methodologies Applicable to Multiple Land-use Categories*", for change in biomass carbon stocks (above-ground biomass, below-ground biomass, dead organic matter). It includes the analysis for Land remaining in a land-use category and lands converted to a new land-use category. The Dominica's GHG inventory was conducted from a series of steps and using a range of data from diverse sources. The estimation of the emissions and removals used a combination of: (a) country-specific methods and data; (b) IPCC methodologies and (c) emission factors (EFs). IPCC methodology tiers 1, and 2 were applied. All definitions, methods and assumptions are described.

The equations were applied to each of the land use dynamics included in the pivot table (figure 68)

[75] Paragraph 10, annex to 17/CP.8, states that the IPCC Guidelines offer a default methodology which includes default emission factors and in some cases default activity data. As these default factors, data and assumptions may not always be appropriate for specific national circumstances, non-Annex I Parties are encouraged to use their country-specific and regional emission factors and activity data for key sources or, where these do not exist, to propose plans to develop them in a scientifically sound and consistent manner, provided that they are more accurate than the default data and documented transparently.

[76] According to paragraph 21, annex to 17/CP.8, Non-Annex I Parties are encouraged to provide information on methodologies used in the estimation of anthropogenic emissions by sources and removals by sinks of GHG not controlled by the Montreal Protocol, including a brief explanation of the sources of emission factors and activity data. If non-Annex I Parties estimate anthropogenic emissions and removals from country- specific sources and/or sinks which are not part of the IPCC Guidelines, they should explicitly describe the source and/or sink categories, methodologies, emission factors and activity data used in their estimation of emissions, as appropriate.

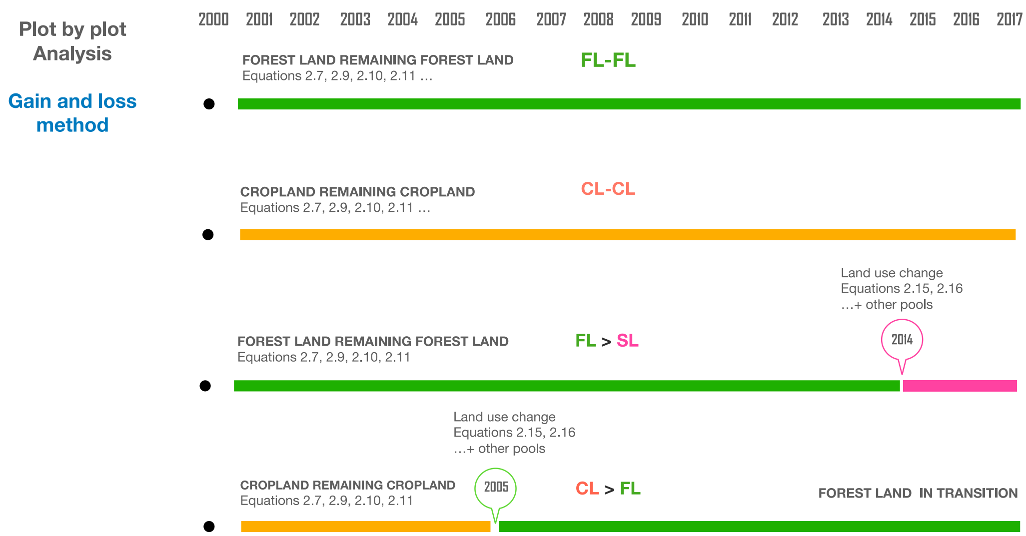


Figure 67 Diagram explaining how IPCC equations for the Gain and Loss method were applied to the land use dynamics.

7.3.1 Annual carbon stock changes for a stratum of a land-use category as a sum of changes in all pools (Equation 2.3, Ch2, V4)

$$\Delta C_{LUi} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{Li} + \Delta C_{HWP}$$

Where:

ΔCLU_i = carbon stock changes for a stratum of a land-use category. subscripts denote the following carbon pools:

AB = above-ground biomass
BB = below-ground biomass
DW = deadwood
LI = litter
SOC = soils
HWP = harvested wood products

Table 14. Carbon pools included

	Included
ΔC_{AB}	Yes
ΔC_{BB}	Yes
ΔC_{DOM_LI}	Yes
ΔC_{SOC}	Yes
ΔC_{HWP}	No

Clarification Notes

Data on HWP is not available as yet.

7.3.2 Change in biomass carbon stocks (above-ground biomass and below-ground biomass) in forest lands remaining in the same category

Annual change in carbon stocks in biomass in forest land remaining in the same category (gain-loss method) (Equation 2.7, Ch2, V4)

$$\Delta C = \Delta C_G + \Delta C_L$$

Where:

ΔC_B = annual change in carbon stocks in biomass for each land sub-category, considering the total area, tonnes C yr^{-1}

ΔC_G = annual increase in carbon stocks due to biomass growth for each land sub-category, considering the total area, tonnes C yr^{-1}

ΔC_L = annual decrease in carbon stocks due to biomass loss for each land sub-category, considering the total area, tonnes C yr^{-1}

Annual increase in biomass carbon stocks due to biomass increment in forest land remaining in the same land-use category (Equation 2.9, Ch2, V4)

$$\Delta C_G = \sum_{i,j} (A_{i,j} \bullet G_{TOTAL\, i,j} \bullet CF_{i,j})$$

Where:

ΔC_G= annual increase in biomass carbon stocks due to biomass growth in land remaining in the same land-use category by vegetation type and climatic zone, tonnes C yr^{-1}

A = area of land remaining in the same land-use category, ha

G_{TOTAL}= mean annual biomass growth, tonnes d. m. ha^{-1} yr^{-1}

i = ecological zone (i = 1 to n)

j = climate domain (j = 1 to m)

CF = carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$

Table 15. Sources of activity data for land remaining

A: area of land remaining in the same land-use category

LU	Sub-Category	Source	Notes
F	Forest lands	Forestry Division	Collect earth assessment - Annual time series 2000-2017
C	Croplands	Forestry Division	Collect earth assessment - Annual time series 2000-2017
G	Grasslands	Forestry Division	Collect earth assessment - Annual time series 2000-2017
W	Wetlands	Forestry Division	Collect earth assessment - Annual time series 2000-2017
S	Settlements	Forestry Division	Collect earth assessment - Annual time series 2000-2017
O	Other lands	Forestry Division	Collect earth assessment - Annual time series 2000-2017

Clarification Notes

Forest land remaining Forest land was separated in 2 main scenarios based on damage degree. Through multiple discussions with country experts, it was estimated that 75% was highly impacted and 25% was slightly impacted by the hurricane:

1) Scenario 1 is the area of forest slightly affected [25%]. Thus, from the total area of Forest land remaining Forest land, 25% was allocated to this section, which is the "No significant damage", which are patches of forest that because of their location and characteristic where not significantly affected by the hurricane.

2) Scenario 2 is the area of forest highly affected [75%]. Thus, from the total area of Forest land remaining Forest land, 75% was allocated to this section. This section had 3 further subdivisions:

   a. Damage I: the stem remained standing but has broken branches or heavy defoliation [60%],
   b. Damage II: the steam and branches are broken, heavy defoliation, and tree was not uprooted [25%].
   c. Damage III: trees are uprooted [15%].

   For each section, from the areas initially estimated at [75%], the 3 further subdivisions were estimated by multiplying the allocated percentage.

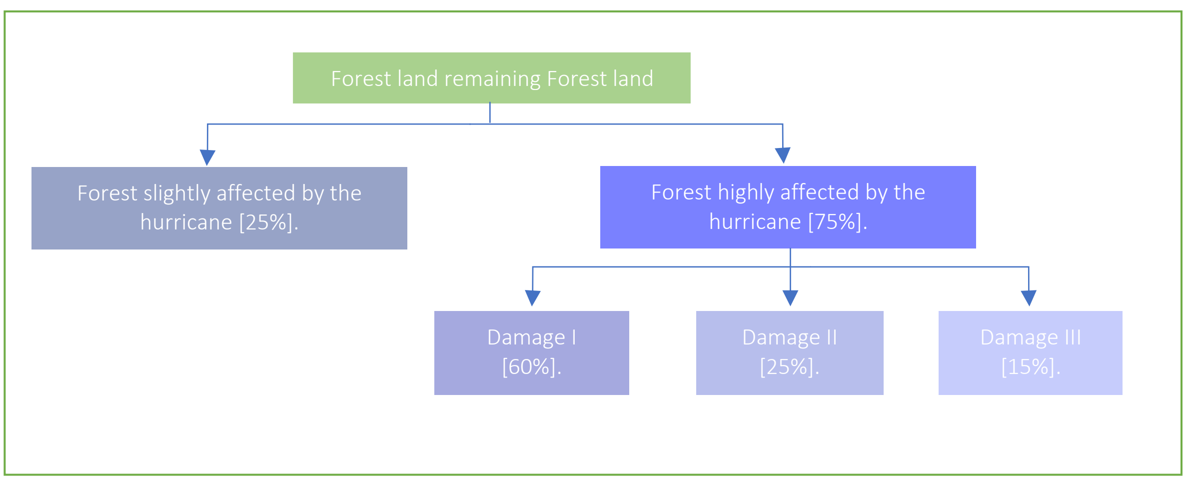


Figure 68 Area distribution in Forest lands remaining forest lands, depending on affectation degree by hurricane Maria (2017)

Table 16. Carbon fraction values

CF: Carbon Fraction t C (t d.m.)-1						
LU	Category	Value	Default Value (tier 1)	Error o range reported	Source	Comments and assumptions
F	Elfin and Cloud forest	0.47	X	(0.44 - 0.49)	2006 IPCC, Vol 4, Ch4, Table 4.3. Carbon fraction of aboveground forest biomass	Tropical/Subtropical forest.
	Montane Forest	0.47	X	(0.44 - 0.49)	2006 IPCC, Vol 4, Ch4, Table 4.3. Carbon fraction of aboveground forest biomass	Tropical/Subtropical forest
	Semi-evergreen Forest	0.47	X	(0.44 - 0.49)	2006 IPCC, Vol 4, Ch4, Table 4.3. Carbon fraction of aboveground forest biomass	Tropical/Subtropical forest
	Deciduous - Coastal Forest	0.47	X	(0.44 - 0.49)	2006 IPCC, Vol 4, Ch4, Table 4.3. Carbon fraction of aboveground forest biomass	Tropical/Subtropical forest
C	Annual Crops	0	X		Assumption	
	Perennial Crops	0.5	X		IPCC 2006, V4, Ch5, p.5.11 (Step 4)	
G	Grasslands	0.47	X		IPCC 2006, V4, Ch6, page 6.29. Step 5 - herbaceous	
	Woody Grasslands	0.5	X		IPCC 2006, V4, Ch6, page 6.29. Step 5 - woody biomass	
W	Wetlands	0	X		Assumption	
S	Non-Woody Settlements	0	X		Assumption	
	Woody Settlements	0.47	X	(0.44 - 0.49)	2006 IPCC, Vol 4, Ch4, Table 4.3. Carbon fraction of aboveground forest biomass	Tropical/Subtropical forest
O	Mining and Other Lands	0	X		Assumption	

Clarification Notes

IPCC 2006/2019 Default values are used as to date not country-specific research has been carried out. Agreed on May 21st 2020 with Forest Division Team.

Table 17. Values of ratio of below to above ground biomass

R: Ratio of below ground biomass to above ground biomass							
LU	Category	Type	Value	Default Value (tier 1)	Error o range reported	Source	Comments and assumptions

F	Elfin and Cloud forest	Natural	0.221	X	SD: 0.036	2019 IPCC RF, Vol 4, Ch4, Table 4.4	Tropical Rainforest, South America, secondary >20yr
	Montane Forest	Natural	0.221	X	SD:0.036	2019 IPCC RF, Vol 4, Ch4, Table 4.4	Tropical Rainforest, South America, secondary >20yr
	Semi-evergreen Forest	Natural	0.284	X	SD:0.061	2019 IPCC RF, Vol 4, Ch4, Table 4.4	Tropical moist deciduous forest, South America, Secondary >20yr
	Deciduous - Coastal Forest	Natural	0.379	X	SD:0.04	2019 IPCC RF, Vol 4, Ch4, Table 4.4	Tropical dry forest, South America, Secondary >20yr
C	Annual Crops		0	X		Assumption	
	Perennial Crops		0.284	X	SD:0.061	2019 IPCC RF, Vol 4, Ch4, Table 4.4	Tropical moist deciduous forest, South America, Secondary >20yr
G	Grasslands (Dry)		2.8	X		IPCC 2006, V4, Ch6, Table 6.4	
	Grassland (Moist)		1.6	X		IPCC 2006, V4, Ch6, Table 6.4	
	Woody Grassland		2.8	X		IPCC 2006, V4, Ch6, Table 6.4	
W	Wetlands		0			Assumption	
S	Non-Woody Settlements		0			Assumption	
	Woody Settlements		0.284	X	SD:0.061	2019 IPCC RF, Vol 4, Ch4, Table 4.4	Tropical moist deciduous forest, South America, Secondary >20yr
O	Mining and Other Lands		0			Assumption	

Average annual increment in biomass [Tier 1] (Equation 2.10, Ch2, V4)

$$G_{TOTAL} = \sum_{i,j} \{ G_W \bullet (1 + R) \}$$

Where:

G_{TOTAL} = average annual biomass growth above and below-ground, tonnes d. m. ha^{-1} yr^{-1}

G_W = average annual above-ground biomass growth for a specific woody vegetation type, tonnes d. m. ha^{-1} yr^{-1}

R = ratio of below-ground biomass to above-ground biomass for a specific vegetation type, in tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$.

Table 18. Values for Net biomass growth tonnes d. m. ha-1 yr-1

GW: Net biomass growth tonnes d. m. ha-1 yr-1							
LU	Category	Type	Value	Default Value o T2	Error o range reported	Source	Comments and assumptions
	Elfin and Cloud forest		0.5	T2		Weaver, 1990; Weaver et al.,1986	Elfin Woodlands and Dwarf Cloud Forest (Puerto Rico) growth rate of is found to be about 0.419 t ha yr-1 (Weaver 1990) and 0.6 t/ha/yr (Weaver et al (1986).
	Montane Rainforest		2.88	T2		Tanner, 1980	The first estimates of the increase of total above-ground tree biomass, ignoring any deaths of individuals, is (kg m-2 yr-1) c. 0.05 (5 Mg ha-1 yr-1) in Mor Ridge forest, c. 0.10 (1 Mg ha-1 yr-1) in Mull Ridge forest, c. 0.20 (2.0 Mg ha-1 yr1) in Wet Slope forest and c. 0.35 (3.5 Mg ha-1 yr-1) in Gap forest (Average = 2.875 Mg ha-1 yr1) (Jamaica)
	Semi-evergreen Forest		5.37	T2		Sherman et al 2012	Dominican Republic ABG 2007 – 1999 = 43 Mg ha-1. Growth Rate: 5.375 Mg ha –1 yr -1
	Coastal Forest	Deciduous Dry Scrub Litoral	1.24	T2			Estimated as AGB/40 Years
	Croplands	Annual	0	X		Assumption	Assumed to be 0 for Annual Croplands remaining Annual Croplands following Tier 1 approach and for lands converted to annual croplands.
		Perennial (Moist)	5.2	X		IPCC 2006, V4, Ch5, Table 5.1	Assumed to be 0 for Perennial Croplands remaining Perennial Croplands following Tier 1 approach and for lands converted to Perennial croplands the value is equal to 5.2 t.d.m ha-1 yr-1. For Tropical moist (Value 2.6 C ha-1 yr-1, this value is divided for the CF=0.5, to obtain de t.d.m)
		Perennial (Dry)	3.6	X		IPCC 2006, V4, Ch5, Table 5.1	Assumed to be 0 for Perennial Croplands remaining Perennial Croplands following Tier 1 approach and for lands converted to Perennial croplands the value is equal to 3.6 d.m ha-1 yr-1.. For Tropical dry (Value 1.8 C ha-1 yr-1,

							this value is divided for the CF=0.5, to obtain de t.d.m)
	Grasslands	Dry	2.3	X		IPCC 2006, V4, Ch6, Table 6.4	Assumed to be 0 for Grasslands remaining Grasslands, following Tier 1 approach.
		Moist	6.2	X		IPCC 2006, V4, Ch6, Table 6.4	
		Woody	1.5	X			Estimated as the AGB divided by 10 years, which was the time indicated by the Dominica team to have woody components in grasslands.
	Wetlands		0	X		Assumption	Assumed to be 0 for Wetlands remaining Wetlands following Tier 1 approach and lands converted to Wetlands
	Settlements	Settlements	0	X		Assumption	Assumed to be 0 for Settlements remaining Settlements following Tier 1 approach and lands converted to Settlements
		Woody Settlement	1.27	X			Assumed to be 0 for Woody Settlements remaining Woody Settlements following Tier 1 approach and for lands converted to Woody Settlements, Gw is equal to 70% is the same value as settlements, 10% is same value a Perennial Crops, 10% is same value as Semi-Evergreen Forest, 10% is same value as Deciduous Forest. These was decided based on expert knowledge on the composition of the woody component in settlements.
	Mining and Other Lands		0	X			Assumed to be 0 for Other Lands remaining Other Lands following Tier 1 approach and lands converted to Other Lands

Clarification Notes

The variation in tropical forest growth rates in the Caribbean islands is a complex interplay of environmental factors, natural disturbances, and human activities. Each island's unique combination of climate, soil, and topography contributes to a distinctive forest ecosystem, highlighting the importance of localized conservation and management strategies.

Forest growth rates are often influenced by the availability of essential nutrients in the soil. Islands with nutrient-rich soils may support faster and more robust plant growth. Soil composition varies across the Caribbean islands

(European Communities, 2011[77]; Madramootoo, 2000); some islands have volcanic soils, while others have limestone or sedimentary soils. The fertility and nutrient content of the soil can significantly impact the growth of vegetation. In addition, the topography of Caribbean islands varies widely, ranging from flat lowlands to mountainous terrain. Altitude can influence temperature and humidity, affecting the types of vegetation that can thrive at different elevations. Forest growth rates may vary with altitude, and certain species may be more adapted to specific elevations, leading to diversity in forest structure and composition (Madramootoo, 2000).

The Caribbean islands also experience a tropical climate, characterized by high temperatures and consistent rainfall. However, there can be variation in precipitation levels and seasonality from one island to another. Disturbances in forests, such as hurricanes, wildfires, or human activities, can have significant impacts on the growth rates of trees and vegetation (Tanner et al 1991; Baker et al 2003; Tanner and Bellingham 2006; Sherman et al 2012; Nino et al 2014; McLaren et al 2019). The effects of disturbances on forest ecosystems are complex and can vary depending on the type and intensity of the disturbance, as well as the specific characteristics of the local environment. The variation in tropical forest growth rates across the Caribbean islands is influenced by a range of factors, including climate, soil conditions, topography, and human activities. It also depends on resource availability and acquisition, defense against natural enemies, and allocation to reproduction. Adequate rainfall and sunlight supporting the photosynthetic processes crucial for plant growth. Islands with more consistent and evenly distributed rainfall might exhibit more stable growth rates.

The Caribbean region is prone to hurricanes and tropical storms. The islands of the Greater Antilles, located in the northern Caribbean, have experienced a high frequency of hurricanes, with an average return interval of 10 years and some sites being struck multiple times (McLaren et al 2019). These extreme weather events can cause widespread damage to forests, including uprooting trees, breaking branches, and altering the forest structure, with potential long-term impacts on forest structure and composition. McLaren et al (2019) indicated that the impact at landscape scales is heterogeneous, resulting in gradients of damage and mortality across the landscape. Abiotic attributes such as soils, geomorphology, and local topography contribute to the heterogeneity of forest disturbance. Biotic features including forest type, species composition, structural attributes, and tree characteristics influence susceptibility and response to wind damage. The spatial patterns of hurricane disturbance influence the degree of structural change, species composition, and rates of recovery within forested stands across landscapes.

In this paper, McLaren et al (2019) discussed the impact of tropical cyclones (hurricanes and typhoons) on tropical forests, focusing on the complex patterns of damage, recovery, and the long-term effects of these disturbances. Results indicate that forest recovery following a hurricane is generally rapid (<10 years) through tree releafing, sprouting, or recruitment of fast-growing species. However, depending on the severity of hurricane disturbance, there may be major structural changes, including a significant reduction in biomass, wood volume, basal area, and canopy height, which may take more than 10 years to recover. Forest susceptibility to wind damage is influenced by previous hurricanes, as the impact of a single hurricane event is not independent of past hurricanes. The

[77] https://esdac.jrc.ec.europa.eu/public_path/shared_folder/Awareness/Calendar2012.pdf

hurricane return interval for affected forest sites in the region is, on average, 10 years, with some areas experiencing hurricanes more frequently.

The immediate impact of hurricanes can be a reduction in forest biomass and canopy cover. This can lead to a temporary decline in growth rates as trees need time to recover and regenerate. Over the long term, trees may experience sudden or delayed mortality, variations in growth rates, alterations in regeneration pathways, and increased species turnover.

The heterogeneity of disturbance facilitates the recruitment and establishment of species with diverse life history strategies, contributing to an increase in tree diversity and richness in forests. An increase in stem density in disturbed areas follows a hurricane, as a lower density of large trees is replaced by more small trees, and this effect lasts for many years.

Forest gaps created by hurricanes lead to increased light penetration, air and soil temperatures, and decreased relative humidity compared to closed forests. Gaps also result in higher soil moisture and increased soil nutrient availability (Tanner et al 1991). Increased canopy illumination has also shown a positive effect on tree growth. For example, in a study conducted in Panama (King, 1994), in a Moist Evergreen Forest, saplings of ten tree species were examined. The research found that these saplings exhibited greater height growth in environments with high light levels. This implies that in areas where the canopy allows more light to penetrate to the forest floor, the saplings of these species experienced better vertical growth. At La Selva in Costa Rica, a study was conducted that involved eight tree species in size classes up to 30 cm diameter. The research found positive correlations between the growth rate of these trees and their crown illumination category. Crown illumination refers to the amount of light that reaches the crown of a tree, which is the upper part containing branches and leaves. The positive correlation indicates that as the level of crown illumination increased, the growth rate of these tree species also increased (Clark & Clark, 1992).

Various studies have been conducted to understand how tropical tree seedlings with different regeneration strategies respond to changes in light intensity (irradiance). Examples of such studies include those by Thompson et al. (1992), Lehto & Grace (1994), and Veenendaal et al. (1996). These studies indicate that under high-light conditions, pioneer species (trees that are the first to colonize disturbed ecosystems) tend to exhibit higher growth rates compared to non-pioneer species. Among adult trees in natural settings, pioneer species generally grow faster than more shade-tolerant species. This is attributed to both higher intrinsic growth rates at a given light intensity and the fact that pioneers are typically found in high-light environments. Shade-tolerant species, particularly as seedlings, often require a substantial increase in canopy illumination as saplings to reach the forest canopy. Some studies referenced (Jones 1956; Clark & Clark 1992; Hawthorne 1995) support the idea that certain species need more light availability as they grow to reach the upper canopy levels. Pioneer species are noted to have greater photosynthetic plasticity, meaning they can adapt their photosynthetic processes to varying light conditions. Consequently, pioneers show more significant growth responses to increased irradiance compared to shade-tolerant species.

In a study in Jamaica that discusses the consequences of long-term vegetative regeneration in tropical dry forests (TDFs) and contrasts the biomass recovery rates of TDFs with wet tropical forests (Nino et al 2010) is indicated that long-term vegetative regeneration leads to the development of high densities of very small tree stems in tropical dry forests. The prevalence of multiple stems may be a natural phenomenon in Caribbean dry forests. Multiple stems are seen as a strategy to enhance resilience to natural disturbances, acting as a "persistence" strategy. The ability of trees to have multiple stems provides a hedge against disturbance, increases resilience, and maintains genetic diversity, even in small populations. The multiple-stemmed growth form may be a response to environmental stress or an active strategy for survival in a dry environment.

In this study, treatments were applied to sampling plots to emulate the techniques used by charcoal burners (partially cut, clear-cut and control plot uncut). They either cleared all trees (clear-cut) to increase access to preferred trees, or selectively removed preferred species. The intensity of disturbance significantly influenced rates of recovery. After 10 years, partially cut plots had recovered considerably, requiring an additional 7.6 years to fully recover pre-treatment AGB. Clear-cut plots, on the other hand, recovered only 26% of the biomass lost after 10 years and were projected to require an additional 35.4 years to recover pre-treatment AGB (approximately 45.4 years in total). This recovery time is longer than some estimates for biomass recovery in tropical rainforest sites after pasture/farm abandonment. In cases of agricultural abandonment TDFs the importance of sexual regeneration increases, especially when stumps are removed, and the soil is severely disturbed. Cleared sites within TDF zones, for agriculture or pasture creation, may not be readily colonized by TDF species. Moreover, successful regeneration by seed in TDFs is less probable due to susceptibility to rainfall seasonality and moisture availability.
Forest chrono sequence studies estimate the time required for secondary wet forests on former pastures in Northeastern Costa Rica to exhibit values comparable to old-growth forests as 21–30 years (Letcher and Chazdon 2009). Secondary forests on abandoned pasture in Puerto Rico took 20 years to reach values comparable to old-growth forests (Marin-Spiotta et al. 2007). In the Bolivian Amazon, secondary forests took 25 years of regrowth to reach 70% of the basal area of mature forests (Peña-Claros 2003).

TDFs generally have lower biomass recovery rates than wet tropical forests. Biomass recovery rates of TDFs following disturbance in the Yucatan Peninsula, Mexico, were approximately half those of tropical secondary forests worldwide (Urquiza-Haas et al. 2007). Estimates of biomass recovery for TDFs in the Southern Yucatan Peninsular Region, Mexico, after shifting cultivation of maize were 55–95 years to return to pre-cultivation levels (Read and Lawrence 2003). Following fire in Quintana Roo, Mexico, TDFs took 70 years to recover values similar to mature forests (Vargas et al. 2008).

Sherman et al 2012 studied stand dynamics and biomass patterns along an altitudinal gradient in a Tropical Montane Forest (TMF) located in the Cordillera Central, Dominican Republic. The Cordillera Central in Hispaniola experiences frequent natural disturbances due to hurricanes and seasonal drought, leading to canopy disturbances, landslides, and wildfires. The forest is in a shifting-mosaic steady state with high demographic rates (mortality, recruitment, and growth) and variable biomass and carbon storage across the landscape. The study aimed at enhancing understanding of TMF composition, structure, and demography by resurveying 75 0.1-ha plots 8 years after establishment. The focus was on quantifying biomass, mortality, recruitment, and growth in this chronically disturbed montane landscape.

Main results were:

- Mortality rates varied widely among species (0 to 7.3% y−1), with a mean of 2.0% y−1.
- Recruitment rates also varied significantly among species (0–7.8% y−1), with a mean of 2.1% y−1.
- Average Relative Growth Rate (RGR) for all species was 0.96% y−1, ranging from 0.42–2.42% y−1.
- RGR showed a trend of decrease with altitude, being highest at lower altitudes and lowest at higher altitudes.
- Basal area increased significantly over the 8-year interval by a plot average of 2.6 m2 ha−1.
- Most plots exhibited a net gain in biomass over the census period. Forest-wide net annual increase in above-ground biomass (AGB) was 3.87 Mg ha−1 y−1 over the 8-year interval. Gains in biomass from the growth of surviving trees averaged 5.79 Mg ha−1 y−1 across all plots
- Live tree above-ground biomass increased from 276 Mg ha−1 in 1999 to 306 Mg ha−1 in 2007, but the increase was not statistically significant.
- AGB accumulation rates were high, potentially reflecting recovery from past disturbances, such as severe hurricanes in 1979 and 1998.
- Spatial variation in AGB was extremely high at the scale of 0.1-ha plots, reflecting both disturbance and local topographic variation.
- Above-ground standing biomass, gains in biomass from growth, and net biomass change decreased significantly with altitude.
- The study suggests that the chronic disturbance regime contributes to maintaining the landscape with high demographic rates and low biomass and carbon storage.

Regarding Cloud and Elfin Forest, two studies were carried in Puerto Rico. Weaver et al (1986) studied the dwarf forest in the Luquillo Mountains in Puerto Rico. The researchers assessed species composition, stem density, basal area, height, and diameter of trees. The study included measurements of leaf area index (LAI), leaf mass, litterfall, and loose litter over a two-year period. d. Permanent tagging and measurements of trees over time allowed for the calculation of annual diameter increment (ADI) and biomass accumulation.

Results showed that the structural and functional parameters used to characterize the dwarf forest show that it is species-poor, dense, inferior in size (leaf area index and biomass), slow-growing, and slow to recycle nutrients. In some respects, the dwarf forest is more similar to exceedingly dry tropical and higher-latitude temperate than to other humid tropical ecosystems. They explained that the heavy rainfalls and frequent fog result in saturated soils which are anoxic and impede root growth. Root space is limited by saturated soil, and roots spread superficially. Wind occasionally fells larger trees, notably Tabebuia rigida, which had been observed prostrate on the soil surface with a tangle of branches developing into new trunks. Of the major species-specific gravity is the lowest, perhaps lending some support to the idea that denser woods on exposed sites counteract the damaging effects of wind, as also indicated by Lawton (1984). The annual increment in tree diameter was low, averaging only 0.03 ± 0.01 cm/yr for all stems. Above- and below-ground biomass accumulation approximated 0.6 t/ha/yr, and total litter production is 3.1 t/ha/yr.

A second study in the Elfin Woodland of the Luquillo Mountains of Puerto Rico, took place in December 1968, where a DC-119 crashed at 1000 m elevation in the Luquillo Mountains of Puerto Rico, causing immediate burning of the area around the fuselage and soil disturbance. Military investigators further disturbed the site for many days. Initial regeneration within the first six years was primarily by ferns and grasses, with woody species seedlings scarce. A visit to the site in late 1986, 18.5 years after the crash, revealed the presence of numerous woody species and average biomass accumulation of 7.76 t/ha, resulting in an annual growth rate of 0.419 t ha yr-1.

Forest ecosystems in the Caribbean have evolved mechanisms to cope with disturbances. Some tree species are adapted to fire, wind, or other natural disturbances, and they may even rely on these events for regeneration.

Wildfires can be a significant disturbance factor. These fires can result from both natural and human causes. Wildfires can lead to the loss of vegetation and nutrients in the soil, affecting the ability of forests to regenerate. The growth rates of certain tree species may be impacted, especially those that are not well-adapted to fire. Logging, agriculture, and urbanization are common human-induced disturbances in both regions. These activities can lead to deforestation, habitat fragmentation, and changes in land use. The impact on growth rates depends on the scale and intensity of human activities. While some tree species may be negatively affected, others might be able to adapt or even benefit from certain types of disturbance.

Specific Characteristics for Forest in Saint Lucia and Dominica

- Elfin Forest and Cloud Forest:

  Elfin forests occur at high elevations where environmental conditions limit tree height. Growth rates are influenced by factors such as temperature, soil conditions, and adaptation of unique species to harsh conditions. Cloud forests are often found on mountain slopes where persistent cloud cover contributes to high humidity. Growth rates may be influenced by the frequency and duration of cloud cover, as well as the presence of epiphytic vegetation.

  Growth rate: Elfin Woodlands and Dwarf Cloud Forest (Puerto Rico) growth rate of is found to be about 0.419 t ha yr-1 (Weaver 1990) and 0.6 t/ha/yr (Weaver et al (1986).

- Montane Rainforest:

  Found at higher elevations, montane rainforests are characterized by cooler temperatures and higher levels of moisture. These forests have high biodiversity. Growth rates can vary based on factors like altitude, climate, and species composition.

  Growth Rate: The first estimates of the increase of total above-ground tree biomass, ignoring any deaths of individuals, is (kg m-2 yr-1) c. 0.05 (5 Mg ha-1 yr-1) in Mor Ridge forest, c. 0.10 (1 Mg ha-1 yr-1) in Mull Ridge forest, c. 0.20 (2.0 Mg ha-1 yr1) in Wet Slope forest and c. 0.35 (3.5 Mg ha-1 yr-1) in Gap forest (Average = 2.875 Mg ha-1 yr1) (Tanner 1980).

- Semi-Evergreen Forest:

  Semi-evergreen forests maintain some green foliage throughout the year but may experience seasonal changes. Growth rates can be influenced by factors such as temperature, precipitation, and the adaptability of species to changing environmental conditions.

  Growth Rate: Dominican Republic ABG 2007 – 1999 = 43 Mg ha-1. Growth Rate: 5.375 Mg ha –1 yr -1

- Semi-Deciduous Forest, Dry Scrub Forest, Littoral Forest:

  Semi-deciduous forests undergo a seasonal shedding of leaves, usually in response to variations in rainfall. Growth rates may vary seasonally, with higher rates during periods of abundant water availability. Dry scrub forests are adapted to arid or semi-arid conditions and may experience seasonal variations in rainfall. While their growth rates might be lower compared to more humid forest types, these ecosystems are adapted to conserve water. Littoral forests are situated along coastlines and are influenced by salt spray and other coastal conditions. Growth rates may be influenced by the tolerance of species to salt exposure and adaptation to coastal environments.

  Growth Rates: no values were found in the literature review that could be used; therefore, the AGB was divided by 40 years, as a proxy value of growth rate, using 40 years as an estimated time by expert judgement on when the forest could potentially reach stability.

These values were agreed on December 2023 with the Forestry Division team from Dominica and Saint Lucia.

In forest land remaining forest lands, the growth rates were applied based on the damage class as follows:

a. For the “No Significant Damage” class, the undisturbed growth rate by forest type was applied from 2000 to 2017.
b. For the “Damage I class”, the undisturbed growth rate by forest type was applied from 2000 to 2017. For the years after the hurricane, after the literature review and local expert consultation, it was assumed that of the total weight of a tree, 65% corresponds to trunk, 30% to the branches and 5% to the leaves. Because in this class the stem remained standing but has broken branches or heavy defoliation, the Gw was only applied to the 35% affected, and assumed to be recovered in 5 years; thus, the estimated value is Gw [branches and leaves] = AGB*35%/5 years
c. For the Damage II and Damage III classes, the undisturbed growth rate by forest type was applied from 2000 to 2017. For the years after the hurricane, the Gw of Disturbance will be used. It is assumed that, even if trees were not uprooted, the recovery growth rate is applied to the whole tree for early successional (pioneer) species established and new recruits in open gaps formed after hurricane disturbances, growing rapidly in the high light environment.

Annual decrease in carbon stocks due to biomass losses in forest land remaining in the same land-use category (Equation 2.11, Ch2, V4)

$$\Delta C_L = \Delta L_{wood\text{-}removals} + \Delta L_{fuelwood} + \Delta L_{disturbance}$$

Where:

ΔC_L = annual decrease in carbon stocks due to biomass loss in land remaining in the same land-use category, tonnes C yr^{-1}

$L_{wood\text{-}removals}$ = annual carbon loss due to wood removals, tonnes C yr^{-1} (See Equation 2.12)

$L_{fuelwood}$ = annual biomass carbon loss due to fuelwood removals, tonnes C yr^{-1} (See Equation 2.13)

$L_{disturbance}$ = annual biomass carbon losses due to disturbances, tonnes C yr^{-1} (See Equation 2.14)

Annual carbon loss in biomass of wood removals (Equation 2.12, Ch2, V4)

$$L_{wood\text{-}removals} = \{ H \bullet BCEF_R \bullet (1+R) \bullet CF \}$$

Where:

$L_{wood\text{-}removals}$ = annual carbon loss due to biomass removals, tonnes C yr^{-1}

H = annual wood removals, roundwood, m^3 yr^{-1}

R = ratio of below-ground biomass to above-ground biomass, in tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$. R must be set to zero if assuming no changes of below-ground biomass allocation patterns (Tier 1).

CF = carbon fraction of dry matter, tonne C (tonnes.m.)$^{-1}$

$BCEF_R$ = biomass conversion and expansion factor for conversion of removals in merchantable volume to total biomass removals (including bark), tonnes biomass removal (m^3 of removals)$^{-1}$

Table 19. Annual wood removals values

H: Annual wood removals, roundwood, m^3 yr^{-1}				
LU	Year	Hardwood -m3	Fuelwood -m3	Source
F		IE		

Clarification Notes

Detailed national statistics on wood removals is not available as yet. However, losses due to wood removals were estimated as an area of cover loss, through the Collect Earth assessment, and allocated as "Logging Disturbance", where a fraction (fd) was determined and then used in eq. 2.14

Table 20. $BCEF_R$ values

$BCEF_R$: biomass conversion and expansion factor, t biomass removal (m^3 of removals)$^{-1}$				
LU	Sub-Category	Value	Range/Error	source
F		NE		

Annual carbon loss in biomass of fuelwood removal (Equation 2.13, Ch2, V4)

$$L_{fuelwood} = [\ \{\ FG_{trees} \bullet BCEF_R \bullet (1+R)\ \} + FG_{part} \bullet D\ ] \bullet CF$$

Where:

$L_{fuelwood}$ = annual carbon loss due to fuelwood removals, tonnes C yr^{-1}

FG_{trees} = annual volume of fuelwood removal of whole trees, $m^3\ yr^{-1}$

FG_{part} = annual volume of fuelwood removal as tree parts, $m^3\ yr^{-1}$

R = ratio of below-ground biomass to above-ground biomass, in tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$

CF = carbon fraction of dry matter, tonne C (tonned.m.)$^{-1}$

D = basic wood density, tonnes d.m. m^{-3}

$BCEF_R$ = biomass conversion and expansion factor for conversion of removals in merchantable volume to biomass removals (including bark), tonnes biomass removal (m^3 of removals)$^{-1}$

Table 21. FGtree and FGpart values

FG_{trees} = annual volume of fuelwood removal of whole trees				
LU	Sub-Category	Source	years	Notes
F	NE	NE		
FG_{part} = annual volume of fuelwood removal as tree parts				
LU	Sub-Category	Sources		Notes
F	NE	NE		

Clarification Notes

Detailed national statistics on fuelwood removals is not available as yet

Table 22. Wood density values

D: wood density, g / cm^3				
LU	Sub-Category	Value	Range/Error	Source
F	Cloud Montane Rainforest	0.598	0.290 – 0.990	Graveson (2009), Reyes *et* al (1992) and Chave *et* al (2007).
	Lower Montane and Montane Rainforest	0.672	0.360 – 0.820	
	Semi-evergreen Seasonal Forest	0.601	0.470 – 0.871	
	Deciduous Seasonal Forest	0.655	0.482 -0.700	

Clarification Note

Graveson (2009), in Appendix 3, added a table of species identified per Forest Class Values (FCV). Therefore, wood density was assigned to these species based on Specie, Genus or Family. Wood Density values were assigned based on Reyes *et* al (1992)[78] and Chave *et* al. (2007)[79] (See Annex III. Wood Density by FCV in the Excel GHG calculation tool).

Annual carbon losses in biomass due to disturbances (Equation 2.14, Ch2, V4)

$$L_{disturbance} = A_{disturbance} \bullet B_W \bullet (1+R) \bullet CF \bullet fd$$

Where:

$L_{disturbances}$ = annual other losses of carbon, tonnes C yr^{-1}

$A_{disturbance}$ = area affected by disturbances, ha yr^{-1}

B_W = average above-ground biomass of land areas affected by disturbances, tonnes d.m. ha^{-1}

R = ratio of below-ground biomass to above-ground biomass, in tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$.

CF = carbon fraction of dry matter, tonne C (tonnesd.m.)$^{-1}$

fd = fraction of biomass lost in disturbance

$A_{disturbance}$: area affected by disturbances, ha yr^{-1}

[78] Reyes, G., Brown, S., Chapman, J., Lugo, Ariel E. 1992. Wood densities of tropical tree species, Gen. Tech. Rep. SO-88 New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 1992, 15p.

[79] Chave, Jérôme & Muller-Landau, Helene & Baker, Timothy & Easdale, Tomás & ter Steege, Hans & Webb, Campbell. (2007). Regional and phylogenetic variation of wood density across 2456 Neotropical tree species. Ecological applications : a publication of the Ecological Society of America. 16. 2356-67. 10.1890/1051-0761(2006)016[2356:RAPVOW]2.0.CO;2.

Figure 69. Land use matrices for disturbances

DISTURBANCES

Land Use and Land Use Change (LULUC)
Vertical: Inicial Use
Horizontal: Final Use

Period	Land use	Affected by Fire	Affected by by Hurricane	Affected by Logging	Affected by Shifting Cultuvation	TOTAL
2016-2017	Elfin and Cloud forest		7009			7,009
	Montane Rainforest		28271			28,271
	Semi-evergreen Forest		10187			10,187
	Deciduous Forest		6916			6,916
	Dry Scrub Forest		1636			1,636
	Litoral Forest		3551			3,551
	Croplands, Annual Crops					0
	Croplands, Perennial Crops					0
	Grasslands (Pastures)					0
						0
	Wetland					0
	Settlement					0
	Woody Settlement					0
	Other Lands					0
	Mining					0
	TOTAL					57,570
2015-2016	Elfin and Cloud forest					0
	Montane Rainforest					0
	Semi-evergreen Forest					0
	Deciduous Forest		47		47	93
	Dry Scrub Forest					0
	Litoral Forest					0
	Croplands, Annual Crops					0
	Croplands, Perennial Crops					0
	Grasslands (Pastures)					0
						0
	Wetland					0
	Settlement					0
	Woody Settlement					0
	Other Lands					0
	Mining					0
	TOTAL					93

Table 23. Average above ground biomass t.d.m ha-1

B_W = average above-ground biomass of land areas affected by disturbances							
LU	Category	Value	Regional value (tier 2)	Default Value (tier 1)	Error o range reported	Source	Comments and assumptions
F	Elfin and Cloud forest	62.9	X			Estimated using equation by Chave (2005) using NFI data and Forest Classes	
	Montane Forest	107.2	X			Estimated using equation by Chave (2005) using NFI data and Forest Classes	

	Semi-evergreen Forest	53.6	X			Estimated using equation by Chave (2005) using NFI data and Forest Classes	
	Deciduous - Coastal Forest	49.4	X			Estimated using equation by Chave (2005) using NFI data and Forest Classes	
C	Annual Crops	0		X			Assumed to be 0 following Tier 1 approach
	Perennial Crops (Moist)	42		X	75%	IPCC 2006, V4, Ch5, Table 5.1	For Tropical moist (Value 21 of C, this value is divided for the CF=0.5, to obtain de t.d.m). Assumed to be 0 for Croplands remaining Croplands, following Tier 1 approach
	Perennial Crops (Dry)	18		X	75%	IPCC 2006, V4, Ch5, Table 5.1	For Tropical dry (Value 9 of C, this value is divided for the CF=0.5, to obtain de t.d.m). This value is used only for conversions from Dry Forest (ex. FDEC,FDRYS, FLIT) to Croplands
G	Grasslands (Dry)	2.3		X		IPCC 2006, V4, Ch6, Table 6.4	Assumed to be 0 for Grasslands remaining Grasslands, following Tier 1 approach
	Grasslands (Moist)	6.2		X		IPCC 2006, V4, Ch6, Table 6.4	Assumed to be 0 for Grasslands remaining Grasslands, following Tier 1 approach
	Woody Grassland	15					Values allocated by expert judgement. The value was selected using as reference the AGB for FEVER and FDEC/FSCRY and Perennial Croplands
W	Wetlands	0		X			Assumed to be 0
S	Non-Woody Settlements	0		X			Assumed to be 0
	Woody Settlements	28.7		X		Estimates as: =(0*0.7)+(0.1*227.6)+(0.1*41.5)+(0.1*18)	70% is the same value as settlements, 10% is same value a Perennial Crops, 10% is same value as Semi-Evergreen Forest, 10% is same value as Deciduous Forest. These was decided based on expert knowledge on the composition of the woody component in settlements.
O	Mining and Other Lands	0		X			Assumed to be 0

Clarification Notes

Chave et al (2005)[80] pantropical biomass allometric equation was selected to estimate biomass in Dominica, and the same approach was considered applicable to Dominica. Tree AGB (kg) was regressed against the product ρ *D^2 * H. The best-fit pantropical model identified was:

$$\langle AGB \rangle_{est} = \rho \times \exp(-1.499 + 2.148\ln(D) + 0.207(\ln(D))^2 - 0.0281(\ln(D))^3)$$

where D is in cm, H is in m, and ρ is in g cm/3. The study relies on a compilation of tree harvest data from 27 published and unpublished datasets spanning tropical forests in America, Asia, and Oceania since the 1950s. The dataset comprises information on 2,410 trees with a diameter at breast height (dbh) greater than or equal to 5 cm. The sites encompass various environmental conditions, classified into wet, moist, and dry forests, with distinctions between young (successional) and old-growth forests. Dataset includes data from Caribbean islands such a Jamaica, Guadeloupe and Puerto Rico. Biometric variables for each harvested tree include trunk diameter, total tree height, and wood specific gravity. The researchers employed regression models to estimate aboveground biomass (AGB), comparing several statistical models based on their simplicity and practicality. These models included variations accounting for different parameters, forest types, and assumptions, allowing for a systematic assessment of the factors influencing AGB in tropical forests

Because the Saint Lucian's forest inventory measured only the 2 biggest trees in the 7m circular sub-plot. The following process was done to estimate the approximate biomass in the other trees reports for the plot:

STEP 1. Select Max DBH1 and Max DBH 2
STEP 2. Organize all DBH in one column
STEP 3. create a Histogram, which will provide ranges of DBH
STEP 4. Estimate the percentages for each DBH class, under different scenarios for maximum DBH reported
STEP 5. Estimate de number of trees according to the percentage per range by multiplying the number of trees by the Percentage of each range, per each plot
STEP 6. Then estimate the AGB using the mid DBH of the range for each of the plots.
STEP 7. Multiple the AGB by the number of trees.
STEP 8. Sum all the AGB values to estimate a total AGB per plot
STEP 9. Estimate AGB values per forest class

[80] Chave, J., Andalo, C., Brown, S. et al. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145, 87–99 (2005). https://doi.org/10.1007/s00442-005-0100-x

Table 24. Fraction of biomass loss due to disturbances

Fd: Fraction of biomass loss due to disturbances				
Forest Type	Disturbance	Fd	Tier 2	Notes
Elfin and Cloud forest	Affected by hurricane	0.6, 0.25, 0.15	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Fire	NO	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Logging	NO	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Shifting Cultivation	NO	x	Forestry Division, Collect Earth Assessment and Expert Judgement
Montane Forest	Affected by hurricane	0.6, 0.25, 0.15	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Fire	NO	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Logging	NO	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Shifting Cultivation	NO	x	Forestry Division, Collect Earth Assessment and Expert Judgement
Semi-evergreen Forest	Affected by hurricane	0.6, 0.25, 0.15	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Fire	NO	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Logging	NO	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Shifting Cultivation	0.60	x	Forestry Division, Collect Earth Assessment and Expert Judgement
Deciduous - Coastal Forest	Affected by hurricane	0.6, 0.25, 0.15	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Fire	NO	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Logging	NO	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Shifting Cultivation	NO	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Fire	NO	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Logging	NO	x	Forestry Division, Collect Earth Assessment and Expert Judgement
	Affected by Shifting Cultivation	NO	x	Forestry Division, Collect Earth Assessment and Expert Judgement

Clarification Notes

Fd values were selected based on expert judgment of the interpreters who did the Collect Earth, estimated as an average of the lost seen in the images, caused the by the indicated disturbance.

In forest land remaining forest lands, the fd were applied based on the damage class as follows:

a. For the "No Significant Damage" class, a fd was applied to the disturbances before hurricane Maria. For example, shifting cultivation in 2015.
b. For the "Damage I class", after local expert consultation and based on what was observed during and right after the Hurricane Maria (2017), assumptions include that 5% of the canopy flew away and the other 95% remained on the forest floor. Therefore, Ldisturbance =Adisturbance [ha] •BW * 0.35 (It is assumed that of the total weight of a tree, 65% of be in the trunk, 30% in branches and 5% in leaves.
c. For the Damage II and Damage III classes, after local expert consultation and based on what was observed during and right after the Hurricane Maria (2017), assumptions include that 10 % was extracted and used for logs, charcoal, firewood and 15% was lost in the waterways. Therefore, a 25% loss is applied to the total tree biomass per ha and 75% remained on the forest floor. Therefore, for Damage II: Ldisturbance ={Adisturbance [ha] •BW [t.d.m/ha]•CF and for Damage III Ldisturbance ={Adisturbance [ha] •BW [t.d.m/ha]• (1+R) • CF, as this class includes uprooted trees

7.3.3 Change in dead organic matter carbon stock in forest land remaining in the same category

As previously indicated, it was observed that the majority leaf litter ended up on the forest floor after the hurricane Maria, which was evident during forest access route restoration immediately after. Approximately 75% of canopy leaves blown off became forest litter. The remaining 25% is considered to be lost through heavy flooding and blown out of the forest structure. Some dead wood was also lost due to land erosion, although some remained trapped because of the nature of the destruction. Some rivers changed their courses due to the volume of water or damming along the streams due to landslides. Mainly dead wood on steep slopes was lost to waterways rather than areas of flat land. Approximately 10-20% of dead wood may have reached the ocean. Form the remaining 80-90%, about 10% was used for lumber, charcoal, fuelwood and composting, with some sinking in the ocean and returned as driftwood. The rest remained in the forest floor and river sides.

In order to capture this dynamic, Dominica team intended to use the Tier 2 approach for calculating DOM in forest lands remaining in the same category. For this estimation, the equations 2.17 and 2.19 were applied.

ANNUAL CHANGE IN CARBON STOCKS IN DEAD ORGANIC MATTER (Equation 2.197, Ch2, V4)

$$\Delta C_{DOM} = \Delta C_{DW} + \Delta C_{LT}$$

C_{DOM} = annual change in carbon stocks in dead organic matter (includes dead wood and litter), tonnes C yr^{-1}

ΔC_{DW} = change in carbon stocks in dead wood, tonnes C yr^{-1}

ΔC_{LT} = change in carbon stocks in litter, tonnes C yr^{-1}

ANNUAL CHANGE IN CARBON STOCKS IN DEAD WOOD OR LITTER (STOCK-DIFFERENCE METHOD) (Equation 2.19, Ch2, V4)

$$\Delta C_{DOM} = [A \bullet (DOM_{t2} - DOM_{t1})/T] \bullet CF$$

ΔC DOM = annual change in carbon stocks in the dead wood/litter pool, tonnes C yr^{-1}

A = area of managed land, ha

DOMt1 = dead wood/litter stock at time t1 for managed land, tonnes d.m. ha^{-1}

DOMt2 = dead wood/litter stock at time t2 for managed land, tonnes d.m. ha^{-1}

T = (t2 – t1) = time period between time of the second stock estimate and the first stock estimate, yr

CF =carbon fraction of dry matter, tonneC(tonned.m.)$^{-1}$

For DOM in t1, the C stock value was used and multiplied by the area of each forest type. For DOM in t2, the DOM value was estimated as the transfer of biomass carbon loss resulting from disturbances to DOM, tonnes C yr^{-}. Therefore:

- For the “No Significant Damage” class, Tier 1 assumption was applied, that the carbon contained in all biomass components that are transferred to dead organic matter pools will be released in the year of the transfer, whether from annual processes (litterfall and tree mortality) (2006 IPCC, V4, Ch2)
- For the “Damage I class”, DOM in the year of the disturbance is equal to DOM C stock from the previous year + 95% of the AGB Loss.
- For the “Damage II class” and “Damage III class”, DOM in the year of the disturbance is equal to DOM C stock from the previous year + 75% of the AGB Loss

Dominica team searched for literature on decomposition rates after disturbances in the region, but information was very scarce.

Kaarik (1974)[81] indicates that decomposition of wood is generally a slow process that involves biological, chemical, and physical processes and that the sequence that these processes act on dead wood varies over time due to changes in physical climate and the chemical and physical makeup of the wood over its decay life. It is also mentioned that each piece of dead wood has a unique chemical and physical makeup and that the difference in chemical and physical composition starts with differences in live trees. Harmon et al. (1986)[82] and Martius (1997)[83], indicate that differences among trees depend on tree species (wood characteristics), nutrient composition of soil,

[81] Kaarik, AA. 1974. Decomposition of wood. In Dickinson, C.H., Pugh, G.J.F., 1974. Biology of Plant Litter Decomposition. Academic Press, NYC, pp. 129–174

[82] Harmon, M.E., Franklin, J.F., Swanson, F.J., Sollins, P., Gregory, S.V., Lattin, J.D., Anderson, N.H., Cline, S.P., Aumen, N.G., Sedell, J.R., Lienkaemper, G.W., Cromack, K., Cummins, K.W., 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research 15, 133-302.

[83] Martius, C., 1997. Decomposition of wood. In Junk, Wolfgang J., 1997. Ecological Studies 126. The Central Amazon Floodplain. Ecology of a Pulsing System. Springer, NYC, 267-276

climate, tree health (including infections by insects, microbes, and fungus), and how the tree died. Noguiera et al. (2005)[84] points out that differences within trees may also be important due to internal variation in wood density.

A study on decomposition and carbon cycling of dead trees in tropical forests of the central Amazon (Cambers et al., 2000) [85] indicates that the measured rate varied by between 0.015 to 0.67 $year^{-1}$, averaging 0.19 $year^{-1}$ with predicted error of 0.026 year; and that a tree of average biomass was predicted to decompose at 0.17 $year^{-1}$. Another study by Powers et al. (2009)[86]about decomposition in tropical forests along a rainfall gradient, indicates that decay rates ranged from 0.47 $year^{-1}$ for raffia decomposing above ground without mesofauna in a dry forest in Thailand (HKK) to 15.10 $year^{-1}$ for bay leaves decomposing above ground with mesofauna in a wet forest in Papua New Guinea (PNG). Palace et al. (2008)[87] estimated that decomposition rates for all pieces of wood was 0.17 $year^{-1}$ for large (>10 cm diameter), 0.21 $year^{-1}$ for medium (5-10 cm diameter), and $year^{-1}$ for small size (2-5 cm diameter) class necromass. Other tropical forest necromass decomposition rates range from 0.03 $year^{-1}$ (Delaney et al. 1998)[88] to 0.51 $year^{-1}$ (Collins, 1981)[89].

For the years after the hurricane Dominica assumes a decomposition rate of 2% annually. Though these estimates of decay are prone to error and hypothetical in nature, they will allow us to attempt estimate the possible dynamics post-hurricane conditions. Based on the natural conditions of Dominica, this decomposition rate is expected to be be applied only after 5 years, where it will be assumed that a percentage will be transferred to the soil.

[84] Nogueira, E.M., Nelson, B.W., Fearnside, P.M., 2005. Wood density in dense forest in central Amazonia, Brazil. Forest Ecology and Management 208, 261–286.

[85] Chambers, J., Higuchi, N., Schimel, J. *et al.* Decomposition and carbon cycling of dead trees in tropical forests of the central Amazon. *Oecologia* **122**, 380–388 (2000). https://doi.org/10.1007/s004420050044

[86] Powers, J.S., Montgomery, R.A., Adair, E.C., Brearley, F.Q., DeWalt, S.J., Castanho, C.T., Chave, J., Deinert, E., Ganzhorn, J.U., Gilbert, M.E., González-Iturbe, J.A., Bunyavejchewin, S., Grau, H.R., Harms, K.E., Hiremath, A., Iriarte-Vivar, S., Manzane, E., De Oliveira, A.A., Poorter, L., Ramanamanjato, J.-B., Salk, C., Varela, A., Weiblen, G.D. and Lerdau, M.T. (2009), Decomposition in tropical forests: a pan-tropical study of the effects of litter type, litter placement and mesofaunal exclusion across a precipitation gradient. Journal of Ecology, 97: 801-811. https://doi.org/10.1111/j.1365-2745.2009.01515.x

[87] Palace, M., M. Keller, H. Silva, (2008). Necromass production: studies in undisturbed and logged Amazon forests. Ecological Applications: 18, 873–884.

[88] Delaney, M., Brown, S., Lugo, A.E. , Torres-Lezama, A., Quintero, N.B., 1998. The quantity and turnover of dead wood in permanent forest plots is six life zones of Venezuela. Biotropica 30(1), 2-11

[89] lins, N.M., 1981. The role of termites in the decomposition of wood and leaf litter in the southern Guinea savanna of Nigeria. Oecologia 51, 389-399.

Figure 70 Photo 25 and 26: Forest stump of Prime Forest Tree Species 42 years after Hurricane David, Aug. 1979

7.3.4 Change in soil organic carbon stock in forest land remaining in the same category

A Tier 2 method was applied from 2000 to 2017 to estimate SOC pool in Forest land remaining in the same land-use category. Based on the landslides and floods assessment triggered by Hurricane Maria (2017), about 5.3 Km2 or 530 ha of soil was lost in Forest lands, with a desegregation by forest type as follows: Elfin and Cloud: 40% (212 ha), Montane Rainforest: 30% (159 Ha), Semi-evergreen forest: 20% (106 ha), Deciduous-Coastal Forest: 10% (53 ha).

Therefore, for Forest land remaining forest lands, to the total area of each forest type the corresponding percentage was applied and the area affected by landslides was estimated. For the SOC after Hurricane due to landslides a value of 0 was given. Thus, the losses due to landslides was estimated as:

Area affected[ha]= Area per forest type * fd(landslide)

ΔSOC [tC/yr]= Area affected * (SOC after Hurricane - SOC before hurricane)

For the years after the hurricane, an annual recovery of SOC after Hurricane due to landslides was estimated as

ΔSOC [tC/yr]= SOC before Hurricane/20 years

Using a Tier 1 approach, it is estimated that it will take 20 years to the soil to recover, either through natural and/or assisted restoration or rehabilitation.

7.3.5 Change in biomass carbon stocks (above-ground biomass and below-ground biomass) in land converted to a new land-use category

Annual change in biomass carbon stocks on land converted to other land-use category (tier 2) (Equation 2.15, Ch2, V4)

$$\Delta C_B = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$

Where:

ΔC_B= annual change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr^{-1}

ΔC_G= annual increase in carbon stocks in biomass due to growth on land converted to another land-use category, in tonnes C yr^{-1}

$\Delta C_{CONVERSION}$ = initial change in carbon stocks in biomass on land converted to other land-use category, in tonnes C yr^{-1}

ΔC_L = annual decrease in biomass carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category, in tonnes C yr^{-1}

Table 25. Sources of area of land converted to a land-use category

A: area of land converted to a land-use category			
LU	Sub-Category	Source	Notes
Non-F>F	Non-Forest Lands > Forest Lands	Forest Division	Collect earth assessment - Annual time series 2000-2017
F>C	Forest lands > Croplands	Forest Division	Collect earth assessment - Annual time series 2000-2017
F>G	Forest lands > Grasslands	Forest Division	Collect earth assessment - Annual time series 2000-2017
F>W	Forest lands > Wetlands	Forest Division	Collect earth assessment - Annual time series 2000-2017
F>S	Forest lands > Settlements	Forest Division	Collect earth assessment - Annual time series 2000-2017
F>O	Forest lands > Other lands	Forest Division	Collect earth assessment - Annual time series 2000-2017

Annual increase in biomass carbon stocks on land converted to other land-use category (tier 2) (Equation 2.9, Ch2, V4)

Annual increase in carbon stocks in biomass due to land converted to another land-use category was estimated using the same approach as in forest lands remaining forest lands.

Initial change in biomass carbon stocks on land converted to another land category (Equation 2.16, Ch2, V4)

$$\Delta C_{CONVERSION} = \sum_{i} \{ (B_{AFTER} - B_{BEFORE}) \bullet \Delta A_{TO\_OTHERS} \} \bullet C$$

Where:

$\Delta C_{CONVERSION}$ = initial change in biomass carbon stocks on land converted to another land category, tonnes C yr^{-1}

B_{AFTER_i} = biomass stocks on land type i immediately after the conversion, tonnes d.m. ha^{-1}

B_{BEFORE_i} = biomass stocks on land type i before the conversion, tonnes d.m. ha^{-1}

$\Delta A_{TO\_OTHERS_i}$ = area of land use i converted to another land-use category in a certain year, ha yr^{-1}

CF = carbon fraction of dry matter, tonne C $(tonnesd.m.)^{-1}$
i = type of land use converted to another land-use category

Note: Change in biomass carbon stocks on land converted to another land category was estimated using the values of Area, Biomass and Carbon Fraction as described above for forest lands remaining in the same category.

Annual decrease in carbon stocks in biomass due to losses, ΔCL (Equation 2.11-2.14, Ch2, V4)

Note: The annual decrease in C stocks in biomass due to losses on converted land (wood removals or felling, fuelwood collection, and disturbances) was estimated using Equations 2.11 to 2.14, as described above for forest lands remaining in a category.

7.3.6 Change in dead organic matter in Carbon stock in land converted to a new land category

Land converted to another land-use category (Equation 2.23, Ch2, V4)

$$\Delta C_{DOM} = \frac{(Cn - Co) * Aon}{Ton}$$

Where:

ΔC_{DOM} = annual change in carbon stocks in dead wood or litter, tonnes C yr-1

C_o = dead wood/litter stock, under the old land-use category, tonnes C ha-1

C_n = dead wood/litter stock, under the new land-use category, tonnes C ha-1

A_{on} = area undergoing conversion from old to new land-use category, ha

T_{on} = time period of the transition from old to new land-use category, yr. The Tier 1 default is 20 years for carbon stock increases and 1 year for carbon losses.

Table 26. Dead wood/litter stock values

Dead wood/litter stock tonnes C ha-1 (For conversion only)						
Pool	Land Use	Value	Tier 1	Error	Source	Note
Litter	Elfin and Cloud forest	NO			n.a	
	Montane Forest	4.8	x	Range: 2.1-16.4	2019 IPCC RF, Vol 4, Ch2, Table 2.2	Tropical rainforest
	Semi-evergreen Forest	5.9	x	Range: 1.9-14.8	2019 IPCC RF, Vol 4, Ch2, Table 2.2	Tropical moist
	Deciduous - Coastal Forest	2.4	x	Range: 2.1-2.7	2019 IPCC RF, Vol 4, Ch2, Table 2.2	Tropical dry
DOM	Elfin and Cloud forest	3.3		n.a	2019 IPCC RF, Vol 4, Ch2, Table 2.2	Tropical mountain System
	Montane Forest	14.8	x	Range: 0.6 - 218.9	2019 IPCC RF, Vol 4, Ch2, Table 2.2	Tropical rainforest
	Semi-evergreen Forest	8.0	x	Range: 1.9-14.8	2019 IPCC RF, Vol 4, Ch2, Table 2.2	Tropical moist
	Deciduous - Coastal Forest	9.0	x	Range:1.3-17.3	2019 IPCC RF, Vol 4, Ch2, Table 2.2	Tropical dry
Litter	Annual	0	x		IPCC 2006, V4, Ch5, page 5.13. Tier 1	
	Perennial	0	x		IPCC 2006, V4, Ch5, page 5.13. Tier 1	
DOM	Annual	0	x		IPCC 2006, V4, Ch5, page 5.13. Tier 1	
	Perennial	0	x		IPCC 2006, V4, Ch5, page 5.13. Tier 1	
Litter	Grassland	0	X		IPCC 2006, V4, Ch6, page 6.31. Tier 1	
DOM	Grassland	0	X		IPCC 2006, V4, Ch6, page 5.31. Tier 1	
Litter	Wetlands	NO				
DOM	Wetlands	NO				
Litter	Settlement	NO				
	Woody Settlement	NO				
DOM	Settlement	NO				
	Woody Settlement	NO				
Litter	Other Lands	NO				
DOM	Other Lands	NO				

Clarification Note

For lands converted to Forest lands, T=20, until Forest lands is considered stable (F>F), then changed to DOM=0. For other conversions, T=1, meaning the loss on DOM happens the year of conversion.

7.3.7 Change in Carbon stock in soils in land converted to a new land category

Annual change in carbon stocks in mineral soils, tonnes C yr-1 (Equation 2.25, Ch2, V4)

$$\Delta C_{\text{Mineral}} = \frac{(SOCo - SOC_{o-t})}{D}$$

$$\Delta SOC = \sum_{c,s,i} \{ (SOC_{REF} * F_{LU} * F_{MG} * F_I * A$$

Where,

$\Delta C_{\text{Mineral}}$ = annual change in carbon stocks in mineral soils, tonnes C yr^{-1}
SOC_0 = soil organic carbon stock in the last year of an inventory time period, tonnes C
$SOC_{(0-T)}$ = soil organic carbon stock at the beginning of the inventory time period, tonnes C
T = number of years over a single inventory time period, yr
D = Time dependence of stock change factors which is the default time period for transition between equilibrium SOC values, yr.
c = represents the climate zones, *s* the soil types, and *i* the set of management systems that are present in a country.
SOC_{REF} = the reference carbon stock, tonnes C ha^{-1}
FLU = stockchangefactorforland-usesystemsorsub-systemforaparticularland-use, dimensionless
FMG = stock change factor for management regime, dimensionless
FI = stock change factor for input of organic matter, dimensionless
A = land area of the stratum being estimated, ha.

Soil information was obtained from the Global Soil Organic Carbon Map -GSOCmap-, from FAO (2019) (figure 71). The web address of the portal is http://54.229.242.119/GSOCmap/. The country was selected, and information was downloaded through the "crop & Download" function. The result of the process is a TIFF file. The TIFF image processing was done in QGIS Desktop version 3.1.6. The TIFF had to undergo a correction for adequate georeferencing, which was done by selecting 4 sampling points and the coordinates were reassigned.

As a result, a CVS file is generated containing the SOC ref values for each sampling point. Information was saved as CSV file. Then, information is organized by land use and sub-category and an average value is estimated.

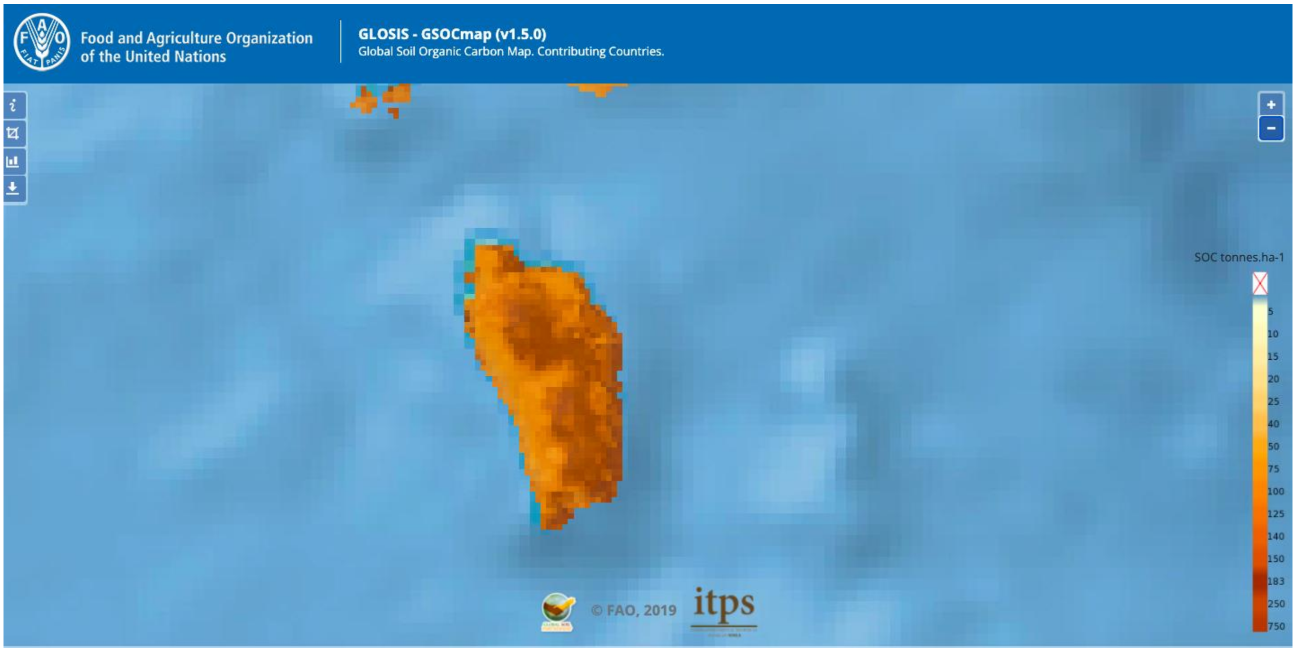


Figure 71 Dominica - Global Soil Organic Carbon Map -GSOCmap-, from FAO (2019).

Dominica has information on land uses obtained through Collect earth assessment described in the activity data section. Thus, the objective is to link the SOC information for each of the plots (figure 72), which then allows allocating the SOC ref value by land use and sub-categories of land use (Table 28). The TIFF image was processed using the Samples Raster Values tool for the process of linking the Collect Earth plots with the SOC shapefile.

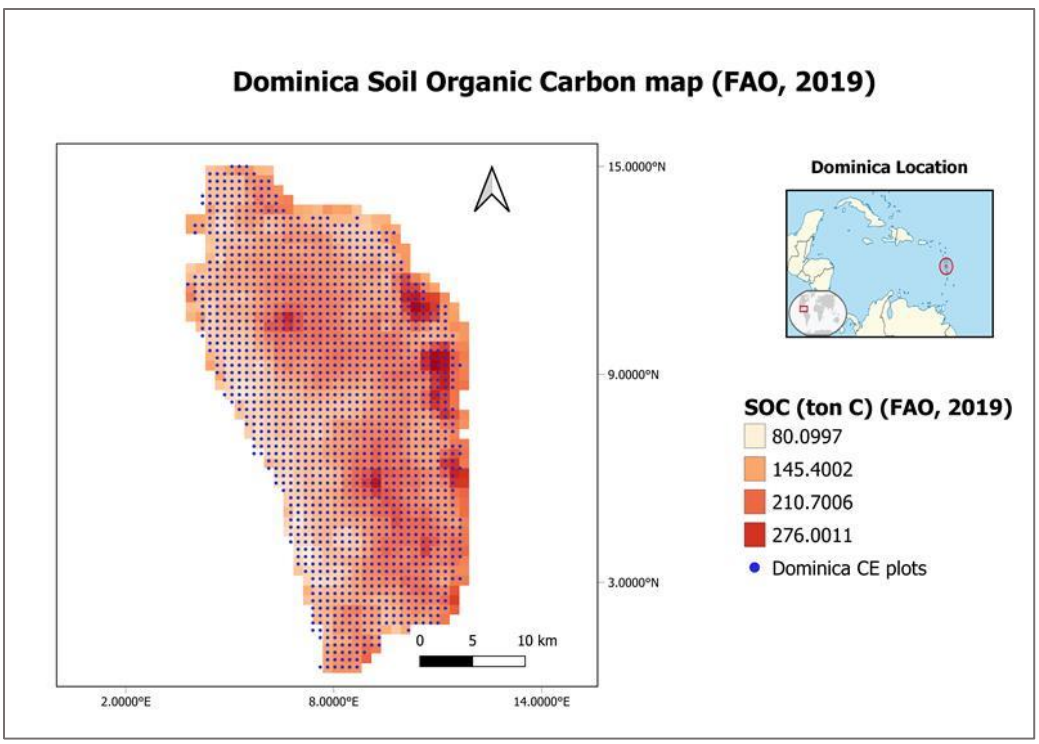


Figure 72 Overlapping FAO SOC map vs Collect Earth sampling grid

Table 27 Soil organic carbon by land use sub-category [tC ha]

Sub-category of land use	Number of plots	Average t C ha	Maximum t C ha	Minimum t C ha	StdDev t C ha
CANNUAL	131	155.4	307.0	93.5	46.6
CPER	87	148.8	292.5	97.4	37.9
FCLOUD	109	187.7	286.0	117.4	28.7
FELF	42	216.8	310.0	150.3	33.8
FCLOD and FELF	151	195.8	310.0	117.4	32.8
FDEC	149	152.6	334.3	88.3	44.4
FDSCRUB	35	125.1	167.6	80.1	20.3
FLIT	77	168.4	295.8	113.6	39.9
FDEC, FDSCRUB,FLIT	261	153.6	334.3	80.1	42.6
FEVER	225	156.9	317.8	98.3	38.2
FRAIN	608	164.8	341.3	101.5	33.2
GGRASS	26	158.7	275.4	103.4	35.1
GWGRASS	30	112.2	167.6	93.5	15.0
OMIN	2	101.8	103.1	100.6	1.8
OOTHER	7	180.2	310.0	121.4	62.4
SSET	25	134.9	259.7	87.6	50.0
SWSET	34	144.8	259.3	80.1	49.8
WWET	4	181.0	250.7	115.4	60.9
Grand Total	1591	161.2	341.3	80.1	40.3

Table 28. FLU, FMG and FI Values for values by Land use and sub-categories of land use

Notation	*FLU*	*FMG*	*FI*		
Parameter	Factor for land use systems	Factor for management regime	Factor for input of organic matter	Tier 1	Source
Units	Dimensionless	Dimensionless	Dimensionless		
Forestland					
Elfin and Cloud forest (FCLOUD)	1.00	1.00	1.00	X	IPCC 2006, Vol 4, Ch 4, pg 4.40
Montane Forest (FRAIN)	1.00	1.00	1.00	X	IPCC 2006, Vol 4, Ch 4, pg 4.40
Semi-evergreen Forest (FEVER)	1.00	1.00	1.00	X	IPCC 2006, Vol 4, Ch 4, pg 4.40
Deciduous - Coastal Forest (FDEC)	1.00	1.00	1.00	X	IPCC 2006, Vol 4, Ch 4, pg 4.40

Deciduous - Coastal Forest (FLIT)	1.00	1.00	1.00	X	IPCC 2006, Vol 4, Ch 4, pg 4.40
Deciduous - Coastal Forest (FDSCRUB)	1.00	1.00	1.00	X	IPCC 2006, Vol 4, Ch 4, pg 4.40
Croplands					
Annual (CANNUALC)	0.48	1.00	0.92	X	IPCC 2006, V4, Ch.5, table 5.5 dry, Moist wet, Long-term Cultivated / Full tillage / Low, tropical, moist wet
Perennial (CPER) (Moist)	1.00	1.15	0.92	X	IPCC 2006, V4, Ch5, Table 5.5 Perennial / Reduce tillage, moist wet, tropical / Low, tropical, moist wet
Perennial (CPER) (Dry)	1.00	1.15	0.92	X	IPCC 2006, V4, Ch5, Table 5.5 Perennial / Reduce tillage, moist wet, tropical / Low, tropical, moist wet
Grassland					
Grassland (GGRASS)(Dry)	1.00	1.00	1.00	X	
Grassland (GGRASS)(Moist)	1.00	1.00	1.00	X	
Settlement					
Settlement (SSET)	0.00	0.00	0.00	x	
Woody Settlement (SWOOD)	1.00	1.00	1.00	x	

Clarification Note

For lands converted to Forest lands, D=20, until Forest lands is considered stable (F>F), then changed to SOC=0. For Forest lands converted to other lands, D=20, until indicating a transitional change of SOC to the new SOC values depending on the conversion.

7.3.8 Non-CO2 Emissions

Estimation of Greenhouse Gas Emissions from s (Equation 2.27, Ch2, V4)

$$Lfire = A \bullet MB \bullet Cf \bullet Gef \bullet 10{-}3$$

Where:

Lfire = amount of greenhouse gas emissions from fire, tonnes of each GHG (CH4, N2O).

A = area burnt, ha

MB = mass of fuel available for combustion, tonnes ha^{-1}.

Cf = combustion factor, dimensionless

Gef = emission factor, g kg-1 dry matter burnt

Table 29. MB, Cf, GefCH4, GefN2O values

		MB	Cf	Gef CH4	Gef N2O
LU	Sub-Category	Mass of fuel available for combustion	Combustion factor	Emission factor- CH4	Emission factor- N2O
		tonnes ha^{-1}	Dimensionless	g kg-1 dry matter burnt	g kg-1 dry matter burnt
F	Deciduous-Coastal Forest	36.2	1	6,8	0,2

A summary of the level of the methods used for activity data and emission factors is included in table 30

Table 30.Methods and EF used for the FRL

Category	CO_2		N_2O		CH_4	
	AD	EF	AD	EF	AD	EF
5. LULUCF						
A. Forest Lands	CS	T1, T2	CS	T1	CS	T1
B. Croplands	CS	T1	NO	NA	NO	NA
C. Grasslands	CS	T1	NO	NA	NO	NA
D. Wetlands	CS	T1	NO	NA	NO	NA
E. Settlements	CS	T1	NO	NA	NO	NA

T1 – Tier 1, T2 – Tier 2, T3 –Tier 3, CS – Country specific, D – IPCC default, IE – Included Elsewhere; NA – Not Applicable; NE – Not Estimates; NO – Not Occurring

7. Results of GHG emissions and Removals 2001-2017

Historical GHG emissions of CO_2, CH_4 and N_2O are reported for the period 2001–2017 associated with Forest land remaining forest land, land converted to Forest land, and Forest land conversion. Based on this time-series, due to country specific circumstances, the national FREL/FRL proposed by Dominica is (figure 73).

Key results for historical emissions and removals

- Historical net GHG emissions and removals average were -258,504 tCO2e from 2001 to 2016 (*this average is just for illustration purposes, as it excludes the year 2017 due to the unusually high emissions during the hurricane*);
- Emissions due to the hurricane Maria (2017) were estimated at 2,850,188 tCO2e for the biomass (AGB+BGB) pools and 339,080 for the SOC pool; However, most of the dead wood remained in the forest floor, resulting in actual 568,402 tCO2 emissions associated to the losses due to wood extraction for logging, charcoal, fuelwood, and biomass lost due to flooding, landslides, heavy rains and strong winds.
- As most biomass losses were transferred to the DOM pool, estimated as -2,333,997 millions tCO2e, the C stocks in the DOM pool increased drastically.
- Average removals from lands converted to Forest lands for the period 2001 to 2016 were estimated as -726 tCO2e/yr and emissions from Forest lands converted to other lands were estimates as 17.632 tCO2e/yr.

[90]Photo:https://www.semanticscholar.org/paper/Perceptions-of-nature-in-the-Caribbean-island-of-Yarde/cf1497bde9823974f51b8ccf73cbe93eb8cf8787

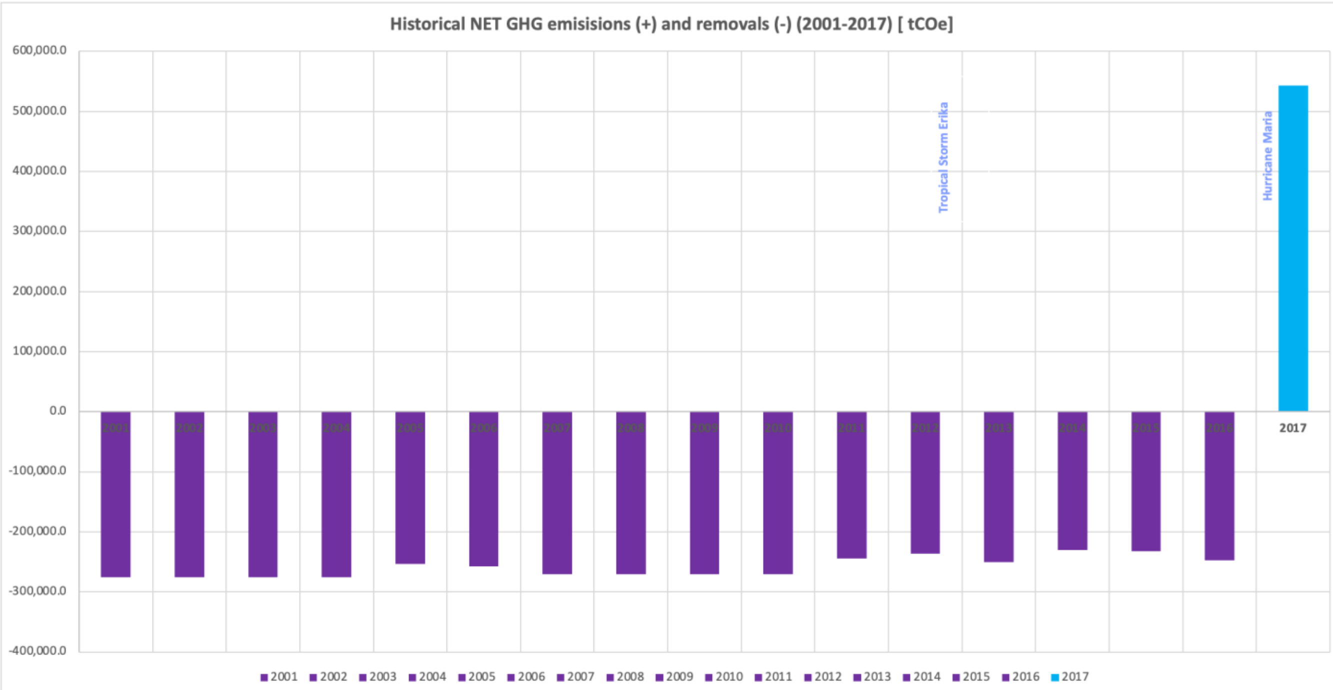


Figure 73 Historical emissions (+) and removals (-) for 2001-2017. All units are in tons of CO_2 equivalent per year.

Historical emissions and removals were estimated using the gain–loss method from the 2006 IPCC Guidelines. All lands were considered as managed. The forest above-ground biomass values were obtained from Saint Lucia's Nation Forest Inventory carried out in 2009, as they share same forest conditions. The FAO GSOCmap and IPCC default values from the 2006 IPCC Guidelines, and the 2019 Refinement to the 2006 IPCC Guidelines were also used. Dominica used global warming potential values from the IPCC Fifth Assessment Report (AR5) based on the effects of GHGs over a 100-year time-horizon to convert CH_4 and N_2O emissions into tons of CO_2e emissions. The analysis includes the pools above-ground biomass, below-ground biomass, dead organic matter and soil organic carbon. Harvested wood products were excluded due to lack of data.

For the estimations of annual GHG emissions and removals, Dominica applied the land representation approach 3, using the sampling method combined with a plot-by-plot annual analysis using 1605 plots of 1ha distributed in a systematic grid 750 m × 750 m that were analyzed annually from 2000 to 2017 to determine land use, land use changes, year of land use change, disturbance and year of disturbance using the Collect Earth software, which contains a combination of high and medium spatial resolution imagery (i.e. 15 m resolution Landsat imagery, 2.5 m resolution SPOT imagery and high-resolution imagery from several other sources) accessible through the Google Earth, Bing Maps and Google Earth Engine platforms. Dominica used the Collect Earth tool to synchronize the view of each sampling point on the three platforms and incorporate the land-use condition for each year of the time series 2001–2017. Forest land was stratified by forest type (Elfin Forest, Cloud Forest, Montane rainforest, Semi-evergreen forest, Deciduous Forest; Littoral Forest and Dry Scrub). Cropland was classified as either annual or perennial cropland, settlements were classified as woody and non-woody. Other land was divided into other land and mining. Grasslands and Wetlands did not have a further subclassification.

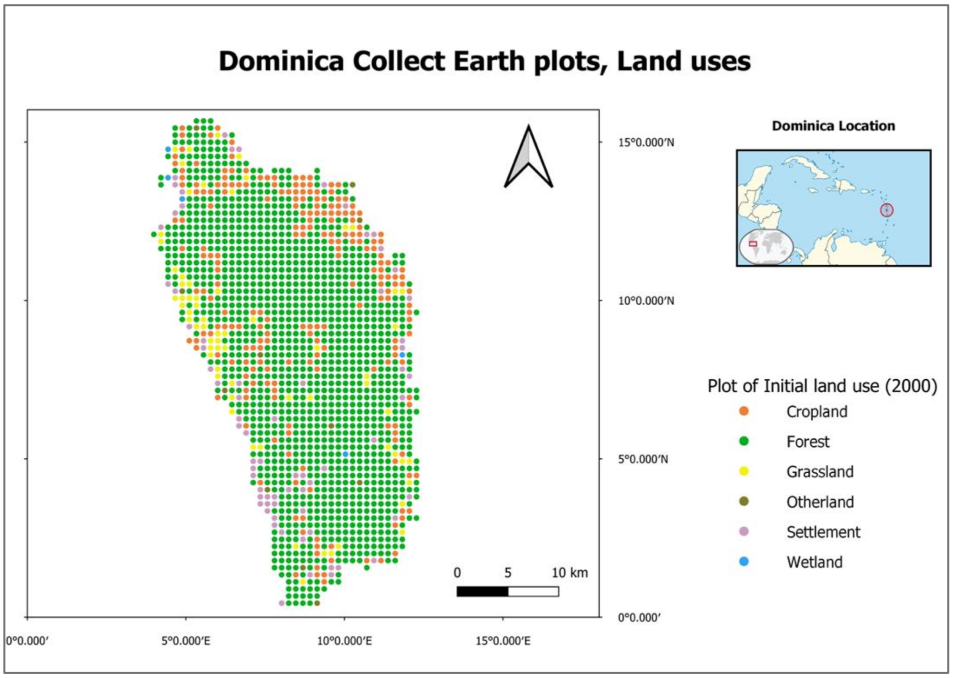


Figure 74 Dominica initial land use in 2000, represented in the sampling plots

The sampling approach combined with an annual plot by plot analysis allowed capturing multiple land use changes for a plot; however, these were not registered; therefore, only the initial Land Use (figure 74) and the Final land use was captured, and only when that second land use reached the definition. Specifically, in conversion to forest, only when the forest reached the definition that conversion would be registered; otherwise, it remained in the initial land use. Also, the survey allowed to capture multiple disturbances; however, only the primary one was accounted.

The land use and land use change analysis indicated that total area of forest lands in 2000 was 58.551 Ha compared to 57.710 Ha in 2017 (figure 75), resulting in a forest loss of 888 Ha in 17 years of about 52Ha per year, locating Dominica in a high forest cover low, deforestation country. However, all forest were severely affected in 2017 by Hurricane Maria, which was a hurricane category 5, removing most of the canopy cover and in some cases uprooting trees, causing also floods and landslides.

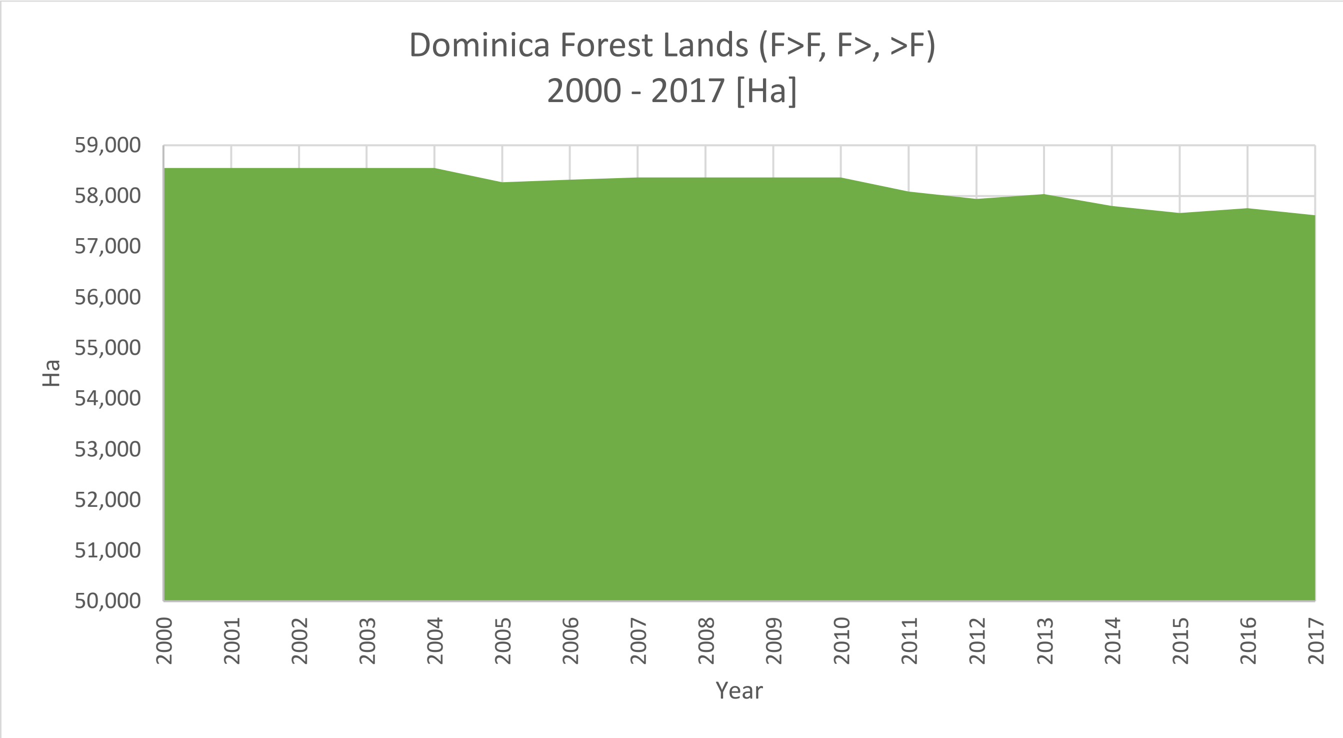


Figure 75 Net balance of forest lands in Dominica (Forest lands remaining and Forest lands converted to and from other land uses) [Ha]

In the period 2001-2017, 280 Ha of forest were converted to croplands, 327 Ha converted to Grasslands, 280 Ha converted to Settlements and 94 Ha converted to Other lands (figure 76).

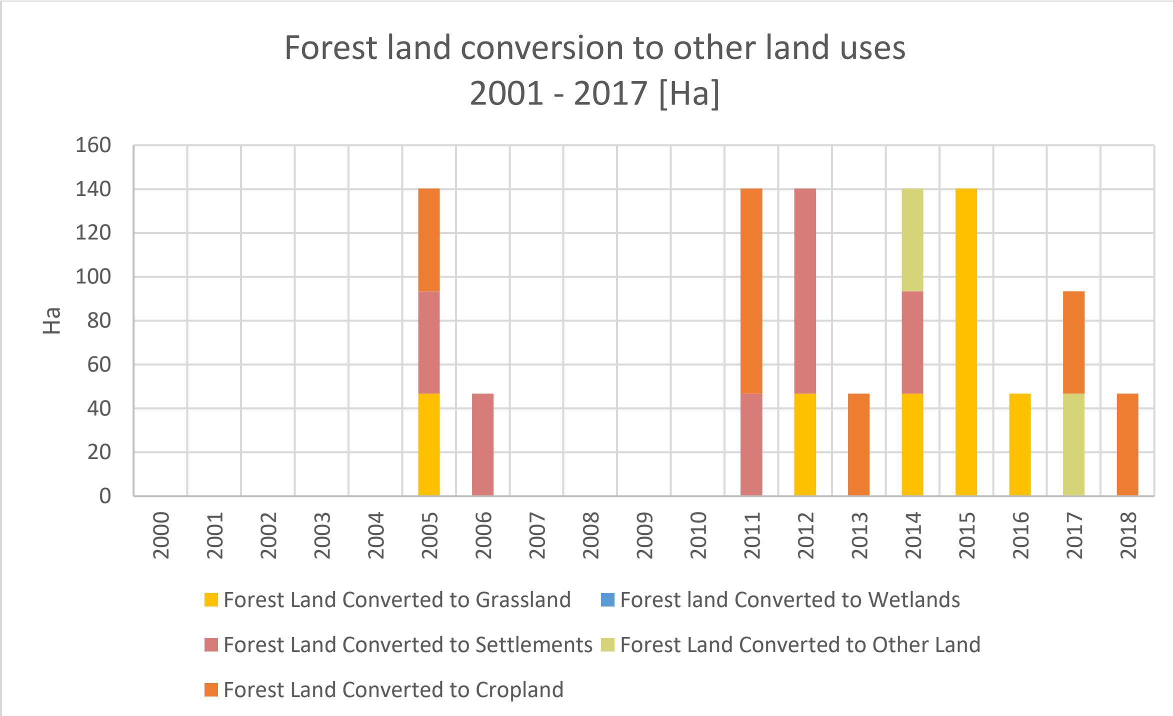


Figure 76 Forest land conversion to other land uses 2001 to 2017 [Ha]

Forest conversion and degradation have a compounding factor which is that small farmers tend to be resource-poor, with low capacity to invest in soil and water conservation measures. In cases where lands are converted to housing and other forms of urban development, land degradation is driven by similar factors particularly where settlements are unplanned and developed without infrastructure to control pollution, runoff, erosion and landslides. In Dominica, land and water resources degradation has been historically driven mainly by clearing of forests in environmentally fragile areas (steep slopes underlain by erodible soils within high rainfall zones) and subsequent replacement by intensive agricultural cultivation. Installation of poorly constructed farm access roads in these areas in many instances contributes to land degradation. Other activities such as poorly managed mining and quarrying operations and expansion of settlement areas in erosion-prone and landslide-prone areas compounds the country's vulnerability to impacts from climate change. However, because of the fallen branches, twigs and tree stumps after the hurricane which initially hindered any major movement of persons into the forested areas, few months after the hurricane access to forest areas became more complicated due to an exposed undergrowth. Those, changes in behavioral patterns are expected to change, which will be monitored in future land use and land use change assessments.

Dominica is one of the few carbon-neutral countries in the world, largely due to carbon sequestration. It is important to note that the forest disturbance regime is driven by storms. Wind damage to forests is not unusual, and the forest types in Dominica developed in the face of intermittent storms. Not the storms as such, but the increased frequency and intensity of storms constitute an unusual threat for Dominica's forests. Forests have been seriously disturbed by Hurricane Maria, but their recovery capacity is naturally high. Agriculturally driven deforestation is no longer a threat. There are no alarming degradation phenomena, no pressing unmet needs for wood, and no indications that forestry problems are closely linked to widespread poverty.

Forest resources management should therefore aim at increasing the resilience of forests to climate change. Specifically, forest adaptation should focus mainly on natural regeneration, while plantations may help increase the value of abandoned agricultural land.

The NET Historical GHG emissions and removals is presented in table 31, which includes CO2, N2O, CH4 [tCO2e]

Table 31 NET Historical GHG emissions and removals, [tCO2e yr-1]

Year	NET Historical GHG Emissions [CO2, N2O, CH4) [tCO2e]
2001	-276,107
2002	-276,107
2003	-276,107
2004	-276,107
2005	-253,044
2006	-257,533
2007	-270,177
2008	-270,177
2009	-270,177
2010	-270,177
2011	-244,557
2012	-236,362
2013	-250,148
2014	-229,814
2015	-232,295
2016	-247,182
2017	543,263

The NET Historical GHG emissions and removals by sub category of land use is presented in table 32

Table 33 NET Historical GHG Emissions by sub- categories [CO2, N2O, CH4) [tCO2eq/yr]

** Undisturbed subcategories in F>F refer to the lands not affected by Hurricane Maria, other disturbances previous 2017 are included in this section as well*

** Disturbed subcategories in F>F refer to the lands affected by Hurricane Maria only*

Sub-category	Carbon Pool	Gas	Units	Equation	2001	2002	2003	2004	2005	2006	2007	2008
Forest lands remaining Forest Lands (Undisturbed) [NET BALANCE ALL]	AGB, BGB, DOM, SOC	CO2, CH4, N20	t CO2e / yr		-276,107	-276,107	-276,107	-276,107	-275,271	-274,667	-274,667	-274,667
Forest remaining Forest lands (Undisturbed) [Net Balance ABG_BGB]	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.7	-276,107	-276,107	-276,107	-276,107	-275,271	-274,667	-274,667	-274,667
F >F (Undisturbed) [Gains]	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.9	-276,107	-276,107	-276,107	-276,107	-275,271	-274,667	-274,667	-274,667
F >F (Undisturbed) [Losses]	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.11	0	0	0	0	0	0	0	0
F >F (Undisturbed) [DOM]	DOM	CO2	t CO2e / yr	Equation 2.23	0	0	0	0	0	0	0	0
F >F (Undisturbed) [SOC]	SOC	CO2	t CO2e / yr	Equation 2.24	0	0	0	0	0	0	0	0

Sub-category	Carbon Pool	Gas	Units	Equation	2009	2010	2011	2012	2013	2014	2015	2016	2017
Forest lands remaining Forest Lands (Undisturbed) [NET BALANCE ALL]	AGB, BGB, DOM, SOC	CO2, CH4, N20	t CO2e / yr		-274,667	-274,667	-273,755	-272,570	-271,966	-270,805	-269,066	-269,620	-67,804
Forest remaining Forest lands (Undisturbed) [Net Balance ABG_BGB]	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.7	-274,667	-274,667	-273,755	-272,570	-271,966	-270,805	-269,066	-269,620	-67,804

F >F (Undisturbed) [Gains]	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.9	-274,667	-274,667	-273,755	-272,570	-271,966	-270,805	-269,922	-269,620	-67,804
F >F (Undisturbed) [Losses]	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.11	0	0	0	0	0	0	-856	0	0
F >F (Undisturbed) [DOM]	DOM	CO2	t CO2e / yr	Equation 2.23	0	0	0	0	0	0	0	0	0
F >F (Undisturbed) [SOC]	SOC	CO2	t CO2e / yr	Equation 2.24	0	0	0	0	0	0	0	0	0

Sub-category	Carbon Pool	Units	Equation	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Forest remaining Forest lands (Disturbed) [NET BALANCE ALL]	**AGB, BGB, DOM, SOC**	**t CO2e / yr**		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Forest remaining Forest lands (Disturbance, before conversion) [Net balance AGB_BGB]	Biomass (AGB+BGB)	t CO2e / yr	Equation 2.7	0	0	0	0	0	0	0	0	0	
F >F (Disturbance) [Gains]	Biomass (AGB+BGB)	t CO2e / yr	Equation 2.9	0	0	0	0	0	0	0	0	0	
F >F (Disturbance) Losses	Biomass (AGB+BGB)	t CO2e / yr	Equation 2.11	0	0	0	0	0	0	0	0	0	
Forest remaining Forest lands (Disturbance, before conversion) [DOM]	DOM	t CO2e / yr	Equation 2.23	0	0	0	0	0	0	0	0	0	
Forest remaining Forest lands (Disturbance, before conversion) [SOC]	SOC	t CO2e / yr	Equation 2.24	0	0	0	0	0	0	0	0	0	
Forest remaining Forest lands (Disturbance, before conversion) [CH4]	Non-CO2 emissions due to biomass burning (CH4)	t CO2e / yr	Equation 2.27	0	0	0	0	0	0	0	0	0	

Forest remaining Forest lands (Disturbance, before conversion) [N2O]	Non-CO2 emissions due to biomass burning (N2O)	t CO2e / yr	Equation 2.27	0	0	0	0	0	0	0	0	0	

Sub-category	Carbon Pool	Gas	Units	Equation	2010	2011	2012	2013	2014	2015	2016	2017
Forest remaining Forest lands (Disturbed) [NET BALANCE ALL]	**AGB, BGB, DOM, SOC**	**CO2, CH4, N20**	**t CO2e / yr**		0	0	0	0	0	0	0	**568,402**
Forest remaining Forest lands (Disturbance, before conversion) [Net balance AGB_BGB]	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.7	0	0	0	0	0	0	0	2,563,319
F >F (Disturbance) [Gains]	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.9	0	0	0	0	0	0	0	-286,869
F >F (Disturbance) Losses	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.11	0	0	0	0	0	0	0	2,850,188
Forest remaining Forest lands (Disturbance, before conversion) [DOM]	DOM	CO2	t CO2e / yr	Equation 2.23	0	0	0	0	0	0	0	-2,333,997
Forest remaining Forest lands (Disturbance, before conversion) [SOC]	SOC	CO2	t CO2e / yr	Equation 2.24	0	0	0	0	0	0	0	339,080
Forest remaining Forest lands (Disturbance, before conversion) [CH4]	Non-CO2 emissions due to biomass burning (CH4)	CH4	t CO2e / yr	Equation 2.27	0	0	0	0	0	0	0	0
Forest remaining Forest lands (Disturbance, before conversion) [N2O]	Non-CO2 emissions due to biomass burning (N2O)	N2O	t CO2e / yr	Equation 2.27	0	0	0	0	0	0	0	0

Sub-category	Carbon Pool	Gas	Units	Equation	2001	2002	2003	2004	2005	2006	2007	2008

Land Converted to Forest	AGB, BGB, DOM, SOC	CO2, CH4, N20	t CO2e / yr		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Land Converted to Forest	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Land Converted to Forest	DOM	CO2	t CO2e / yr	Equation 2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Land Converted to Forest	SOC	CO2	t CO2e / yr	Equation 2.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Land Converted to Forest	Non-CO2 emissions due to biomass burning (CH4)	CH4	t CO2e / yr	Equation 2.23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Land Converted to Forest	Non-CO2 emissions due to biomass burning (N2O)	N2O	t CO2e / yr	Equation 2.24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Sub-category	Carbon Pool	Gas	Units	Equation	2009	2010	2011	2012	2013	2014	2015	2016	2017
Land Converted to Forest	AGB, BGB, DOM, SOC	CO2, CH4, N20	t CO2e / yr		0.0	0.0	0.0	0.0	-4250.6	-1243.3	-1243.3	-3936.5	-1669.4
Land Converted to Forest	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.7	0.0	0.0	0.0	0.0	-3290.0	-282.7	-282.7	-1645.1	621.9
Land Converted to Forest	DOM	CO2	t CO2e / yr	Equation 2.9	0.0	0.0	0.0	0.0	-167.9	-167.9	-167.9	-335.8	-335.8
Land Converted to Forest	SOC	CO2	t CO2e / yr	Equation 2.11	0.0	0.0	0.0	0.0	-792.7	-792.7	-792.7	-1955.5	-1955.5
Land Converted to Forest	Non-CO2 emissions due to biomass burning (CH4)	CH4	t CO2e / yr	Equation 2.23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Land Converted to Forest	Non-CO2 emissions due to biomass burning (N2O)	N2O	t CO2e / yr	Equation 2.24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Sub-category	Carbon Pool	Gas	Units	Equation	2001	2002	2003	2004	2005	2006	2007	2008
Forest converted to other land uses	AGB, BGB, DOM, SOC	CO2, CH4, N20	t CO2e / yr		0	0	0	0	22,227	17,134	4,490	4,490
Forest converted to other land uses	Biomass (AGB+BGB)	CO2	t CO2e / yr		0	0	0	0	13,290	9,286	0	0
Forest converted to other land uses	DOM	CO2	t CO2e / yr		0	0	0	0	5,860	3,358	0	0
Forest converted to other land uses	SOC	CO2	t CO2e / yr		0	0	0	0	3,078	4,490	4,490	4,490
Forest converted to other land uses	Non-CO2 emissions due to biomass burning (CH4)	CH4	t CO2e / yr		0	0	0	0	0	0	0	0
Forest converted to other land uses	Non-CO2 emissions due to biomass burning (N2O)	N2O	t CO2e / yr		0	0	0	0	0	0	0	0
Forest converted to Cropland	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.16	0	0	0	0	5,489	0	0	0
Forest converted to Cropland	DOM	CO2	t CO2e / yr	Equation 2.23	0	0	0	0	1,953	0	0	0
Forest converted to Cropland	SOC	CO2	t CO2e / yr	Equation 2.24	0	0	0	0	696	696	696	696
Forest converted to Grassland	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.16	0	0	0	0	3,562	0	0	0
Forest converted to Grassland	DOM	CO2	t CO2e / yr	Equation 2.23	0	0	0	0	1,953	0	0	0
Forest converted to Grassland	SOC	CO2	t CO2e / yr	Equation 2.24	0	0	0	0	1,066	1,066	1,066	1,066
Forest converted to Wetland	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.16	0	0	0	0	0	0	0	0
Forest converted to Wetland	DOM	CO2	t CO2e / yr	Equation 2.23	0	0	0	0	0	0	0	0
Forest converted to Wetland	SOC	CO2	t CO2e / yr	Equation 2.24	0	0	0	0	0	0	0	0
Forest converted to Settlement	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.16	0	0	0	0	4,238	9,286	0	0
Forest converted to Settlement	DOM	CO2	t CO2e / yr	Equation 2.23	0	0	0	0	1,953	3,358	0	0
Forest converted to Settlement	SOC	CO2	t CO2e / yr	Equation 2.24	0	0	0	0	1,315	2,728	2,728	2,728
Forest converted to Other land	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.16	0	0	0	0	0	0	0	0
Forest converted to Other land	DOM	CO2	t CO2e / yr	Equation 2.23	0	0	0	0	0	0	0	0
Forest converted to Other land	SOC	CO2	t CO2e / yr	Equation 2.24	0	0	0	0	0	0	0	0

Sub-category	Carbon Pool	Gas	Units	Equation	2009	2010	2011	2012	2013	2014	2015	2016	2017
Forest converted to other land uses	AGB, BGB, DOM, SOC	CO2, CH4, N20	t CO2e / yr		4,490	4,490	29,197	36,208	26,069	42,234	38,014	26,375	44,335
Forest converted to other land uses	Biomass (AGB+BGB)	CO2	t CO2e / yr		0	0	17,167	17,134	10,537	18,968	12,009	3,610	16,074
Forest converted to other land uses	DOM	CO2	t CO2e / yr		0	0	4,472	7,693	3,358	7,265	6,717	2,382	5,740
Forest converted to other land uses	SOC	CO2	t CO2e / yr		4,490	4,490	7,559	11,381	12,174	16,001	19,289	20,384	22,520
Forest converted to other land uses	Non-CO2 emissions due to biomass burning (CH4)	CH4	t CO2e / yr		0	0	0	0	0	0	0	0	0
Forest converted to other land uses	Non-CO2 emissions due to biomass burning (N2O)	N2O	t CO2e / yr		0	0	0	0	0	0	0	0	0
Forest converted to Cropland	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.16	0	0	11,677	0	10,537	0	0	0	5,537
Forest converted to Cropland	DOM	CO2	t CO2e / yr	Equation 2.23	0	0	2,519	0	3,358	0	0	0	2,382
Forest converted to Cropland	SOC	CO2	t CO2e / yr	Equation 2.24	696	696	2,450	2,450	3,242	3,242	3,242	3,242	3,967
Forest converted to Grassland	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.16	0	0	0	3,562	0	9,240	12,009	3,610	0
Forest converted to Grassland	DOM	CO2	t CO2e / yr	Equation 2.23	0	0	0	1,953	0	3,358	6,717	2,382	0
Forest converted to Grassland	SOC	CO2	t CO2e / yr	Equation 2.24	1,066	1,066	1,066	2,132	2,132	3,328	6,617	7,712	7,712
Forest converted to Wetland	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.16	0	0	0	0	0	0	0	0	0
Forest converted to Wetland	DOM	CO2	t CO2e / yr	Equation 2.23	0	0	0	0	0	0	0	0	0
Forest converted to Wetland	SOC	CO2	t CO2e / yr	Equation 2.24	0	0	0	0	0	0	0	0	0
Forest converted to Settlement	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.16	0	0	5,489	13,572	0	4,238	0	0	0
Forest converted to Settlement	DOM	CO2	t CO2e / yr	Equation 2.23	0	0	1,953	5,740	0	1,953	0	0	0
Forest converted to Settlement	SOC	CO2	t CO2e / yr	Equation 2.24	2,728	2,728	4,043	6,799	6,799	8,115	8,115	8,115	8,115
Forest converted to Other land	Biomass (AGB+BGB)	CO2	t CO2e / yr	Equation 2.16	0	0	0	0	0	5,489	0	0	10,537
Forest converted to Other land	DOM	CO2	t CO2e / yr	Equation 2.23	0	0	0	0	0	1,953	0	0	3,358
Forest converted to Other land	SOC	CO2	t CO2e / yr	Equation 2.24	0	0	0	0	0	1,315	1,315	1,315	2,728

8. Risk Assessment[91]

Small Island Developing States, in particular those in the Caribbean Region are amongst the most vulnerable to the effects and negative impacts of climate change and other natural hazards. Since the 1950's the Caribbean has had 324 disasters, representing more than 64% of all natural disasters globally. Such disasters bring with them devastating human and economic impacts. Hurricane Maria in 2017, is estimated to have cost Dominica 225 percent of its GDP (Ötker & Srinivasan, 2018)[92]. Table 33 provides a summary of all natural disasters for Dominica over the years.

After the devastating effects of Hurricane Maria in 2017, the Government of Dominica has commenced its attempts to transform the island into the world's first climate resilient country. In its efforts to do this, the country has developed a National Development Resilient Strategy (NDRS), enacted a new Climate Resilience Act, 2018 and established CREAD- a Climate Resilience Execution Agency of Dominica, to implement Dominica's recovery and resilience plan.

Dominica's Protected Areas (PA) System[93] plays a critical role in both disaster prevention and recovery by maintaining intact and healthy ecosystems necessary to mitigate natural disasters. Intact habitats and vegetation help stabilize soils, reducing floods, drought, and landslide occurrences as well as sedimentation runoff, and provide a physical barrier for tsunamis and ocean incursion. In addition, PA's provide opportunities for temporary and permeant employment in often rural and marginalized communities, to engage in climate change and mitigation management and education and outreach activities with communities and conserve the many natural resources that are harvested by local and indigenous communities either for commercial or subsistence use. It is not surprising therefore, that the establishment and effective management of the countries protected areas plays a critical role in Enhancing the resilience of ecosystems and sustainable use of natural resources, which is one of seven development objectives in the NDRP.

[91]Photo: https://www.dominica-island.info/dominica-land-crab/

[92] Ötker, I and Srinivasan, K. 2018. Bracing for the storm: For the Caribbean, building resilience is a matter of survival", March 2018 . International Monetary Fund. Finance and Development, Volume 55 (1)pp 48-51

[93] Source: Draft Dominica Protected Areas system Plan 2020

Table 32 Historic Natural Disasters in Dominica (1979-2013)

Date	Event	Impact	Date	Event	Impact
2013 Dec 24	Trough, flash flooding and landslides	Damage to housing and infrastructure	2003	Seismic activity north	
2013 April	Heavy rains, 30+ landslides across the country	Damage to roads and agriculture	2001	Drought	
2013 Sept 5	Landslide Morne Prosper	Roads blocked	1999 April	Landslides in the north 100+	Damage to roads and housing
2011 Jul 29	Landslide Soufriere	Roads blocked	1999	Hurricane Lenny	Coastal Damage
2011 Jul 28	Miracle Lake flooding ayou)	Damage to ecosystem, agriculture, fisheries and road network	1998 to 2000	Seismic activity in the south	
2011	Storm Ophelia	Damage to housing and infrastructure	1997	Landslide Bagatelle	
2010-2011	Severe Drought and extended rainy season of 2010	Loss of income in agricultural sector	1995	Hurricane Luis	Damage to housing, agriculture and infrastructure
2010 May 24	San Sauver Landslide	Disaster Zone	1995	Hurricane Marilyn (Cat 1)	Damage to housing, agriculture and infrastructure
2009 Jul	Flooding	Damage to infrastructure	1995	Hurricane Iris	Damage to housing, agriculture and infrastructure
2008	Hurricane Omar	Damage to coast and fishing industry	1989	Hurricane Hugo	
2007	Hurricane Dean (Cat 2)	Damage to agriculture and housing	1988	Hurricane Gilbert	
2007	Landslide Campbell		1986 Nov 11	Landslide Good Hope	
2007	Landslide		1986 Nov 12	Landslide Castle Bruce	
2007 Nov 29	Earthquake (6.5 Richter Scale)	Housing Infrastructure	1984	Hurricane Klaus	
2004 Nov 21	Earthquake	Damage to churches and housing in the north	1983	Landslide Bellevue Chopin	
2004 Nov	Series of landslides	1980	Hurricanes Frederick & Allen (Cat 1)	Economy Agriculture	
2003	Carholm landslide	Damage to agriculture and Tourism	1979 Aug 29	Hurricane David (Cat 5)	Total devastation
2003	Landslide Bellevue Chopin				

There are three main categories of natural hazards-:

i) *Geological hazards*: driven by the earths processes i.e. earthquakes, tsunamis and volcanic activity

ii) *Meteorological & Hydrological hazards*: driven by weather processes i.e extreme temperatures, high winds, cyclones, hurricanes, storms, floods, droughts, landslides

iii) *Biological hazards*: driven by biological processes i.e disease epidemics and insect/animal plagues

Dominica is particularly prone to geophysical and meteorological hazards. While Dominica's NPAS are important contributors of Disaster Risk Reduction, PA's themselves are also at risk from climate change and natural hazards. A risk analysis of climate change and natural hazards to Dominica's PAS is presented in table 34.

Table 33 A Natural Hazard Risk Assessment for Dominica's Protected Areas System

		Impact				
		Negligible	**Minor**	**Moderate**	**Major**	**Catastrophic**
Likelihood	**Almost certain**				Landlsides, Floods	Hurricanes & Storms
	Likely					
	Possible			Phreatic eruption	Earthquakes	
	Unlikely			Sea-level rising, temperature increases		
	Rare		Pandemics		Droughts	Volcano eruption, Tsunami

Risk Level	Low	Moderate	High	Extreme

9. Uncertainty Assessment

As indicated in the 2006 IPCC guidelines, uncertainty estimates are an essential element of a complete inventory of greenhouse gas emissions and removals. This why Dominica has determined the uncertainties of the emission factors, activity data and estimates of emissions and removals from the different categories used to estimate the FREL/FRL ; also, identifying significant sources of uncertainty to help prioritize data collection and efforts to improve the GHG inventory and REDD+ reporting.

For the Uncertainty Assessment Dominica applied Approach 1 (Propagation of Error), as described in detail in the 2006 IPCC Guidelines (Volume 1, Chapter 3, section 3.2.3.1).

Using this approach to estimate uncertainty required estimates of the uncertainty for each input, as well as the equation through which all inputs are combined to estimate an output. The simplest equations include statistically independent (uncorrelated) inputs, and this is the assumption made throughout this analysis. For uncorrelated uncertainties, the Guidelines provide two equations: one when the quantities (emission factors, activity data and other estimation parameters) are to be combined by multiplication, reproduced below in equation 3.1 (IPCC 2006 GLs, V. 1, Ch3); and another where the uncertain quantities are to be combined by addition or subtraction, reproduced in equation 3.2 (IPCC 2006 GLs, V. 1, Ch3).

EQUATION 3.1
COMBINING UNCERTAINTIES – APPROACH 1 – MULTIPLICATION

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \ldots + U_n^2}$$

Where,

U_{total} = is the percentage uncertainty in the product of the quantities
U_i = denotes the percentage uncertainties with each of the quantities

EQUATION 3.2
COMBINING UNCERTAINTIES – APPROACH 1 – ADDITION AND SUBTRACTION

$$U_{total} = \frac{\sqrt{(U_1 \bullet x_1)^2 + (U_2 \bullet x_2)^2 + ... + (U_n \bullet x_n)^2}}{|x_1 + x_2 + ... + x_n|}$$

Where,

U_{total} = is the percentage uncertainty in the sum of the quantities (expressed as a percentage)
U_i **=** is the percentage uncertainty associated with source/sink i
x_i = is the emission/removal estimate for source/sink i

9.2 Estimation of uncertainties for emission and removal factors

Some of the emission factor estimates of uncertainty ranges were generated by expert judgement, involving country experts who decided on the mean value as well as the uncertainty range. For the values selected by IPCC defaults, the rages provided were used. AGB values as well as SOC ref values, the standard deviation was calculated using the source data.

The uncertainty of each selected value was estimated using the following equation *(See Excel fille > EF-Values sheet)*:

If the range values were provided:

$$U(EF) = \frac{(\,Upper\ Limit\ (EF) - Lower\ Limit\ (EF))/2}{EF} \ * 100$$

If the standard deviation was provided:

$$U(EF) = \frac{Z_{a/2} x\ SD(EF)}{EF} \ * 100$$

Where,

Z: 1.96
SD: Standard deviation of the EF value
EF: Emissions Factor value

Table 34 Uncertainty values for selected emission factors

Parameter in the IPCC	Notation	Units according to the IPCC	Category		Value	National Value (tier 2)	Default Value (tier 1)	Error o range reported	Lower CI	Upper CI	SD	Uncertainty (%)
Wood carbon fraction of dry matter			**Elfin and Cloud forest**	FCLOUD	**0.47**		X	(0.44 - 0.49)	0.44	0.49		5.3
	Cf	[t C (t d.m.)$^{-1}$]	**Montane Rainforest**	FRAIN	**0.47**		X	(0.44 - 0.49)	0.44	0.49		5.3
			Semi-evergreen Forest	FEVER	**0.47**		X	(0.44 - 0.49)	0.44	0.49		5.3
			Deciduous - Coastal Forest	FDEC, FDRYS, FLIT	**0.47**		X	(0.44 - 0.49)	0.44	0.49		5.3
Average annual ABG growth for a specific woody vegetation type	Gw	[t d.m. ha-1 yr-1]	**Elfin and Cloud forest**	Undisturbed	**0.63**		X					0
				Disturbed (Hurricane, fire, logging, Shift.Cult)	**1.57**		X	SD:1.6			1.6	71.3
			Montane Rainforest	Undisturbed	**1.07**		X					0
				Disturbed (Hurricane, fire, logging, Shift.Cult)	**2.68**		X	SD: 2.3			2.3	76.4
			Semi-evergreen Forest	Undisturbed	**0.54**		X	SD: 1.1			1.1	79.9
				Disturbed (Hurricane, fire, logging, Shift.Cult)	**1.34**		X	SD: 2.5			2.5	94.2
			Deciduous - Coastal Forest	Undisturbed	**0.49**		X	SD: 1.1			1.1	134.8
				Disturbed (Hurricane, fire, logging, Shift.Cult)	**1.24**		X	SD: 2.4			2.4	120.6
Rario of below ground biomass to above ground biomass	R		**Elfin and Cloud forest**	Natural	**0.221**		X	SD: 0.036			0.036	31.9
			Montane Rainforest	Natural	**0.221**		X	SD:0.036			0.036	31.9
			Semi-evergreen Forest	Natural	**0.284**		X	SD:0.061			0.061	42.1
			Deciduous - Coastal Forest	Natural	**0.379**		X	SD:0.04			0.04	20.7

Basic Wood Density	D	[t C m-3]	**Elfin and Cloud forest**		**0.598**						0.99	324.30
			Montane Rainforest		**0.672**						0.82	239.00
			Semi-evergreen Forest		**0.601**						0.87	283.99
			Deciduous - Coastal Forest		**0.655**						0.70	209.37
Above-ground biomass	AGB - BW, B_BEFORE, B_AFTER	[t d.m. / ha]	**Elfin and Cloud forest**		**62.9**	X						45.4
			Montane Rainforest		**107.2**	X						130.3
			Semi-evergreen Forest		**53.6**	X						225.5
			Deciduous - Coastal Forest		**49.4**	X						122.5
Fraction of biomass loss due to disturbances	fd		**Elfin and Cloud forest**	**Affected by hurricane**	**0.85**	x			0.8	0.9		5.9
			Montane Rainforest	**Affected by hurricane**	**0.90**	x			0.85	0.95		5.6
			Semi-evergreen Forest	**Affected by hurricane**	**0.90**	x			0.85	0.95		5.6
				Affected by Shifting Cultivation	**0.60**	x			0.55	0.65		8.3
			Deciduous - Coastal Forest	**Affected by hurricane**	**0.85**	x			0.8	0.9		5.9
Litter Stocks	Litter	[t C ha-1]	**Elfin and Cloud forest**		**0.00**				0	0		0
			Montane Rainforest		**4.80**		x	Range: 2.1-16.4	2.1	16.4		149.0
			Semi-evergreen Forest		**5.90**		x	Range: 1.9-14.8	1.9	14.8		109.3
			Deciduous - Coastal Forest		**2.40**		x	Range: 2.1-2.7	2.1	2.7		12.5
Dead wood	DW	[t C ha-1]	**Elfin and Cloud forest**		**3.3**				3	3.6		9.1
			Montane Rainforest		**14.8**		x	Range: 0.6 - 218.9	9.8	19.8		33.8
			Semi-evergreen Forest		**8.0**		x	Range: 1.9-14.8	1.9	14.8		80.6
			Deciduous - Coastal Forest		**9.0**		x	Range:1.3-17.3	1.3	17.3		88.9

Soil organic carbon	SOC ref	[t C/ ha]	**Elfin and Cloud forest**		**195.8**	x					32.8	32.8
			Montane Rainforest		**164.8**	x					33.2	39.4
			Semi-evergreen Forest		**156.9**	x					38.2	47.7
			Deciduous - Coastal Forest		**153.6**	x					42.6	54.4
Factor for land use	FLU	Dimensionless	**Forestland**		**1.0**		x					75
Factor for manageme	FMG	Dimensionless	**Forestland**		**1.0**		x					75
Factor for input	FI	Dimensionless	**Forestland**		**1.0**		x					75

The calculated values were then used in equations 3.1 and 3.2 for the combination of uncertainties with the uncertainties of the activity data.

9.3 Estimation of uncertainties for LULUCF activity data

For the uncertainty of the activity data, the IPCC suggest following equation:

$$U(AD) = \frac{Z^* \times s\_ADi}{ADi} \times 100$$

Where,

Z= 1,96if ni>30 or 2,365 if ni<30*s_AD/ADi*100

Standard Error (ADi) is equal to:

$$s_{ADi} = \text{Country Total Area} \times \sqrt{\frac{(\text{pi} \times (1 - \text{pi})}{(\text{N} - 1)}}$$

ni: Number of plots per subcategory of land use

N: Total Number of plots (21991)

pi: ni/N

Table 35 Example of Uncertainties calculated for Activity Data

LULUC transition		pi	ADi	SD_ADi	U_ADi
			ha	ha	%
Row Labels	Count of Transition Coding	[ni/N]	[pi* total area]	[TotalArea*SQRT(pi*(1-pi)/(N-1))	[1,96if ni>30 or 2,365 if ni<30*s_AD/ADi*100]
CC/CANNUAL/_	130.0	0.1	6074.8	510.9	16.5
CC/CPER/_	84.0	0.1	3925.2	417.1	20.8
CF/CANNUAL>FRAIN_2013/Hurricane_2017	1.0	0.0	46.7	46.7	236.5
CG/CANNUAL>GGRASS_2014/_	1.0	0.0	46.7	46.7	236.5
CG/CPER>GGRASS_2014/_	1.0	0.0	46.7	46.7	236.5
CG/CPER>GGRASS_2018/_	1.0	0.0	46.7	46.7	236.5
CG/CPER>GWGRASS_2017/_	1.0	0.0	46.7	46.7	236.5
CS/CANNUAL>SSET_2016/_	1.0	0.0	46.7	46.7	236.5
CS/CPER>SSET_2014/_	1.0	0.0	46.7	46.7	236.5
FC/FCLOUD>CANNUAL_2011/_	1.0	0.0	46.7	46.7	236.5
FC/FDEC>CANNUAL_2005/_	1.0	0.0	46.7	46.7	236.5
FC/FDSCRUB>CANNUAL_2011/_	1.0	0.0	46.7	46.7	236.5
FC/FEVER>CANNUAL_2017/_	1.0	0.0	46.7	46.7	236.5
FC/FEVER>CANNUAL_2018/_	1.0	0.0	46.7	46.7	236.5
FC/FRAIN>CANNUAL_2013/_	1.0	0.0	46.7	46.7	236.5
FF/FCLOUD/Hurricane_2017	108.0	0.1	5046.7	469.1	18.2
FF/FDEC/Hurricane_2015	1.0	0.0	46.7	46.7	236.5
FF/FDEC/Hurricane_2017	148.0	0.1	6915.9	541.8	15.4
FF/FDSCRUB/Hurricane_2017	35.0	0.0	1635.5	273.5	32.8
FF/FELF/Hurricane_2017	42.0	0.0	1962.6	298.9	29.9
FF/FEVER/Hurricane_2017	218.0	0.1	10186.9	641.6	12.3
FF/FEVER/Shifting Cultivation_2015	1.0	0.0	46.7	46.7	236.5
FF/FLIT/Hurricane_2017	76.0	0.0	3551.4	397.7	22.0
FF/FRAIN/Hurricane_2017	603.0	0.4	28177.6	906.9	6.3
FG/FDEC>GWGRASS_2012/_	1.0	0.0	46.7	46.7	236.5
FG/FDSCRUB>GWGRASS_2005/_	1.0	0.0	46.7	46.7	236.5
FG/FEVER>GWGRASS_2015/_	2.0	0.0	93.5	66.1	167.2
FG/FEVER>GWGRASS_2016/_	1.0	0.0	46.7	46.7	236.5
FG/FLIT>GGRASS_2015/_	1.0	0.0	46.7	46.7	236.5
FG/FRAIN>GGRASS_2014/_	1.0	0.0	46.7	46.7	236.5
FO/FDSCRUB>OMIN_2014/_	1.0	0.0	46.7	46.7	236.5
FO/FRAIN>OOTHER_2017/_	1.0	0.0	46.7	46.7	236.5
FS/FDSCRUB>SSET_2011/_	1.0	0.0	46.7	46.7	236.5
FS/FDSCRUB>SWSET_2005/_	1.0	0.0	46.7	46.7	236.5
FS/FDSCRUB>SWSET_2014/_	1.0	0.0	46.7	46.7	236.5
FS/FEVER>SWSET_2012/_	1.0	0.0	46.7	46.7	236.5
FS/FRAIN>SWSET_2006/_	1.0	0.0	46.7	46.7	236.5
FS/FRAIN>SWSET_2012/_	1.0	0.0	46.7	46.7	236.5
GF/GWGRASS>FRAIN_2016/Hurricane_2017	1.0	0.0	46.7	46.7	236.5
GG/GGRASS/_	26.0	0.0	1215.0	236.4	46.0
GG/GWGRASS/_	29.0	0.0	1355.1	249.4	43.5
OO/OMIN/_	2.0	0.0	93.5	66.1	167.2
OO/OOTHER/_	7.0	0.0	327.1	123.4	89.2
SS/SSET/_	27.0	0.0	1261.7	240.8	45.1
SS/SWSET/_	34.0	0.0	1588.8	269.7	33.3
WW/WWET/_	5.0	0.0	233.6	104.4	105.6
Sum					**7729.8**

However, it is not considered appropriated as it penalizes transitions with low number of plots. This also leads to the misconception that the sample should be intensified to reduce the uncertainty. However, as the sample is not taking static parameters, such as a forest inventory, but is taking samples of transitions that represent dynamics, it is not possible to intensify a sample in dynamic that does not frequently occur. For instance, fires in cloud forest or conversions of settlements to forest lands.

This is why a new method has been proposed which is based on the interpretation error, rather than the proportions. To estimate the interpretation error, a sub-sample equivalent to 10% for each land use subcategory was taking, for those classes with more than 10 plots. For the classes with less than 10 plots (wetlands and other lands), all samples were reassessed by a GIS expert from the Coalition for Rainforest Nations, evaluating independently a total of 174 samples (Croplands: 22, Forest lands: 124, Grasslands: 5, Wetlands: 5; Settlements: 7, Other lands: 11).

The land use given by Dominica team were compared by the land use given by the GIS expert. The results for each land use category and sub-category are given in the following tables:

		Category	Sub-Category
Total, all land uses	Count	174	174
	Coincidence	169	161
	Percentage of Coincidence	97%	93%
	Interpretation Error [%]	3%	7%

		Category	Sub-Category
Cropland	Count	22	22
	Coincidence	19	17
	Percentage of Coincidence	86%	77%
	Interpretation Error [%]	14%	23%

		Category	Sub-Category
Forest lands	Count	124	124
	Coincidence	124	118
	Percentage of Coincidence	100%	95%
	Interpretation Error [%]	0%	5%

Forest lands, sub-categories	Dry Scrub	Littoral Evergreen Forest	Montane – Cloud Forest	Montane – Elfin forest	Montane – Elfin forest	Seasonal Decidious	Seasonal Semi Evergreen
Count	3.00	8.00	12.00	3.00	63.00	15.00	23.00
Coincidence	2.00	8.00	12.00	0.00	62.00	12.00	22.00
Percentage de Coincidencia	67%	100%	100%	0%	98%	80%	96%
Interpretation Error [%]	33%	0%	0%	100%	2%	20%	4%

		Category	Sub-Category
Grasslands	Count	6	6
	Coincidence	5	4
	Percentage of Coincidence	83%	67%

		Category	Sub-Category
	Interpretation Error [%]	17%	33%

		Category	Sub-Category
Wetlands	Count	5	5
	Coincidence	5	5
	Percentage of Coincidence	100%	100%
	Interpretation Error [%]	0%	0%

		Category	Sub-Category
Settlements	Count	7	7
	Coincidence	7	7
	Percentage of Coincidence	100%	100%
	Interpretation Error [%]	0%	0%

		Category	Sub-Category
Other Lands	Count	11	11
	Coincidence	10	8
	Percentage of Coincidence	91%	73%
	Interpretation Error [%]	9%	27%

These values of interpretation error were the ones selected for the uncertainty analysis *(The full analysis can be found in the excel file > Annex. Interpretation error)*

9.4 Methodology used for the estimation of uncertainties

The analysis in this submission involves mainly the sum of products of emission factors and activity data. Equations 3.1 and 3.2 were used to combine the uncertainties of individual uncertainties estimated for the emission factors and activity data for each land use sub-category (Forest land, Cropland, Grassland, Wetland, Settlement and Other Lands) as provided in the attached Excel file *(See Excel file > EF-Values sheet)*[94], and each equation applied for estimating GHG emissions and removals following the methodological guidance from 2006 IPCC GLs, V4, Ch2, as indicated in the above section Chapter 5. Then, the uncertainties associated with the emissions and removals for each land-use category were combined to obtain the uncertainties in the whole categories of Forest land remaining forest land and forest land converted to and from other land-use categories.

In discussions with the technical experts of the Coalition for Rainforest Nations and IPCC, for the propagation of uncertainties some adjustments were also necessary, in order to correctly calculate the uncertainties.

Combination of variables under addition and subtraction

The IPCC Guidelines provide an equation to estimate uncertainties when the quantities are combined under addition and subtraction:

[94] Add link

where

- the percentage uncertainty in the sum of the quantities (half the 95% confidence interval divided by the total (i.e., mean) and expressed as a percentage);
- quantities to be combined; x_i may be a positive or a negative number;
- the percentage uncertainties associated with each of the quantities.

Equation 3.2 does not clarify if the same equation has to be applied equally if the quantities are combined under addition and subtraction. This clarification is important specifically for the FOLU sector, as removals are indicated with a negative sign and emissions with a positive sign, especially when the equation 2.15 for conversion to other land uses is applied. Based on different simulations that we run, we concluded that the denominator of the equation should be written according to the way the variables are involved (either under addition or under subtraction) (See figure 77).

Simulation.

The simulation is based on uncertainty estimates for a subtraction of two variables A and B in three ways, and then the results are compared.

On one hand, the definition of uncertainty is applied:

On the other hand, uncertainties are estimated based on Equation 3.2 with

a negative sign in the denominator

and then with a positive sign in the denominator

Under the assumptions that both variables are not correlated, and each variable has a coefficient of variation which is less than 30%, the uncertainty of A-B based on the definition, and the uncertainty of A-B with a negative sign in the denominator converge almost to the same value. This conclusion indicates that Eq. 3.2 should take into account the sign under which each variable is combined.

Simulation inputs:

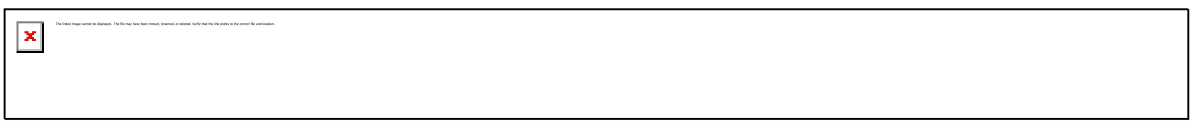
Results: 

The complete simulation using R can be found in Annex XXX

Figure 77 Simulation

Combination of quantities (emissions and removals) under addition

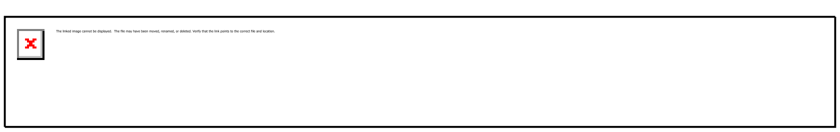
This is a special case for FOLU sector while combining emissions and removals to obtaining the overall inventory. It came to our attention that by applying the Equation 3.2 for addition of quantities with different signs such as emissions and removals, the uncertainty estimate for the overall inventory is overestimated.


or

For example:

	Emissions/ Removals [tCO2e]	Uncertainty [%]
Forest lands	-12,846,072	47.88
Croplands	1,806,550	9.04%
Total	-11,039,522	55.73

When applying this approach, the total uncertainty is even higher than the individual uncertainties. This is why, for the FOLU sector, when the quantities to be combined by addition are of different signs (- and +), understanding the need to capture the difference between emissions and removals, this adjusted equation was applied:



where

- the percentage uncertainty in the sum of the quantities (half the 95% confidence interval divided by the total (i.e., mean) and expressed as a percentage);
- quantities to be combined; x_i may be a positive or a negative number;
- the percentage uncertainties associated with each of the quantities.

With this approach, using the same individual uncertainties the total is lower and within the maximum values of the individual uncertainties

	Emissions/ Removals [tCO2e]	Uncertainty [%]
Forest lands	-12,846,072	47.88
Croplands	1,806,550	9.04%
Total	-11,039,522	41.99

Properly representing the uncertainties of the estimations for the country is important because of the implications higher or lower uncertainties may represent in terms of decision making, national planning and the carbon market.

For the application of the equations, the process started from the result towards the individual equations.

For this FRL/FRL, the analysis was divided into 4 sections: Forest land remaining forest land (undisturbed), Forest land remaining forest land (disturbed), land converted to forest lands[95] and forest lands converted to other lands [96]. In each section, the uncertainties for each of the equations (gains, losses, conversions, DOM, SOC), for each scenario of damage (Not Significant damage, Damage I, II and III) and each forest type (Elfin, Cloud, Montane, Semi evergreen, Deciduous, Dry Scrub, Littoral) was estimated (see figure 78).

This is an example of how the uncertainties in the gains for F>F (undisturbed) were estimated:

	Activity Data		Emission Factor								Removals		
Gains- No significant Damage	AD	U_AD	Gw[B]	U_Gw[BB]	R[I]	U_R[BI]	Cf[K]	U_Cf[BK]	EF	U_EF	Removals	U_Removals	U*x^2
FF/FELF/Hurricane_2017	502	4.84	0.0	0.0	0.22	31.93	0.47	5.32	0.00		0.00		
FF/FCLOUD/Hurricane_2017	1,215	4.84	0.0	0.0	0.22	31.93	0.47	5.32	0.00		0.00		
FF/FRAIN/Hurricane_2017	7,009	4.84	0.0	0.0	0.22	31.93	0.47	5.32	0.00		0.00		
FF/FEVER/Hurricane_2017	2,629	4.84	2.7	79.9	0.28	42.10	0.47	5.32	1.63	65.46	-15.70	65.64	1062451
FF/FEVER/Shifting Cultivation_20	47	4.84	2.7	79.9	0.28	42.10	0.47	5.32	1.63	65.46	-0.28	65.64	336
FF/FDEC/Hurricane_2017	47	4.84	1.6	134.8	0.38	20.69	0.47	5.32	1.04	104.73	-0.18	104.85	347
FF/FDSCRUB/Hurricane_2017	1,565	4.84	1.6	134.8	0.38	20.69	0.47	5.32	1.04	104.73	-5.95	104.85	389468
FF/FLIT/Hurricane_2015	456	4.84	1.6	134.8	0.38	20.69	0.47	5.32	1.04	104.73	-1.73	104.85	32991
FF/FLIT/Hurricane_2017	993	4.84	1.6	134.8	0.38	20.69	0.47	5.32	1.04	104.73	-3.78	104.85	156711
											-27.62	46.40	1642303

This approach was replicated for each of the equations. For the totals, the errors were propagated accordingly.

[95] File: 3B1a - 2017 Forest Land Nov 2022

[96] Files: 3B2bi - 2017 Cropland Nov 2022, 3B3bi - 2017 Grassland Nov 2022, 3B5bi - 2017 Settlements Nov 2022, 3B6bi - 2017 Other Lands Nov 2022

Figure 78 Flowchart of uncertainty estimations

The results indicated that forest related emissions and removals have a total uncertainty of 3.76%. The highest uncertainty identified was the one related to forest growth rates, ad those were default values from the IPCC. The uncertainty associated to each category can are indicated in the table 37.

Table 36 Total uncertainty of the estimations

Land use	Gas	2017 [tCO2e/yr]	Uncertainty [%]
Forest Land	CO_{2e}	700.62	3.76
Forest Land Remaining Forest Land (undisturbed)	CO_2	-28.90	44.34
Forest Land Remaining Forest Land (disturbed)	CO_2	730.65	3.50
Land Converted to Forest Land	CO_2	-1.13	5.37
Cropland Converted to Forest Land	CO_2	0.20	7.04
Grassland Converted to Forest Land	CO_2	-1.33	6.09
Wetlands Converted to Forest Land	CO_2	0.0	0.0
Settlements Converted to Forest Land	CO_2	0.0	0.0
Other Land Converted to Forest Land	CO_2	0.0	0.0
Forest Land Converted to Cropland	CO_2		11.55
Forest Land Converted to Grassland	CO_2		8.01
Forest Land Converted to Settlements	CO_2	7.46	0.0
Forest Land Converted to Other Land	CO_2		10.20
Aggregate Sources and Non-CO_2 Emissions Sources on Land	CH_4 & N_2O	**0**	**0**
Emissions from Biomass Burning	CH_4	0	0
Emissions from Biomass Burning	N_2O	0	0

10. Improvement Plan

The Government of the Commonwealth of Dominica (GoCD) is seeking to improve its capacities in forest resources management by developing a Capacity and Needs Assessment (Phase 1) and subsequently an updated National Forest Inventory (Phase 2), as a critical input to support long-term sustainable forestry management[97]. Phase 1 of this consultancy will focus on enabling Dominica to clearly identify needs and goals as it relates to the Forestry sector, including building capacity within the forestry sector to undertake and maintain the forestry inventory. Phase 2 will consist of the development of an updated National Forest Inventory that includes a high-resolution forest cover GIS database. Both phases are expected to:

1. Inform various forest resource management and conservation planning activities (e.g. development of sustainable forest management plans, a timber and lumber industry, reforestation of degraded/deforested areas, community (Kalinago) forest management projects, among others);
2. Support compliance with reporting responsibilities and other commitments under the various international conventions to which Dominica is a signatory (UNFCCC, UNCBD, UNESCO, UNCCD, etc);
3. Support the advancement of Dominica's resilience and environmental agendas;
4. Collect data necessary to quantify risk associated with impacts of climate change and natural hazards on forests, in order to better plan for budgetary allocations and other risk financing instruments; and
5. Inform future REDD+ (Reducing Emissions from Deforestation and Forest Degradation) initiatives in Dominica that can ultimately lead to the establishment of a Payment for Ecosystem Services (PES) scheme.

It is anticipated that the project will be executed in two phases over a total period of 12 months. Phase 1 is expected to last approximately 3 to 4 months and Phase 2 is expected to be carried out in 9 months.

Changes from previously submitted information

The following are the main modifications implemented by Dominica for the FREL/FRL submitted in 2022:

[97] The estimated funding envelope for this consultancy assignment is approximately USD 350,000. Interested firms should keep this estimate in mind when expressing interest in this consultancy and also when preparing full technical and financial proposals.

Improvements with respect to the original FREL/FREL submitted:

1. Improvements in the description of national circumstances after the Hurricane Maria affected the island in 2017
2. Improvements in the description of how hurricane affect forest dynamics and forest biomass
3. Improvements in Above-ground data estimations for all forest classes
4. Improvements in Growth rates data estimations for all forest classes
5. Improvements in the methodology for estimating emissions and removals. Activity data and E/R were estimated based on 4 scenarios depending on the damage caused by the hurricane:
    a. No significant damage, which are patches of forest that because of their location and characteristics were not significantly affected by the hurricane.
    b. Damage I, the stem remained standing but had broken branches or heavy defoliation,
    c. Damage II: the steam and branches were broken, full defoliation, but trees were not uprooted.
    d. Damage III: trees were totally uprooted.
6. Improvements to DOM estimations, including transfers among pools.
7. Application of the Zero FREL/FRL approach

11. References

Arnone, E, Dialynas, Y. G., Noto, L. V. & Bras, R. L. (2015) Accounting for soil parameter uncertainty in a physically based and distributed approach for rainfall-triggered landslides. Hydrological Processes 30, 927–944.

Arnone, E., Noto, L. V., Lepore, C & Bras, R. L. (2011) Physically-based and distributed approach to analyze rainfall-triggered landslides at watershed scale. Geomorphology 133, 121–131.

Baker, Timothy & Swaine, M D & Burslem, David. (2003). Variation in tropical forest growth rates: Combined effects of functional group composition and resource availability. Perspectives in Plant Ecology, Evolution and Systematics. 6. 21-36. 10.1078/1433-8319-00040.

Byer, M. D., & Weaver, P. L. (1977). Early Secondary Succession in an Elfin Woodland in the Luquillo Mountains of Puerto Rico. Biotropica, 9(1), 35–47. https://doi.org/10.2307/2387857

Błońska, E., Lasota, J., Piaszczyk, W. (2018). The effect of landslide on soil organic carbon stock and biochemical properties of soil. J Soils Sediments 18, 2727–2737 https://doi.org/10.1007/s11368-017-1775-4.

Boose, E. R., Serrano, M. I. & Foster, D. R. (2004). Landscape and regional impacts of hurricanes in Puerto Rico. Ecological Monographs 74, 335–352

Chambers, J., Higuchi, N., Schimel, J. (2000). Decomposition and carbon cycling of dead trees in tropical forests of the central Amazon. Oecologia 122, 380–388 . https://doi.org/10.1007/s004420050044

Chambers, J. Q., Fisher, J. I., Zeng, H., Chapman, E. L., Baker, D. B. & Hurtt, G. C. (2007). Hurricane Katrina's Carbon Footprint on U.S. Gulf Coast Forests. Science 318, 1107

Chave, J., Andalo, C., Brown, S. *et al.* (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia* 145, 87–99. https://doi.org/10.1007/s00442-005-0100-x

Chave, Jérôme & Muller-Landau, Helene & Baker, Timothy & Easdale, Tomás & ter Steege, Hans & Webb, Campbell (2007). Regional and phylogenetic variation of wood density across 2456 Neotropical tree species. Ecological applications: a publication of the Ecological Society of America. 16. 2356-67. 10.1890/1051-0761(2006)016[2356:RAPVOW]2.0.CO;2.

Chave, Jérôme & Muller-Landau, Helene & Baker, Timothy & Easdale, Tomás & ter Steege, Hans & Webb, Campbell. (2007). Regional and phylogenetic variation of wood density across 2456 Neotropical tree species. Ecological applications: a publication of the Ecological Society of America. 16. 2356-67. 10.1890/1051-0761(2006)016[2356:RAPVOW]2.0.CO;2.

Chave, Jérôme & Réjou-Méchain, Maxime & Burquez, Alberto & Chidumayo, Emmanuel & Colgan, Matthew & Delitti, Welington & Duque, Alvaro & Eid, Tron & Fearnside, Philip & Goodman, Rosa & Henry, Matieu & Martinez-Yrizar, Angelina & Mugasha, Wilson & Muller-Landau, Helene & Mencuccini, Maurizio & Nelson, Bruce & Ngomanda, Alfred & Nogueira, Euler & Ortiz, Edgar & Vieilledent, Ghislain. (2014). Improved allometric models to estimate the aboveground biomass of tropical trees. Global Change Biology. 20. 3177-3190. 10.1111/gcb.12629.

Clark DA & Clark DB (1992) Life history diversity of canopy and emergent trees in a neotropical rainforest. Ecological Monographs 62: 315–344European Communities (2011). Soils of Latin America and the Caribbean 2012

Cole, L. E. S., Bhagwat, S. A. & Willis, K. J. (2014). Recovery and resilience of tropical forests after disturbance. Nature communications 5, 3906

Delaney, M., Brown, S., Lugo, A.E. , Torres-Lezama, A., Quintero, N.B (1998). The quantity and turnover of dead wood in permanent forest plots is six life zones of Venezuela. Biotropica 30(1), 2-11

Everham, M. E. III & Brokaw, N. V. L. (1996). Forest damage and recovery from catastrophic wind. The Botanical Review 62, 2, 113–185

Flynn, D. F. B. (2010). Hurricane disturbance alters secondary forest recovery in Puerto Rico. Biotropica 42, 149–157

Frangi, J. L. & Lugo, A. E. (1991). Hurricane damage to a flood plain forest in the Luquillo Mountains of Puerto Rico. Biotropica 23, 324–335

Government of Dominica (2010). National Environmental Summary Commonwealth of Dominica 2010.

Government of Dominica (2012). Dominica Low-Carbon Climate-Resilient Development Strategy 2012-2020

Government of Dominica (2017) https://reliefweb.int/report/dominica/fao-agricultural-damage-assessment-mission-dominica-following-hurricane-dean

Government of Dominica (2020). Draft Dominica Protected Areas system Plan 2020

Graveson (2009). National Forest Demarcation and Bio-Physical Resource Inventory Project Caribbean – Saint Lucia: The Classification Of The Vegetation Of Saint Lucia. FCG International Ltd in association with AFC Consultants International GmbH

Hall, J., Muscarella, R., Quebbeman, A., Arellano, G., Thompson, J., Zimmerman, J. K. & Uriarte, M. (2020). Hurricane-induced rainfall is a stronger predictor of tropical forest damage in Puerto Rico than maximum wind speeds. Scientific Reports 10, 4318

Harmon, M.E., Franklin, J.F., Swanson, F.J., Sollins, P., Gregory, S.V., Lattin, J.D., Anderson, N.H., Cline, S.P., Aumen, N.G., Sedell, J.R., Lienkaemper, G.W., Cromack, K., Cummins, K.W. (1986). Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research 15, 133-302.

Hawthorne, W.D. (1995) Ecological profiles of Ghanaian forest trees. Tropical Forestry Papers 29: 1–345.

Heartsill Scalley, T. (2017) Insights on forest structure and composition from long-term research in the Luquillo mountains. Forests 8, 204

Heartsill Scalley, T., Scatena, F. N., Lugo, A. E., Moya, S. & Estrada, C. R. (2010). Changes in structure, composition, and nutrients during 15 years of hurricane-induced succession in a subtropical wet forest in Puerto Rico. Biotropica 42, 455–463

Ilins, N.M. (1981). The role of termites in the decomposition of wood and leaf litter in the southern Guinea savanna of Nigeria. Oecologia 51, 389-399.

IPCC. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. S Eggleston, L Buendia, K Miwa, et al. (eds.). Hayama, Japan: Institute for Global Environmental Strategies. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl.

IPCC. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Edited by E Calvo Buendia et al., IPCC, 2019, https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/.

Jones, E.W. (1956) Ecological studies on the rain forest of southern Nigeria IV. The plateau forest of the Okomu Forest Reserve Part II: The reproduction of the forest. Journal of Ecology 44: 83–117.

Kaarik, AA. (1974). Decomposition of wood. In Dickinson, C.H., Pugh, G.J.F., 1974. Biology of Plant Litter Decomposition. Academic Press, NYC, pp. 129–174.

King, D.A. (1994) Influence of light level on the growth and morphology of saplings in a Panamanian forest. American Journal of Botany 81: 948–957.

Lawton,R. 0. (1982). Wind stress and elfin stature in a montane rain forest tree: an adaptive explanation. Am. J. Bot. 69: 1224-1230. 1984. Ecological constraints on wood density in a tropical montane rain forest. Am. J. Bot. 71: 261- 267

Lehto T & Grace J. (1994) Carbon balance of tropical tree seedlings: a comparison of two species. New Phytologist 127: 455–463.

Lepore, C., Arnone, E., Noto, L. V., Sivandran, G., & Bras, R. L. (2013). Physically based modeling of rainfall-triggered landslides: a case study in the Luquillo forest, Puerto Rico. Hydrology and Earth System Sciences 17, 3371–3387

Lepore, C., Kamal, S. A., Shanahan, P. & Bras, R. L. (2012) Rainfall-induced landslide susceptibility zonation of Puerto Rico. Environmental Earth Sciences 66,1667– 1681

Letcher, S.G, Chazdon R.L. (2009) Rapid recovery of biomass, species richness and species composition in a forest chronosequence in northeastern Costa Rica. Biotropica 41:608–61.

Lindroth, A. (2009) Storms can cause Europe-wide reduction in forest carbon sink. Global Change Biology 15, 346–355

Lugo, A. E. (2008) Visible and invisible effects of hurricanes on forest ecosystems: an international review. Austral Ecology 33, 368–398

Marín-Spiotta E., Ostertag R., Silver W.L. (2007) Long-term patterns in tropical reforestation: plant community composition and aboveground biomass accumulation. Ecol Appl 17:828–839

Mclaren, K.,Luke, D., Tanner, E., Bellingham, P.,Healey, J. (2019). Reconstructing the effects of hurricanes over 155 years on the structure and diversity of trees in two tropical montane rainforests in Jamaica. Agricultural and Forest Meteorology. 276-277. 10.1016/j.agrformet.2019.107621

Madramootoo C. (2000). An Integrated Approach to Land and Water Resources Management in the Caribbean. Bridgetown, Barbados

Martius, C. (1997). Decomposition of wood. In Junk, Wolfgang J., 1997. Ecological Studies 126. The Central Amazon Floodplain. Ecology of a Pulsing System. Springer, NYC, 267-276

Nogueira, E.M., Nelson, B.W., Fearnside, P.M. (2005). Wood density in dense forest in central Amazonia, Brazil. Forest Ecology and Management 208, 261–286.

Nino, L., Mclaren, K., Mielby, H., Lévesque, M., Wilson, B., Mcdonald, M.A. (2014). Long-term changes in above ground biomass after disturbance in a neotropical dry forest, Hellshire Hills, Jamaica. Plant Ecology. 215. 10.1007/s11258-014-0367-2

Land Use, Protecting Carbon Sinks, and Enhancing the Resilience of Natural Ecosystems: https://unfccc.int/files/cooperation_support/nama/application/pdf/dominica_low_carbon_climate_resilient_strategy__%28finale%29.pdf

Negrón-Juárez, R. I. (2010). Widespread Amazon Forest tree mortality from a single cross- basin squall line event. Geophysical Research Letters 37, L16701

Ötker, I and Srinivasan, K. (2018). Bracing for the storm: For the Caribbean, building resilience is a matter of survival", March 2018 . International Monetary Fund. Finance and Development, Volume 55 (1)pp 48-51

Palace, M., M. Keller, H. Silva (2008). Necromass production: studies in undisturbed and logged Amazon forests. Ecological Applications: 18, 873–884.

Parker, L & Booth, W. Hurricane Hugo rips through South Carolina. The Washington Post. Friday, September 22, 1989.

Peña-Claros, M. (2003) Changes in forest structure and species composition during secondary forest succession in the Bolivian Amazon. Biotropica 35:450–461 Quesada M, Sanchez-Azofeifa GA, Alvarez-Anorve

Powers, J.S., Montgomery, R.A., Adair, E.C., Brearley, F.Q., DeWalt, S.J., Castanho, C.T., Chave, J., Deinert, E., Ganzhorn, J.U., Gilbert, M.E., González-Iturbe, J.A., Bunyavejchewin, S., Grau, H.R., Harms, K.E., Hiremath, A., Iriarte-Vivar, S., Manzane, E., De Oliveira, A.A., Poorter, L., Ramanamanjato, J.-B., Salk, C., Varela, A., Weiblen, G.D. and Lerdau, M.T. (2009), Decomposition in tropical forests: a pan-tropical study of the effects of litter type, litter placement and mesofaunal exclusion across a precipitation gradient. Journal of Ecology, 97: 801-811. https://doi.org/10.1111/j.1365-2745.2009.01515.x

Read L, Lawrence D. (2003) Recovery of biomass following shifting cultivation in dry tropical forests of the Yucatan. Ecol Appl 13:85–97

Reyes, G., Brown, S., Chapman, J., Lugo, Ariel E. (1992). Wood densities of tropical tree species, Gen. Tech. Rep. SO-88 New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 1992, 15p.

Ruth E. Sherman, Timothy J. Fahey, Patrick H. Martin and John J. Battles (2012). Patterns of growth, recruitment, mortalityand biomass across an altitudinal gradient in a neotropical montane forest, Dominican Republic. Journal of Tropical Ecology,28, pp 483-495 doi:10.1017/S0266467412000478

Scatena, F. N., & Larsen, M. C. (1991) Physical aspects of hurricane Hugo in Puerto Rico. Biotropica 23, 317–323

Scatena, F. N., Silver, W., Siccama, T., Johnson, A. & Sanchez, M. J. (1993). Biomass and nutrient content of the Bisley Experimental Watersheds, Luquillo Experimental Forest, Puerto Rico, before and after hurricane Hugo, 1989. Biotropica 25, 15–27

Shiels AB, Walker LR (2013) Landslides cause spatial and temporal gradients of multiple scales in the Laquillo Mountains of Puerto Rico. Ecol Bull 54:211–221

Shiels AB, Walker LR, Thompson DB (2006) Organic matter inputs variable resource patches on Puerto Rico landslides. Plant Ecol 184:223–236

Shiels, A. B., Gonzalez, G., Lodge, D. L., Willing, M. R. & Zimmerman, J. K. (2015). Cascading effects of canopy opening and debris deposition from a large-scale hurricane experiment in a tropical rain forest. BioScience 65, 871–881

Tanner, E. V. J., Kapos, V., & Healey, J. R. (1991). Hurricane Effects on Forest Ecosystems in the Caribbean. Biotropica, 23(4), 513–521. https://doi.org/10.2307/2388274

Tanner, Edmund & Bellingham, Peter. (2006). Less diverse forest is more resistant to hurricane disturbance: Evidence from montane rain forests in Jamaica. Journal of Ecology. 94. 1003 - 1010. 10.1111/j.1365-2745.2006.01149.x.

Thompson WA, Kriedemann PE & Craig IE (1992) Photosynthetic response to light and nutrients in sun-tolerant and shade-tolerant rainforest trees. I. Growth, leaf anatomy and nutrient content. Australian Journal of Plant Physiology 19: 1–18.

Uriarte, M., Thompson, J. & Zimmerman, J. K. (2019). Hurricane Maria tripled stem breaks and doubled tree mortality relative to other major storms. Nature Communications 10, 1362

Urquiza-Haas T, Dolman PM, Peres CA (2007) Regional scale variation in forest structure and biomass in the Yucatan Peninsula, Mexico: effects of forest disturbance. For Ecol Manag 247:80–90

Walker, L. R. (1991). Tree damage and recovery from hurricane Hugo in Luquillo Experimental Forest, Puerto Rico. Part A. special issue: ecosystem, plant, and animal responses to hurricanes in the Caribbean. Biotropica 23, 379–385

Walker, L. R., Voltzow, J., Ackerman, J. D., Fernandez, D. S. & Fetcher, N. (1992). Immediate impact of hurricane Hugo on a Puerto Rico rain forest. Ecology 73, 691–694

Wang, G. & Eltahir, E. A. B. (2000). Biosphere-atmosphere interactions over West Africa. II: Multiple climate equilibria. Quarterly Journal of the Royal Meteorological Society 126, 1261–1280

Weaver, P. L. (1989). Forest changes after hurricanes in Puerto Rico Luquillo Mountains. Interciencia 14, 181–192

Vamdermeer, J. & de la Cerda, I. G. (2004). Height dynamics of the thinning canopy of a tropical rain forest: 14 years of succession in a post-hurricane forest in Nicaragua. Forest Ecology and Management 199, 125–135

Vargas R., Allen M.F, Allen E.B. (2008) Biomass accumulation in a fire chronosequence of a seasonally dry tropical forest. Glob Change Biol 14:109–124

Veenendaal E.M., Swaine M.D., Lecha R.T., Walsh M.F., Abebrese I.K. & Owusu-Afriyie K. (1996) Responses of West African forest tree seedlings to irradiance and soil fertility. Functional Ecology 10: 501–511.

Weaver, P. L. (1986). Hurricane damage and recovery in the montane forests of Puerto Rico. Caribbean Journal of Science 22(1-2):53-70.

Weaver, P.L. (1990). Succession in the elfin woodland of the Luquillo Mountains of Puerto Rico. Biotropica, 22, 83-89.

Zhang, J. (2021). Forest recovery from hurricane disturbances: the influence of changing climate. Georgia Institute of Technology

Zimmerman, J, K. (1994). Responses of tree species to hurricane winds in subtropical wet forest in Puerto Rico: Implications for tropical tree life histories. Journal of Ecology 82, 911–922

13. ANNEXES

13.1 ANNEX 1. Simulation of uncertainties using R

```
# SUBTRACTION

rm(list=ls())
set.seed(5)

# Simulate
# "n" values from two normal distributions: "A" and "B"

n   <-  1000
A   <-  rnorm(n, mean = 3, sd = 0.3)
B   <-  rnorm(n, mean = 2, sd = 0.2)

# Correlation(A,B)
Correlation_A_B     <-  cor(A,B)

# Mean, Variance, Standard deviation
MeanA       <-  mean(A)
MeanB       <-  mean(B)

StandardDeviation_A <-  sd(A)
StandardDeviation_B <-  sd(B)

VarianceA               <-  var(A)
VarianceB               <-  var(B)

# Define the random variable "A-B"

SubtractionAB               <-  (A-B)
Mean_SubtractionAB          <-  mean(SubtractionAB)
Variance_SubtractionAB      <-  var(SubtractionAB)
StandardDeviation_SubtractionAB <-  sd(SubtractionAB)


#Uncertainty 1: Uncertainty of "A-B" using the Definition

U_SubtractionAB_1       <-  ((1.96*StandardDeviation_SubtractionAB/sqrt(n))
```

```
                                                  /abs(Mean_SubtractionAB))*100

# Uncertainty 2: Uncertainty of "A-B" using Eq. 3.2 , Vol. 1, Cap. 3 (IPCC 2006, IPCC 2019)
# with negative sign in the denominator

MeanA        <-  mean(A)
MeanB        <-  mean(B)

StandardDeviation_A <-  sd(A)
StandardDeviation_B <-  sd(B)

U_A     <-  (1.96 * StandardDeviation_A /sqrt(n)/MeanA) * 100
U_B     <-  (1.96 * StandardDeviation_B /sqrt(n)/MeanB) * 100

U_SubtractionAB_2       <-  sqrt((U_A * MeanA)^2 + (U_B * MeanB)^2)/abs(MeanA - MeanB)

# Uncertainty 3: Uncertainty of "A-B" using Eq. 3.2 , Vol. 1, Cap. 3 (IPCC 2006, IPCC 2019)
# with positive sign in the denominator

MeanA        <-  mean(A)
MeanB        <-  mean(B)

StandardDeviation_A <-  sd(A)
StandardDeviation_B <-  sd(B)

U_A     <-  (1.96 * StandardDeviation_A /sqrt(n)/MeanA) * 100
U_B     <-  (1.96 * StandardDeviation_B /sqrt(n)/MeanB) * 100

U_SubtractionAB_3       <-  sqrt((U_A * MeanA)^2 + (U_B * MeanB)^2)/abs(MeanA + MeanB)


# Print the results
options(digits = 5)
    print(Correlation_A_B)

## [1] 0.018155

    print(MeanA)

## [1] 3.0052

    print(MeanB)

## [1] 2.0146

    print(VarianceA)

## [1] 0.092176

    print(VarianceB)

## [1] 0.039414

    print(StandardDeviation_A)

## [1] 0.3036
```

```
    print(StandardDeviation_B)

## [1] 0.19853

    print(Variance_SubtractionAB)

## [1] 0.1294

    print(StandardDeviation_SubtractionAB)

## [1] 0.35972

    print(U_SubtractionAB_1)

## [1] 2.2507

    print(U_SubtractionAB_2)

## [1] 2.2697

    print(U_SubtractionAB_3)

## [1] 0.4479

# END
```