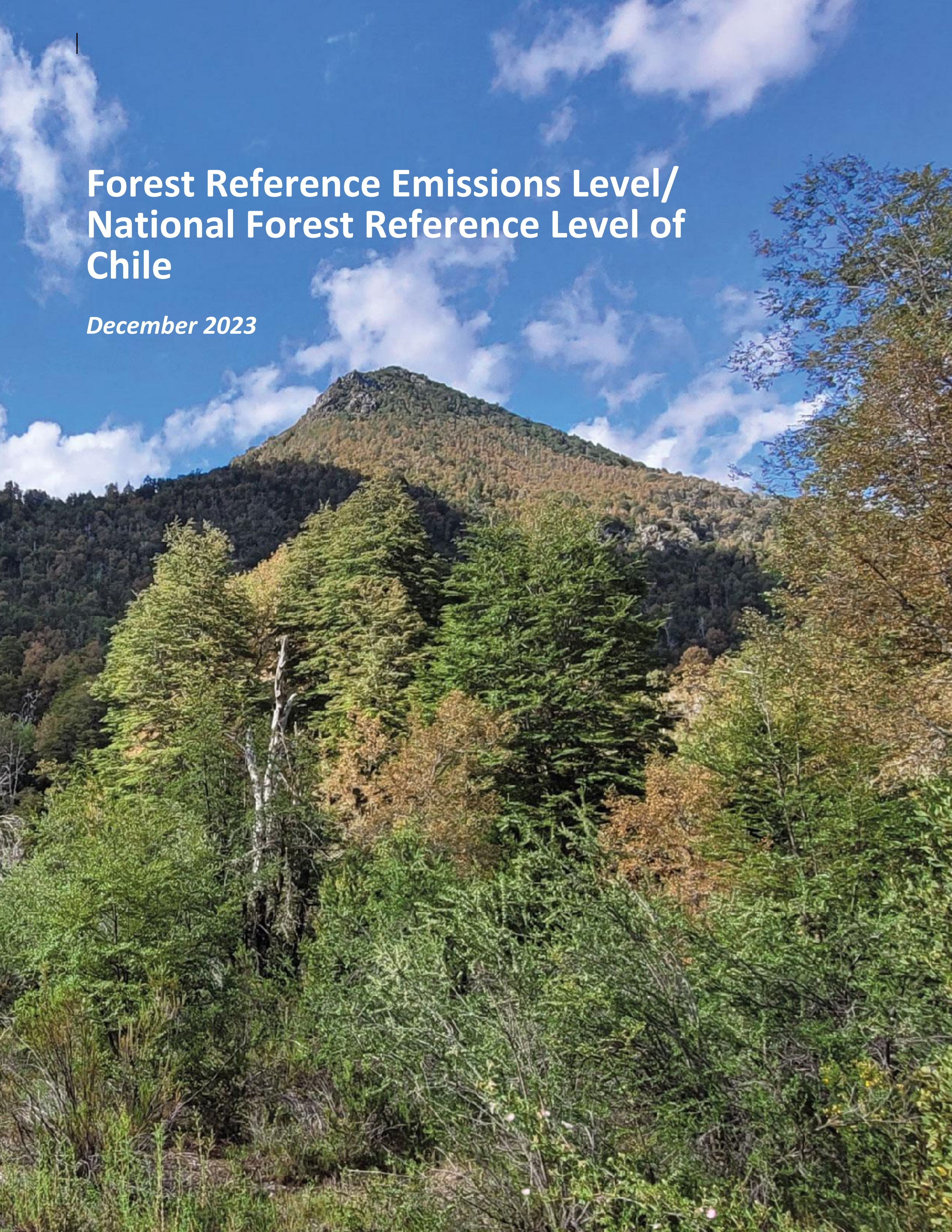
Forest Reference Emissions Level/ National Forest Reference Level of Chile

December 2023



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1. INTRODUCTION

In 2016, as part of Chile's commitment to the United Nations Framework Convention on Climate Change (UNFCCC), and in response to the UNFCCC invitation issued under decision 12/CP.17 paragraphs 9 and 11, Chile voluntarily submitted its first Forest Reference Emission Levels/Forest Reference Levels (FREL/FRL)[1] at the sub-national level using a historical average for the period 2001-2013.

In this document, with the aim of strengthening the country's commitment under the UNFCCC and ensuring compliance with the Warsaw Framework in the context of payments for REDD+ results, Chile presents a proposal to update and expand its FREL/FRL, which incorporates, among other improvements, the estimation of emissions and removals covering 99.3 percent of the country's forest area.

According to decision 12/CP. 17 paragraph 7 of the UNFCCC, an FREL/FRL is a reference point to evaluate the performance of countries that are implementing their REDD+ activities in the context of financing based on the results of measured, reported and verified emission reductions or removals. An FREL/FRL must analyse the historical emissions of greenhouse gases (GHG) and project them into the future in order to assess the performance of the policy approach associated with REDD+.

In this regard, in 2016 Chile presented its first FREL/FRL at the sub-national level, which corresponds to the period 2001-2013 for land use change activities and 2001-2010 for activities that occur in permanent forest, including the following REDD+ activities: reduction of emissions from deforestation, reduction of emissions from degradation, enhancement in carbon stocks and forest conservation. The first sub-national FREL/FRL included five regions of the country with a high presence of native forest, representing 22 percent of the national territory and 41 percent of the total area of native forest. In addition, it is based on the annual average of captures and/or emissions of carbon dioxide, including methane and nitrous oxide in the activity of reducing emissions caused by degradation.

On that occasion, the FREL/FRL was prepared through a "stepwise" approach, which allowed its continuous improvement and expansion on a national scale, based on the optimization of the methods used and the development of better information. In addition, implementing this approach in both the first FREL of Chile, and the REDD+ Technical Annex[2] to the Third Biennial Update Report of Chile presented to the UNFCCC in 2018 (including the results of emission reductions and removals achieved for the periods 2014, 2015 and 2016 for land use change activities, and 2011, 2012, 2013, 2014, 2015 for activities in permanent forest), and their respective assessment reports by the UNFCCC roster of experts, enabled the identification of a number of areas for improvement to develop the capacities needed for subsequent FREL/FRL.

According to the 2016 assessment report,[3] the areas for improvement identified during the technical assessment processes include progress in developing methodologies to generate biennial activity data (AD), the improvement in parameters and emission factors (EF), the incorporation of the Mediterranean and southern climate regions of Chile, and the use of alternative technologies for the treatment of satellite information in regions with high cloud cover.

[1] Document available at https://www.enccrv.cl/nref

[2] Document available at https://www.enccrv.cl/anexo-redd

[3] https://unfccc.int/resource/docs/2016/tar/chl.pdf

This proposal to update and expand the FREL/FRL is implemented at the national scale, since it includes 12 of the 16 regions of the country from Coquimbo to Magallanes, six of which were included in the first FREL/FRL[4] (Maule, Ñuble, Biobío, La Araucanía, Los Ríos, and Los Lagos Regions).

This document and its annexes have been prepared in accordance with the modalities and guidelines established in decision 12/CP.17 Section II and Annex and following the methodological guidelines of the Intergovernmental Panel on Climate Change (IPCC, 2006). In this regard, the stated assumptions, where necessary, are consistent with those defined under the National Inventory of Greenhouse Gases (INGEI by its Spanish acronym) of Chile for the period 1990-2018, which was provided to the Secretariat of the Convention in 2020 through Chile's Fourth Biennial Update Report on Climate Change (IBA by its Spanish acronym).[5]

The updated and expanded FREL/FRL has been developed under the criteria of consistency and aligned with Chile's INGEI, and describes all the information and methods used in a transparent, complete and detailed manner, including:

- Chile's definition of forest for REDD+ policy approaches, in addition to the definition of the four REDD+ activities considered.
- The sources of information and methodological protocols used to develop the national FREL/FRL of Chile.
- The carbon and GHG sinks considered in the FREL/FRL of each REDD+ activity.

The proposal to update the FREL/FRL presented in this document has been prepared by CONAF, led by its Department of Climate Change and Ecosystem Services (DCCSE), in collaboration with the Department of Monitoring Ecosystems and Climate Change (DMECC), with the technical support of the World Bank, which acts as the Implementing Agency of the FCPF. The technical team has also received the support of the Forestry Institute (INFOR) and the United Nations agencies FAO, UNEP and UNDP, as part of the United Nations REDD Programme (UN-REDD), in which Chile has participated since 2014.

[4] The province of Ñuble was split from the Biobío Region in September 2018, giving rise to the new Ñuble Region.

[5] https://www4.unfccc.int/sites/SubmissionsStaging/NationalReports/Documents/574160_Chile-BUR4-1-Chile_4th%20BUR_2020.pdf

2. BACKGROUND

2.1 National Circumstances

The National Forestry Corporation (CONAF) as Chile's REDD+ focal point before the UNFCCC, has decided to focus efforts on updating and expanding the FREL/FRL to the national level, covering the territories that represent the greatest area and diversity of forests in the country, in addition to presenting strong anthropic pressure. As a result, 12 of the 16 administrative regions of the country are considered in this proposal, from the Coquimbo Region to the Magallanes Region (see Figure 1).

For the purpose of this proposal, the FREL/FRL will be considered national in scope since it covers practically all of the native forest areas of Chile. In these regions, the forest ecosystems of the Mediterranean, temperate and southern forests of the country are found. These 12 regions represent 65.5 percent of the total land area of Chile with almost 50 million hectares and they represent 99.3 percent of the forest area, including the 12 forest types defined at the national level.

The remaining regions – Arica and Parinacota, Tarapacá, Antofagasta and Atacama – are located in the extreme north of the country and correspond to desert ecosystems subjected to high aridity regimes. The current vegetation resources in these regions total 95,000 hectares of forests, equivalent to 0.006 percent of the national total, together with 12,400 hectares of grasslands and scrublands. In addition, 74 percent of the areas devoid of vegetation in the country are located in these regions.

2.1.1 Institutional framework

Since Chile ratified the UNFCCC in 1994, and later becoming part of the Kyoto Protocol (United Nations, 1997) in 2002, the country's climate change institutions have registered important advances that have been reflected in the implementation, in 2014, of the Council of Ministers for Sustainability and Climate Change, a deliberative body for public policy and general regulation on environmental matters, which is chaired by the Ministry of the Environment.[6]

In January 2010, Law 20,417 was promulgated, which created the Ministry of the Environment (MMA) that was also designated as Focal Point before the UNFCCC, which has made it possible to better coordinate and guide government actions to address the challenges and opportunities imposed by climate change at the level of public policy.[7] Prior to the creation of the Ministry of the Environment, and after Chile ratified the UNFCCC in 1994, the National Advisory Committee on Global Change (CNACG) was established. Made up of representatives from both the public sector and academia, in 2006 the CNACG prepared the National Climate

[6] The Council includes the Ministry of Agriculture; the Ministry of Finance; the Ministry of Health; the Ministry of Economy, the Ministry of Development and Tourism; the Ministry of Energy; the Ministry of Public Works; the Ministry of Housing and Urbanism; the Ministry of Transport and Telecommunications; the Ministry of Mining; the Ministry of Social Development and Family; the Ministry of Education; and the Ministry of Science, Technology, Knowledge and Innovation (Law 21,455, Art. 46 No. 12).

[7] Law 20,417 establishes in article 70, letter h, that "(...) it will be especially up to the MMA to propose policies and formulate plans, programmes and action plans on climate change."

Change Strategy[8] that established adaptation, mitigation, and the creation and strengthening of capacities as the main axes to be executed through the National Action Plan for Climate Change 2017-2022 (PANCC).[9]

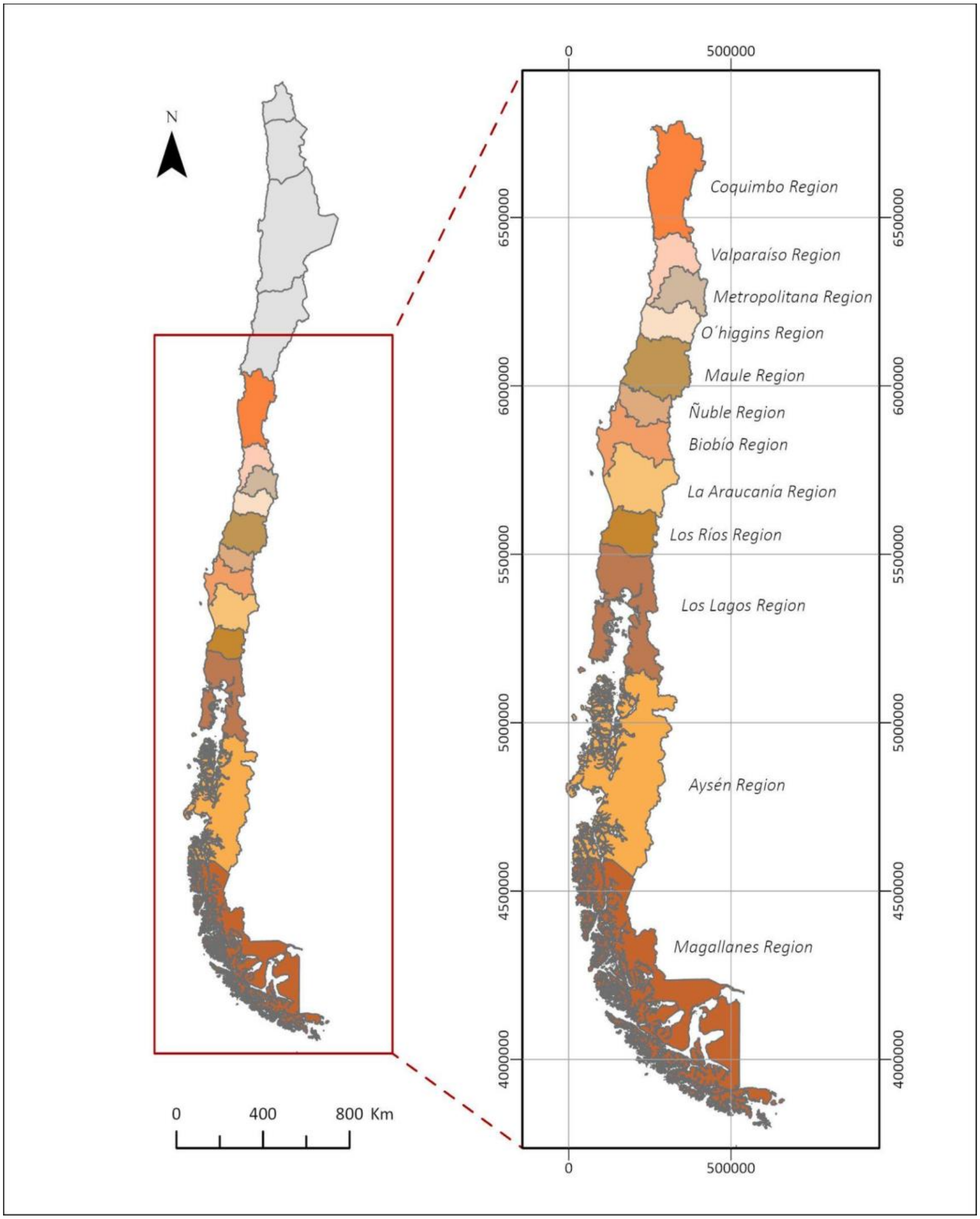

Figure 1. Area covered by the National FREL/FRL

[8] National Climate Change Strategy: http://www.bcn.cl/carpeta_temas_profundidad/temas_profundidad.2007-04-11.5841476988/Estrategia%20nacional%20_2006.pdf

[9] https://mma.gob.cl/wp-content/uploads/2017/07/plan_nacional_climatico_2017_2.pdf

In 2010, when the Ministry of the Environment was formed, the Climate Change Office was created to support inter-institutional cooperation, particularly in the framework of international negotiations on climate change and the national commitments that arise from them, under the auspices of the Undersecretariat for the Environment. This office has the mission of actively participating "in the international negotiation processes associated with the implementation of the UNFCCC and its main functions are coordinating the Committee of the Designated National Authority (DNA) of the Clean Development Mechanism (CDM), acting as focal point of the Intergovernmental Panel on Climate Change (IPCC), and holding the position of technical secretariat of the inter-ministerial committees on climate change".[10]

In this context, due to the complexity of the issues addressed in the UNFCCC on the Land Use, Land Use Change and Forestry (LULUCF) sector, and specifically those linked to the decisions of the Convention that promote the development of national strategies to reduce emissions from deforestation and forest degradation, and support actions aimed at conservation, sustainable management of forests and the enhancement of forest carbon reserves, commonly known as REDD+, the National Forestry Corporation of Chile (CONAF), under the Ministry of Agriculture (MINAGRI), was designated as the REDD+ Focal Point to the UNFCCC.[11] CONAF carries out this role through its Department of Climate Change and Ecosystem Services (DCCSE), as part of the Forest and Xerophytic Ecosystems Conservation Management (GCEBX).

CONAF's mission is to guarantee the conservation, restoration and sustainable management of the country's forest and xerophytic ecosystems, through actions aimed at conservation, ecosystem management, monitoring and tree planting, in order to satisfy the current and future demand for ecosystem goods and services and contribute to the territorial development of indigenous peoples, vulnerable communities and the valuation of biodiversity in a scenario of climate crisis.

CONAF's strategic objectives have recently been updated, according to the following list:

1. Conservation: ensure the conservation of forest and xerophytic ecosystems in State Protected Wilderness Areas and other areas, reducing the risk of environmental disasters caused by anthropic and non-anthropic action, with a preventive approach to fires and other causes of ecological damage.
2. Management of ecosystems: promote and manage landscapes and forest and xerophytic ecosystems for multifunctional purposes, promoting the management and restoration of native forests and xerophytic formations, through nature-based solutions, as well as forest management practices in plantations that protect environmental components.
3. Monitoring: monitor the behaviour of forest and xerophytic ecosystems at different scales, in order to predict and identify natural and anthropic processes that impact the supply of ecosystem goods and services and the conservation of biodiversity.
4. Tree planting: promote and develop ecological actions for the creation and strengthening of green areas that contribute to resilience in cities and territories, recognizing cultural heritage in the work approaches with indigenous peoples and vulnerable communities.

[10] Chile's First Biennial Update Report under the United Nations Framework Convention on Climate Change. MMA, 2014. Page 55. https://www4.unfccc.int/sites/SubmissionsStaging/NationalReports/Documents/574160_Chile-BUR4-1-Chile_4th%20BUR_2020.pdf

[11] This designation was based on the decision taken at the COP19 in Warsaw where countries were invited to nominate National Focal Points or Designated National Entities for REDD+, through Official Letter No. 99 of the Ministry of Agriculture on 19 February 2014.

5. Public policy: promote technical-political dialogue and the development of coordinated public policy instruments for the fulfillment of the proposed objectives in terms of mitigation and adaptation to climate change, and with territorial approaches in a local, regional, national and international context.
6. Public-private partnerships: generate partnerships for forestry development and promote public-private collaboration for institutional development and compliance with the objectives and goals associated with climate change and CONAF.
7. Employment: offer training, employment and forest development opportunities associated with the protection, conservation and management of forest and xerophytic ecosystems and biodiversity, contributing to the territorial development of indigenous peoples and vulnerable communities.
8. Public transparency: ensure the transparency of the use of public resources in institutional management, administration and the timely delivery of information, and the development of human resources.

Considering CONAF's role as a State forest service, as well as its mission and strategic objectives, in 1995 it was designated as Focal Point of the United Nations Convention to Combat Desertification (UNCCD), expanding the scope of its efforts to include the actions required to respond to its commitments under both conventions (UNCCD and UNFCCC), as well as to the obligations related to its role as technical advisor to MINAGRI, in coordination with other ministerial institutions that have competencies related to forest management in Chile.

In 2014, the Intraministerial Technical Committee on Climate Change (CTICC by its Spanish acronym) was created, which is coordinated by the Office of Agrarian Studies and Policies (ODEPA) that brings together the various services that make up MINAGRI,[12] including CONAF. It is expected that the CTICC will soon be represented in all 16 regions of the country, possibly being chaired by the Regional Ministerial Secretariats (SEREMI) of agriculture with the participation of representatives of the various public services linked to the agriculture and forestry sector.

2.1.2 Legislation

Chile has different regulations developed directly and indirectly for the use and protection of forest resources. The application and effectiveness of these legal norms have had different impacts on the development of the country and have directly influenced the current situation of its forests.

Among the relevant regulations for the forestry sector is the **Forest Law** (DL No. 656 of 1925, according to the modified text established by DS No. 4363 of the Ministry of Lands and Colonization in 1931), which highlights the importance of forests for the protection and improvement of soils, for the regulation of river flow and for the conservation of water resources in general, as well as a source of raw materials for numerous industries, and a source of health for the population. This law substantially improved a series of important elements such as the rules on the use of fire, maintaining a prohibition on the use of fire to clear forest land; norms related to protected wild areas, consecrating the power of the President to create National Parks and Forest Reserves; and norms associated with the system of sanctions, establishing fines for the case of non-compliance with sanctions ranging from imprisonment to monetary fines (Saelzer, 1973). Among the most important are the

[12] Other MINAGRI institutions that have responsibility for forests are the Office of Agrarian Studies and Policies (ODEPA), the Institute of Agricultural Development (INDAP), the Foundation for Agrarian Innovation (FIA), the Institute of Agricultural Research (INIA), the Forestry Institute (INFOR), the Natural Resources Information Center (CIREN), and the Agricultural and Livestock Service (SAG).

prohibitions that remain in force today, such as those related to the ban on cutting native trees and shrubs located near springs or on slopes of more than 45 percent.

One of the most important regulations for the forestry sector is **Decree Law No. 701 on Forestry Promotion**. It was enacted in 1974 and developed a forest policy based on two main pillars: incentives for afforestation and protection of forest resources. Under this framework, the classification of land as Preferably Suited for Afforestation (APF) creates a technical-legal requirement, whereby a forestry specialist must prove that the lands, due to their climate and soil conditions, cannot be permanently cultivated and that they may suffer degradation if used for agriculture, fruit growing or livestock. If the classification is approved by the authority, the owner may be able to receive certain benefits such as tax exemptions and a bonus for afforestation, while also being required, as expressed in article 22, to reforest after the clearing of forests or timber production.

In addition, another technical-legal instrument, the Forest Management Plan, was incorporated as a concept in 1979 by DL No. 2,565 that modified DL No. 701 of 1974. The Forest Management Plan is defined in article 2 of DL No. 701 as an instrument that regulates the rational use of renewable natural resources on a given piece of land, in order to obtain the maximum benefit from them, while ensuring the preservation, conservation and improvement of these resources and their ecosystem. This instrument has become the central axis of the system and is understood as a programme for the rational use of forest resources that can be plantations or native forests. Thus, the Forest Management Plan has two main dimensions: a technical component, since it must be prepared by a specialized forestry engineer or agronomist who must determine the characterization of the site and the forest resource, the management objectives, and the silvicultural method, among others, and a legal component since, once approved, it requires the owner to execute the management plan, imposing sanctions in case of non-compliance.

Later, the legal definition of different Forest Types of Chilean native forest was incorporated into the technical regulation of DL No. 701, through Supreme Decree No. 259 in 1980, which also establishes the silvicultural methods that can be applied in each type.

DL No. 701 considered three types of regulations: those that guaranteed the right to property, tax incentives and economic incentives. The latter consisted of a bonus granted by the State for afforestation and initial management of the plantations, on APF-qualified land, in accordance with the previously approved Forest Management Plan. The State “offers a one-time payment for each area, corresponding to a percentage of the net costs of various activities such as afforestation on fragile and degraded soils, soil recovery activities or dune stabilization, establishment of windbreaks, and the first pruning or thinning carried out by small-scale forest owners,[13] among others”.[14] This law does not incorporate incentives for the management of native forests.

DL No. 701 of 1974, with its various modifications, resulted in Chile becoming one of the countries with the highest rate of forestation in relation to its size and population, and it established the foundation for the creation of one of country's largest industries based on the production of pulp and sawn wood associated with fast-growing exotic forest species.

In 1996, the forest subsidy of DL No. 701 expired, but it was extended in 1998 with the enactment of Law 19,561 until 2011, when a new extension was approved until 2012. However, since 2013, Chile has not offered specific

[13] Before 1998, pruning and thinning by forestry companies was subsidized for many years, as were the administration payments; later, with Law No. 19,561 of 1998, this work was focused on small and medium-sized forests ().

[14] http://www.leychile.cl/Navegar/index_html?idNorma=99208

economic incentives for afforestation, and a new forestry development law is being designed that takes a different approach, focusing the use of public resources on forest plantations, mainly with native species, that provide permanent cover, balancing industrial aspects with the provision of environmental services such as the protection of water courses, generation of non-timber forest products, and the protection of biological diversity, among others.

Since its promulgation in 2008, Law 20,283 on Native Forest Recovery and Forest Promotion seeks to protect, recover, and improve the country's native species, ensuring their forest sustainability through management and conservation plans. The law includes 26 definitions of concepts and elements, aimed at unifying criteria and homogenizing the understanding of forestry regulations. Many of these definitions come from previous regulations and have been modified. Among the most important are the definitions of Forest, Native Forest, Small-scale Forest Owner, Management Plan and Environmental Services.

Regarding the definition of Forest Types, and the management methods applicable to them, Law No. 20,283 on Native Forest Recovery and Forest Promotion is based on those established in the regulations of DL 701 of 1974 on Forestry Development, but it indicates that a new typology should be proposed based on scientific and technical studies and validated through a consultation with public and private stakeholders.

Law 20,283 also establishes that CONAF will maintain a permanent forest cadastre, in which it must identify and establish, at least cartographically, the existing forest types in each region of the country, their current condition, and those areas where there are ecosystems with native forest of special interest for conservation or preservation. According to the law, the forest cadastre must be updated at least every ten years and its information must be made available to the public, which is a requirement that has been met through the website of CONAF's Territorial Information System (SIT).[15]

The concept of the Forest Management Plan, established in DL 701, is complemented in this law with the creation of the Preservation Management Plan as an alternative tool for those forests where the main objectives are the preservation and recovery of the native forest; and with the Forestry Planning Management Plan, whereby projects that incorporate forest planning forestry management methodologies that ensure the sustainable management of forests in the long term will receive a special economic benefit.

With respect to environmental protection regulations, the law includes biodiversity conservation and measures to prevent and combat forest fires. In addition, through the regulation of soils, waters and wetlands, it contemplates restrictions on felling and productive activities in certain areas, including measures to protect soils, as well as the quality and quantity of the flow of water courses.

To access incentives for native forest management, under the framework of Law 20,283, the Conservation Fund and the Native Forest Research Fund were created.

The Fund for the Conservation, Recovery and Sustainable Management of Native Forest,[16] which was created in 2008, is a competitive mechanism that is designed to help cover the cost of activities considered in the forest management plans that promote the sustainable use of this renewable natural resource.

[15] https://sit.conaf.cl/

[16] https://concursolbn.conaf.cl/ayuda/2018/83f_Reglamento_Fondo_Conservacion.pdf

This fund considers an economic benefit intended to help cover the cost of the activities necessary to promote the regeneration, recovery or protection of xerophytic formations of high ecological value or native forest conservation, to obtain non-timber products, and to manage and recover native forests for timber production purposes, with an additional benefit offered for the preparation of forest management plans that incorporate the use of area-based management tools.

In addition to this fund, the Native Forest Research Fund (FIBN),[17] which was also created in 2008, is aimed at scientific and technological research related to native forests and the protection of their biodiversity, with the protection of the soil, water resources and flora and fauna of the ecosystems associated with native forests, and the establishment of training, education and technology transfer programmes for the members of rural communities whose livelihoods depend on native forests, among other activities.

The technical details of the operation and implementation of these funds were established in Law 20,283, which has been modified twice since its promulgation.

Since the Native Forest Research Fund was created, a total of 203 projects have been financed with a total investment of CLP 9,929,490,438 (see Table 1).

Finally, one of the most important recent environmental milestones in the country has been the approval of the Climate Change Framework Law,[18] which came into force in June 2022. This law positions the fight against climate change as a State policy and defines the mechanisms that the country will use for this purpose. In particular, it establishes concrete actions to be carried out by 17 ministries, granting powers and obligations at the central, regional, and local levels, and facilitating participation and coordination at the territorial scale in order to achieve the goal of making Chile carbon neutral and climate resilient by 2050 at the latest. In addition, it strengthens public participation processes during the development of climate change management instruments and incorporates the obligation on the part of the Ministry of the Environment to make periodic reports to National Congress on progress in climate action, while strengthening transparency through monitoring, reporting and verification for all management instruments.

[17] https://www.conaf.cl/wp-content/files_mf/1396624849DTO28_19OCT2013.pdf

[18] Law N° 21,455, available at: https://www.bcn.cl/leychile/navegar?idNorma=1177286

Competition	Year	N° of projects	Financing
I Edition FIBN	2009/2010	24	660,573,395
II Edition FIBN	2010/2011	21	798,298,409
III Edition FIBN	2011/2012	26	811,632,022
IV Edition FIBN	2012/2013	13	691,439,534
V Edition FIBN	2013/2014	12	808,430,751
VI Edition FIBN	2014/2015	11	852,874,532
VII Edition FIBN	2015/2016	12	626,096,249
VIII Edition FIBN	2016/2017	13	690,897,898
IX Edition FIBN	2017/2018	15	927,185,967
X Edition FIBN	2018/2019	17	956,640,210
XI Edition FIBN	2019/2020	19	993,393,396
XII Edition FIBN	2020/2021	10	577,993,375
XIII Edition FIBN	2021/2022	10	534,034,700
Total		**203**	**9,929,490,438**

Table 1. Number of projects and amount financed by the Native Forest Research Fund per year. Source: CONAF, 2022

2.1.3 Chile's Nationally Determined Contribution NDC

In terms of the main commitments regarding climate change that involve the work of these institutions, there is the commitment made in 2020 to the Secretariat of the UNFCCC to update Chile's Nationally Determined Contribution (NDC).[19]

The update presents quantitative goals that are part of Chile's broader goal to achieve GHG neutrality and climate resilience by 2050, as established in the Framework Law on Climate Change.

In relation to the reduction of emissions, the fulfillment of the goals requires a multisectoral effort of public policies and measures that promote the effective and permanent reduction of GHG emissions over time. In addition, regarding the increase in carbon sequestration from the atmosphere, Chile must advance in the approval of management instruments that make it possible to protect, maintain and increase natural carbon sinks, while also considering the multiple ecosystem services they provide.

Thus, Chile has included within the integration component a specific goal for the LULUCF sector, which takes into account the importance of the role of terrestrial ecosystems in the capacity to sequester carbon, in achieving carbon neutrality and in adaptation to the impacts of climate change.

The specific contribution in terms of LULUCF considers the ecosystem function of forests to capture and sequester large amounts of carbon dioxide through the accumulation of biomass and organic matter accumulated in the soil, considering as part of the State's commitment its role in supporting forest owners and integrating a gender approach, thereby allowing the development of more transparent and inclusive initiatives.

[19] https://cambioclimatico.mma.gob.cl/wp-content/uploads/2020/08/NDC_2020_Espanol_PDF_web.pdf

Considering the above, and in accordance with the Sustainable Development Goals (SDGs),[20] Chile has committed to the sustainable management and recovery of 200,000 hectares of native forests (representing the capture of 0.9 to 1.2 $MtCO_2e\ yr^{-1}$) and the afforestation of 200,000 hectares (representing the capture of between 3.0 and 3.4 $MtCO_2e\ yr^{-1}$), of which 100,000 hectares correspond to permanent forest cover, with at least 70,000 hectares of native species.

LULUCF sector goal (ha)	CO_2 goal	ENCCRV activities	SDG
Sustainable Management and Recovery 200,000 ha	0.9 to 1.2 $MtCO2e\ yr^{-1}$	MT5 Ecological Restoration IF2 Restoration of burned areas US1 Sustainable planning forest management	**13 Climate action** **15 Life of terrestrial ecosystems**
Forestation 200,000 ha	3.0 to 3.4 $MtCO2e\ yr^{-1}$	MT4 Afforestation with native species US1 Sustainable forest management	
Reduction of emissions from the forestry sector due to degradation and deforestation of the native forest by 25% by 2030, considering the period 2001-2013	3.1 $MtCO2e\ yr^{-1}$	IF3 Preventive silviculture IF2 Restoration of burned areas US1 Sustainable forest management US3 Wood energy programme PF1 Phytosanitary protection programme	

Table 2. Goals of the LULUCF sector in Chile's NDC. Source: MMA, 2020

In addition, the sectoral commitment to reduce emissions from deforestation and degradation of forests by 25 percent by 2030 is incorporated in this goal, considering the average emissions in the period 2001-2013. In this regard, the actions of the ENCCRV are required to improve the management models in forest fire prevention and restoration of burned areas, strengthen phytosanitary protection and promote adaptive management, among others.

In order to achieve the LULUCF sector goals, the ENCCRV has been identified by the Ministry of Agriculture, through CONAF, as the main tool for this task, since it specifically considers direct and facilitating action measures focused on facing climate change, desertification, degradation of land and drought, through adequate management of vegetation resources.

2.1.4 National Climate Change and Vegetation Resources Strategy (ENCCRV)

The ENCCRV is a public policy instrument, approved in 2016, which aims to "reduce the social, environmental and economic vulnerability of the communities that depend on vegetation resources to climate change, desertification, land degradation and drought, in order to increase the resilience of ecosystems and contribute to mitigating climate change, while promoting the reduction and capture of greenhouse gas emissions in Chile."

[20] https://www.chileagenda2030.gob.cl/

The ENCCRV includes key elements related to adaptation to climate change and the fight against desertification, land degradation and drought, and seeks to contribute to Chile's national and international commitments under the UNFCCC and the UNCCD.

As part of the preparation process of the ENCCRV, different goals were established for adaptation and mitigation in the period 2017-2025, which are as follows:

- **Mitigation:** reduce GHG emissions associated with forest degradation and deforestation by 20 percent by 2025, based on emissions from the period 2001-2013, as well as increasing the capacity of vegetation resources as a carbon sink.
- **Adaptation:** reduce the vulnerability associated with the risk of land degradation through the management of vegetation resources, with direct intervention on at least 264,000 hectares between 2017 and 2025. The contribution to the reduction of vulnerability will be evaluated in terms of indicators associated with biodiversity, provision of ecosystem services, such as the regulation of water flows and quality, as well as soil productivity.

To achieve the proposed goals, 26 action measures were established, of which seven are direct actions and 19 are enabling activities. The direct action measures include actions such as the implementation of afforestation (MT4), ecological restoration (MT5), post-fire restoration (IF2), preventive silviculture (IF3), planning forestry management (US1), wood energy (US3) and livestock management activities to ensure compatibility with vegetation resources (MG1).

The national efforts in the implementation of REDD+ actions, and the advances in the implementation of the ENCCRV, have allowed the country to access economic benefits associated with its performance in reducing emissions and removals resulting from the actions implemented at the sub-national level, and estimated based on Chile's first FREL, which in the context of REDD+ is described as results-based payment.

After the presentation of the first Technical Annex of Chile's REDD+ Results to the UNFCCC in 2018, in accordance with the guidelines of Decision 4 CP/19, the country presented its emissions reductions for the periods 2014, 2015 and 2016. Based on the results in the Technical Annex, in 2019 Chile presented its emissions reduction programme to access the results-based payments of the Green Climate Fund, which was approved in November 2019 and represents a total of USD 63 million in results-based financing for a total reduction of 6.1 $MtCO_2e\ yr^{-1}$. This financing has facilitated the results-based payments phase of the ENCCRV, through the +Bosques project.

The +Bosques, together against climate change, project is led by the Ministry of Agriculture, through CONAF, and implemented with support from the Food and Agriculture Organization of the United Nations (FAO).

With the investment received by the country, the +Bosques project has been carrying out, since 2021, actions to sustainably manage more than 25,000 hectares of native forest, thereby generating social, environmental, and economic benefits for nearly 90,000 people in the Maule, Ñuble, Biobío, Araucanía, Los Ríos and Los Lagos Regions.

To achieve these goals, the project implements direct action and enabling measures of the ENCCRV, focused on increasing the country's forest area, restoring degraded ecosystems and landscapes, and protecting forests from the main causes that generate degradation and deforestation.

As a result of its sustainable management, afforestation and forest restoration activities, the project hopes to achieve the reduction and/or capture of 256,000 tonnes of CO_2 equivalent per year, starting in 2030, which will go directly towards the NDC commitment of the LULUFC sector.

In this context, the work associated with the ENCCRV, and coordinated by CONAF, is important, since it plays a leadership role in the implementation of the national and international technical and financial mechanisms required to advance in the development of the initiatives in the country and ensure compliance with Chile's various emission reduction commitments.

2.2 Structure and operation of the National Forest Monitoring System

2.2.1 Institutional arrangements and structure

According to the Global Forest Observation Initiative (GFOI), which was established in 2016, the essential elements for the proper functioning of an institutional system include a network of solid and sustainable institutions, with the necessary range of knowledge and clearly defined roles and responsibilities, as well as a single entity in charge of overall coordination.

Based on Decision 10/CP19 of the UNFCCC, which invites countries to nominate National Focal Points or Designated National Entities for REDD+, Chile's National Forestry Corporation (CONAF), under the Ministry of Agriculture (MINAGRI), was designated as the REDD+ Focal Point before the UNFCCC. This nomination was made through Official Letter No. 99 of 19 February 2014 sent by the Minister of Agriculture and addressed to his counterpart from the Ministry of Foreign Affairs, who formalized this designation before the Secretariat of the Convention.

CONAF, in its role as Focal Point for REDD+, is the body in charge of coordinating the generation and reporting of the elements linked to REDD+. Implicitly included is the coordination of the National Forest Monitoring System (SNMF), the generation and reporting of the FREL/FRL and the Technical Annexes of the REDD+ results.

For its part, CONAF's Department of Ecosystem Monitoring and Climate Change (DMECC), as part of the Supervision and Environmental Evaluation Management (GEF), plays a key role in the generation of basic information for the SNMF. The DMECC is responsible for executing the mandate established in Article 4 of Law No. 20,283 of 2008 on Native Forest Recovery and Forest Promotion[21] which establishes that CONAF "will maintain a permanent forest cadastre, in which it must identify and establish, at least cartographically, the existing forest types in each region of the country, their current condition and those areas where there are ecosystems with native forests of special interest for conservation or preservation according to the criteria established in this law. The forest cadastre must be updated at least every ten years and its information will be made public".

Together with CONAF, the Forestry Institute (INFOR), an institution dependent on MINAGRI, plays a highly important role in Chile's forestry industry and in the SNMF. As part of its mission, it has the mandate to carry out inventories of the country's forest resources, which means it receives public financing from MINAGRI for the design, technological development, implementation and execution of the National Forest Inventory that promotes the generation of information through data collected periodically in the field. Although to date there

[21] https://www.bcn.cl/leychile/navegar?idNorma=274894

are no formal agreements that are binding within the framework of the SNMF, CONAF and INFOR carry out joint activities within the framework of voluntary cooperation.

Additionally, MINAGRI has developed an institutional structure that facilitates the organization of actions related to climate change mitigation and adaptation, which was formalized on 4 December 2017 through Exempt Decree No. 360 of MINAGRI[22] that "creates the Intraministerial Technical Committee on Climate Change (CTICC)".

The CTICC is chaired by the National Director of the Office of Agrarian Studies and Policies (ODEPA), which includes, in addition to CONAF and INFOR, the Undersecretariat of Agriculture, the Agricultural and Livestock Service (SAG), the Agricultural Development Institute (INDAP), the National Irrigation Commission (CNR), the Agricultural Research Institute (INIA), the Natural Resources Information Centre (CIREN), and the Agricultural Communications, Training and Culture Foundation (FUCOA), among others (see Figure 2).

The objectives of the CTICC include, according to Article 2, literal iv. "Encouraging and fostering the generation of information systems and supporting the ministerial decisions adopted...", in order to support the monitoring and evaluation of climate change policies, and the promotion of instruments to generate structural and organizational improvements in this area, such as the Measurement and Monitoring System (SMM) of the ENCCRV, which is mentioned in this document.

[22] https://www.odepa.gob.cl/wp-content/uploads/2017/12/Dex-360.pdf

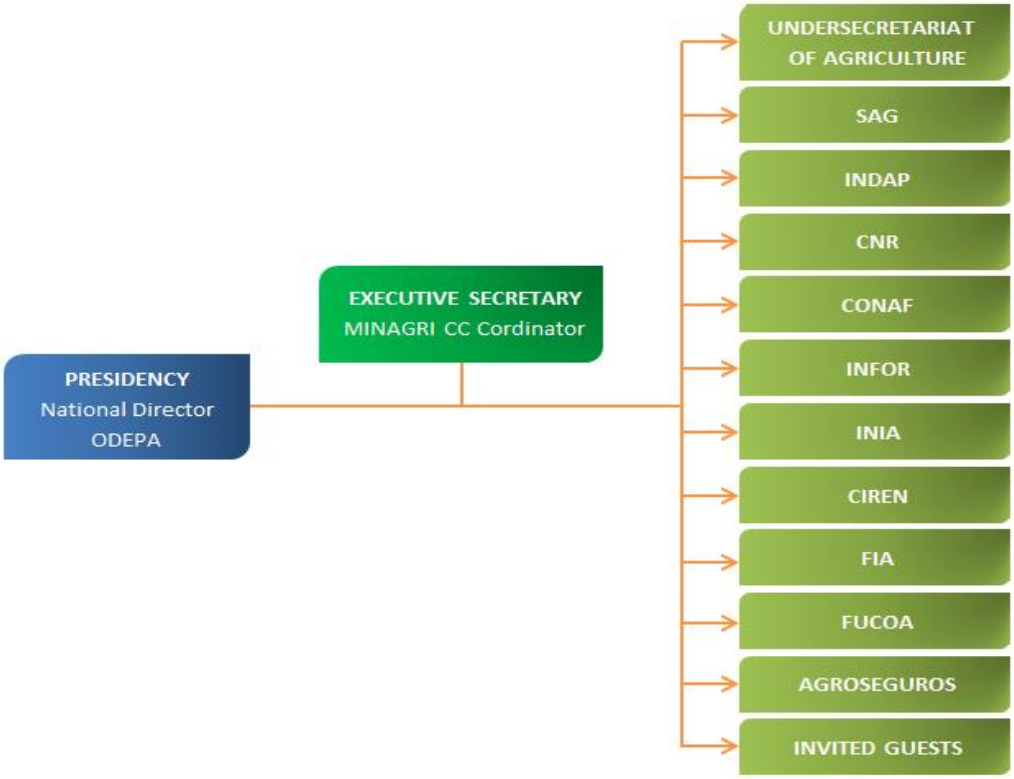

Figure 2. Structure of the Intraministerial Technical Committee on Climate Change (CTICC)

2.2.2 Functions in the generation of base information

The SNMF requires information sources that provide the data to estimate the following parameters:

- Areas of land use categories and areas of land use changes associated with forests.
- Carbon content and variations in carbon content of forests.

These elements are generated through two basic inputs, respectively:

- Forest cadastre of land uses and vegetation, developed by CONAF.
- National Forest Inventory, developed by INFOR.

The Cadastre of Native Vegetation Resources of Chile (hereinafter, Forest Cadastre) generates the country's official information regarding land use and change of use. Since 1997, with the publication of the results of the areas for different land uses, updates have been developed at the regional level that allow the following information, among other aspects, to be generated:

- Area of permanent forest, referring to the area of forest land that remains forest land between the initial cadastre and the different updates.
- Area of deforestation, referring to the transformation of land from forest to another land use on a permanent basis.
- Area of transformation of native forest into forest plantation.
- Area of transformation of forest plantation to native forest.

- Area of increase in forest area, referring to the area of land used for purposes other than forest, which have been transformed into native forest.
- Forest conservation area refers to the area of native forest under formal public conservation processes through the National System of State Protected Wilderness Areas (SNASPE).

For its part, the National Forest Inventory involves periodic measurements of dasometric parameters in permanent plots distributed between the Coquimbo and Magallanes Regions. The first cycle of the Inventory was carried out between 2001 and 2010, including the baseline measurement and the first update.

INFOR currently carries out the inventory in four-year cycles, taking measurements of 25 percent of the plots annually, and making a projection for the remaining 75 percent. The information generated through the inventory allows the following activities to be carried out:

- Development and updating of biomass stock values by forest type.
- The interpolation of data related to carbon stocks for the estimation of emissions/removals in permanent forest.

Other relevant sources of secondary information for the estimation of emissions and removals linked to REDD+ are information on forest fires and information on Private Conservation Initiatives (ICP).

CONAF is the institution responsible at the national level for generating official land area statistics by type of forest cover affected by fires, through the Forest Fire Protection Management (GEPRIF). This information is permanently updated through the Digital Information System for Operations Control (SIDCO),[23] generating annual reports for each season, which runs from 1 July to 30 June of the following year.

For their part, Private Conservation Initiatives are defined as “an area of land of any size that:

i) is managed for the primary purpose of conserving biodiversity.
ii) is protected with or without formal government recognition; and,
iii) is managed by, or through, individuals, communities, corporations or non-governmental organizations (Langholz, J. & Krug, 2003)". In addition, they are included in the National Registry of Protected and Conservation Areas maintained by the Ministry of the Environment (MMA).[24]

The following figure graphically shows the participation of each source of information in the generation of information for the estimation of forest carbon emissions and removals.

[23] https://sidco.conaf.cl/login/index.php

[24] National Registry of Protected Areas: includes records of public and private, marine and terrestrial protected areas, as well as priority areas for conservation. It provides spatial, legal, ecological, management information and a specialized bibliography. (mma.gob.cl)

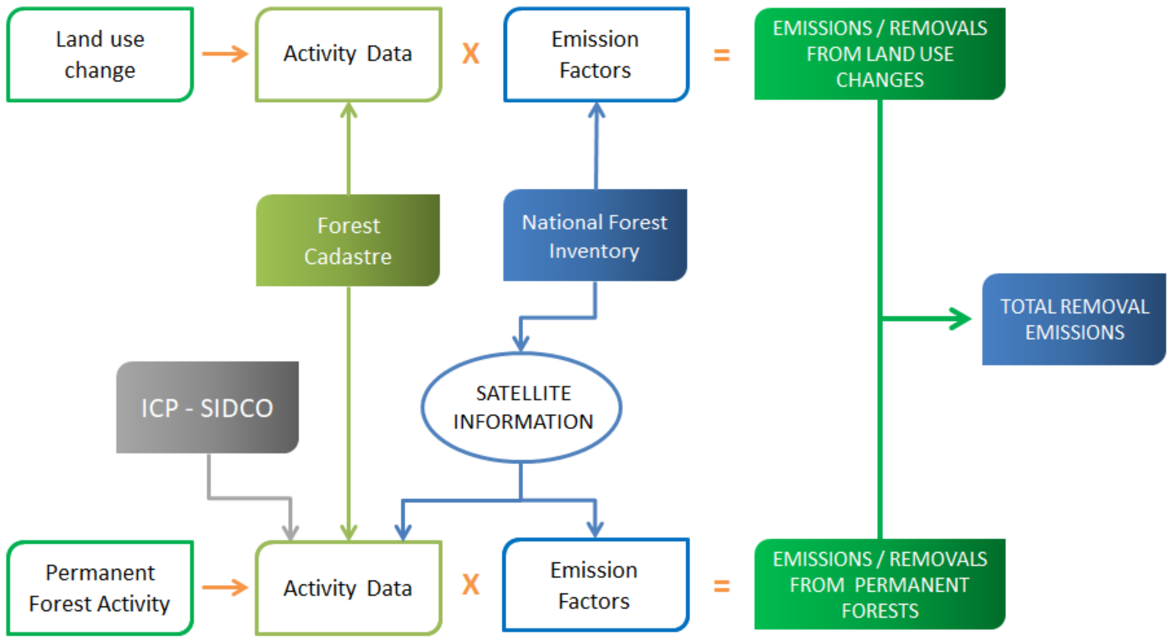

Figure 3. Sources of information for estimates of forest carbon emissions and removals

An important aspect in relation to the sources of information and institutional arrangements is to highlight that both CONAF, through the DCCSE and the DMECC, as well as INFOR, are part of Chile's National GHG Inventories System (SNIChile),[25] coordinated by the MMA. Both institutions participate in the generation of GHG inventories, which collect information used to estimate parametric data included in the SNMF, such as the root-stem ratio, carbon contents for different land uses and forest carbon stocks, and the basic density of wood. This data comes from different academic and scientific sources, including national and international bodies.

2.2.3 Financing and sustainability

Since the preparation of the sub-national FREL/FRL in 2016, the SNMF has received financing mainly from international sources, with the main objective of generating specific inputs to reduce information gaps, as well as national financing that has been mainly used for the generation of base inputs, such as the Cadastre of Vegetal Resources and the National Forest Inventory, together with the management of the monitoring, reporting and verification system for REDD+ that CONAF has systematized as the ENCCRV Measurement and Monitoring System (SMM).[26] For the purposes of this report, SNMF and SMM can be considered as the same concept.

The main sources of international financing for the SNMF are diverse and have different aims and scope. Below are the main characteristics of these sources:

[25] https://snichile.mma.gob.cl
[26] https://www.enccrv.cl/smm

- ✓ Green Climate Fund (GCF), through the Food and Agriculture Organization of the United Nations (FAO), with a projected contribution of USD 2,365,000 through 2026 for the following activities:
  - Support staff for MRV functions at the central level and regional implementation teams.
  - Technical advice, consultancies and specific studies.

- ✓ UN-REDD National Programme, through FAO, executed until 2021 with a total contribution of USD 248,000 allocated to:
  - Support for the generation of the first REDD+ Results Annex report.
  - Support for strengthening the National Forest Monitoring System.
  - Implementation of methodologies and development of semi-automatic tools to estimate the uncertainty of the REDD+ Results Annexes.
  - Development of socialization workshops for the ENCCRV SMM.

- ✓ Forest Carbon Partnership Facility (FCPF), implemented through the World Bank until 2021, with a total contribution of USD 900,000 allocated to:
  - Updating of the FREL/FRL at the sub-national level.
  - Expansion and updating on a national scale of maps of forest carbon fluxes in permanent forest.
  - Development of density diagrams for the forest types of greatest national importance.
  - Creation of the ENCCRV Information Management Platform[27] as a key transversal element for storage, data management and report generation.

- ✓ Global Environment Facility (GEF), through the Chilean Native Forest Ecosystem Monitoring System (SIMEF),[28] with a contribution of USD 1,550,000 until 2020, of which a fraction is allocated to:
  - Development of the sub-national map of changes in land use.
  - Updating of the baseline of the Forest Cadastre at the level of land use, according to the IPCC categories.
  - Biennial updates of land use change maps.

- ✓ GEF Sustainable Land Management Project, with a contribution of USD 800,000 until 2020, used for:
  - Hiring of professionals for the design and operation of the SNMF.
  - Development of the Prioritization System.

Regarding national financing, this is the funding available annually according to the national budget. As a contribution to the SNMF, two main budget allocations are recorded:

- ✓ CONAF budget for the development of updates, improvements, and the management of the Forest Cadastre, which amounts to approximately USD 500,000 per year.
- ✓ INFOR budget to carry out the National Forest Inventory, which amounts to USD 400,000 per year.

[27] https://plataforma.enccrv.cl/
[28] https://simef.minagri.gob.cl/

2.3 Preparation of the Chilean national FREL/FRL and REDD+ results

2.3.1 First FREL/FRL of Chile

As previously mentioned, Chile presented its first FREL/FRL in 2016 with a sub-national focus on five administrative regions (currently six). In absolute terms, the sub-national area corresponds to 16,522,077 hectares and the forest area represents 5,853,387 hectares. The area contains temperate forest ecosystems, with the presence of 11 of the 12 forest types defined at the national level, with the potential to reduce and absorb GHG emissions, in addition to producing environmental benefits not associated with carbon.

Chile developed the FREL/FRL for four of the five activities mentioned in paragraph 70 of Decision 1/CP.167:

a) Reduction of emissions from forest degradation.
b) Reduction of emissions from deforestation.
c) Conservation of forest carbon stocks.
d) Enhancement forest carbon stocks.

Sustainable forest management activity was not included due to the lack of spatially explicit information necessary for its quantification. However, the changes in carbon stocks resulting from this activity were considered in an aggregated manner in the activity of reducing emissions from forest degradation if the result is an emission, or under the improvement of forest carbon stocks if the result is removal.

The FREL/FRL presented for the four activities are the following:

a) Emissions of 3,452,885 $tCO_2e\ yr^{-1}$ from deforestation.
b) Emissions of 9,149,392 $tCO_2e\ yr^{-1}$ from forest degradation.
c) Absorption of 2,430,438 $tCO_2e\ yr^{-1}$ from the conservation of forest carbon stocks; and,
d) Absorption of 10,012,012 $tCO_2e\ yr^{-1}$ from the enhancement in forest carbon stocks.

The FREL/FRL proposed by Chile are based on the annual average of CO_2 emissions and/or removals. In addition, the activity to reduce emissions from forest degradation includes methane (CH_4) and nitrogen oxide (N_2O) emissions from forest fires. The established FREL/FRL applies from the end of the reference period defined for its estimation, until 2025, according to the effective date established for Chile's National Strategy on Climate Change and Vegetation Resources (ENCCRV).

SUBNATIONAL FREL/FRL		
Regions		Maule, Biobío, La Araucanía, Los Ríos, Los Lagos
Final year of elaboration		2016
Period	Land Use Change	2001/2013
	Permanent forest	2001/2010
Activities	Deforestation	✓
	Forest Degradation	✓
	Enhancement	✓
	Forest Conservation	✓
	Sustainable Forest Management	X
Carbon Pool	Aboveground Biomass	✓
	Belowground Biomass	✓
	Dead Organic Matter	✓
	Litter	X
	Soil Organic Carbon	X
Gases	CO_2	✓
	CH_4	Only estimated for emissions resulting from de forest fires
	N_2O	

Table 3. Regions, periods, activities, forest carbon pools and GHG considered in sub-national FREL/FRL

However, in accordance with the stepwise approach applied in its development, the FREL/FRL may be updated and expanded once better data and methodologies become available.

The reference period used to estimate the FREL/FRL for Chile is determined by the availability of information necessary for its development, and by the different methodologies applied to estimate emissions and removals from activities and sub-activities. The FREL/FRL considers two different periods, one for activities or sub-activities related to land use change, and another for activities or sub-activities that occur in permanent forest.

The activities that present changes in land use correspond to the reduction of emissions from deforestation, emissions from degradation due to the conversion of native forest into forest plantations, increased removals from the conversion of forest plantations into native forest, and the increase in forest area. These activities consider a reference period of 13 years, between 2001 and 2013.

The activities in forest that remains as forest correspond emissions due to degradation in permanent forest, emissions of non-CO_2 gases as a result of forest fires, the enhancement in carbon stocks due to the recovery of degraded forests and forest conservation. These activities consider a reference period of 10 years between 2001 and 2010.

2.3.2 Technical Annex of REDD+ results

On 3 December 2018, and as an Annex to the third BUR[29], Chile voluntarily presented, in the context of results-based payment, its first Technical Annex of REDD+ Results for the period 2014-2015 and 2016 in terms of activities that occur due to and use changes, and the period 2010-2015 for activities that occur in permanent forest.

The technical annex provided information and data on activities to reduce emissions from deforestation, reduce emissions from forest degradation, conserve forest carbon stocks, and enhancement carbon stocks, as indicated in Decision 1/CP.16, covering the same sub-national forest territory considered in the development of the FREL/FRL carried out in August 2016 (Maule, Biobío, Araucanía, Los Ríos and Los Lagos Regions). As in the FREL/FRL, the sustainable forest management activity was not included due to the lack of information for its quantification, which is a situation that persists.

The results presented in the implementation report of the four REDD+ activities, calculated considering the sub-national FREL/FRL, included an estimated total reduction of emissions of 6.136.475 $tCO_2e\ yr^{-1}$, derived from the following:

- A reduction in emissions from deforestation of 148,513 $tCO_2e\ yr^{-1}$.
- An increase in emissions from forest degradation of 4,530,732 $tCO_2e\ yr^{-1}$.
- A reduction in emissions of 3,854,177 $tCO_2e\ yr^{-1}$, due to the replacement of native forest with plantations of exotic species.
- An increase in emissions of 8,384,909 $tCO_2e\ yr^{-1}$ due to permanent forest degradation, including forest fires.
- An increase in carbon removals of 1,519,769 $tCO_2e\ yr^{-1}$ due to the conservation of carbon stocks.
- An increase in carbon removals of 8,998,925 $tCO_2e\ yr^{-1}$ due to the enhancement in carbon stocks.
- Removals of 128,868 $tCO_2e\ yr^{-1}$ from the enhancement in carbon stocks due to the increase in native forest areas resulting from the conversion of other lands to forest lands, including restitution.
- Emission reductions of 8,870,057 $tCO_2e\ yr^{-1}$ due to the recovery of degraded forests resulting in an enhancement in carbon stocks.

As a general result of the evaluation, there was consistency between the methodologies, definitions and completeness of information provided between the reference level and the results of REDD+ activities. The data provided is transparent, consistent, complete, and accurate, as well as being aligned with Decision 14/CP.19, paragraph 9.

[29] https://mma.gob.cl/wp-content/uploads/2018/12/3rd-BUR-Chile-SPanish.pdf

TECHNICAL ANNEX OF REDD+ RESULTS		
Regions		Maule, Biobío, La Araucanía, Los Ríos, Los Lagos
Final year of elaboration		2018 & 2020
Period	Land Use Change	2014/2016 & 2017/2018
	Permanent forest	2011/2015 & 2016/2018
Activities	Deforestation	✓
	Forest Degradation	✓
	Enhancement	✓
	Forest Conservation	✓
	Sustainable Forest Management	X
Carbon Pool	Aboveground Biomass	✓
	Belowground Biomass	✓
	Dead Organic Matter	✓
	Litter	X
	Soil Organic Carbon	X
Gases	CO_2	✓
	CH_4	Only estimated for emissions resulting from de forest fires
	N_2O	

Table 4. Regions, periods, activities, forest carbon pools and GHG considered in the Technical Annex

2.3.3 Update of the first FREL

The process of updating Chile's FREL/FRL began in 2019, with the work of correcting the activity data, incorporating methodological improvements in the identification of REDD+ activities. In addition, initially it was proposed to increase the representation of different forest types in the detection of forest degradation, the use of EF by forest type instead of regional EF, and the correction of EF to achieve greater alignment with the national INGEI reports.

As part of the process of incorporating these improvements in the estimation of the reference levels, other findings and opportunities for technical correction were detected. Among them, the unintentional errors identified during the process were corrected, which are summarized below:

- ✓ Incorporation of regions that have areas with forest cover

The update of the FREL/FRL considered the expansion of the geographical scope of the estimates, going from including the temperate forest regions of Chile from the Maule region to the Los Lago region, to considering the Mediterranean and southern regions of the country, covering the area from the Coquimbo region to the Magallanes region. As a result, the coverage of forest monitoring increased from 40 to 99.3 percent of the lands with native forest, which is the result of the different activities carried out in the country.

- ✓ Update of emission factors (EF)

An inconsistency was detected in the dead organic matter (DOM) value used in the GHG inventory from 1990 to 2010 after the FREL/FRL submission. This was corrected in the updated reports of the Chilean INGEI, also applying the corrected value to the baseline and ensuring consistency with the GHG inventory 1990-2018 (MMA, 2021).

The DOM values are estimated based on the National Forest Inventory (NFI). Chile considered regional values in the FREL/FRL, but the estimated DOM for the following forest types has been applied so that these values are consistent with the EF update. The DOM data is estimated for the forest types Alerce, Araucaria, Lenga, Coihue de Magallanes, Roble-Raulí-Coihue, Coihue-Raulí-Tepa, Esclerófilo and Siempreverde. The remaining forest types – Ciprés de las Guaitecas, Ciprés de la Cordillera and Roble-Hualo – do not have associated data, so estimates based on other forest types have been applied for them.

- ✓ Regional EFs are replaced by EFs by forest type based on data from the national forest inventory.

The reference level applied regional values for the EFs; however, Chile has estimates of biomass content (aboveground and root) for most forest types in native forests, and it also has biomass estimates in secondary forests for some forest types. All forest types have information on average annual growth in volume, used to estimate absorption in areas with an enhancement in carbon content.

- ✓ Improvements in the Activity Data used in the estimation of degradation emissions.

The estimation of the reference level considered the use of degradation thresholds from the model of a specific type of forest cover (RORACO) to estimate degradation. However, Chile has made progress in this area and since then it has modelled data for the following forest types: Siempreverde with Canelo forest subtype, Lenga, Roble-Hualo (RoHua), Coihue-Raulí-Tepa (CoRaTe), Coihue de Magallanes, Esclerófilo with Espinal forest subtype.

These degradation thresholds are represented through density management diagrams (DMD), which have been integrated and used for the development of a new map of CO_2 stocks and fluxes, which is the main input for estimating degradation.

- ✓ Inclusion of spatially explicit data for the historical reference period.

Emissions in the reference period 2001-2013 for land use changes were estimated through interpolated DAs based on information from the Vegetation Resources Cadastre, since Chile did not have land use map data for the initial and final years in all regions of the monitored area.

The update considered the elaboration of maps of land use for the initial and final years, and the detection of changes between them through spectral analysis. As a result, there is a map of land use for each year during the monitoring period, enabling the spatial identification of the occurrence of land use change.

- ✓ Use of multi-pixel mosaics

Among the corrections made, the use of conventional satellite mosaics, based on stitching together complete digital scenes, was changed to the use of multi-pixel mosaics of Landsat images as the main input for the elaboration of the maps for the initial and final years (2001, 2010 and 2013). As a result, the DAs for land use change and degradation estimation are calculated on the basis of multi-pixel mosaics with specific start and end dates for the corresponding year.

In the correction phase, it is possible to consider that each reference period includes the entire initial and final year in its analysis, and, therefore, the value of 13 years can be used to obtain annualized rates for activities that generate changes in land use, while the value of 10 years can be used for activities occurring in forests that remain as forests.

Thus, two different periods are maintained for the estimation of the national FREL/FRL to ensure consistency with the sub-national reference level and the Technical Annex. This decision is based mainly on the availability of information and the interest in identifying changes in estimates derived from corrections and updates.

- ✓ Considerations for arborescent scrubland

The reference level submitted in 2016 considered that land uses classified as arborescent scrub in the native forest cadastre may constitute forests according to the definition of other wooded lands. Since a legal definition of forest was established in Law 20,283 of 2008, it was possible to apply this definition to updates of the native forest cadastre. Under this definition, those areas classified as arborescent scrub do not constitute forests. Thus, arborescent shrublands are not counted in the native forest area for the reference level updates.

- ✓ Improvements in the degradation estimation algorithm

For the specific case of degradation estimates, improvements were made to the algorithm, specifically increasing the K value from five to seven by implementing the k-nearest neighbors (k-NN model).

- ✓ Improvements in the land use changes detection method

For the development of spatially explicit DA, a detection method for land use changes was developed based on the application of the Multi-Index Integrated Change Analysis (MIICA) methodology (Jin *et al.*, 2013), which was used for the development of the Annex of REDD+ Technical Results submitted to the UNFCCC.

- ✓ Accuracy in the identification of forest carbon pools by REDD+ activity

During the baseline update process, inconsistencies were found in the carbon pools estimated by the REDD activity and those reported in the FREL/FRL. For example, DOM is estimated for deforestation, substitution and forest fires activities but not in all activities as previously stated.

- ✓ Carbon fraction value adjustment

The carbon factor is corrected from 0.5 to 0.47 to be consistent with the 2006 IPCC Guidelines.

- ✓ Integration process

Integration of emissions and captures results for the Chilean sub-national reference level was done through simple Excel spreadsheets separated by REDD+ activity. Through the implementation of the update, and with the purpose of increasing the transparency and replicability of the results, these spreadsheets were updated to use semi-automated tools based on PostgreSQL, odbc and database resources, which allow manage larger amounts of information without affecting the performance of the work system.

✓ Estimation of uncertainty

As indicated in the evaluation process of the Technical Results Annex, paragraph 39 literal f), the update of the FREL/FRL included the estimation of uncertainty using the Monte Carlo approach, which is described in chapter 8 of this document.

In summary, considering Tables 3 and 4 above, the FREL/FRL update proposal includes the following information:

NATIONAL FREL/FRL		
Regions		Coquimbo, Valparaíso, Metropolitana, O'Higgins, Maule, Ñuble, Biobío, La Araucanía, Los Ríos, Los Lagos, Aysén, Magallanes
Final year of elaboration		2022
Period	Land Use Change	2001/2013
	Permanent forest	2001/2010
Activities	Deforestation	✓
	Forest Degradation	✓
	Enhancement	✓
	Forest Conservation	✓
	Sustainable Forest Management	X
Carbon Pool	Aboveground Biomass	✓
	Belowground Biomass	✓
	Dead Organic Matter	✓
	Litter	X
	Soil Organic Carbon	X
Gases	CO_2	✓
	CH_4	Only estimated for emissions resulting from de forest fires
	N_2O	

Table 5. Regions, periods, activities, forest carbon pools and GHG considered in the national FREL/FRL

2.3.4 Recommendations and areas for improvement identified in the technical evaluation of sub-national FREL/FRL and the Technical Results Annex

During the technical evaluation processes of the REDD+ reports submitted by Chile to the UNFCCC, a series of areas for improvement have been identified, which, to a large extent, have been addressed by the country in updating the FREL/FRL.

2.3.4.1 Areas for improvement in the Technical Assessment Report (TAR)[30] on the FREL/FRL of Chile

In accordance with paragraphs No. 22, 41, 42, 43 and 44, the following areas for improvement have been identified:

- Paragraph 22

a) 1. Improve DA: development of tools and methodologies for the biennial updating of the cadastres as a primary source of information for the estimation of DA, as well as for the activities included in future BUR reports; and 2. Generation of an integrated platform that allows the storage and generation of semi-automated reports, visualization of results and the dissemination of both spatial and database information.
b) 1. Improve parameters and EF: development of new stock charts for relevant forest types not included in the 2016 FREL/FRL; and 2. Further research on forest degradation through the intensive use of biomass and carbon monitoring systems.
c) Improve methodologies for monitoring activities and carbon fluxes in permanent forests in areas with a high cloud cover probability (austral macrozone) and with strong phenological variations in vegetation (radar and Lidar images).
d) Include new regions and biomes: the Mediterranean macrozone and the austral macrozone.
e) Include new activities: development of management plans based on spatially explicit information that could allow the inclusion of other activities, such as sustainable forest management and activities that occur at farm level of 10 hectares or less.

- Paragraph 41

An area for technical improvement was detected in relation to deforestation DA, since the land registry map data used for the FREL/FRL was different from that used for the national GHG inventory.

- Paragraph 42

During the evaluation of carbon pools and GHG, it was identified that the soil organic carbon (SOC) was excluded, which was justified given the lack of information necessary to determine the rates of change in this pool. For carbon stock enhancement activity, the exclusion of SOC is likely to be conservative in the context of the FRL. In the case of GHG, no significant exclusions were identified because CH_4 and N_2O from forest fires were taken into account. However, areas for improvement in the treatment of DOM emissions

[30] http://unfccc.int/resource/docs/2016/tar/chl.pdf

and the inclusion of SOC were identified, unless the country can demonstrate that both types of carbon pools are not sources of emissions.

- Paragraph 43

The country aims to continuing monitoring forest degradation; to assess whether reduced deforestation is leading to the displacement of emissions; to include emissions from forest degradation in future FREL/FRL submissions when new and relevant data and information becomes available; and to extend FREL/FRL to other biomes, as part of efforts to move towards a national FREL.

Paragraph 44

During the Technical Assessment, information was requested from Chile on its on-going or planned efforts to improve its data and information for future FREL/FRL submissions, as part of its gradual implementation approach. In this regard, Chile identified several areas as part of its on-going efforts (see Paragraph 22 above). Chile further noted that it is improving the capacities of CONAF's Monitoring Department, such as developing internal capacities to perform uncertainty analysis, training staff in the development of GHG inventories, and using new tools such as Collect Earth and Google Earth Engine to land cover mapping.

2.3.4.2 Areas for improvement in the Technical Assessment Report (TAR)[31] on the REDD+ Technical Annex

The technical assessment report on the technical analysis of the Technical Annex to the third BUR of Chile (TATR) identifies a series of areas for improvement, as established in paragraphs N° 36, 37 and 39 of the report. These are discussed below:

- Paragraph 36

This indicates the following areas for improvement identified in the technical assessment of the FREL/FRL and that also apply to the provision of the information in the Technical Annex:

a) Expand the number of carbon pools included, in particular including the SOC for all activities and the DOM for enhancement of forest carbon stocks.

b) Extend the reference level to cover other biomes as part of efforts to move towards a national FREL/FRL.

c) Consider the use of the same reference period for all activities in the selected regions by using the same methodology to estimate AD.

d) Consider the use of a more consistent time series by using the same satellite data sources for the entire AD period.

- Paragraph 37

The LULUCF (Land Use, Land-Use Change and Forestry) expert team indicates that the country should consider recalculating the AD using satellite images with the same classification approach, spatial

[31] https://unfccc.int/sites/default/files/resource/tatr1_2019_CHL.pdf

resolution, and timeframe for all sub-national areas or for national coverage, with the aim of improving the consistency and accuracy of the estimates in future presentations.

- Paragraph 39

As indicated in this paragraph, after the technical exchanges with the experts, Chile identified the following needs for technical support and capacity building to promote improvements in the estimation of AD and EF:

a) Improve the accuracy in the identification of land use change from non-forest to native forest.
b) Develop methodologies for monitoring activities in regions with high cloud cover.
c) Strengthen the technical capacity to monitor other regions and forest types under the SNMF.
d) Include sustainable forest management activity and the associated changes in carbon stocks.
e) Include the SOC carbon pool in national level estimates.
f) Apply the Monte Carlo approach for the uncertainty analysis of the estimates.

2.3.4.3 Activities carried out to improve the quality of the information.

Based on the areas for improvement identified in the technical assessment processes of the FREL/FRL and in the Technical Results Annex, from 2017 onwards a series of activities were developed that translate into the points of this proposal for expansion of Chile's FREL/FRL.

The main activities are described below:

- Development of a methodology for the elaboration of maps of use and land use change with biennial periodicity

As of 2017, CONAF's DMECC, with financial support from the Global Environment Facility (GEF) for the Integrated Forest Ecosystem Monitoring System (SIMEF) project, began work to develop a methodology for detecting land use changes on a biennial basis. As a result of this effort, the new methodology for mapping changes in land use was established in Standard Operating Procedure (SOP) N°02,[32] which is attached to this report.

This work considered, as a first task, the elaboration of maps of use and land use change for the regions included in Chile's sub-national FREL/FRL between the period 2013/2017, which were used in the estimation of emissions of the Technical Annex of REDD+ results. Subsequently, CONAF has continued to advance in the implementation of the method, which has been applied in other regions and for different biennial periods. These maps are available on the SIMEF platform of the Ministry of Agriculture.[33]

- Elaboration of density diagrams for the main forest types

Chile's sub-national FREL/FRL considered the density diagram of the RORACO forest type for the estimation of emissions from forest degradation in permanent forest. The development of this improvement activity began with the use of the density diagram of the Lenga Forest type, prepared in 2017 by INFOR with the financial support of CONAF through the Research Fund of the Native Forest Law.

In 2018, INFOR, under the mandate of CONAF, prepared the density diagrams for the Roble-Hualo (RoHua) and Coigüe-Raulí-Tepa (CoRaTe) forest types. In 2019, the density diagram for the Coigüe de Magallanes and the Esclerófilo Espinal forest subtype was developed, followed by the diagram for Esclerófilo forest subtype in 2020.

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[32] https://drive.google.com/file/d/1V5CqxBRsy-cUVBbeaOb1mYzWAtlZOmd1/view?usp=drive_link

[33] https://esri-ciren.maps.arcgis.com/apps/MapSeries/index.html?appid=fbfaca8c5b8b429c853439b8262e1b60

For all cases, the methodology proposed by Gingrich (1967) and adapted by Bahamóndez *et al.* (2009), Bahamóndez and Thompson (2016) and Müller-Using *et al.* (2012) for the Roble-Raulí-Coigüe forest type was used.

Thus, the national FREL/FRL considers the density diagrams for: RORACO, Lenga, Siempreverde with Canelo forest subtype, RoHua, CoRaTe, Coigüe de Magallanes, Esclerófilo and Espinal forest subtype.

- Elaboration of multi-pixel mosaics for the generation of activity data

As part of the continuous improvement process of the SNMF, and with the aim of having more consistent time series, CONAF's DCCSE established a methodology for the generation of multi-pixel mosaics, with time windows associated with the dry season, which ensures consistency in the information base for the generation of activity data, both on land use change and permanent forest cover. The methodology for the elaboration of the mosaic is described in SOP 01.[34]

- Development of an ENCCRV information management platform to facilitate the use, transparency and dissemination of information

In 2021, with the financing of the FCPF, the development of the ENCCRV Information Management Platform[35] began, which is a tool with the main objective of monitoring the implementation of the ENCCRV action measures. It is characterized as being a modular system that includes project management and monitoring of property implementation, co-benefits, and the implementation of the Safeguards information system.

The platform is hosted on a system of physical servers in the CONAF Data Centre, which is managed by the IT Department. The emissions calculation system, which is made up of the base inputs that generate the activity data and applications that allow the semi-automated processing of carbon estimates for the national FREL/FRL and future calculations of REDD+ results, is also located on these servers.

During 2022, an improved version of the platform was developed, which was financed by the GCF.

- Preparation of maps of land use and land use change for the reference period

During the second half of 2019, work began to prepare maps of land use change for the period 2001-2013, using the methodology developed by the SIMEF project and based on the native forest cadastre, with the objective of obtaining land use changes spatially explicit.

The work considered the elaboration of maps based on the cadastre for all the regions of the FREL/FRL for 2001, and 2013. Then, based on multi-pixel mosaics, the SIMEF methodology for detection of spectral changes was applied to the maps, as defined in the SOP 02.

This result constitutes the information used to define the Activity Data for this national FREL/FRL, leaving aside the interpolation method used at the sub-national reference level.

- Analysis and application of methodologies for the estimation of GHG emissions and removals as a result of forest degradation and the enhancement in permanent forest stocks for the Aysén and Magallanes Regions

During 2019, and through financing from the FCPF, the methodology for estimating emissions from degradation was expanded in the Aysén and Magallanes Regions through a public tender.

[34] https://drive.google.com/file/d/1V6cXkhx--Y1tqe08QRfTdzjpa3eFkVn9/view?usp=drive_link

[35] https://plataforma.enccrv.cl/

For its development, the same methodological criteria as in the other regions were considered, using satellite mosaics that integrated Landsat and Modis data to achieve sufficient cloud cover for the estimation. The result of this work is incorporated into the national FREL/FRL, and the procedure for its implementation is attached in SOP 05.[36]

- Development of studies to analyse carbon fluxes in areas with extensive cloud cover

In 2021, and through financing from the FCPF, Chile developed a pilot study on the estimation of carbon fluxes in the Los Lagos, Aysén and Magallanes Regions, all with high cloud cover. The study considered the use of data from the Alos Palsar sensor combined with information from the plots of the National Forest Inventory (IFN), in different periods of time, aiming to standardize the results of the sub-national FREL/FRL and the REDD+ Technical Annex.

In general, the results were coherent and consistent, however, the lack of availability of information from RADAR data makes it difficult to apply this approach in carrying out biennial monitoring.

[36] https://drive.google.com/file/d/1_ebmQI1izKLh3NeWN_IIVU6NFFQavAIY/view?usp=drive_link

3 DEFINITION OF FOREST AND REDD+ CONCEPTS[37]

3.1 Definition of Forest

The country's forest cover, as described in the previous chapter, is mainly made up of native forests and forest plantations. Law 20,283[38] on Native Forest Recovery and Forest Promotion defines **Forest** as a "*site populated with plant formations in which trees predominate and that occupies an area of at least 5,000 square meters, with a minimum width of 40 meters, with coverage of tree crown that exceeds 10% of said total area in arid and semi-arid conditions and 25% in more favorable circumstances*".

The law also defines **Native Forest** as a "*forest formed by autochthonous species, resulting from natural generation, natural regeneration, or plantation under canopy with the same species existing in the original distribution area, which may have an accidental presence of randomly distributed exotic species*.

Regarding Forest Plantations, Law 20,283 does not establish any definition. According to FAO (2012),[39] **Forest Plantations or Planted Forests** are considered to be "*forests predominantly composed of trees established by planting and/or deliberate seeding*", taking into account that: "*1) Predominantly means that the trees planted or seeded are expected to constitute more than 50% of the mass in its mature stage; 2) Includes the regrowth of trees that were originally planted or seeded; 3) Includes rubber, cork oak and Christmas tree plantations; 4) Excludes naturally regenerated trees of introduced species*". In the same document, FAO describes as **Exotic Forest Plantations** as "*those Forest Plantations composed in their adult stage of development of more than 50% exotic species*".

At present, practically all of the forest plantations in Chile are monospecific plantations of exotic species with a timber production objective, while there is little representation in terms of quantity or area of Native Forest Plantations.[40] One of the few registered experiences of forest plantations with native species are the Tamarugo forest plantations, located in the Tarapacá and Antofagasta Regions.[41]

In this regard, this national FREL/FRL proposal considers the total Forest Plantations as a uniform set, since monospecific plantations with exotic species and a timber production objective represent practically the entire area of national forest plantations.

In addition, all lands defined as native forest under current legislation will be considered in this proposal.

[37] The definition of Forest and REDD+ activities were determined for the establishment of the sub-national FREL/FRL of Chile, through a CONAF initiative, together with national and international experts who made continuous contributions to the original proposal and its later versions. The definitions were submitted for discussion and validation at the "Second International Workshop for the preparation of Forest Carbon Reference Levels – Forest Reference Levels and MRV Analysis, Chilean context" where the latest modifications were made, and the final definitions were agreed upon.

[38] http://www.conaf.cl/cms/editorweb/transparencia/potestades/Ley-20283_bn.pdf

[39] http://www.fao.org/docrep/017/ap862e/ap862e00.pdf

[40] According to the INFOR Continuous Inventory (2020), 3.2% of the plantations correspond to Other Species, which can include both exotic and native species. Source: INFOR https://ifn.infor.cl/index.php/descargas-recursos/descargas/send/2-documentos-inventario-forestal/37-informe-ifc-2020

[41] This information comes from the monitoring and updating of the cadastre in 2018 and 2019 of the Tarapacá and Antofagasta Regions. Source: CONAF.

For clarity, the following observations are listed:

1. Under the concept of operation of the FREL/FRL, those lands defined as such by the native forest cadastre will be considered as forest, including those areas defined as Native Forest or Mixed Forest by the use and land use change maps.

2. In line with the environmental goals promoted through the ENCCRV, the reference level will not consider in its accounting the carbon fluxes produced in areas considered as Forest Plantations, which are associated with forests planted with exotic species that have an industrial timber objective.

3. To comply with the concept of data completeness, carbon fluxes in forest plantations will continue to be reported in the INGEI.

4. As indicated in section 2.3, according to the definition of forest established in Law 20,283 of 2008, those areas classified as arborescent scrub will not constitute forest according to the legal definition. Thus, arborescent shrublands are not included in the native forest area for the reference level updates.

It is important to clarify that the definition of forest used in Chile's national FREL/FRL is different from the definition used in the INGEI for Forest Lands, in which Native Forests are integrated with Forest Plantations. This definition has been determined in consideration of the objective of the ENCCRV on supporting the recovery and protection of native forest and xerophytic formations, as well as promoting the establishment of vegetation formations on soils that can be planted as mitigation and adaptation measures related to the effects of change climate and the fight against desertification.

In addition, and as can be seen from the results of the "ENCCRV Formulation and Participation Workshops",[42] there remains a general approach among the different actors in the territory to promote an increase in the area of native forest managed sustainably, as well as in the total area covered by this type of forest, instead of exotic industrial plantations, since it is assumed that these are managed by for-profit companies.

3.2 Coverage of Forest Lands

Chile's forest resources are characterized by their diversity due to the wide latitudinal distribution that ranges from parallel 18°S to 56°S. This geographical condition generates a gradient of natural units that begins in the northernmost zone in the Coquimbo Region with arid and semi-arid environments dominated by desert climates, transitioning to temperate environments dominated by Mediterranean climates in the central zone, and by humid, cold humid, oceanic and sub-Antarctic climates as you move towards the extreme south in the Aysén and Magallanes Regions.

This latitudinal gradient, which, combined with a mainly mountainous physiography with a strong presence and influence of the Andes Mountains, has generated ideal conditions for the development of a wide diversity of native forest ecosystems, composed of discrete and continuous communities that are distributed throughout the national territory, covering an area of more than 14 million hectares.

These natural conditions, added to historical processes of landscape transformations, have led to the establishment of an area of forest monocultures covering slightly more than three million hectares, which have

[42] http://www.conaf.cl/cms/editorweb/ENCCRV/PLAN-SALVAGUARDAS-ENCCRV.pdf

been concentrated mainly in the temperate zone, and which in their vast majority are intended for the wood and pulp industry (see Table 6).

Forest Lands	Area (ha)	%
Plantations[43]	3,114,125	17.3%
Native Forest	14,737,485	81.7%
Mixed Forest	179,125	1%
Total	**18,030,735**	**100%**

Table 6. Forest lands in Chile. Source: sit.conaf.cl

Almost 24 percent of Chile's national territory is occupied by forest lands, together with a considerable proportion of lands with grassland and scrub formations (39.9 percent) (see Table 7). A significant amount of these scrublands are forests in advanced states of degradation that could be restored, as well as other degraded soils that are currently without tree vegetation and are potentially forestable soils.

Land Uses	Area (ha)	%
Urban and industrial areas	796,720	1.1%
Agricultural land	3,230,542	4.3%
Grasslands and shrublands	30,240,377	39.9%
Native forests and forest plantations	18,030,735	23.8%
Wetlands	854,896	1.1%
Areas without vegetation	17,347,106	22.9%
Snow and glaciers	3,466,361	4.6%
Water bodies	1,431,227	1.9%
Unrecognized areas	331,199	0.4%
Total	**75,529,163**	**100%**

Table 7. Land uses in Chile, 2021. Source: sit.conaf.cl

[43] Refers to land use area not forest cover.

3.2.1 Native Forest

The area of the country covered by native forest forest lands is classified according to various systems that characterize forest communities. However, the most widely applied classification is the one that is used in current forestry regulations, which defines 12 forest types.

This classification typology, on which the Chilean Native Vegetation Resources Cadastre[44] is also based, has been in existence for more than three decades, and corresponds to a practical simplification of the enormous diversity of existing natural forest conditions, acting as a basis of classification for the country's forest monitoring systems, and facilitating the regulation of the use of these resources.

The most important forest types are the Siempreverde and Lenga types, each representing 25 percent of the total area of native forest, followed by the Coihue de Magallanes and Esclerófilo types. As can be seen in Figure 4, the distribution of forest types has a transition gradient, in which the different types of forest are incorporated, mixed and removed depending on the latitude. In the same figure, it is possible to visualize that the regions that concentrate the largest area of forests are those in the sourthern parts of the country, covering more than 80 percent of the country's native forest.

In the Norte Grande, there is a small area of semi-wooded natural formations, mainly xerophytic species (adapted to arid climates) such as the Queñoa (*Polylepis tarapacana*) and other similar species, which are isolated from the rest of the country's forests because of the Atacama Desert, and that add up to an area of 54,451 hectares dispersed in small groves (Teillier, 1999).

To the south of the Norte Chico, larger xerophytic and Esclerófilas formations (hard leaves with sclerenchyma) start to appear, giving the name to the main forest type of these areas, dominated by species adapted to the temperate Mediterranean climate with prolonged summer periods. Under better conditions of water availability and further south of this zone, Esclerófiloforests appear, which in some sectors reach important dimensions and coverage areas (Lubert and Pliscoff, 2006).

It is important to mention that the Mediterranean ecosystems in the country present an important biodiversity, as well as a high anthropic impact due to land use changes (mainly towards agricultural and urban uses), fires, overgrazing, and the unsustainable use of forests, scrublands, and xerophytic formations that have been a source of fuel and other primary goods for decades. Added to this is the fact that the uses of the resource sometimes occur informally, generating clear degradation processes over time, which can represent greater difficulties in quantifying this phenomenon.

[44] Description available at:
https://sit.conaf.cl/varios/Catastros_Recursos_Vegetacionales_Nativos_de_Chile_Nov2021.pdf

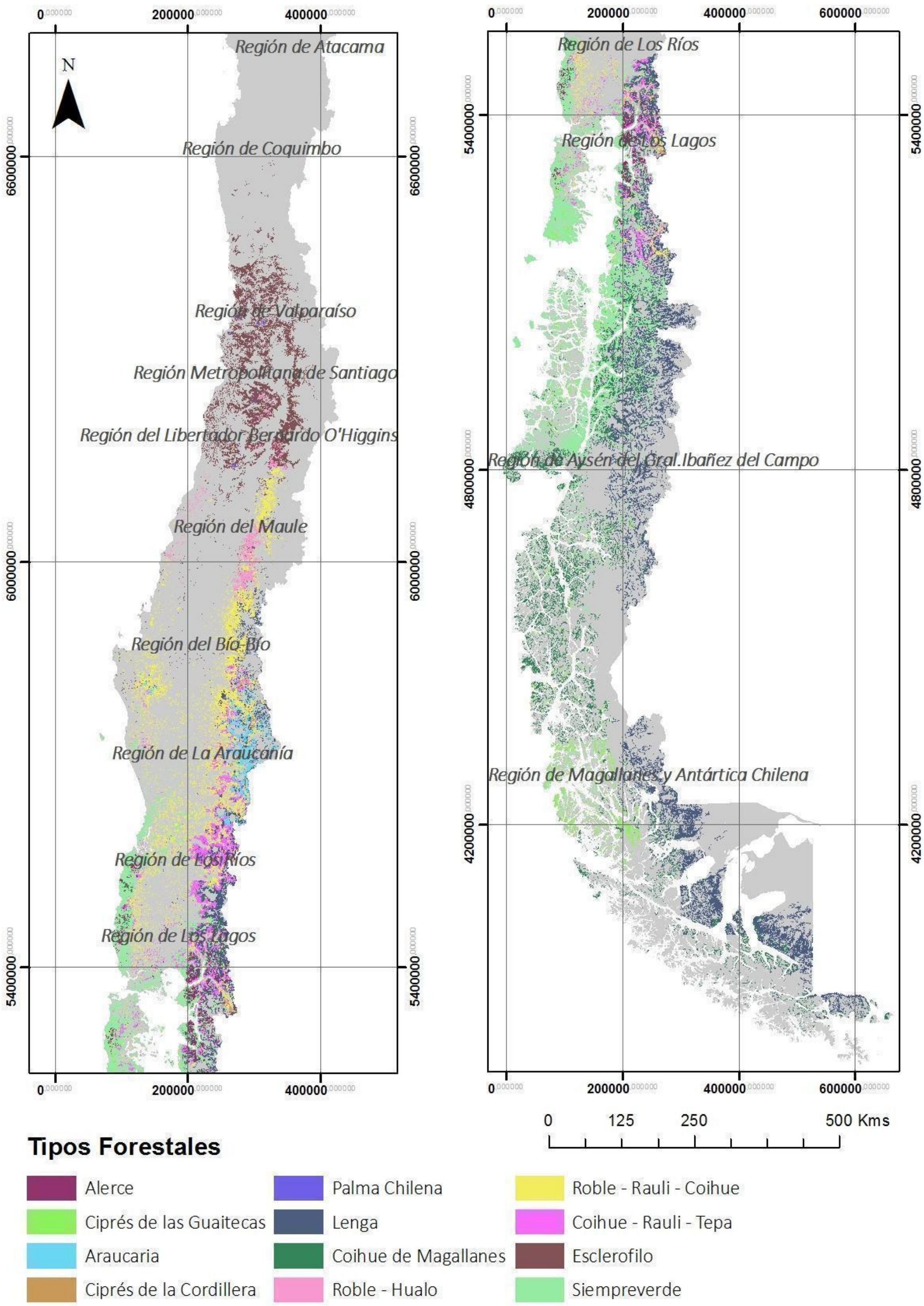

Figure 4. Geographic distribution of forest types in Chile. Source: Own elaboration

Despite the existence in these ecosystems of potential to generate wood products, high value non-wood products (e.g. saponins from *Quillaja saponaria*; boldines from *Peumus boldus*) and conservation services that allow sustainable management, this occurs on a small scale due to the current state of forest degradation and to the low public and private investment destined to the recovery of this resource, which is, moreover, the last natural barrier against desertification (Honeyman *et al.*, 2009).

Continuing towards the Southern Zone, the humid temperate climate gives way to forest formations dominated by deciduous species of the genus *Nothofagus*, where the forest types Roble-Hualo and Roble-Raulí-Coihue (RORACO) dominate the forest landscape with complex ecotonal transitions.

These forests are mostly in a state of renewal, that is, they are secondary forests generated after processes of overexploitation, forest fires, or recolonization of soils abandoned by agriculture. Another phenomenon that affected these forests in the 1980s was the change in land use to forest plantations (substitution), especially in the Maule and Biobío Regions (Donoso *et al.*, 2014).

In general, the forests dominated by *Nothofagus* are dense forests, reaching great heights (more than 40 metres) and crown coverage greater than 100 percent. These formations are mostly contemporaneous (similar ages) and tend to form pure forests or with few dominant species, therefore their management is relatively easier. As a result, a large part of the silvicultural activities of forest management are carried out in these young forests, although their commercial use is marginal compared to the industry associated with fast-growing exotic species.

In the higher altitude areas in the forests of the Southern Zone, the forest type Lenga (*Nothofagus pumilio*) dominates, forming forests of this deciduous species, which grows in a stunted way (bushy growth) as an adaptation to the complex environmental conditions. As the latitude increases, the Lenga begins to drop in altitude and becomes dominant in the austral formations until reaching sea level (Donoso, 2015).

Also appearing in the Southern Zone are forest formations dominated by ancient conifers such as the *Araucaria Araucana* (Araucaria), the *Fitzroya cupressoides* (Alerce), and *Pilgerodendron uviferum* (Ciprés de la Guaitecas), species that give rise to three forest types with similar names. Both the Araucaria and the Alerce are currently protected by law, due to the critical conservation condition in which they were found after decades of overexploitation, encouraged by the high quality and durability of their woods (Donoso, 2015), and are included in Appendix I[45] of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Continuing south, the Siempreverde forest type appears, one of the two most important types regarding its surface, and which is dominated by perennial species of different genera and families, forming what is known as the Valdivian Temperate Forest or Cold Rainforest, given its high biodiversity and stratification. These are large forests, generally of high density and cover, accumulating high levels of biomass per hectare.

These forests are extensive, complex, and highly variable, which is why five subtypes can be distinguished: forests on Ñadis soils, Olivillo Costero forests, Siempreverde forests with shade intolerant species, Siempreverde forests with shade tolerant species, and Canelo forests, all of them covering large areas in the Los Lagos and Aysén Regions, especially in the coastal zone of channels and archipelagos (Donoso, 2015).

[45] Appendices I, II and III: https://cites.org/esp/app/appendices.php

The evergreen formations also present states of anthropic alteration, processes caused by overexploitation, fires, overgrazing and land use change, as well as, although to a lesser extent, substitution by forest plantations and agricultural and livestock activities.

Despite their complexity, these forests are also managed for the extraction of timber products, mainly firewood, and non-timber products, as well as the frequent practice of selective extraction of the best quality and largest individual trees (known in Chile as *Floreo*) intended for the timber industry. As in the previous types, the informality of such activities is a significant problem in the context of resource management and conservation (Donoso *et al.*, 2014).

	Forest Type (ha)												
Region	Alerce	Ciprés de las Guaitecas	Araucaria	Ciprés de la Cordillera	Lenga	Coihue de Magallanes	Roble-Hualo	Roble-Raulí-Coihue	Coihue-Raulí-Tepa	Esclerófilo	Siempreverde	Palma Chilena	TOTAL
Arica y Parinacota	-	-	-	-	-	-	-	-	-	47,151	-	-	47,151
Tarapacá	-	-	-	-	-	-	-	-	-	33,246	-	-	33,246
Antofagasta	-	-	-	-	-	-	-	-	-	11,899	-	-	11,899
Atacama	-	-	-	-	-	-	-	-	-	3,224	-	-	3,224
Coquimbo	-	-	-	-	-	-	-	-	-	48,194	281	-	48,475
Valparaíso	-	-	-	49	-	-	1,224	-	-	475,194		7,648	484,115
Metropolitan	-	-	-	76	-	-	10,348	-	-	350,437	-	3,094	363,955
O'Higgins	-	-	-	2,901	-	-	33,187	-	-	418,879	-	4,343	459,310
Maule	-	-	-	12,960	9,680	-	172,737	172,506	-	213,631	-	-	581,514
Ñuble	-	-	-	6,076	49,908		13,375	153,974	3,679	19,390	1,578		247,980
Biobío	-	-	38,796	18,220	97,709	-	-	360,084	48,416	20,755	13,593	-	597,573
La Araucanía	-	-	199,460	13,560	108,655	-	-	470,860	120,421	636	50,562	-	964,154
Los Ríos	7,770	83	13,961	-	143,023	4,337	-	252,801	280,321	203	206,032	-	908,531
Los Lagos	208,360	43,088	-	19,163	509,898	126,502	-	244,655	393,084	499	1,282,188	-	2,827,437
Aysén	-	159,334	-	-	1,400,378	939,169	-	-	-	-	1,899,864	-	4,398,745
Magallanes y La Antártica	-	228,094	-	-	1,373,880	888,098	-	-	-	-	270,105	-	2,760,177
TOTAL	216,130	430,599	252,217	73,005	3,693,131	1,958,106	230,870	1,654,880	845,921	1,643,340	3,724,201	15,085	14,737,486

Table 8. Regional distribution of forest types. Source: Cadastre of Vegetation Resources and Land Use[46] (CONAF, 2020)

[46] Cadastre of Vegetation Resources and Land Use: https://www.conaf.cl/nuestros-bosques/bosques-en-chile/catastro-vegetacional/

Finally, in the Austral Zone, the forest types of Lenga (*Nothofagus pumilio*) and Coihue de Magallanes (*Nothofagus betuloides*) become more common, forming both pure forests or mixtures of both species. These forests can also reach large dimensions and high coverage, but they have less biodiversity than the forest types present in the temperate and Mediterranean zones, covering large areas in territories where anthropic pressure is significantly less intense due to low population density. However, it is possible to observe in the landscape the evidence of large fires that affected this area last century, devastating large areas of these forests to make way for cattle ranches (Donoso, 2015).

In summary, despite the fact that Chile has an extensive and diverse native forest resource, its current use does not represent a significant contribution to the Gross Domestic Product (GDP) (1.9 percent in 2017), and it is not known with any certainty the real dimension of this use and exploitation, since there is a high level of informality that could exceed 80 percent, according to unofficial data. These forests currently provide environmental services, such as the provision of biomass for firewood in the communities and shelter for livestock, which have generated degradation processes.

These processes of forest degradation have been detected in large areas of the territory, being intensified by forest fires that have had an increasing impact as a result of the prolonged drought that has affected the country. This phenomenon, which has continued for decades, has generated a significant loss of the ecological and economic value of forests, reducing their capacity to provide goods and services, including carbon capture and storage, thereby generating a substantial loss of the country's natural capital.

This degradation process has also triggered the neglect of forests and, in some cases, their deforestation and change of use towards other productive uses of greater profitability, further increasing emissions associated with the unsustainable use of forest resources (Donoso *et al.*, 2014).

3.2.2 National System of Protected Wilderness Areas of the State (SNASPE)

SNASPE has under its administration an area of 18.6 million ha, which includes native forests that are in a formal state of conservation and preservation, as well as wetlands, salt flats and other non-forest conservation areas (National Parks and Reserves) (see Table 9 and Figure 5).

In addition, there is a growing number of Private Protected Areas (APP) in Chile, which are created for different reasons, ranging from altruism to the development of ecotourism.

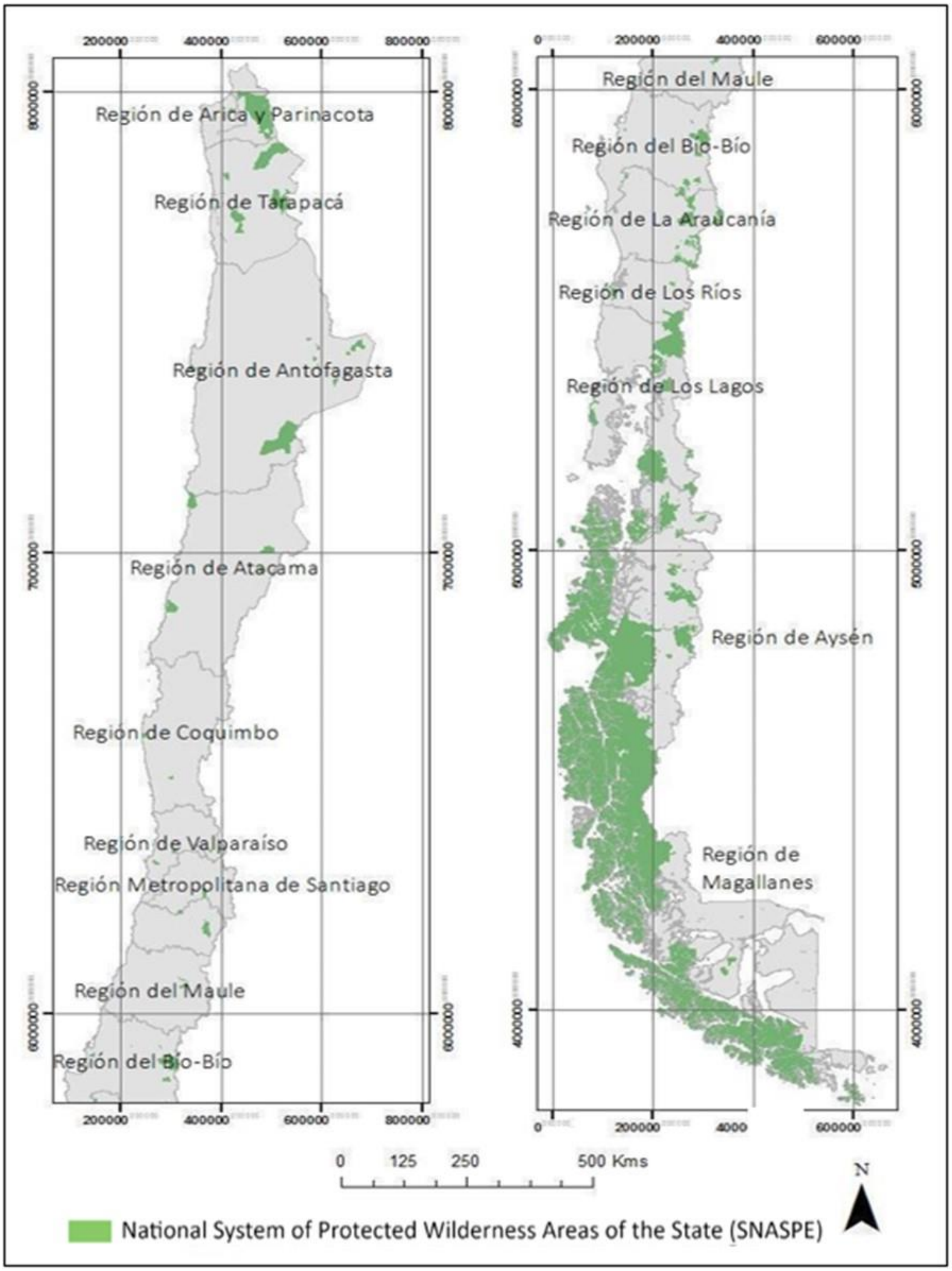

Figure 5. Regional distribution of areas belonging to SNASPE. Chile 2020

Region	SNASPE areas	Area (ha)
Arica y Parinacota	5	369,648.8
Tarapacá	2	301,893.0
Antofagasta	6	360,119.0
Atacama	3	148,544.0
Coquimbo	4	15,175.0
Valparaíso	7	44,494.5
Metropolitan	3	16,379.1
O´Higgins	3	46,461.0
Maule	8	18,668.0
Ñuble	2	57,969.0
Biobío	6	54,928.0
Araucanía	12	298,158.0
Los Ríos	2	21,512.0
Los Lagos	12	1,406,861.7
Aysén	17	4,576,220.7
Magallanes	14	10,889,434.8
Total	**106**	**18,626,466.6**

Table 9. Regional distribution of areas in SNASPE. Source: CONAF

3.2.3 Forest plantations

Forest monocultures in Chile cover an area of approximately three million hectares, which are concentrated in the Central Zone, mainly in the coastal mountain range and foothills of the Maule, Ñuble, Biobío, and Araucanía Regions, where 80 percent of the forest plantations in the country are found (Table 10).

The two main species that make up the majority of the forest plantations in the country are *Pinus radiata* (Pino insigne) and *Eucalyptus globulus*, with 60 and 33 percent of the planted area, respectively. Both species are used in the pulp and paper, lumber, board and manufacturing industry, which are the main export products of the national forestry sector, representing the second largest share of the country's total exports after copper.[47] There are also, to a lesser extent, productive plantations associated with other coniferous or eucalyptus species in the southern zone, which together account for about 10 percent of the national area.

[47] http://www.infor.cl

In the semi-arid zone, through an effort over more than 10 years on the part of the State, plantations of shrub species of the *Atriplex* genus were established covering 60,000 hectares, with the aim of recovering degraded soils, and providing a source of food for extensive livestock farming in the zone.

There are also compensatory and experimental plantations in Chile, which are not officially registered and so their dimensions and current condition are unknown.

The great heritage of productive forest plantations the result of 40 years of a public policy to promote forest plantations, which allowed the development of an important industry, which, as previously mentioned, now has a significant share of national exports.[48]

Region	Area (ha)	Percentage
Arica y Parinacota	20.8	0.00%
Tarapacá	29,264,0	0.94%
Antofagasta	3,050,0	0.10%
Atacama	276.0	0.01%
Coquimbo	12,285.0	0.39%
Valparaíso	68,758.0	2.21%
Metropolitan	9,181.0	0.29%
O'Higgins	130,536.0	4.19%
Maule	634,894.0	20.39%
Ñuble	380,715.0	12.23%
Biobío	875,178.0	28.10%
La Araucanía	632,289.0	20.30%
Los Ríos	208,775.0	6.70%
Los Lagos	96,599.0	3.10%
Aysén	32,017.0	1.03%
Magallanes y de La Antártica	286.0	0.01%
Total	**3,114,123.8**	**100.00%**

Table 10. Regional distribution of the areas occupied by forest plantations. Source: CONAF

[48] http://www.conaf.cl

3.3 REDD+ activities

The national FREL/FRL of Chile describes the emissions and removals produced in the native forests during the reference period for the activities of reduction of emissions caused by deforestation, reduction of emissions caused by degradation, conservation of forest carbon stocks and enhancement of carbon stocks.

These activities are based on the concepts shown in Figure 6, where improvement activities imply an enhancement in carbon stocks and an improvement in forest conditions or forest area; and the activities that deteriorate the situation are those that decrease the carbon stock.

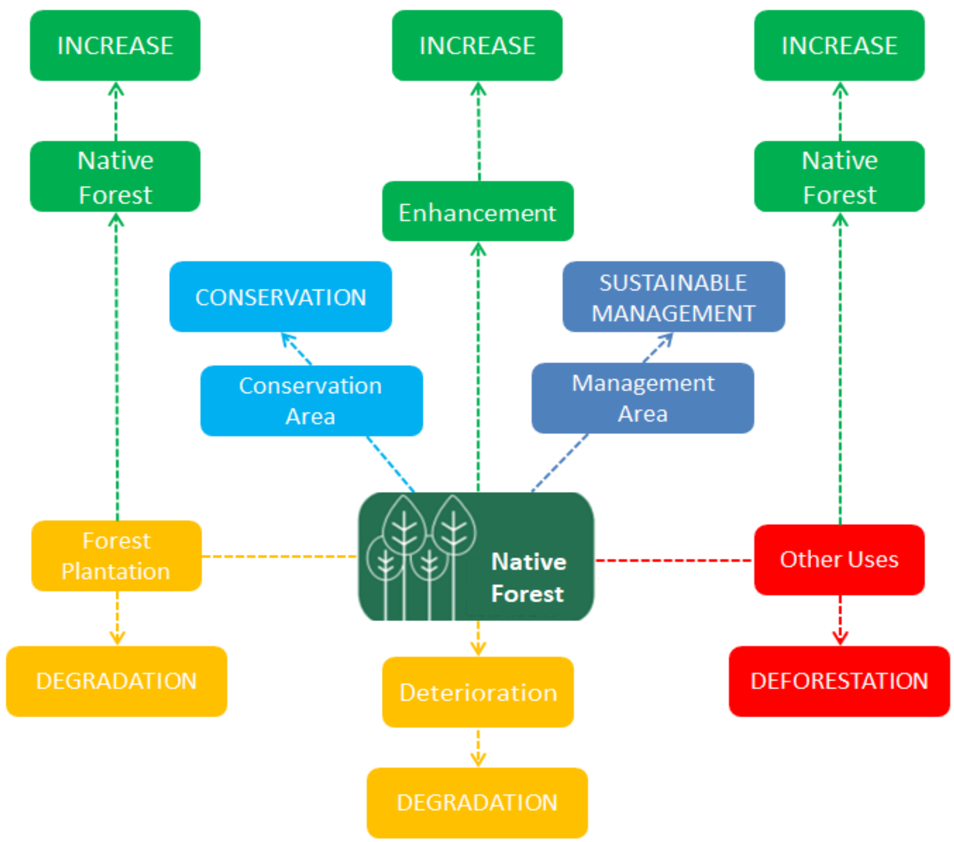

Figure 6. Concepts of REDD+ activities

Although the Sustainable Forest Management activity was an area of improvement considered in both the first FREL and the Technical Annex, and their respective TARs, in the update of this FREL/FRL it has not been feasible to include this activity. This is due to limited availability of official information that would allow spatial delimitation of the forest area subject to on-going management actions. In this regard, and as considered in the first FREL/FRL, the management activities implemented under the Forest Management Plans stipulated in Law 20,283 on Native Forest Recovery and Forest Promotion are implicitly incorporated into the changes of carbon stocks caused by the activities of degradation, forest conservation and the enhancement of carbon stocks in areas of permanent forest.

3.3.1 Deforestation

Defined as the transformation of forest areas into another land use permanently or where it is not certain how and when the restitution of the forest would occur.

Considerations:

1. The land use change from forest (according to the definition above) to forest plantation will not be considered Deforestation. This land use change will be reported under the Degradation activity, allowing consistency with the INGEI to be maintained.

2. Clearcuts areas or where trees have been removed will not be considered Deforestation, as long as a natural or assisted regenerative activity is planned, reported and documented.

3.3.2 Forest degradation

Defined as any reduction in the carbon content of a forest that is induced by humans with an intensity that suggests forestry activity should cease, but that does not cause a land use change.

Considerations:

1. Emissions produced in forests that remain forests subject to formal conservation processes will not be considered as part of degradation in the FREL/FRL, since they are accounted for in the Conservation activity.

2. Any land use changes from forest to forest plantation, also called Substitution, will be considered degradation. The carbon content of the plantations after the substitution will be considered as "0", as a consequence of the process of removal of the vegetation necessary for the establishment of a plantation. The quantification of carbon fluxes after the establishment of the plantations is not included in the REDD+ Reference Level but is included in the INGEI.

3. Non-CO_2 emissions produced by forest fires are considered in the Degradation activity.

3.3.3 Enhancement in forest carbon stocks

Defined as the enhancement in forest carbon stocks in areas subject to a land use change from non-forest to forest, and the enhancement in forest carbon stocks as a result of the recovery of degraded forests.

Considerations:

1. Those stocks produced in forests that remain forests subject to formal conservation processes will not be considered in the enhancement in carbon stocks activity, since they are accounted for in other activities.

2. Any change of use from forest plantation to native forest (also called restitution) will be considered as an increase in stocks, allowing consistency with the substitution concept applied to forest degradation. Considering that restitution is a process that happens after the harvest of the plantation, it should be considered that the carbon content prior to the restitution is "0".

3.3.4 Forest conservation

Defined as the variations in carbon content and an enhancement in stocks in areas of native forest subject to formal conservation processes.

Considerations:

1. Depending on the information available, those identified by preservation forest types (Chilean Palm, Alerce and Araucaria) will be considered as native forests subject to formal conservation processes, in addition to the forest areas that are part of the SNASPE and those registered as areas protected by a private forest conservation initiative.

3.3.5 Sustainable forest management

Understood as variations in carbon content due to degradation and enhancement in carbon stocks in forest areas subject to formal management processes.

The following considerations must be taken:

1. Activities carried out under the following mechanisms are considered formal management processes:

    a. Native Forest Management Plan (including those structured according to specific forest types).

    b. Native Forest Planning Management Plan.

    c. Forest Management Plan for Small Areas.

2. In the future, new institutional mechanisms could be included that are developed and legally established as tools for forest sustainability, paying special attention to the ENCCRV and other mechanisms that may be developed in the future.

3. Among the management mechanisms considered as sustainable are those aimed at promoting forest restoration.

At present it is not possible to locate and delimit spatially, through the country's official maps, the native forest areas subject to forest management through the formal processes established in section 1. For now, and as long as the situation does not improve, the variations in carbon stocks due to forest management are only included in the reference levels of Degradation and Enhancement of carbon stocks in permanent forest. If the official spatial information is provided, the methodologies must be established so that the activity is included in the REDD+ carbon calculation for the country.

3.3.6 General considerations

The emissions and removals resulting from REDD+ activities included in the updated reference level have been estimated using IPCC methodologies, taking into account the base information available and the methods used. For this reason, the estimates were made at the level of activity and sub-activity, considering those that cause a land use or sub use change and those that occur in forests that remain forests.

For those that generate land use changes, AD is estimated through the Historical Maps of Land Use and Land Use changes; and for those that occur in permanent forest, remote sensing techniques are used, in combination with information from the National Forest Inventory, through a methodology designed by the country. The MHCUT are used as an input to prepare the BUR4 and the National Inventory of GHG.

For greater clarity of this FREL/FRL update proposal, the methodologies will be described at the sub-activity level when applicable and are then organized according to the corresponding REDD+ activity.

As can be seen in Table 11, the Degradation activity is divided into three sub-activities: substitution of native forest, identified as a land use change; permanent forest degradation, identified as changes in carbon stocks in forests that remain as forests; and, finally, forest fires, whereby the non-CO_2 gases emitted by forest fires in permanent forests are estimated.

Activity	Change in use/sub-use	Permanent forest
Deforestation	Deforestation	
Forest degradation	Substitution of native forest	Degradation of permanent forest
		Forest fires
Enhancement in forest carbon stocks	Increase in forest area	Enhancement in permanent forest
	Restitution of native forest	
Conservation of existing forest carbon stocks		Degradation and recovery of permanent forest in areas subject to some type of conservation

Table 11. Identification of REDD+ sub-activities

4 INFORMATION SOURCES

4.1 National Inventory of Greenhouse Gases of Chile

Since 2012, in order to comply with the reporting commitments by Chile, the Climate Change Office of the Ministry for the Environment designs, implements and coordinates the National System of Inventories of Greenhouse Gases of Chile (SNICHILE),[49] which administers the institutional, legal and procedural measures established for the biennial update of the INGEI, thus guaranteeing the sustainability of the preparation of GHG inventories in the country, the coherence of the reported GHG fluxes and the quality of the results.

The SNICHILE structure (Figure 7) consists of a decentralized organization, where the INGEI is the result of the collective and permanent effort of various public services that make up the national GHG inventory team, including the ministries of agriculture, energy, and the environment. In addition, national and international experts collaborate in all areas, contributing their expertise on related topics.

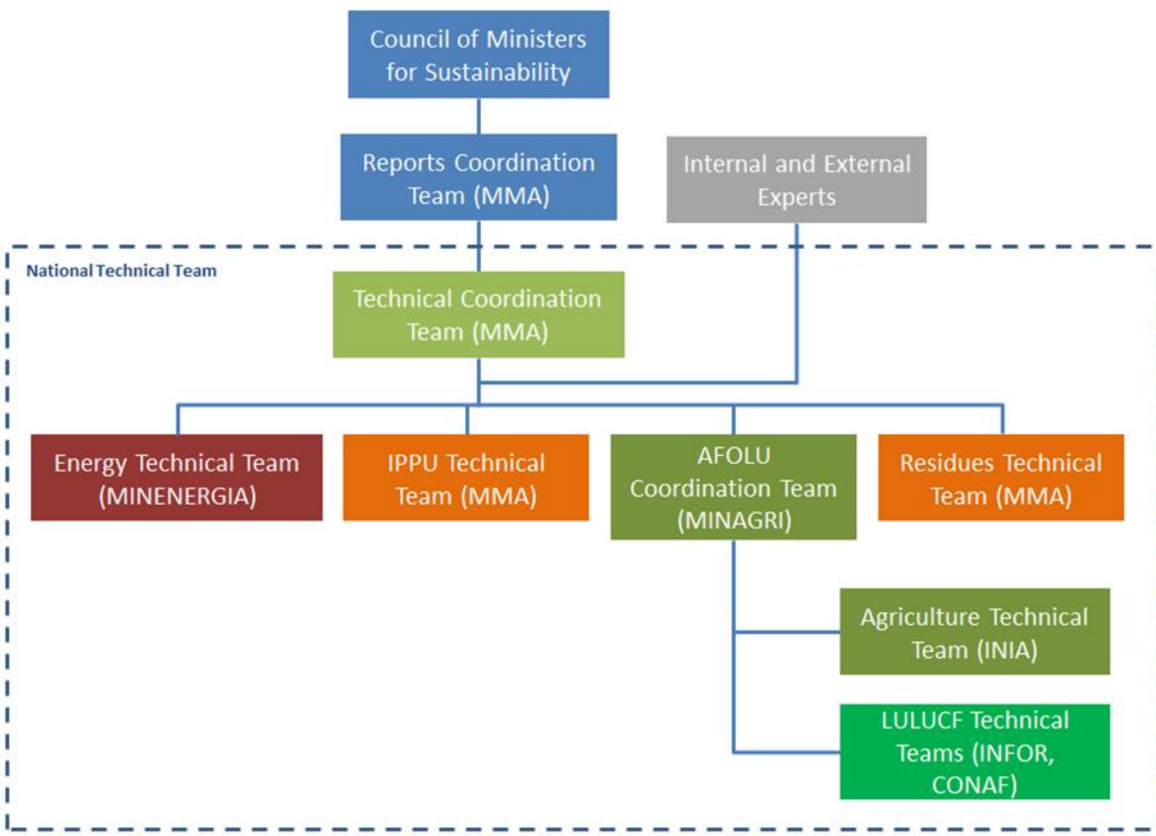

Figure 7. Organizational structure of SNI Chile

[49] https://snichile.mma.gob.cl/

Chile's Sixth GHG Inventory Report is part of the Fourth Biennial Update Report[50] and was submitted to the UNFCCC in December 2020. This report, and previous reports prepared by the country, was prepared following the 2006 IPCC Guidelines for national inventories of greenhouse gas emissions,[51] covering the entire national territory (continental, insular and Antarctic territories). Emissions and removals of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6) are included in a time series from 1990 to 2018.

The process of elaboration of the INGEI of Chile, during 2019 and 2020, is the result of the compilation of the GHG inventories of the energy sectors; industrial processes and use of products (IPPU); agriculture; land use, land use change and forestry (LULUCF); and residues (Figure 7).

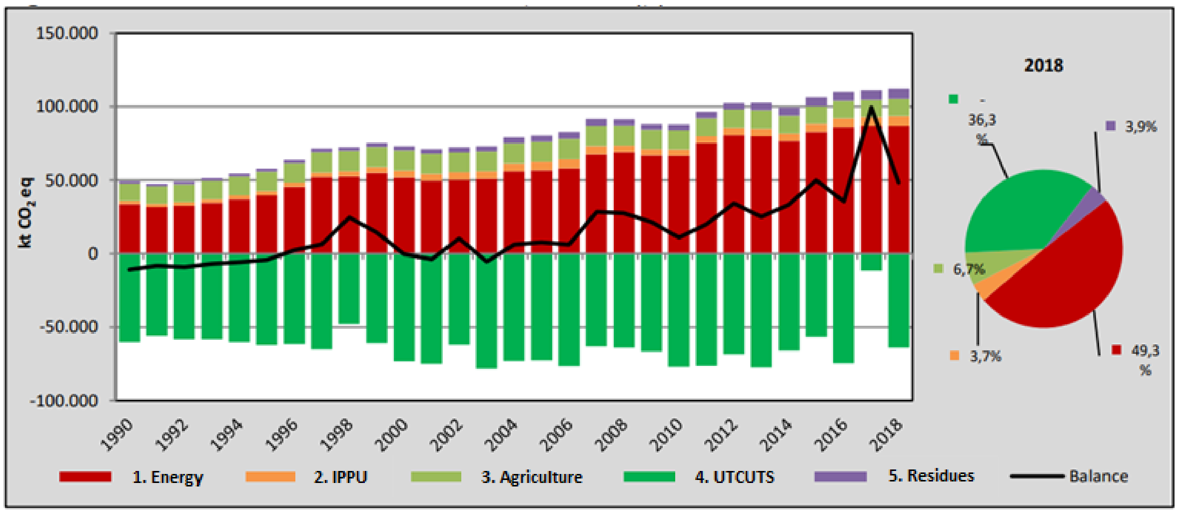

Figure 8. Chile's INGEI: Trend of GHG emissions and removals by sector, series 1990-2018. Source: MMA, 2021

The sixth INGEI of Chile indicates a two percent increase in emissions since 2016 and 129 percent since 1990, also indicating that emissions are dominated by CO_2, with the energy sector being the main emitter with 77 percent of total emissions. In the following figure, the impact of the forest fires that affected the country in 2017, linked to the LULUCF sector, on the removals, emissions and CO_2 balance can be clearly seen.

The LULUCF Sectoral Report is prepared by MINAGRI, with ODEPA coordinating the work of CONAF on issues related to land use change and of INFOR regarding the preparation of the INGEI of the sector. The main data used comes from the Monitoring System for land use change and vegetation and the National Forest Inventory (IFN). For the most part, emissions and removals were estimated with country specific EFs, while default EFs from the IPCC Guidelines were used for other land uses. The results are segregated at the regional level, in order to better represent the different environmental conditions of the country.

[50] https://cambioclimatico.mma.gob.cl/wp-content/uploads/2021/01/Chile_4th_BUR_2020.pdf

[51] http://www.ipcc-nggip.iges.or.jp/public/2006gl/spanish/index.html

The DA and EF used in Chile's INGEI can be downloaded from Chile's INGEI Database.[52]

The LULUCF Sector is the only sector that reports CO_2 removals in the country. In 2018, the GHG balance recorded a removal of -63,991.9 $ktCO_2e$. Throughout the entire time series, the GHG balance has been favourable, increasing its sink condition by 6.4 percent since 1990. The implementation of the REDD+ approach by CONAF is directly linked to the LULUCF sector, as the forest land category is the most important in the sector, maintaining its condition as a sink in the time series.

4.2 Chilean Native Forest Ecosystem Monitoring System

The Cadastre and Evaluation of Vegetation Resources of Chile (hereafter the Cadastre), started in 1993, had the main objective of developing a National Cadastre of land uses and plant formations, especially those related to native forest, forest plantations and scrub, constituting the baseline of vegetation cartographic information for Chile.

The information provided by the Cadastre is periodically updated by CONAF's Ecosystem and Climate Change Monitoring Department, through continuity projects of regional scope with the following objectives:

- **Monitor** the changes and analysis of the processes that affect the different uses of the soil or land, with emphasis on vegetation.
- **Map** and characterize forests, including land use associated with forest plantations, other natural plant formations, and land use in general (cities, agricultural land, waterbodies, snow, glaciers, wetlands, deserts).
- **Provide** the georeferenced digital database in a system for public use, management, and decision-making.

Article 4 of Law No. 20,283 on Native Forest Recovery and Forest Promotion strengthens the Monitoring System by establishing that "the Corporation (CONAF) will maintain a permanent forestry cadastre, in which it must identify and establish, at least cartographically, the existing forest types in each region of the country, their condition and those areas where there are ecosystems with the presence of native forests of special interest for conservation or preservation, according to the criteria established in the regulations of this law...", and "... which must be updated at least every ten years and its information is to be made public".

The results of the base year Cadastre were published in September 1997, and the monitoring and updating processes began in 1998. Over time, access to better technology allowed the development of a methodology that made it possible to correct defects or errors typical of the instruments used in the Cadastre phase, especially the lack of accuracy in locating the limits of the land use polygons that were initially identified.

The methodology used to classify the use of the land and the different plant formations is called the Land Use Chart (LUC), a methodology developed by the Louis Emberger Center for Phytosociological and Ecological Studies (CEPE) in Montpellier and adapted by Etienne and Prado (1982).

[52] https://snichile.mma.gob.cl/Documentos/

This methodology describes the vegetation through the plant formations or plant types, cover, height and dominant species. As for land use, it detects whether the land is being used for anthropic or natural events through remote sensors and/or analysis of the terrain, waterbodies, wetlands, snow, urban areas, agricultural land, and land without vegetation. This description is objective, it does not describe whether the vegetation or forest has a certain quality (for example, whether it has been degraded, used for timber, or protected through conservation).

The Cadastre describes nine uses and 20 sub-uses, as well as other categories determined by height, coverage and structure.

The monitoring and updating processes (see Table 12) carried out since 1998 have made it possible to determine the types of changes that have occurred in the different land uses and sub-uses, the direction of these changes and the identification of their primary causes.

Region	Base year	First update	Second update	Third update	Fourth update
Arica y Parinacota	1997	2014			
Tarapacá		2016			
Antofagasta		2018-2020			
Atacama		2018			
Coquimbo		2003	2015		
Valparaíso		2001	2013	2020	
Metropolitan		2001	2013	2020	
O'Higgins		2001	2005	2013	2020
Maule		1999	2009	2016	
Ñuble[53]		2015			
Biobío		1998	2008	2015	
La Araucanía		2007	2014		
Los Ríos		1998	2006	2014	
Los Lagos		1998	2006	2013	
Aysén		2010-2011	2020		
Magallanes		2005	2017-2019		

Table 12. Year of publication of cadastres and updates by region

Public access to the Cadastre information, as stipulated under Law 20,283 (art. 4), is provided by SIT-CONAF[54] through a web map server for consultation of the Cadastre and its subsequent monitoring and updating processes. SIT-CONAF has around 1,400 registered users, and has received more than 2,000 visits in 2015, with the most frequent query related to the area and spatial distribution of native species in Chile.

[53] Incorporation of the new Ñuble Region considers the update at the level of administrative limits only.

[54] http://sit.conaf.cl/ In annex: *Access Protocol for SIT CONAF,* includes "User Manual" and "Manual of other functionalities of the Platform".

With the purpose of updating Chile's FREL/FRL, the methodology developed by the Forest Ecosystem Monitoring System (SIMEF) project was used, which was implemented by CONAF in 2017. This methodology is based on the application of a multi-index method for the detection of spectral changes in the vegetation, which allowed the preparation of land use maps for the reference period 2001-2013 in all the regions included in this extended FREL/FRL, from Coquimbo to Magallanes, as well as spatially explicit maps of land use change in these regions.

The maps produced to date with the multi-index method are described below:

Region	Reference period	First update period	Second update period	Fourth update
Coquimbo	2001-2013	2014-2016	2016-2018	
Valparaíso	2001-2013	2013-2016	2016-2018	2018-2019
Metropolitan	2001-2013	2013-2016	2016-2018	2018-2019
O'Higgins	2001-2013	2013-2016	2016-2018	2018-2019
Maule	2001-2013	2013-2016	2016-2018	2018-2019
Ñuble[55]	2001-2013	2014-2016	2016-2018	2018-2019
Biobío	2001-2013	2014-2016	2016-2018	2018-2019
La Araucanía	2001-2013	2013-2016	2016-2018	2018-2019
Los Ríos	2001-2013	2013-2016	2016-2018	2018-2019
Los Lagos	2001-2013	2013-2016	2016-2018	2018-2019
Aysén	2001-2013			
Magallanes	2001-2013			

Table 13. Update of maps of use and land use change through 2021 in regions of the updated FREL/FRL

4.3 National Forest Inventory[56]

The National Forestry Inventory (IFN) executed by the Forestry Institute (INFOR) has been in operation since 2000 and its purpose is to support decision-making processes, international processes and different areas of current and future interest. The IFN constitutes a statistical-mathematical tool that enables the collection of data and information regarding the state and condition of the country's forests from an ecosystem perspective in order to promote sustainable development.

The IFN is designed under a two-stage statistical concept in conglomerates of three concentric circular plots with an area equivalent to 500m^2, distributed in a systematic grid of 5x7 km (see Figure 9).

[55] Incorporation of the new Ñuble Region considers the update at the level of administrative limits only.
[56] https://ifn.infor.cl/

The IFN is based on the generation of a first cycle of measurements of permanent sampling plots that covers 9.38 million hectares of native forest between the Coquimbo and Magallanes Regions, which was completed in the period 2001-2010, and the second cycle of measurements on an annual basis under the partial replacement system with growth projection support.

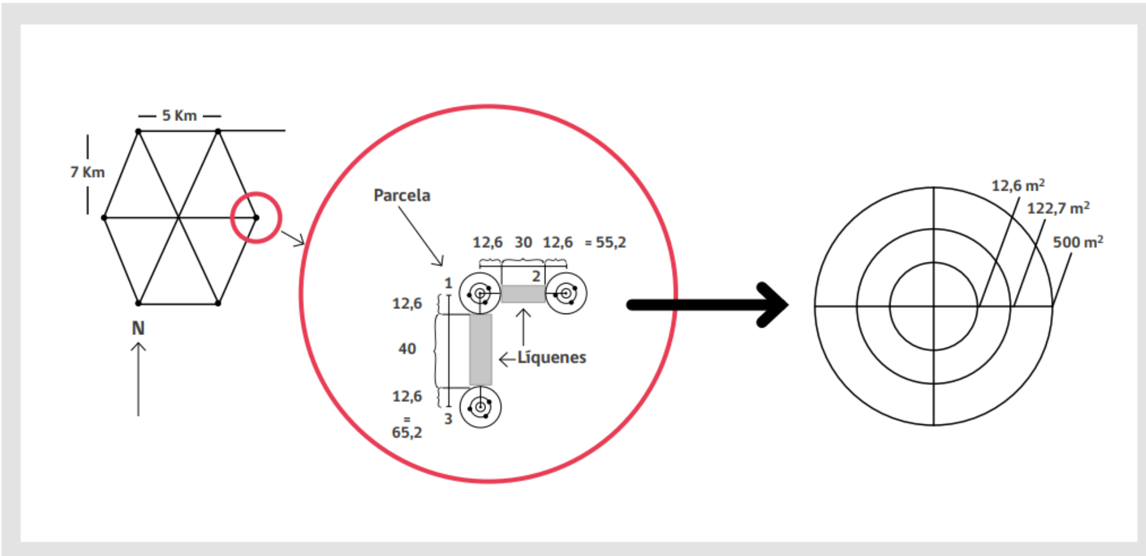

Figure 9. IFN plot design. Source: INFOR

The IFN collects information on trees with a Diameter at Breast Height (DBH) greater than or equal to 25 cm in the 500 m^2 plot, trees with a DBH greater than or equal to eight centimetres in the 122 m^2 plots, and trees with DBH greater than or equal to four centimetres in plots of 12.6 m^2.

At the individual level, the species, DBH, bark thickness, crown diameter and health status are recorded. To obtain a sub-sample in each plot, more detailed information is obtained on total height, crown start height, stump height, etc.

At the plot level, $1m^2$ sub-plots are established in order to measure all the vegetation present, as well as regeneration, woody residues, dead trees, etc. For each conglomerate, general descriptions on the degree of anthropic intervention, the presence of civil works, degradation and evolutionary status are made reflecting what was observed in each of the three plots.

4.4 Multi-pixel mosaic made from LANDSAT satellite images

The main input for the calculation of the variation of carbon content in the forests that remain forests, and the elaboration of the maps of use and land use change, is the multi-pixel mosaic,[57] which is created using the Google Earth Engine (GEE) platform from LANDSAT satellite images.

The multi-pixel mosaics correspond to a composition of cloud-free and shadow-free pixels, representative of the country's dry season (October to March), which are obtained from LANDSAT images. The algorithm used to create the mosaic corresponds to the medoid algorithm, described by Flood (2013). This algorithm consists of obtaining the multidimensional median for each pixel from a series of LANDSAT images that meet the quality requirements.

The LANDSAT earth observation programme, which began obtaining images of land cover in 1972, with the launch of LANDSAT-1, and continues today through LANDSAT-8, provides a tool of great interest for the study of temporal phenomena, as has been demonstrated in a large number of publications. The images from the different LANDSAT missions are publicly accessible and free from different platforms such as Glovis, Earthexplorer (United States Geological Survey) or INPE (National Institute of Space Research).

The images corresponding to the period used for the elaboration of the multi-pixel mosaics come from the Enhanced Thematic Mapper Plus (ETM+) sensor on board LANDSAT-7. The technical characteristics of these sensors are specified in Table 14.

Spectral Bands Landsat 7 – ETM+	Wavelength	Spatial resolution
Band 1 - Blue	0.45 - 0.52 µm	30 m
Band 2 - Green	0.52 - 0.60 µm	30 m
Band 3 - Red	0.63 - 0.69 µm	30 m
Band 4 - Near Infrared	0.76 - 0.90 µm	30 m
Band 5 - Shortwave Infrared	1.55 - 1.75 µm	30 m
Band 6 - Thermal Infrared	10.4 – 12.5 µm	60 m
Band 7 - Shortwave Infrared	2.08 - 2.35 µm	30 m
Band 8 - Panchromatic	0.50 - 0.90 µm	15 m

Table 14. Characteristics of Landsat-7 ETM+ sensor. Source: LCDM Press Kit. NASA

[57] SOP_01_Satellite mosaic elaboration: https://drive.google.com/file/d/1V6cXkhx--Y1tqe08QRfTdzjpa3eFkVn9/view?usp=drive_link

5 ESTIMATION METHODOLOGY OF THE NATIONAL FREL/FRL

5.1 *Tiers* and approaches

The IPCC Guidelines for GHG inventories use different approaches and levels to represent the complexity and detail of the data used in the methodology.

IPCC (2003) describes the different approaches recommended for the representation of land uses (AD):

- **Approach 1:** The data only represent net land use changes in recorded areas over time and do not provide spatially explicit information, exact locations, or patterns of land use change. Changes from one category to another are also not recorded.
- **Approach 2:** Information on net gains and losses in specific land use categories, including conversions from/to other categories, is included in the data, but without explicit spatial location data.
- **Approach 3:** Provides spatially explicit observations of land use categories and conversions, often recording patterns at specific locations and/or using grid maps, such as those derived from satellite imagery processed with remote sensing techniques.

Similarly, IPCC (2003) describes the different levels or *Tiers* that refer to the level of complexity of the methods used to estimate emissions:

- ***Tier* 1:** Use of default EFs, provided through the Emission Factors database (EFDB), or alternatively from the IPCC guidelines. The IPCC suggests that this method "should be feasible for all countries".
- ***Tier* 2:** Use of country specific EFs or other specific factors not set by default. EFs from the EFDB could be included here if they are country specific.
- ***Tier* 3:** Higher order methods are used, such as models or inventory measurement systems designed to reflect national circumstances, repeated over time, guided by high-resolution AD, and developed at specific sub-national scales. If properly implemented, *Tiers* 2 and 3 are expected to result in more accurate estimates than lower levels.

All activities in the updated FREL/FRL proposal used information derived from an IPCC Approach 3, that is, geographically explicit data, and a *Tier* 2 for calculations, with the exception of the forest fire sub-activity where Approach 2 and *Tier* 1 were used, since for the years covered by this NREF there is neither spatialized information nor the necessary information to meet the specific requirements for a higher *Tier*. Regarding the fourth BUR of Chile, the National GHG Inventory corresponding to the 1990-2018 series applies *Tier* 1 and 2 for all land uses.

5.2 Carbon pools and GHG

Aboveground and belowground biomass was considered for all REDD+ activities included in the FREL/FRL update, with the exception of the forest fires sub-activity, where belowground biomass was not considered, since it is assumed that everything burned is aboveground.

Dead organic matter or necromass considers only the deposit of dead wood since there are no national data available for leaf litter. This value was included in deforestation and degradation activities, specifically in the forest fires and substitution sub-activities. It was not included in the enhancement in forest carbon stock activity because there is no information on the rate of necromass accumulation in areas converted to forest land. The necromass values are included in the permanent forest, and Chile's INGEI, after a transition period of 20 years.

REDD+ activity	Sub-activity	Approach	*Tier*	Carbon pool	GHG included
Deforestation	N/A	3	2	Aboveground biomass	CO_2
		3	2	Belowground biomass	
		3	2	Dead organic matter	
Forest degradation	Degradation in permanent forest	3	2	Aboveground biomass	CO_2
		3	2	Belowground Biomass	
	Substitution	3	2	Aboveground biomass	CO_2
		3	2	Belowground Biomass	
		3	2	Dead organic matter	
	Forest fires	2	1	Aboveground biomass	CH_4 - N_2O
		2	1	Dead organic matter	
Conservation of existing forest carbon stocks	N/A	3	2	Aboveground biomass	CO_2
		3	2	Belowground Biomass	
Enhancement of existing forest carbon stocks	Enhancement in existing permanent forest	3	2	Aboveground biomass	CO_2
		3	2	Belowground Biomass	CO_2
	Restitution	3	2	Aboveground biomass	
		3	2	Belowground Biomass	
	Increase in forest area	3	2	Aboveground biomass	
		3	2	Belowground Biomass	

Table 15. Levels, carbon pools and GHG considered for each REDD+ activity in Chile's proposed national FREL/FRL

Regarding soil carbon emissions, the information available is very general and does not include greater detail to be able to carry out analyses at a spatial level in order to estimate the relationship between the activities and soil, so this carbon stock was not included in this national FREL/FRL proposal, or in the initial proposal in 2016.

As indicated in 2016, the preparation of the first sub-national reference level was based on an estimate of the emissions in soil organic carbon (SOC) caused by deforestation, using a *Tier* 1 methodology, which determined the emissions from this source to be 128,005 tonnes $CO_2e\ yr^{-1}$, representing 7.7 percent of the total 1,653,819 tonnes $tCO_2e\ yr^{-1}$ of emissions of living biomass and necromass resulting from deforestation.[58]

Considering that Chile is one of the countries participating in the Carbon Fund, the exclusion of this group is also justified with respect to compliance with Criterion 4, Indicator 4.1.i of the FCPF Methodological Framework.[59] In addition, this decision is based on indicator 4.2.ii; "the excluded pools underestimates the emissions reduction".

5.3 Reference period

The reference period used for the estimation of Chile's national FREL/FRL is determined by the availability of the necessary information and by the methodology used to estimate the emissions and removals of the activities and sub-activities.

Considering these conditions, the sub-national FREL/FRL established two reference periods: the first for activities or sub-activities related to land use or sub use change that corresponds to the period 2001-2013, according to the availability of information from native forest cadastres; and the second for activities or sub-activities that occur in permanent forest, which considers the period 2001-2010, in accordance with the first cycle of the National Forest Inventory.

In this national FREL/FRL proposal, these different reference periods have been maintained, mainly due to the following considerations:

- The need to keep the 2001-2010 period in line with the IFN cycle and the difficulty in generating information on changes in land use for 2010, instead of 2013. There are no native forest cadastres for 2010 in the regions from Coquimbo to Magallanes, which generates a lack of base information for the elaboration of maps of land use change.
- The need to maintain consistency with the FREL/FRL used in the Emissions Reduction Programme of the Carbon Fund, based on which the technical improvements defined in this FREL proposal were applied in the programme regions (Maule to Los Lagos), and where no modifications of the reference periods were allowed. Therefore, it was considered inappropriate to have separate FREL/FRL for the FCPF and the UNFCCC.

[58] The tool used to estimate Soil Organic Carbon emissions is available at: https://docs.google.com/spreadsheets/d/1gDbE_6mcwqmk6DN7gi9IW0ta2wMvBRz?rtpof=true&authuser=mrv.uccsa%40conaf.cl&usp=drive_fs

[59] https://www.forestcarbonpartnership.org/carbon-fund-methodological-framework

5.3.1 Land use or sub-use changes

Activities and sub-activities related to land use or sub-use changes include:

1. **Deforestation:** Transformation of native forest to non-forest, other land uses.
2. **Substitution:** Transformation of native forest to forest plantation, corresponding to the Degradation activity.
3. **Enhancement in carbon stocks due to conversion to forest from other land uses:** Conversion of other land uses to native forest lands, corresponding to the enhancement in carbon stocks activity.

The data source for the activities and sub-activities related to land use or sub-use changes are the Historical Maps of Land Use and Land Use Change (MHCUT), which define the use and sub-use according to the IPCC for each of the regions from Coquimbo to Magallanes in the period 2001-2013. These maps were generated in CONAF based on the Cadastre and Evaluation of Vegetation Resources of Chile and the multi-pixel mosaics of the period 2001-2013.

The elaboration of the Historical Maps of Land Use and Land Use Change[60] consists of the use of a multi-index method, or *MIICA*, for the detection of changes in land use, whereby the spectral losses and gains detected based on the multi-pixel mosaics were combined with the map of the Vegetation Resources Cadastre closest to the analysis period. In this way, standardized land use change maps were obtained for the period 2001-2013 in each of the regions analysed.

In this FREL/FRL update proposal, the use of land area interpolation techniques for the generation of AD for land use changes is not considered.

5.3.2 Permanent forest

The activities and sub-activities that occur in permanent forest are:

- **Degradation in permanent forest:** Emissions in permanent forests produced by degradation, including forest fires, extraction of wood and non-wood products, and others.
- **Enhancement in carbon stocks due to the recovery of degraded forests:** Enhancement in the carbon stock resulting from the recovery of degraded forests, corresponds to the enhancement in forest carbon stocks activity.
- **Forest conservation:** Net fluxes of emissions in permanent forest, including degradation, and removals from the recovery of degraded forests in formal conservation areas.

Emissions and removals in permanent forest were estimated using the methodology described in Bahamóndez *et al.* (2009), which uses an approach based on information from the National Forest Inventory plots together with multi-pixel mosaics, made from Landsat 7 satellite images for 2001 and 2010.

The methodology consists of generating maps of carbon stocks, through the K-nn extrapolation method,[61] for the entire area of the permanent forest in the period for which land measurements of the National Forest Inventory are available. Therefore, considering that the first measurement cycle of the National Forest

[60] SOP_02_LULUCF Maps Elaboration: https://drive.google.com/file/d/1V5CqxBRsy-cUVBbeaOb1mYzWAtlZOmd1/view?usp=drive_link

[61] https://drive.google.com/file/d/1_ebmQI1izKLh3NeWN_IIVU6NFFQavAIY/view?usp=share_link

Inventory corresponds to the period 2001-2010, the reference period for activities and sub-activities in permanent forest corresponds to this period.

5.4 Methods for estimating emissions and removals

According to the structure of activities and sub-activities, as in the current subnational NREF, this update of the reference level, was developed through two different methodologies: 1) activities that imply a change of use or sub-use of the land, where the gain and loss method applies, and 2) activities that occur in permanent forests, where the stock change method is applied.

5.4.1 Land use or sub-use changes.

5.4.1.1 Deforestation and degradation by substitution

The methodology for calculating the updated FREL for deforestation in Chile is based on the IPCC equations[62] for forest land, which are also used in the INGEI to calculate emissions from forests converted to other land uses. Aboveground biomass, Belowground biomass and necromass stocks were included.

To calculate the FREL in tonnes of CO_2e, the following equation is used:

$$FREL_{Def} = \frac{\sum_t \quad \Delta C_{B_{t,Def}}}{p} * \frac{44}{12} \qquad \text{Eq. 2}$$

Where:

$FREL_{Def}$ = average annual loss of carbon stocks from native forest converted to non-forest or plantation during the reference period, in tonnes of CO_2e per year.

$\Delta C_{B_{t,Def}}$ = change in carbon stocks in native forest converted to non-forest or plantation in year t of the reference period, in tonnes C. Aboveground biomass, Belowground biomass and necromass stocks are included.

p = years of the reference period. Since it corresponds to an activity related to land use change, the analysis period is 2001-2013, therefore, p = 13.

$\frac{44}{12}$ = factor to convert carbon to carbon dioxide equivalent, in tonnes of CO_2e tonnes C^{-1}

The *Tier* 2 of the IPCC methodology is used in the estimates of emissions from deforestation, since the carbon stocks in native forest uses before conversion are specific to Chile, and the conversion areas are broken down by type of original soil cover (Sidman *et al.*, 2015). For non-forest land uses, some default EFs and others that are country-specific are used.

As recommended in the IPCC (2006), Equation 2.15 is used to calculate the annual carbon stock change of forested land converted to other land use categories (in the case of deforestation, any area of forest converted to non-forest land):

[62] Intergovernmental Panel on Climate Change (IPCC) (2006). Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use.

$$\Delta C_{B_{t,Def}} = \Delta C_{G_t} + \Delta C_{CONVERSION_t} - \Delta C_{L_t}$$ Eq. 3 (Eq. 2.15 IPCC, 2006)

Where:

$\Delta C_{B_{t,Def}}$ = annual change of carbon stocks in forest lands, in the case of Chilean native forest, converted to non-forest or plantations in year *t* under deforestation activity (Def), in tonnes C
ΔC_{G_t} = annual increase in carbon stocks due to growth in forest land (native forest) converted to non-forest or plantations in year *t*, in tonnes C
$\Delta C_{CONVERSION_t}$ = initial change in carbon stocks in biomass on forest land (native forest) converted to non-forest or plantations in year *t*, in tonnes C
ΔC_{L_t} = annual loss of carbon stocks in biomass as a result of firewood extraction, timber harvesting and other disturbances in areas of forest land converted to non-forest in year *t*, in tonnes C

In this equation, the changes in carbon stocks from gains and losses due to any activities other than conversion (ΔC_G and ΔC_L) are added to the net gain or loss due directly to conversion ($\Delta C_{CONVERSION}$; in the case of deforestation, generally resulting in a negative value given the loss of forest carbon stocks) to calculate the total change in carbon stocks.

For Chile's deforestation FREL, ΔC_G is included, which represents carbon sequestration from non-forest uses after conversion (agricultural, urban, others). This variable will be left equal to zero, since it does not affect the analysis of loss due to deforestation.

Equation 4 (IPCC 2006 Equation 2.16) calculates the parameter $\Delta C_{CONVERSION}$ for inclusion in Equation 2.2:

$$\Delta C_{CONVERSION_t} = \sum_i \left\{ \left(B_{AFTER_i} - B_{BEFORE_i} \right) * \Delta A_{TO_{OTHERS_{i,t}}} \right\} * CF$$ Eq. 4 (Eq. 2.16 IPCC, 2006)

Where:

$\Delta C_{CONVERSION}$ = initial biomass carbon stock change on forest land (native forest) converted to non-forest or plantations, in tonnes C per year
B_{AFTER_i} = existence of biomass in non-forest or plantation land use type *i* after conversion, in tonnes of dry biomass per hectare
B_{BEFORE_i} = existence of biomass in the forest type before conversion, in tonnes of dry biomass per hectare
$\Delta A_{TO_{OTHERS_{i,t}}}$ = area of forest type *i* converted to non-forest in year t, in hectares
CF = fraction of carbon in dry biomass, in tonnes of carbon by tonnes of dry biomass

In the case of deforestation, these equations can be represented with two essential inputs: the area of forest converted to other uses ($\Delta A_{TO\_OTHERS i}$) or activity data and the amount of carbon stock emitted due to conversion ($B_{AFTER i}$ - $B_{BEFORE i}$), called emission factors. The $B_{AFTER i}$ and $B_{BEFORE i}$ parameters included only aboveground and belowground biomass, so the inclusion of necromass was done by adding the ΔC_{DOM} parameter calculated according to Equation 5:

$$\Delta C_{DOM_t} = \frac{(C_n - C_o) * A_{on_t}}{T_{on}}$$ Eq. 5 (Eq. 2.23 IPCC, 2006)

Where:

ΔC_{DOM_t} = change in carbon stocks in necromass in year t, tonnes C
C_n = carbon stocks of dead wood and litter in non-forest or plantation land use after conversion, in tonnes C per year
C_o = carbon stocks of dead wood and forest litter before conversion to non-forest or plantation, in tonnes C per year
A_{on_t} = area converted from forest to non-forest in year t, ha
T_{on} = time period of transition from forest to non-forest

In this equation, A_{on} corresponds to the activity data, or $\Delta A_{TO_{OTHERS_i}}$ according to the parameter of Equation 4, which is described above. In order to simplify the calculation, necromass emissions were accounted for in the year of conversion, so T_{on} has a value of 1.

5.4.1.2 Degradation by substitution

To estimate degradation of native forests converted to plantations (substitution), Equation 2.8 of the IPCC (2006) is used, which is recommended for calculating carbon fluxes in land remaining in the same land use category:

$$\Delta C_{B_{t,DegFNF}} = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)}$$ Eq. 6 (Eq. 2.8 IPCC, 2006)

Where:

$\Delta C_{B_{t,Deg}}$ = annual change in carbon stocks in forest land converted to plantations, considering the total area, under degradation activity (Deg_{FNF}), in tonnes C
C_{t_2}= total forest carbon in year t_2, in tonnes C
C_{t_1}= total forest carbon in year t_1, in tonnes C

As in the 2016 submission, the FREL/FRL does not consider arborescent scrub as part of native forest areas, therefore this change of use is not part of forest degradation, but rather corresponds to deforestation.

5.4.1.3 Restitution and increase of forest area

As in the other activities, the methodology for the updated FRL of increases in other land converted to forests is consistent with the methodology used in the INGEI, which is based on Equations 2.9, 2.10, and 2.15 of the IPCC (2006).

To calculate the annual change in carbon stocks in aboveground and belowground biomass (the only stocks included in the increase estimates) for land converted to another land use (in this case, non-forest to forest land), the general equation, corresponding to *Tiers* 2 and 3, is Equation 2.15 of the IPCC (2006):

$$\Delta C_{B_{t,ANFF}} = \Delta C_{G_t} + \Delta C_{CONVERSION_t} - \Delta C_{L_t}$$ Eq. 7 (Eq. 2.15, IPCC 2006)

Where:

$\Delta C_{B_{t,ANFF}}$ = change in carbon stocks in year t, coming from non-forest land converted to native forest during the reference period, under stock increase activity(A), in tonnes C

ΔC_{G_t} = increase in carbon stocks due to growth in non-native forest land converted to forest in year t, in tonnes C

$\Delta C_{CONVERSION_t}$= initial change in carbon stocks in non-forest land converted to native forest in year t, in tonnes C

ΔC_{L_t} = annual reduction in carbon stocks due to timber harvests, fuelwood removals and disturbances on non-forest land converted to forest in year t, in tonnes C

In the FRL of stock increase ΔCL is assumed to be zero, due to the lack of sufficient data to quantify losses in non-forest areas that are converted to native forest. For the $\Delta C_{CONVERSION}$ parameter, Equation 2.16[63] of the IPCC (2006) is used:

$$\Delta C_{CONVERSION_t} = \sum_i \left\{ \left(B_{AFTER_i} - B_{BEFORE_i} \right) * \Delta A_{TO_{OTHERS_{i,t}}} \right\} * CF$$ Eq. 8 (Eq. 2.16 (IPCC 2006)

Where:

$\Delta C_{CONVERSION_t}$ = initial carbon change in non-forest land converted to native forest in year t, in tonnes C

B_{AFTER_i} = biomass stock in forest type i immediately after conversion, in tonnes per m.s. ha

B_{BEFORE_i}= biomass stock on land type i before conversion, in tonnes per d.m. ha

$\Delta A_{TO_{OTHERS_{i,t}}}$ = non-forest land use area converted to forest in year t, in hectares

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

For the ΔC_G parameter (the increase due to forest growth), the INGEI uses Equation 2.9 of the IPCC 2006 for a *Tier* 2-3 calculation. However, the INGEI only uses it for lands converted to forest in the year of conversion. After 20 years, these lands move to the Forest Land Remaining Forest Land category, which includes their increases. The FRL for enhancement should continue to account for increases from areas converted to forest during the entire reference period. For example, an area that is converted to forest in the first year of the reference period will continue to increase its carbon stock in the second, third, and other remaining years of the period. The increases in the second year that come from the areas planted/restored in the first year are accounted for in the second year, together with the increases in the areas planted/restored in the second year. Thus, the increases continue to accumulate for 20 (years) and are always considered under the activity

[63] In the INGEI, the loss of carbon stocks from non-forest land use that is lost during conversion to forest is counted as ΔC_L, not $\Delta C_{CONVERSION}$. However, the GL2006 defines ΔC_L as loss due solely to timber harvesting, fuelwood extraction, and disturbance, and non-forest carbon stock loss is accounted for under $\Delta C_{CONVERSION}$.

of enhancement, as in the INGEI, where they also accumulate for a reference period of 20 years, after which they become part of the category of forest land that remains as forest land.

Equation 2.9 of the IPCC (2006) calculates annual increases in carbon. However, this equation does not consider the captures that continue to accumulate in stratum "i" converted in previous years, so it was necessary to modify Equation 2.9 of the IPCC (2006) in the following way to achieve consistency:

$$\Delta C_{G_t} = \sum_i \sum_x \left(A_{i,x} * G_{TOTAL_i} * CF\right)$$

Eq. 9 (adapted from Eq. 2.9 IPCC, 2006)

Where:

$\Delta C_{G\ i,t}$= increase in carbon stocks in year t, due to growth on non-forest land converted to forest type *i* during the reference period, in tonnes C
$A_{i,x}$= area converted to forest *i* in year x of the reference period, in ha
G_{TOTAL_i}= average annual growth of biomass on non-forest land converted to forest type *i*, in tonnes per d. m. hectares per year
CF = carbon fraction of dry matter, tonnes C (ton d.m.)$^{-1}$

Equation 9 considers that to calculate $\Delta C_{G\ i,t}$ in year *t*, the captures from converted areas in each year *x* before year *t* of the reference period must be added, along with captures from converted areas in year *t*. When the forest reaches the transition period of 20 years, it is no longer counted as an increase and passes to permanent forest accounting. However, it was assumed that this does not occur during the reference period 2001-2013.

5.4.2 Forest Remaining Forest

5.4.2.1 Degradation in permanent forest

To estimate the change in carbon stocks due to degradation in forest lands that remain as forest lands, Equation 2.8 from IPCC (2006) was used:

$$\Delta C_{B_{t,DegFF}} = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)}$$

Eq. 10 ([IPCC 2006] Eq. 2.8)

Where:

$\Delta C_{B_{t,Deg}}$ = annual change in carbon stocks in forest lands remaining as forest lands, considering the total area under degradation activity (*DegFF*), in tonnes C
C_{t_2}= total forest carbon in year t_2, in tonnes C
C_{t_1}= total forest carbon in year t_1, in tonnes C

For the calculation of the reference level, the methodology described in Bahamóndez *et al.* (2009)[64] was used, which uses the stock difference method shown in Equation 11 (Equation 2.8 of the IPCC 2006), that is, it accounts for carbon stocks at different points of time, identifying stock change zones in native forest areas. For its part, the INGEI uses, for the GHG calculation, the gain and loss method based on Equation 2.7 of the IPCC (2006). This includes tabular data to estimate the volume extracted through selective logging, statistics from INFOR and MINENERGIA for firewood, and tabular data from CONAF for the area of forest fires.

The methodology used in the FREL, which was based on robust and independent information sources, enabled spatially explicit data to be obtained through Approach 3.

To calculate the carbon stocks at the beginning and end of the reference period (C_1 and C_2 in Equation 11), Equation 2.8 of the IPCC was used:

$$C_t = A_{Deg} * EF * CF \qquad \text{Eq. 11 (IPCC, 2006 Eq. 2.8)}$$

Where:

$C_{t,i}$= total forest carbon in year t, in tonnes C
A_{Deg}= area of degradation in forest land that remains as forest land, in ha
EF= stock of carbon in forest land that remains as forest land, in tonnes of biomass per ha
CF= carbon fraction, in tonnes C per t of biomass

5.4.2.2 Recovery of degraded forests

To calculate the increase in carbon stocks in permanent forest due to the recovery of degraded forests, the methodology described in the section on degradation in permanent forest areas was used. Therefore, for the calculation of annual stock increases, Equation 2.8 of IPCC (2006) was used.

$$\Delta C_{B_{t,AFF}} = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)} \qquad \text{Eq. 12 (Eq. 2.8, IPCC 2006)}$$

Where:

$\Delta C_{B_{t,AFF}}$ = annual change in carbon stocks in forest land remaining forest land, considering the total area, under stock enhancement activity (*DegFF*), in tonnes C per year
C_{t_2}= total forest carbon in year t_2, in tonnes C
C_{t_1}= total forest carbon in year t_1, in tonnes C

The carbon stocks in t_1 (2001) and t_2 (2010) were obtained from the results of the implementation of the methodology that allows the identification of areas that at the beginning of the reference period are below the threshold or line B.

[64] Bahamóndez, C., Martin, M., Muller-Using, S., Rojas, Y. and Vergara, G., 2009. *Case Studies in Measuring and Assessing Forest Degradation: An Operational Approach to Forest Degradation.* (Forest Resources Assessment Working Paper). Forestry Department, FAO.

5.4.2.3 Forest conservation

As explained in the previous chapters, the Reference Level for Forest Conservation was estimated by adding the emissions from forest degradation in permanent forest and the removals through the recovery of degraded forests within forest areas under formal conservation processes.

$$\Delta C_{B_{t,ConFF}} = \Delta C_{B_{t,AFF}} - \Delta C_{B_{t,DegFF}}$$ Eq. 13 (Eq. 2.8 IPCC, 2006)

Where:

$\Delta C_{B_{t,C}}$= annual change in carbon stocks in forest lands subject to formal conservation processes in year t, in tonnes C

$\Delta C_{B_{DegC}}$= annual change in carbon stocks due to forest degradation in forest lands subject to formal conservation processes, in tonnes C per year

$\Delta C_{B_{AC}}$= annual change in carbon stocks on non-forest land converted to forests within forest land subject to formal conservation processes

5.4.2.4 Non- CO_2 Emissions from Forest Fires

CO_2 emissions from forest fires are included in the calculations of emissions from permanent forest degradation, through the methodology of Bahamóndez *et al.* (2009). To calculate the non-CO_2 emissions from forest fires, which were not estimated in the Bahamóndez methodology, Equation 2.27 of the IPCC (2006) was used:

$$L_{fire} = A * M_B * C_f * G_{ef} * 10^{-3}$$ Eq. 14 (Eq. 2.27 IPCC, 2006)

Where:

L_{fire} = amount of greenhouse gas emissions caused by fire, tonnes of each GHG gas per year
A = area burned, hectares per year
M_B= mass of fuel available for combustion, tonnes per ha
C_f= combustion factor, dimensionless
G_{ef} = emission factor, g per kg of dry matter burned

To convert L_{fire} to CO_2e, as required in Equation 14, Equation 15 is used:

$$GEI_{fire} = L_{fire} * CF$$ Eq. 15

Where:

CF = conversion factor from non- CO_2 gas to CO_2e, tonnes of non- CO_2 gas, tonnes of CO_2e^{-1}

5.5 Activity data

As previously mentioned, the AD was calculated using the different sources of information available to ensure the most accurate and complete data inputs possible for the implementation of the methodologies. This chapter describes the methods used to estimate the AD for each group of REDD+ activities and sub-activities included in the FREL/FRL update, including those related to land use or sub-use change and those that occur in permanent forest.

5.5.1 Land use or sub-use changes

Based on the Historical Maps of Land Use and Land Use Change (MHCUT), the area of native forest converted to other uses (cropland, grasslands, settlements, wetlands, and other land uses) and sub-uses (forest plantations), or vice versa, was estimated. This section includes the Deforestation activity and the sub-activities of Substitution, Restitution and Increase of forest area, which are described above.

Each map contains the use and sub-use of the land in accordance with the categories specified in the Consolidated Document of the Project for Updating and Monitoring Cadastres of Vegetation Resources,[65] which were standardised in line with the classification of land uses and sub-uses established by the IPCC (see Table 16).

Categories of sub-uses in the Native Forest Cadastre	IPCC use	IPCC sub-use
City-town-industrial zone; industrial mining	Settlements	Settlements
Land for agricultural use; crop rotation	Croplands	Agricultural land
Highland steppe; northern Andean steppe; annual grasslands; perennial grasslands; central Andean steppe; Patagonian steppe	Grassland	Grassland
Grassland scrub; scrubland; scrub with succulents; formation of succulents; scrub plantation		Scrubland
Arborescent scrub		Arborescent scrub
Mature plantation; young or newly harvested plantation; plantation with wild exotic species	Forest land	Plantations
Mature native forest; native forest renewal; mature native forest-renewal; stunted native forest; mixed forest; native forest-plantation; native forest with wild exotic species		Native forest
Herbaceous riparian vegetation; herbaceous marsh; Ñadi herbaceous scrubland; peat bog; wetlands; estuaries; other wetlands	Wetlands	Wetlands
Ocean; river; lake-lagoon-reservoir-dam		Waterbodies
Beach and dune; rocky outcrop; land on the altitudinal limit of vegetation; lava flows; landslide without vegetation; salt flats; other areas without vegetation; river channels	Other land uses	Areas without vegetation
Snow; glacier; icefield		Snow and glaciers

Table 16. Land uses registered by the Cadastre and homologated for use and sub-use by the IPCC

[65] https://sit.conaf.cl/

The corresponding REDD+ activities and sub-activities are defined according to the initial and final IPCC sub-use during the period, and the land use transition that is carried out (see Table 17).

Initial IPCC sub-use	Final IPCC sub-use	REDD+ sub-activity	REDD+ activity
Native forest	Settlements	Deforestation	Deforestation
	Agricultural land		
	Grasslands		
	Scrub		
	Arborescent scrub		
	Wetlands		
	Waterbodies		
	Areas without vegetation		
	Snow and glaciers		
	Plantations	Substitution	Forest degradation
Settlements	Native forest	Increase in forest area	Enhancement in forest carbon stocks
Agricultura land			
Grasslands			
Scrub			
Arborescent scrub			
Wetlands			
Waterbodies			
Areas without vegetation			
Snow and glaciers			
Plantations		Restitution	Enhancement in forest carbon stocks

Table 17. Initial and final IPCC sub-uses and the respective REDD+ activities and sub-activities

5.5.2 Forest Remaining Forest

The permanent forest area, from Coquimbo to Magallanes, was identified through the permanent forest cover obtained from the MHCUT. This layer was obtained by filtering all the forest areas that remained as forest land during 2001 and 2013, and then identifying the forest types and structure of each forest.

To estimate the area affected by permanent forest degradation, the increase in permanent forest stocks and forest conservation, the methodology detailed in Bahamóndez *et al.* (2009) was used, which uses a system based on the number of trees per hectare and basal area data recorded in the plots of the National Forest Inventory to estimate spatially explicit carbon stocks, and then extrapolate them using the knn method and multi-pixel mosaics.

Forest Inventory plots are located on a density diagram, or population graph, based on the number of trees and basal area per hectare. The density diagram considers several thresholds or lines that determine, for different forest types, their condition at the time of measurement (degradation thresholds). This information identifies the condition of the plots, distinguishing between degraded and non-degraded plots (Bahamóndez *et al.*, 2009).

In the case of the methodology used in the FREL/FRL, the established threshold, or line B, made it possible to identify the degradation and enhancement of carbon stocks in permanent forest.

Line B represents the limit at which trees can develop large crowns and fully occupy the capacity of the site without excessive competition (Gingrich, 1967), which is why it is considered the natural resilience threshold of a forest. The delimitation of this threshold was established through the field work of experts and is specific for each type of forest (INFOR, 2014). The plots located below the threshold, or line B, are not recommended for productive management (see Figure 10).

The density diagram is a tool that allows the description of the condition of a forest at a static moment. However, the activities and sub-activities needed to analyse the FREL/FRL are processes that develop over time. The density diagram records data collected from fieldwork that can generate estimates, but it does not contain spatially explicit information covering the entire study area. To determine the plots subjected to degradation or recovery processes, the displacement in the population graph caused by the variation of the basal area, and the difference in the number of trees per hectare between two measurements were analysed (see Figure 11).

- Plots that move towards the axis of origin of the graph, crossing or remaining below line B, are considered degradation plots.
- Plots that move away from the axis of origin of the graph, crossing or staying below line B, are considered plots of recovery of degraded forests.
- Plots that move above line B, regardless of direction, are not considered in the FREL/FRL, since the variations are a neutral effect and the plots are within the natural resilience threshold.

Figure 10. Density graph and line B. Based on National Forest Inventory (INFOR)

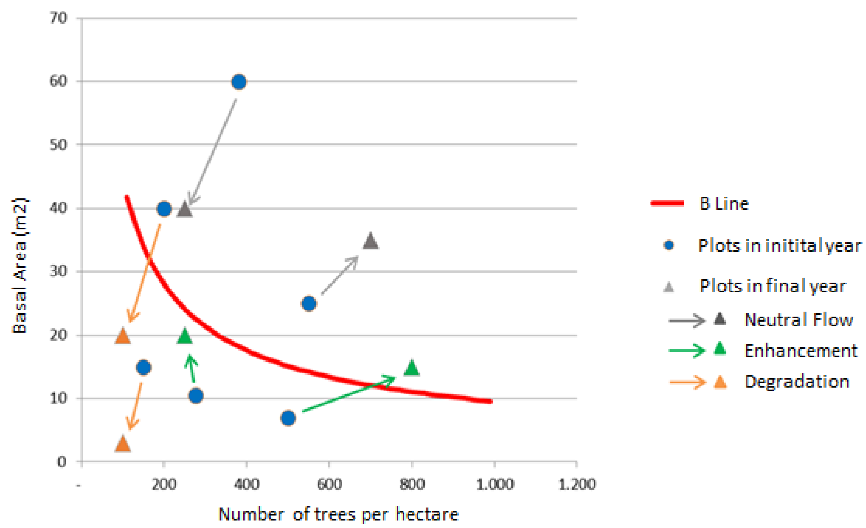

Figure 11. Example of carbon fluxes representing enhancement (green arrow), degradation (red arrow) and natural fluxes (grey arrow)

Change of location in the carbon stock graph	Carbon Fluxes	Corresponding activity
Above B in 2001 and under B in 2010	Emission	Degradation
Under B in 2001 and under B in 2010	Emission	Degradation
Under B in 2001 and under B in 2010	Absorption	Enhancement of existing stock
Under B in 2001 and above B in 2010	Absorption	Enhancement of existing stock
Above B in 2001 and above B in 2010	N/A	Not included

Table 18. Possible changes in the density graph during the time period and REDD+ activities in which they are counted

The density diagrams used to obtain the AD in permanent forest correspond to the forest types of Lenga, Siempreverde sub-type Canelo, Roble-Raulí-Coihue (RORACO), Coihue-Raulí-Tepa, Roble-Hualo Esclerófilo, sub-type Espinal and Coihue de Magallanes.[66] For the spatial identification of each of the forest types, and thus to apply the corresponding density diagram, the permanent forest cover from the MHCUT was used. If the described forest type did not coincide with any of the available density diagrams, the default RORACO forest type was used. Each of these density diagrams has been subjected to validation through a technical workshop with experts in the area.

To obtain spatially explicit information for estimating areas subject to each of the detailed activities, a non-parametric K-nearest neighbour extrapolation was applied to permanent forest areas, modified by weighting neighbours as detailed in Tomppo (1991). This method is widely used in the analysis of forest inventories and

[66] SOP 5 https://drive.google.com/file/d/1_ebmQI1izKLh3NeWN_IIVU6NFFQavAIY/view?usp=drive_link

allows the simultaneous extrapolation of plot state variables, such as basal area and number of trees per hectare.

The Euclidean distance *dpi,p* in the space of the auxiliary or explanatory variables (bands 1 to 5 of Landsat 7) is considered as the distance between pixel *p* and pixel *pi* that contains ground truth. Then, a certain number k of elements with ground truth must be considered with a minimum distance *dpi,p* in the space of the explanatory variables so that (Tomppo, 1991):

$$d_{p_1,p},\ldots\ldots,d_{p_k,p},(d_{p_1,p} \leq \ldots\ldots \leq d_{p_k,p}),k \approx 5-10$$ Eq. 16

Through these Euclidean distances, and their rearrangement into k nearest neighbours, we proceed to calculate a set k of weights *wi* with *i=1,k*; so that the linear combination of these weights provides the estimate of the stand state vector in unobserved positions (pixels). The weights are calculated as follows:

$$w_{i,p} = \begin{cases} \dfrac{1}{d^2_{p_i,p}}\left[\displaystyle\sum_{j=1,k} 1 \Big/ d^2_{p_j,p}\right]^{-1} & ,si \quad i \in \{i_1(p),\ldots\ldots,i_k(p)\} \\ 0 & ,si \quad i \notin \{i_1(p),\ldots\ldots,i_k(p)\} \end{cases}$$ Eq. 17

Where:

ij(p) = indicates the ground truth plots that are closest in distance in the multidimensional space of the auxiliary variables. Considering these expressions, the estimated value of those pixels not observed on the ground is calculated as a linear combination:

$$y_{est} = \sum_{i=1,k} w_{i,p} y_i$$ Eq. 18

After applying the procedure, the pixels are resampled to one hectare for the 2001 and 2010 Landsat 7 images, which cover the entire area of permanent forest in the study area.

To differentiate the conservation areas, spatial data from SNASPE and Nature Reserves were used, which is provided by the Integrated Territorial Information System of the Library of the National Congress of Chile. The data on the private protected areas was obtained from the National Registry of Private Conservation Initiatives.

To account for non-CO_2 emissions, tabular data with information on the area affected by forest fires in the INGEI 2020 Annexes was used. The original source of this data is the Historical Forest Statistics of CONAF/Companies from 1985 to 2018. Reported data includes total annual forest fire areas in each region between 1971 and 2018. However, in the FREL, only data from 2001 to 2010 is included to maintain consistency with the permanent forest reference period.

5.6 Emission factors

5.6.1 Land use or sub-use changes

5.6.1.1 Deforestation

Carbon stocks before deforestation (B_{BEFORE})

Forest carbon stocks before deforestation were obtained from the information bases of the INGEI of Chile. These figures are obtained from the INFOR national forest inventory to reach an estimate of *Tier* 2 live aerial biomass, where the values are estimated for each forest type. In the case of Belowground biomass (B_{BEFORE} of Equations 4 and 8), the values are estimated based on the values of living aboveground biomass by forest type, provided by INFOR, and the relationship between belowground biomass (roots) and aboveground biomass (R) estimated at the country level by the INGEI.

As for necromass (Co of Equation 5), the data used is a value by forest type corresponding to the average dead wood per structure, from INFOR's national forest inventory. Finally, under deforestation accounting, the carbon stock of harvested wood products (HWP) was assumed to be zero, due to the lack of reliable data sources to distinguish HWP from deforestation and degradation.

Carbon stocks after deforestation (B_{AFTERi})

In the INGEI, default values from the IPCC (2006) are used for B_{AFTERi}. However, these values are assumed to be growth in non-forest land use, which actually corresponds to ΔC_G and not B_{AFTERi}.[67] For the FREL estimates, carbon stocks directly after deforestation on deforested lands were assumed to be zero.

Changes in carbon stocks apart from the deforestation event (ΔC_G and ΔC_L)

Post-deforestation carbon stocks (ΔC_G) are determined in one of two ways:

- Values taken from a literature review of non-forest carbon stocks, preferably studies carried out within Chile (such as Gayoso, 2006[68]). If these are not available, data from other regional studies (temperate areas of South America with similar management regimes) can be used. This is the preferred method and represents a *Tier* 2 or 3.
- When these values are not available, the IPCC (2006) default values can be used. This is the method currently used by the INGEI, but it represents a *Tier* 1.

Lastly, losses due to timber harvesting, firewood extraction, and disturbances (ΔC_L), were calculated under the assumption that these are zero in areas of deforestation, applying the same assumption as INGEI. In the case of INGEI, Equation 2.15 of the IPCC is used and includes all forest losses due to harvesting, firewood and disturbances.

[67] In the INGEI estimates, ΔC_G was calculated by multiplying $B_{BEFOREi}$ by the fraction of carbon in the dry biomass (the value of 0.5 was used). Similarly, ΔCL was calculated by multiplying B_{AFTERi} by 0.5. B_{AFTERi} values were assumed to be the carbon stocks of non-forest land uses after one year of growth.

[68] Gayoso JA (2006) inventory of carbon in grasslands and scrublands for the baseline study of the SIF Regions VII and VIII project. Universidad Austral de Chile, Valdivia.

5.6.1.2 Degradation by substitution

For the EFs of changes from native forest to plantation, the estimates of carbon stocks based on the Forest Inventory plots and other studies of carbon stocks from other land uses were used.

Estimates of carbon stocks before conversion (B_{BEFORE}), carbon stocks after conversion (B_{AFTER}), and biomass losses due to firewood extraction, timber harvesting, and other disturbances (ΔC_L) are the same as those used in the Deforestation activity. Also, the values for existing biomass in the plantations after the substitution (ΔC_G) were assumed to be zero (0), since Chile does not include plantations in its REDD+ programme.

5.6.1.3 Restitution and increase in forest area

For the calculation of restitution and increase in forest area, the B_{AFTERi} values depend on the existing land use prior to the establishment of new forests. For the case of agricultural land and urban and industrial areas, the value of B_{AFTERi} was assumed to be zero, since carbon stocks from non-forest land use converted to forest have been removed before the forest was established. For natural land uses, mainly grasslands and scrublands, it was assumed that B_{AFTER} is equal to B_{BEFORE}, since it is assumed that these lands are not cleared prior to forest establishment, but naturally converted to forest without losing initial carbon stocks. The existence of $B_{BEFORE\textit{i}}$ carbon stocks is equivalent to non-forest land use carbon stocks. For these stocks, regional or national scientific reports were used, such as Gayoso (2006), which estimate carbon stocks in non-forest land uses.

In Equation 9, the average annual growth of biomass per hectare for each forest type (G_{TOTAL}) was calculated with Equation 19 (modified from Equation 2.10 in IPCC 2006).

$$G_{TOTAL} = \Sigma_i(I_{Vi} \cdot BCEF_i \cdot (1+R_i)) \qquad \text{Eq. 19 (Eq. 2.10 IPCC, 2006)}$$

Where:

G_{TOTAL} = average annual growth of aboveground and belowground biomass, tonnes of d.m. per hectare per year

I_i = average net annual increase for a forest type, m^3 per hectare per year

$BCEF_I$ = biomass conversion and expansion factor for conversion of net annual increase in volume (including bark) to aboveground biomass growth for a forest type, in tonnes of aboveground bark growth (m^3 of average annual increase)

R = ratio between belowground and aboveground biomass for a forest type in tonnes m.s. of belowground biomass (tonnes d.s. of aboveground biomass).

The average net annual increase values, I, were compiled using the INGEI data set, based on forest inventory data, which estimates values for the forest types: Alerce, Ciprés de las Guaitecas, Araucaria, Ciprés de la Cordillera, Lenga, Coihue de Magallanes, Roble Hualo, Roble-Raulí-Coihue, Coihue-Raulí-Tepa, Esclerófilo, and Siempreverde. To calculate $BCEF_I$, Equation 20 is used:

$$BCEF_I = BEF_I \cdot D_i \qquad \text{Eq. 20}$$

Where:

BEF_I= Biomass expansion factor of a forest type. This factor expands the total volume of aerial biomass to compensate for the non-marketable components of the increase, without dimension.

D = basic density value of wood, tonnes m^{-3}

The biomass expansion factor (*BEF_l*), and the basic density value of wood (*D*), come from the INGEI data set. In the case of *BEF_l* for native forests, the value is taken from Gayoso (2002), being a single value for all forest types. Similarly, there is only one basic wood density value for native species, which is found in the INGEI.

The relationship between belowground and aboveground biomass for native forests (*R*) was estimated by Gayoso (2002) and is found in the INGEI data set.

5.6.2 Forest Remaining Forest

The carbon stocks in forests that remain as forests were calculated using Equation 22. This formula applies to the calculation of degradation in permanent forest, the enhancement in carbon stocks in permanent forest and the conversion of forests.

The EFs come from INFOR's continuous forest inventory, where the basal area of each hectare of forest was determined in t1 and t2. Based on this data, the total volume of each hectare is calculated:

$$Vol = KAB^{\beta}$$

Eq. 21

Where:

Vol= Volume of trees in forest, cubic meters per ha
AB= Basal area, square meters per ha
K= constant, value of 2.9141
β = constant, value 1.2478

Then, to convert volume to CO_2, Equation 22 is used:

$$EF = Vol * D * BEF$$

Eq. 22

Where:

EF = carbon stocks in forest that remains as forest, tonnes of biomass per ha
Vol= Volume of trees in forest, cubic meters per ha
D= average forest density, tonnes per m^3
BEF= biomass conversion and expansion factor for conversion of net annual increase in volume (including bark) to aboveground biomass growth for a forest type, tonnes of aboveground bark growth (m^3 average annual increase).

5.7 Aggregation of activities that include land use change and forest that remains as forest

For forest carbon stock enhancement and degradation activities, some sub-activities were analysed using the land use conversion methodology, and others using the forest that remains as forest methodology. However, to obtain a complete set of information and reference levels for these activities, the sub-activities were combined using the methods described below.

5.7.1 Forest degradation

According to the definitions, there are the following sub-activities are defined under the Degradation activity:

1. A forest that remains as forest and loses carbon stock
2. A native forest converted to a plantation

For each type of sub-activity, different methodologies were used as previously described. To calculate the FREL in tonnes of CO_2e, considering the different methodologies and reference periods, the following equation is used:

$$FREL_{Deg} = \frac{\left(\sum_t \Delta C_{B_{t,DegFF}} + \sum_t \Delta C_{B_{t,DegFNF}}\right) * \frac{44}{12} + \sum_t GEI_{fire}}{p} \quad \text{Eq. 23}$$

Where:

$FREL_{Deg}$ = average annual loss of carbon stocks due to forest degradation during the reference period, in tonnes of C per year

$\Delta C_{B_{t,DegFF}}$ = change in carbon stocks in forest land remaining as forest land in year t of the reference period, in tonnes of C

$\Delta C_{B_{t,DegFNF}}$ = change in carbon stocks in forest land that is converted to plantations in year *t* of the reference period, in tonnes of C

GEI_{fire}= amount of non-CO_2 gas emissions from forest fires, in tonnes of CO_2e

p = years of the reference period

$\frac{44}{12}$ = factor to convert carbon to carbon dioxide equivalent, in tonnes of CO_2e per tonne of C

5.7.2 Enhancement in forest carbon stocks

Under the category of Enhancement, the captures associated with areas that have a land use change from non-forest to forest use were recorded, as well as the captures of forest areas that remain as forest. According to the established definitions, this category includes the following two sub-activities:

1. Non-forest areas converted to native forest
2. Captures in forest areas that remain as forest

In the same way as for the FREL of degradation, the FREL activity data for the enhancement in forest carbon stocks was estimated using differentiated methodologies for forest that remains forest, and for the identification of non-forest areas converted to forests.

$$FRL_A = \frac{(\sum_t \quad \Delta C_{B_{t,ANFF}} + \sum_t \quad \Delta C_{B_{t,AFF}}) * \frac{44}{12}}{p}$$ Eq. 24

Where:
FRL_A = average of annual increases in carbon stocks during the reference period, in tonnes of CO_2e per year
$\Delta C_{B_{t,ANFF}}$ = change in carbon stocks in year t, coming from non-forest land or plantations converted to forest during the reference period, under enhancement activity *(A)*, in tonnes of C
$\Delta C_{B_{t,AFF}}$ = annual change of carbon stocks in forest areas that remain as forest, considering the total area, in tonnes of C per year
p = years of the reference period

6 RESULTS

6.1 Activity data

6.1.1 Land use or sub-use changes[69]

6.1.1.1 Deforestation

Table 19 shows the deforested area in the Los Lagos Region, followed to a lesser extent by the Valparaíso and Araucanía Regions. The Los Ríos and Biobío Regions are next, respectively, in terms of the size of the deforested area.

The deforested area in the Los Lagos Region during the reference period can be associated with the 10,711 hectares of forests that were burned and changed land use after the eruption of the Chaitén volcano in May 2008. In addition, there were significant areas of deforestation as a result of large forest fires that occurred in 2002 in the Biobío and La Araucanía Regions and in 2013 in the Maule Region.

Region	Deforested area (ha yr^{-1})
Coquimbo	74.3
Valparaíso	1,420.9
Metropolitan	221.8
O'Higgins	233.2
Maule	634.4
Ñuble	424.5
Biobío	1,147.2
La Araucanía	1,319.2
Los Ríos	1,280.7
Los Lagos	3,256.5
Aysén	179.7
Magallanes	48.9
Total	***10,241.3***

Table 19. Deforested area by year and region

6.1.1.2 Degradation by substitution

Table 20 shows the area affected by substitution of native forest, which is a sub-activity included in the forest degradation activity, by region and year. The distribution of substitution area by region is closely related to the distribution of forest plantations in the country, with more than 80 percent of the plantations located in the Maule, Biobío and Araucanía Regions.

[69] Spatial information is available at: https://drive.google.com/drive/folders/11xA2Pg9hfDJ6mV-dkUUNPkLKMRC9ripu?usp=drive_link

Region	Substitution area (ha yr^{-1})
Coquimbo	0.0
Valparaíso	14.2
Metropolitan	14.9
O'Higgins	215.5
Maule	1,846.0
Ñuble	771.0
Biobío	1,478.5
La Araucanía	2,731.8
Los Ríos	893.7
Los Lagos	609.4
Aysén	39.9
Magallanes	0.0
Total	***8,614.9***

Table 20. Area of degradation by substitution by year and region

6.1.1.3 Restitution and increase in forest area

Table 21 presents data for forest restitution and the increase in forest area, which are both sub-activities of the enhancement in forest carbon stock activity, in terms of area (hectares) per year. The restitution of native forest in forested areas with plantations is of great importance in the Biobío Region during the period. The restitution areas in the Maule and La Araucanía Regions are also considerable, although to a lesser extent. The increase in land use from non-forest to forest is very significant in the Maule Region, followed by Araucanía and Los Ríos Regions.

Region	Forest restitution (ha yr^{-1})	Increase in forest area (ha yr^{-1})	Total area (ha yr^{-1})
Coquimbo	-	0.9	0.9
Valparaíso	1.6	24.2	25.8
Metropolitan	-	68.2	68.2
O'Higgins	-	7.9	7.9
Maule	535.9	5,703.4	6,239.3
Ñuble	205.7	340.4	546.1
Biobío	927.7	867.0	1,794.7
La Araucanía	360.7	2,184.4	2,545.0
Los Ríos	292.3	1,175.5	1,467.7
Los Lagos	25.5	903.9	929.4
Aysén	-	5.3	5.3
Magallanes	-	-	0.0
Total	***2,349.3***	***11,281.2***	***13,630.4***

Table 21. Annual area of forest restitution and increase of native forest area in the reference period, by region

The following map shows the distribution of activities and sub-activities corresponding to those related to use and sub-use changes.

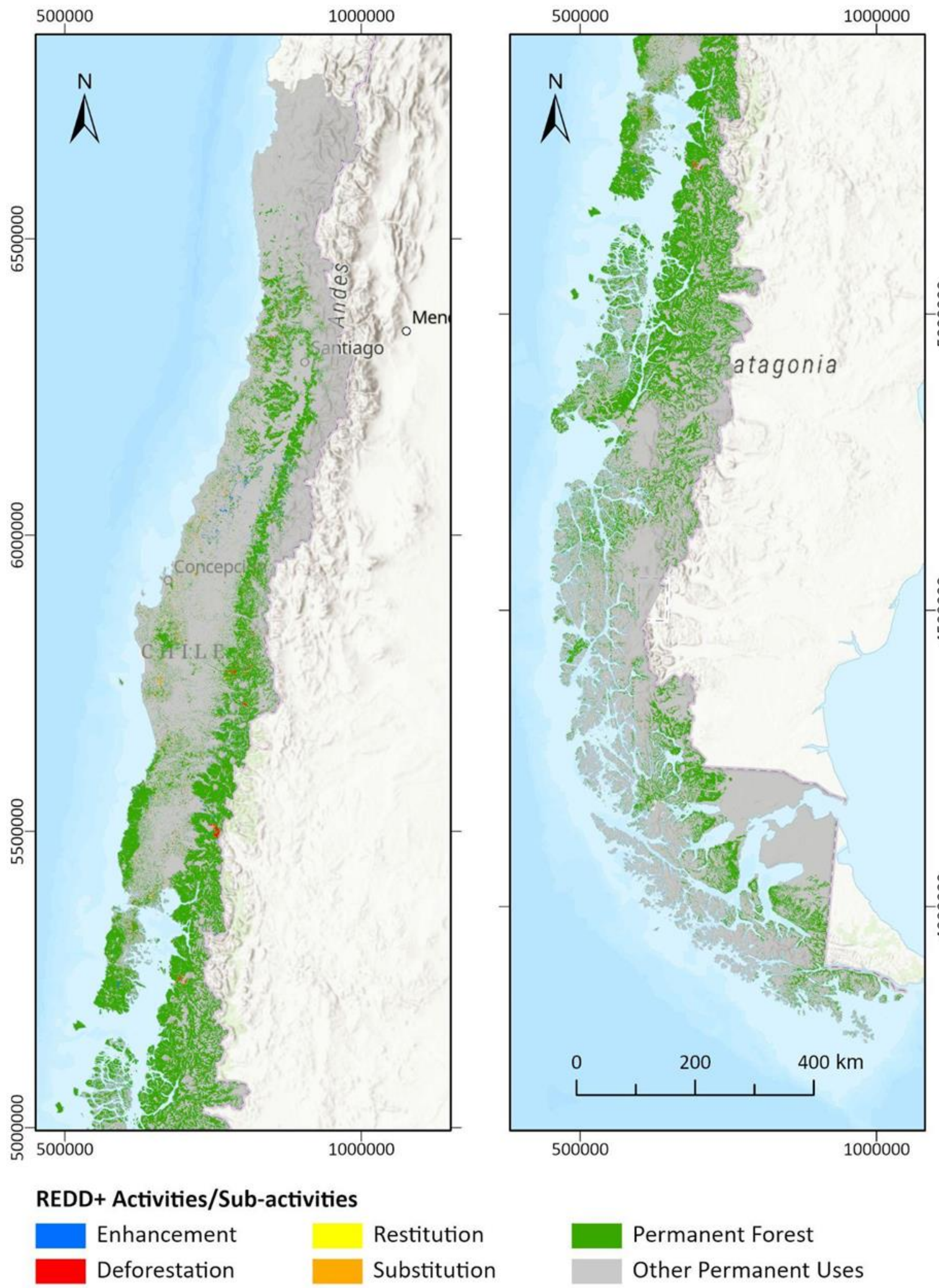

Figure 12. Map of REDD+ activities and sub-activities

6.1.2 Activities in forest remaining forest

6.1.2.1 Degradation in permanent forest[70]

Table 22 shows the information on the degraded area (in hectares) by region during the period 2001-2010. Among the results, the area of degradation in the extreme southern regions of Aysén and Magallanes stand out, which can be associated with the lack of adequate forest management in these forests. Next is the Los Lagos Region, which is related to the high level of intervention in the forests of Chiloé province, as well as the eruption of the Chaitén volcano, which had a significant impact in this region during the reference period. Finally, the regions from Valparaíso to Maule, and even the Metropolitan Region, are characterized by high pressure on the use of forest resources.

Region	Area (ha)
Coquimbo	21,322.0
Valparaíso	117,454.0
Metropolitan	82,629.0
O'Higgins	111,745.0
Maule	121,155.0
Ñuble	44,461.0
Biobío	71,956.0
La Araucanía	88,607.0
Los Ríos	38,736.0
Los Lagos	133,165.0
Aysén	241,846.0
Magallanes	217,134.0
Total	***1,290,210.0***

Table 22. Area of degradation in permanent forest, by region, between 2001 and 2010

6.1.2.2 Recovery of degraded forests

Table 23 shows the recovery of degraded forests in terms of the area of permanent forest that has generated an enhancement in forest carbon stocks. The Los Lagos, Maule and Valparaíso Regions show the largest areas in this regard.

[70] Spatial information available at: https://drive.google.com/drive/folders/1xilbilNPK8zd_bl-K8J20SqW07tHVtNy?usp=share_link

Region	Area (ha)
Coquimbo	22,762.0
Valparaíso	142,807.0
Metropolitan	104,367.0
O'Higgins	137,382.0
Maule	148,484.0
Ñuble	50,423.0
Biobío	103,520.0
La Araucanía	116,122.0
Los Ríos	60,883.0
Los Lagos	156,055.0
Aysén	71,062.0
Magallanes	75,122.0
Total	***1,188,989.0***

Table 23. Area of enhancement in carbon stocks in permanent forest, by region, between 2001 and 2010

6.1.2.3 Forest conservation

Forest conservation considers the net flux of carbon between areas that are degrading and those that are recovering. Table 24 shows the total degraded and recovered area within the conservation areas.

Region	Total area (ha)	Degraded area (ha)	Recovered area (ha)
Coquimbo	93.0	54.0	39.0
Valparaíso	7,837.0	3,056.0	4,781.0
Metropolitan	10,502.0	4,896.0	5,606.0
O'Higgins	7,602.0	3,455.0	4,147.0
Maule	5,267.0	2,357.0	2,910.0
Ñuble	12,615.0	6,541.0	6,074.0
Biobío	20,489.0	9,147.0	11,342.0
La Araucanía	35,164.0	17,876.0	17,288.0
Los Ríos	29,213.0	11,832.0	17,381.0
Los Lagos	102,411.0	56,125.0	46,286.0
Aysén	459,898.0	333,543.0	126,355.0
Magallanes	414,082.0	335,503.0	78,579.0
Total	***1,105,173.0***	***784,385.0***	***320,788.0***

Table 24. Total degraded and recovered area in forests of conservation areas, by region, between 2001 and 2010

6.1.2.4 Non-CO_2 emissions from forest fires

Non-CO_2 emissions from forest fires are determined by the area of fires in each region. Table 25 shows the area by region for the reference period 2001-2010. It should be noted that, in the summer of 2002, the occurrence of large fires caused by lightning affected Nature Reserves, National Parks and private lands with Araucaria and *Nothofagus* forests in the Araucanía Region (González *et al.*, 2010),[71] and also affected the Biobío Region. Among the fires in 2002, the fire in the Malleco National Reserve burned 14,536 hectares over a period of 74 days.[72] Figure 13 shows the areas affected by forest degradation.

Region	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha
Coquimbo	9.1	101.0	148.6	139.1	180.9	3.2	40.3	9.7	15.6	41.0
Valparaíso	310.7	447.6	1,680.3	2,565.2	2,565.5	362.4	441.4	650.2	652.8	2,470.1
Metropolitan	106.5	68.0	1,193.5	1,270.5	651.4	184.4	63.9	29.4	2,771.2	2,166.6
O'Higgins	58.0	549.1	780.1	851.9	1,715.6	746.6	730.9	2,192.9	576.8	2,944.8
Maule	25.5	147.2	504.4	170.8	140.0	62.4	9.4	344.1	3,998.7	431.9
Ñuble	20.0	117.1	128.9	14.7	277.9	89.7	199.4	86.7	59.4	398.6
Biobío	69.4	7443.2	30.3	196.5	117.8	57.4	747.4	143.7	898.3	581.2
Araucanía	63.6	18,764.6	225.9	268.4	71.7	73.2	39.3	307.2	725.7	41.8
Los Ríos	0.9	904.1	2.9	175.2	18.7	6.9	4.8	118.8	270.6	0.8
Los Lagos	9.4	2551.9	27.5	90.9	47.3	207.4	52.2	4,233.9	598.1	0.6
Aysén	10.3	153.3	14.0	212.4	76.7	387.3	9.5	187.0	64.9	2.5
Magallanes	4.6	33.9	10.1	1.9	2,255.7	29.5	5.9	33.0	0.0	0.1
Total	***687.7***	***3,1280.7***	***4,746.4***	***5,957.6***	***8,119.1***	***2,210.2***	***2,344.4***	***8,336.7***	***10,632.1***	***9,079.8***

Table 25. Burned area affected by forest fires, by region, between 2001 and 2010

[71] http://revista.bosquenativo.cl/volumenes/46/indice.htm
[72] http://www.lignum.cl/2015/02/17/grandes-e-historicos-incendios-forestales-que-debes-conocer/

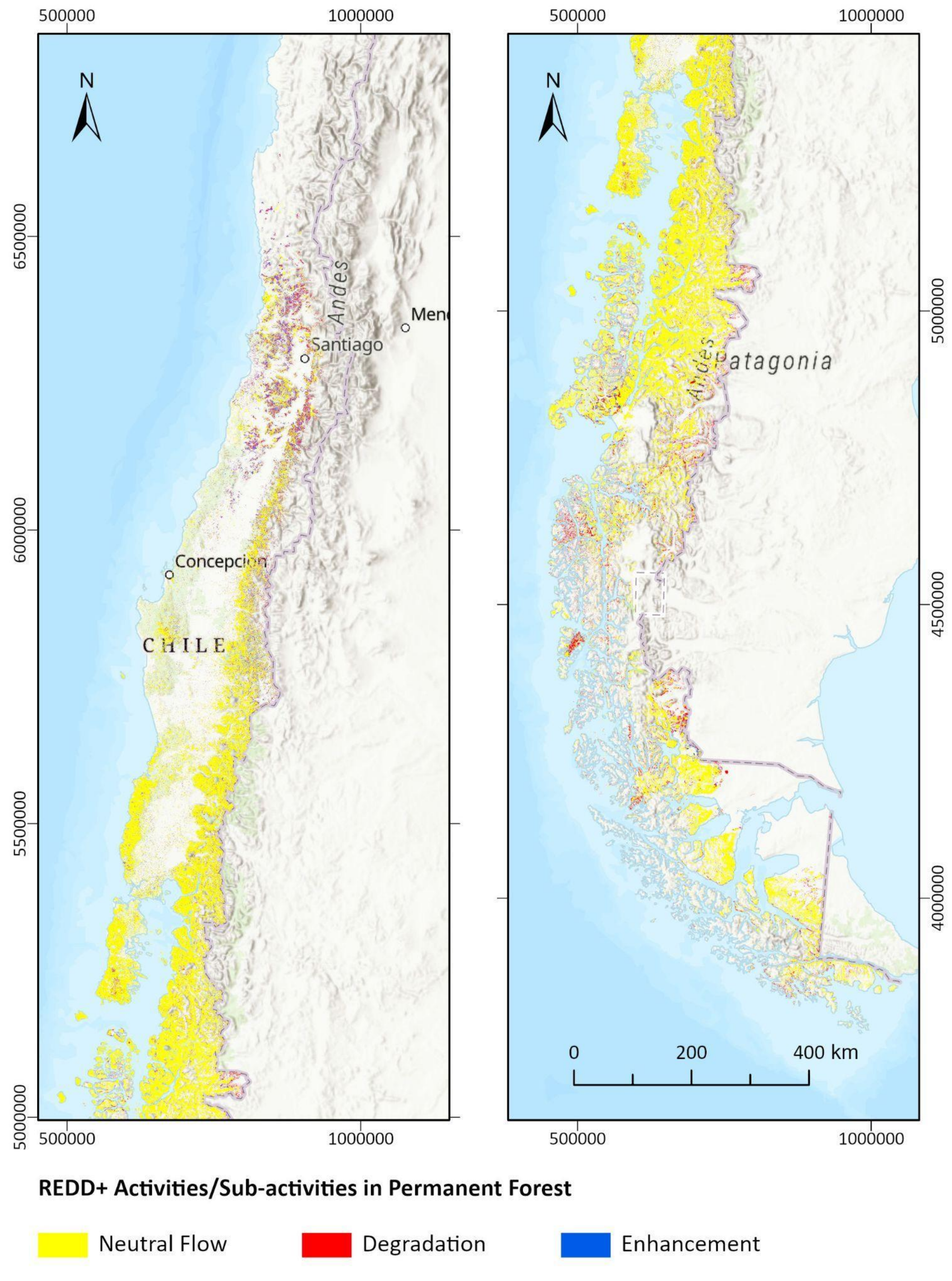

Figure 13. Map of REDD+ activities and sub-activities in permanent forest

6.2 Emission factors

6.2.1 Land use or sub-use changes

6.2.1.1 Deforestation and degradation by substitution

The EFs used in this update of the FREL of deforestation and degradation by substitution are at the forest type level and were obtained based on a combination of data from different Levels. For aboveground biomass, *Tier* 2 EFs from the aboveground biomass estimation of the Continuous Forest Inventory were used, which presents different carbon stocks by forest type in line with the INGEI. Depending on the structure and the forest type, an equal biomass stock was assumed for mature and stunted growth, and for young/mature-young growth. This assumption was used for those forest types that have separate data available for young and mature trees, and for those that do not have it the value of the forest type was assumed for all structure class.

The belowground biomass is the result of applying the root-stem relationship to the aboveground biomass (Gayoso, 2002).[73] For the DOM, regional *Tier* 2 EFs from the 2020 INGEI were used, which were also based on the Continuous Forest Inventory. Table 26 shows the EF used for the FREL of deforestation and degradation by substitution, by forest type and carbon pool.

Forest type	Structure class	Dry aboveground biomass t/ha	Dry belowground biomass t/ha	Dry necromass tC/ha
Alerce	Mature	339.11	97.29	121.40
Alerce	Young	203.59	58.41	121.40
Alerce	Mature/Young	203.59	58.41	121.40
Alerce	Stunted	339.11	97.29	121.40
Ciprés de las Guaitecas	Mature	198.03	56.81	62.11
Ciprés de las Guaitecas	Young	198.03	56.81	62.11
Ciprés de las Guaitecas	Mature/ Young	198.03	56.81	62.11
Ciprés de las Guaitecas	Stunted	198.03	56.81	62.11
Araucaria	Mature	421.40	120.90	133.40
Araucaria	Young	219.13	62.87	133.40
Araucaria	Mature/ Young	219.13	62.87	133.40
Araucaria	Stunted	421.40	120.90	133.40
Ciprés de la Cordillera	Mature	124.02	35.58	62.11
Ciprés de la Cordillera	Young	124.02	35.58	62.11
Ciprés de la Cordillera	Mature/Young	124.02	35.58	62.11
Ciprés de la Cordillera	Stunted	124.02	35.58	62.11
Palma Chilena	Mature	21.31	6.11	38.24

[73] Belowground biomass stocks have already been calculated for grasslands, scrub, arborescent scrub, and succulent formations by Gayoso (2006). However, this article also applied a root/stem ratio to identify those estimated aboveground values.

Forest type	Structure class	Dry aboveground biomass t/ha	Dry belowground biomass t/ha	Dry necromass tC/ha
Palma Chilena	Young	21.31	6.11	38.24
Palma Chilena	Mature/Young	21.31	6.11	38.24
Palma Chilena	Stunted	21.31	6.11	38.24
Lenga	Mature	198.46	56.94	43.40
Lenga	Young	237.24	68.06	43.40
Lenga	Mature/Young	237.24	68.06	43.40
Lenga	Stunted	198.46	56.94	43.40
Coihue de Magallanes	Mature	129.15	37.05	140.10
Coihue de Magallanes	Young	129.15	37.05	140.10
Coihue de Magallanes	Mature/Young	129.15	37.05	140.10
Coihue de Magallanes	Stunted	129.15	37.05	140.10
Roble - Hualo	Mature	114.93	32.97	62.11
Roble - Hualo	Young	114.93	32.97	62.11
Roble - Hualo	Mature/Young	114.93	32.97	62.11
Roble - Hualo	Stunted	114.93	32.97	62.11
Roble - Raulí - Coihue	Mature	178.57	51.23	52.90
Roble - Raulí - Coihue	Young	152.77	43.83	52.90
Roble - Raulí - Coihue	Mature/Young	152.77	43.83	52.90
Roble - Raulí - Coihue	Stunted	178.57	51.23	52.90
Coihue - Raulí - Tepa	Mature	377.03	108.17	74.40
Coihue - Raulí - Tepa	Young	377.03	108.17	74.40
Coihue - Raulí - Tepa	Mature/Young	377.03	108.17	74.40
Coihue - Raulí - Tepa	Stunted	377.03	108.17	74.40
Esclerófilo	Mature	18.57	5.33	16.70
Esclerófilo	Young	18.57	5.33	16.70
Esclerófilo	Mature/Young	18.57	5.33	16.70
Esclerófilo	Stunted	18.57	5.33	16.70
Siempreverde	Mature	361.64	103.76	64.80
Siempreverde	Young	127.28	36.52	64.80
Siempreverde	Mature/Young	127.28	36.52	64.80
Siempreverde	Stunted	361.64	103.76	64.80

Table 26. Emission factors considered in the analysis

The biomass values for land use after deforestation used in the calculation are as follows:

Land use	Sub-use	Dry biomass t/ha (aboveground)	Dry biomass t/ha (belowground)	Source
Urban and industrial areas		2	0	INGEI 2020 (MMA, 2021).
Agricultural land		10	2	INGEI 2020 (MMA, 2021).
Grasslands and scrublands	Grasslands	4.73	8.13	Gayoso (2006)
Grasslands and scrublands	Scrub-grassland	9.04	14.99	Gayoso (2006)
Grasslands and scrublands	Scrub	9.04	14.99	Gayoso (2006)
Grasslands and scrublands	Arborescent scrub	21.78	35.25	Gayoso (2006)
Grasslands and scrublands	Scrubland with succulents	9.04	14.99	Gayoso (2006)
Grasslands and scrublands	Formation of succulents	4.73	8.13	Assumption, equal to grasslands
Grasslands and scrublands	Scrub plantation	9.04	14.99	Gayoso (2006)
Forest	Plantation	0	0	National panel of experts
Wetlands		0	0	Assumption
Areas without vegetation		0	0	Assumption
Snow and glaciers		0	0	Assumption
Water courses		0	0	Assumption

Table 27. Emission factors in other use categories

6.2.1.2 Forest restitution and increase in forest areas

The *Tier* 2 EFs for the different types of forests were derived from those in INGEI 2020, which in turn, except for Araucaria forests, were obtained from data in the Continuous Forest Inventory (see Table 28). In the INGEI, average annual growth values per diameter category were applied for second-growth forests, and a general increase value per forest type for managed forests.

Annual growth rates for young forests were also applied to young-mature forests. Growth rates for mature forests were also applied to stunted forests, since they are assumed to have reached maturity and are likely to have slower growth than young and/or secondary forests.

The average net growth was calculated for mixed forests in each region, taking the average net growth of all these types of forests found in that region, as identified by the Cadastre.

Type of forest	Structure Class	Average annual growth (m3/ha year)
Alerce	Mature	0.5
Alerce	Young	0.5
Alerce	Mature/Young	0.5
Alerce	Stunted	0.5
Ciprés de las Guaitecas	Mature	3.9
Ciprés de las Guaitecas	Young	3.9
Ciprés de las Guaitecas	Mature/Young	3.9
Ciprés de las Guaitecas	Stunted	3.9
Araucaria	Mature	4.6
Araucaria	Young	4.6
Araucaria	Mature/Young	4.6
Araucaria	Stunted	4.6
Ciprés de la Cordillera	Mature	5
Ciprés de la Cordillera	Young	2.7
Ciprés de la Cordillera	Mature/Young	2.7
Ciprés de la Cordillera	Stunted	5
Palma Chilena	Mature	
Palma Chilena	Young	
Palma Chilena	Mature/Young	
Palma Chilena	Stunted	
Lenga	Mature	5.8
Lenga	Young	3.9
Lenga	Mature/Young	3.9
Lenga	Stunted	5.8
Coihue de Magallanes	Mature	2.6
Coihue de Magallanes	Young	3.7
Coihue de Magallanes	Mature/Young	3.7
Coihue de Magallanes	Stunted	2.6
Roble - Hualo	Mature	5.1
Roble - Hualo	Young	3.5
Roble - Hualo	Mature/Young	3.5
Roble - Hualo	Stunted	5.1
Roble - Raulí - Coihue	Mature	6.6
Roble - Raulí - Coihue	Young	4.1
Roble - Raulí - Coihue	Mature/Young	4.1
Roble - Raulí - Coihue	Stunted	6.6
Coihue - Raulí - Tepa	Mature	5.8
Coihue - Raulí - Tepa	Young	4.9
Coihue - Raulí - Tepa	Mature/Young	4.9
Coihue - Raulí - Tepa	Stunted	5.8
Esclerófilo	Mature	1.5

Type of forest	Structure Class	Average annual growth (m3/ha year)
Esclerófilo	Young	1.6
Esclerófilo	Mature/Young	1.6
Esclerófilo	Stunted	1.5
Siempreverde	Mature	6
Siempreverde	Young	4.1
Siempreverde	Mature/Young	4.1
Siempreverde	Stunted	6

Table 28. Average annual growth by forest type and structure class. Source: INGEI 2020 (MMA, 2021)

Sub-use	Region	Average annual growth (m3/ha año)	Period
Mixed forest	Maule	2.06	NR
Mixed forest	Biobío	3.71	NR
Mixed forest	Araucanía	4.19	NR
Mixed forest	Los Ríos	4.14	NR
Mixed forest	Los Lagos	4.17	NR
Mixed forest	Ñuble	2.77	NR
Mixed forest	Maule	4.24	RP1
Mixed forest	Biobío	3.97	RP1
Mixed forest	Araucanía	4.10	RP1
Mixed forest	Los Ríos	4.17	RP1
Mixed forest	Los Lagos	4.89	RP1
Mixed forest	Ñuble	2.44	RP1
Mixed forest	Coquimbo	1.60	NR
Mixed forest	Valparaíso	1.60	NR
Mixed forest	Metropolitan	1.60	NR
Mixed forest	O'Higgins	1.60	NR
Mixed forest	Aysén	5.80	NR
Mixed forest	Magallanes		NR

Table 29. Average annual growth in Mixed Forest area by region. Source: Own elaboration based on INGEI 2020

6.2.2 Activities in Forest Remaining Forest

For these values, the volume and then the carbon stocks were estimated for each pixel in the 2001 and 2010 images. These stocks are converted to EF using a stock-difference approach to determine the specific carbon emissions for each pixel that: 1) experienced a loss or gain in carbon stock between 2001 to 2010; and 2) was in a state of degrading or increasing stock or at risk of degradation in 2010,[74] as determined by the native forest types stock table. This analysis was carried out only in the forest areas that remained as forests, as explained in the estimation of activity data.

The EF for the biomass available for combustion are the same as those described as the EF of the Deforestation FREL. The combustion, emissions and conversion factors used are IPCC (2006) default factors, as shown in Table 30.

GHG	Conversion factor to CO_2e	Combustion factor	Emissions factor
CH_4	28	0.45	4.70
N_2O	265	0.45	0.26

Table 30. Emissions, combustion, and conversion factors for non-CO_2 emissions

[74] Database available at: https://drive.google.com/drive/u/1/folders/12daGSd6JiLGtmXJD9w2vZtTC51DDW8iO

7 NATIONAL FREF/FRL OF CHILE

7.1 Deforestation[75]

Total annual average emissions from deforestation in the expanded FREL amount to about 5.40 million tCO_2e (see Table 31).

FREL Deforestation				
Region	Deforested area (ha yr^{-1})	Living biomass (tCO_2e yr^{-1})	Necromass (tCO_2e yr^{-1})	Total (tCO_2e yr^{-1})
Coquimbo	74.3	1,871.76	4,546.85	6,418.61
Valparaíso	1,420.9	-28,703.23	90,643.15	61,939.92
Metropolitan	221.8	5,698.33	13,591.90	19,290.23
O'Higgins	233.2	4,292.93	14,352.09	18,645.02
Maule	634.4	60,556.28	75,520.70	136,076.98
Ñuble	424.5	140,044.35	76,294.50	216,338.85
Biobío	1,147.2	534,954.07	222,581.32	757,535.39
La Araucanía	1,319.2	681,339.04	361,675.68	1,043,014.72
Los Ríos	1,280.7	517,416.76	249,248.42	766,665.18
Los Lagos	3,256.5	1,479,362.58	741,733.49	2,221,096.08
Aysén	179.7	76,802.35	41,395.81	118,198.16
Magallanes	48.9	24,072.43	9,600.59	33,673.02
Total	***10,241.3***	***3,497,707.66***	***1,901,184.51***	***5,398,892.18***

Table 31. Total emissions from deforestation in the Chilean national FREL area

7.2 Forest degradation

The calculations of the emissions produced in the forests that remain forests, the substitution of Native Forest by Forest Plantation, in addition to the non-CO_2 GHG emissions produced by forest fires, are considered independently. All the different sources are added to integrate the FREL of forest degradation, equivalent to 24,55 million tCO_2e yr^{-1} (see Table 32).

[75] The tool used to estimate emissions from deforestation is available at: https://drive.google.com/drive/folders/13uQuujlCtorgKnW9DbdS-nL-pwf_i_xK?usp=drive_link

FREL Degradation (tCO_2e yr^{-1})				
Region	**CO_2**	**CH_4**	**N_2O**	**Total**
Coquimbo	110,156.60	235.15	155.06	110,546.81
Valparaíso	769,361.58	3,671.60	2,421.07	775,454.25
Metropolitan	576,058.33	2,801.27	1,847.17	580,706.77
O'Higgins	965,758.33	3,974.14	2,620.56	972,353.03
Maule	2,270,426.15	4,101.21	2,704.35	2,277,231.71
Ñuble	1,096,988.60	2,002.36	1,320.36	1,100,311.32
Biobío	2,257,688.15	14,790.91	9,753.19	2,282,232.26
La Araucanía	3,596,209.98	45,470.04	29,983.14	3,671,663.16
Los Ríos	1,584,117.08	3,634.57	2,397.65	1,590,148.30
Los Lagos	3,925,398.18	16,016.66	10,561.45	3,951,976.29
Aysén	3,758,357.59	2,355.14	1,552.99	3,762,265.71
Magallanes	3,466,160.10	4,792.60	3,160.26	3,474,112.96
Total	***24,376,680.67***	***103,845.65***	***68,476.25***	***24,549,002.58***

Table 32. FREL of forest degradation

The emissions from forest degradation are detailed below based on the different methodologies and information sources used for their estimation:

7.2.1 Degradation by substitution[76]

Total annual average emissions from native forests converted into plantations and arborescent scrub are approximately 4,2 million tCO_2e, as shown in Table 33, with a greater contribution from the Biobío and La Araucanía Regions, where there is a greater presence of exotic plantations.

[76] The tool used to estimate emissions from degradation by substitution is available at: https://drive.google.com/drive/folders/13y3nRy8y7-tvhfhJeQkXjKrx85TJB_y_?usp=drive_link

FREL Degradation by substitution				
Region	Substituted forest area (ha yr^{-1})	Living biomass emissions (ha yr^{-1})	Necromass emissions (tCO_2e yr^{-1})	Total emissions (tCO_2e yr^{-1})
Coquimbo	0.0	0.00	0.00	0.00
Valparaíso	14.2	593.40	866.58	1,459.98
Metropolitan	14.9	612.03	909.90	1,521.93
O'Higgins	215.5	8,878.47	13,195.06	22,073.53
Maule	1,846.0	262,574.95	217,612.60	480,187.55
Ñuble	771.0	188,683.48	116,282.52	304,966.00
Biobío	1,478.5	544,396.03	268,682.22	813,078.25
La Araucanía	2,731.8	1,091,966.49	596,789.19	1,688,755.68
Los Ríos	893.7	351,955.13	192,219.75	544,174.88
Los Lagos	609.4	230,071.66	124,951.53	355,023.19
Aysén	39.9	17,570.60	6,352.69	23,923.29
Magallanes	0.0	0.00	0.00	0.00
Total	***8,614.9***	***2,697,302.24***	***1,537,862.04***	***4,235,164.28***

Table 33. Emissions due to the conversion of native forests into exotic plantations in the national FREL/FRL area of Chile

7.2.2 Degradation of permanent forest[77]

Total annual average emissions from native forests that remain native forests (for example, from fuelwood collection, selective logging, etc.) are approximately 20.14 million tCO_2e, as shown in Table 34.

Region	Area (ha)	Emissions (tCO_2e yr^{-1})
Coquimbo	21,322.0	110,156.60
Valparaíso	117,454.0	767,901.60
Metropolitan	82,629.0	574,536.40
O'Higgins	111,745.0	943,684.80
Maule	121,155.0	1,790,238.60
Ñuble	44,461.0	792,022.60
Biobío	71,956.0	1,444,609.90
Araucanía	88,607.0	1,907,454.30
Los Ríos	38,736.0	1,039,942.20
Los Lagos	133,165.0	3,570,375.00
Aysén	241,846.0	3,734,434.30
Magallanes	217,134.0	3,466,160.10
Total	***1,290,210.0***	***20,141,516.40***

Table 34. Annual emissions from native forests that remain native forests by region

[77] The tool used to estimate emissions and removals in permanent forest is available at: https://drive.google.com/drive/folders/13NlJghgJOaTVJuXf5n-vQ99LoTEnUrZg?usp=drive_link

7.2.3 Non-CO_2 emissions from forest fires[78]

The total annual average emissions of non- CO_2 gases from forest fires are approximately 0.17 million t CO_2e, as shown in Table 35. This figure is relatively small because it only considers emissions of methane (CH_4) and nitrous oxide (N_2O), since CO_2 emissions from fires are accounted for in the category of degradation of forests that remain as forests in the section above.

Region	Affected area (ha yr^{-1})	Emissions (tCO_2e yr^{-1})
Coquimbo	68.8	390.21
Valparaíso	1,214.6	6,092.67
Metropolitan	850.5	4,648.43
O'Higgins	1,114.7	6,594.70
Maule	583.4	6,805.56
Ñuble	139.2	3,322.72
Biobío	1,028.5	24,544.11
La Araucanía	2,058.1	75,453.18
Los Ríos	150.4	6,031.22
Los Lagos	781.9	26,578.11
Aysén	111.8	3,908.13
Magallanes	237.5	7,952.86
Total	***8,339.5***	***172,321.91***

Table 35. Non-CO_2 gas emissions by region

The annual distribution of the forest fire data (see Table 36) makes it possible to identify the impact produced in 2002, excluding the rest of the years in the reference period.

Year	Area affected (ha)	Emissions (tCO_2e)
2001	687.7	8,163.73
2002	31,280.6	1,005,992.27
2003	4,746.4	40,250.98
2004	5,957.6	60,121.38
2005	8,119.1	121,887.82
2006	2,210.2	36,034.03
2007	2,344.4	33,756.76
2008	8,336.7	193,554.70
2009	10,632.1	151,478.43
2010	9,079.8	71,978.96
Annual average	**8,339.5**	**172,321.91**

Table 36. Emissions of non-CO_2 gases by year

[78]The tool used to estimate emissions from forest fires is available at: https://drive.google.com/drive/folders/13K95VE5F82COTpmKyRHSaRhTpukkLXEu?usp=drive_link

7.3 Enhancement in forest carbon stocks

The calculations of removals produced in the forests that remain forests are considered independently from those derived from land use changes (from other lands to forests), which includes the transformation from forest plantation to native forest. The different sources are added to the FRL to calculate the enhancement in forest carbon stocks, which is equivalent to 20.17 million $tCO_2e\ yr^{-1}$ (see Table 37).

Region	Other lands to forests $tCO_2e\ yr^{-1}$	Forests that remain forests $tCO_2e\ yr^{-1}$	Total $tCO_2e\ yr^{-1}$
Coquimbo	-5.27	-160,455.30	-160,460.57
Valparaíso	-521.09	-1,075,124.00	-1,075,645.09
Metropolitan	-1,434.92	-806,625.30	-808,060.22
O'Higgins	-150.52	-1,240,135.70	-1,240,286.22
Maule	-166,662.48	-2,326,485.00	-2,493,147.48
Ñuble	-19,772.76	-902,966.30	-922,739.06
Biobío	-87,074.35	-2,257,979.40	-2,345,053.75
Araucanía	-135,324.66	-2,569,014.70	-2,704,339.36
Los Ríos	-81,410.89	-1,724,496.80	-1,805,907.69
Los Lagos	-52,199.79	-4,187,451.70	-4,239,651.49
Aysén	-418.00	-1,173,189.20	-1,173,607.20
Magallanes	0.00	-1,197,979.90	-1,197,979.90
Total	***-544,974.73***	***-19,621,903.30***	***-20,166,878.03***

Table 37. Removals due to enhancement in carbon stocks in the area of the expanded FRL of Chile

The removals due to the enhancement in forest carbon stocks are detailed below, based on the different methodologies and sources of information used for their estimation:

7.3.1 Restitution and increase of forest area[79]

The total annual average removals due to the enhancement in carbon stocks caused by other lands being converted to forests and the transformation from forest plantation to native forest are approximately 544,975 tCO_2 (see Table 38).

[79] The tool used to estimate removals by restitution is available at: https://drive.google.com/drive/folders/13y3W9XJ2reU-haP4s4DsEQdkypX4l0xt?usp=drive_link

Region	Area of increase (ha yr^{-1})	$tCO_2e\ yr^{-1}$
Coquimbo	0.9	-5.27
Valparaíso	25.8	-521.09
Metropolitan	68.2	-1,434.92
O'Higgins	7.9	-150.52
Maule	6,239.3	-166,662.48
Ñuble	546.1	-19,772.76
Biobío	1,794.7	-87,074.35
Araucanía	2,545.0	-135,324.66
Los Ríos	1,467.7	-81,410.89
Los Lagos	929.4	-52,199.79
Aysén	5.3	-418.00
Magallanes	-	-
Total	***13,630.4***	***544,974.72***

Table 38. Removals due to conversion of non-forest land to forest land

7.3.2 Recovery of degraded forests[80]

The total annual average removal due to the enhancement in carbon stocks in forests that remain forests is approximately 19.62 million tCO_2e, the majority being generated by the Los Lagos and Los Ríos Regions (see Table 39).

Region	Area (ha)	Removals ($tCO_2e\ yr^{-1}$)
Coquimbo	22,762.0	-160,455.30
Valparaíso	142,807.0	-1,075,124.00
Metropolitan	104,367.0	-806,625.30
O'Higgins	137,382.0	-1,240,135.70
Maule	148,484.0	-2,326,485.00
Ñuble	50,423.0	-902,966.30
Biobío	103,520.0	-2,257,979.40
Araucanía	116,122.0	-2,569,014.70
Los Ríos	60,883.0	-1,724,496.80
Los Lagos	156,055.0	-4,187,451.70
Aysén	71,062.0	-1,173,189.20
Magallanes	75,122.0	-1,197,979.90
Total	***1,188,989.0***	***-19,621,903.30***

Table 39. Carbon removals by forests that remain forests in the national FRL area

[80] The estimation of carbon removals in permanent forest is included at: https://drive.google.com/drive/folders/13NlJghgJOaTVJuXf5n-vQ99LoTEnUrZg?usp=drive_link

7.4 Forest conservation[81]

The FREL/FRL for conservation of carbon stocks consisting of the net flux of removals and emissions produced in conservation areas corresponds to approximately 8.27 million tCO_2e of annual emissions (see Table 40). The highest annual emissions occur in the Aysén and Magallanes Regions.

Region	Area in degradation (ha)	Emissions due to degradation ($tCO_2e\ yr^{-1}$)	Increased area (ha)	Captures due to increased area ($tCO_2e\ yr^{-1}$)	Carbon Fluxes ($tCO_2e\ yr^{-1}$)
Coquimbo	54.0	534.00	39.0	-275.90	258.10
Valparaíso	3,056.0	20,831.10	4,781.0	-36,969.60	-16,138.50
Metropolitan	4,896.0	36,895.80	5,606.0	-45,840.00	-8,944.20
O'Higgins	3,455.0	35,672.20	4,147.0	-45,701.40	-10,029.20
Maule	2,357.0	36,500.20	2,910.0	-52,061.20	-15,561.00
Ñuble	6,541.0	121,690.90	6,074.0	-101,689.10	20,001.80
Biobío	9,147.0	169,695.60	11,342.0	-225,862.60	-56,167.00
La Araucanía	17,876.0	391,991.80	17,288.0	-354,093.80	37,898.00
Los Ríos	11,832.0	301,744.40	17,381.0	-477,154.10	-175,409.70
Los Lagos	56,125.0	1,547,989.90	46,286.0	-1,228,264.80	319,725.10
Aysén	333,543.0	5,623,327.30	126,355.0	-1,955,515.60	3,667,811.70
Magallanes	335,503.0	5,623,365.00	78,579.0	-1,115,469.70	4,507,895.90
Total	***784,385.0***	***13,910,238.20***	***320,788.0***	***-5,638,897.80***	***8,271,340.00***

Table 40. Net forest carbon fluxes in Conservation areas, by region

Total annual average emissions occurring within conservation areas in forests that remain as forests is approximately 13.91 million tCO_2e (see Table 41).

[81] The estimate of the Forest Conservation Reference Level is included at: https://drive.google.com/drive/folders/13NlJghgJOaTVJuXf5n-vQ99LoTEnUrZg?usp=share_link

Region	Total area (ha)	Emissions ($tCO_2e\ yr^{-1}$)
Coquimbo	54.0	534.00
Valparaíso	3,056.0	20,831.10
Metropolitan	4,896.0	36,895.80
O'Higgins	3,455.0	35,672.20
Maule	2,357.0	36,500.20
Ñuble	6,541.0	121,690.90
Biobío	9,147.0	169,695.60
La Araucanía	17,876.0	391,991.80
Los Ríos	11,832.0	301,744.40
Los Lagos	56,125.0	1,547,989.90
Aysén	333,543.0	5,623,327.30
Magallanes	335,503.0	5,623,365.00
Total	***784,385.0***	***13,910,238.20***

Table 41. Forest emissions within conservation areas by region.

The amount of annual GHG removals that occurs within these conservation areas is close to 5.64 million tCO_2e (see Table 42). The largest removals are generated in the southernmost regions (Los Lagos, Aysén and Magallanes).

Region	Total area (ha)	Removals ($tCO2e\ yr^{-1}$)
Coquimbo	39.0	-275.90
Valparaíso	4,781.0	-36,969.60
Metropolitan	5,606.0	-45,840.00
O'Higgins	4,147.0	-45,701.40
Maule	2,910.0	-52,061.20
Ñuble	6,074.0	-101,689.10
Biobío	11,342.0	-225,862.60
La Araucanía	17,288.0	-354,093.80
Los Ríos	17,381.0	-477,154.10
Los Lagos	46,286.0	-1,228,264.80
Aysén	126,355.0	-1,955,515.60
Magallanes	78,579.0	-1,115,469.70
Total	***320,788.0***	***-5,638,897.80***

Table 42. Forest carbon removals within conservation areas, by region.

7.5 National FREL/FRL of native forest in Chile[82]

In accordance with the above, Chile presents this national FREL/FRL proposal for four REDD+ activities with annual average emissions of 5.40 million tCO_2e due to deforestation; 24,55 million tCO_2e due to degradation and annual removals of 20.17 million tCO_2e due to carbon stock enhancement and 8.27 million tCO_2e of emissions due to conservation, as shown in Table 43.

FREL/FRL ($tCO_2eq\ yr^{-1}$)					
REDD+ activity	**Deforestation**	**Degradation**	**Carbon stock Enhancement**	**Conservation**	**Total**
Coquimbo	6,418.61	110,546.81	-160,460.57	258.10	-43.237.04
Valparaíso	61,939.92	775,454.25	-1,075,645.09	-16,138.50	-254.389.41
Metropolitan	19,290.23	580,706.77	-808,060.22	-8,944.20	-217.007.42
O'Higgins	18,645.02	972,353.03	-1,240,286.22	-10,029.20	-259.317.37
Maule	136,076.98	2,277,231.71	-2,493,147.48	-15,561.00	-95.399.79
Ñuble	216,338.85	1,100,311.32	-922,739.06	20,001.80	413.912.92
Biobío	757,535.39	2,282,232.26	-2,345,053.75	-56,167.00	638.546.90
La Araucanía	1,043,014.72	3,671,663.16	-2,704,339.36	37,898.00	2.048.236.52
Los Ríos	766,665.18	1,590,148.30	-1,805,907.69	-175,409.70	375.496.09
Los Lagos	2,221,096.08	3,951,976.29	-4,239,651.49	319,725.10	2.253.145.98
Aysén	118,198.16	3,762,265.71	-1,173,607.20	3,667,811.70	6.374.668.38
Magallanes	33,673.02	3,474,112.96	-1,197,979.90	4,507,895.30	6.817.701.38
Total	***5,398,892.18***	***24,549,002.58***	***-20,166,878.02***	***8,271,340.40***	***18.052.357.14***

Table 43. FREL/FRL expanded to the national scale of Chilean forests

[82] The tool used to estimate the FREL/FRL is available at (It is recommended to download file for easy viewing): https://docs.google.com/spreadsheets/d/11pulAuff2P9ur89T1uy0IFKhJJqDj17q/edit#gid=1868350245

8 ESTIMATION OF UNCERTAINTY[83]

The estimation of uncertainty constitutes an essential element of a complete GHG inventory, which is not aimed at questioning the validity of the estimates but rather to prioritize efforts to improve the accuracy of future inventories and guide decisions on methodologies (IPCC, 2001). To estimate uncertainty, it is necessary to know the sources of error and their contribution to the total uncertainty. Some sources of error, such as sampling errors, the accuracy of the instruments and the statistical variance of the models are well defined and easy to characterize, while others are more difficult to characterize. In this chapter, the sources of error for the estimation of uncertainty are described, including the associated error and its evaluation, applying the Monte Carlo simulation approach as part of the area of methodological improvements incorporated in this FREL/FRL.

8.1 Identification and evaluation of sources of uncertainty

This section presents the main sources of uncertainty and an analysis of their contribution to the uncertainty of the Reference Level. Also included are operational procedures implemented to address these sources of uncertainty as part of the monitoring process. The main sources of error of the reference level correspond to the land use change maps derived from the classification of multi-pixel mosaics and the mapping of carbon fluxes in permanent forest.

8.1.1 Activity data

8.1.1.1 Areas of land use and use changes

The AD for land use changes are derived from the maps of land use and use change. These maps go through a process of quality control and continuous improvement, to ensure that the geometry of the polygons complies with the corresponding quality standards.[84]

Once the MHCUTs are ready to provide the necessary information for the DAs, the error and uncertainty associated with the map change categories are estimated.[85] Errors related to land use change are calculated following the good practices described in Olofsson *et al.* (2014)[86] and using the complex area estimator from Cochran (1977).

To implement this approach, the change-of-use categories were validated using Collect Earth,[87] which is a validation tool using high-resolution Google Earth images. Through Collect Earth, the different interpreters

[83] The tools used for uncertainty estimation are available at: https://docs.google.com/spreadsheets/d/1UprMkrSRysyLRMZU8Z25m1oqeL1fpqko/edit?usp=drive_link&ouid=103115075145926052872&rtpof=true&sd=true

[84] SOP_03 Standardization and quality control protocol for land use change maps: https://drive.google.com/file/d/1V4W6EcSJffkq38nfzQZEgOrXzxibRsyd/view?usp=drive_link

[85] SOP_04_Uncertainty Assessment on Land Use Change: https://drive.google.com/file/d/1V1jaj241AJ3YhrjOT3SNvV1Xa0iAuIa7/view?usp=drive_link

[86] Olofsson, P.; Foody G. M.; Herold M.; Stehman S. V.; Woodcock C. E.; Wulder M. A. 2014. Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment 148, 42-57 pp.

[87] More information available at: http://www.openforis.org/tools/collect-earth.html

are consulted on the initial and final use of the polygon (2001-2013), which must be verified in Google Earth, thus determining the category of change (ground truth).

Data collection and calculation of the number of samples for uncertainty estimation follow the good practices described by Oloffson *et al.* (2014). The data collection consisted of carrying out a pre-sampling of 30 samples per category of change and validating them by means of high-resolution satellite images of the period. This allowed obtaining the total number of samples per region with a standard error for global precision of 0.01. Of the total number of samples, 25 percent were assigned to two interpreters (duplicate), so that it goes through a cross-validation between interpreters. In case of discrepancies, a third interpreter evaluated the sample to determine the definitive category.

In total, 12,601 samples from Coquimbo to Magallanes were evaluated, which is equivalent to 227,692 hectares (see Table 44)

Region	N° of polygons mapped	Regional area (ha)	N° of polygons sampled	Sample area (ha)
Coquimbo	64,884	4,058,043.0	431	15,437.6
Valparaíso	89,556	1,595,948.2	2,495	49,137.1
Metropolitan	76,808	1,540,399.3	835	12,967.7
O'Higgins	202,139	1,634,683.1	2,445	13,808.6
Maule	111,859	3,036,197.3	575	7,684.1
Ñuble	108,850	1,310,516.6	1,590	12,477.3
Biobío	243,043	2,400,085.1	745	6,092.4
Araucanía	111,398	3,181,894.6	400	6,752.9
Los Ríos	58,833	1,834,899.6	400	6,461.2
Los Lagos	174,482	4,837,762.9	1,529	34,397.0
Aysén	126,457	10,695,710.0	754	48,965.9
Magallanes	311,695	13,273,502.4	402	13,510.0
Total	**1,680,004**	**49,399,642.0**	**12,601**	**227,691.9**

Table 44. Number of polygons, samples, area mapped, and area sampled per region using Collect Earth

Based on the validation, a confusion matrix of the categories of changes of use was created for each region, in order to be able to contrast the truth of the terrain with that of the map. However, the uncertainty calculation described by Olofsson *et al.* (2014) is based on the analysis and sampling of pixels, so the application of the described estimators becomes complex, since, in the case of Chile, each sampled polygon has a different geometry and area. In this context, it was determined that the calculation of the optimal uncertainty for the conditions of the country would be to use the complex area as the main estimator (formulas sec. 6.10 - Cochran, 1977). The sample in each stratum is a simple random sample of polygons, from a list of all available polygons in that stratum, where the estimator of the estimated total area of each category is defined by Equation 25:

$$\hat{Y}_{Rs} = \sum_{h=1}^{H} \frac{\underline{y}_h}{\underline{x}_h} X_h \qquad \text{Eq. 25}$$

In addition, the estimated variance is given by Equation 26:

$$\hat{V}(\hat{Y}_{Rs}) = \sum_{h=1}^{H} \quad N_h^2 \left(1 - \frac{n_h}{N_h}\right)(s_{yh}^2 + \hat{R}_h^2 s_{xh}^2 - 2\hat{R}_h s_{xyh})/n_h \qquad \text{Eq. 26}$$

Where:
N_h = number of polygons in stratum h (population)
n_h = number of polygons in the sample of stratum h selected from available Nh
H = number of strata (h corresponds to a stratum, h=1,2,….H)
y_{hu} = area of the feature of interest to be estimated for polygon u of the sample in stratum h (for example, u = area of deforestation of polygon u). We assume that the polygon has a unique class label (i.e., the polygon is homogeneous). If the polygon is not the target class being estimated, yhu = 0 (these 0 values are included in the data when calculating the estimates).
x_{hu} = area of polygon u in stratum h (this does not depend on the polygon attribute, since it is just the area)
X_h = total area of all polygons in stratum h (total population)
$\underline{y_h}$ = sample mean of yhu in stratum h
$\underline{x_h}$= sample mean of xhu in stratum h
s_{yh}^2= sample variance of yhu in stratum h
s_{xh}^2 = sample variance of xhu in stratum h
s_{xyh} = sample covariance of xhu and yhu in stratum h

Lastly, the uncertainty estimate for each category of change and region (Table 45) was defined from the standard error of the estimated total, which corresponds to the square root of the estimated variance.

Region	Percentage increase	Continuous forest	Deforestation	Other permanent uses	Substitution
Coquimbo	85%	67%	89%	3%	NA
Valparaíso	98%	15%	42%	7%	100%
Metropolitan	230%	15%	61%	7%	57%
O'Higgins	24%	11%	23%	5%	31%
Maule	25%	8%	47%	2%	49%
Ñuble	87%	5%	60%	3%	70%
Biobío	88%	16%	95%	6%	78%
Araucanía	131%	7%	221%	3%	44%
Los Ríos	61%	2%	100%	3%	62%
Los Lagos	68%	4%	33%	5%	77%
Aysén	73%	15%	61%	10%	100%*
Magallanes	NA	19%	73%	5%	NA

* An uncertainty of 100% is assumed since the estimated area is 0 and therefore the calculation is indeterminate.

Table 45. Uncertainty by exchange rate and region for the reference period

8.1.1.2 Forest degradation and increase in permanent forest stocks

ADs for carbon degradation and increase in permanent forest lands are obtained from integration of satellite imagery and IFN biomass information.

A protocol has been prepared to facilitate the reproduction of the mapping process based on the digital processing of satellite images and IFN biomass information. The protocol describes all the procedures for preparing the mapping of carbon fluxes, stocks, and degradation in the permanent forest. This protocol includes a methodological description, spatial and dasometric information, and satellite data processing necessary to estimate ADs for carbon degradation and enhancement in carbon stocks.

The sources of error for estimating ADs of carbon degradation and increase in permanent forest lands are:

a. Uncertainty associated with the forest density plots used to determine the direction of carbon flux (neutral, loss, or gain) for each pixel. This uncertainty has been estimated at 32.8 percent.
b. Uncertainty associated with the integration of satellite data from the multi-pixel mosaic with dasometric variables. This uncertainty has been estimated by calculating the standard error of estimation of the k-nn volume function. This uncertainty has been estimated at 57 percent.

8.1.1.3 Representativeness

For the land use and land use change zones, and for the analysis of the permanent forest, multi-pixel mosaics including a temporal range with cloud-free pixels are prepared to obtain representative satellite images of the beginning and end of each period. The multi-pixel mosaic is an image made up of pixels from different images extracted based on the definition of a time range or window. The selection of each pixel seeks to define the best information available in a specific area, prioritising above all that they are cloud-free and cloud-shadow free pixels. Given the high level of cloudiness present in southern Chile, a window of ±3 months is used for the start and end date of the annualized period. For example, considering 2001, the start date is 1 January 2001, the range or time window will be from 1 October 2000 to 31 March 2001, and the multi-pixel mosaic time window for the end of the 2013 period is from 1 October 2013 to 31 March 2014.

8.1.2 Emissions factors

8.1.2.1 Aboveground biomass

The uncertainty estimate for the aboveground biomass estimate depends on the source of the carbon density data. To obtain information on aboveground biomass of native forest and mixed forest, information from the National Forest Inventory is collected using the SOP_06 Field Operations Manual.

For some forest types it was possible to fit the probability distribution function, while for forest types with a given number of inventory plots, the uncertainty propagation with Monte Carlo analysis uses the following information:

- Error of diameter at breast height: 0.2 percent, based on data from INFOR's National Forest Inventory.
- Error of volume estimation: 0.07 percent, based on data from INFOR's National Forest Inventory.
- Error of the biomass expansion factor (BEF): 18 percent, from the information collected in the country during the study by Gayoso (2002), which was also used by INGEI 2020. This value is for native species and has a national spatial scale. The error is based on statistical data from the biomass and carbon stock inventory of the Universidad Austral de Chile.

- Wood density error: 5.6 percent. This calculation was made using basic density data collected from the growth of native species in Chile. A bibliographic review of the basic densities of forest species in Chile was carried out and there were no changes to the value reported by Gayoso (2002) and INGEI 2020 (MMA, 2021).

These uncertainties were combined with the IPCC error propagation approach 1, resulting in a total uncertainty of 18.85 percent[88]

8.1.2.2 Aboveground biomass from non-forest land uses

The Monte Carlo analysis uses the estimation error published in INGEI 2020 (MMA, 2021), Gayoso (2006) and the expert judgment estimation (IPCC, 2006). The error corresponding to urban and industrial areas, agricultural land, and grasslands and scrublands is considered. For wetlands, areas devoid of vegetation, glaciers and perpetual snow, and bodies of water, the carbon stock is assumed to be zero.

8.1.2.3 Average Annual Growth

The average annual growth (IPA in Spanish) is estimated based on the Field Operations Manual (SOP_06) and the measurements made in the National Forest Inventory. For some forest types it was possible to fit the probability distribution function, while for forest types with a limited number of sample plots, the uncertainty propagation with Monte Carlo uses an uncertainty calculation for IPA based on the confidence interval of 95 percent for the rate of removal by type of forest, calculated with data from INFOR's National Forest Inventory.

8.1.2.4 Sampling

The Continuous Inventory of Forest Ecosystems or National Forest Inventory (hereinafter the National Inventory) is administered by INFOR and has been operational since 2000. The Continuous Inventory was created based on a two-stage statistical design in three conglomerates of circular sampling plots in an area equivalent to 500 m2 distributed in a systematic area of 5x7 km. The sampling units have been systematically distributed throughout the national territory from the Maule Region to the Magallanes Region.

8.1.2.5 Root-stem ratio (R Factor)

The R Factor has a 40 percent error that comes from the information collected in the country (Gayoso, 2002; MMA, 2021). This value is within the range indicated in the 2006 IPCC guidelines for temperate forests (between 0.20 and 0.46, according to Table 4.4; Chapter 4; Volume 4), and with the values available on a global scale, where the value for the R Factor is in the range of 0.09 and 0.33. This value is for native species and has a national scale. The error calculation is based on the biomass and carbon stock inventory of the Universidad Austral de Chile.

Finally, the uncertainties of the aboveground biomass and the R Factor are combined following the IPCC error propagation approach 1, resulting in a total uncertainty of 44.2 percent.

8.1.2.6 Representativeness

This source of uncertainty is not applicable. Chile generates estimates of carbon densities by forest type and non-forest land uses. Different types of forests and growth are used to classify native forest. Each type of forest has its biomass value depending on the availability of data. Non-forest lands include the following uses:

88 https://docs.google.com/spreadsheets/d/1UprMkrSRysyLRMZU8Z25m1oqeL1fpqko/edit?usp=drive_link&ouid=103115075145926052872&rtpof=true&sd=true

urban and industrial zones, agricultural land, grassland, scrubland, arborescent scrub, scrub with succulents, succulent formations, plantations, wetlands, areas devoid of vegetation, glaciers and perpetual snow, bodies of water and unrecognized areas.

8.1.3 Integration

8.1.3.1 Model

Special tools have been developed to estimate the emissions during the reference period for each REDD activity. Each of these tools uses its own formula to estimate emissions and captures. Chile prepared these tools to ensure that the same calculation methods are used in all monitoring events and to avoid errors during data processing and preparation.

8.1.3.2 Integration

EFs were calculated for each region and forest type according to the location of the aboveground biomass sampling plots to ensure comparability between AD and EF transition classes. This source of uncertainty is considered in the AGB inventory sampling error.

8.2 Parameters and assumptions used to calculate uncertainty

Parameters included in the modelling	Parameter values	Error	Probability distribution function	Assumptions
Activity data				
Non-Forest land - Forest Maule Reference Period (ha/yr)	7,012.55	27.98 %	Normal	The uncertainty of the ADs used in the Monte Carlo analysis was calculated using the confidence limits of the sample-based areas of land-use change estimates for the reference and monitoring periods.
Non-Forest land - Forest Ñuble Reference Period (ha/yr)	1,144.04	24.05 %	Normal	
Non-Forest land - Forest Biobío Reference Period (ha/yr)	2,156.59	36.83 %	Normal	
Non-Forest land - Forest Araucanía Reference Period(ha/yr))	2,948.47	57.52 %	Normal	
Non-Forest land - Forest Los Ríos Reference Period (ha/yr)	1,545.03	34.85 %	Normal	
Non-Forest land - Forest Los Lagos Reference Period (ha/yr)	1,004.49	36.91 %	Normal	
Forest land – Non-Forest Maule Reference Period (ha/yr)	828	78.00 %	Normal	
Forest land – Non - Forest Ñuble Reference Period (ha/yr)	453	48.81 %	Normal	
Forest land – Non-Forest Biobío Reference Period (ha/yr)	1,296	58.61 %	Normal	
Forest land – Non-Forest Araucanía Reference Period(ha/yr))	1,537	50.22 %	Normal	

Parameters included in the modelling	Parameter values	Error	Probability distribution function	Assumptions
Forest land – Non-Forest Los Ríos Reference Period (ha/yr)	1,529	36.26 %	Normal	
Forest land – Non-Forest Los Lagos Reference Period (ha/yr)	3,530	25.25 %	Normal	
Aum No Conserv under C in 2001, and between [B-C] in 2010 RP (ha/yr)	54,672	32.80 %	Normal	Precision of degradation mapping estimated by INFOR.
Aum No Conserv between [B-C] in 2001 and over B in 2010 RP (ha/yr)	271,368	32.80 %	Normal	
Aum No Conserv under C in 2001 and over B in 2010 RP (ha/yr)	167,695	32.80 %	Normal	
Aum No Conserv under C in 2001 and under C in 2010 RP (ha/yr)	59,742	32.80 %	Normal	
Aum No Conserv between [B-C] in 2001, between [B-C] in 2010 RP (ha/yr)	38,912	32.80 %	Normal	
Deg No Conserv over B in 2001 and under C in 2010 RP (ha/yr)	121,830	32.80 %	Normal	
Deg No Conserv between [B-C] in 2001 and under C in 2010 RP (ha/yr)	45,625	32.80 %	Normal	
Deg No Conserv over B in 2001, between [B-C] in 2010 RP (ha/yr)	224,752	32.80 %	Normal	
Deg No Conserv under C in 2001 and under C in 2010 RP (ha/yr)	53,030	32.80 %	Normal	
Deg No Conserv between [B-C] in 2001, between [B-C] in 2010 RP (ha/yr)	37,029	32.80 %	Normal	
Aum Conserv under C in 2001, between [B-C] in 2010 RP (ha/yr)	10,541	32.80 %	Normal	
Aum Conserv between [B-C] in 2001 and over B in 2010 RP (ha/yr)	53,982	32.80 %	Normal	
Aum Conserv under C in 2001 and over B in 2010 RP (ha/yr)	28,729	32.80 %	Normal	
Aum Conserv under C in 2001 and under C in 2010 RP (ha/yr)	10,265	32.80 %	Normal	
Aum Conserv between [B-C] in 2001, between [B-C] in 2010 RP (ha/yr)	8,272	32.80 %	Normal	
Deg Conserv over B in 2001 and under C in 2010 MP (ha/yr)	26,389	32.80 %	Normal	
Deg Conserv between [B-C] in 2001 y under C in 2010 MP (ha/yr)	9,675	32.80 %	Normal	
Deg Conserv over B in 2001, between [B-C] in 2010 MP (ha/yr)	51,707	32.80 %	Normal	
Deg Conserv under C in 2001 and under C in 2010 MP (ha/yr)	9,548	32.80 %	Normal	
Deg Conserv between [B-C] in 2001, between [B-C] in 2010 MP (ha/yr)	7,888	32.80 %	Normal	

Parameters included in the modelling	Parameter values	Error	Probability distribution function	Assumptions
Forest land - Forest Plantation Maule RP (ha/yr)	2,004	59.02 %	Normal	The uncertainty of the ADs used in the Monte Carlo analysis was calculated using the confidence limits of the sample-based areas of land-use change estimates for the reference and monitoring periods.
Forest land - Forest Plantation Ñuble RP (ha/yr)	778	37.64 %	Normal	
Forest land - Forest Plantation Biobío RP (ha/yr)	1,590	62.23 %	Normal	
Forest land - Forest Plantation La Araucanía RP (ha/yr)	2,772	64.36 %	Normal	
Forest land - Forest Plantation Los Ríos RP (ha/yr)	944	77.14 %	Normal	
Forest land - Forest Plantation Los Lagos RP (ha/yr)	664	76.22 %	Normal	
Forest fires area Maule RP (ha/yr)	583.4	15%	Normal	INGEI
Forest fires area Ñuble RP (ha/yr)	139.2	15%	Normal	
Forest fires area Biobío RP (ha/yr)	1,028.5	15%	Normal	
Forest fires area Araucanía RP (ha/yr)	2,058.1	15%	Normal	
Forest fires area Los Ríos RP (ha/yr)	150.4	15%	Normal	
Forest fires area Los Lagos RP (ha/yr)	781.9	15%	Normal	
Carbon content of Non-Forest Lands				
AGB Urban and Industrial Areas	2.00	95%	Normal	INGEI, 2020 (MMA, 2021).
AGB Agricultural land	10.00	75%	Normal	INGEI, 2020 (MMA, 2021).
AGB Grasslands and scrublands Grasslands	4.73	27.7%	Normal	(Gayoso, 2006)
AGB Grasslands and scrublands Scrub-grassland	9.04	34.6%	Normal	
AGB Grasslands and scrublands Arborescent scrub	21.78	22.4%	Normal	
Carbon content of Native Forest				
BGB Agricultural land	2.00	53.2%	Normal	Uncertainty for the non-forest land BGB is based on the propagation error estimate following the IPCC approach 1 of the Shrub-Tree AGB error (22.42%) and the R-Factor
BGB Grasslands and scrublands Grasslands	8.13	53.2%	Normal	
BGB Grasslands and scrublands Scrub-grassland	14.99	53.2%	Normal	

Parameters included in the modelling	Parameter values	Error	Probability distribution function	Assumptions
BGB Grasslands and scrublands Arborescent scrub	35.25	53.2%	Normal	error (48.27%) estimated by Gayoso (2002), resulting in a total uncertainty of 53.2%.
AGB Alerce Mature (t dry biomass/ha)	339.109	18.85%	Normal	For forest types with a limited number of sample plots, uncertainty propagation with Monte Carlo analysis uses the following information: i. DAP measurement error (0.2%), calculation based on data from INFOR's Continuous Forest Inventory; ii. Volume estimation error (0.07%), calculation based on data from INFOR's Continuous Forest Inventory, iii. Error of the Biomass Expansion Factor (BEF) (18.0%), BEF comes from information collected in the study by Gayoso (2002) and used in INGEI 2020 (MMA, 2021). This value is for native species and has a national spatial level. The calculation of the error is based on statistical data from the Biomass and Carbon Stocks Inventory of the Universidad Austral de Chile (UACh); and iv. Wood density (5.6%) calculated using basic density data collected from native species growing in Chile. Finally, these uncertainties are combined following the IPCC error propagation approach 1, resulting in a total uncertainty of 18.85%.
AGB Alerce Young (t dry biomass/ha)	203.590	18.85%	Normal	
AGB Ciprés de las Guaitecas Mature (t dry biomass/ha)	221.848	18.85%	Normal	
AGB Araucaria Mature (t dry biomass/ha)	β: 222.628; k: 1.886	PDF	Gama 2; P:0.998; n: 16	
AGB Araucaria Young (t dry biomass/ha)	219.131	18.85%	Normal	
AGB Ciprés de la Cordillera Mature (t dry biomass/ha)	97.116	18.85%	Normal	
AGB Ciprés de la Cordillera Young (t dry biomass/ha)	124.019	18.85%	Normal	
AGB Lenga Mature (t dry biomass/ha)	µ: 207.038; s: 84.017	PDF	Logistic; P:0.958; n:10	
AGB Lenga Young (t dry biomass/ha)	α: 0.431; β:0.439	PDF	Beta4; P:0.776; n:8	
AGB Coihue de Magallanes Mature (t dry biomass/ha)	129.148	18.85%	Normal	
AGB Roble - Hualo Mature (t dry biomass/ha)	β: 17.695; k: 5.884	PDF	Gamma (2); P:0.808; n: 17	
AGB Roble - Raulí - Coihue Mature (t dry biomass/ha)	λ: 0.006	PDF	Exponential; P:0.850; n: 65;	
AGB Roble - Raulí - Coihue Young (t dry biomass/ha)	λ: 0.006	PDF	Exponential; P:0.709; n: 71	
AGB Coihue - Raulí - Tepa Mature (t dry biomass/ha)	β: 1.162; γ:414.153	PDF	Weibull (2); P: 0.831; n: 57	
AGB Coihue - Raulí - Tepa Young (t dry biomass/ha)	β: 117.880; k: 1.720	PDF	Gamma (2); P:0.989; n: 12	
AGB Esclerófilo Mature (t dry biomass/ha)	β: 0.721; γ:12.840	PDF	Weibull (2); P: 0.858; n: 33	
AGB Siempreverde Mature (t dry biomass/ha)	µ: 5.765; σ: 0.646	PDF	Log-normal; P: 0.194; n: 49	
AGB Siempreverde Young (t dry biomass/ha)	β: 1.584; γ:139.543	PDF	Weibull (2); P: 0.673; n: 25	
AGB Maule Mixed Forest Reference Period (t dry biomass/ha)	58.85	18.85%	Normal	
AGB Biobío Mixed Forest Reference Period (t dry biomass/ha)	210.75	18.85%	Normal	

Parameters included in the modelling	Parameter values	Error	Probability distribution function	Assumptions
AGB Araucanía Mixed Forest Reference Period (t dry biomass/ha)	246.71	18.85%	Normal	
AGB Los Ríos Mixed Forest Reference Period (t dry biomass/ha)	194.05	18.85%	Normal	
AGB Los Lagos Mixed Forest Reference Period (t dry biomass/ha)	221.64	18.85%	Normal	
AGB Ñuble Mixed Forest Reference Period (t dry biomass/ha)	58.85	18.85%	Normal	
BGB Maule Mixed Forest Reference Period (t dry biomass/ha)	70.78	44.2%	Normal	The uncertainty for the belowground biomass BGB is based on the IPCC error propagation approach 1 following the estimate of the aboveground biomass AGB error (18.85%) and the R-factor error of root-shoot ratio (9.40 %) estimated by Gayoso (2002), resulting in a total uncertainty of 44.2%.
BGB Biobío Mixed Forest Reference Period (t dry biomass/ha)	55.67	44.2%	Normal	
BGB Araucanía Mixed Forest Reference Period (t dry biomass/ha)	63.59	44.2%	Normal	
BGB Los Ríos Mixed Forest Reference Period (t dry biomass/ha)	47.21	44.2%	Normal	
BGB Los Lagos Mixed Forest Reference Period (t dry biomass/ha)	12.47	44.2%	Normal	
BGB Ñuble Mixed Forest Reference Period (t dry biomass/ha)	37.80	44.2%	Normal	
Dead matter Maule Mixed Forest RP (t dry biomass/ha)	72.30	28.4%	Normal	Estimated error from permanent plots of the INFOR Continuous Forest Inventory.
Dead matter Biobío Mixed Forest RP (t dry biomass/ha)	52.91	28.4%	Normal	
Dead matter Araucanía Mixed Forest RP (t dry biomass/ha)	61.16	28.4%	Normal	
Dead matter Los Ríos Mixed Forest RP (t dry biomass/ha)	47.61	28.4%	Normal	
Dead matter Los Lagos Mixed Forest RP (t dry biomass/ha)	18.92	28.4%	Normal	
Dead matter Ñuble Mixed Forest RP (t dry biomass/ha)	45.49	28.4%	Normal	
Annual Periodic Increase of Native Forest				
IPA Maule Mixed Forest Reference Period (t dry biomass/ha)	4.20	28.7%	Normal	Average IPA error for all forest types due to missing data.
IPA Biobío Mixed Forest Reference Period (t dry biomass/ha)	4.14	28.7%	Normal	
IPA Araucanía Mixed Forest Reference Period (t dry biomass/ha)	4.06	28.7%	Normal	
IPA Los Ríos Mixed Forest Reference Period (t dry biomass/ha)	2.21	28.7%	Normal	
IPA Los Lagos Mixed Forest Reference Period (t dry biomass/ha)	3.70	28.7%	Normal	

Parameters included in the modelling	Parameter values	Error	Probability distribution function	Assumptions
IPA Ñuble Mixed Forest Reference Period (t dry biomass/ha)	4.03	28.7%	Normal	
IPA Alerce Mature (m3/ha/yr)	0.5	58.47%	Normal	The greater uncertainty of the estimated errors for IPA is assumed due to lack of data.
IPA Ciprés de las Guaitecas Mature (m3/ha/yr)	3.9	58.47%	Normal	
IPA Araucaria Mature (m3/ha/yr)	µ: 4.882; σ: 2.516	PDF	Normal; P:0.923; n: 16	
IPA Ciprés de la Cordillera Mature (m3/ha/yr)	5.0	15.83%	Normal	Estimated error from permanent plots of the INFOR Continuous Forest Inventory
IPA Ciprés de la Cordillera Young (m3/ha/yr)	2.7	9.97%	Normal	
IPA Lenga Mature (m3/ha/yr)	k: 5; γ:0.921	PDF	Erlang; P:0.986; n:10	
IPA Lenga Young (m3/ha/yr)	µ: 2.995; β:2.054	PDF	Fisher-Tippett (2); P:0.907; n:8	
IPA Coihue de Magallanes Mature (m3/ha/yr)	2.6	13.42%	Normal	Estimated error from permanent plots of the INFOR Continuous Forest Inventory
IPA Coihue de Magallanes Young (m3/ha/yr)	3.7	7.68%	Normal	
IPA Roble - Hualo Mature (m3/ha/yr)	µ: 1.534; σ: 0.507	PDF	Log Normal; P:0.873; n: 17	
IPA Roble - Hualo Young (m3/ha/yr)	3.5	54.47%	Normal	The greater uncertainty of the estimated errors for IPA is assumed due to the lack of data.
IPA Roble - Raulí - Coihue Mature (m3/ha/yr)	µ: 1.335; σ: 1.106	PDF	Log Normal; P:0.257; n: 65;	
IPA Roble - Raulí - Coihue Young (m3/ha/yr)	β: 1.777; γ:4.664	PDF	Weibull (2); P:0.760; n: 71	
IPA Coihue - Raulí - Tepa Mature (m3/ha/yr)	β: 1.403; γ:6.264	PDF	Weibull (2); P: 0.789; n: 57	
IPA Coihue - Raulí - Tepa Young (m3/ha/yr)	µ: 4.364; s: 1.558	PDF	Logistic; P:0.825; n: 12	
IPA Esclerófilo Mature (m3/ha/yr)	β: 0.667; γ:0/875	PDF	Weibull (2); P: 0.512; n: 33	
IPA Esclerófilo Young (m3/ha/yr)	1.6	21.31%	Normal	Estimated error from permanent plots of the INFOR Continuous Forest Inventory
IPA Siempreverde Mature (m3/ha/yr)	α: 13.411; β:29.589	PDF	Beta4; P: 0.940; n: 49	
IPA Siempreverde Young (m3/ha/yr)	µ: 4.664; s:0/893	PDF	Logistic; P: 0.994; n: 25	
Degradation and Enhancement in permanent forest				

Parameters included in the modelling	Parameter values	Error	Probability distribution function	Assumptions
Carbon stock change in permanent forest	Values depending on density diagram change and forest type	57%	Normal	Error estimate based on the standard error of the volume estimate of the k-nn algorithm.
Carbon content of forest lands (forest fires)				
AGB Maule (t dry biomass/ha/yr)	80.35	18.85%	Normal	This uncertainty is estimated using the IPCC error propagation approach 1, resulting in a total uncertainty of 18.85%.
AGB Biobío (t dry biomass/ha/yr)	149.88	18.85%	Normal	
AGB Araucanía (t dry biomass/ha/yr)	252.33	18.85%	Normal	
AGB Los Ríos (t dry biomass/ha/yr)	310.35	18.85%	Normal	
AGB Los Lagos (t dry biomass/ha/yr)	230.41	18.85%	Normal	
AGB Ñuble (t dry biomass/ha/yr)	149.88	18.85%	Normal	
BGB Maule (t dry biomass/ha/yr)	23.05	44.2%	Normal	The uncertainty for the belowground biomass BGB is based on the IPCC error propagation approach 1 for the aboveground biomass AGB error (18.85%) and the R-factor error of the proportion of roots and shoots (40 .0 %) estimated by Gayoso (2002), resulting in a total uncertainty of 44.2%.
BGB Biobío (t dry biomass/ha/yr)	43.00	44.2%	Normal	
BGB Araucanía (t dry biomass/ha/yr)	72.39	44.2%	Normal	
BGB Los Ríos (t dry biomass/ha/yr)	89.04	44.2%	Normal	
BGB Los Lagos (t dry biomass/ha/yr)	66.10	44.2%	Normal	
BGB Ñuble (t dry biomass/ha/yr)	43.00	44.2%	Normal	
Dead matter Maule (t dry biomass/ha)	52.60	28.4%	Normal	Estimated error from permanent plots of the INFOR Continuous Forest Inventory.
Dead matter Biobío (t dry biomass/ha)	122.10	28.4%	Normal	
Dead matter Araucanía (t dry biomass/ha)	165.50	28.4%	Normal	
Dead matter Los Ríos (t dry biomass/ha)	146.90	28.4%	Normal	
Dead matter Los Lagos (t dry biomass/ha)	157.00	28.4%	Normal	
Dead matter Ñuble (t dry biomass/ha)	122.10	28.4%	Normal	

Parameters included in the modelling	Parameter values	Error	Probability distribution function	Assumptions
Other Factors				
Combustion factor	0.45	36.0%	Normal	IPCC, 2006
Emission Factor CH4	4.7	29.0%	Normal	
Emission Factor N2O	0.26	43.8%	Normal	

Table 46. Parameters and assumptions used to estimate uncertainties

8.3 Estimation of uncertainty

The uncertainties of the FREL/FRL of deforestation, degradation, and enhancement in carbon stocks were estimated using the Monte Carlo simulation. The Monte Carlo approach involves the repeated simulation of samples within the probability density functions of the input data. The probability density functions (PDF) explain the range of potential values of a given variable and the probability that different values represent the true value. PDFs are represented graphically as distributions. Common examples include normal (Gaussian), lognormal, triangular, and uniform distributions.

Monte Carlo simulations are run using algorithms that generate stochastic values (i.e., from random data) based on the PDF. The goal of these repeated simulations is to produce distributions that represent the probability of different estimates. Once the simulations have been run, they are applied to the model, which could be complex or be a simple equation developed to calculate the final estimate. To calculate the uncertainty, the confidence interval can be identified for the final distributions.

The estimated global uncertainty for the reference level has been developed using the XLSTAT tool, presenting the result below in Table 47 and Table 48:

	Deforestation	Enhancement in No Conservation from F-F	Degradation No Conservation F-F	Enhancement from NF-F	Sustitution	Forest fires	Enhancement in Conservation from F-F	Degradation Conservation from F-F
Upper limit 95%	7,675,165	-15,633,363	24,399,407	-358,824	6,562,021	315,508	-4,083,829	18,917,974
Lower limit 5%	3,222,103	-23,626,946	15,868,134	-817,807	2,635,096	59,369	-7,221,072	8,936,032
Median	5,209,388	-19,598,794	20,152,484	-538,464	3,919,295	164,190	-5,642,383	13,904,215
Confidence interval 90%	2,226,531	3,996,792	4,265,636	229,492	1,963,463	128,070	1,568,621	4,990,971
Uncertainty	***42.7%***	***20.4%***	***21.2%***	***42.6%***	***50.1%***	***78.0%***	***27.8%***	***35.9%***

Table 47. Uncertainty in the Emissions of Reference Period according to REDD+ activity

	FREL/FRL	Degradation	Enhancements	Deforestation	Conservation
Upper limit 95%	26,218,105	29,270,731	-16,188,913	7,675,165	13,508,655
Lower limit 5%	9,488,283	19,783,993	-24,209,548	3,222,103	3,027,948
Median	17,902,167	24,443,617	-20,151,580	5,209,388	8,270,036
Confidence interval 90%	8,364,911	4,743,369	4,010,318	2,226,531	5,240,354
Uncertainty	***46.7%***	***19.4%***	***19.9%***	***42.7%***	***63.4%***

Table 48. Global uncertainty FREL/FRL

9 RELATIONSHIP BETWEEN FREL/FRL AND THE GHG INVENTORY OF CHILE

Chile's national FREL/FRL that is proposed through this report is the product of the National Forest Monitoring System (SNMF), which operates with MINAGRI institutions as the main actors and collaborators. At the same time, as part of the institutional work, CONAF, together with INFOR, shares the responsibility for preparing activity data and emission estimates for the LULUCF sector for the INGEI. CONAF's Department of Climate Change and Ecosystem Services (DCCSE), together with the Department of Ecosystem Monitoring and Climate Change (DMECC) and the Forest Fire Analysis Unit, participate directly with the IFN Continuous Forest Inventory and Climate Change Adaptation and Mitigation research teams, as well as the INFOR Climate Change team, to develop REDD+ and GHG inventory reports.

In this context, the improvements and corrections implemented in the FREL/FRL, and its expansion to the national scope, aim to improve consistency and technical alignment with the INGEI, maintaining the criteria and assumptions assumed in the preparation of the reports.

Even so, there are intrinsic differences between the formulation of a forest reference level and a national GHG inventory, depending on the availability of information for the geographical scope applied, and the use of methods of greater or lesser scope and precision. In addition, the definition of the REDD+ approach for Chile establishes considerations in the activities that may present variations and similarities with respect to the GHG inventory.

The elements that were changed in the FREL/FRL to achieve the greatest consistency with the INGEI, include the use of emission factors and parameters, such as the biomass values of the native forest, the necromass values and the fraction value. carbon. Thanks to these changes, the information coincided with the National GHG Inventory Report published in 2020 (MMA, 2021).

In relation to the differences that persist between the FREL/FRL and the National GHG Inventory report, the most important corresponds to the definition of forest lands that are considered in the accounting of carbon fluxes, which integrates forest plantations and native forest for the INGEI, while in the case of REDD+ it only includes the native forest.

As another important difference, the activity data used for each estimation should be mentioned. The REDD+ approach uses CONAF's Historical Maps of Land Use Change, which represent direct information on changes between 2001 and 2013, while the INGEI uses a combined methodology including the Native Forest Cadastre Data and CONAF's Biennial Change Maps, as well as change rate interpolations to complete the 1990-2018 series. It is worth remembering the consideration indicated in sections 2 and 3 of the document related to arborescent scrub, which is considered as native forest on Native Forest Cadastre maps, but not on Land Use Change maps. This implies that, for the purposes of the INGEI, this loss of forest area is considered as deforestation, with an annual rate of 6,409 hectares of deforested arborescent scrub.

The points of consistency and variations between the INGEI and the FREL/FRL are detailed below by activity. Estimates of average historical emissions/removals by REDD+ activity is also presented to compare the results of FREL/FRL and the INGEI. To perform the congruence analysis, the following should be considered:

- The national FREL/FRL considers 99.3 percent of the country's native forest area, from the Coquimbo Region to the Magallanes Region, with the remaining native forest (0.7 percent) found in the Arica-Parinacota and Atacama Regions. INGEI, for its part, incorporates all 16 regions of the country from Arica-Parinacota to the Magallanes Region. For this relationship analysis, it was considered that the difference in native forest area between FREL/FRL and the INGEI is not significant, since the comparison of carbon emissions and removals is carried out in sub-categories related to native forest.

- The activities of degradation and enhancement of carbon stocks in permanent forest are integrated into the estimation of emissions and removals produced in forest lands that remain as forest lands in the INGEI. However, there is a difference in the calculation method to determine the annual change of carbon since the stock-difference method is used for the FREL/FRL and the profit and loss method in the INGEI.

- The REDD+ activities of deforestation and the enhancement of carbon stocks from non-forest to forest land correspond to the conversion of lands from and to forest lands in INGEI.

- The forest conservation activity in REDD+ considers emissions and removals due to degradation or increase in permanent forest stocks in conservation areas, while INGEI considers annual increases in biomass in park areas and national reserves.

- For the comparative analysis of activities that occur in permanent forest, the average emissions and captures of the INGEI period 2001-2010 were considered, while for activities that generate land use change, the average in the period 2001-2013 was considered.

9.1 Deforestation

In the INGEI, deforestation activity includes the categories of forest land converted to cropland, pasture, wetlands, settlement, and other land uses (including areas devoid of vegetation, snow and glaciers, bodies of water, and unrecognized areas).

For the calculation of Activity Data, the FREL/FRL considers the historical maps of land use and land use change (MHUCUT) as base information, while the INGEI considers the Native Forest Cadastre and Biennial Maps of Land Us Change, which are both CONAF sources that use the gain and loss method in estimating carbon.

Regarding the emission factors used in the FREL:

- The same emission factors were used to determine forest carbon stocks before deforestation.

- As in the INGEI, certain IPCC default values are used to determine carbon stocks after deforestation for some non-forest land use classes. However, the FREL/FRL uses Chile-specific values from Gayoso (2006) for scrub, arborescent scrub, grassland, and succulent formations.

- For dead organic matter, regional *Tier* 2 emission factors from the 2020 INGEI were used, which are based on the National Forest Inventory (for deforestation and degradation by substitution).

- Belowground biomass is the result of applying the root-stem ratio to aboveground biomass, a value established in the INGEI, according to Gayoso (2006).

Average annual emissions from deforestation for the period 2001-2013, according to the FREL ($tCO2e\ yr^{-1}$)	Average annual emissions from deforestation for the period 2001-2013, according to the INGEI ($tCO2e\ yr^{-1}$)
5,398,892	**3,179,115**

Table 49. Comparison of estimates of emissions from deforestation, FREL/FRL and INGEI

To compare the results, the value of the INGEI report excludes soil carbon stocks, since these stocks are not included in REDD+.

9.2 Forest degradation

The INGEI categories that correspond to degradation activity include forest lands that remain as forest lands (both plantations and native forest), commercial timber harvesting, firewood harvesting and forest fires. The REDD+ reference report, for its part, considers biomass losses using the stock change method in the degradation methodology, without considering statistical information, except in the case of non-CO_2gases.

The estimation in the inventory uses a gain-loss method based on Equation 2.7 of the IPCC (2006), however, the FREL/FRL uses the stock difference method based on Equation 2.8 of the IPCC (2006).

The 2020 INGEI uses statistical data from INFOR for forest removals, statistics from INFOR and MINENERGIA for firewood, and statistics on the area of native forest fires and forest plantations from CONAF to determine losses due to fires. Regarding the data on firewood extraction, it should be considered that the information is based on population consumption surveys, which does not distinguish between formal and informal origins of the extraction. However, it is a good representation of biomass loss from firewood.

For non- CO_2 GHGs resulting from forest fires, both reports apply the same accounting method based on CONAF tabular data for each fire season.

Annual degradation emissions for the period 2001-2010, according to the FREL ($tCO_2e\ yr^{-1}$)	Annual degradation emissions for the period 2001-2010, according to the INGEI ($tCO_2e\ yr^{-1}$)
20,313,837	**14,740,000**

Table 50. Comparison of estimates of emissions caused by forest degradation in the FREL/FRL and INGEI

Within the degradation activity, the FREL/FRL considers the replacement of native forest by plantations, assuming the complete loss of forest biomass, which means only the emissions resulting from the change of land use are estimated. INGEI also considers the complete loss of forest biomass and includes the removals in the plantations generated after the substitution. For this comparison, the growth of plantations estimated by INGEI is not included.

Annual emissions from degradation by substitution the period 2001-2013, according to the FREL (tCO_2e yr^{-1})	Annual emissions from degradation by substitution for the period 2001-2013, according to the INGEI (tCO_2e yr^{-1})
4,235,164	**3,026,000**

Table 51. Comparison of estimates of emissions due to degradation by substitution of the FREL/FRL and the INGEI

9.3 Enhancement in existing forest carbon stocks

In the INGEI, the enhancement in stocks is accounted for in the categories of land converted to forest land and in the enhancement in biomass in forest land that remains as forest land. In the case of the FREL/FRL, the activity data for the increase in non-forest areas converted to forest land comes from the historical maps, and for INGEI it comes from the native forest cadastre.

For the elaboration of the FREL/FRL, the same values of average net annual increase (by forest type and structure) used by the INGEI were used. Carbon stocks based on INFOR data were included for all forest types.

Similarly, in order to calculate the biomass conversion and expansion factor, for the conversion of the net annual increase in volume (including bark) to growth in aboveground biomass for a specific forest type, the biomass expansion factor and the basic density value of the wood from the INGEI were used.

However, there are relevant methodological differences in the calculation of increases in permanent forest, which leads to differences in the estimates. INGEI includes increases in biomass of forest plantations and all native forest under management in the country, while FREL/FRL only includes increases in biomass in native forests that recover from degradation and enhancement in forests of other land uses. In addition, a key difference is that the FREL/FRL includes removals due to recovery of degraded forest, while INGEI considers the growth of all forest under management in the country, so the FREL/FRL represents only a sub-set of the forest included in the INGEI.

Annual removals in permanent forest for the years 2001-2010, according to the FREL (tCO_2e yr^{-1})	Annual removals due to biomass increases in forest lands that remain as forest lands for the period 2001-2010, according to the INGEI (tCO_2e yr^{-1})
-19,621,903	**-91,011,302**

Table 52. Comparison of estimates of removals due to the enhancement in forest carbon stocks that remain as forests in the FREL/FRL and INGEI. Conservation areas are not considered

In addition, to calculate the enhancement in carbon stocks due to forest growth, the INGEI uses Equation 2.9 of the IPCC 2006 for *Tier* 2-3 calculation, for lands converted to forest in the year of conversion and then continues to account for this growth annually for 20 years until the land converted to forest changes to forest land remaining as forest land. Similarly, in the FREL/FRL, the enhancement in carbon stocks continues to include removals coming from areas that were converted to forest during the entire reference period.

Annual removals due to enhancement in uses from non-forest to forest for the period 2001-2013, according to the FREL ($tCO_2e\ yr^{-1}$)	Annual removals due to enhancement in biomass due to the conversion of land to forest land for the period 2001-2013, according to INGEI ($tCO_2e\ yr^{-1}$)
-544,975	**-217,060**

Table 53. Comparison of estimates of removals due to the enhancement in carbon stocks in forests that remain as forests in the FREL/FRL and INGEI. Conservation areas are not considered

9.4 Forest conservation

The FREL/FRL of carbon stocks for forest conservation considers the net flux of removals and emissions produced in areas under conservation processes, applying the methodology of stock differences in permanent forest. The INGEI, for its part, estimates the increase in biomass in national parks and reserves within the category of forest lands that remain as forest lands.

Annual removals in conservation areas in the period 2001-2010, according to the FREL ($tCO_2e\ yr^{-1}$)	Annual removals in conservation areas in the period 2001-2010, according to the INGEI ($tCO_2e\ yr^{-1}$)
-5,638,898	**-20,282,960**

Table 54. Comparison of estimates of removals due to the enhancement in carbon stocks in forests that remain as forests in the FREL/FRL and INGEI

For the estimation of carbon fluxes in conservation areas, in addition to removals from enhancement in permanent forest the FREL/FRL includes removals from recovery of degraded forest, while INGEI includes all increases in degraded and non-degraded forests in conservation areas.

10 CAPACITY BUILDING NEEDS, AREAS OF FUTURE TECHNICAL IMPROVEMENT AND PROJECTS IN DEVELOPMENT

Based on the launch of the sub-national FREL/FRL during 2016 and the REDD+ Technical Annex in 2018, it was possible to identify a series of gaps, needs and relevant technical improvements to be addressed during the preparation of the national FREL. As indicated in section 2.3, Chile has made progress in activities related to the preparation of biennial and historical change of land use maps, the preparation of activity data, emission factors, degradation estimation, multi-pixel mosaics, the incorporation of regions and biomes, and the development of the ENCCRV Platform.

However, there are training needs that have been previously highlighted and that persist in the SNMF. These are described as follows:

- Estimation of uncertainty through the Monte Carlo approach: although this methodological improvement has been incorporated at the reference level, the process is carried out using paid software by a consultant, which means the country does not have the permanent capacity to implement this approach. In this regard, the MRV is advancing together with the UN REDD+ team in the development of training courses in uncertainty analysis and the Monte Carlo method, prioritising the use of free access software, which are expected to be offered in the first half of 2023.

- Estimation of carbon fluxes in areas with high cloud cover: although progress was made in the study with data from Alos Palsar, it is considered highly important to promote the training of professionals to strengthen technical capacities in topics such as the generation and management of high-resolution satellite information from active sensors, as well as in matters related to forest inventories and sampling statistics. Also, free access to Lidar or Radar data information is crucial to contribute to the monitoring process.

- Closely linked to the above, the need to improve analysis capacity of high-resolution satellite images of the Planet type has been identified for the monitoring of forest management activities that allow progress in the incorporation of this activity in the SNMF.

- In the context of the transition from the Biennial Update Reports (BURs) to the Biennial Transparency Reports (BTRs), under the Enhanced Transparency Framework (ETF), providing support for the training of the technical team is considered important to comply with the required transparency standards, thereby aligning REDD+ reports with future BTRs.

There are a number of technical improvements in different areas of the SNMF, which have been identified by experts during the technical evaluation processes of the sub-national FREL/FRL and the Technical Annex, along with others that have been identified by the national team. These include some improvements that are in the process of analysis and discussion, such as the following:

- Evaluate the possibility of changing the satellite from which the images that make up the multi-pixel mosaics are obtained to another with higher spatial and temporal resolution of the Sentinel type.

- Evaluate the need for a tool to measure degradation in the Araucaria and Alerce forest types, and develop density diagrams for other sub-types that could be relevant to more accurately represent the behaviour of the Chilean forest.
- Maintenance and continuous improvement of the different systems that make up the integrated platform of the ENCCRV.
- Improve the estimation of degradation of southern forests through the use of active sensors (RADAR or LiDAR technologies) with public access.
- Need for support in obtaining high resolution images (Planet).
- Improvement in the infrastructure required for data processing.
- Work on updating the Reference Level period, considering a more modern reference period.
- Incorporate forest fire activity data, including the spatial component, once the FREL temporality is updated.
- Development of emission factors and activity data linked to soil organic carbon fluxes, as the gap persists in the national FREL/FRL.
- Generation of spatial information for management plans to facilitate the incorporation of the REDD+ activity.

Currently, through various contributions from both national and international sources, a series of projects are being developed aimed at reducing the gaps and needs identified in the process of construction and updating of the Reference Levels:

- In the process of including the sustainable forest management activity, progress is being made to improve the availability and quality of information for its quantification, through the centralization and standardization of management plan databases, in addition to incorporating their geographic location.
- Activities have been carried out to exchange experiences with international experts in the area of forest monitoring, within the framework of the "*Regional seminar on the exchange of experiences related to the assessment processes of FREL/FRL and REDD+ technical annexes, according to the requirements of the UNFCCC/other initiatives*", organized by SilvaCarbon and the UNFCCC in July 2022.
- During the second half of 2022, two tenders have been developed aimed at studying the impact of the mega-drought on forest degradation, with a view to temporarily adapting the national reference levels.

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