FREL / FRL

Forest Reference Emission Level / Forest Reference Level of Native Forests in Chile

August 31st, 2016

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ESTRATEGIA NACIONAL DE CAMBIO CLIMÁTICO Y RECURSOS VEGETACIONALES
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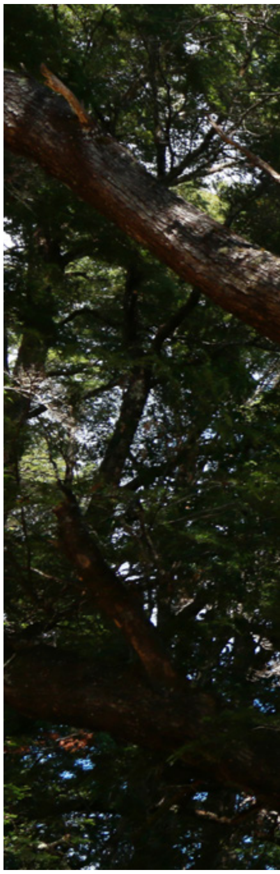

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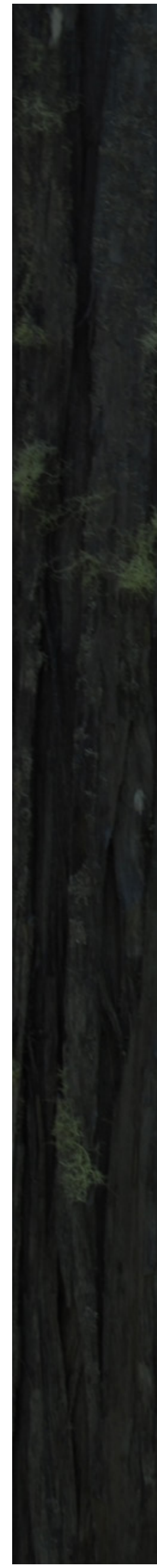

1. Introduction

1. Introduction

Chile voluntarily presents its subnational Forest Reference Emission Level/Forest Reference Level (FREL/FRL) for native forests, as part of Chile's commitment to the United Nations Framework Convention on Climate Change (UNFCCC) and in response to the invitation extended by the UNFCCC under decision 12/CP.17 paragraphs 9 and 11. In doing so, Chile adheres to the Convention's objective to encourage developing countries to develop and implement policies and measures to promote reducing emissions from deforestation and forest degradation, conservation, sustainable management of forests, and the enhancement of forest carbon stock, also known as REDD+.

As stated in decision 12/CP.17 paragraph 7 of the UNFCCC, an FREL/FRL is a benchmark with which to evaluate the effectiveness of the country's implementation of REDD+ activities. A FREL/FRL must create a historical inventory of greenhouse gases (GHG) found in the country and future projections of these to use as a reference when evaluating the effectiveness of the implemented policies related to REDD+ activities.

This document and its annexes were prepared in accordance with the modalities and guidelines established in decision 12/CP.17 Section II and Annex, and following the Guidelines for National Greenhouse Gas Inventories by the Intergovernmental Panel on Climate Change (IPCC, 2006). This document also includes the assumptions used in the National Greenhouse Gas Inventory (NGHGI for its initials in Spanish) of Chile for the time period 1990-2010, consigned to the Secretariat of the Convention in 2014 through the first Biennial Update Report (BUR).

This submission was conducted on a subnational scale which included 5 regions of the country with high native forest coverage. Additionally, the same area was used in the Emissions Reduction Program, which Chile is currently developing to be submitted to the Forest Carbon Partnership Facility.

A "step-wise" approach has been applied that will allow for improvements and expansion of the FREL/FRL to a national scale as methods are optimized and new information is developed.

The submission has been developed in consistency and congruency with NGHGI of Chile, and presents all the information and methods in a transparent, complete and precise manner including:

- The definition of forest used by Chile for the purpose of REDD+ activities, as well as a definition for each of the 5 REDD+ activities;
- The resources and methodological protocols used to construct the Chilean subnational FREL/FRL;
- The carbon and other GHGs considered in the FREL/FRL of each REDD+ activity.

The FREL/FRL presented in this document has been developed by National Forest Corporation (CONAF for its initials in Spanish) of Chile through a joint project headed by the Climate Change and Environmental Services Unit (UCCSA for its initials in Spanish) and the Department of Forest Ecosystem Monitoring. Technical support was provided by the World Bank, who also acts as the Facility Management Team of the FCPF, and voluntary funds Chile in its progress with REDD+ activities. The technical team also received support from Winrock International, the Austral University of Chile (UACh for its initials in Spanish), the Forest Institute (INFOR for its initials in Spanish) and the agencies of the United Nations, FAO, UNEP, UNDP, affiliated with the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation (UN-REDD), which Chile has participated in since 2014.

2. Background

a. National Circumstances

As the main focal point to the UNFCCC for REDD+ activities in Chile, CONAF has decided to focus its efforts in developing the FREL/FRL in the subnational area of the central-southern zone of Chile. This area contains the highest concentration and largest variety of forests in the country, as well as a strong anthropogenic presence. This subnational area is covers 5 administrative regions, since Maule Region to Los Lagos Region (Figure 1.). The temperate rainforest ecosystem is found in this area, which has a large potential to reduce/absorb GHG emissions, and the capacity to produce non-carbon environmental benefits, such as: improving the water balance, soil preservation, maintaining biodiversity, and allowing communities dependent upon these ecosystems to access the positive ecological benefits of these services. These 5 regions represent 22% of the total surface area of Chile (16,522,077 hectares), and contain 41% of the native forests (5,853,387 hectares) which represent 11 of the 12 types of national forests.

i. Institutionally

Following Chile's ratification of the UNFCCC in 1994 and joining the Kyoto Protocol in 2002, the institutionalization of climate change in the country has registered important advances that have been reflected in the implementation of the Council of Ministers for Sustainability and Climate Change (CMSCC for its initials in Spanish) in 2014. CMSCC deliberates on public policies and general regulations regarding environmental material. The council is presided over by the Ministry of the Environment[1].

Since 2010, when the Ministry of the Environment of Chile was formed, it has been the Chilean focal point in the UNFCCC. This enables better coordination and orientation of governmental actions in addressing the challenges and opportunities imposed by climate change for public policies[2]. Prior to the creation of the Ministry of the Environment and following Chile's ratification of the UNFCCC, the National Advisory Committee for Global Change (CNACG for its initials in Spanish) was established. It is composed by representatives of the public sector and academy. In 2006, the CNACG developed the National Strategy for Climate Change[3] which establishes the main objectives of adaptation, mitigation, and the promotion of capacity-building. These are executed through the National Action Plan for Climate Change (PANCC) 2008-2012 which is currently in the process of being updated for the 2016-2021 term[4].

1 The Ministries that make up this institution are Agriculture, Treasury, Health, Economy, Development and Reconstruction, Energy, Public Works, Housing and Urban Development, Transportation and Telecommunications, Mining, and Social Development.

2 Ley 20.417, Article 70, sub-clause h, specifically states "(...) it be part of the MMA duties to propose policies and formulate plans of action in the matter of climate change. "Original text in Spanish: "(...) le corresponderá especialmente al MMA el proponer políticas y formular los planes, programas y planes de acción en materia de cambio climático".

3 Strategy for Climate Change, http://www.enccrv-chile.cl/descargas/consulta-ciudadana/6-estrategia-nacional-de-cambio-clim%C3%A1tico-y-recursos-vegetacionales-2017-%E2%80%93-2025/file

4 Proposal for structure and content for Plan de Acción Nacional de Cambio Climático 2016-2021 (National Plan of Action for Climate Change 2016-2021). http://portal.mma.gob.cl/wp-content/uploads/2015/08/Propuesta-contenidos-PANCC-2016-2021-Fase-II-Licitacion_con-anexos.pdf

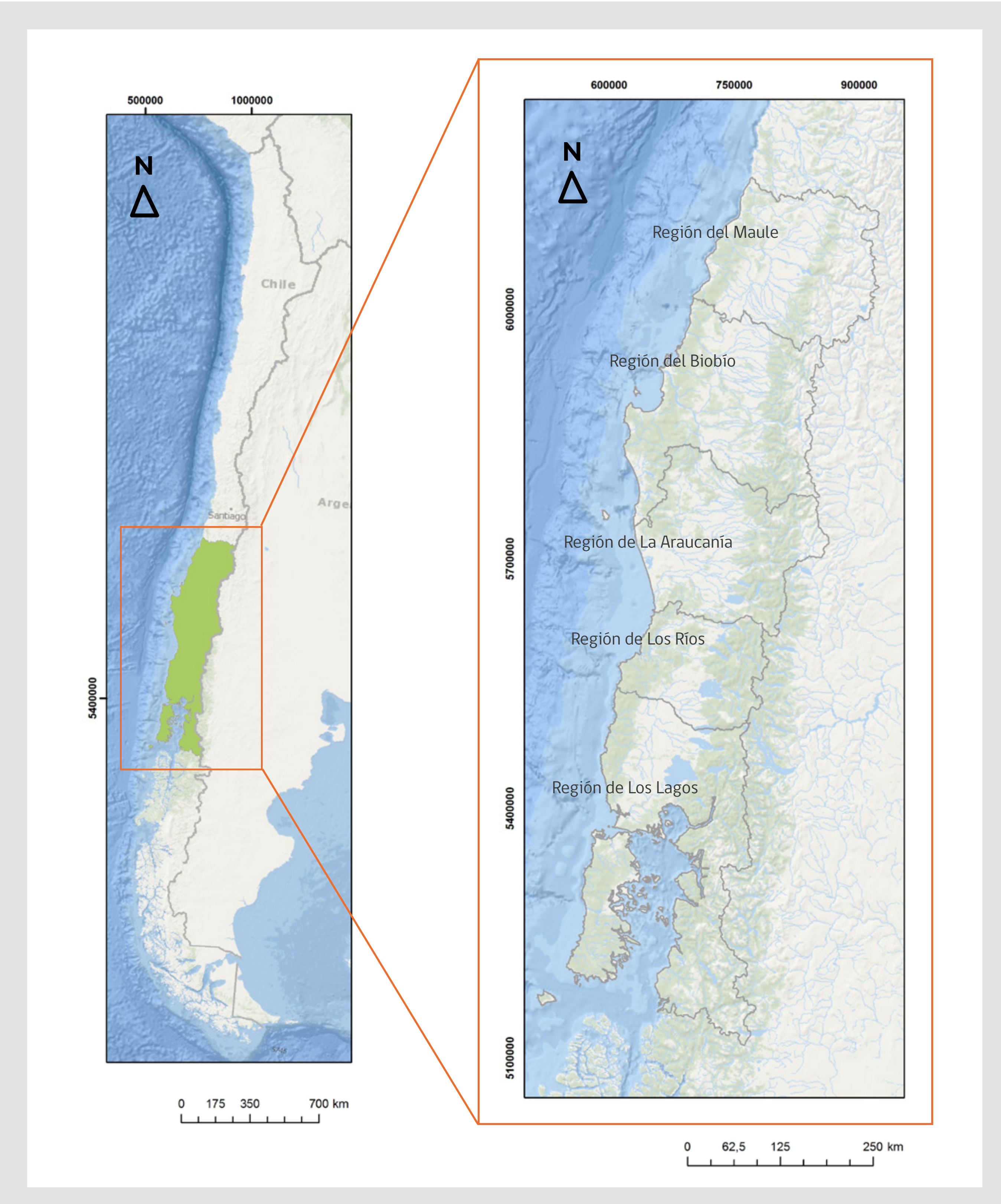

Figure 1. Area included in the subnational FREL/FRL of Chile.

In 2010, the Ministry of Environment was created, and along with the Climate Change Office, with the support of the Secretariat of the Ministry of Environment, has the mission to actively participate in "the process of international negotiations associated with the implementation of the UNFCCC whose mandate is: to coordinate the Committee of the Designated National Authority (DNAA) of the Clean Development Mechanism (CDM), act as the focal point for the Intergovernmental Panel for Climate Change (IPCC) and to hold the post of technical secretariat in the inter-ministry committees on climate change"[5, 6].

In this context and due to the complexity of the topics that are discussed in the UNFCCC regarding Land Use, Land Use-Change and Forestry (LULUCF), and those specifically related to the decisions of the Convention that promote establishing national strategies for reducing emissions caused by deforestation and forest degradation, and encouraging the role of conservation, sustainable management of forests and the enhancement of forest carbon stock (abbreviated as REDD+), the National Forest Corporation of Chile (CONAF), an independent institution of the Ministry of Agriculture (MINAGRI) was designated as the focal point for REDD+[7] activities in Chile. CONAF fulfills this role specifically though the Climate Change and Environmental Services Unit (UCCSA) of the Administration of Forest Promotion and Development (GEDEFF).

CONAF's mission is the sustainable management of native forests, xerophyte plants and forest plantations by fostering development, the enforcement of environmental and forestry-related legislations and the protection of vegetation resources, such as the conservation of biological diversity through The National System of Protected Wild Areas (SNASPE), for the benefit of society, having as strategic objectives:

1. Supervise and encourage the sustainable management of native forests, xerophyte plants and forest plantations and the protection of protected species, through the application and dissemination of forestry and environmental legislations;

2. Improve access for small and medium-sized producers of forestry products and indigenous people, for the benefits of forestry activities and conservation tourism, through the use of instruments that promote forestry and offer technical assistance for the valuation of their goods and services in accordance to other public services;

3. Encourage the development of environmental services through the promotion and care of urban trees, peri-urban parks, and natural infrastructure, and other types of plants with patrimonial and cultural value, and disseminating the benefits they provide for society;

4. Protect society from the threat created by forest fires, forest pests, invasive forest tree species, and the effects of climate change affecting native forests, xerophyte plants, planted forests, and patrimonial components present in the SNASPE;

[5] First BUR from Chile for the UNFCCC. MMA, 2014. Pg 55. http://portal.mma.gob.cl/wp-content/doc/2014_1IBA_Chile_Espanol-1.pdf

[6] Original text in Spanish: "en los procesos de negociación internacional asociados a la implementación de la CMNUCC, cuyas funciones son: coordinar el Comité de la Autoridad Nacional Designada (AND) del Mecanismo de Desarrollo Limpio (MDL), actuar de punto focal del Grupo Intergubernamental de Expertos sobre el Cambio Climático (IPCC, por sus siglas en inglés) y ostentar el cargo de secretaría técnica de los comités interministeriales en cambio climático".

[7] This assignation was based on the decision accorded by the CoP-19 in Warsaw where countries were invited to nominate focal points or Designated National Entities for REDD+, through the Carta Oficial N°99 of February 19, 2014 the Ministry of Agriculture Mr. Luis Mayol, directed towards his counterpart in the Ministry of Foreign Affairs who formalized this assignation before the Secretariat of the Convention.

5. Preserve the biological diversity, through the reinforcement of SNASPE, other instruments of conservation and support of native forests and xerophyte plants contributing to a better quality of life for society and the local communities.

Due to its role as State's forest service, CONAF, in 1995, was appointed as the focal point for the United Nations Convention to Combat Desertification (UNCCD) in Chile. This appointment broadened the spectrum of CONAF's tasks, compelling the institution to integrate into their efforts the necessary actions to respond to the commitments rising out of both Conventions alongside the obligations imposed upon them in their institutional role. In addition, as the technical advisor for MINAGRI, CONAF must lead coordination with other ministry institutions that contain Chilean forest expertise.

In 2014, the Interministerial Technical Committee on Climate Change (CTICC) was created. It is coordinated by the Office of Agrarian Studies and Policies (ODEPA), which unites the different services that comprises the MINAGRI[8], including CONAF. It is expected that soon CTICC will have representation in all 15 regions of the country, and be presided over by the Regional Ministerial Secretariat (SEREMI) of Agriculture with the participation of representatives of the diverse Agroforestry sector of public services.

In September 2015 Chile consigned before the Secretariat of the UNFCCC, its participation with the Intended Nationally Determined Contribution (INDC)[9], through this, acknowledging the importance of the agreements reached in the Conference of the Parties to the UNFCCC (CoP) held in Paris in December 2015 (CoP 21). As part of the specific commitments in the LULUCF sector, the country committed to the sustainable management of 100,000 hectares of forest, primarily native forests, as well as the reforestation of 100,000 hectares of primarily native species.

As the INDC documents indicate, the achievement of these commitments will be backed through the implementation of the National Strategy for Climate Change and Vegetation Resources (ENCCRV in Spanish) that impels CONAF to collaborate with different actors on a national and regional level in the forestry sector. As is the case with Information Center of Natural Resources (CIREN), which contributed to the development of the definitions of deforestation and degradation of native forests drivers, or INFOR, which has contributed to the development of the FREL/FRL of Chile, as well as provided improvements to the measurement, reporting, and verification (MRV) required.

The objective of the ENCCRV is to "To reduce the social, environmental and economic vulnerability caused by climate change, desertification, land degradation and drought on vegetation resources and human communities that they depend on them, in order to increase the resilience of ecosystems and contribute to mitigate climate change, promoting emission reductions and removals of greenhouse gases in Chile[10]"[11].

[8] Other institutions of the MINAGRI that have responsibalities regarding the forests are Oficina de Estudios y Políticas Agrarias (ODEPA), Instituto de Desarrollo Agropecuario (INDAP), Fundación para la Innovación Agraria (FIA), Instituto de Investigaciones Agropecuarias (INIA), Instituto Forestal (INFOR), Centro de Información de Recursos Naturales (CIREN), Servicio Agrícola y Ganadero (SAG).

[9] Intended Nationally Determined Contributions for Chile (INDC) Paris Climate Agreement 2015. Gobierno de Chile, 2015. http://portal.mma.gob.cl/wp-content/uploads/2015/09/INDC_1609c1.pdf

[10] Original text in Spanish: "Disminuir la vulnerabilidad social, ambiental y económica que genera el cambio climático, la desertificación, la degradación de las tierras y la sequía sobre los recursos vegetacionales y comunidades humanas que dependen de éstos, a fin de aumentar la resiliencia de los ecosistemas y contribuir a mitigar el cambio climático fomentando la reducción y captura de emisiones de gases de efecto invernadero en Chile".

[10] Intended Nationally Determined Contributions for Chile (INDC) Paris Climate Agreement 2015. Gobierno de Chile, 2015. Pg. 13.

ENCCRV in concerned with the key elements in the area of adaptation to climate change and fights against desertification, degradation of the land and drought, the objectives of UNCCD, as well as with the REDD+– related decisions of the UNFCCC. As such, within this framework, initiatives are developed to achieve the goals defined by the INDC for the LULUCF. These initiatives are then implemented with adjustments for the information system and management that enables the maintenance and increase of forest reserves of GHG, how to avoid emissions by stabilizing and reducing the rates of deforestation and native forest degradation, and to later receive the benefits associated with the positive performance of the actions, which within the context of REDD+ is the exchange of payment for results. As such, in CoP 21 a definition of the international financial structure was provided in order to ensure the sustainability through time of these national initiatives given by the Green Climate Fund (GCF).

It is within this context that the work associated with ENCCRV coordinated by CONAF acquires relevance, as it represents a pilot element for the technical mechanisms and the national finances that must be achieved, by giving certainty to the conditions and elements that will need to be developed, in relation to payment schemes for replicable results on a national scale and equally valid internationally.

ii. Legislations

In the recent history of our country, different legal norms have directly and indirectly related to the protection of forests. The application and validity of these legal bodies have had significant impact on the development of the country, and dictate the current situation of forest resources, as summarized in the previous section.

The first legal norm pertinent to the forest sector with continued relevance to date is **Forest Law** (Decree-Law 656) of 1925 according to the consolidated text established by Supreme Decree 4363 of 1931 by the Ministry of Lands and Colonization. This law highlighted the importance of the forests, their protection and improvements of their lands, for the regulation of river flows, for the general conservation of water resources, as sources of primary materials for numerous industries and as a source of health for the population. Additionally, this law improved the norms regarding the use of fire, the application of sanctions, and the norms concerning National Parks and Forest Reserves. However, the most significant attribute of this law was the incorporation of prohibitions which are still applied to date, which prevents the cutting of native trees and shrubs close to springs or on terrain with an inclination of more than 45%.

The Forest Law upheld the ban on the use of fire to enable new forest areas, and established in regards to protected wild areas, the creation of Tourism National Parks and Forest Reserves, through the power of the President.

Finally, the Forest Law established penalties for violations of these prohibitions, ranging from monetary fees to jail term (Saelzer, 1973).

The second legal norm and probably the most relevant for the forest sector, is the Decree-Law 701 on Forest Promotion. It was promulgated in 1974, starting a forestry policy supported on the two main pillars of incentive for forestation and the protection of the forest resources.

Within this framework, the appraisal of territories as Suitability for Forest Lands (APF, in Spanish), through a technical-judicial amendment which decrees that a forester must appraise the land as un-arable land, through climate and soil conditions, and that its use in agriculture, fruit crops, or animal husbandry will lead to degradation. Once the appraisal of the land has been approved by the authorities, the landowner is granted rights such as tax exemptions, and the possibility of receiving monetary remunerations for forestation. This also generates, through Article 22, the obligation to replant after cutting or exploitation of the forests.

Moreover, an additional technical-judicial amendment Management Plans was incorporated in 1979 by Decree-Law 2565, which modified the Article 2 of Decree-Law 701 of 1974, declaring it a legal body to regulate the use and sustainable management of renewable natural resources in a determined area, with the objective of maximizing the benefits, assuring the preservation, conservation and increase of these natural resources and their ecosystem.

This legal body formed the central axis of the system and is a program for the sustainable use of forestry national resources of native forests or planted forests. As such, the management plans have two dimensions, a technical dimension which is written by a forest engineer or a specialized agronomist who must, amongst other duties, provide a profile of the site and the forestry resources, define the objectives of the management plan and the silviculture treatment; and a legal dimension, which once the appraisal and management plans are approved, are granted the power to impose sanctions on the landowner for noncompliance with the management plan.

The Supreme Decree 259 of 1980 modified Decree-Law 701 through a technical regulation that provided the legal definitions of the Forest Types for native forests in Chile, and also established the silvicultural methods that can be applied to each type.

The Decree-Law N°701 included three types of regulations, the right to property, tax incentive and economic incentives. The latter two regulations include a monetary remuneration given by the State for the reforestation and the initial management of planted forests in lands that have been labeled suitable for forest lands in accordance to the previously approved management plans. The state "will reimburse, only once, a percentage of the net costs for every area where diverse activities such as forestation of fragile and degraded lands, activities of soil recovery or sand dune stabilization, planting of windbreak ridges, and the first pruning and thinning amongst others have been performed by small forest property owners[12]" [13, 14]. The law does not include incentives for the sustainable management of native forests.

Due to Decree-Law 701 of 1974 with its many modifications, Chile has received recognition as one of the countries with the highest indices of forestation, in relation to its size and population. Due to these conditions, one of the biggest national industries of Chile is the production of cellulose and sawn timber of introduced fast-growing forest species.

[12] Before 1998 forestry companies received for many years a supplementary pay for the trimming and thinning as well as payments for management. After Ley N° 19561 in 1998 this was given to small and medium properties.

[13] Original text in Spanish: "bonifica, por una sola vez en cada superficie un porcentaje de los costos netos de las diversas actividades como forestación en suelos frágiles y degradados, actividades de recuperación de suelos o de estabilización de dunas, establecimiento de cortinas cortavientos, y la primera poda o raleo realizadas por pequeños propietarios forestales, entre otras".

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

The economic incentive for forestation activities under Decree-Law 701 expired in 1996, and in 1998 with Law 19.561 these incentives were extended until 2011. In 2011, the law achieved its last extension until 2012 after which, the law no longer held an incentive component.

Since 2013, Chile no longer has any legal economic incentives for forestation; however Chile is currently working on developing a new law using a different approach. The new law should aim to promote the establishment of planted forests of primarily native species for permanent cover, with balanced aspects between industries and the provision of environment services, such as water source protection, production of non-timber forest products, and the protection of biological diversity. Projections for the new Law of Promotion propose that by 2016, significant advances in the formulation and parliamentary processing would have taken place.

The most recent law, **Law 20.283** Recovery of Native Forest and Forest Promotion was promulgated in 2008, after a 16 years debate, due to its intentions to include the interests of all parties regarding native forests.

This law calls for the protection, recovery and improvement of native forests; thus ensuring forestry sustainability and environmental policies. The law includes 26 definitions of concepts and elements aimed to unify criteria and improve understanding of the document. Many of the definitions in this document were modified from definitions used in previous documents. Amongst the most relevant definitions are the definitions for forest, native forest, small forest landowner, management plan, and environmental services.

For the definitions of the forest types and the methods to manage them, Law 20.283, looked to Decree-Law 701 from 1974 for the established definitions. However, the law establishes a need to create a new typology based on scientific studies and validated by the public and private parties of the field. It has been nine years since its promulgation, and this clause has yet to be updated.

Additionally, Law 20.283 established that CONAF will maintain a permanent forestry cadaster where it will identify and describes, cartographically, the types of forests found in each region, the state of the forest, and the location of forest with native forest ecosystems of special interest for conservation and preservation. The law established that the must be updated at least every 10 years and the information made available to the public. As such, CONAF has established the Territorial Information System (SIT, in Spanish) web site for the distribution of its updates.

Through Law 20.283 the concepts of the Management Plan of Decree-Law 701 are complemented with the onset of the Management Plan for Preservation. The new management plan is an alternative tool for forests aiming for preservation and recovery of native forests, with ordination management plans. Additionally, monetary incentives are proposed for projects that include methodologies for forest management that ensures the sustainable management of the land in the long run.

Law 20.283 proposed environmental protection norms for the conservation of biological diversity, and the prevention and suppression of forest fires. Under the law's regulation of soils, waters and wetlands, restrictions on logging and commercial exploitation are dependent on given conditions and resources; it includes measures for soil protection and the quality and quantity of flow rate in rivers.

As a means of accessing the incentives for native forest management the Fund for Conservation, Recovery, and Sustainable Management of Native Forests was created. The Fund functions as a grant-fund destined for the conservation, recovery, or sustainable management of native forests. The remunerations are expected to contribute to the costs of regeneration, recovery or protection of xerophyte plants of high ecological value or the preservation of native forests for non-timber products, and the management and recovery of native forests used for timber production. Additionally, remuneration is granted for forestry management plans passed on ordination criteria. Law 20.283 also established an annual fund of 8 million USD for the Fund. However, after six years, annual use of the funds has not exceeded 15%. Attempts to rectify this situation are underway through suggested changes to the law and changes in management and administration of the law through CONAF.

The Fund for Native Forest Research (FIBN, in Spanish) was created as a complementary fund that aims to promote and increase the understanding of forestry ecosystems.

The details for the operation and implementation of the funds were established in the regulations of Law 20.283, which have been modified twice since its promulgation.

During the seven years since the creation of the Fund for Native Forest Research, 98 projects have received funding totaling $ 4,322,918,033 Chilean Peso (Table 1).

Requests For Proposals	Year	Number of Projects	Funding
I Edition FIBN	2009/2010	23	$ 638.873.395
II Edition FIBN	2010/2011	21	$ 798.298.409
III Edition FIBN	2011/2012	18	$ 533.001.412
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
Total		**98**	**$ 4.322.918.033**

Table 1. Number of projects and funding for the FIBN request for proposals by year. Source: CONAF.

Written in the investigation parameters for the request for proposals for FIBN VII of 2015, and relevant input in the framework of the ENCCRV, establishes in Line 5 "Development of allometric equations for the calculation of carbon stocks in native forests at a national level"[15] and "Developing allometric equations to determine the amount of carbon above and below ground for the calculation of carbon stock in the next update of the Greenhouse Gas Inventory of Chile and for the monitoring of mitigation strategies for climate change with the State fosters through the National Forestry Corporation to compliment initiatives developed on the matter in the sector…"[16]. The funding budget of $65,500,000 Chilean Pesos is also determined the document.

b. Description of national forest lands

Continental Chile possesses extensive and complex forest resources, which is determined by the wide latitudinal distribution which spans between latitudinal lines 18° and 56°. This geographical condition generates a climatic gradient that begins with arid and semi-arid environments dominated by desert climates in the extreme north, temperate environments dominated by a Mediterranean climate in the central zone, and humid, cold, oceanic and sub-Antarctic climates as the forest progresses to the south.

This gradient combined with the predominantly mountainous physiographic territory (80% of the national territory) has generated ideal conditions for the development of a rich diversity of native forest ecosystems composed of discrete and continuous communities that are distributed along the territory occupying 14 million hectares.

These conditions combined with the historical process of the transformation of the landscape have also generated, in Chile, an extension of monoculture forestry of almost 3 million hectares, which is predominantly located in the temperate zone, the majority of which is dedicated to timber and cellulose pulp industry (Table 2).

Forestry Lands	Surface area (ha)	%
Forest Plantations	3.036.407[17]	17%
Native forest	14.316.822	82%
Mixed forest	167.620	1%
Total	**17.520.849**	**100%**

Table 2. Forestry lands in Chile. Source: sit.conaf.cl

[15] Original text in Spanish: **"Desarrollar funciones alométricas para estimar existencias de carbono en bosque nativo a nivel nacional"** http://www.investigacion.conaf.cl/ayuda/varios/2016/Lineas_Investigacion_VII_concurso_2016.pdf

[16] Original text in Spanish: *"Desarrollar funciones alométricas para determinar carbono bajo y sobre el suelo como sustento para la contabilidad de carbono a incluir en próximas actualizaciones del Inventario de Gases de Efecto Invernadero (NGHGI) de Chile y para el monitoreo de las opciones estratégicas de mitigación al cambio climático que impulsa el Estado a través de la Corporación Nacional Forestal (CONAF), para complementar iniciativas equivalentes que se desarrollen en la materia, en el sector…"* http://www.investigacion.conaf.cl/ayuda/varios/2016/Lineas_Investigacion_VII_concurso_2016.pdf

[17] This number is derived from the latest regional updates to the Cadastre and can be found in sit.conaf.cl, this data differs from the data register for INFOR in the Permanent Program for Updates Forests Plantations, where planted forests are considered to be 2,447,591 hectares. This variation is due to the different methodologies applied and the dates of updates of both reports.

Therefore, 23% of the national surface territory is forest lands. An additional portion of the surface area is composed of grassland and shrubland formations (27%) (Table 3). An important portion of the grasslands and shrublands are actually forests in an advanced stage of degradation which have the potential for restoration, as is the case with other degraded lands that are currently without tree vegetation and possess the potential for reforestation.

Land use	Surface area (ha)	%
Industrial and urban areas	354.135	0%
Agricultural lands	3.335.157	4%
Grasslands and shrublands	20.320.990	27%
Native forests and forest plantations	17.520.849	23%
Wetlands	3.596.533	5%
Areas without vegetation	24.675.320	33%
Snow and glaciers	4.156.261	6%
Bodies of wather	1.343.762	2%
Unrecognized area	283.198	0%
Total	**75.539.056**	**100%**

Table 3. Land use in Chile by area of land 2015. Source: sit.conaf.cl

i. Native Forest

The important portion of the territory covered by native forest lands have been described and classified, and a wide classification of forest communities have been found within the country. Nonetheless, the system of categorization, established as the legal method for classification according to the current forestry legislation, defines 12 forest types for Chile (Table 4). This classification that has been present for three decades is a practical simplification of the enormous diversity of the conditions of the natural forests. This classification is used for the regulation of resources and functions that are the basis for the forestry management system.

The regions with the most forest coverage in Chile are located in the Southern and Austral zones including more than 80% of the native forests in the country. They also possess a large diversity of forest types, especially in the regions of Los Rios and Los Lagos which have 9 of the 12 described forest types.

The most prominent types of forests are the Siempreverdes and the Lenga. Each one has a total surface area of 25% of native forests and are present in 8 and 7 regions respectively.

As seen in Figure 2, the forest types are distributed along a transitional gradient where the different forest types are incorporated, mixed and separated as the forest progresses through the latitudes.

In the Norte Grande natural region, a small surface area is covered by a natural semi-wooded species, primarily xerophyte species (adapted to the arid climates) such as the Queñoa *(Polylepis tarapacana)* and other similar species which are isolated from the rest of the forests due to the Atacama Desert. These species have a total surface area of 54,451 hectares dispersed in small groves (Teillier, 1999). In the region of Tarapacá, the protected National Reserve Pampa del Tamarugal covers an area of 27,000 ha of planted forests with species of the genus *Prosopis*. This was a reforestation initiative by the State that has prospered in the most arid desert of the world for many decades. This resource has generated an oasis of biological diversity in the zone, and a source of timber and non-wood products for the neighboring communities, primarily firewood and forage for the livestock. The large portion of the extraction of these goods is executed through formal plans managed and supported by CONAF.

To the south of Norte Chico natural region begins the appearance of xerophytes and sclerophyll plants (hard leaves with sclerenchyma) in greater quantities. The latter ones give the name to the main forest type of these zones, and they are dominated by species that are adapted to the temperate Mediterranean climate, with periods of prolonged summers. In conditions with higher water availability and to the south of this zone, sclerophyll forests appear; in some sectors, these forests reach important sizes and levels of coverage (Lubert y Pliscoff, 2006).

It is important to mention that Mediterranean ecosystems present the highest amount of biodiversity in the country, and also present strong anthropogenic alterations. This is due to the changes of forest land use for agricultural and urban purposes, fires, and overgrazing, and for the unsustainable use of the forests, grasslands and xerophyte plants that have been used as a source of combustion and other primary goods. The use of these resources occurs in an informal manner, which leads to difficulty in evaluating the degradation process.

Although there is potential for these ecosystems to generate timber-based products and non-timber chemical products of high value (e.g. Saponins from *Quillaja saponaria*; Boldinas of *Peumus boldus*) and conservation services that allow for sustainable management, conservation of these forests occurs on a small scale due to the current state of forest degradation and the small amount of public and private investment for the recovery of these resources, which are the last natural barriers against desertification (Honeyman *et al*, 2009).

In the south zone, the temperate humid climate gives way to forests dominated by deciduous species of the genus *Nothofagus* where the forest types Roble-Hualo *(Lophozonia Glauca)* and Roble-Rauli-Cohiue *(Lophozonia Alpina)* trees dominate the landscape and create complex ecotone transitions.

Most of these types of forests are in a state of removal or secondary forest. They are secondary forests generated subsequent to the process of overexploitation, forest fires, or reforestation of the lands abandoned by agriculture. Additionally, in the 1980s, many of these forests were lands that were converted into forest plantation (substitution) mostly in the regions of Maule and Biobío (Donoso *et al*, 2014).

Forests dominated by *Nothofagus* are dense forests, reaching great heights (more than 40 meters) with canopy coverage of over 100%. Most of these forests are coeval forests (meaning of the same age) and tend to form pure forests or forests with few dominant species, therefore, their management is simpler. These characteristics are largely due to the formal management of forestry activities that are mostly conducted on these secondary forests. Additionally, the forests commercial use is marginal compared to the industry of introduced species of rapid growth.

The areas of high altitude in the forests of the South zone are dominated by the Lenga forest type. Forests of these deciduous species also belong to the genus *Nothofagus*, these grow in a shrub-like manner, an adaptation to the complex environmental conditions. At higher altitudes the Lenga shrinks and is dominant in the Austral zone until it reaches sea level (Donoso, 2015).

In the south zone the forest areas are dominated by conifer trees, such as the *Araucaria Araucana* (Araucaria), the *Fitzroya cupressoides* (Alerce), and Cipres de las Guaitecas *(Pilgerodendron uviferum)*, species that give origin to three forest types of similar names. The Araucaria forests, like the Alerce, are currently protected by law, due to their critical conservation condition that arose after decades of overexploitation, caused by the high wood quality and durability (Donoso, 2015). They are included in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Continuing towards the south the Siempreverde forest type appears, one of the two most important forest types in the area, which is dominated by perennial species of different gender and families. These make up forests such as the Valdivian Rainforest or Cold Rainforest due to its high biodiversity and stratification. These are big forests with thick density and coverage, accumulating high levels of biomass per hectare.

These forests are extensive, complex and of large variety, reasons for which five subtypes are identified: the forests on Ñadís soil, forests of Olivillo *(Aextoxicon punctatum)*, the evergreen forests with intolerant emergents, evergreen forests with tolerants emergents, and the secondary forests of Canelo, all of these cover a large area of the regions Los Lagos and Aysen, especially in the coastal zone of channels and archipelagos (Donoso, 2015).

The Siempreverde forests also experience anthropogenic alterations caused by overexploitation, forest fires, overgrazing and land use changes. On a smaller scale, conversion of forest lands to planted forests and the adaptation of the lands for agriculture and livestock also occur in these forests.

Despite the Siempreverde forests complexity, these forests are also managed for the harvest of wood products, primarily firewood and non-timber. A frequent practice is also the selective extraction of individual trees of higher quality and bigger dimensions (described at the national level as Floreo, or thinning) destined for the timber production industry. As with the previously mentioned types, the informality of these activities is a significant issue for the sustainable management and conservation of the resources (Donoso *et al*, 2014).

	Forest Type (ha)					
Region	Alerce	Ciprés de las Guaitecas	Araucaria	Ciprés de la Cordillera	Lenga	Coihue de Magallanes
Arica y Parinacota	–	–	–	–	–	–
Tarapacá	–	–	–	–	–	–
Antofagasta	–	–	–	–	–	–
Atacama	–	–	–	–	–	–
Coquimbo	–	–	–	–	–	–
Valparaíso	–	–	–	49	–	–
Metropolitana	–	–	–	76	–	–
O'Higgins	–	–	–	2.901	–	–
Maule	–	–	–	8.893	8.692	–
Biobío	–	–	39.918	18.233	136.472	–
La Araucanía	–	–	199.460	13.560	108.655	–
Los Ríos	7.770	83	13.961	–	143.023	4.337
Los Lagos	208.360	43.088	–	19.163	509.898	126.502
Aysén	–	159.334	–	–	1.400.376	939.166
Magallanes y La Antártida	–	377.462	–	–	1.314.089	929.346
Total	**216.130**	**579.966**	**579.965**	**62.875**	**3.621.025**	**1.999.351**

Table 4. Regional distribution of the types of forest. Source: CONAF.

Lastly, in the Austral Zone the predominant forest types are Lenga *(Nothofagus pumilio)* and Cohiue de Magallanes *(Nothofagus betuloides)*, with these species forming either pure or mixed forests. These forests can cover large areas of land and have high canopy coverage; however they have less biodiversity than other types of forests that are present in the temperate and Mediterranean zones. Forests in the Austral Zone cover a large expanse of territory where the anthropogenic effects are significantly less, due to low population density. However, forest fires that have affected the area in the past century have devastated a large portion of these forests and caused transformation into cattle farms (Donoso, 2015).

The management of these forests, particularly those dominated by Lenga, produces the largest amount of native sawn timber for exportation, highly valued products in foreign markets for the aesthetic and structural characteristics of the wood[18].

[18] www.infor.cl

Forest Type (ha)						
Roble-Hualo	Roble-Raulí-Coihue	Coihue-Raulí-Tepa	Esclerófilo	Siempreverde	Palma Chilena	Unclassified
-	-	-	-	-	-	47.151
-	-	-	7.300	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	31.096	170	-	-
1.224	-	-	475.194		7.648	-
10.348	-	-	350.437	-	3.094	-
33.187	-	-	418.878	-	4.343	-
161.973	153.432	-	50.977	747	-	-
13.724	480.840	47.875	19.205	12.285	-	-
-	470.860	120.421	636	50.562	-	-
-	252.801	280.321	203	206.032	-	-
-	244.655	393.084	499	1.282.188	-	-
-	-	-	-	1.899.869	-	-
-	-	-	-	50.697	-	-
220.456	**1.602.588**	**841.701**	**1.354.425**	**3.502.550**	**15.085**	**47.151**

In conclusion, although Chile possesses an extensive and diverse national forest resources, its current use does not present a significant contribution to the Gross Domestic Product (GDP) (representing only 3% of the total forestry exportation sales for the country). Additionally, due to the informal nature of control and management, there is no accurate calculation of the use and exploitation of the resources. However, unofficial data suggest that could be over 80%. Today native forests are essentially providers of environmental services, suppliers of biomass for wood energy use by communities and cattle shelter. These last two services and fires have caused degradation on a significant surface area.

Due to the decades-long extensive mismanaged use of these forests, a significant portion of the ecological and economic value of these forests has been lost, diminishing the capacity of the forests to provide goods and services such as the capture and storage of carbon. This generates a substantial loss of natural capital and significant GHG emissions. This phenomenon has also encouraged the abandonment of the forests, deforestation and permanent land-use change to other private and higher production value uses, increasing emissions levels due to misuse of the resources (Donoso *et al*, 2014).

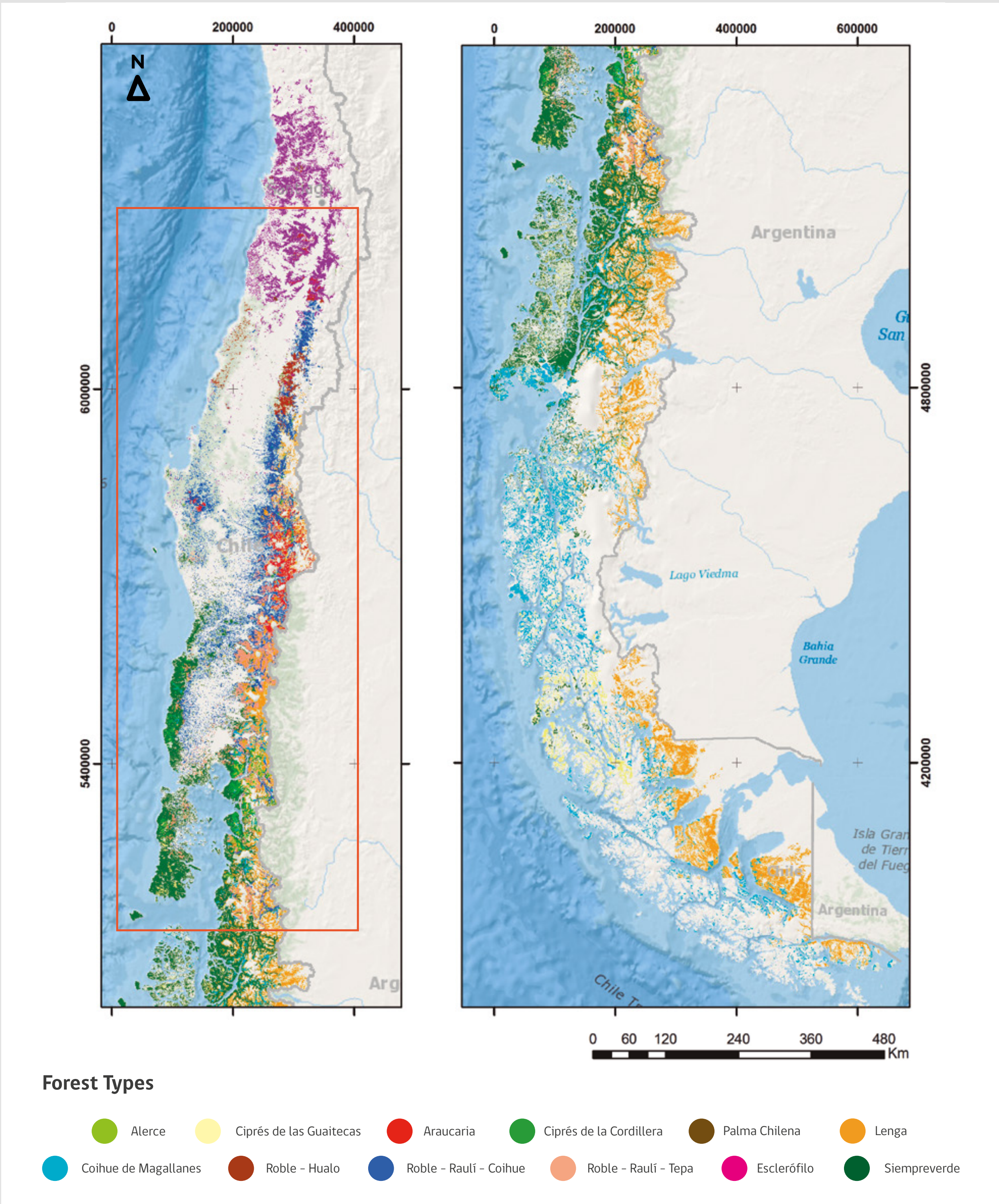

Figure 2. Map of forest type distributions. Source: Prepared by authors.

ii. National System of Protected Wild Areas (SNASPE)

SNASPE possesses under its administration a n area of 14.5 million hectares, a large amount by international standards, within which exists a representation of the native forests that are in an official state of conservation and preservation of lands such as wetlands, salt pans, and other zones of non-forest lands. (National Parks and Reserves) (Table 5 and Figure 3).

Region	Number of SNASPE areas	Area (ha)
Arica y Parinacota	5	366.073
Tarapacá	3	384.011
Antofagasta	11	355.355
Atacama	3	143.555
Coquimbo	4	14.286
Valparaíso	5	21.913
Metropolitana	3	22.065
O'Higgins	1	38.299
Maule	9	17.532
Biobío	7	127.121
La Araucanía	13	277.326
Los Ríos	2	32.161
Los Lagos	11	869.178
Aysén	21	5.070.583
Magallanes y La Antártida	10	6.921.275
Total	**108**	**14.660.733**

Table 5. Regional distribution of SNASPE. Source: CONAF.

At the same time, in Chile there is a growing conformation of Private Protected Areas (PPPs) that are created by different motivations, from altruism to ecotourism development.

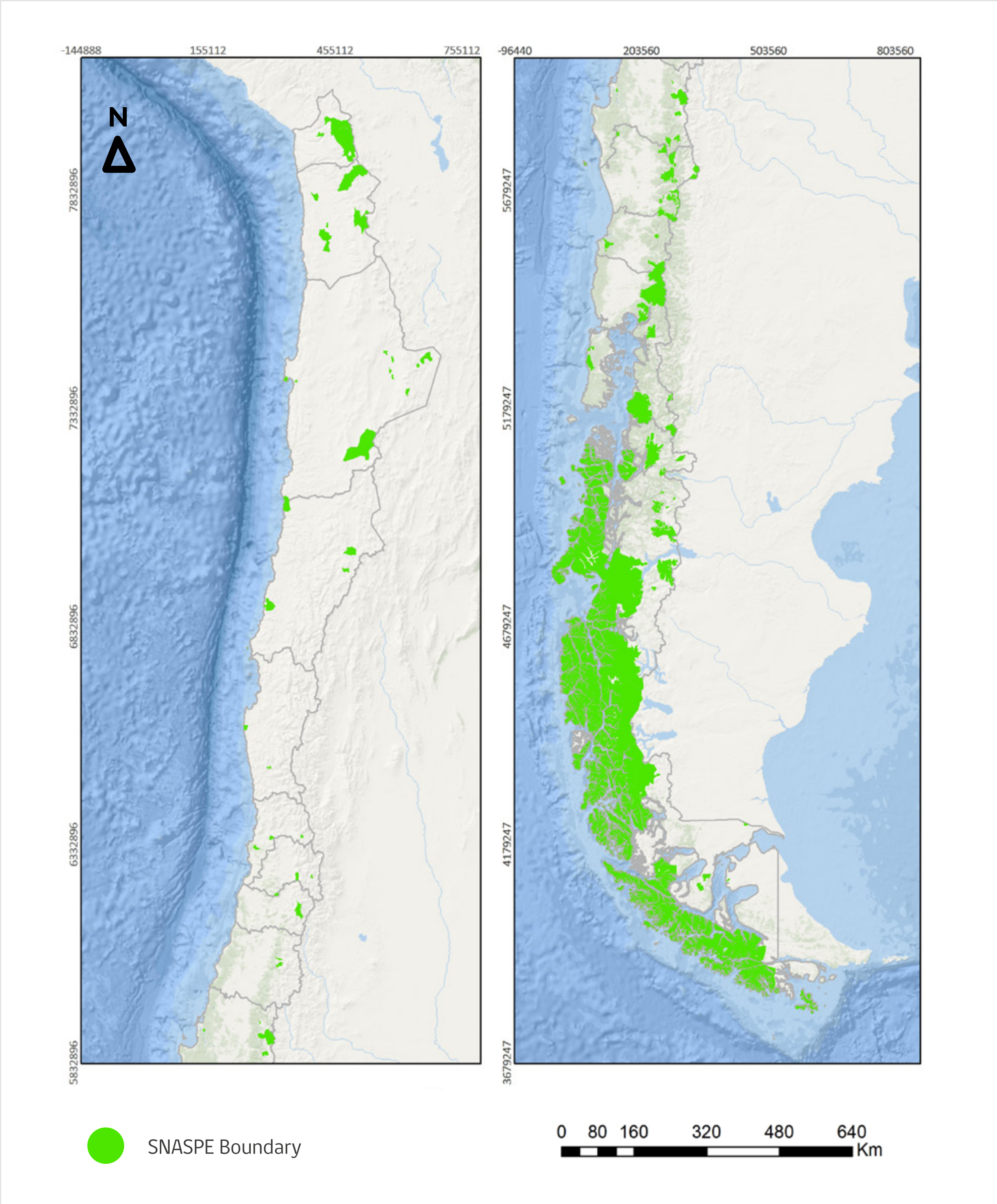

Figure 3. Map of SNASPE distribution. Source: Prepares by authors.

iii. Forest Plantation

In Chile, forest monocultures cover an area of 3 million hectares and they are predominantly located in the Central zone, mainly on the coastal mountain range and at the base of the Andes of Maule, Biobío, and Araucanía regions. This area hosts 80% of the planted forests (Table 6).

The two main species that make up the majority of planted forests are *Pinus radiata* and *Eucalyptus globulus*, 60% and 23% of them occupy the plantation surface areas respectively. Both species are used in the industry of cellulose pulp production, sawmill, plywood and structural boards. All of these are the main exporting products of the national forestry sector, which represents the second strongest exporting power in the country following the copper industry[19].

There are productive plantations of other coniferous or eucalyptus trees in the Southern zone which jointly add up to 10% of the national surface area.

In the semi-arid zone, through a state effort spanning 10 years, 60.000 hectares of forest plantations have been planted with shrubs from the genus Atriplex. The objective of these plantations was to recover the degraded lands and to deliver forage for the livestock of the region.

Compensatory and experimental plantations also exist in Chile, but these are not officially included in the Cadastre and their current proportions and aspects are unknown.

The current productive plantations are a result of policies enacted 40 years ago that encourage establishing forest plantations. This enabled the development of important industries, which as previously mentioned; make a significant contribution to national exportations[20].

	Arica y Parinacota	Tarapacá	Antofagasta	Atacama	Coquimbo	Valparaíso	Metropolitana	O'Higgins
Area (ha)	-	26.974,9	3.411,2	-	2.936,8	68.757,9	9.181,0	130.536,4
Percentage	0,0%	0,9%	0,1%	0,0%	0,1%	2,3%	0,3%	4,3%

	Maule	Biobío	Araucanía	Los Ríos	Los Lagos	Aisén	Magallanes	Chile
Area (ha)	597.117,4	1.227.788,6	632.289,0	208.775,2	96.598,8	32.017,3	22,8	**3.036.407,3**
Percentage	19,7%	40,4%	20,8%	6,9%	3,2%	1,1%	0,0%	**100,0%**

Table 6. Regional distribution of forest plantations. Source: CONAF.

19 www.infor.cl
20 www.conaf.cl

3. Definition of Forest and REDD+ Concepts[21]

a. Definition of forest

Law 20.283[22], enacted in 2008 defines **Forest** as a: *"a place populated with vegetation formations in which trees predominate and which cover a surface area of at least 5,000 square meters, with a minimum width of 40 meters, with arboreal canopy cover that surpasses 10% of the surface area in arid and semi-arid conditions and 25% in more favorable conditions"*[23].

The same Law 20.283 states the following definition for **Native Forest**: *"forest composed of native species deriving from natural production, natural reproduction, or planted under the same canopy with the same species in the area of original distribution, which can exhibit the presence of randomly distributed introduced species"*[24].

Heading into the adequate carbon accounting for the respective reference levels should be included the concept of Other wooded land as defined by the National Report of Chile to the Global Forest Resources Assessment 2015 (FRA2015) as *"land not defined as forest land which extends more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use"*.

Other wooded land concept aims to adjust records in the Cadastre, which until 2014 included the average height parameter to differentiate between native forest and arborescent scrubland, to the native forest legal definition, established by Law 20.283, which not consider this parameter. Since 2015 Cadastre updates, which include technological and conceptual improvements to adjust operating parameters to the legal definition, the previously identified as other wooded land were integrated into the native forest category.

Law 20.283, as well as the Decree-Law 701, of 1974 and its updates, does not stipulate a definition for Planted Forests. Nonetheless, based on international categories, it is important to analyze the definition provided by the FAO (2015)[25], which defines **Planted Forest** as: "Forest

[21] More details about the mechanism to establish the Forest and REDD+ Activities definition are available on http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/51-anexo-acta-taller-nr/file and http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/53-Anexo-Definiciones-actividades-REDD/file

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

[23] Original definition of forests in Ley 20.283: "sitio poblado con formaciones vegetales en las que predominan árboles y que ocupa una superficie de por lo menos 5.000 metros cuadrados, con un ancho mínimo de 40 metros, con cobertura de copa arbórea que supere el 10% de dicha superficie total en condiciones áridas y semiáridas y el 25% en circunstancias más favorables".

[24] Original definition of Nativs Forests in Ley 20.283: "bosque formado por especies autóctonas, provenientes de generación natural, regeneración natural, o plantación bajo dosel con las mismas especies existentes en el área de distribución original, que pueden tener presencia accidental de especies exóticas distribuidas al azar".

[25] www.fao.org/docrep/017/ap862e/ap862e00.pdf

predominantly composed of trees established through planting and/or deliberate seeding. Explanatory notes: 1) In this context, predominantly means that the planted/seeded trees are expected to constitute more than 50 percent of the growing stock at maturity; 2) Includes coppice from trees that were originally planted or seeded; 3) Includes rubber wood, cork oak and Christmas tree plantations; 4) Excludes self-sown trees of introduced species". In the same document **Planted forest of introduced species** is defined as "Planted forest, where the planted/seeded trees are predominantly of introduced species. Explanatory note: 1) In this context, predominantly means that the planted/seeded trees of introduced species are expected to constitute more than 50 percent of the growing stock at maturity".

The combination of the previously stated definitions represent the current national reality, including native forests and forests plantations, which are classified in Native Species Forests Plantations and Introduce Species Forests Plantations.

Currently, practically all of the planted forests in Chile are industrial, single-species and composed of introduced species, with significantly less planted forests composed of native species[26]. Of the few native species planted forests is the planted forest of the native species Tamarugo, found the regions of Tarapacá and Antofagasta[27].

Therefore for practical reasons, based on the available data to date (historical reference period), all planted forests registered up to the last update of the Cadastre will be considered as a uniform group, since single-species planted forests of introduced species intended for wood production make up the majority of planted forests in the country.

Nonetheless, the intent for stratification of plantations with the purpose of identifying conclusively in upcoming milestones of monitoring, planted forest of native species and those with objective and processes oriented towards the mitigation and adaptation to climate change, fight against desertification and conservation of the biological diversity with the objective to quantify their contributions in the capture of carbon with their respective intentions for future interventions, based on the potential strategic options of the ENCCRV. These objective can include the establishment and significant increase of surface area and the number planted forests, even more so when the goals set by Chile in its Intended Nationally Determined Contributions (INDC) refer to a forestation of 100,000 hectares which are to be primarily planted with national species, according for which it was validated when submitted to public inquiry and for which it receive approval from the Council of Ministers for Sustainability and Climate Change (CMSCC).

[26] According to the report INFOR Continuous Inventory (2014) in Chile in 2013 there were 2,447,591 hectares of forest plantations, of which 60,772, 2.5% correspond to the species Atriplex, mainly of exotic species Atriplex nummularia, which despite being a forage bush, it was subsidized as forest plantation and are located entirely in the Coquimbo Region; 2,319,799 hectares, representing 94.7% corresponding to Pinus ponderosa, Pinus radiata, Eucalyptus globulus, Eucalyptus nitens and Psedotsuga menziesii, all exotic species. The remaining 2.7% corresponds to other species, where it should include both exotic and native. Source: INFOR.http://mapaforestal.infor.cl/phocadownload/Informe_Inventario_Continuo_2014.pdf

[27] It is noteworthy that the Continuous inventory INFOR does not collect data from the regions located to the north of the Region of Coquimbo, as well as due to methodological and temporary differences of information there is a gap between the data from this source and data Cadastre. This information comes from monitoring and updating of Cadastre 2015 of the Region of Antofagasta. Source: CONAF.

For the context of REDD+, which dictates the FREL/FRL for Native Forests in Chile, a forest will be considered as all lands that are defined as Native Forest under the current Chilean legislation.

Observations:

1. From an operational point of view, all lands that are defined as Native Forest or Mixed Forest by the Cadastre will be considered forests.
2. In order to create a uniform definition, lands that are defined by the Cadastre as arborescent shrublands for the Updates of the Cadastre for the Mediterranean Eco-region (Region of Valparaíso, Metropolitana and Libertador Bernardo O'Higgins) prior to 2013, and the Updates of the Cadastre of Eco-regions located towards the south prior to 2015[28].
3. Given the environment aims that the ENCCRV hopes to promote, the reference level of CO_2 flux due to lands that the Cadastre considered Plantation Use, which are associated with planted forests of introduced species for industrial harvested-wood purposes.
4. So as to follow the concept of completeness the CO_2 flux in planted forests will continue to be reported on by the NGHGI.
5. New planted forests will be included into the calculation if the future, so long as they are planted forests that are destined for permanent cover and are consistent with the goals set by the INDC.

The definition applied to the FREL/FRL for native forest in Chile is different to the definition applied to the NGHGI for Forestry Territories, in which both native forest and planted forests are included[29]. This was done in order to comply with the safeguards set for the REDD+ agreed on in the CoP-16, Cancun[30], Appendix 1 sub clauses 2.e[31] and 2.a[32]. As a result it is becomes imperative to follow the objectives of the ENCCRV, which aims to encourage the recovery and protection of the native forest and xerophyte plants, as well as advance the establishment of vegetation formations in viable lands planted as measures of mitigation and adaptation to the effects of climate change and against desertification. The previously mentioned goals are to be achieved through the design and implementation of a state mechanism that will facilitate access to communities and landowners of forest lands, xerophyte plants, and viable lands for planting, to the benefits associated to the environmental services of these ecosystems, additionally satisfying the international commitments that Chile has made in the matter of climate change and against desertification.

[28] As of 2015, the updates to the Cadastre consider native forests to be area that in previous updates were considered arborescent shrubland. In the regions of Valparaíso, Metropolitana and Libertador Bernardo O'Higgins, this change has been included in the updates since 2013.

[29] Anexo Plantaciones Forestales describes emissions and captures in Forest Plantations (http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/65-Anexo-Plantaciones-Forestales/file)

[30] http://unfccc.int/resource/docs/2010/cop16/spa/07a01s.pdf

[31] Original text in spanish: "La compatibilidad de las medidas con la conservación de los bosques naturales y la diversidad biológica, velando por que las que se indican en el párrafo 70 de la presente decisión no se utilicen para la conversión de bosques naturales, sino que sirvan, en cambio, para incentivar la protección y la conservación de esos bosques y los servicios derivados de sus ecosistemas y para potenciar otros beneficios sociales y ambientales".

[32] Original text in spanish: "La complementariedad o compatibilidad de las medidas con los objetivos de los programas forestales nacionales y de las convenciones y los acuerdos internacionales sobre la materia".

As such, and as it deviated from the results of the “Workshop for Formulation and Participation in the ENCCRV”[33], there is a generalized approach amongst the different actors of the territory towards the encouragement and promotion to increase the surface areas of native forest through sustainable management, as well as the areas already covered by this resource. Industrial planted forests of introduced species are not encouraged, as these are controlled by businesses for autonomous profitable gains.

b. REDD+ Activities

The FREL/FRL of Chile describes the emissions and removals in the temperate native forests during the reference period due to the activities of deforestation, forest degradation, forest conservation and enhancement of forest carbon stock. These are based on the concepts found in Figure 4.

As will be explained further on, the FREL/FRL for sustainable forest management has not been calculated due to the current lack of official data that would enable an accurate calculation of the area where the activity occurs. Nonetheless, an ad hoc program is being developed in order to be able to include this activity in the future.

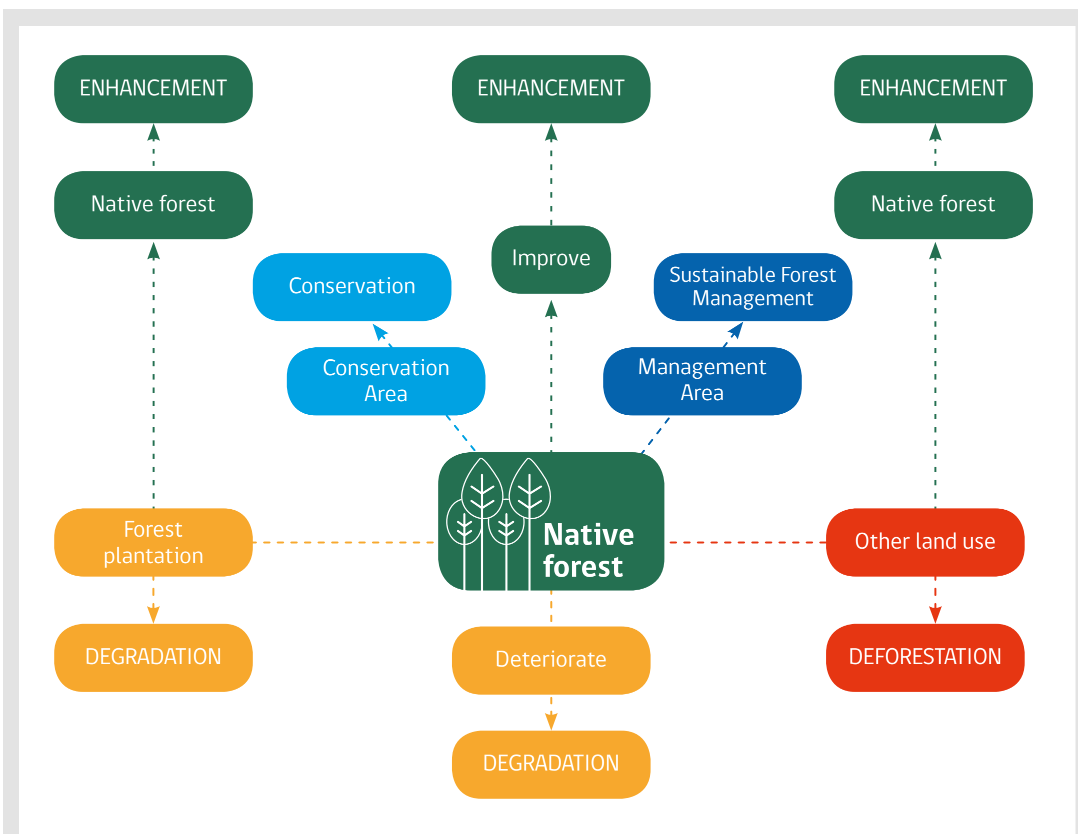

Figure 4. Logical schema for REDD+ activities.

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

i. Deforestation

Conversion of forest lands into non-forest lands permanently or without knowing when or how they will be restored.

Notes:

1. In accordance with the previously provided definition, it will not be considered deforestation when forest lands are converted into plantations. This change will be reported under forest degradation to maintain consistency with NGHGI.

2. Based on the criteria for the Cadastre, it will not be considered deforestation when forest lands are converted to arborescent shrublands[34], and will hence be considered forest degradation.

3. It will not be considered deforestation when areas are temporarily stripped of stock and revegetation has been planned, reported, and documented as a natural or assisted regenerative process.

ii. Forest Degradation

All forms of carbon reduction in a forest induced by human activity to such an extensive degree that a halt of all regular forestry activities are required, but does not provoke a change in land-use.

Notes:

1. The emissions produced by forest lands that remain forest lands subjected to processes of sustainable forest management or conservation will not be considered as part of the FREL/FRL of forest degradation, since they are accounted for in the other defined activities by the UNFCCC for REDD+ according to what has been stipulated in the present document.

2. Any change of use of the land from Forest to Forestry Plantation (also known as Substitution) will be considered forest degradation. The carbon stock in plantations after the substitution will be consider as "0" regarding to the process of clearing necessary for the establishment of a plantation. Accounting from carbon flows in plantations not be held in the REDD + reference level, but in the NGHGI.

3. Non CO_2 emissions, product of forest fires will be consider into Degradation activity.

[34] As of the 2013 updates to the Cadastre in the Mediterranean Ecoregion and 2015 for the rest of the Ecoregions, the Use of Native Forest will include those places previously classified as Arborescent Shrubland.

iii. Enhancement of forest carbon stock

Increase in forest carbon stocks in areas subject to land-use change from non-forest lands to forest lands, and the increase of forest carbon stocks result of the recovery of degraded forests.

Notes:

1. Forest carbon stock Increases in forest lands that remain forest lands that are subjected to official processes of sustainable management or conservation, will not be considered enhancement of forest carbon stocks, since such increases are considered in the other REDD+ activities as per the information stated in this document.

2. No increase produced in areas which have been converted from Forest to Forestry Plantation will be considered to be an Increase of Stocks, as this is considered to fall within the definition of degradation as explained above.

3. Any change of use from Forestry Plantation to Forest (also known as Restitution) will be considered to be an Increase of Stocks which maintains consistency with the concept of substitution applied in forest degradation activity. Considering that restitution is a process that occurs after harvesting, shall be deemed to carbon stock prior to the restitution it is "0".

iv. Conservation

Changes in carbon stock by degradation or recovery of degraded forests in areas of Native Forest subject to formal conservation procedures.

Notes:

1. In terms of practical application and subject to the constraints of the information available, Native Forests subject to formal conservation procedures are considered to be those identified as containing Forest Conservation Species (Chilean Palm, Larch and Araucaria [monkey puzzle]), as well as the forested areas which form part of the SNASPE and those registered as APP (Private Protected Areas) for forestry conservation.

2. It may still be possible to incorporate those areas which are characterized as Native Forests subject to formal conservation procedures by making a declaration of Forestry Conservation Management or other current or future official (legal) designation.

v. Sustainable Forest Management

Changes in carbon stock by degradation or recovery of degraded forests in areas of forest lands that have been subject to official sustainable forest management process.

Notes:

1. Sustainable forest management methods are activities that are conducted under the following mechanisms:
    a. Forest Management Plan of Native forests (including plans structured for specific forest types).
    b. Management Plan of Native Forests under Land Planning Criteria.
    c. Forest Management Plan for Small Areas.
2. In the future, institutional mechanisms will need to be developed and legally stipulated as tools for sustainable forest management, specifically those developed by the Strategies for Native Forest Sustainability[35], the ENCCRV and other institutions that may arise.
3. Included in the planning mechanisms considered to be methods for sustainable management are the mechanisms directed at Forest Restoration.

It is currently not possible to locate and delineate areas of forest that are subject to forest management processes stipulated in Clause 1 through official maps of the country. The ENCCRV is developing tools and capabilities that will enable the location and delineation of these areas for the identification and monitoring of present and future forest observations. In the meantime the stock variation through management actions have been included in the reference levels for degradation and enhancement of forest carbon stocks. Once the necessary area data is processed, the reference level for sustainable forest management will be presented.

[35] Strategies for Native Forest Sustainability are developing by CONAF under the Executive Director mandate. Aims to create new tools for the sustainable native forest management.

vi. General considerations

Emissions and removals produced by the REDD+ activities considered in the Reference Level have been estimated using different IPCC methodologies for each, considering the available information and methods used, among those activities and sub-activities that cause a land use or sub-use change, for which the activity data was estimated using the Cadaster; and those that occur in forests remaining forests, where increase or decrease in carbon stock since the initial condition was measured using remote sensing techniques in combination with information from the Continuous Forest Inventory.

In order to keep clarity in this document, methodologies will be described at the sub-activity level if applicable, to subsequently integrate them in the corresponding REDD+ activity.

As shown in Table 7, the activity of Deforestation relates exclusively to actions that cause changes in land use and that of Conservation relates exclusively to actions that occur in permanent forests. However, Forest degradation and Enhancement of carbon stock contain sub-activities related to both land use or sub-use change and those activities inherent to permanent forests.

Activity	Land use change/sub-use	Bosque permanente
Deforestation	Deforestation	
Forest Degradation	Substitution Native Forest	Degradation of forest remaining forest
Enhancement of Forest Carbon Stock	Increased forest area Return of Native Forest	Recovery of degraded forests
Conservation		Degradation and Recovery in forest remaining forest

Table 7. Identification sub activities.

4. Information Sources

a. National GHG Inventory of Chile

In order to comply with Chile's commitment to report on GHGs, in 2012 the Office for Climate Change of the Ministry of Environment designed, implemented and coordinates the National System of Inventories of GHGs of Chile (SNIChile). This Office administrates the institutional, judicial, and procedural measures established for the biennial updates of the NGHGI. In this manner it guarantees the sustainability of the GHG inventory preparation for the country in relation to the changes in known GHGs and the quality of the results.

The structure of SNIChile (Figure 1) consists of a decentralized organization where the NGHGI is the result of the collective efforts of different public services offices that comprise the national team of GHG inventories, including the Ministry of Agriculture, Energy, and the Environment. Additionally with the cooperation of national and international experts that offer their expertise in the topics related to the NGHGI.

Chile's NGHGI is part of the first Biennial Update Report of Chile[36] and the first National Inventory of GHG report[37] presented before the UNFCCC on December 10, 2014 and February 5, 2015 respectively.

Chile's NGHGI was produced following the Guidelines of the IPCC 2006 for GHG inventories[38]. All of the national territory was included (continental, insular and Antarctic territories); it also included CO_2, CH_4, and N_2O, HFC and PFC emissions and CO_2 removals in the reference period from 1990 to 2010.

Chile's NGHGI, produced during 2013 and 2014, is the result of the compilation of GHG inventories generated from the following sectors: Energy, Industrial Processes, the Use of Dissolvent and Other Products, Agriculture, Land Use Land Use Change and Forestry (LULUCF) and residues (Figure 1).

The LULUCF was provided by the Ministry of Agriculture, through which Office for Agriculture Studies and Planning (ODEPA) coordinated with CONAF regarding the changes of land use, and information regarding forest lands was provided by INFOR. Primary data comes from Monitoring Systems of Changes in Land use and Vegetation and the Continuous Forest Inventory. For the most part emissions and removals were calculated using country-specific emission factors,

36 http://www.snichile.cl/sites/default/files/documentos/2014_1iba_chile_espanol.pdf

37 http://www.snichile.cl/sites/default/files/documentos/2014_iin_cl.pdf

38 http://www.ipcc-NGHGIp.iges.or.jp/public/2006gl/spanish/index.html

whereas for the other land uses the emission factors used were default factors from the IPCC Guidelines. The results are separated into regions in order to accurately represent the different environmental conditions in the country.

The activity data and the emissions factors used in Chile's NGHGI can be downloaded from the Chile NGHGI database[39].

The LULUCF is the only body that reports CO_2 removals in the country. In 2010 the GHG balance calculated removals of -49,877.4 $GgCO_2e$. Throughout the reference period the GHG flux has been favorable for GHG removals, even though it has declined in 1.9% since 1990 (Figure 5).

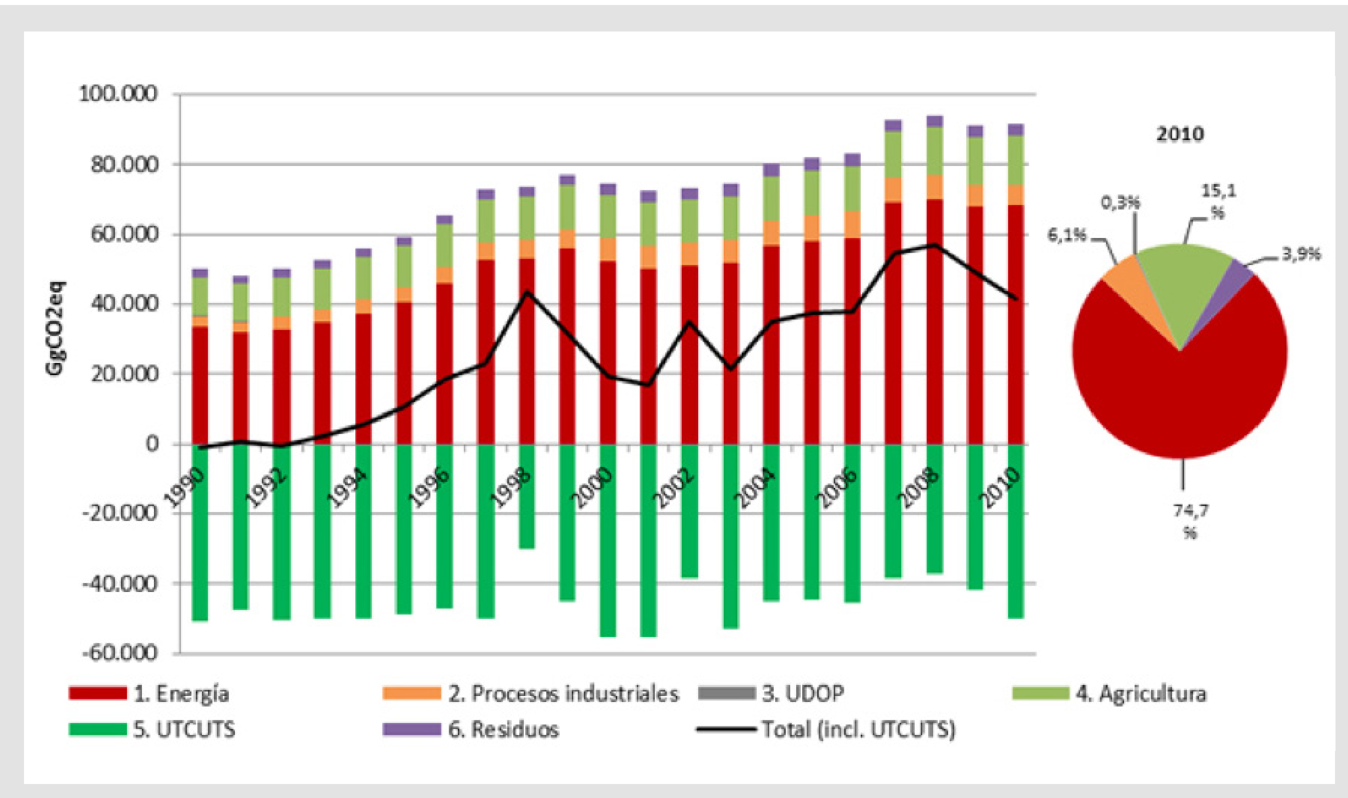

Figure 5. Chile NGHGI: emission and removal tendencies of GHG by sector, 1990-2010. Source: SNICHILE.

39 http://www.snichile.cl/sites/default/files/documentos/2014_bdingei_cl.xlsx

b. Monitoring System of changes in land use and vegetation based on the Cadastre of the Native Forest[40]

The Cadastre and Evaluation of Vegetation Resources in Chile, henceforth referred to as the Cadastre, was enacted in 1993. The Cadastre's main objective was the elaboration of a National Cadastre of the use of lands and vegetation groupings, especially those related to the native forest, forest plantations and grasslands, constituting the baseline for vegetation mapping in Chile.

The information provided by the Cadastre is periodically updated by the Forest Ecosystem Monitoring Unit of CONAF through regional projects that have the following objectives:

- **Monitor** the changes and analyze the different process that affect the land and land use with an emphasis on vegetation.
- **Map** and label the forests including the land use associated with forest plantations, other vegetation groupings and the general use of the land (cities, crop lands, bodies of water, snow glaciers, wetlands and deserts).
- **Provide** a database of digitally geo-referenced locations in a system for public use for managing and decision-making.

Article 4 of Law of Recuperation of Native Forest and Forest Promotion (Ley N°20.283) reinforces the Monitoring System establishing that "the corporation (CONAF) will maintain a permanent forest cadastre, through which it will identify and establish, at least cartographically, the types of existing forests in each region of the country, their state and the areas where there is an existence of ecosystems of native forests with interest for conversation or preservation, according to the criteria established in the ruling of this law," and "...that it will be updated every 10 years and its information will be available to the public".

The official publication of the reference period of the Cadastre was in September 1997 with monitoring and updating procedures beginning in 1998 (Table 8). The improvements of technology enabled the changes to the methodology that enabled the correction of errors and defects caused by the instruments used in the first interpretation, specifically the lack of accuracy and precision in the limits of the states.

The methodology used to classify the use of lands and the distinct vegetations is called Land Use Chart (COT, in Spanish) developed by the Centre d'Ecologie Fonctionnelle & Evolutive Louis Emberger (CEPE of Montpellier) and adapted by Etienne and Prado in 1982.

This methodology describes vegetation through the vegetation grouping's form of life, structure, canopy coverage, height and species. The classified land use corresponds to the anthropogenic or natural land use that is present by at the moment of detection, either my remote sensing or on site, such as: bodies of water, wetlands, snow, urban areas, crop lands, lands without vegetation.

[40] http://sit.conaf.cl/tmp/obj_830392/171_Catastro_de_los_Recursos_Vegetacionales__1997-2011_.pdf

These classifications are objective observations as they do not judge the quality of the land (for example: degraded, wood harvest forests, or protected).

The Cadastre describes 9 uses and 20 sub-uses and within these subuses are other subsections for height, coverage and structure.

The process of monitoring and updating (Table 8) conducted since 1998, has enabled the understanding of the types of changes that have occurred on the different land uses, the direction of these changes and the reasons for these changes.

For the definition of the FREL/FRL of native forest, only the Cadastre updates that have been adjusted and rectified using improved technology are used for the regions composing the subnational area selected (Table 9), enabling consistent, complete and detailed information of the changes in land use.

The public interface of the Cadastre information according to the Native Forest Law (art. 4), is found in SIT-CONAF[41], through the use of a sitemap consultation of the Cadastre and its process of monitoring and updates. SIT-CONAF has 1400 registered users, and received more than 2000 visits in 2015. The most viewed information was in regards to the surface area and distribution of native Chilean vegetation species.

Region	Reference year	First update	Second update	Third update
Arica y Parinacota		2014		
Tarapacá		2015[40]		
Antofagasta		2009[39]		
Atacama		2008[42]		
Coquimbo		2003	2008[39]	2015[43]
Valparaíso		2001	2013	
Metropolitana		2001	2013	
O'Higgins	1997	2001	2005	2013
Maule		1999	2009	2015[40]
Biobío		1998	2008	2015[40]
La Araucanía		2007	2014	
Los Ríos		1998	2006	2014
Los Lagos		1998	2006	2013
Aysén		2010-2011		
Magallanes y La Antártida		2005		

Table 8. Cadastre publication date and update dates by region.

41 http://sit.conaf.cl/

42 Update developed only in the Biodiversity Conservation Priority Sites.

43 Update in process.

Region and year of Cadastre/update use			
Maule	1997	2009	2016
Biobío	1997	2008	2014
La Araucanía	1997	2007	2013
Los Ríos	1997	2006	2013
Los Lagos Norte	1997	2006	2013
Los Lagos Sur	1997		2013

Table 9. Dates of Cadastre and/or update of relevant regions, used in the construction of FREL/FRL.

c. Continuous Inventory of Forestry Ecosystem[44]

The Continuous Inventory of Forestry Ecosystems, henceforth referred to as the Continuous Inventory, managed by INFOR, and has been operational since 2000. The purpose of this inventory is to aid in the process of decision-making related to government institutions, international processes and in different areas of inters for the present and future.

The Continuous Inventory was designed under a statistical bi-stage design in three circular sample plot clusters in an area equivalent to 500m^2 distributed in a systematic area of 5x7km (Figure 6).

The Continuous Inventory is based on the generation of first cycle measurements of permanent sample plots that cover 9.38 million hectares of native forest between the regions of Coquimbo and Magallanes established for the years 2001 to 2010. The second cycle of measurements is partially-updated annually with the support of growth projections.

The Continuous Inventory gathers information for trees that have a diameter at breast height (dbh) equal to or greater than 25 cm in the 500m^2 plots, dbh equal to or greater than 8 cm in 122m^2 plots, and dbh equal to or greater than 4cm in 12.6m^2 plots.

Each tree is registered under species, dbh, bark thickness, canopy diameter, and health state. More detailed information is taken from a subsample of each plot, such as total height, base canopy height, height of the tree stump etc.

For each plot, a 1m^2 subplot is delineated in order to measure all vegetation present: regeneration, firewood residues, dead trees, etc.

For each plot cluster, general descriptions of the observed state of the three plots regarding the degree of anthropogenic interventions, presences of public works, degradation and its evolutionary state are noted.

[44] http://mapaforestal.infor.cl/phocadownload/Informe_Inventario_Continuo_2014.pdf

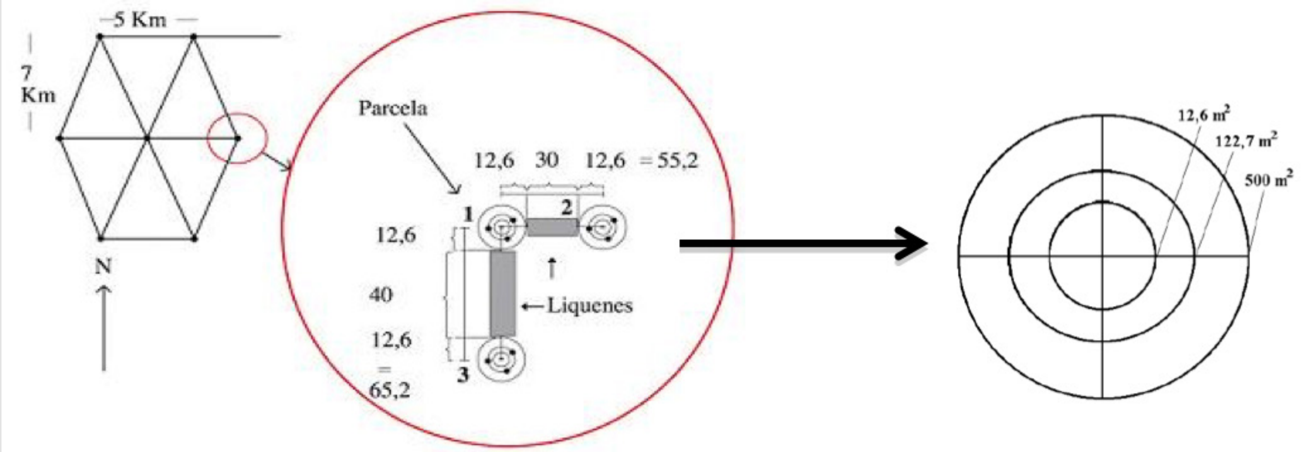

Figure 6. Design of the *Inventario Continuo* sample plots. Source: INFOR.

d. LANDSAT satellite imagery

The calculation of variations in carbon stock in forest lands that remain forest lands for the Degradation FREL, Forest Carbon Stock Enhancement FRL, and Conservation of carbon stocks FREL was computed by the Continuous Inventory and the application of remote sensing data techniques on LANDSAT satellite images.

The LANDSAT observation program has obtained images of land coverage beginning with the LANDSAT 1 in 1972 and most recently the LANDSAT 8. These images are of great public interest particularly dealing with climatic phenomenon, as has been depicted in various publications. The images of the different LANDSAT satellites are available to the public free of charge through different platforms such as Glovis, Earthexplorer (United States Geological Survey) or INPE (Instituto Nacional de Pesquisas Espaciais).

The images used for the reference period were obtainedfrom the Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) onboard of the LANDSAT 5 and the LANDSAT 7 respectively. The technical characteristics of each sensor are described in Table 10 and Table 11.

LANDSAT 5 -TM Spectral Bands	Wavelength	Resolution Spatial
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 - Short-wave Infrared	1,55 - 1,75 µm	30 m
Band 6 - Thermal Infrared	10,4 - 12,5 µm	120 m
Band 7 - Near Infrared	2,08 - 2,35 µm	30 m

Table 10. Characteristics of the LANDSAT 5 Thematic Mapper. Source: LCDM Press Kit. NASA.

LANDSAT 7 -ETM+ Spectral Bands	Wavelength	Resolution Spatial
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 - Short-wave Infrared	1,55 - 1,75 µm	30 m
Band 6 - Thermal Infrared	10,4 - 12,5 µm	60 m
Band 7 - Short-wave Infrared	2,08 - 2,35 µm	30 m
Band 8 - Panchromatic	0,50 - 0,90 µm	15 m

Table 11. Characteristics of the Landsat7 Enhanced Thematic Mapper Plus. Source: LCDM Press Kit. NASA.

5. Methodology

a. Tier, levels and approaches used

The IPCC Guidelines for GHG Inventories present different Approaches and Tier levels to represent the different levels of complexity in the methodology.

The IPCC (2003) provides the following descriptions of approaches to represent the activity data:

- **Approach 1**
  This data only presents net changes in land use in the registered area over time, but it does not provide any explicit information, exact locations, or patterns of change in land use. The changes from one land use category to another are not registered either.

- **Approach 2**
  This data requires national and regional information of losses and gains in the area of specific land use categories and what these changes represent. This includes data on the conversions between categories; however, it does not include data of explicit locations.

- **Approach 3**
  This data requires observations of explicit spatial observation of the land use of and land use changes. This is achieved through the registering of differences in location and using detailed maps like those derived from radar data sources.

The IPCC (2003) also describes the different Tier levels used to describe the complexity of the methods used to calculate emissions:

- **Tier 1**
  Default emission factors, facilitated through the EFDB or alternatively through the IPCC Guidelines. The IPCC suggests that this method should be viable for all countries.

- **Tier 2**
  Use of specific emission factors for the country or other emission factors that are more specific than the default factors.

- **Tier 3**
  The use of higher order methods including models and inventories specifically designed for the countries necessities, repeated over time, and driven by high-resolution activity data and disaggregated into subnational sub scales. If implemented accurately, Tiers 2 and 3 can produce calculation that is more exact than Tier 1.

All activates in the proposed FREL/FRL are derived using information from Approach 3 of the IPCC, meaning geographically-explicit information. A mixture of Tiers 2 and 3 were used, given that Tier 2 was used when the necessary information needed to reach Tier 3 specification was unavailable. Table 12 summarized the Tiers used for reach activity for the FREL/FRL proposal.

b. Carbon pools and GHG considered

Aboveground and belowground biomass is considered for all REDD+ activities included in the FREL/FRL.

Necromass is included in the activities of deforestation, degradation and conservation. It is not included in enhancement of forest carbon stocks because no information about the rate of Necromass accumulation in areas converted to forest lands is available. Necromass values after a transition period (25 years) are included to permanent forests.

In order to remain consistent with the NGHGI, which does not count emissions of carbon from the soil due to the absence of data at national level and the inaccuracy of existing sources of information at global level, this carbon pool will not be included in the proposed FREL/FRL.

Specifically, the decision to exclude this carbon pool is based on the fact that soil carbon stock depends heavily on local site conditions (in relation to climate, soil type and management factors). As a result, the more general default values are unrealistic. Moreover, the country has no official geo-referenced information that allows estimation of the relationship between activities and soil.

In order to make this decision more robust an estimate of the emissions caused by deforestation from the above mentioned reservoir was made using Tier 1 methodology, which determined the emissions from this reservoir as 128,005 tonne CO_2e/year-1, on top of 1,653,819 tonne CO_2e/year-1 of emissions from Live Biomass and Necromass resulting from Deforestation, representing 7.7% of the total[45].

Considering that Chile is part of the Carbon Fund participating countries, the exclusion of this pool is additionally justified regarding compliance of Criterion 4, Indicator 4.1.i of the FCPF Methodological Framework and in parallel, based on the indicator 4.2.ii; "Underestimates the excluded reservoir reducing emissions".

[45] Tool used to estimate SOC emissions is available in the link: http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/62-Anexo-Justificaci%C3%B3n-SOC/file

Activity REDD+	Sub-Activity	Tier	Carbon pool	GHG included
Deforestation	N/A	3	Above-ground Biomass	CO_2
		2	Below-ground Biomass	
		3	Dead organic material	
Forest Degradation	Permanent forest degradation	3	Above-ground Biomass	CO_2
		2	Below-ground Biomass	
		3	Dead organic material	
	Substitution	3	Above-ground Biomass	CO_2
		2	Below-ground Biomass	
		3	Dead organic material	
	Forest fires	1	Combustion Emissions	CH_4 - N_2O
Conservation of Forest Carbon Stock	N/A	3	Above-ground Biomass	CO_2
		2	Below-ground Biomass	
		3	Dead organic material	
Enhancement of Forest Carbon Stock	Rehabilitation degraded forest	3	Above-ground Biomass	CO_2
		3	Below-ground Biomass	
	Restitution	3	Above-ground Biomass	
		3	Below-ground Biomass	
	Increase forest area	3	Above-ground Biomass	
		3	Below-ground Biomass	

Table 12. Levels, CO2 deposits, and included GHGs for each REDD+ activity included in the subnational FREL/FRL Chilean proposal.

c. Reference Period

The reference period used for Chile's subnational FREL/FRL of native forests is determined by the availability of the necessary information to construct the reference level as well as differences in the methods used to estimate emissions and removals by activities and sub-activities.

Considering the circumstances; two different reference periods were stipulated, one for activities or sub-activities that cause a land use or sub-use change; and other for activities or sub-activities that occur in permanent forests.

i. Land use or sub-use change

The activities and sub-activities involving land use or sub-use changes are:

- **Deforestation:** Transformation from Native forest to non-forest, other land uses.
- **Substitution:** Transformation from Native forest to Forest plantation, corresponding to the Degradation activity.
- **Increases in forest area:** Transformation from Other land use to Native forest, corresponding to Enhancement of carbon stock.
- **Restitution:** Transformation from Forest plantation to Native forest, corresponding to Enhancement of carbon stock.

The data source for all activities involving land use change (deforestation, degradation by substitution and forest carbon stock enhancements due to land use change) is the Land Registry and Assessment of Vegetation Resources in Chile which is updated at different times for each region (Table 8.1). As thus, different regions have maps produced in different years, with each region having at least three distinct land cover maps. In addition, the region of Los Lagos is divided into two geographical sections, since an update in 2006 related solely to the north of the region. As can be seen from the variable dates for which the land cover maps are available, data on estimating the activity for each of the regions included in this FREL is variable.

In order to achieve consistency within the region, and taking into consideration the fact that the carbon stock fluxes involved in these activities indicated in the FREL consist of projecting historical averages due to national circumstances without making any adjustments, the reference period for the forest emissions reference levels is set at 2001 to 2013. This consistent reference level is achieved using interpolation of emissions and removals from the dates of the maps to the dates of the reference period.

The interpolation was applied to the annual area of change for each activity using the following equation:

$$A_i = \frac{A_{p1} - A_{p1}\left(\frac{b_{p1}}{t_{p1}}\right) + A_{p2} - A_{p2}\left(\frac{b_{p2}}{t_{p2}}\right)}{t_{p1} + t_{p2} - b_{p1} - b_{p2}}$$

Eq. 1

Where

A_i = annual area of change (ha)
Ap = area of change in period p (ha)
b = interpolated time (years; e.g. if interpolation is between 2013 and 2015, b = 2)
t = time in period p (years)

In the case of the initial year, interpolation is required in all regions since the initial Cadaster map in all regions is from 1997. In the case of the final year, interpolation is necessary only in the Maule and Biobio regions for which data are available in 2014 and 2016 respectively (Tabla 13).

Date reference period							
Region	Date map 1	Date map 2	Date map 3	Start reference period	End reference period	Interpolation start year (b_1)	Interpolation end year (b_2)
Maule	1997	2009	2016			4	3
Biobío	1997	2008	2014			4	1
La Araucanía	1997	2007	2013	2001	2013	4	0
Los Ríos	1997	2006	2013			4	0
Los Lagos Norte	1997	2006	2013			4	0
Los Lagos Sur	1997		2013			4	0

Table 13. Dates Cadastral maps used, start and end of the reference period and years interpolated by Region.

Whereas the interpolation process may overestimate the emissions and removals of forest carbon if occurred a year with an unusual variation, a sample of 869 control points were analyzed to estimate the year of change in the five regions between 1998 and 2008 and a sample of 287 control points between 2008 and 2015 for the regions of Maule and Biobío. As shown in Figure 7 and 8 the distribution of polygons that change per year shows a normal distribution that allows application of the interpolation methodology for the proposed years without overestimation.

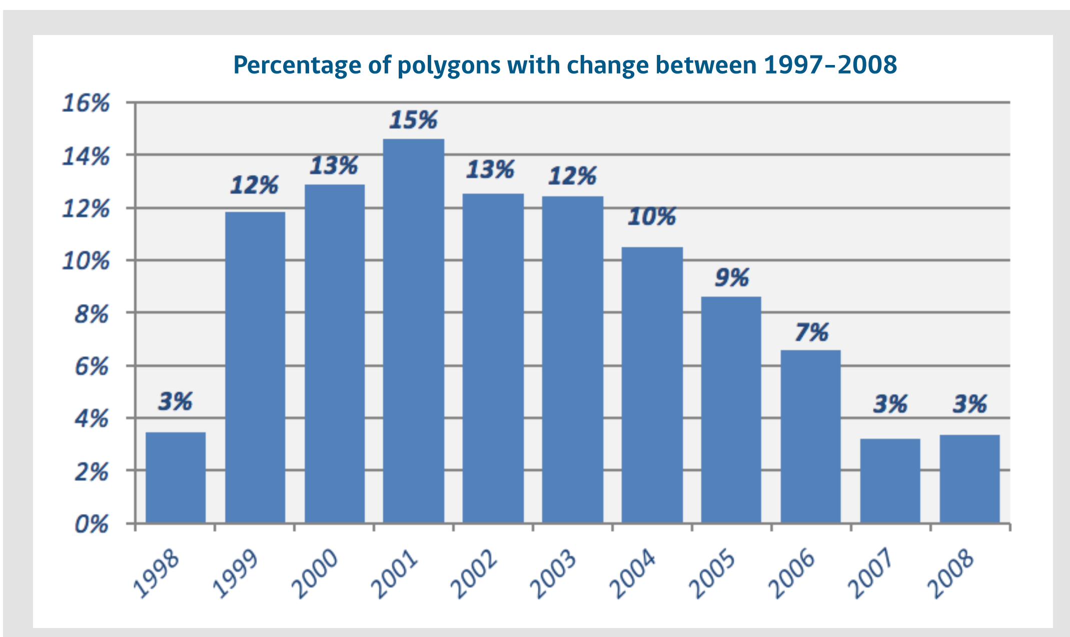

Figure 7. Percentage of polygons with land change use and sub-use of 1998-2008 in total accounting area.

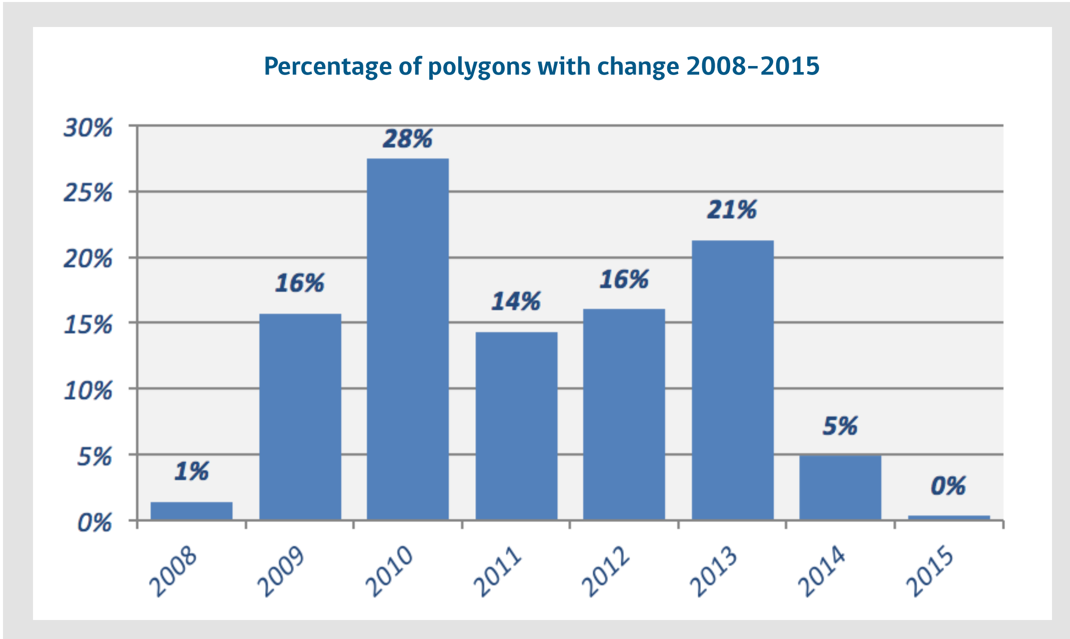

Figure 8. Percentage of polygons with land change use or sub-use of 2008-2015 in the region of Maule and Bío-Bío.

ii. Forest remaining forest

Activities and sub-activities that occur in forests remaining forests are:

- **Degradation of permanent forest**
  Emissions in forests remaining forests produced by degradation, including forest fires, harvested wood and non-wood product extraction, among others.

- **Recovery of degraded forests**
  Increase on carbon stock resulting from the recovery of degraded forests, corresponding to the Enhacement of forests carbon stock activity.

- **Forest conservation**
  Net flux of emissions in permanent forest, including degradation and removals from the recovery of degraded forests in formal forest conservation areas.

Emissions and removals in forests remaining forests were estimated using the methodology described by Bahamóndez *et al.* (2009), which uses an approach based on data from the plots in the Continuous National Inventory of Forest Ecosystems and the images from Landsat 5 and 7.

The methodology creates maps of forest carbon stock relating to the years when field measurements of Continuous Forest Inventory were acquired. The plots recorded are extrapolated to the entire forest using the method K-nn. As specified in Chapter 4.c, the first cycle of Continuous Forest Inventory corresponds to the period 2001-2010, taking measurements in the referred years. The K-nn extrapolation was applied to imagery for those years, so the reference period for these activities and sub-activities corresponds to this period of 2001-2010.

d. Methods for estimating emissions and removals

According to the structure of activities and sub-activities, the construction of the FREL/FRL has been developed using two different methodologies: 1) activities involving a land use or sub-use change, which applies the gains and losses method, and 2) the activities occurring in forests remaining forests, where the stock change method is applied.

i. Land use or sub-use change

Deforestation

The methodology for calculating the deforestation FREL in Chile is based on the IPCC 2006[46] equations for forested land converted to other types of land, which the NGHGI also uses to calculate the emissions from forests converted to other land uses. This includes reservoirs of aerial biomass, underground biomass and necromass.

The following equation is used to calculate the FREL in tonnes of CO_2e:

$$\mathrm{FREL}_{Def} = \frac{\sum_t \Delta C_{B\,t,Def}}{p} * \frac{44}{12}$$

Eq. 2

Where

$\mathbf{FREL_{Def}}$ = annual mean losses of carbon stocks from forested land converted to non-forest land during the reference period, in tonnes of CO_2e year^{-1}

$\boldsymbol{\Delta C_{B\,t,Def}}$ = change in carbon stocks in forested land converted to non-forested land in year t of the reference period, in tonnes of C. Reference is made to the reservoirs included below.

$\boldsymbol{p}$ = years in the reference period

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

Tier 3 of the IPCC methodology is used in the estimates of emissions caused by deforestation, since the carbon stocks for land uses before and after conversion are specific to Chile, and the conversion areas are broken down per type of cover of the original ground.

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

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

$$\Delta C_{B_{t,Def}} = \Delta C_{G_t} + \Delta C_{CONVERSION_t} - \Delta C_{L_t}$$

Eq. 3 (Eq. 2.15 IPCC, 2006)

Where

$\Delta C_{B_{t,Def}}$ = annual change of carbon stocks in forested land converted to non-forested land for the year *t* because of the activity of deforestation (Def), in tonnes of C

ΔC_{G_t} = annual increase of carbon stocks due to the growth in forested land converted to non-forested land in the year *t*, in tonnes of C

$\Delta C_{CONVERSION_t}$ = initial change in carbon stocks in biomass in forested land converted to non-forested land in the year t, in tonnes of C

ΔC_{L_t} = annual loss of carbon stocks in biomass due to timber harvesting, collection of firewood and disturbances in forested land converted to non-forested land in the year t, in tonnes of C

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

For the FREL of deforestation in Chile, ΔC_G which represents carbon acquisitions from non-forestry uses following the conversion (agricultural, urban, other) is included. This variable will be left at a value of zero, since it does not affect the analysis of the loss through deforestation.

Equation 4 (IPCC, 2006 Equation 2.16) calculates the parameter $\Delta C_{CONVERSION}$ for inclusion in Equation 3:

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

Eq. 4 (Eq. 2.16 IPCC, 2006)

Where

$\Delta C_{CONVERSION}$ = initial change of carbon stocks from biomass in forested land converted to non-forested land, in tonnes of C per year^{-1}

B_{AFTER_i} = existences of biomass in the type of use of non-forested land *i* after conversion, in tonnes of dry biomass per hectare

B_{BEFORE_i} = existence of biomass in the type of forest prior to conversion, in tonnes of dry biomass per hectare

$\Delta A_{TO_{OTHERS_{i,t}}}$ = area of type of forest *i* converted to non-forested land in the year t, in ha

CF = fraction of carbon in dry biomass, in tonnes of carbon per 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 ($\Delta A_{TO\_OTHERS_i}$), frequently referred to as data activity (DA), and the quantity of carbon stocks emitted due to the conversion (B_{AFTER_i} – B_{BEFORE_i}), frequently referred to as emissions factors (EF). The parameters B_{AFTER_i} and B_{BEFORE_i} only include aerial and underground biomass, and necromass is included by adding the parameter ΔC_{DOM} calculated in accordance with 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 the year t, tonnes of C

C_n = carbon stocks from dead wood and necromass in the use of the non-forested land after conversion, tonnes of C per year^{-1}

C_o = carbon stocks from dead wood and necromass from forest prior to conversion to non-forest, tonnes of C year^{-1}

A_{on_t} = area converted from forest to non-forest in the year t, hectares

T_{on} = period of time of the transition from forest to non-forest

In this equation, A_{on} corresponds to the activity datum, or $\Delta A_{TO_{OTHERS_i}}$ in accordance with the parameter of equation 4, described above. In order to simplify the accounting process, the emissions from necromass will be counted in the year of the conversion (which means that it is assumed that T_{on} has a value of 1).

In order to remain consistent with the NGHGI, which does not count emissions of carbon from the soil, this pool will not be included in the proposed FREL.

Forest Degradation by Substitution

In order to estimate degradation of native forests converted into plantations (SUBSTITUTION), the IPCC 2006 Equation 2.8 is used, which is recommended for flows in the use of land which remains unchanged:

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

Eq. 6 (Eq. 2.8 IPCC, 2006)

Where

$\Delta C_{B_{t,Deg}}$ = annual change in carbon stocks in forested land which is converted to plantations, taking into consideration the total area, subject to the degradation activity (Deg_{FNF}), tonnes of C

C_{t_2} = total carbon from forest in year t_2, tonnes of C

C_{t_1} = total carbon from forest in year t_1, tonnes of C

This equation is used due to the decision, stems from the classification of exotic plantations as a forest, and thus substitution of native forests by exotic plantations is considered "degradation" and not "deforestation". However, in order to count the flows involved in these changes, the methodology associated with the conversion of land use is utilized since it is the recording of the updates in the Land Registry which allow this process to be reliably identified.

Restitution and Incrase of Forest Area

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

In order to calculate the annual change in carbon stocks in aboveground and underground biomass (the only pools included in the estimated increases) and in land converted to other land uses (in this case, non-forested to forested), the general equation which corresponds to Tier 2 and 3 is IPCC (2006) equation 2.15:

$$\Delta C_{B_{t,ANFF}} = \Delta C_{G_t} + \Delta C_{CONVERSION_t} - \Delta C_{L_t}$$

Eq. 7 (Eq. 2.15, IPCC 2006)

Where

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

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

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

ΔC_{L_t} = annual reduction in carbon stocks due to timber harvests, collection of firewood and disturbances in non-forested land converted to forest in year t, in tonnes of C

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

Eq. 8 (Eq. 2.16 IPCC, 2006)

Where

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

B_{AFTER_i} = biomass stocks in the type of forest i immediately after conversion, tonnes d.m. (dry matter) ha^{-1}

B_{BEFORE_i} = biomass stocks in the type of forest i prior to conversion, tonnes of d.m. ha^{-1}

$\Delta A_{TO_{OTHERS_{i,t}}}$ = usable surface of non-forested land converted to forest in a year t, ha

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

For parameter ΔC_G (the increase due to forest growth), the NGHGI uses the IPCC 2006 Equation 2.9 for a Tier 2-3 calculation. However, the NGHGI only uses it for land converted to forest in the year of conversion. Afterwards, this land moves into the category of land which remains unchanged, and its amounts are counted in this category. Increases which come from areas which are converted into forest during the reference period must continue to be counted In the FRL of increases for the whole period. For example, an area which is converted to forest in the first year of the reference period continues to increase its carbon stocks in the second, third and the rest of the years in the reference period. The increases in the second year which comes from the areas which have been sown/restored in the first year are counted in the second year, together with the increases from the areas which were sown/restored in the second year. In this way, increases continue to accumulate, and are always counted under the activity of increases in stocks, and they do not move into the category of forests which remain unchanged in the NGHGI. However, the next update of the NGHGI will count acquisitions from areas converted to forest in previous years (up to 20 years before the accounting year) under a category of "forests in transition".

IPCC (2006) Equation 2.9 calculates annual carbon increases. However, equation 9 does not take into consideration acquisitions which continue to accumulate in stratum "i" converted in previous years. So IPCC (2006) equation 2.9 needs to be amended in the following way for the stocks to be counted correctly:

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

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 in non-forested land converted to forested type *i* during the reference period, in tonnes of C

$A_{i,x}$ = Area converted to forest *i* in year *x* of the reference period, ha

G_{TOTAL_i} = annual mean growth of biomass in non-forested land converted to forest type *i*, tonnes of d. m. ha^{-1} year^{-1}

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

Equation 2.9 takes into account the fact that in order to calculate $\Delta C_{G_{i,t}}$ in year t, the acquisitions which come from areas converted in each year x before the year t of the reference period must be added to acquisitions from areas converted in year t. If a forest reaches adult age and stops acquiring CO_2 from the atmosphere, it should be eliminated from the process of counting increases. However, it is assumed that this does not occur during the reference period as this is a short period.

ii. Forest remaining forest

Degradation in forest remaining forest

IPCC (2006) Equation 2.8 is used to estimate the change in carbon stocks in forest land which remains unchanged due to degradation:

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

Eq. 10 (Eq. 2.8 IPCC, 2006)

Where

$\Delta C_{B_{t,Deg}}$ = annual change in carbon stocks on unchanged forest land, taking into consideration the total area, subject to the activity of degradation (*DegFF*), tonne C

C_{t_2} = total carbon from forest in year t_2, tonnes of C

C_{t_1} = total carbon from forest in year t_1, tonnes of C

The methodology described by Bahamondez *et al.* (2009)[47] is used for accounting. This methodology accounts for the carbon stocks at different points of time when the difference in carbon stocks in forest land is considered to be degradation in the event of losses. However, the NGHGI uses a gain-loss method, applying Equation 2.7 of the IPCC (2006) rather than the stock difference method in equation 2.8 del IPCC 2006. which incorporates INFOR tabular data in order to estimate the volume extracted as a result of selective felling, INFOR and MINENERGIA statistics for firewood, and CONAF tabular data for the surface area affected by fires in the native forest and forest plantations. According to national experts, data about collection of firewood is not very reliable or representative of degradation as a whole. The methodology used in the FREL is able to obtain results for Approach 3. This data is spatially explicit, and is based on reliable and independent sources of information.

Carbon stock was estimated for the initial and final reference period years (C1 y C2 in equation 10), using Equation 2.8 IPCC:

$$C_t = A_{Deg} * EF * CF$$

Eq. 2.8, IPCC 2006

[47] Bahamóndez, C., Martin, M., Muller-Using, S., Rojas, Y., Vergara, G., 2009. Case Studies in Measuring and Assessing Forest Degradation: An Operational Approach to Forest Degradation. (Forest Resources Assessment Working Paper). Forestry Department, Food and Agriculture Organization of the United Nations.

Where

$C_{t,i}$= total carbon from the forest in year t, tonnes of C

A_{Deg}= area of degradation in unchanged forest, ha

EF= carbon stocks in unchanged forest, tonnes of biomass ha^{-1}

CF= carbon fraction, t carbon t biomass^{-1}

Recovery of Degraded Forests

The methodology described in the section on degradation in the areas of forest which remain unchanged is used. IPCC (2006) equation 2.8 was used to calculate the enhancement for each year individually:

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

Ec. 12 (Ec. 2.8, IPCC 2006)

Where

$\Delta C_{B_{t,AFF}}$ = annual change of carbon stocks in forest areas which remain unchanged, taking into consideration the total area, in tonnes of C year^{-1}

C_{t_2}= total forest carbon in time t_2, tonnes of C

C_{t_1}= total forest carbon in time t_1, tonnes of C

The stocks in t_1 (2001) and t_2 (2010) are obtained from the results of the methodology for all the areas which begin the reference period below the B-line according to the stocking charter.

Forests Conservation

As explained in previous chapters, the reference level for Forest Conservation is estimated by summing emissions from forest degradation in permanent forests and removals by recovery of degraded forests within formal forests conservation areas.

$$\Delta C_{B_{t,ConFF}} = \Delta C_{B_{t,AFF}} - \Delta C_{B_{t,DegFF}}$$

Eq. 13

Where

$\Delta C_{B_{t,ConFF}}$ = annual change of carbon stocks in forest areas which remain unchanged, taking into consideration the conservation area, in tonnes of C year^{-1}

$\Delta C_{B_{t,AFF}}$ = annual change of carbon stocks in forest areas which remain unchanged, taking into consideration the total area, subject to the sub-activity of Recovery of Degraded Forest (*AFF*), in tonnes of C year^{-1}

$\Delta C_{B_{t,DegFF}}$ = annual change in carbon stocks on unchanged forest land, taking into consideration the total area, subject to the activity of degradation (*DegFF*), in tonnes of C year^{-1}

Accounting For non-Co_2 Emissions from Forest Fires

Bahamondez's methodology only estimates emissions of CO_2, so Equation 2.27 is used in order to calculate non-CO_2 emissions from forest fires IPCC (2006):

$$L_{fire} = A * M_B * C_f * G_{ef} * 10^3$$

Eq. 14 (Eq. 2.27 IPCC, 2006)

Where

L_{fire} = quantity of emissions of greenhouse gases caused by the fire, tonnes of each greenhouse gas year^{-1}
A = surface area burned, ha year^{-1}
M_B = mass of fuel available for combustion, tonnes ha^{-1}
C_f = combustion factor, no dimensions used
G_{ef} = emission factor, g kg^{-1} of dry material burned

Equation 15 is used to convert L_{fire} to CO_2e, which is necessary for equation 14:

$$GEI_{fire} = L_{fire} * CF$$

Eq. 15

Where

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

e. Activity Data

As explained above, the activity data were calculated using different available sources of information in order to apply the methodologies with the highest possible accuracy and completeness. This chapter describes the methods applied to estimate activity data for each group of REDD+ activities and sub-activities included in the FREL/FRL, linked to land use or sub-use changes and those that occur in permanent forests.

i. Land use or sub-use change

The area of native forest converted to other land uses (agricultural land, pasture and / or settlements) and sub-uses (forests plantations) as well as conversions from other land uses and sub-uses to native forest was estimated using land use change maps derived from the Cadaster calculations. This section includes Deforestation and sub-activities Substitution, Restitution and increase of forest area described above.

Each map contains the associated land use according to the categories specified in the Cadastre Manual[48], which were reassigned to different land uses and sub-uses. According to the estimation of land use and sub-use change the affected areas were established for each activity and sub-activity REDD+ as specified in Table 14.

Land use Cadastre	Land use start	Land use end	Sub-Activity	REDD+ Activity
Adult Native Forest	Bosque Nativo	Plantation	Substitution	Degradation Forest
Mixed Native Forest		Other land use	Deforestation	Deforestation
Scrub arborescente		Native Forest	N/A	N/A
Plantation	Plantaciones	Plantation	N/A	N/A
		Other land use	N/A	N/A
		Native Forest	Restitution	Enhancement of Forest Carbon Stock
Industrial and urban areas	Other land use	Native Forest	Incremento superficie forestal	Enhancement of Forest Carbon Stock
Agricultural lands				
Grasslands and scrublands		Plantation	N/A	N/A
Wetlands				
Areas without vegetation				
Snow and glaciers		Other land use	N/A	N/A
Bodies of water				

Table 14. Land uses recorded by the Cadastre, reallocation of categories and definition of activity and sub-activities REDD+.

48 Manual de Catastro http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/63-Anexo-Manual-Catastro-1995/file

ii. Forest remaining forest

To estimate the affected area by degradation in permanent forests, recovery of degraded forests and forest conservation a methodology detailed in Bahamondez *et al.* (2009) was used, which uses a system based on number of trees per hectare and basal area data recorded in the Continuous Forest Inventory plots, to estimate spatially explicit carbon stocks for different dates, coinciding with the field measurements of the Continuous Inventory.

The Continuous Inventory plots are located on a graph of density, or stocking chart, based on the number of trees and basal area per hectare. The stocking chart considers various thresholds, or lines, that determine, for different types of forest, their status at the moment of measurement. This information identifies the status of the plots, distinguishing between degraded and non-degraded plots (Bahamondez, 2009).

In the case of the methodology applied in the FREL/FRL, the threshold or line B will be the one that allows identifying degradation in permanent forests and recovery of degraded forests.

B Line represents the limit where trees can develop a large canopy and fully occupy the capacity of the site without excessive competition (Gingrich, 1967). The delimitation of this threshold was established through expert field work and it is specific for each forest type (INFOR, 2012). B Line is considered the threshold of natural resilience of a forest. The plots located below the threshold or B line, are not recommended for productive management (Figure 9)[49].

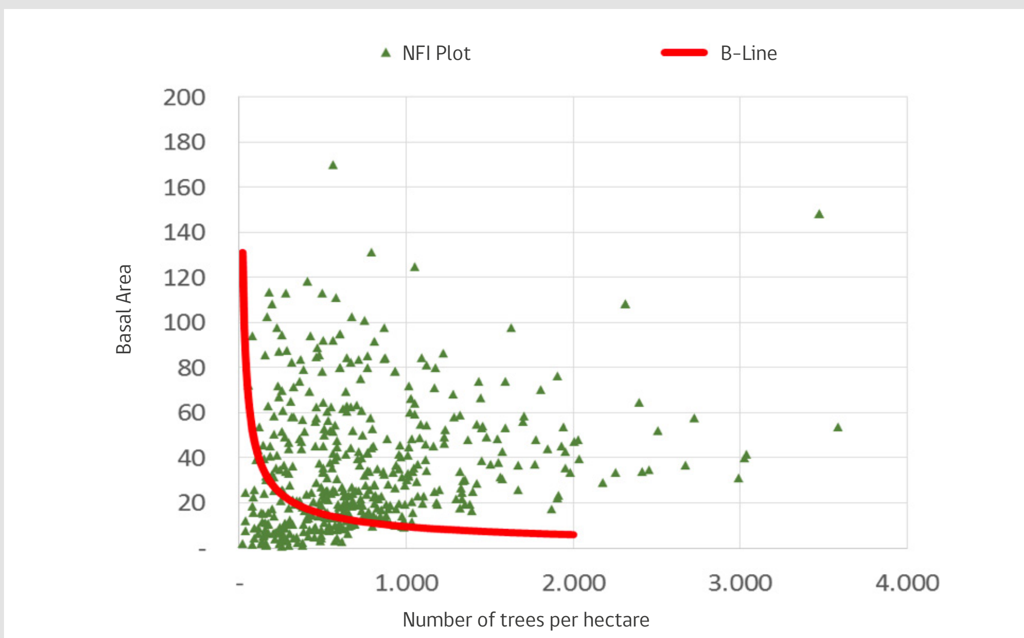

Figure 9. Stocking charter and line B. Based on data generated from field measurements Continuous Inventory (INFOR) used in the FREL/FRL.

[49] Information about plot parameters available in the link:
http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/52-anexo-datos-inventario-continuo/file

The stocking chart is a tool to allow the description of the state of a forest in a static moment. However the activities and sub-activities to analyze the FREL/FRL are processes that happen through the time. The stocking chart also records collected data from field work, which can generate estimates but do not contain spatially explicit information. To determine the plots subjected to degradation or recovery processes, the displacement on the stocking chart caused by the variation of basal area and number of trees per hectare between two measurements is analyzed (Figure 10, Table 15).

- Plots moving towards the chart origin axis, transferring or below the B line are considered as degradation plots.

- Plots moving away from the chart origin axis, transferring or below the B line are considered as recovery of degraded forest plots.

- Plots moving above the B line, regardless direction, are not considered in the FREL/FRL, as it is considered that variations are a natural effect and the plots are within the natural resilience threshold.

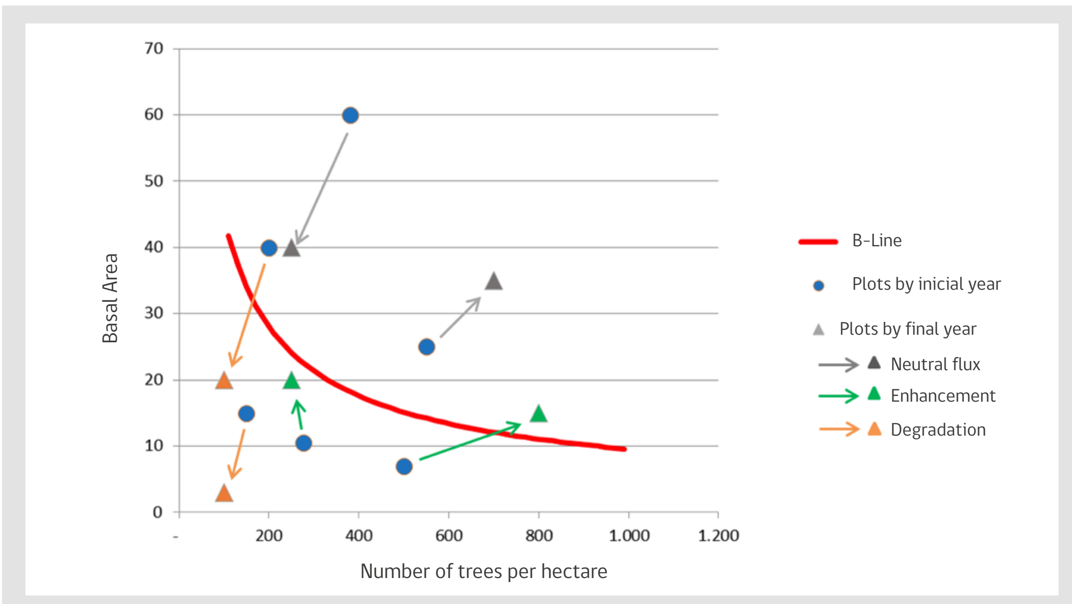

Figure 10. Examples of flows of gains (green arrow), losses (red arrow) and natural (grey arrow) between periods.

Change in stocking charter	Flow of CO_2	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 2011	Absortion	Enhancement
Under B in 2001 and above B in 2010	Absortion	Enhancement
Above B in 2001 and above B in 2010	N/A	Not counted

Table 15. Possible changes in the stocking charter between the two periods of time, and the REDD+ activities in which they are counted

At the date of this study, only the stocking chart associated with the forest type Roble-Rauli-Coihue (Ro-Ra-Co) was validated and published. The stocking charts for the forest types Siempreverde (Evergreen) and Lenga are currently being developed. Once these are completed, they will be submitted for validation in extended technical workshops. This study includes non-validated versions of Siempreverde and Lenga, the latter of which was generated based on forests of southern Argentina. In the case of Siempreverde, the most relevant in area, the stocking chart was compared to the already validated Ro-Ra-Co chart.

To obtain spatially explicit information for the estimation of surfaces subject to each of the detailed activities, a non-parametric K-nearest neighbor extrapolation is applied, modified by weighting neighbors detailed in Tomppo (1991). This method is widely applied in the analysis of forest inventories and allows the simultaneous extrapolation of plots state variables such as basal area and number of trees per hectare.

The Euclidean distance *dpi,p* is considered in the space of the auxiliary or explicatory variables (bands 1-5) as that distance between pixel *p* and *pi* that contains ground truth. Then a certain number k of the ground truth elements are considered that present 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 reordering in k nearest neighbors, a k set of weights wi with i=1,k are calculated, so that the linear combination of these weights provides the estimate of the vector state of the stand in unobserved stands (pixels). The weights are calculated as:

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

Eq. 17

Where

ij(p) = the ground truth plots that are found closest in distance in the multidimensional space of the auxiliary variables. Considering these expressions, the estimated values of those no-observed pixels on the ground is estimated as the linear combination:

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

Eq. 18

The procedure is applied and then pixels are resampled to 1 hectare for both, 2001 Landsat 5 and 2010 Landsat 7 imagery, covering the entire area of permanent forests in the study area.

To differentiate conservation areas the most recent Land Registry maps of each region are used to identify the total surface area of forests of Larch and Araucaria. Spatial data from the SNASPE provided by the Integrated System of Territorial Information of the Library of the National Congress of Chile is used to identify the surface areas of public protected areas. Data about the surface areas in private protected regions is taken from the Private Conservation Initiative.

To account for non-CO2 emissions, the tabular data with information about area affected by forest fires in the NGHGI 2015 Annexes were used. The original source of this data is the Forest Historical Statistics of CONAF-Companies 1985 to 2012. Data reported include the total annual areas of forest fires in each region from 1971 to 2012. However, in the FREL, only data from 2001 to 2010 are included to maintain consistency with the forests remaining forests reference period.

f. Emission Factors

i. Emission Factors for land use or sub-use change

Deforestation

Carbon stocks prior to deforestation

The carbon stocks in the forest prior to deforestation were obtained from the NGHGI of Chile information sources. These figures are taken from the INFOR Continuous Forest Inventory and are used to produce an estimate of Tier 3 live aboveground biomass. Estimates are stratified at regional level, where each of the regions in the sub-national FREL has its own estimate of forest carbon stocks prior to deforestation. While the Continuous Forest Inventory provides data by forest type, CONAF is responsible for providing information on land use change for the NGHGI. This land use change information does not include data on forest type. It only includes data on land use change from native forests to other uses and from planted forests to other uses. As a result, to be consistent with the level of detail of the land use change data, carbon stocks of native forests for each region, rather than for different forest types, are used in the NGHGI. The regional emission factors are calculated by calculating the average of the forest types within each region, weighted by the total area of each forest type within that specific region.

The aboveground and underground biomass (B_{BEFORE} from equation 8.4), and necromass (C_o from Equation 8.5) are obtained from the INFOR Continuous Inventory. Under deforestation accounting, it is assumed that the carbon stocks from harvested timber products (HWP) is zero, due to the lack of reliable data sources for differentiating between HWP from deforestation and those due to degradation.

Carbon stocks after deforestation (B_{AFTERi})

For the FREL estimates, it will be assumed that the carbon stocks in deforested land directly after deforestation are zero. In the NGHGI, IPCC 2006 default values are used for B_{AFTERi}, but it is assumed that these values are the growth of non-forest land use which actually corresponds to ΔC_G, no B_{AFTERi}[50].

Changes of carbon stocks separate from the event of deforestation (ΔC_G y ΔC_L)

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

- Values taken from a literary review of non-forested carbon stocks, preferably studies conducted within Chile (such as Gayoso 2006[51]). If these are not available, data from other regional studies are used (temperate South America with similar management systems). This is the preferred method and represents a Level 2 or 3 approach.

[50] In the NGHGI calculations, ΔC_G is was calculated by multiplying $B_{BEFOREi}$ by the fraction of carbon in dry biomass (the value of 0.5 was used). In a similar way, ΔC_L was calculated by multiplying B_{AFTERi} by 0.5. It was assumed that the values of B_{AFTERi} are the carbon stocks resulting from the uses of non-forested land after one year of growth.

[51] Gayoso JA (2006) Inventory of carbon in meadows and scrub for the Project SIF Regions VII and VIII baseline study. Universidad Austral de Chile, Valdivia.

- If these values are not available, IPCC 2006 default values are used. This is the method currently used by the NGHGI, but it represents a Level 1 method.

It is also assumed that losses due to harvesting timber, collection of firewood, and disturbances (ΔC_L) are zero in areas of deforestation, using the same NGHGI assumption.

Forest Degradation by Substitution

The estimates of carbon stocks from the plots in the continuous forest inventory as well as other studies on carbon stocks resulting from other uses of the land are utilized to obtain the removal factors for changing from native forest to plantations. Estimates of the existence of biomass in plantations assume this value to be zero (0), since Chile does not include plantations in its REDD+ programme.

Restitution and Increase Forests Area

In equation 8, it is assumed that the value of B_{AFTERi} is zero for agricultural land and urban and industrial areas, given that carbon stocks from using non-forested land converted to forest were eliminated before the forests were established. In terms of natural uses of the land, mainly meadows and scrubland, it is assumed that B_{AFTER} is the same as B_{BEFORE}, as it is assumed that no procedures for clearing or cleaning this land are carried out prior to establishing the forest but that it converts naturally to forest without losing the initial carbon stocks. The $B_{BEFOREi}$ carbon stocks are equivalent to the carbon stocks from using non-forested land. Regional or national scientific reports will be used to obtain these stocks, such as the one produced by Gayoso (2006) which estimated carbon stocks in non-forested land.

In equation 9, G_{TOTAL}, the mean annual growth of the biomass per hectare for each type of forest is calculated using Equation 10 (amended from IPCC 2006 Equation 2.10).

$$G_{TOTAL} = \Sigma_i(I_{Vi} \bullet BCEF_i \bullet (1+R_i))$$

Eq. 19 (Eq. 2.10 IPCC, 2006)

Where

G_{TOTAL} = mean annual growth of aerial and underground biomass, tonnes d. m. ha^{-1} year^{-1}
I_i = net mean annual increase for a forest type, m^3 ha^{-1} year^{-1}

$BCEF_i$ = biomass conversion and expansion factor for conversion of the net annual increase by volume (including cutting) in the growth of aerial biomass for a forest type, tonnes of growth of aerial cutting (m^3 mean annual increase)$^{-1}$

R = relationship between underground and aerial biomass for a forest type in tonnes d.m. of underground biomass (tonnes d.m. of aerial biomass)$^{-1}$.

The values for the net mean annual increase, *I*, are collected in the NGHGI data set, based on data from the INFOR forestry inventory, which estimates values for forest types: Alerce, Ciprés de las Guaitecas (Cypress of the Guaitecas), Araucaria, Ciprés de la Cordillera (Cypress of the Cordillera), Lenga, Coihue de Magallanes, Roble Hualo (Hualo Oak), Roble-Rauli-Coihue (Rauli-Coihue Oak), Coihue-Rauli-Tepa, (sclerophyll), and evergreens. Equation 20 is used to calculate the $BCEF_I$:

$$BCEF_I = BEF_I \bullet D_i$$

Eq. 20

Where

BEF_I = Expansion factor of biomass from a forest species. This factor increases the total volume of aerial biomass in order to compensate for the non-marketable constituents of the increase (no dimensions used)

D = value of basic density of timber, tonne m^{-3}

The biomass expansion factor, BEF_I, and the value of basic density of timber, *D*, are taken from the NGHGI data set, as a BEF_I value for native forests, not broken down per forest type, is indicated by Gayoso et al (2002). Likewise, there is only a timber density value for native species, without NGHGI defining the originating source, which is used to ensure consistency with the NGHGI.

The relationship between the underground and aboveground biomass for native forests, *R*, was estimated by Gayoso *et al* (2002) and can be found in the NGHGI data set.

ii. Forest remaining forest

Degradation on forest remaining forest, recovery of degraded forests and conservation of forest use the same methodology to calculate the emission factors used in the FREL.

The emission factors will be taken from the INFOR continuous forest inventory, which is the basis for the methodology. The methodology determines a basal area for each hectare of forest in t_1 and t_2. The total volume of each hectare is calculated on the basis of this information:

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

Eq. 21

Where

Vol = Volume of trees in forest, cubic metres ha^{-1}

AB = Basal area square metres ha^{-1}

K = constant, value of 2.9141

β = constant, value of 1.2478

$$EF = Vol * D * BEF$$

Ec. 22

Where

$\boldsymbol{EF}$ = carbon stocks in unchanged forest, tonnes of biomass ha^{-1}

$\boldsymbol{Vol}$ = Volume of trees in forest, cubic metres ha^{-1}

$\boldsymbol{D}$ = mean density of forests, metric tonnes^{-3}

BEF*I* = biomass conversion and expansion factor for conversion of the net annual increase by volume (including cutting) to the growth of aerial biomass for a forest type, tonnes of growth of aerial cutting (m^3 mean annual increase)$^{-1}$

g. Addition of sub-activities

With regard to activities involving forest degradation and enhancement of carbon stock, there are some sub-activities which are counted using the methodology for the conversion of land use and others which are counted using the methodology of unchanged forest. However, in order to obtain full accounting and a complete reference level for these activities, the sub-activities will be combined using the methods described below.

i. Forest degradation

According to the definitions two sub-activities are included under the degradation activity:

1. Degradation in forest remaining forest
2. Degradation by substitution

Different methodologies are used for each type of sub-activity, as has been described and justified previously, in order to calculate the FREL, adding together the various methodologies and reference periods, in tonnes of CO_2e, using the following equation:

$$\mathrm{FREL}_{Deg} = \frac{\left(\sum_t \Delta C_{B_{t,DegFF}} + \sum_t \Delta C_{B_{t,DegFNF}}\right) * \frac{44}{12} + \sum_t GEI_{fire}}{p}$$

Eq. 23

Where

$\mathbf{FREL_{Deg}}$ = annual mean losses of carbon stocks due to forest degradation during the reference period, in tonnes of C year[-1]

$\Delta C_{B_{t,DegFF}}$ = change in carbon stocks in forested land which remains unchanged in year *t* of the reference period, in tonnes of C

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

GEI_{fire} = quantity of emissions of non-CO_2 gases from forest fires, tonnes of CO_2e

p = years in the reference period

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

ii. Enhancement of carbon stock

Under the category of increases of stocks, acquisitions associated with the areas which have changed from non-forested to forested land are counted, as well as acquisitions from forested areas which remain unchanged. According to the definitions established, this category includes two sub-activities:

1. Restitution and Increase of forest area
2. Recovery of degraded forests

In the same way as for the FREL for degradation, information on the FRL activity for increasing forest carbon stocks is estimated using methodologies which are differentiated between those for forests which remain unchanged and those for identifying non-forested areas converted to forests.

$$\mathrm{FRL}_A = \frac{\left(\sum_t \Delta C_{B_{t,ANFF}} + \sum_t \Delta C_{B_{t,AFF}}\right) * \frac{44}{12}}{p}$$

Eq. 24

Where

$\mathbf{FRL}_A$ = annual mean increases in carbon stocks during the reference period, in tonnes of CO_2e year[-1]

$\Delta C_{B_{t,ANFF}}$ = change in carbon stocks in year t, which comes from non-forested land converted to forests during the reference period, under the activity of stock increases (*A*), in tonnes of C

$\Delta C_{B_{t,AFF}}$ = annual change of carbon stocks in forest areas which remain unchanged, taking into consideration the total area, in tonnes of C year[-1]

p = years in the reference period

6. Results

a. Activity Data

i. Land use or sub-use change[52]

Deforestation

As shown in Table 16, the large area deforested in Biobío and Araucanía in Period 1, and in Maule in Period 2, is highlighted. These large deforested areas are the result of the large forest fires occurring in 2002 in the regions of Biobío and Araucanía, and in 2013 in the region of Maule.

It should be noted that the deforested area in the whole reference period for Los Lagos Sur represents 14.164 hectares, of which over 10.000 hectares is forest that became a land devoid of vegetation and forests transformed into grasslands and scrubland due to the eruption of the Chaitén volcano in May of 2008.

Region	Deforestation Period 1 (ha/year^{-1})	Deforestation Period 2 (ha/year^{-1})	Interpolated Area (ha/year^{-1})
Maule	575	1.464	**872**
Biobío	1.994	607	**1.416**
La Araucanía	2.922	339	**1.630**
Los Ríos	851	679	**751**
Los Lagos Norte	996	291	**585**
Los Lagos Sur*	1.216		**1.216**
Total	**8.555**	**4.596**	**6.470**

*The *Lagos Sur* has information of a single period

Table 16. Deforested area by year and region.

Degradation by Substitution

Table 17 disaggregates the area per region and per year affected by Substitution of native forest, a sub-activity included within the activity of forest degradation. The substantial reduction in area of native forest to forest plantation transformed, between the two periods, coincides with the passing of Law 20.283 in 2008, which penalizes this practice. The distribution of Substitution area per region is closely related to the distribution of forest plantations in the country, as more than 80% of the plantations are located in the regions of Maule, Biobío and Araucanía.

[52] The spatial data based used to estimate land use change Activity data and regional maps are available in the link: http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/67-Mapas-cambio-uso/file

Region	Substitution Period 1 (ha/year^{-1})	Substitution Period 2 (ha/year^{-1})	Interpolated area (ha/year^{-1})
Maule	3.912	1.687	**3.170**
Biobío	6.004	2.561	**4.570**
La Araucanía	4.085	965	**2.525**
Los Ríos	1.685	373	**920**
Los Lagos Norte	533	406	**459**
Los Lagos Sur*	277		**277**
Total	**16.496**	**6.269**	**11.921**

* The *Lagos Sur* has information of a single period

Table 17. Surface replacement by period and interpolated

Restitution and Increase Forest Area

In the case of the Restitution of native forest, a sub-activity included within the activity Enhancement of carbon stock, Table 18 shown that this transformation is mostly produced in the first period of analysis. One of the potential causes could be the technological improvement deriving from the increased spatial resolution of satellite images that allows the identification of small native forests in riparian areas surrounded by areas of forest plantations that could not be identified in the baseline of Cadastre 1997 but in subsequent updates.

Most of the increases in forest area are due to forest growth in areas of grasslands and shrubland resulting in the transformation into arborescent shrub and native forest. As can be perceived, there is an increase in transformed area from the southern regions to the north, which is closely related to the spatial distribution of native shrubland.

Region	Restitution Period 1 (ha/year^{-1})	Restitution Period 2 (ha/year^{-1})	Restitution Reference Period (ha/year^{-1})	Increase Forest Period 1 (ha/year^{-1})	Increase Forest Period 2 (ha/year^{-1})	Increase Reference Period (ha/year^{-1})	Total Area (ha/year^{-1})
Maule	1.165	474	**934**	8.026	4.793	**6.949**	**7.883**
Biobío	2.342	206	**1.452**	3.542	1.673	**2.763**	**4.215**
La Araucanía	969	28	**499**	3.628	1.431	**2.530**	**3.028**
Los Ríos	405	634	**222**	855	572	**690**	**912**
Los Lagos Norte	199	-	**83**	1.132	245	**615**	**698**
Los Lagos Sur*	0		-	283		**283**	**283**
Total	**16.496**	**6.269**	**3.190**	**17.467**	**8.999**	**13.830**	**17.020**

* The *Lagos Sur* has information of a single period

Table 18. Restitution surface of native forest and increase of forest area for specific period and reference period

The map in Figure 11 shows the spatial distribution of activities and sub-activities corresponding to those that cause land use or sub-use changes.

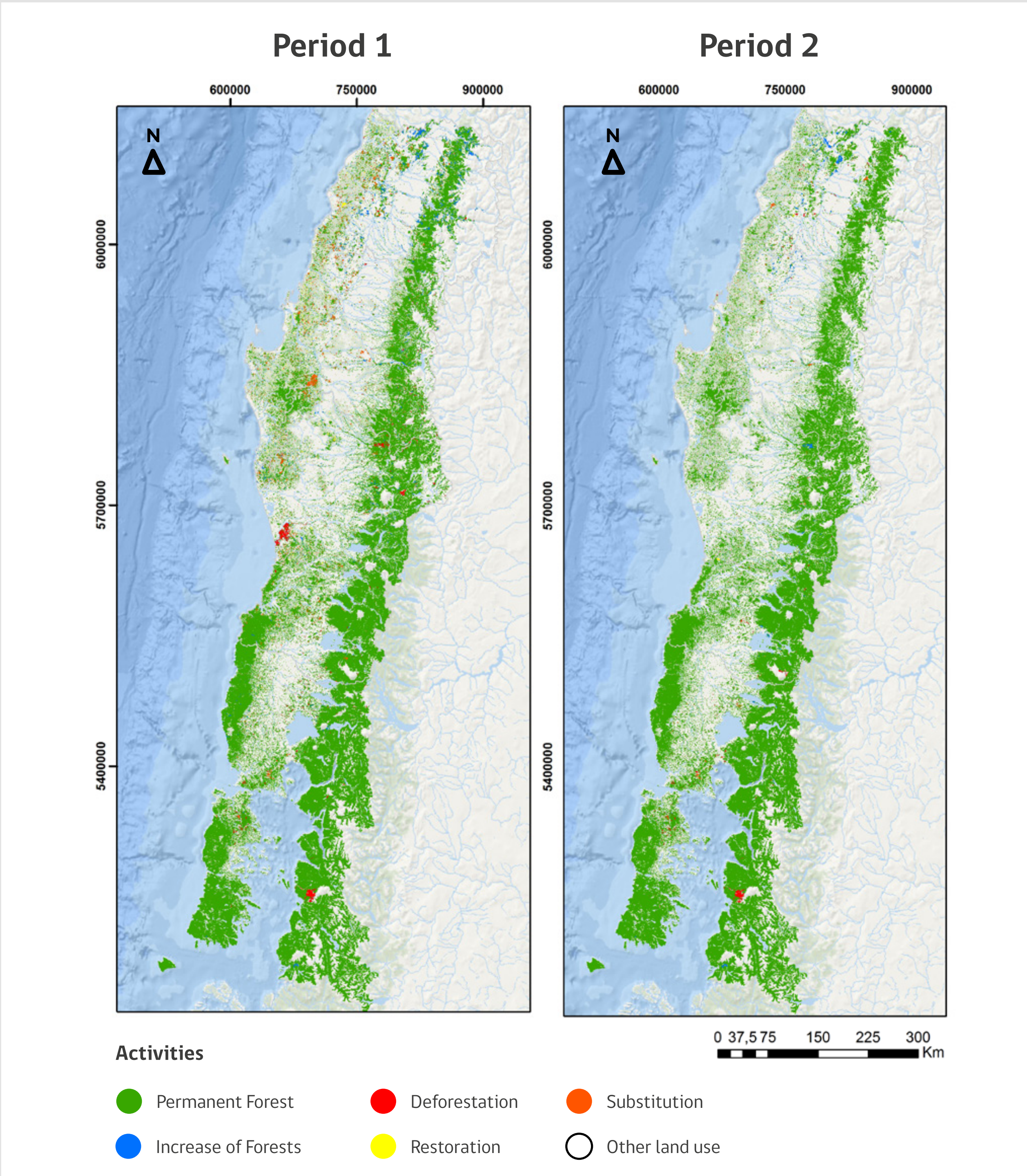

Figure 11. Map of activity and sub-activities REDD+.

ii. Forest remaining forest[53]

Degradation in Forest Remaining Forest

Table 19 disaggregates information about forest degradation area per region during the reference period 2001-2010. This highlights the area subject to degradation in the region of Los Lagos, coinciding with a strong informal intervention in the forests of Chiloe Province, which was not registered by the available tools (Cadaster) at that time. In addition, the Chaitén volcano , caused a great impact in this region during the reference period.

Region	Area (ha)
Maule	53.666
Biobío	62.399
Araucanía	34.183
Los Ríos	42.905
Los Lagos	268.078
Total	**461.231**

Table 19. Degraded area in forests that remains as forests by region between 2001 and 2010

Recovery of Degraded Forests

Table 20 disaggregates the area of recovery of degraded forests during the reference period, 2001-2010.

Region	Area (ha)
Maule	34.903
Biobío	417.846
Araucanía	118.176
Los Ríos	17.468
Los Lagos	89.276
Total	**677.669**

Table 20. Enhancement stock carbon area in forests that remains as forests by region between 2001 and 2010.

[53] The spatial data based used to estimate de Activity data in forest remaining forests and regional maps are available in the link: http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/64-Mapas-bosque-permanente/file

Forest Conservation

Table 21, disaggregates total conservation area, degraded and recovery area within conservation areas per region. As shown there is a direct relationship between degraded and recovered area with the total area of conservation.

Region	Total area (ha)	Degraded area (ha)	Recovered area (ha)
Maule	17.803	476	1.890
Biobío	97.255	4.099	11.813
Araucanía	164.340	9.883	18.553
Los Ríos	225.862	14.702	32.998
Los Lagos	930.671	76.473	101.401
Total	**1.435.931**	**105.633**	**166.655**

Table 21. Total area, degradation and recovery of forest conservation areas by region between 2001 and 2010.

Non-CO_2 Emissions From Forest Fires

In Table 22, information regarding the surface area degraded by forest fires for each region for the reference period 2001-2010 is presented.

It should be noted that in the summer of 2002, a large occurrence of forest fires caused by lightening affected Reserves, National Forests, and private lands with Araucaria and *Nothofagus* forests in the region of the Araucanía (González, M.E. *et al*, 2010)[54] which also affected the region of Biobío. Due to the forest fires which occurred in 2002, 14,536 hectares of the Malleco Forest Reserve were consumed in a period of 74 days[55].

	2001-2010	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Region	ha/año	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha
Maule	599	26	147	504	171	140	62	9	464	4.030	432
Biobío	1.237	89	7.560	159	211	396	148	947	267	958	1.635
Araucania	2.116	64	18.765	226	369	212	74	41	351	1.012	42
Los Ríos	151	1	904	3	184	19	7	5	119	271	1
Los Lagos	782	9	2.552	28	91	47	207	52	4.234	598	1
Total	**4.884**	**189**	**29.928**	**920**	**1.026**	**814**	**498**	**1.054**	**5.435**	**6.869**	**2.110**

Table 22. Area affected by forest fire by region between 2001 and 2010.

54 http://www.bosquenativo.cl/descargas/Revista_Bosque_Nativo/RBN_46_art_tec2web.pdf

55 http://www.lignum.cl/2015/02/17/grandes-e-historicos-incendios-forestales-que-debes-conocer/

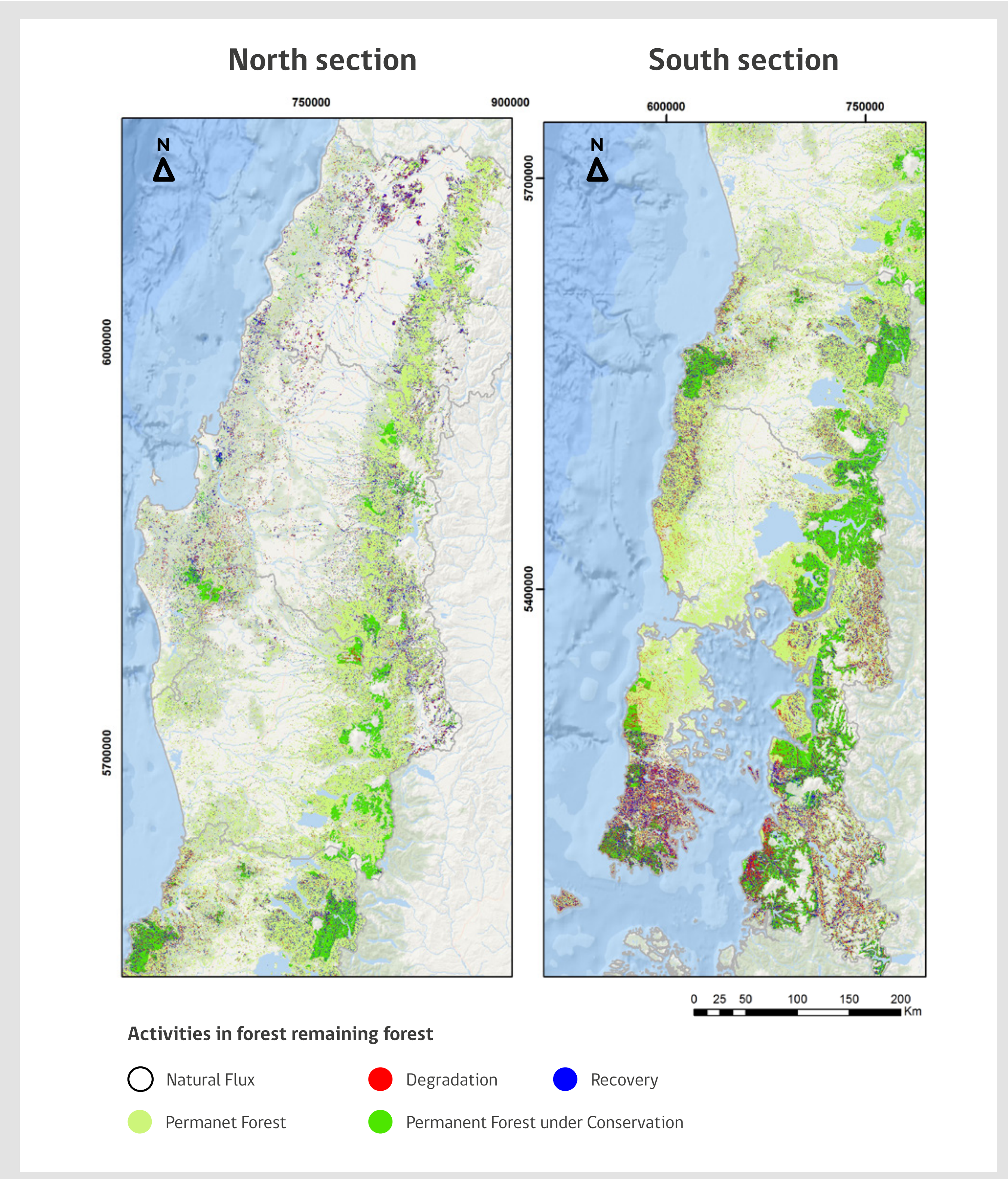

Figure 12. Map of activities and sub-activities REDD+ in forest that remains as forest.

b. Emission Factors

i. Land use or sub-use change

Deforestation and Degradation by Substitution

The emission factors applied in the FREL for Deforestation resulted from a combination of data from different Levels. Level 3 emission factors taken from the estimate of aboveground biomass in the Continuous Forest Inventory, which records different carbon contents per region, were used for the aboveground biomass in consistency with the NGHGI.

The belowground biomass is a result of applying the root-shoot ratio to the aboveground biomass (Gayoso, 2002)[56].

As far as dead organic matter is concerned, Level 2 regional emission factors from the NGHGI of 2015 and in turn were based on the Continuous Forest Inventory.

Table 23 shows the emission factors used for the FREL for Deforestation, per region and pool.

Region	Biomass (t d.m. ha^{-1})	Necromass (t d.m. ha^{-1})	Total (t d.m. ha^{-1})
Maule	103,4	4,6	**108,0**
Biobío	192,9	10,0	**192,9**
La Araucanía	334,8	46,9	**202,9**
Los Ríos	422,6	117,4	**381,7**
Los Lagos Sur	348,1	69,4	**417,5**
Los Lagos Norte	348,1	69,4	**417,5**

Table 23. Regional emission factors for native forest disaggregated per carbon reservoirs taken into consideration in the analysis.

[56] Underground biomass stocks were already calculated for meadows, bushes, and shrubland and succulent formations in Gayoso (2006). Nevertheless, the article also applied a root/stem ration in order to identify those estimated aerial values.

Restitution and Increase Forest Area

The Level 3 removal factors for the various forest types were taken from the NGHGI, which, with the exception of Araucaria forests, were based on data from the Continuous Forest Inventory (Table 24). The growth rate of Araucaria is taken from regional data from a dissertation about *Araucaria auracana* in the south of Chile (Mujica, 2000).

The annual growth rates for renoval or secondary forests were also applied to adult-renoval forests. The growth rates for adult forests were also applied to stunted forests, because it is assumed that they have reached maturity and it is very probable that young and/or secondary forests grow more slowly.

The growth rates for adult *esclerófilo* forests were applied to the scrubland, since they are more physionomically similar to their forest types. This is also a conservational approach, as the adult *esclerófilo* forests have some of the lowest growth rates of all the forest types. The mean net growth was calculated for mixed forests in each region, taking the net mean growth of all the forest types found in this region, as identified in the Land Registry.

Forest Type	Renoval	Adult
	(m3/ha/año)	
Alerce	0,45	0,45
Ciprés de Las Guaitecas	3,9	3,9
Araucaria	4,6	4,6
Ciprés de La Cordillera	4,7	3,9
Lenga	6,0	5,2
Coihue de Magallanes	6,1	4,6
Roble Hualo	4,6	3,0
Roble-Raulí-Coihue	6,1	5,0
Coihue-Raulí-Tepa	5,1	4,0
Esclerófilo	2,2	1,9
Siempreverde	5,8	3,2

Table 24. Average annual increment by forest type. Sources: Annex unpublished NGHGI

ii. Forests remaining forests

With regard to these values, the volume and then the carbon stock are estimated for each pixel in the images for 2001 and 2010. These stocks are converted into emission factors, using an approach involving the stock-difference in order to determine the specific emission of each pixel which 1) experienced a loss in carbon stocks between 2001 and 2010; and 2) was in a state of degradation or at risk of degradation in 2010, as determined by the picture of stocks from the species of native forests. This analysis was only performed in the forest areas which remained unchanged as explained in the estimate of activity data.

Non-CO_2 Emissions from Forest Fires

The emission factors for the biomass available for combustion are the same as those described as emission factors of the FREL for Deforestation. The combustion, emission and conversion factors are default factors of the IPCC (2006), as shown in Table 25.

GEI	Conversion Factor CO_2e	Combustion Factor	Emission Factor
CH4	28	0,45	4,70
N2O	265	0,45	0,26

Table 25. Emission Factors, combustion and conversion for emission no-CO_2

7. FREL/FRL Subnational of Chile

a. Deforestation[57]

The average annual emission levels due to deforestation in the proposed subnational FREL are 3,5 million t CO_2 year^{-1} (Table 26).

FREL Deforestation				
Region	Deforested area (ha year^{-1})	Biomass (tCO_2e year^{-1})	Necromass (tCO_2e year^{-1})	Total (tCO_2e year^{-1})
Maule	872	77.632	7.351	84.982
Biobío	1.416	370.682	25.963	396.645
La Araucanía	1.630	918.816	140.251	1.059.067
Los Ríos	751	483.105	161.591	644.696
Los Lagos Sur	585	326.822	74.408	401.230
Los Lagos Norte	1.216	711.578	154.687	866.265
Total	**6.470**	**2.888.634**	**564.251**	**3.452.885**

Table 26. Total emissions by deforestation in the FREL subnational of Chile.

b. Forest Degradation

CO_2 emissions in forest lands that remain forest lands, native forests that become arborescent shrublands (according to the Cadastre), the conversion of native forests and arborescent shrublands to forest plantations, and the emissions of non-CO_2 gases produced by forest fires are calculated independently of one another. All of the different sources are added to form the FREL for forest degradation, equivalent to 9,1 millones de tCO_2e año^{-1} (Table 27).

[57] Tool used to estimate emissions by deforestation available in the link:
http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/56-Herramienta-Deforestaci%C3%B3n/file

Degradation FREL				
	CO_2	CH_4	N_2O	Total tCO_2e
Maule	604.393	3.008	1.576	608.976
Biobío	1.192.046	11.712	6.132	1.209.890
La Araucanía	1.848.728	38.473	20.143	1.907.344
Los Ríos	1.366.994	3.994	2.091	1.373.080
Los Lagos	4.026.126	15.738	8.240	4.050.103
Total	**9.038.288**	**72.924**	**38.181**	**9.149.392**

Table 27. Forest Degradation FREL

The following section elaborates on the emissions from forest degradation based on the different methodologies and sources of information used for their assessments.

i. Degradation by Substitution[58]

The annual emission levels due to the conversion of native forests to forest plantations are approximately 4,1 million tCO_2e, as shown in.

FREL Substitution				
Region	Degraded area (ha $year^{-1}$)	Biomass (tCO_2e $year^{-1}$)	Necromass (tCO_2e $year^{-1}$)	Emisiones Total (tCO_2e $year^{-1}$)
Maule	3.170	407.951	26.743	434.685
Biobío	4.570	894.837	83.781	978.618
La Araucanía	2.525	1.196.118	217.196	1.413.313
Los Ríos	920	576.777	197.845	774.622
Los Lagos Sur	459	146.281	35.276	181.556
Los Lagos Norte	277	234.833	58.413	293.246
Total	**11.921**	**3.456.797**	**619.254**	**4.076.040**

Table 28. Emissions from conversion native forest to exotic plantation and tree-shrub in the FREL subnational of Chile.

58 Tool used to estimate emissions by substitution (including the total Degradation FREL) available in the link: http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/60-Herramienta-Sustituci%C3%B3n/file

ii. Forest remaining forest[59]

The annual emissions of forest lands that remain as forest lands (for example, fuelwood collection, selective logging, etc) are approximately 5,0 million tCO_2e, as shown in Table 29.

Region	Area (ha)	Emissions (tCO_2e año^{-1})
Maule	53.666	169.708
Biobío	62.399	213.428
La Araucanía	34.183	435.415
Los Ríos	42.905	592.373
Los Lagos	268.078	3.551.324
Total	**461.231**	**4.962.248**

Table 29. Annual emissions of native forest remaining forest by region.

iii. Non CO_2 emissions from Forest Fires[60]

The annual emissions of non-CO_2 gases due to forest fires are approximately 0,1 million tCO_2e, as shown in Table 30. This number is small because it only considers the emissions of methane (CH_4) and nitrous oxide (N_2O). CO_2 emissions have been estimated and recorded in the previous category (as shown above) of the degradation in forest lands that remain as forest lands.

Emissions		
Region	Degraded area (ha)	Emissions (tCO_2e año^{-1})
Maule	599	4.582
Biobío	1.237	17.843
La Araucanía	2.116	58.616
Los Ríos	151	6.085
Los Lagos	782	23.977
Total	**4.884**	**111.103**

Table 30. Emissions of non-CO_2 gases by region.

[59] Tool used to estimate emissions and captures in permanent forests available in the link:
http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/64-Mapas-bosque-permanente/file

[60] Tool used to estimate emissions by forest fires available in the link:
http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/57-Herramienta-Incendios/file

The distribution of the annual data of forest fires (Figure 13) illustrates the significant impact of 2002, with emission levels significantly higher than the rest of the years of the reference period.

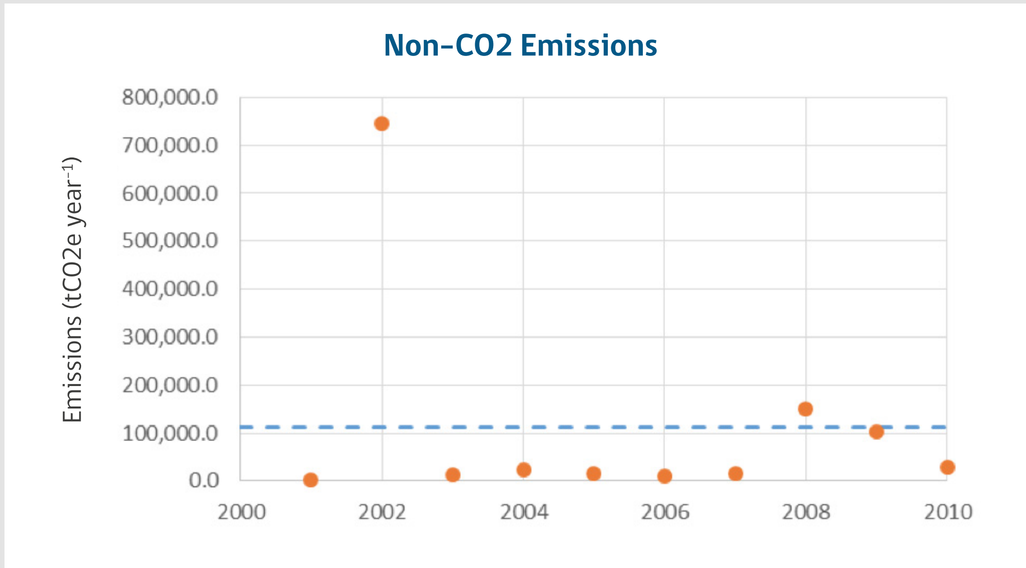

Figure 13. Emissions non-CO2 gases represented by year.

c. Enhancement of forest carbon stock

Removals in forest lands that remain forest lands are calculated independently from removals due to the conversion of other land uses to forest lands, including the transformation of forest plantations into native forests and arborescent shrublands (according to Cadastre). The different sources are added together to integrate the FRL for enhancement of forest carbon stock equivalent to 10 million tCO_2e año^{-1} (Table 31).

Absorption average of CO_2e per year			
Region	Other forested land	Forest remaining Forest	Total
	tonnes CO_2e year^{-1}	tonnes CO_2e year^{-1}	tonnes CO_2e year^{-1}
Maule	-391.180	-790.982	-1.182.162
Biobío	-202.770	-1.079.374	-1.282.143
La Araucanía	-189.330	-1.328.564	-1.517.894
Los Ríos	-53.356	-1.968.685	-2.022.041
Los Lagos Sur	-38.354	-3.953.636	-4.007.772
Los Lagos Norte	-15.782		
Total	**-890.773**	**-9.121.239**	**-10.012.012**

Table 31. Absorption for the enhancement forest carbon stock in the FREL area.

The following elaborates on the removals due to enhancement of forest carbon stock based on the different methodologies and sources of information used for their assessments:

i. Restitution and Increase in forest area[61]

The average annual removal by enhancement of forest carbon stocks due to the change of non-forest lands into forest lands, the transformation of arborescent shrubland into forest lands, and the transformation of forest plantations into native forests and arborescent shrubland is approximately 0,9 million $tCO_2año^{-1}$ (Table 32).

Increased conversion from land non forest to forest		
Region	**Increase Area (ha $year^{-1}$)**	**Tons CO_2e $year^{-1}$**
Maule	7.883	-391.180
Biobío	4.215	-202.770
Araucanía	3.028	-189.330
Los Ríos	912	-53.356
Los Lagos Sur	283	-15.782
Los Lagos Norte	698	-38.354
Total	**17.020**	**-890.773**

Table 32. Absorption by conversion from land non forest to forest by region in the FREL subnational of Chile.

ii. Recovery of degraded forests[62]

The average annual removal amounts due to the enhancement of forest carbon stock in forest lands that remain as forest lands is approximately 9,1 million tCO_2 $year^{-1}$. The majority of the removals emerges from the regions Los Lagos and Los Rios (Table 33).

Region	Area (ha)	Removal (tCO_2e $año^{-1}$)
Maule	34.903	-790.982
Biobío	417.846	-1.079.374
Araucanía	118.176	-1.328.564
Los Ríos	17.468	-1.968.685
Los Lagos	89.276	-3.953.636
Total	**677.669**	**-9.121.239**

Table 33. Absorptions from land non-forest to land forest in the FREL area.

[61] Tool used to estimate emissions by substitution (including the total Degradation FREL) available in the link: http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/54-Herramienta-Aumentos/file

[62] The estimation of captures in forest remaining forest is include in "Herramienta Bosque permanente"

d. Conservation of forest[63]

The FREL/FRL of conservation of forest carbon stocks consists of the net emissions and removals produced in areas of conservation and is approximately 2,4 million tCO_2e of annual net removals (Table 34).

Region	Total area (ha)	Flow (tCO_2e año^{-1})
Maule	17.803	-14.780
Biobío	97.255	-72.359
La Araucanía	164.340	-334.741
Los Ríos	225.862	-710.081
Los Lagos	930.671	-1.298.478
Total	**1.435.931**	**-2.430.439**

Table 34. Conservation of forest carbon stock by region in the FREL/FRL subnational of Chile.

The annual total emissions of forest lands that remain as forest lands occurring in areas of conservation are approximately 1,3 million tCO_2e (Tabla 35).

Region	Total area (ha)	Flow (tCO_2e año^{-1})
Maule	476	2.670
Biobío	4.099	11.090
La Araucanía	9.883	116.065
Los Ríos	14.702	187.292
Los Lagos	76.473	969.464
Total	**105.633**	**1.286.581**

Table 35. Emission of forest inside conservations areas by region.

[63] The estimation of Conservation of forest carbon stock is include in "Herramienta Bosque permanente"

The amount of annual GHG removals that occur within areas of conservation is approximately 3,7 million de tCO_2e (Tabla 36).

Region	Total area (ha)	Removals (tCO_2e año^{-1})
Maule	1.890	-17.450
Biobío	11.813	-83.448
La Araucanía	18.553	-450.806
Los Ríos	32.998	-897.373
Los Lagos	101.401	-2.267.942
Total	**166.655**	**-3.717.019**

Table 36. Carbon absorption of forest in conservation areas by region.

e. Native forest FREL/FRL subnational of Chile[64]

As previously stated, Chile presents a FREL/FRL at the subnational scale for native forests in four REDD+ activities with annual emissions of 3,4 million tCO_2e for deforestation, 9,1 million tCO_2e for degradation and annual removals of -2,4 million tCO_2e for conservation of forest carbon stocks and -10,0 million tCO_2e for enhancement of forest carbon stocks, as shown in Table 37.

FREL/FRL					
Activity REDD+	Deforestation	Degradation	Conservation	Increase	Total
Maule	84.982	608.976	-14.780	-1.182.162	**-502.985**
Biobío	396.645	1.209.890	-72.359	-1.282.143	**252.033**
La Araucanía	1.059.067	1.907.344	-334.741	-1.517.894	**1.113.776**
Los Ríos	644.696	1.373.080	-710.081	-2.022.041	**-714.346**
Los Lagos	1.267.494	4.050.103	-1.298.478	-4.007.772	**11.348**
Total	**3.452.885**	**9.149.392**	**-2.430.439**	**-10.012.012**	**159.826**

Table 37. FREL/FRL subnacional of Chile.

[64] Tool used to estimate the FREL/FRL available in the link: http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/66-total-frel-frl/file

8. Uncertainty Calculation[65]

Uncertainty is an essential element of FRELs/FRLs, since projections of emissions and removal differ from the real underlying value. Some causes of uncertainty, such as sampling errors, mapping errors, instrument precision, and the statistical variance of models, can be estimated for inclusion in the quantification of uncertainty. Other causes, such as bias, are more complicated.

a. Activity data

i. Land use and sub-use changes[66]

The REDD+ activities and sub-activities in this category are:

- Deforestation
- Degradation due to substitution
- Increases in forest carbon due to conversion of non-forest land to forest land

Activity data on changes in land usage are taken from the Cadaster. Throughout the digital cartography mapping and drafting process, layers are updated in the Cadaster. Mapping is updated using Spot 6 and 7 with a five-metre resolution, Landsat 8 images and OLI sensor with a resolution of thirty metres, and RapidEye with a resolution of ten metres.

The imaging equipment then goes on to verify the terrain if image interpretation is correct. During each update, 30% of all land use polygons are verified on the ground. Of the 30% verified, 90% are primarily used to verify the areas of native forest located in polygons with changes and polygons extrapolated or corrected in comparison with the original. The remaining 10% is used to verify the quality of visual interpretation of other types of land use. This verification process allows data extrapolated from the final mapping procedure to be corrected and final maps to be reconstituted. Validation of the final mapping process as part of updates to the Cadaster is performed post-processing using a confusion matrix (3% of final mapping polygons).

Errors in relation to use and sub-use as characterized by the Cadaster, are calculated following the good practices for assessing accuracy of land change as described in Olofsson *et al.*, (2014)[67]. To employ this approach, the land use change classes were validated using Collect Earth[68], where

[65] Tool used to estimate uncertainty is available in the link:
http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/59-Herramienta-Incertidumbre/file

[66] Land use change maps confussion matrix are available in the link:
http://www.enccrv-chile.cl/index.php/descargas/nivel-de-referencia/61-Anexo-Incertidumbre-mapas-de-cambio/file

[67] 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.

[68] More details at: http://www.openforis.org/tools/collect-earth.html

a total of 4.519 polygons accounting for an area of 92.676 ha were validated using the online tool. Table 38 shows the division of number of polygons and area validated per region per period of imagery considered in the reference levels.

	Period 1		Period 2	
Region	# of polygons	ha	# of polygons	ha
Maule	475	7.221	425	6.061
Biobío	450	3.260	400	3.531
La Araucanía	450	11.148	359	9.602
Los Ríos	425	5.922	360	9.319
Los Lagos Norte	425	11.960	350	12.549
Los Lagos Sur	400	12.102	n.a.*	n.a.*

Table 38. Number of polygons and mapped area per region and per period validated using Collect Earth

From this validation, confusion matrices per region for each period of land cover and land cover change used in the reference period, and the 95% confidence interval per land use cover change class was estimated. From this, error was estimated per class and included in the error propagations for calculating uncertainties per sub-activity and per activity.

Activity	Region / Period	Maule	Biobío	La Araucanía	Los Ríos	Los Lagos Norte	Los Lagos Sur
Deforestation	Period 1	32,49%	46,52%	2,81%	11,67%	4,99%	8,08%
	Period 2	70,06%	132,59%	3,78%	119,21%	26,81%	N/A
Substitution	Period 1	4,79%	4,48%	7,77%	9,85%	5,87%	3,38%
	Period 2	5,40%	42,01%	69,91%	8,04%	2,23%	N/A
Restitution	Period 1	6,56%	6,15%	3,55%	57,52%	4,81%	N/A
	Period 2	409,55%	5,18%	6,26%	59,88%	N/A	N/A
Forest Increased	Period 1	8,06%	130,61%	13,38%	54,58%	5,59%	87,70%
	Period 2	24,49%	219,62%	2,49%	67,25%	588,47%	N/A
Forest Permanent	Period 1	2,74%	6,56%	1,14%	0,49%	1,13%	0,31%
	Period 2	6,56%	2,01%	0,95%	1,61%	1,61%	N/A
Other Permanent Use	Period 1	0,59%	2,91%	0,57%	0,66%	1,02%	0,55%
	Period 2	1,90%	1,12%	0,43%	1,59%	0,87%	N/A

Table 39. Uncertainty by type change, period and region.

ii. Forests remaining forests

There are four sources of error in the forest remaining forest activity data: 1) error due to mapping of forest remaining forest by the Cadaster, 2) error related to the radiometric and geometric performance of the satellite equipment used, 3) error due to interpolation of basal area using the k-nn algorithm; and, 4) error of mapping degradation in the ER program.

Mapping of forest remaining forest by the Cadastre

The source of this error is discussed in section above detailing the validation of the land changes using Collect Earth. It is important to note that one of the classes validated is the forests remaining forests, mask used for executing the k-nn. The error in forest remaining forest was calculated using the Olofsson *et al.*, (2014) approach and varied per region and per period as shown in Table 40 below.

Activity	Region / Period	Maule	Biobío	La Araucanía	Los Ríos	Los Lagos Norte	Los Lagos Sur
Forest Permanent	Period 1	2,74%	6,56%	1,14%	0,49%	1,13%	0,31%
	Period 2	6,56%	2,01%	0,95%	1,61%	1,61%	N/A

Table 40. Uncertainty by type of change, period and region.

Radiometric and geometric performance of the satellite equipment used

For the estimation of uncertainties related to the geometric performance of the satellite equipment used, scientific articles published by Storey (2008[69], 2014[70]) were used, whose results are summarized in Table 41.

Evaluated performance type	Precision ETM+(m)	Precision OLI (m)	Measuring error type
Co-registration of bands	3,00	4,1 (all bands)	LE90
		3,4 (wihtout cirrus)	
Absolute Geodesic	45-190	0,18	CE90
Relative Geodesic	17,00		CE90
Coregistration of images	10,50	6,60	LE90
Geometric with field correction	15*	7-13	CE90

* Based on all the bands, including cirrus. Precision of band 9 is 3.4m

Tabla 41. Geometric performance of Landsat 7 (Storey et al., 2008) y Landsat 8 OLI (Storey *et al.*, 2014).

[69] Storey *et al.*, 2008. J. Storey, K. Lee, M. Choate. Geometric performance comparison between the OLI and the ETM +. Proceedings of the PECORA 17 Conference (2008, November 18-20). 8pp

[70] Storey, J.; Choate, M.; Lee, K. Landsat 8 Operational Land Imager On-Orbit Geometric Calibration and Performance. Remote Sensing. 2014, Vol. 6, Núm. 11, pp 11127-11152.

In relation to the previous table, the co-registration of bands corresponds to the adjustment or wedge that is produced between the different spectral bands that make up an image, in other words, how well the data recorded in the different bands relate to any relative observation for the same scene. The absolute geodesic precision allows for the determination of the positioning of the data, derived from systematically corrected data and without using control points; based on attitude, ephemeris, and (when available) GPS platform data. The accuracy of image co-registration compares the position of the specific pixels for captures of two or more dates on the same area; therefore, it is relevant when doing studies based on multi-temporal series and where high absolute accuracy is not required. Finally, the geometric accuracy with field correction is obtained for systematically corrected equipment that uses control points in the field and additionally incorporates the use of a digital elevation model to correct for variations in scale of a scene.

Generally, the actual geometric performances of Landsat 7 and Landsat 8 for non-emissive bands significantly exceed their technical specifications for circular and linear errors with 90% confidence intervals (USGS, 1998[71]. USDOI, 2016[72]).

Radiometric Performance

The radiometric performance of images for classification of calculation of indices can be done with absolute or relative approximations. Absolute approximations, based on physical models of radiative transfer require a significant amount of input parameters; which are not always available. On the other hand, relative calibrations can demonstrate great utility when it is not necessary to obtain values of a physical nature sustained over time.

In terms of absolute calibration, in accordance with studies performed under optimal conditions with equipment from Landsat 7 and Landsat 8 platforms, it can be seen that the calibration of both sensors in terms of the radiance recorded, is about 3 percent (Mishra *et al.*, 2014[73]. Flood, 2014[74]), with similar patterns for reflectance values at the top of the atmosphere; with the largest deviations present in closest infrared band. This is found within the uncertainty threshold values for radiance values established for OLI, indicative of good calibration, but also of good radiometric compatibility between the spectral bands of the two sensors (Mishra *et al*, 2014). Flood (2014) notes that some of the differences found appear to be systematic, so they can be correct.

In a similar fashion, comparisons of absolute performance made by Chander *et al.* (2003)[75] for Landsat 5 and Landsat 7 found differences in radiometric performances less than 5% (USGS,

[71] USGS, 1998. Landsat 7 Data Science Users Handbook. Revised edition. 207pp. descargado Julio 01, 2016 desde: https://landsat.gsfc.nasa.gov/wp-content/uploads/2016/08/Landsat7_Handbook.pdf

[72] USDOI, USGS, 2016. LSDS-174 Landsat 8 (L8) Data Users Handbook v2.0. Marzo 29, 2016. 98pp. descargado Julio 01, 2016 desde: https://landsat.usgs.gov/documents/Landsat8DataUsersHandbook.pdf

[73] Mishra, N.; Haque, M.O.; Leigh, L.; Aaron, D.; Helder, D.; Markham, B. Radiometric Cross Calibration of Landsat 8 Operational Land Imager (OLI) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+). Remote Sens. 2014, 6, pp 12619-12638

[74] Flood, N. Continuity of Reflectance Data between Landsat-7 ETM+ and Landsat-8 OLI, for Both Top-of-Atmosphere and Surface Reflectance: A Study in the Australian Landscape. Remote Sensing. 2014, Vol. 6, Núm. 9, pp 7952-7970

[75] Chander, G.; Markham, B.; Micijevic, E.; Teillet, P.; Helder, D. Improvement in absolute calibration accuracy of Landsat-5 TM with Landsat-7 ETM+ data. Proc. SPIE 5882. Earth Observing Systems X, 588209 (September 07, 2005). doi:10.1117/12.620136

1998) by making pre-calculated calibration tables. They found agreement degrees of 96% for the optic bands and around 94% for short-wave infrared bands. On the other hand, in an analysis of digital equipment accounts TM and ETM+, Vogelmann (2001)[76] found a high degree of similarity, implying the possibility of monitoring based on these sources.

Regarding relative calibration methods such as those used in this study, Hu *et al.* (2011)[77] found that methods such as multivariate detection of alterations can yield results of higher quality than the absolute methods. This would preclude the necessity for atmospheric correction of images. On the other hand, more elemental methods can typically deliver results with mean square errors in terms of digital accounts, whose values oscillate between 7 and 15 (Yang and Lo, 2000[78]).

To evaluate the performance of the relative radiometric corrections carried out on images used in this study, reference scenes located in the Araucania region were used. For this purpose, equipment with P232R87 designation was used by the Landsat satellite series. The scenes used corresponded with the following pair:

Identifier	Platform	Sensor	Date of capture
LE72320872001342EDC01	Landsat 7	ETM+	08-12-2001
LT52320872009004COA01	Landsat 5	TM	04-01-2009

While these images to two different sensors, they were first taken to a common framework. This was carried out through a calculation of their radiance values, then they were calibrated between each other using the histogram equalization technique.

To determine the performance of the correction, an area was selected covering close to one and a half million hectares of the mountainous and foothill zone with high presence of native forests, as well as zones without vegetation and less important participation of forest plantation, agricultural crops and pasture area. For this sample, the differences were calculated between the reference image and the adjusted image (times t0 and t1) at the level of each band. Then from this, the mean square error was calculated as shown in the following equation:

$$RMSE_b = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (EA'_b - ER_b)^2}$$

Eq. 25

[76] Vogelmann, J.; Helder, D.; Morfitt, R.; Choate, M.; Merchant, J.; Bulley, H. Effects of Landsat 5 Thematic Mapper and Landsat 7 Enhanced Thematic Mapper Plus radiometric and geometric calibrations and corrections on landscape characterization, Remote Sensing of Environment, Vol. 78, Núm. 1-2, October 2001, pp 55-70.

[77] Hu, Y.; Liu, L.; Liu, L.; Jiao, Q. Comparison of absolute and relative radiometric normalization use Landsat time series images. Proc. SPIE 8006. MIPPR 2011: Remote Sensing Image Processing, Geographic Information Systems, and Other Applications. 800616 (November 23, 2011); doi:10.1117/12.902076.

[78] Yang, X., Lo, C.P.. Relative Radiometric Normalization Performance for Change Detection from Multi-Date Satellite Images , Photogrammetric Engineering & Remote Sensing, Vol. 66, Núm. 8, Agosto 2000, pp 967-980.

Where

$RMSE_b$ = mean square error for the band b
EA'_b = pixel value for the adjusted band
ER_b = pixel value for the reference band
n = number of pixels in the sample

The results obtained from this exercise are in Table 42, where the values of the mean square error oscillate between 1,27 and 8,39 $W * m^{-2} * sr^{-1} * \mu m^{-1}$, with a mean square error in percentage terms 16,37%.

Band	Spectral image	Squar d sum	Number of pixels	Mean squared error (W * m⁻² * sr⁻¹ * µm⁻¹)	Mean squared error (%)
1	Blue	1.231.313.084	17.477.169	8,39	16,23
2	Green	1.189.376.347	17.477.169	8,25	18,44
3	Red	1.002.400.029	17.477.169	7,57	20,66
	Near infrared	1.179.447.720	17.477.169	8,21	13,43
5	Sortwave infrared	28.248.691	17.477.169	1,27	13,09
			Mean Error:	6,74	16,37

Table 42. Radiometric performance based on reference images used in the study.

From this, and assuming a bias of 0,0, the 95% confidence interval was calculated, and the uncertainty of the radiometric error as percent of the mean estimated to be 0,05%. Mean square error (RMSE) is calculated by:

$$\sigma_{y_{est}} = \sqrt{\frac{\sum_{i=1,k}(y_{est} - y)^2}{k}}$$

Eq. 26

With a bias according to:

$$e_{y_{est}} = \frac{\sum_{i=1,k}(y_{est} - y)}{k}$$

Eq. 27

In this specific case, the typical estimation error for all the territory reaches a mean squared error of 13,7 m^2 with an accuracy of 3,64 m^2 for an observed mean of 29,0 m^2. Based on these values, the 95% confidence interval was calculated at ±0,48 m^2, and the, and the uncertainty of the as percent of the mean estimated to be 1,6%.

Mapping of Forests remaining forests in the Subnational Area

Validation of polygons that shown to be degraded during the analysis was performed by selecting 612 points and verifying signs of degradation from Google Earth multi-temporal images (Figure 14). These analyses gave a Cohen's kappa coefficient of 0,58 and, as a result, a mapping uncertainty of 42%.

Figure 14. Google Earth image used for degradation mapping validation

Forest fires surface

Forest fires area is reported by the CONAF field brigades who combat fires on the ground. There uncertainty for the area impacted by forest fires, at 15%, comes from Chile's National Greenhouse Gas Inventory database.

b. Emission factors

This section is not divided into change in land usage and forests remaining forests, as all emission factors are derived from three primary sources:

- The Continuous Forest Inventory of the Forestry Institute (INFOR)
- The CONAF Biomass Inventory
- Default factors of the IPCC (2006)

All sources of uncertainty relating to the emission factors for the various REDD+ activities can be found in "Herramienta_incertidumbre"[79].

Errors in carbon content

The uncertainty of aboveground biomass in native forests arises from field measurement errors, errors in the functions to calculate individual tree species volume, the error in the biomass expansion factor, and error in the basic wood density value for native forests:

Uncertainty due to diameter at breast height (DBH) field measurements

Based on a control sample of DBH measurements, consisting in 30 trees each with 10 measurements, the standard error of the estimate (SEE) was estimated according to the follow equation (Berger *et al.* 2014[80]):

$$SEE = \frac{1}{n-1}\sqrt{([Dif_1] - \overline{[Dif_1]})^2}$$

Eq. 28

Where

SEE = Standard error of the estimate

Dif_1 = Average difference between the observed DBH and the measured DBH

$$\widehat{SEE} = \beta_1 + \beta_2\left[1 - e^{(\beta_3 DAP)}\right]$$

Eq. 28

Where

β_1 : -0.02 β_2 : 0.077 β_3 : -0.066

The following table summarizes the SEE based on measurement errors corrected by √2.

[79] http://www.enccrv-chile.cl/descargas/nivel-de-referencia/59-Herramienta-Incertidumbre/file

[80] Berger, A., Gschwantner, T., McRoberts, R.E. and Schadauer, K., 2014. Effects of measurement errors on individual tree stem volume estimates for the Austrian National Forest Inventory. Forest Science, 60(1), pp.14-24.

DBH(cm)	SEE (cm)
<= 10	0,012164
12	0,015644
16	0,021366
20	0,025760
24	0,029135
28	0,031727
32	0,033717
36	0,035246
40	0,036420
44	0,037321
48	0,038014
>= 52	0,038545

Table 43. SEE based on measurement errors corrected by √2.

Taking into account all the trees measured in the inventory, the estimated SEE weighted by density for the measurement of DBH is 0,03384 cm, with the mean DBH of 32,8 cm, according to table 44.

DBH	Density (trees/ha)	DBH	Density (trees/ha)
10	326	58	27
13	237	61	26
16	183	64	25
19	154	67	26
22	134	70	24
25	75	73	25
28	44	76	24
31	39	79	24
34	35	82	22
37	33	85	25
40	32	88	24
43	31	91	24
46	28	94	24
49	29	97	24
52	28	100	27
55	26		

Table 44. SEE weighted by density for the measurement of DBH.

Volumetric function for estimation of biomass (excludes basal area factor)

The standard errors of the estimate (S_{yx}) of the individual tree volumetric equations were taken from the database of INFOR's Continuous Forest Inventory. The uncertainty associated with the use of the volumetric equations is estimated in this inventory. In order to calculate this uncertainty, the following procedure identified in

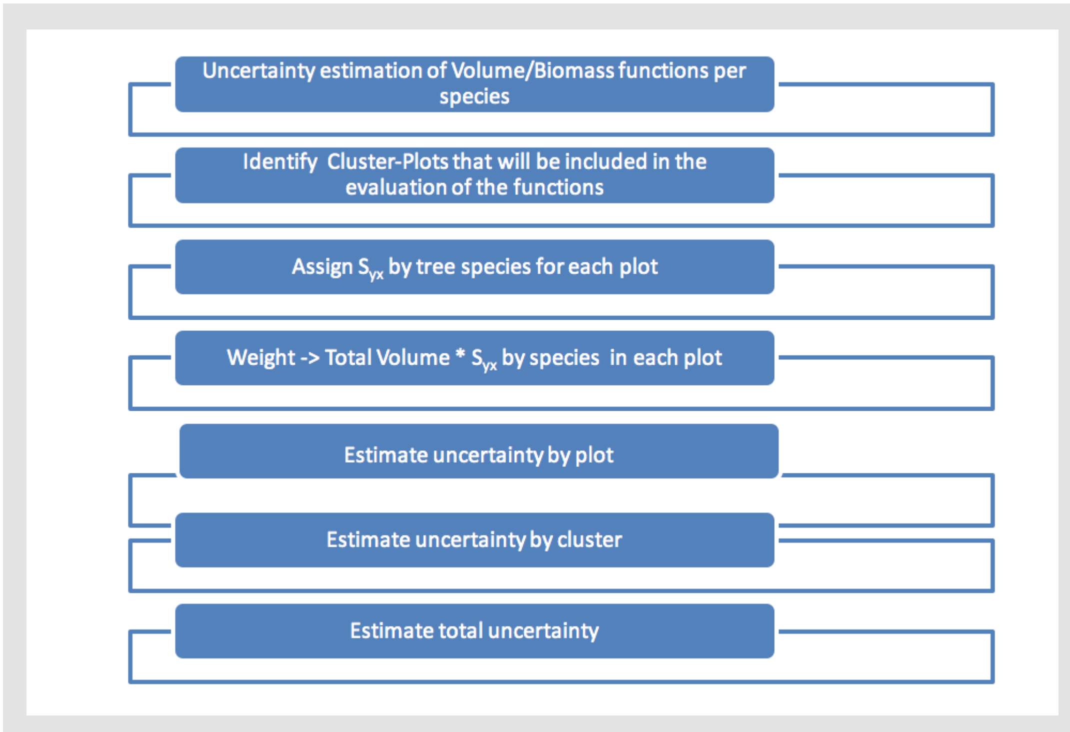

Figure 15. Procedure to estimate uncertainty due to the application of volumetric equations.

This results in uncertainty by hectare and by tree described in the Table 45:

Number of trees	6,96
Number of species	52,00
Clusters used	244,00
Standard deviation (m3/tree)	0,01
Standard deviation (m3/ha)	3,90
Mean (m3/tree)	0,31
Mean (m3/ha)	122,27

Table 45. Variables in estimating uncertainty related to using volumetric functions

Given the data presented in table above the estimated uncertainty (at the 95% confidence interval) for estimating tree volumes is 0,07%.

Expansion factor for native forest

The native forest expansion factor, which expands merchantable volume to total aboveground biomass volume, was estimated based on Gayoso(2002)[81]. The uncertainty for the native forest expansion factor is 18% and was calculated in the statistical database of the CONAF Biomass Inventory.

Native species basic density

The error of the estimation of native species basic density is 5.6%. It was calculated using basic wood density data compiled for species growing in Chile.

Root-to-shoot ratio (R factor) for native forests

The error of this ratio is 40% and was calculated in the statistical database of the CONAF Biomass Inventory run by the Universidad Austral de Chile. R factor error is a result of the type sampling design of the CONAF Biomass Inventory. Sampling was performed proportional to the surface area of each stratum with a random distribution of plots measuring 500 m^2. The stratum used was subpopulation of forest type and sub-type and structure of forests in each region. The error calculation includes stratum variances in biomass and carbon, the Student's t-test to obtain 90% statistical certainty and, as a denominator, the number of stratum plots.

[81] Gayoso, J. 2002. Medicion de la capacidad de captura de carbono en bosques de chile y promocion en el mercado mundial. Informe Técnico. Universidad Austral de Chile.

Necromass

The necromass errors detected arise as a result of variances in sampling averages (i.e. sampling error) of INFOR's Continuous Inventory. These sampling averages are non-biased estimators of population variance. Stratified sampling was not performed in order to obtain forecasts according to region.

Biomass of arborescent shrubland

Uncertainties associated with arborescent shrubland, grassland, shrubland-grassland, shrubland, shrubland with suculents, suculents, and shrub plantation aboveground biomass, as well as their root-to-shoot ratio, was the result of random sampling error (Gayoso 2006)[82].

Biomass of other land uses

Uncertainties for aboveground biomass in agricultural lands and urban and industrial lands were identified in Chile's National Greenhouse Gas Inventory database.

Volumetric function for biomass extraction (includes basal area factor)

For the uncertainty analyses of biomass extraction (degradation), enhancements in forests remaining forests, and conservation of forest carbon stocks, the errors described above from field measurements, expansion factor and basic wood density are included as well as the error of the volumetric function *Vol = AExp(B * Basal Area)*. The estimation of the error from this volumetric functions uses the following parameters:

Parameter	Value
N	417
A	2,91
B	1,24
Standard error of the estimate (m3/ha)	111,69
Mean (Vol/ha)	320,52

Table 46. Variables in estimating uncertainty related to using volumetric functions

Based on these parameters the 95% confidence interval of ±218,91 m^3/ha was calculated, and the uncertainty of the as percent of the mean estimated to be 68.3%.

82 Gayoso, J. 2006. Inventario de carbono en praderas y matorrales para el estudio de linea de base. Proyecto SIF Sociedad Inversora Forestal S.A. Regiones VII Y VIII.

Item	Error (%)	Source
Diameter at breast height measurements	0,20	INFOR Continuous Forest Inventory
Volumetric equations	0,07	INFOR Continuous Forest Inventory
Biomass expansion factor	18,00	CONAF Biomass Inventory
Basic Density of Native Species	5,60	INFOR Continuous Forest Inventory
Root-to-shoot ratio for native forests	40,00	CONAF Biomass Inventory
Dead organic material (standing dead biomass)	28,00	Estimated error of permanent plots from the INFOR Continuous Forest Inventory.
Dead organic material (residues on the ground)	24,00	Estimated error of permanent plots from the INFOR Continuous Forest Inventory.
Arborescent shrubland aboveground biomass	22,42	Gayoso, J. 2006.
Root-to-shoot ratio for Arborescent shrubland	48,27	Gayoso, J. 2006.
Agricultural land Aboveground biomass	75,00	INGEI
Grassland (pradera) aboveground biomass	27,70	Gayoso, J. 2006.
Shrubland-grassland (matorral-pradera) aboveground biomass	34,60	Gayoso, J. 2006.
Shrubland aboveground biomass	34,60	Gayoso, J. 2006.
Shrubland with suculents aboveground biomass	34,60	Gayoso, J. 2006.
Suculents aboveground biomass	27,70	Gayoso, J. 2006.
Shrub plantations	34,60	Gayoso, J. 2006.
Urban and industrial areas	95,00	INGEI
Plantations	8,00	INGEI
Estimated basal area	1,60	Calculation based on the average basal area (29.0 m^2) and error of the estimated basal area (13.7 m^2).
Volumetric function for estimation of biomass	0,10	INFOR Continuous Forest Inventory
Volumetric function for biomass extraction (based on basal area)	68,30	INFOR Continuous Forest Inventory
Combustion factor, Regions	36,00	Error forecast using the standard deviation and median default combustion factor of GL-2006.
CH_4 emission factor	29,00	Error forecast using the standard deviation and median default emission factor of the IPCC (2006).
N_20 emission factor	43,80	Error forecast using the standard deviation and median default emission factor of the IPCC (2006).

Table 47. Sources of uncertainty relating to the emission factors for the various REDD+ activities.

Item	Error (%)	Source
Periodic Annual Increment for Alerce young	58,47	Conservatively assumed to be the highest estimated IPA error given lack of data for this forest type.
Periodic Annual Increment for Alerce adult	50,47	Conservatively assumed to be the highest estimated IPA error given lack of data for this forest type.
Periodic Annual Increment for Cipres de la guaitecas young	12,02	INFOR Continuous Forest Inventory
Periodic Annual Increment for Cipres de la guaitecas adult	50,47	Conservatively assumed to be the highest estimated IPA error given lack of data for this forest type
Periodic Annual Increment for Araucaria young	58,47	Conservatively assumed to be the highest estimated IPA error given lack of data for this forest type
Periodic Annual Increment for Araucaria adult	50,47	Conservatively assumed to be the highest estimated IPA error given lack of data for this forest type
Periodic Annual Increment for Cipres de la cordillera young	9,97	INFOR Continuous Forest Inventory
Periodic Annual Increment for Cipres de la cordillera adult	15,83	INFOR Continuous Forest Inventory
Periodic Annual Increment for Lenga young	58,47	INFOR Continuous Forest Inventory
Periodic Annual Increment for Lenga adult	50,18	INFOR Continuous Forest Inventory
Periodic Annual Increment for Coihue de Magallanes young	7,68	INFOR Continuous Forest Inventory
Periodic Annual Increment for Coihue de Magallanes adult	13,42	INFOR Continuous Forest Inventory
Periodic Annual Increment for Robre hualo young	10,19	INFOR Continuous Forest Inventory
Periodic Annual Increment for Roble hualo adult	20,58	INFOR Continuous Forest Inventory
Periodic Annual Increment for Roble rauli coihue young	11,60	INFOR Continuous Forest Inventory
Periodic Annual Increment for Roble rauli coihue adult	28,75	INFOR Continuous Forest Inventory
Periodic Annual Increment for Coihue rauli tepa young	9,19	INFOR Continuous Forest Inventory
Periodic Annual Increment for Coihue rauli tepa adult	20,51	INFOR Continuous Forest Inventory
Periodic Annual Increment for Esclerofilo young	21,31	INFOR Continuous Forest Inventory
Periodic Annual Increment for Esclerofilo adult	32,49	INFOR Continuous Forest Inventory
Periodic Annual Increment for Siempreverde young	11,50	INFOR Continuous Forest Inventory
Periodic Annual Increment for Siempreverde adult	21,91	INFOR Continuous Forest Inventory
Periodic Annual Increment for Matorral arborescente	11,13	Gayoso (2006)
Periodic Annual Increment for Bosque Mixto	27,57	Assumed to be the average across all forest type given lack of data

c. Calculating the uncertainty of the reference level

i. Projection of uncertainty

Uncertainties regarding the FRELs/FRLs of deforestation, degradation, conservation and enhancement of carbon stocks were estimated according to the propagation of error method described in equations 3.1 and 3.2 of the IPCC (2006) (equations 30 and 31 respectively).

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

Eq. 3.1 IPCC, 2006

Where

U_{total} = percentage uncertainty of the product of quantities (half the 90% confidence interval, divided by the total and expressed as a percentage)

U_i = percentage uncertainty associated with each of the quantities.

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

Eq. 3.1 IPCC, 2006

Dónde

U_{total} = percentage uncertainty of the sum of quantities (half the 95% confidence interval, divided by the total (i.e. the median) and expressed as a percentage). The term "uncertainty" is based on the 95% confidence interval

x_i y U_i = absolute uncertainty and associated percentage uncertainties, respectively.

La propagación de errores sin ponderación (ecuación 30) fue utilizada cuando los parámetros eran directamente multiplicados para estimar el resultado final (por ejemplo: para estimación de emisiones por deforesNon-weighted error propagation (equation 30) was used where parameters were directly multiplied in order to estimate the final result (e.g. to estimate emissions from deforestation, area of forest loss was directly multiplied by the emission factor resulting from the change in land use). Conversely, weighted error propagation was used where parameters were added together to forecast the final result (e.g. emission factors for deforestation are the result of summing aboveground biomass to belowground biomass and necromass).

This method was used because uncertainty in emission and removal levels reported in the FREL/FRL for Chile can be propagated from uncertainties in activity data and emission factors. Furthermore, ranges of uncertainty of these parameters remain stable throughout the historical reference period. It is assumed that the same will be true for the performance period.

Uncertainty was estimated for each source or sink of emissions contained in the FRELs/FRLs according to each individual REDD+ subactivity (e.g. degradation by substitution, enhancement in forests remaining forests). The subactivities are kept separately aiming for transparency on the report of uncertainties, because different accounting methods are used for different subactivities, each with varying degrees of uncertainty. Thus, errors were propagated for different subactivities activities before finally being integrated into the total uncertainty.

Deforestation

The first step in the error propagation for deforestation involved estimating the uncertainty of the carbon content of the different pools of native and mixed forests and arborescent shrubland (aboveground biomass, belowground biomass, and standing dead organic matter and litter). The total emission factor uncertainties for each region are calculated by weighting these uncertainties first by the carbon content of each pool.

Components	Error (%)	Source
Aboveground biomass for native and mixed forests	18.90	Measurement error, Volumetric equation error, Expansion factor error, and Basic wood density error
Belowground biomass for native and mixed forests	44.20	Measurement error, Volumetric equation error, Expansion factor error, Basic wood density error, and Root to shoot ratio error
Dead organic material (standing)	28.40	Estimated error of permanent plots from the INFOR Continuous Forest Inventory
Dead organic material (litter)	24.20	Estimated error of permanent plots from the INFOR Continuous Forest Inventory
Arborescent Shrubland	34.00	Gayoso (2006)
Root-to-shoot ratio for Arborescent shrubland	48.27	Gayoso (2006)

Table 48. Deforestation Emission Factor Uncertainties

Total uncertainties for emissions factors in each region were calculated using equation 2, weighted by the tonnes of carbon per hectare in each of the pool in each region.

Region	Error (%)
Maule	16,9
BioBio	16,8
La Araucanía	15,7
Los Ríos	14,4
Los Lagos	15,0

Table 49. Deforestation Emission Factor Uncertainties for Native and Mixed Forests by Region

Region	Error (%)
Maule	32,7
Biobío	31,3
La Araucanía	24,7
Los Ríos	19,2
Los Lagos	22,3
Matorral arborescente	32,7

Tabla 50. Deforestation Emission Factor Uncertainties for Arborescent Shrubland by Region

For activity data, confusion matrices generated using Collect Earth were analysed following the Olofsson *et al.* (2014) good practices, and estimated uncertainty at the 95% for the land use change class of deforestation are show below for each period of the imagery used in the reference period (e.g. 2 maps are used resulting in two periods over the reference period).

Region	Error (%)
Maule period 1: Deforestation	32,5
Maule period 2: Deforestation	70,1
Biobío period 1: Deforestation	46,5
Biobío period 2: Deforestation	132,6
Araucanía period 1: Deforestation	2,8
Araucanía period 2: Deforestation	3,8
Los Ríos period 1: Deforestation	11,7
Los Ríos period 2: Deforestation	119,2
Los Lagos Norte period 1: Deforestation	5,0
Los Lagos Norte period 2: Deforestation	26,8
Los Lagos Sur: Deforestation	8,1

Tabla 51. Deforestation Activity Data Uncertainties by Region per Period

The uncertainty of activity data for each period was combined to result in one uncertainty per region as follows.

Region	Error (%)
Maule	43,9
Biobío	44,1
La Araucanía	2,6
Los Ríos	46,2
Los Lagos	5,7

Tabla 52. Deforestation Activity Data Uncertainties by Region.

Using the unweighted method for combining the uncertainty of emission factors per region with the uncertainty of activity data per region, the uncertainty of emissions per region was estimated.

Region	Error (%)
Maule	57,3
Biobío	56,7
La Araucanía	29,3
Los Ríos	52,1
Los Lagos	27,5

Tabla 53. Deforestation Emissions Uncertainties by Region

Finally, the combination of the uncertainties for each region was conducted by weighting the regional emissions' uncertainty by the actual emissions occurred in each region, resulting in a total **deforestation uncertainty of 17,9%.**

Forest degradation

Uncertainties for forest degradation were divided by the uncertainties of the following subactivities: substitution of native forests by plantations, forest fires, and biomass extraction.

Substitution

Similarly to deforestation, the first step is to estimate the uncertainty of degradation by substitution is by estimating the uncertainty of the emission factor per region by weighting the contribution of each carbon pool into the emission factor uncertainty. Aboveground biomass, belowground biomass, and necromass (standing and lying dead organic matter) for native forests, mixed forests and arborescent shrublands, were considered.

The following step is to estimate the activity data uncertainty per region. For this, Olofsson *et al.* (2014) approach was applied to the substitution land use change class of the confusion matrices generated, giving the following results.

Region	Error (%)
Maule	4,0
BioBio	8,7
La Araucanía	11,0
Los Ríos	8,5
Los Lagos	2,7

Table 54. Substitution Activity Data Uncertainties by Region.

From this the unweighted propagation of errors of emission factors and activity data per region results in the estimated uncertainty of emissions per region.

Region	Error (%)
Maule	37,0
BioBio	36,6
La Araucanía	31,2
Los Ríos	25,5
Los Lagos	27,0

Tabla 55. Substitution Emissions Uncertainties by Region.

Finally, the combination of the uncertainties for each region was conducted by weighting the regional emissions' uncertainty by the actual emissions from substitution that occurred in each region, resulting in a total **degradation by substitution uncertainty of 15,6%.**

Non-CO_2 emissions from forest fires

For forest fires, the uncertainty of the mass available for combustion was estimated based on the aboveground biomass and necromass (standing and lying dead organic matter) of native forests. As mentioned above, regional estimates of biomass differ, which is why it is also necessary to forecast the uncertainty of the mass available for combustion at regional level. These estimates are then weighted by the amount of biomass in each pool considered.

Region	Error (%)
Maule	17,9
BioBio	17,7
La Araucanía	16,2
Los Ríos	14,7
Los Lagos	15,5

Table 56. Uncertainty of Combustible Mass per Region.

The uncertainty of each GHG released during forest fires (CH_4 and N_2O) are estimated by propagation the error associated with the emission factor of each of these GHG and weighting it according to the amount of CH_4 and N_2O emissions (it is assumed that CO_2 emissions are recorded according to the k-nn algorithm, which is not concerned with the cause of degradation, under the sub-activity of degradation due to biomass extraction).

Region	Error (%)
Maule	24,3
BioBio	24,3
La Araucanía	24,3
Los Ríos	24,3
Los Lagos	24,3

Table 57. Uncertainty of GHG Emitted by Forest Fires per Region.

Finally, the uncertainty of the mass of combustible available to burn was combined with the uncertainty of GHG released to generate forecasts of the uncertainty of regional combustion factors.

Region	Error (%)
Maule	46,9
BioBio	46,9
La Araucanía	46,3
Los Ríos	45,8
Los Lagos	46,1

Table 58. Uncertainty of Combustion Factor per Region.

The partial uncertainty of **degradation due to forest fires was estimated at 27,4%.**

The area of burnt forests reported by the CONAF is expressed in tabular form without any estimate of the associated uncertainty. Thus, the partial uncertainty of degradation due to forest fires is not combined with the uncertainty of activity data.

Degradation in forests remaining forests

The uncertainty of biomass extraction combines the error from mapping degraded areas with errors from estimating the amount of biomass lost in the event of degradation.

The mapping of degraded areas is based on the unweighted propagation of errors from estimating the basal area for calibrating the k-nn algorithm (equal to 1,6%), with the error from the radiometric performance of the Landsat imagery to generate the thematic maps used to run the k-nn algorithm (estimated to be 0,05%). Then combined with the errors from the Cadaster of mapping forest remaining forest, which required application of Olofsson *et al.* (2014) approach, and the error from actual mapping degraded pixels using the k-nn algorithm in the thematic Landsat maps over the area of forest remaining forest (reported at 42%).

Region	Error (%)
Basal area error to calibrate k-nn	1,6
Radiometric performance of imagery	0,1
Maule period 1: Deforestation	2,7
Maule period 2: Deforestation	6,6
BioBio period 1: Deforestation	6,6
BioBio period 2: Deforestation	2,0
Araucania period 1: Deforestacion	1,1
Araucania period 2: Deforestacion	1,0
Los Rios period 1: Deforestacion	0,5
Los Rios period 2: Deforestacion	1,6
Los Lagos Norte period 1: Deforestation	1,1
Los Lagos Norte period 2: Deforestation	1,6
Los Lagos Sur: Deforestation	0,3
Degradation mapping accuracy	42,0

Table 59. Uncertainty Factors in Mapping Degradation

The resulting error of mapping degradation, estimated at 43,3% is then combined with the error from the estimation of the carbon stock, which is the result of the unweighted propagation of error from field measurements of DBH (0,2%), error from volumetric functions employing basal areas for estimation of tree volume (68,3%), expansion factor for estimation of total tree volume (18%) and the basic wood density for conversion of volume into biomass (5,6%).

Region	Error (%)
DBH Measurements	0,2
Volumetric function *[Vol = AExp(B * Basal Area)]*	68,3
Expansion factor	18,0
Basic Wood density	5,6

Table 60. Uncertainty Factors in Estimating Degraded Carbon Stocks

The result of the propagation of errors from mapping degradation and estimating degraded carbon stocks gives the estimated **uncertainty for forest degradation in forest remaining forest 82,4%.**

Enhancements of Forest Carbon Stock

Uncertainties for forest carbon stock enhancements were divided by the uncertainties of the following sub-activities: enhancements due to conversion of non-forest to forest, and enhancements in forest remaining forests.

Restitution and increase of forest area

The uncertainty for enhancements from conversion of non-forest to forest was estimated by first estimating the uncertainty of the removal factor of every possible conversion from 13 non-forest cover classes that could be converted to either young or adult of one of the 13 forest types encountered in the ER Program area (including arborescent shrubland and mixed forest). This creates 312 unique possibilities of conversion classes, each with its own estimated error. That is because each non-forest class has an estimated error of the standing carbon stocks, and each of the 13 forest types has two estimates of periodic annual increment (PAI) (one for young and another for adult). It is worth noting that although there are 4 forest structures mapped by the Cadaster for each forest type (young, young/adult, adult, and dwarfed), for conservatism purposes, and due to lack of data, PAI of a "young" forest structure was assumed for every conversion to a "young/adult" forest conversion, and PAI for an "adult" forest structure was assumed for every "dwarfed" forest conversion.

The estimated error for activity data for this subactivity is estimated by applying the good practices recommended by Olofsson et al. (2014) to forest remaining forest class of the Cadaster maps. Given confusion matrices generated from the validation of the Cadaster maps reported results by "enhancements" (aumentos) and restitution (restitución – conversion of plantations back to native forests), the combination of the error of each of these two classes estimated applying the Olofsson was conducted.

Region	Error (%)
Maule	12,0
BioBio	73,0
La Araucanía	8,9
Los Ríos	34,0
Los Lagos	59,7

Table 61. Non-Forest to Forest Activity Data Uncertainties by Region

The combination of the errors from the removal factors with the errors from the activity data was conducted by estimating the area of each of the 312 possible transitions took place in each of the regions, and weighting by the respective area. This resulted in the estimation of uncertainty of removals per region.

Region	Error (%)
Maule	32,3
BioBio	77,3
La Araucanía	18,5
Los Ríos	39,8
Los Lagos	62,7

Table 62. Uncertainty of Removals from Non-Forest to Forest by Region

The final uncertainty for this subactivity was estimated by combining the regional uncertainty of removals and weighting it by the respective removals contributed by each region to the total removals from conversion of non-forest to forest. This resulted in an estimated **uncertainty from conversion of non-forest to forest of 23,4%.**

Recovery of degraded forests

The uncertainty for forest carbon enhancements in forest remaining forests is estimated in the exactly same way as the uncertainty for the forest degradation in permanent forests. As such, the uncertainty in the area mapped as enhanced is estimated by combining the errors (unweighted) from estimating the basal area for calibrating the k-nn algorithm (equal to 1,6%), with the error from the radiometric performance of the Landsat imagery to generate the thematic maps used to run the k-nn algorithm (estimated to be 0,05%). Then combining with the errors from the Cadaster of mapping forest remaining forest, following the Olofsson et al. (2014) approach, and the error from actual mapping degraded pixels using the k-nn algorithm in the thematic Landsat maps over the area of forest remaining forest (reported at 42%). This results in an uncertainty for mapping forest remaining forest with enhanced carbon stocks of 42,0%.

This uncertainty is then combined with the error from the estimation of the carbon stock, derived from the error from field measurements of DBH (0,2%), error from volumetric functions employing basal areas for estimation of tree volume (68,3%), expansion factor for estimation of total tree volume (18%) and the basic wood density for conversion of volume into biomass (5,6%). Thus resulting in an uncertainty for the estimation of carbons stocks of 70,9%.

The result of the propagation of errors from mapping forest remaining forest areas with enhanced carbon stocks resulted in an estimated **uncertainty of 82,4%.**

Conservation of Forest

The estimation of error for conservation of forest carbon stocks is based on the very same factor described above in degradation in permanent forests and the forest carbon stock enhancements in forest remaining forests, because the methodology applied is the same, but the emissions and/or removals that occurred inside areas subject to formal conservation processes are then associated with the activity of conservation of forest carbon stocks.

However, given the conservation activity include emissions degradation by biomass extraction and removals from forest carbon stock enhancements in forests remaining forests, the errors from these two activities are combined and weighted by the absolute numbers of emissions and removals that occurred within the conservation areas. This results in an estimated **uncertainty for conservation of 64,8%.**

ii. Total uncertainty

The total uncertainty consists of the propagation of errors of uncertainties from all the subactivities described above. Error propagation was weighted according to the absolute total emission/removal caused by each activity, resulting in a total uncertainty of 33,4% (Table 58).

	Parameter	Uncertainty (%)	Weighting (absolute value)
Deforestation	$U_{Deforestación}$	17,93%	3.452.885,1
Degradation by Substitution	$U_{Deg\_Sustitución}$	15,60%	4.076.040,3
Degradation by Forest Fires	$U_{Deg\_Incendios}$	27,37%	222.206,9
Degradation in Forests remaining Forests	$U_{Deg\_Extracción}$	82,39%	4.962.248,1
Enhancements from No-Forest to Forest	$U_{Aumentos\_NB-B}$	23,37%	890.772,9
Enhancements in Forest Remaining Forest	$U_{Aumentos\_B-B}$	82,39%	9.121.239,4
Conservation of Forest Carbon Stocks	$U_{Conservación}$	64,76%	5.003.601,3
Conservation of Forest Carbon Stocks	**U_{TOTAL}**	**33,29%**	**N.A.**

Table 63. Total uncertainty of the subnational proposal of the FREL/FRL for Chile.

9. Relationship between the FREL/FRL and the NGHGI

There is strong consistency between the FREL/FRL of the native forest in Chile as presented in this document and the NGHGI for Chile. Nevertheless, it is important to take into account the intrinsic differences in existence between a reference level and a GEI (GG) inventory.

The authority responsible for the AFOLU (Agriculture, Forestry and Other Land Use) sector for the NGHGI for Chile is in fact the Ministry of Agriculture and those in charge of producing the specific calculation for the UTCUTS sector are CONAF and INFOR, both entities with responsibilities for compiling the FREL/FRL of the native forest in Chile. The variations presented in the FREL/FRL are improvements resulting from better data availability and the use of more accurate methods to be incorporated in the 2018 biennial report for updating the NGHGI.

The points of consistency and the variations in existence between the NGHGI and the FREL/FRL are listed below per activity. The estimated mean historic emissions/removals per REDD+ activity are also presented so that the FREL/FRL and NGHGI results can be compared. The fact that the activity of Degradation and some of the Increase in stocks would be incorporated in the calculation of emissions and removals produced in unchanged forest in the NGHGI and that the activity of Deforestation and the remaining part of the Increase of stocks would be linked to the change of land use from Forest Use to Other Uses and from Other Uses to Forest Use, respectively, must be taken into consideration. The same criteria and data as those used as for the above activities are used for the activity of stock Conservation and so a special section is not included for this.

Since the FREL/FRL only includes estimates for the five regions in the RE Programme, the NGHGI database was used to take comparable values from the NGHGI. The mean annual emissions/removals from the NGHGI from 2001 to 2010 were calculated.

a. Deforestation

In the NGHGI, deforestation activity includes the following categories: forestland converted to agricultural land, forest land converted to grazing land, forest land converted to settlements, and forest land converted to other land (including areas without vegetation, and areas of snow and glaciers, bodies of water, and unrecognized areas).

The same source of information as in the NGHGI, the Land Registry, is used to calculate the Activity Data. However, the dates on some of the Land Registry maps were different when the NGHGI was produced from the dates used for the same maps in the FREL. This produces a difference in annual emissions when the conversion area is divided up between all the years in the period between Land Registry updates. This difference is due to the confusion created by the oldest maps in the Land Registry, which used a mosaic of aerial images from various years. Between the most recent update of the NGHGI and compilation of the FREL, the decision was taken to change the dates of the maps, so the dates in the next update of the NGHGI will not be inconsistent with those in the FREL.

With regard to the Emission Factors:

- The same data as for the NGHGI was used to determine the forest carbon stocks prior to deforestation.
- The NGHGI and the FREL use certain IPCC default values in order to determine carbon stocks after deforestation caused by some methods of using non-forested land. However, the FREL uses values specific to Chile from Gayoso (2006) for undergrowth, scrubland, meadow, and succulent formations in order to obtain more emission factors specific to the country.
- With regard to the estimate of changes of carbon stocks other than those resulting from the event of deforestation, both in the NGHGI and in the FREL the losses due to harvesting wood, collection of firewood, and disturbances are considered zero in areas that have undergone deforestation.

Mean annual emissions from deforestation according to the FREL (tCO_2e)	Mean annual emissions from deforestation according to the NGHGI for years 2001-2010 (tCO_2e)
3.452.885,00	1.057.992,00

Table 64. Comparison of estimated emissions from deforestation between the FREL/FRL and the NGHGI

b. Forest degradation

The categories of the NGHGI which correspond to the activity of degradation include: 1) the harvesting of commercial wood from native and exotic species, 2) the harvesting of firewood, and 3) fires. The fact that the FREL includes the conversion of native forest to scrubland as degradation must be pointed out. In the NGHGI, this conversion is a subcategory of forested land converted to pastures. However, this activity is considered to fall under the activity of deforestation since it includes other uses of the land such as undergrowth and meadows.

The NGHGI uses a gain-loss method according to Equation 2.7 of the IPCC (2006) in order to count forest degradation; however the FREL/FRL uses the stock difference method based on Equation 2.8 of the IPCC (2006).

The NGHGI uses tabular data from INFOR for forest removals, and INFOR and MINENERGIA statistics for firewood, and CONAF tables for the surface areas of fires in native forests and forest plantations for disturbances.

Data about collection of firewood are extremely complex, since most collection is carried out informally which makes it very difficult to estimate the accuracy and reliability of this information. Consequently, a different methodology, felt to be more robust, is used to count the reference level of degradation.

This methodology does not count the three sub-activities separately, but counts the carbon stocks in forests at different points of time.

For non-CO_2 GG produced by combustion as a result of forest fires, the same accounting as that used by the NGHGI for Chile is used.

Another reason, which explains the difference between the annual emissions, is that the NGHGI counts the increase of carbon in forest plantations, whereas in the sub-activity for native forests converted to forest plantations in the FREL carbon stocks in plantations are considered to be zero.

Annual emissions from degradation (including in conservation areas) according to the FREL (tCO_2e)	Annual emissions from degradation according to the NGHGI for years 2001-2010 (tCO_2e)
10.239.334,46	938.197,00

Table 65. Comparison of estimated emissions from deforestation between the FREL/FRL and the NGHGI

c. Enhancement forest carbon stock

In the NGHGI, stock increases include the following categories: 1) land converted to forested land, 2) the expansion of biomass in unchanged forests, and 3) land in transition.

The much higher estimate of removals in the NGHGI is due to the difference in the methodology applied for increases in unchanged forest and also because the NGHGI includes increases of biomass from forest plantations whereas the FREL/FRL only includes increases of biomass in native forests.

With regard to the increase due to forest growth, the NGHGI uses Equation 2.9 of the IPCC 2006 to calculate Level 2-3. However, the NGHGI only uses it for land converted to forest in the year of conversion. Subsequently, this land moves into the category of land in transition, and then its increases are counted.

Removals from areas that are converted into forest during the reference period must continue to be counted in the FRL of stock increases for the whole period.

For example, an area which is converted to forest in the first year of the reference period continues to increase its carbon stocks in the second, third and the rest of the years in the reference period. The increases in the second year that come from the areas that have been sown/restored in the first year are counted in the second year, together with the increases from the areas that were sown/restored in the second year. In this way, the increases continue to accumulate, and are always counted under the activity of stock increases.

In the NGHGI, the estimate of activity data from the increase from non-forested areas which are converted to forest and of unchanged forest are taken from the Land Registry in the same way as for the FRL for Increases.

The values for the net mean annual increase, used as a Removal Factor are the same as those used in the NGHGI, based on INFOR data. There are values for the following forest types: Larch, Ciprés de las Guaitecas (Cypress of the Guaitecas), Araucaria, Ciprés de la Cordillera (Cypress of the Cordillera), Lenga, Coihue de Magallanes, Roble Hualo (Hualo Oak), Roble-Rauli-Coihue (Rauli-Coihue Oak), Coihue-Rauli-Tepa, Sclerophyll, and Evergreens.

Likewise, the values used to calculate the factor for the conversion and expansion of biomass for converting the net annual increase by volume (including cutting) into growth of aerial biomass for a forest type, use the factor of expansion of biomass and the basic density value of wood, taken from the NGHGI.

Annual removals of increases (including in conservation areas) according to the FREL for years 2001-2010 (tCO_2e)	Annual removals of increases according to the NGHGI for years 2001-2010 (tCO_2e)
-13.729.032,00	**-101.071.840,00**

Table 66. Comparison of estimates for removals of stock increases between the FREL/FRL and the NGHGI

10. Capacity building needs, areas for future technical improvement and work in progress

a. Capacity building needs

The Subnational Reference Level of Chile has been developed by CONAF with the support of a Consortium formed by Winrock International, Instituto Forestal (INFOR) and the University Austral de Chile. With regard to activities related to the national expansion of the Reference Level, as well as to the execution of future Monitoring, Reporting and Verification events, we consider that it is important to improve institutional and national technical capacities, Forming a critical mass within the institutions that are designated to fulfill the related commitments, both in CONAF with special emphasis on the Department of Forest Ecosystem Monitoring and the Unit on Climate Change and Environmental Services, as well as on other institutions linked to natural resources belonging to the Government of Chile and in the academic field. To this end, it's key issue the collaboration that the Convention can provide in the organization of regional and national workshops and support to facilitate the attendance of experts distributed throughout the country to these bodies.

The greatest difficulties experienced in the development of the Reference Level have been identified in the area of 1) uncertainty estimation, and 2) high resolution cartography, for local use at the owner level and its territorial control, so we consider it is important to develop greater skills in the training of professionals, integrating experts in forest inventories and mainly forest sampling statistics within the technical team and, in the estimation of error and uncertainty of the base information, in which there are still some gaps.

Of particular interest is the analysis of new active satellite technologies (RADAR and LIDAR) for the analysis of carbon fluxes in permanent forests in areas with high probability of cloud cover and strong phenological variations in vegetation.

The construction of the Reference Level for sustainable forest management represents a series of challenges regarding the different scale of actions and results that should be analyzed in detail and for which the support of the Convention is considered important.

Together with the previous bullets, it is considered as an important need, the support for the generation of the REDD+ Annex, that should be included in the next BUR of Chile to be presented in 2018.

b. Areas for future technical improvement

There are a number of technical improvement areas that are in the process of analysis and discussion, of which we can highlight the following:

- Development of tools and methodologies for the biennial updating of the Cadastre, as a source of primary information for the estimation of activity data related to Land Use / Sub-use Changes.
- Development of automation processes for the pre-processing of satellite images that support the estimation of carbon fluxes in permanent forests.
- Development of new stock charts for relevant forest types.
- Analysis of methodologies for estimation of carbon fluxes in southern forests.
- Generation of an integrated platform that allows storage, semi-automated generation of reports, visualization of results and dissemination of both spatial and database information.
- Development of emission factors and activity data linked to soil organic carbon fluxes.
- Further research on forest degradation, through the intensive use of the biomass and carbon monitoring system.

c. Work in progress

Currently, through various international support under ENCCRV, CONAF are developing a series of projects aimed to reducing the gaps and needs identified in the process of generating the Reference Levels.

- In order to generate national biennial updates of the Cadastre, several initiatives are being developed aimed to identifying appropriate methodologies and tools for management:
    - Support from four professionals assigned to these tasks that work integrated in the Department of Monitoring of CONAF during the next three years.
    - Sources of information are being analyzed and semiautomated algorithms are being developed for the processing of optical satellite images both through Google Earth Engine and external systems based on free software.
    - Works with Collect Earth (OpenForis tool), as one of the elements to increase the frequency of updating Land Use Cadastre, especially as a tool for the generation of confusion matrices.

- There are work underway on the specialization of management plans to include future data on sustainable forest management activity.

- In the coming months, the process for the expansion of the Reference Level to the regions of the Mediterranean macro zone of Chile (3 Regions in the northern boundary of the sub-national area) will be completed, in parallel the analysis of gaps for the regions of the Austral macrozone (2 Regions in the Southern limit of the subnational area) and the first advances are made to finalize in the National Reference Level appropriation during 2018.

- During the year 2016, through the Research Fund of the Native Forest Law, the Stock Chart for the Lenga Forest Type has been developed and validated. Subsequently, stock charts will be developed for the main Forest Types of the country.

- Specific trainings are being conducted in:
    - Training Course on GHG Inventory and Reference Levels: October 2016, by Aether Spain and GHG Institute.
    - Google Earth Engine: November 2016, by experts from the University of Gottingen.
    - SEPAL / Google Earth Engine: January 2017, by FAO experts.

- During November 2016, experience exchange activities were carried out with international forest monitoring experts within the framework of the International Congress ForestSAT2016, where part of the technical team of CONAF participated.

- Participation in National Forest Monitoring Systems For REDD + Reporting Capacity Building Workshop Rome 28-November-02 December 2016.

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