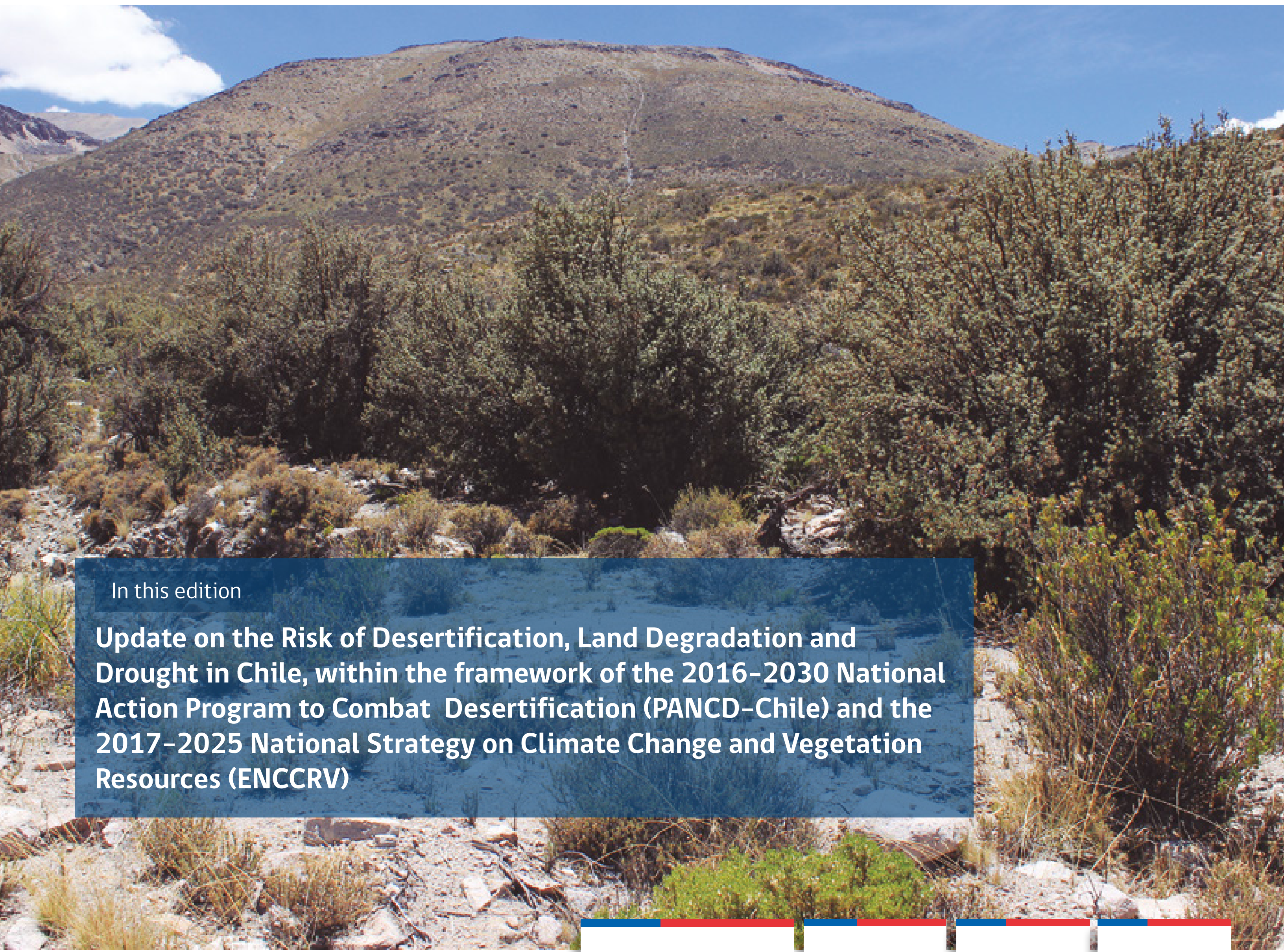
# Informative Note

# ENCCRV

05

## NATIONAL STRATEGY ON CLIMATE CHANGE AND VEGETATION RESOURCES

Santiago, December, 2016



In this edition

**Update on the Risk of Desertification, Land Degradation and Drought in Chile, within the framework of the 2016-2030 National Action Program to Combat Desertification (PANCD-Chile) and the 2017-2025 National Strategy on Climate Change and Vegetation Resources (ENCCRV)**

Climate Change and Environmental Services Unit (UCCSA)
Forest Development and Promotion Management Department (GEDEFF)
National Forestry Corporation (CONAF)
Chilean Ministry of Agriculture

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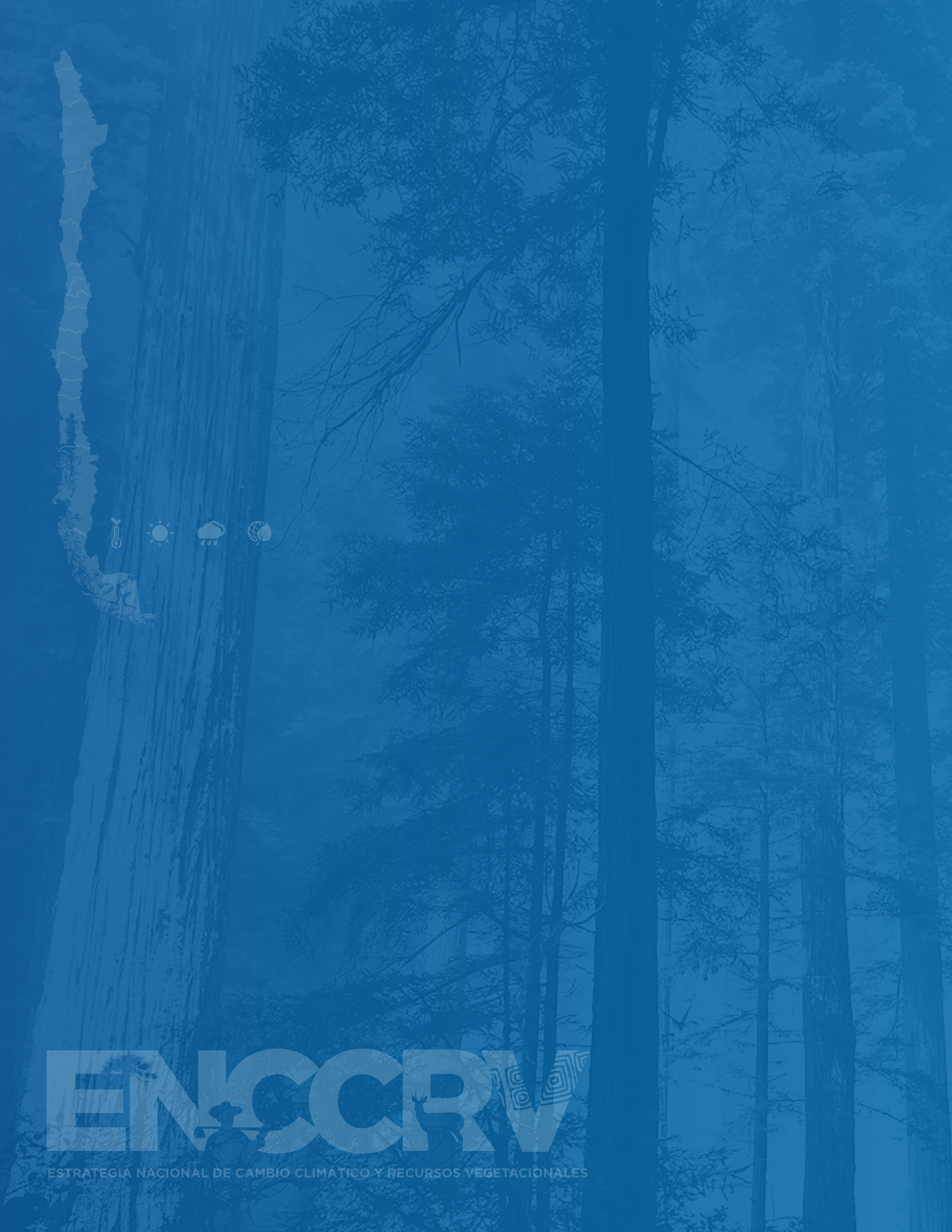
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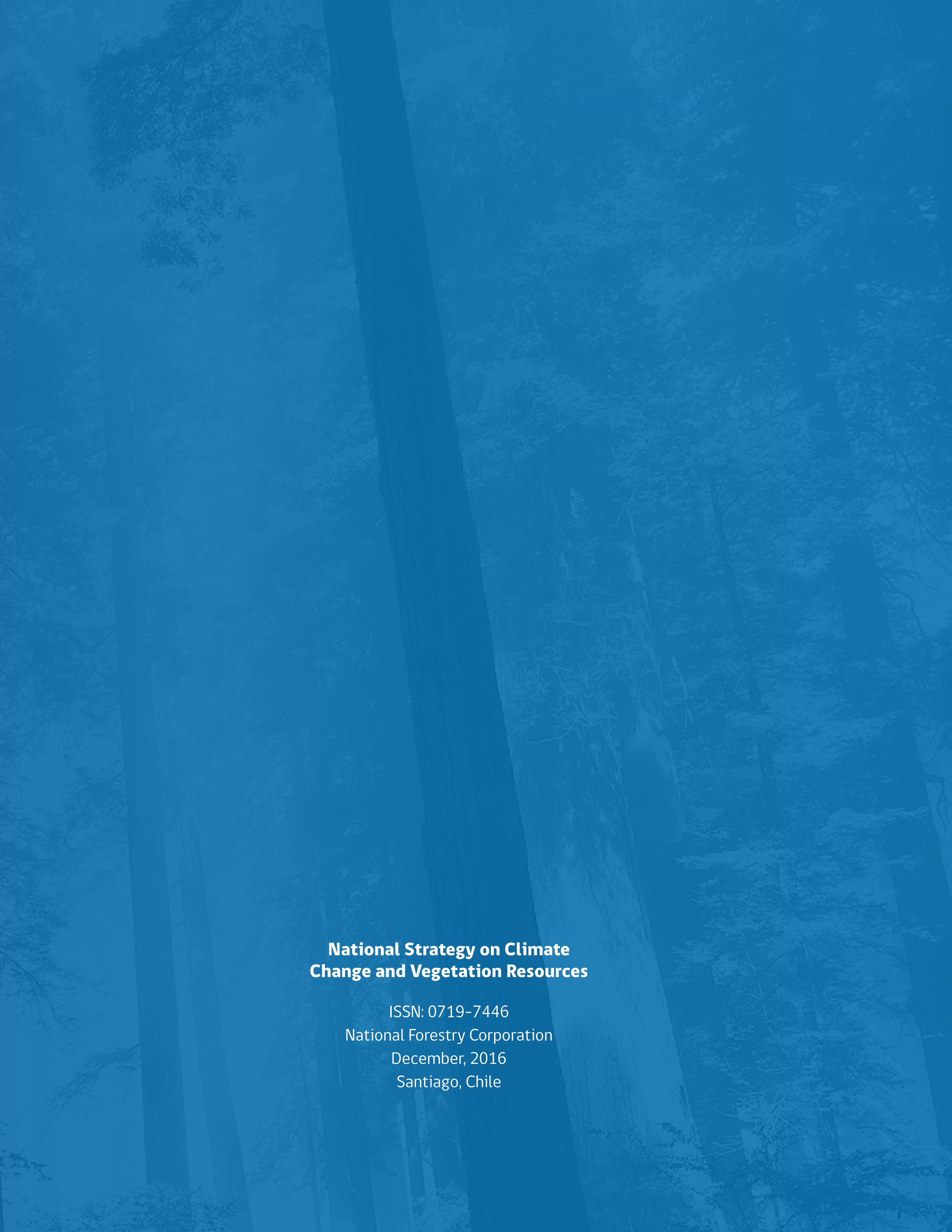

**National Strategy on Climate Change and Vegetation Resources**

ISSN: 0719-7446
National Forestry Corporation
December, 2016
Santiago, Chile

# Update on the Risk of Desertification, Land Degradation and Drought in Chile, within the framework of the 2016-2030 National Action Program to Combat Desertification (PANCD-Chile) and the 2017-2025 National Strategy on Climate Change and Vegetation Resources (ENCCRV)


## Acknowledgements

We would like to thank the United Nation's Environment Program (UNEP) and the Global Environment Fund (GEF) for their contribution in funding this study, which was awarded by public tender to Sud Austral SpA under the title "2016-2030 National Action Program to Combat Desertification, Land Degradation and Drought, PANCD-Chile" ID No. 633-66LE14.

Formulated by CONAF and Sud Austral Consulting SpA.

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# Introduction

Land degradation is a significant factor in climate change at a global level, since it produces Greenhouse Gas (GHG) emissions and reduces the potential of soil carbon sequestration in production systems (Emanuelli *et al.*, 2015). Soil carbon accounts for the third largest carbon stock in the planet, after oceans (38,400 gigatons, Gt) and geological strata (4,130 Gt), estimated at 2,500 Gt, surpassing the stock contained in the atmosphere and the biosphere (1,320 Gt). Soil organic carbon accounts for approximately 1550 Gt, with the difference being inorganic carbon (Lal, 2004; Milyan, 2015). One of the effects of desertification is that it may transfer large amounts of carbon into the atmosphere; estimates indicate that every year, drylands release 300 million tons of carbon, which is equivalent to approximately 4% of global emissions when considering all sources (Niemeijer *et al.*, 2005). The significance and speed of these land degradation and desertification processes is such, that they have become a global issue, as can be seen in the interactive[1] map, prompting the creation of different international instances aimed at addressing this situation from an environmental, social and economic point of view.

Chile has joined the UN's Convention to Combat Desertification (UNCCD), considering the concept of Land Degradation Neutrality (LDN) and has also ascribed to the United Nations Framework Convention on Climate Change (UNFCCC), adopting the REDD+[2] approach, which considers positive policies and incentives for reducing emissions from deforestation and forest degradation, along with promoting the increase of forest carbon sinks.

In turn, the country has focused its 2017-2025 National Strategy on Climate Change and Vegetation Resources (ENCCRV) on fulfilling the general objective of: "Reducing the social, environmental and economic vulnerability generated by climate change, desertification, land degradation and drought on vegetation resources and human communities that depend on these for increasing ecosystem resilience and contributing towards mitigating climate change, thus promoting the reduction and capture of greenhouse gas emissions in Chile".

[1] Online Interactive map: www.sciencemag.org/cgi/content/summary/304/5677/1614

[2] REDD+ refers to the use of positive policies and incentives for Reducing Emissions from Deforestation and Degradation (REDD) and supporting the conservation existing forest carbon stocks, sustainable management of forests, and enhancement of forest carbon stocks(+) in developing countries.

**National Strategy on Climate Change and Vegetation Resources (ENNCRV)**

Set of direct and facilitating action measures which -based on a national technical and participatory formulation process- focus on addressing Climate Change, Desertification, Land Degradation and Drought (DLDD) through the proper management of vegetation resources in order to avoid or reduce the historical rates of deforestation, devegetation and degradation of native forests, xerophytic formations and other vegetation formations, along with promoting the recovery, afforestation, revegetation and sustainable management of Chile's native resources.

The Chilean territory is seriously affected by desertification, land degradation and drought, therefore it is urgent to implement measures for reducing their effects on the quality of life of its inhabitants. During Chile's first desertification assessment -conducted in 1978- an estimated area of 48,334,300 hectares was affected by it, equivalent to almost two thirds[3] of the continental territory (CONAF, 1999). Desertification has been classified as one of Chile's most severe environmental issues. The arid and semi-arid territories affected by these processes exceed 60% of the national territory, concentrating the greatest impacts on land, biodiversity, and agroforestry and livestock system productivity in general. This is why the rural population living in these environments suffer consequences in a direct manner, with

[3] Considering a surface area of 75,250,200 hectares, according to the Military Geographic Institute (IGM).

high rates of poverty, lack of opportunities and strong migration rates (Frau *et al*., 2010).

In order to prioritize the issue at a national level , Universidad de Chile (2013) stated that the regions with the most complex overview -classified as severe- are: Aysen del General Carlos Ibanez del Campo (60.0%); Magallanes and the Chilean Antarctica (55.6%); Coquimbo (53.3%); Antofagasta (44.5%); Valparaíso (40.0%); la Araucanía (36,7%); and El Maule, with 27.6%. In addition, scientists predict that by 2030, in the latitudes between Arica and Chiloe, an average warming of 2 to 4 degrees Celsius will occur, with an intensification of the aridity of northern Chile, a desert advance towards the south, a water reduction in central Chile, a precipitation increase in the south, along with glacier reductions (Universidad de Chile, 2013).

In light of the above, and given the fact that Chile is a member country of the UNCCD, with the support of institutions such as the Food and Agriculture Organization (FAO), the United Nation's Environment Program (UNEP), the Ministry of Agriculture (MINAGRI) and CONAF, the National Action Program to Combat Desertification (PANCD) was implemented in 1997 - through an Advisory Committee- and was coordinated by CONAF (Salinas, 2011). The PANCD allowed channeling the policies needed in order to combat desertification; for example, out of a total of 36.9 million eroded hectares, 4 million have been intervened since 1998 through MINAGRI's development instruments (Alfaro, 2014).

According to the map of desertification in Chile, published by CONAF in 1999 (Alfaro, 2014), 270 (93%) out of 290 rural communes accounted for some level of desertification, land degradation or threat of drought: 76 communes (27%) were severely affected by desertification and 108 (36%) accounted for a moderate category of desertification . According to data from the Population Census of 2002, 1,479,163 rural inhabitants are affected by the desertification phenomenon in some of its categories. According to CONAF (1999), the rural population affected by desertification within the 'severe' category accounted for 365,532 persons. On the other hand, the 'moderate' category accounted for around 657,726 persons.

Currently, Chile's 2016-2030 PANCD is aligned with the UNCCD's Ten-year Strategy, the LDN initiative, and the United Nation's Sustainable Development Goals (SDGs). In parallel, the Chile's 2016-2030 PANCD is raised in a complementary manner and in accordance with the country's actions within the framework of the Convention on Biological Diversity (CBD), the UNFCCC and the ENCCRV, implemented by CONAF in the entire national territory.

The provisions of the 2016-2030 PANCD-Chile contribute to the fulfilment of the three specific objectives of the ENCCRV, which are:

**1.**

To contribute to the fulfillment of the commitments assumed by Chile in terms of vegetation resources before the UNFCCC, UNCCD, CBD and other national and international instances.

**2.**

To Influence in technical, political and financial decision-making that allows positioning the role of vegetation resources with regard to mitigation and adaptation to climate change, and the fight against desertification, land degradation and drought as priority axes within the sectoral development policies.

**3.**

To manage the valuation and valorization mechanisms of the environmental services provided by native vegetation resources, including performance-based payment systems that respect benefit-sharing arrangements and the environmental and social safeguards.

Land degradation estimates depend on the approaches and methods used. Global Assessment of Human-induced Soil Degradation (GLASOD) conducted a qualitative global valuation -largely based on expert criteria- which distinguished the main processes that cause degradation, such as water and wind erosion, soil and water salinization, the loss of soil-organic carbon (SOC), soil nutrients, etc. (Oldeman et al., 1991). This data allowed for the creation of the first World Atlas of Desertification (1992), which was created by UNEP, according to which more than 70% of the world's arid areas were affected by this issue. Subsequently, the Land Degradation Assessment in Drylands (LADA) incorporated quantitative variables to the analysis, such as socio-economic agents, carbon balance and biodiversity as components of the functional system of land use and its degradation (LADA, 2006). These and other studies have made progress from identifying the effects on 'soil' to explicitly including the notion of 'lands' and, ultimately, considering interactions at a global level between desertification, drought, land-use systems and variations in biodiversity. This trend has been largely supported by the UNCCD, whose definition of desertification refers to "land degradation in arid, semi-arid and dry sub-humid areas, resulting from various factors, including climatic variations and human activities".

The preliminary diagnosis of desertification in Chile was conducted using variables and classifications defined by an expert panel. The identified variables were: the aridity regime, the length of the dry period, erosion, poverty and the tendency in desertification processes in general. These combined variables determined a state of desertification which was classified into five categories: Severe (G), Moderate (M), Mild (L), Not affected (NA) and No Information (SI, for its acronyms in Spanish) (CONAF, 1999; Figure 1). Subsequently, the critical areas of desertification were identified throughout Chile, along with the need of intervening in some territories in order to monitor their progress (CONAF, 2005; Figure 2).

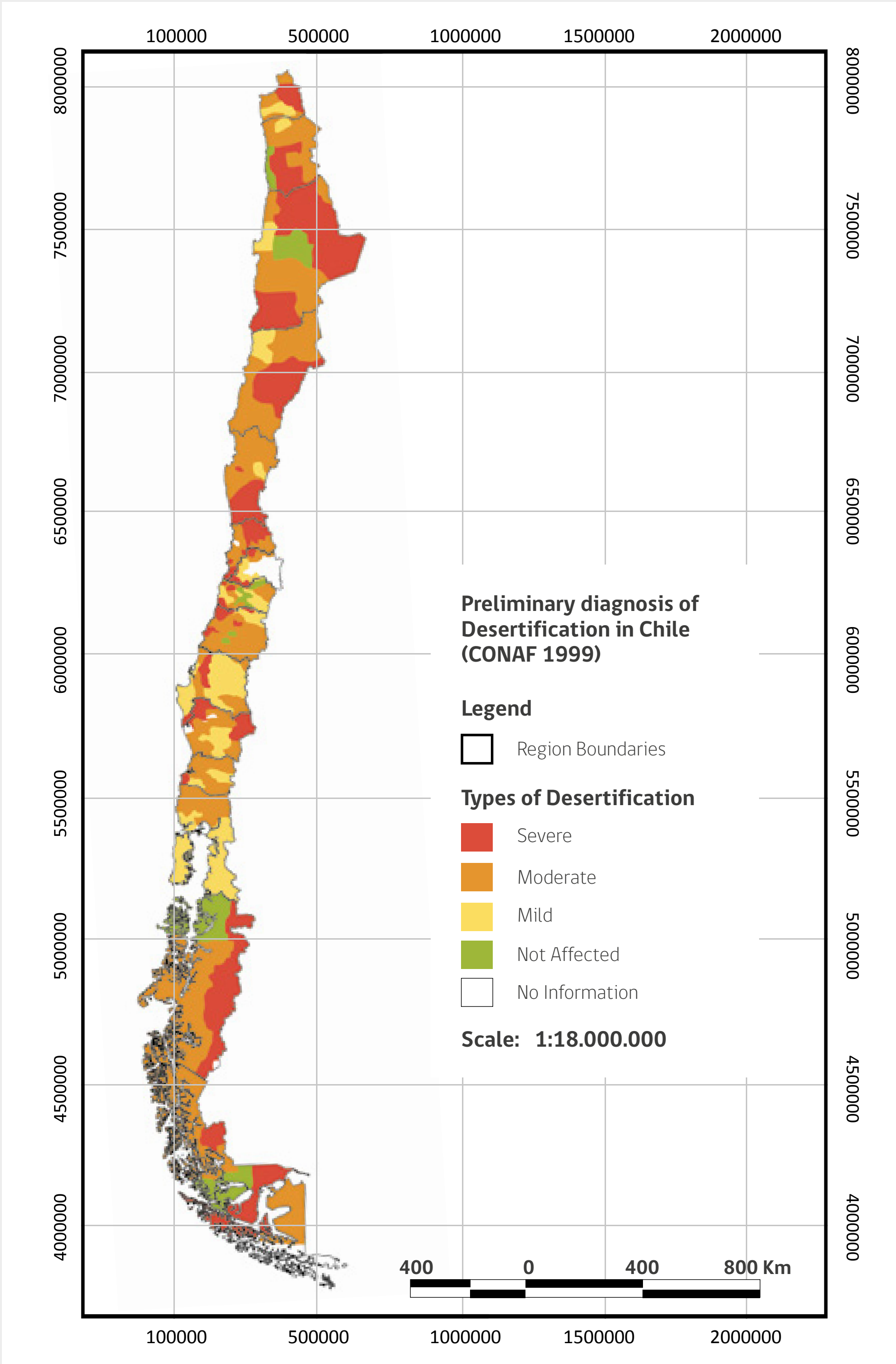



**Figure 1.** Preliminary Diagnosis of Desertification in Chile, CONAF (1999).

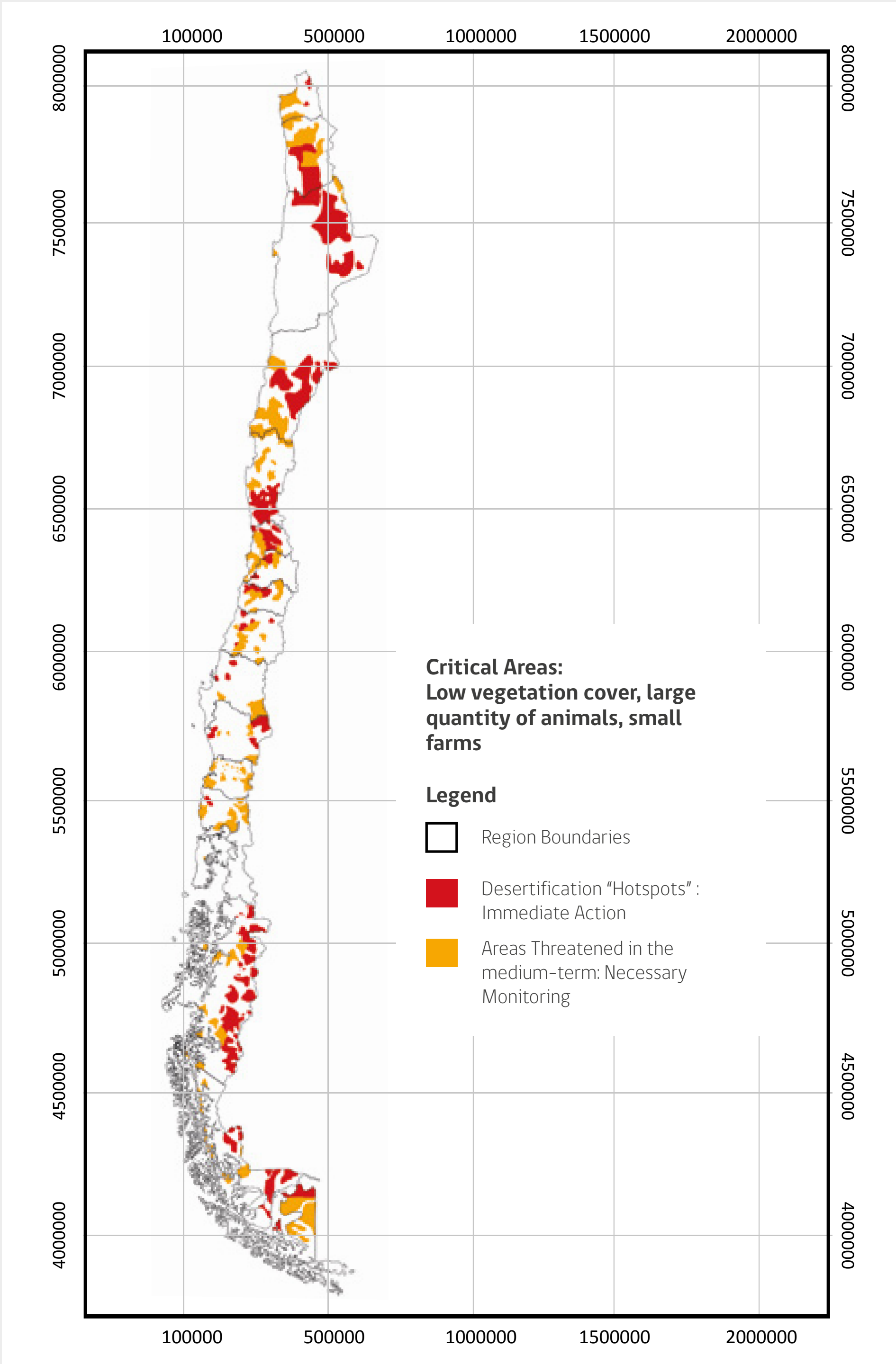



**Figure 2.** Critical Areas of Desertification in Chile, CONAF (2005).

Within the framework of the alignment process agreed to by the countries Part of the UNCCD in 2008, the alignment of Chile's PANCD with the 10-Year Strategy of the Convention required a study that included the revision of the DLDD figures in the Chile. **The aim of this study was to provide and implement a methodological framework for updating the issues' main figures for 345 communes of Chile**. The results presented herein are part of the general publications of Chile's 2016-2030 PANCD.

# Materials and Method

## Cartographic information and data assessment

The first methodological step was collecting, systematizing and gathering the existing geographic information, both in vector and raster formats. All of the information layers identified were adjusted and projected in UTM datum WGS 84 coordinates for Huso 19S. The approach used for gathering the necessary background information considered only official national and international information sources, available at no cost, which were subsequently systematized and interrelated through geospatial processes, ensuring a robust and trustworthy product with a transparent methodology which would allow its future replication. The assessment of the collected information was incorporated into an Exploratory Data Analysis (EDA). A total of 59 variables were analyzed within the EDA, which allowed detecting failures, identifying and assessing the significance of absent data, identifying outliers and estimating -using statistical techniques- the level of relevance of each variable when predicting the existing desertification categories[4].

All variables were analyzed in order to establish their relationship with the desertification and land degradation processes at a commune level. For this purpose, we initially conducted an analysis of simple correlation between all variables in order to identify those that would present higher linkage values and would, in turn, properly relate to the desertification categories proposed by CONAF (1999). Once we knew what the correlation coefficients between the total available variables for analysis were, we performed graphic tests and simple and multiple regressions tests with the purpose of reducing the base of variables potentially linked to desertification and land degradation.

Based on these analyses we managed to identify the following variables: drylands, current risk of erosion (rain erosivity, soil erodibility and vegetation cover), forest fires and poverty, such as those directly related to desertification and land degradation processes (Table 1). These variables were integrated to Chile's map of administrative division (at a commune level), thus allowing the spatial representation of desertification and land degradation at a national level.

[4] Further detail can be found in the report "Actualización de cifras y mapas de desertificación; degradación de la tierra y sequía en Chile a nivel de comunas. PANCD, Chile 2016-2030: alineado con la estrategia decenal de la CNULD, la iniciativa de degradación neutral de la tierra y los objetivos del desarrollo sostenible" (Update of figures and maps of desertification, land degradation and drought in Chile at a commune Level, 2016-2030 PANCD Chile: aligned with the 10-Year Strategy of the UNCCD, land degradation neutrality and the sustainable development goals), formulated by CONAF in 2016.

**Table 1.** Variables and information sources used for generating Chile's map of desertification and land degradation.

| Model variable | Data used | Product and source |
|---|---|---|
| Drylands | Bioclimatic models of temperature and precipitation | Ad-hoc interpolations. The variables included were: monthly precipitation and temperature, monthly total and monthly average, minimum and maximum. Period of Analysis 1950-2000. Global Historical Climatology Network (GHCN), World Meteorological Organization (WMO) and the International Center for Tropical Agriculture (CIAT). |
| Current Risk of erosion (rain erosivity, soil erodibility and vegetation cover) | Risk of erosion | Raster layer with a spatial resolution of 30m (CIREN, 2010). |
| Forest Fires | Forest Fires | Vector layer: comprises the spatial location of forest fires detected between 1985 - 2014 (CONAF). |
| Poverty [socio-economic factor] | Socio-economic Data | Data published at a commune level with regard to population, poverty, education, health, housing, income and environment (Observatorio Social, 2014). |
| Commune | Administrative Divisions | Territorial administrative units. Vector Layer (SUBDERE and IGM, 2014). |

# Description of the selected variables

## Drylands

Drylands are "arid, semi-arid and dry sub-humid areas whose ratio of average annual precipitation to potential average annual evapotranspiration is between indexes of 0.05 and 0.65. Areas with a ratio lower than 0.05 are considered hyperarid deserts" (UNEP, 1997). Drylands can be classified according to the so-called Aridity Index.

Through bioclimatic models of temperature and precipitation we were able to establish the geographic cover of drylands in Chile, by applying 3 different indexes to categorize territory:

De Martonne Aridity Index (De Martonne, 1926), UNEP Aridity Index (Verbist *et al.*, 2010) and Water Regimes (Santibanez *et al.*, 2008).

The De Martonne Index, considered one of the most suitable for applying in cold climates, was calculated through the formula I=P/(Tm+10), with Tm being the average annual temperature in C° and P being the average annual precipitation in mm. With this index, each geographical location was classified according to their level of aridity, as per the values shown in Table 2.

**Table 2.** Classification of the aridity index according to the De Martonne methodology.

| Aridity Index | Climate |
|---|---|
| > 60 | Per-humid |
| 60 - 30 | Humid |
| 30 - 20 | Sub-humid |
| 20 - 15 | Semi-arid (Mediterranean) |
| 15 - 5 | Arid (steppe) |
| 5 - 0 | Hyper-arid (desert) |

The UNEP Aridity Index accounts for the division between precipitation and evapotranspiration (P/ETP). Chile's index values were obtained from Verbist *et al*. (2010). The level of aridity is shown in Table 3.

**Table 3.** Classification of the aridity index according to the UNEP methodology.

| Pp/ETP | Climate |
|---|---|
| > 1,00 | Humid |
| 0,65 - 1,00 | Humid subhumid |
| 0,50 - 0,65 | Dry subhumid |
| 0,20 - 0,50 | Semi-arid |
| 0,05 - 0,20 | Arid |
| < 0,05 | Hyperarid |

With regard to Water Regimes, information was obtained from Santibanez *et al*. (2008), where humidity regimes were classified considering the annual coefficient of precipitation (Pp) and potential evapotranspiration (ETP), according to the scale defined in Table 4.

**Table 4.** Classification of the aridity index according to Water Regime methodology.

| Pp/ETP | Climate |
|---|---|
| 0,50 - 0,65 | Subhumid |
| 0,20 - 0,50 | Semi-arid |
| 0,05 - 0,20 | Arid |
| < 0,05 | Hyperarid |

Given the differences in the results of each of the classifications -mainly due to their scale of application- we used a combination of all three (3), through the creation of a unique aridity index which follows the methodology of Kosmas et al. (1999) for establishing environmental sensitivity indexes. This index included, as a base criteria, the classification of the index developed by the Ministry of the Environment (MMA), i.e, if the classification of the three indexes is different, the MMA classification will prevail. If the other two indexes are equal but different from the MMA, the De Martonne index will prevail. This methodology generates a new classification, shown in Table 5, over which the applied aridity index is built.

**Table 5.** Results of the classifications of the three aridity indexes and the combined index, by number of communes and % of communes, with regard to a total of 345 communes. Codes D0, D1, D2, D3 and D4 mean: Not Applicable, Without Desertification, Mild Desertification, Moderate and Severe Desertification, respectively.

| Method | Number of Communes | | | | | Percentage of Communes | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | D0 | D1 | D2 | D3 | D4 | D0 | D1 | D2 | D3 | D4 |
| MMA Matrix | 150 | 13 | 101 | 58 | 23 | 43% | 4% | 29% | 17% | 7% |
| De Martonne Matrix | 221 | 19 | 60 | 28 | 17 | 64% | 6% | 17% | 8% | 5% |
| UNEP Matrix | 14 | 14 | 111 | 99 | 107 | 4% | 4% | 32% | 29% | 31% |
| Combined Matrix | 150 | 13 | 103 | 59 | 20 | 43% | 4% | 30% | 17% | 6% |
| MMA Geometric Mean | 150 | 11 | 90 | 77 | 17 | 43% | 3% | 26% | 22% | 5% |
| De Martonne Geometric Mean | 221 | 29 | 42 | 39 | 14 | 64% | 8% | 12% | 11% | 4% |
| UNEP Geometric mean | 15 | 48 | 105 | 141 | 36 | 4% | 14% | 30% | 41% | 10% |
| Combined Geometric Mean | 150 | 11 | 69 | 92 | 23 | 43% | 3% | 20% | 27% | 7% |

## Current risk of erosion

The information layer generated by CIREN (2010) was used. This layer results from the application of a potential erosion model together with land-use cover, and accounts for a soil loss rate within the current conditions of erodibility, topography, climate and land use. CIREN (2010) created a qualitative empirical model for calculating the Index of Potential and Current Risk of Erosion (IREPOT) based on the conceptualization of potential erosion described by Wischmeier and Smith (1978). The model is based on the assumption that potential of erosion is independent from the current use and management of soil. That is to say that the losses, drag or transport of soil particles are those that would occur with soil devoid of vegetation; therefore, these losses are maximum or potential. In this manner, IREPOT integrates the results of runoff aggressiveness with soil erodibility, vegetation cover protection and climatic aggressiveness. Once these indexes were created, the current risk of erosion was categorized as per Table 6.

**Table 6.** Classification and description of the types of current risk of erosion.

| Type of current risk of erosion | Description |
|---|---|
| Null or Low current risk of erosion **(1)** | Risk where the site conditions (climate, soil, topography), which cannot be significantly modified by human action, minimize the potential of water erosion. |
| Moderate current risk of erosion **(2)** | Risk where the site conditions (climate, soil and topography) - which cannot be significantly modified by human action- may generate moderate erosion. In other words, without vegetation cover or soil conservation practices, it could be manifested in sheet erosion, mid-level mantle erosion or rill erosion. If manifested, one shall identify one or more of the following on-site erosion indicators:<br>**a)** Presence of subsoil in an area lower than 15% of the surface area.<br>**b)** Presence of erosion pedestals and pavement in at least 15% of the surface area.<br>**c)** Loss of original soil between 20 and 60%.<br>**d)** Presence of rills of a depth lower than 0.5 meters.<br>**e)** Loss of more than 30% of the A-horizon (organic-mineral) (Figure 3). |
| Severe current risk of erosion **(3)** | Risk where the site conditions (climate, soil and topography), which cannot be significantly modified by human action, may generate severe erosion. In other words, without vegetation cover or soil conservation practices, it could be manifested in sheet erosion or intensive mantle erosion or rill erosion. If manifested, one shall identify one or more of the following on-site erosion indicators:<br>**a)** Presence of subsoil in an area between 15 and 60% of the surface area.<br>**b)** Presence of erosion pedestals and pavements in between 15% and 60% of the surface area.<br>**c)** Loss of original soil between 60 and 80%.<br>**d)** Presence of ditches or badlands with depths from 0.5 to 1 meter, and in an average distance of 10 to 20 meters.<br>**e)** Loss of up to 30% of the B-horizon (Figure 3). |
| Extremely severe current risk of erosion **(4)** | Accounts for the risk where the site conditions (climate, soil and topography), which cannot be significantly modified by human action, can generate extremely severe erosion. In other words, it could be manifested in sheet erosion or highly-accelerated mantle erosion or rill erosion. If manifested, one shall identify one or more of the following indicators:<br>**a)** Subsoil is visible and the soil source material is visible in more than 60% of the surface area.<br>**b)** Presence of erosion pedestals and pavements in over 60% of the surface area.<br>**c)** Loss of original soil between 80 and 100%.<br>**d)** Presence of badlands with a depth greater than 1 meter, and in an average distance of 5 to 10 meters.<br>**e)** Loss of more than 30% of the B-horizon. |
| Other uses **(5)** | Other uses or no information. |

As soil formation begins, horizontal layers with different colors, composition and structure appear; these are called horizons. The set of horizons is called the soil profile. In mature and well-developed soil we can distinguish four horizons: O, A, B, and C.

**O HORIZON**

Strata or layers dominated by organic material such as leaves, branches, mosses, lichens and waste, all of which have been accumulated over the area. They are not saturated with water for prolonged periods.

**A HORIZON**

It is the most superficial and dark layer, since it has a large accumulation of humus. Within it, we can find raw organic wastes, such as leaf-litter. It is characterized for being the washout area, i.e., water flows through it, dragging material such as clay and mineral salts to the lower horizons.

**B HORIZON**

It lacks organic matter and accumulates ions, clay and iron oxides derived from the washout in horizon A.

**C HORIZON**

It is the bedrock, either fresh or partially fragmented.

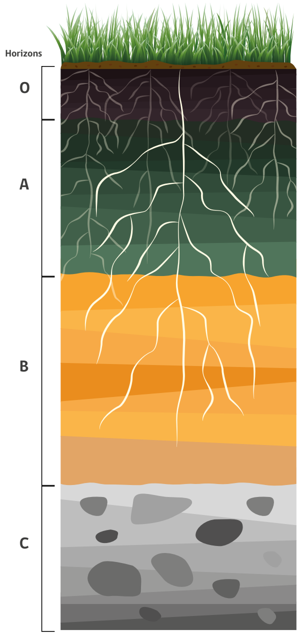
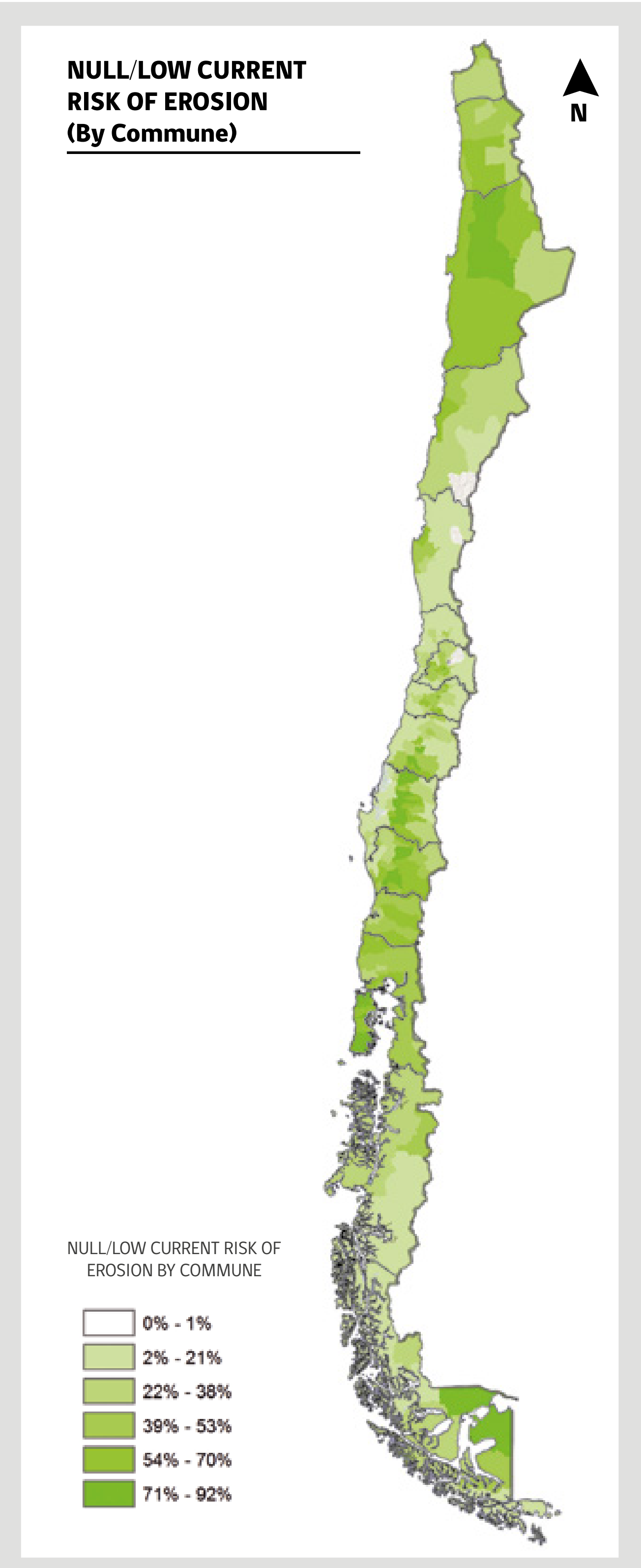



**Figure 3.** Brief description of soil profiles.

There are four maps that show the areas with current risk of erosion within the different categories: low or null, moderate current risk of erosion, with severe current risk of erosion and the delimitation of areas with extremely severe current risk of erosion, with predominant values from 2% and 52% of risk (Figure 4).



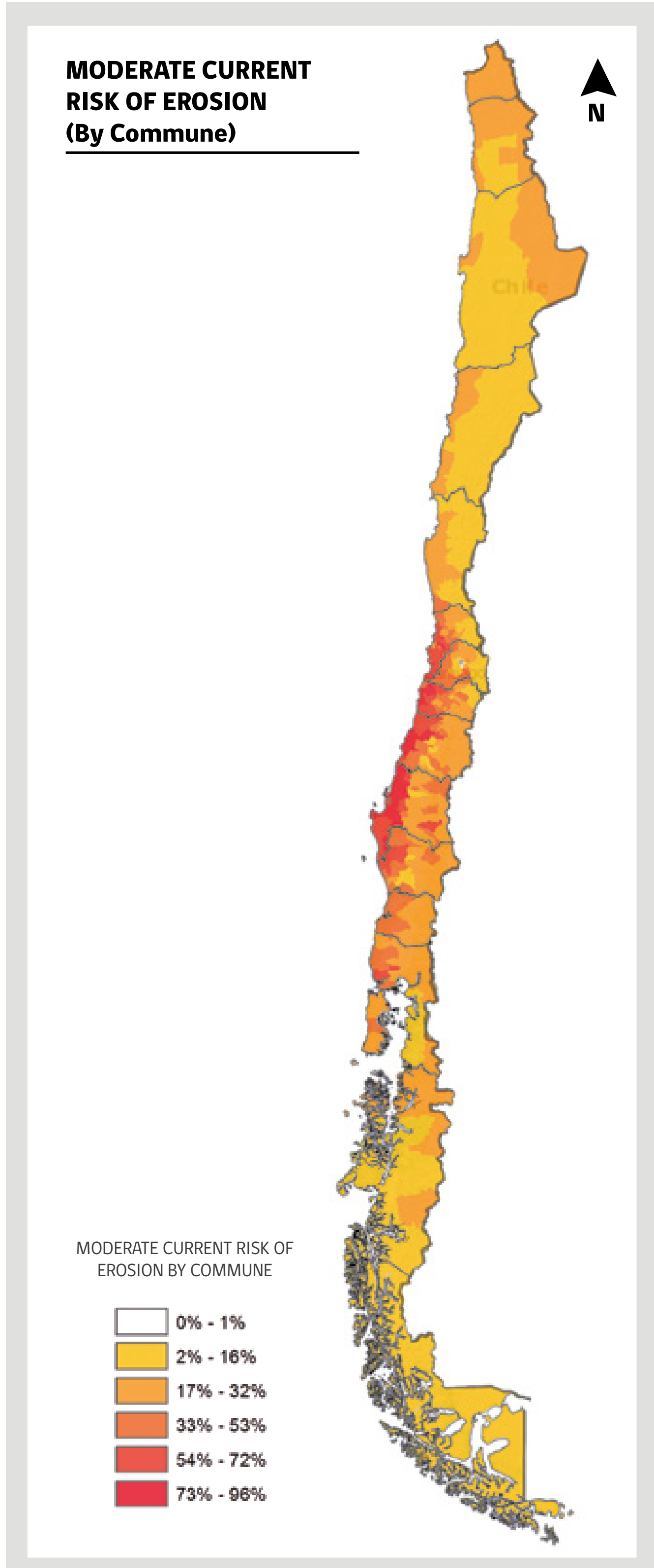
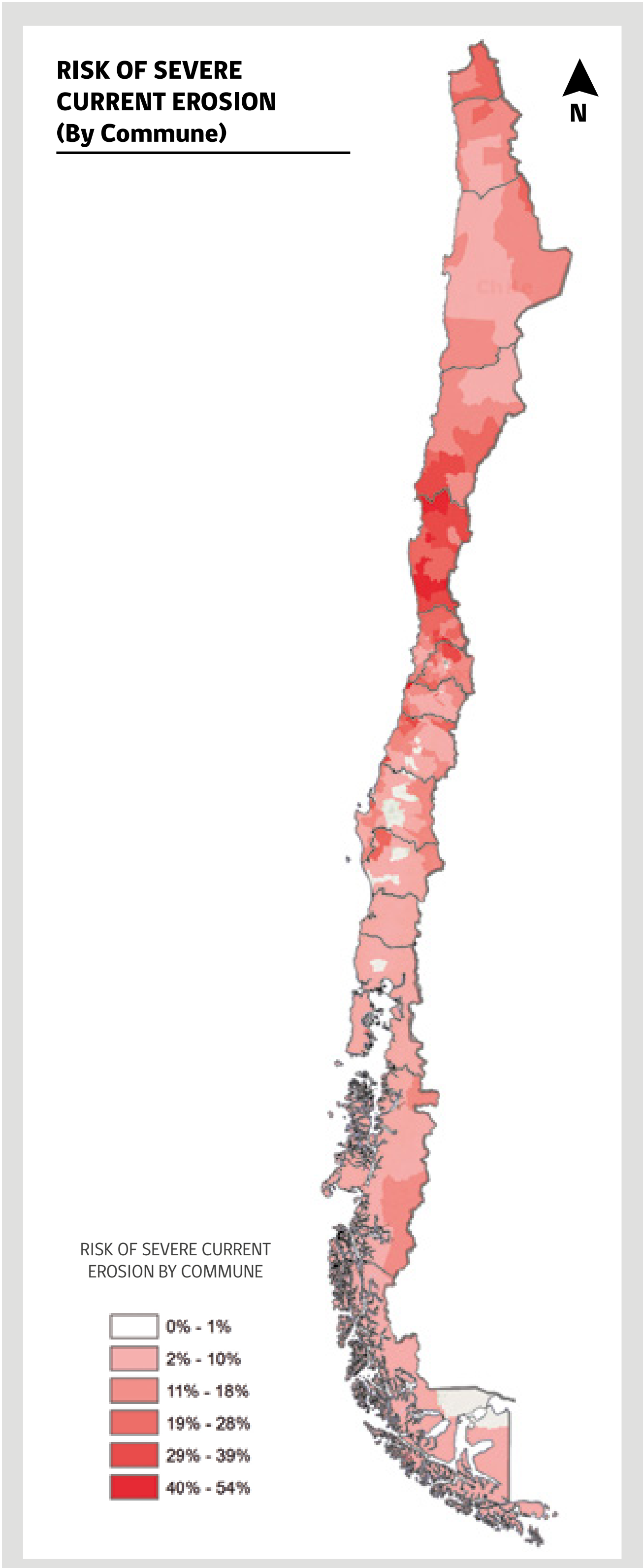




**Figure 4a.** Areas with current risk of erosion by commune in categories in low or null and moderated categories.



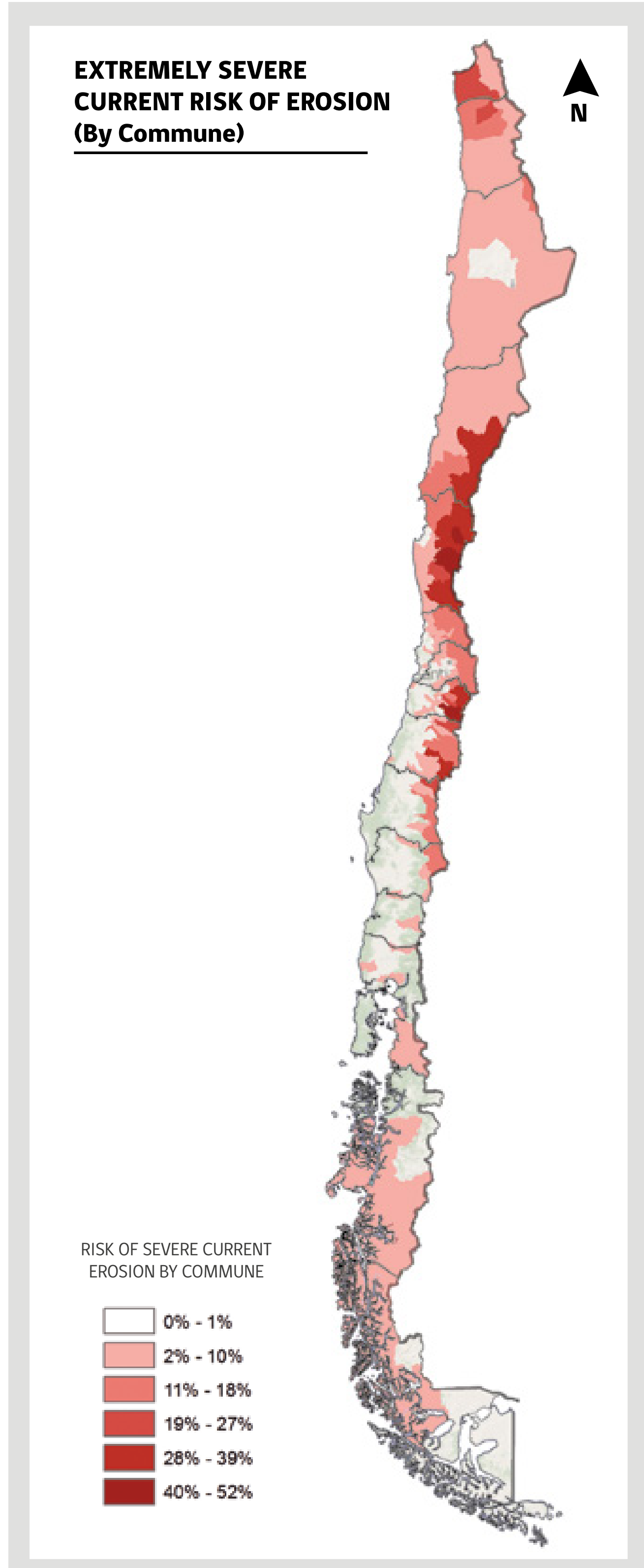




**Figure 4b.** Areas with current risk of erosion by communes within the severe and extremely severe categories.

## Forest Fires

It is estimated that the affected area in each forest fire period averages 52,000 hectares, but with extreme values that have fluctuated between 10,000 to 101,000 hectares. The greatest damage was caused was to grasslands and scrublands; and -on a smaller scale- to natural trees and forest plantations[5].

The database used for incorporating the fire index into the desertification risk model was provided by CONAF's Forest Fire Protection Management Department (GEPRIF) which, through on-site information gathering, characterized the affected area, including geographical coordinates of the site where the fire occurred, along with its corresponding date. The information used for this study corresponds to the period between 1985 and 2010. With this variable, an index of forest fires (IF) was calculated: *IF=n/(ha of forests)*, with n being the number of forest fires between 1985-2010 and ha of forests being the sum of the area of native forests and forest plantations.

The results were finally categorized into the following four types: 1, values with a frequency of less than 25% of occurrence; 2, with frequency of between 25 and 50% of occurrence; 3, of 75% of occurrence; and 4, those communes with a fire incidence higher than 75%.

## Socio-economic Factor

From the social point of view, drought, desertification and land degradation drive poverty when breaking social and family structures, and cause economic instability. Morales *et al*, (2005) in his publication titled "Poverty, desertification and degradation of natural resources" discusses how desertification and land degradation impact the productivity of land, thus bringing -as a main consequence- high levels of migration and poverty. While more degradation, lower productivity, hence lower agricultural and livestock income and vice versa. This is why the Poverty Index variable (IP) was included, which corresponds to the Incidence of commune poverty (CASEN, 2011).

[5] http://www.conaf.cl/incendios-forestales/incendios-forestales-en-chile/

# Description of the models used

## Desertification Risk Model

he model used for estimating the risk of desertification considered four variables that were obtained according to the aforementioned, which are: drylands, current risk of erosion, the forest fire factor and a socio-economic factor. The current risk of erosion (CIREN, 2010) was formulated with the rainfall erosivity variables (R-Factor), Soil erodibility (E-Factor), vegetation cover (CV factor) and soil-organic carbon (C factor) (Figure 5).

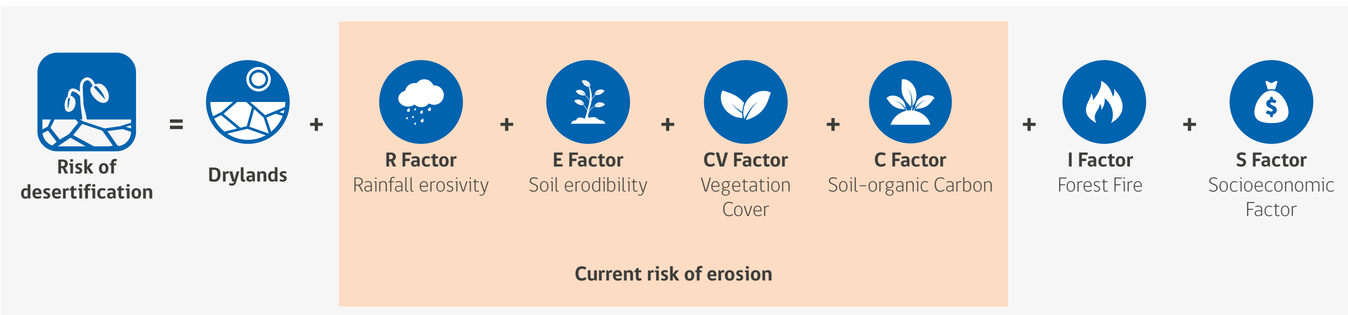



**Figura 6.** Diagram showing the variables that participate in the estimation of the Risk of Desertification.

The model's variables were related based on the approach of the European Mediterranean Desertification and Land Use (MEDALUS) Project, which identified areas with a different level of average environmental sensitivity from the calculations made in an index that incorporates information pertaining to environmental quality factors (climate, soil and vegetation), as well as other anthropogenic sources related to the use and management of soil (Benabderrahmane & Chenchouni, 2010; Lavado *et al*., 2010; Portilla *et al*., 2014). Similarly, the Interregional European Cooperation Project, DesertNet II, part of the Interreg III B Program, establishes the need of identifying the degradation or desertification risk factors, even when its effect on the environment does not show any deterioration. The establishment of follow-up indicators of the factors involved (defined in DESERNET I) -either directly or through their consequences- can provide for an early diagnosis of the issues and promote a rapid and economic fix for them. In turn, these indicators allow for the establishment of sensitive or vulnerable areas, thus determining the fragility of the territories and their potential to suffer from this phenomenon (Moreira and Rodriguez, 2008; Rodriguez *et al*., 2008).

Within this framework, the relationship between the variables is established as follows:

$$RDs = \sqrt[4]{(IAts^{0,4} \times REA^{0,1} \times IP^{0,25} \times IF^{0,25})}$$

Whereas,

| | |
|---|---|
| **RDs** | Risk of Desertification |
| **IAts** | Index of Dryland Aritity |
| **REA** | Current Risk of Erosion |
| **IP** | Poverty Index |
| **IF** | Risk of Forest Fires |

The constants present in the model respond to the weights assigned to each variable, which were determined in work meetings with experts. Finally, the values obtained were classified into 4 types according to their percentile distribution (Table 7). Hyperarid areas were not considered in the analysis, since this aridity level "does not apply" to the definition of Desertification provided by the UNCCD.

**Table 7.** Classification of the categories for defining the risk of desertification.

| Risk of Desertification | Classification (Class) |
|---|---|
| 1,100 - 1,171 | Severe |
| 1,171 - 1,242 | Moderate |
| 1,242 - 1,313 | Mild |
| 1,313 - 1,383 | No desertification |

## Land Degradation Risk Model

To build the land degradation risk model, we use basically the same variables used in the desertification risk model, except for aridity, since in order to fulfill the targets of the study herein, land degradation must be analyzed for all of Chile's communes, regardless of their location being in drylands or other lands. Based on the above, the applied land degradation risk model considers the variables indicated in Figure 6.


**Figure 6.** Land degradation risk model

These model's variables are similarly related to the model above for the risk of desertification:

$$RDT = \sqrt[4]{(IA^{0,4} \times REA^{0,1} \times IP^{0,25} \times IF^{0,25})}$$

Whereas,

**RDT** Risk of Land Degradation
**IA** Aridity Index
**REA** Current Risk of Erosion
**IP** Poverty Index
**IF** Forest Fire Index

The constants within the model, respond to the weights defined for each variable determined in work meetings with experts. Finally, the values were classified in 4 types (Table 8).

**Table 8.** Classification of final categories for defining Risk of Land Degradation.

| Risk of Land Degradation | Type |
|---|---|
| 1,000 - 1,096 | Severe |
| 1,096 - 1,192 | Moderate |
| 1,192 - 1,289 | Mild |
| 1,289 - 1,385 | No degradation |

## Drought Index

The combined drought index, formulated by Nunez *et al*. (2011) was used for quantifying the effect of drought with regard to area and population at a commune level in Chile. The latter informs on the current condition of drought in Chile, combining meteorological drought indexes (Standardized precipitation Index, SPI), hydrological drought (Standardized Flow Index, SFI) and Agricultural Drought, estimated through the Normalized Difference Vegetation Index (NDVI). The combined drought index considers three impacts according to intensity levels: Level 1, mild drought resulting from a precipitation deficit; Level 2, moderate drought resulting from a flow rate deficit that is additional to the precipitation deficit, and; Level 3, severe drought resulting from soil water deficit, which affects vegetation, along with a flow rate and precipitation deficit.

## Integration of the risk of Desertification, Land Degradation and Drought (DLDD)

With the aim of generating a technical management instrument that allows monitoring the integrated evolution of desertification, land degradation and drought, we created an indicator that combines the estimated risks of these three assessments. The integration was performed by weighting desertification by 0.4; land degradation by 0.3 and drought by 0.3. Desertification has a major global impact, therefore it was weighted with larger weight. This analysis allowed creating a map at a commune level, which integrates each one of the pillars that will allow providing proper follow-up to land degradation neutrality.

# Results

## Risk of desertification

The national risk of desertification expressed in surface area reflects that approximately 21.7% of the country has some level of risk of desertification (mild, moderate or severe), considering a total surface area of 75,643,227 ha subject to desertification. The affected population with some level of risk of desertification amounts to 6,816,661 inhabitants, which is equivalent to 37.9% of Chile's inhabitants and in 156 out of the country's current 345 communes. With regard to the surface area and the population likely to be affected by the desertification process, the 'moderate' category accounts for the largest surface area (11.7% of the total) and in turn, the largest number of inhabitants likely to be affected (16.2% of the total). Information regarding the affected area and population -aggregated at a regional level- is available in Annex 1.

Table 9 shows a summary of the number of communes associated to the area and population in risk of desertification. In this regard, the communes declared under category "Not Applicable" are those not located in drylands, due to the fact that their aridity index is humid, per-humid, or since they are simply located in areas where climate is extremely dry (hyperarid). Based on the concept of desertification coined within the framework of the UNCCD, these communes should not be catalogued within risk of desertification, particularly given the characteristics of their ecosystems associated to temperature, precipitation or evapotranspiration, among others. The communes classified as urban use -those with more than 95% of their area destined for that purpose- were excluded from the analysis conducted in the study herein.

**Table 9.** Number of communes, population and area with risk of desertification at a national level in their different categories.

| Risk of desertification | Number of commune | Commune Proportion | Population | Population Proportion | Area (ha) | Surface area proportion |
|---|---|---|---|---|---|---|
| Severe Desertification | 19 | 5,5% | 2.277.604 | 12,6% | 2.708.606 | 3,6% |
| Moderate Desertification | 85 | 24,6% | 2.915.621 | 16,2% | 8.851.704 | 11,7% |
| Mild Desertification | 52 | 15,1% | 1.623.436 | 9,0% | 4.819.032 | 6,4% |
| No Desertification | 7 | 2,0% | 61.218 | 0,3% | 3.649.475 | 4,8% |
| *N/A* | *150* | *43,5%* | *5.621.054* | *31,2%* | *55.411.347* | *73,3%* |
| *Urban use* | *32* | *9,3%* | *5.507.282* | *30,6%* | *203.064* | *0,3%* |
| **Total** | **345** | **100%** | **18.006.215** | **100%** | **75.643.227** | **100%** |

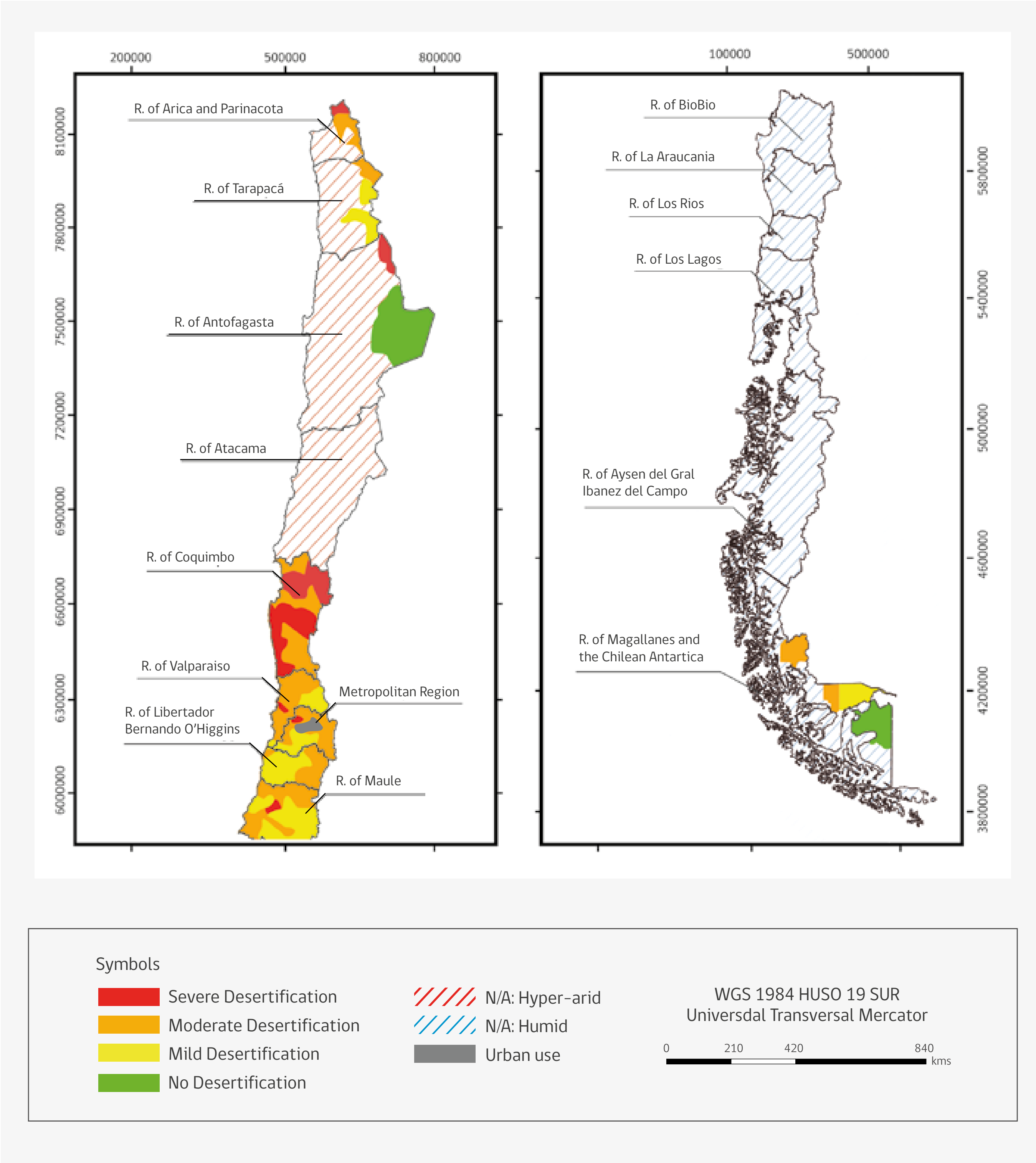



**Figure 7.** Risk of desertification by regions of Chile.

# Risk of Land Degradation

The classification of lands according to their level of degradation was performed through an analysis of 100% of Chile's communes[6]; therefore, the analysis was conducted regardless of the type of bioclimatic area (aridity) of land.

The risk of land degradation at a national level expressed in surface area reflects that approximately 79.1% of Chile has some level of risk of land degradation in its different categories (mild, moderate, and severe) These figures account for approximately 59,863,662 hectares. The population that is affected with some level of risk of land desertification amounts to approximately 12,064,099 inhabitants, which is equivalent to 67.1% of the country's inhabitants (Table 10; Figure 8). Information regarding the affected area and population -aggregated at a regional level- is available in Annex 1.

**Table 10.** Number of communes, population and area with risk of land degradation at a national level in their different categories.

| Risk of degradation | No. of communes | Commune Proportion | Population | Population Proportion | Area (ha) | Surface Area Proportion |
|---|---|---|---|---|---|---|
| Severe Degradation | 55 | 15,9% | 3.829.624 | 21,3% | 4.492.152 | 5,9% |
| Mild Degradation | 75 | 21,7% | 2.600.033 | 14,4% | 31.924.876 | 42,2% |
| Moderate Degradation | 162 | 47,0% | 5.634.442 | 31,3% | 23.446.635 | 31,0% |
| No Degradation | 21 | 6,1% | 434.834 | 2,4% | 15.576.501 | 20,6% |
| *Urban use* | *32* | *9,3%* | *5.507.282* | *30,6%* | *203.064* | *0,3%* |
| **Overall Total** | **345** | **100%** | **18.006.215** | **100%** | **75.643.227** | **100%** |

This analysis shows the prevalence of the moderate risk of land degradation (Figure 8). The three regions with the greatest participation of surface areas in moderate condition are located in the Region of Atacama (5.0 million hectares), followed by the Region of Tarapaca (3.7 million hectares) and the Region of Maule (2.7 million hectares). Between all three regions, they contribute 49% of the total area, corresponding to the category of moderate risk of land degradation. With regard to the 'severe' category, the Region of Coquimbo is in first place (with 2.2 million hectares) and accounts for 50% of this condition in that region. Finally, the condition of mild land degradation is concentrated, firstly, in the Region of Antofagasta (12.3 million hectares), followed by the Region of Aysen, with 5.5 million hectares. Both regions account for 56% of the total area in this risk category.

[6] The analysis for determining the risk of land degradation was conducted at a commune level.

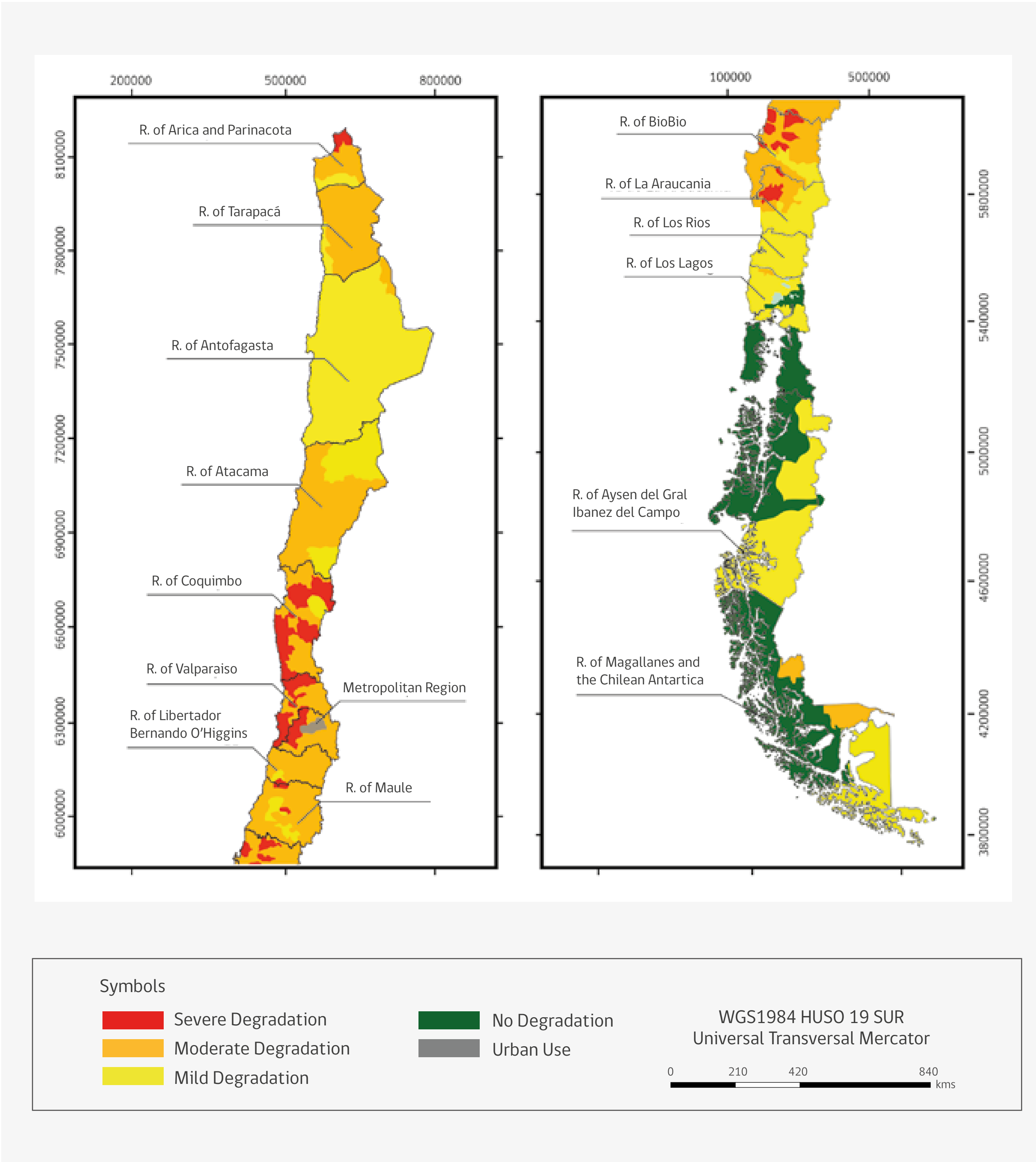



**Figure 8.** Risk of land degradation by regions of Chile

# Drought Index

The issue of drought at a national level, quantified in terms of surface area, reflects that approximately 72% of Chile's lands have some level of drought in their different categories (mild, moderate, severe) (Table 11). These figures account for approximately 55 million hectares. With regard to population with a high risk of drought, this amounts to approximately 16 million inhabitants, which accounts for 90% of Chile's inhabitants (Figure 9, for regional level, see Annex 1).

The region with the largest number of population affected by drought in the 'severe' category is the Metropolitan Region of Santiago, with 6.7 million inhabitants, followed by the Region of Valparaiso with 1.7 million inhabitants. Drought is considered severe when there is water deficit that affects vegetation within territories, precipitation deficit and deficit in the surface and underground flow rate for an extended period of time. These deficits cause serious impacts on vegetation, fauna, population and soil, among others. The regions with the greatest land areas affected by severe drought include, in the first place, the Region of Coquimbo, with approximately 3.9 million hectares, followed by the Region of Atacama , with 1.8 million hectares.

The regions with the greatest land areas affected by moderate drought are the Region of Magallanes and Region of Biobio, with approximately 3.2 and 3.1 million hectares, respectively. Territories with deficit in surface and underground flow rates, in addition to a precipitation deficit for an extended period of time are considered 'moderate' drought.

**Table 11.** Number of communes, population, and surface area with drought at a national level in their different categories.

| Type of drought | No. of communes | Commune Proportion | Population | Population Proportion | Area (ha) | Surface area proportion |
|---|---|---|---|---|---|---|
| Severe | 128 | 37,1% | 10.217.408 | 56,7% | 9.102.283 | 12,0% |
| Moderate | 135 | 39,1% | 4.494.897 | 25,0% | 19.031.823 | 25,2% |
| Mild | 54 | 15,7% | 1.528.428 | 8,5% | 26.636.833 | 35,2% |
| No Drought | 28 | 8,1% | 1.765.482 | 9,8% | 20.872.288 | 27,6% |
| **Overall Total** | **345** | **100,0%** | **18.006.215** | **100,0%** | **75.643.227** | **100,0%** |

There is a prevalence of the severe drought index in the regions of Coquimbo, south zone of Atacama, Valparaiso and the Metropolitan Region of Santiago. These account for a total of 8.1 million hectares, where approximately 9.3 million inhabitants live.

In the 'moderate' drought index, in terms of surface area, there is a prevalence of the Magallanes Region (3.2 million hectares), Biobio Region (3.1 million hectares) and the La Araucania Region, Region, with 2.8 million hectares. These three regions account for 48% of the national area affected with moderate drought. The representation of population in this category amounts to 2.7 million inhabitants.

Finally, within the mild drought index category, the first place goes to the Region of Aysen, Region of Magallanes and the north of the Atacama Region, which add up to a total of 17.1 million hectares with 377.655 inhabitants affected with mild drought.

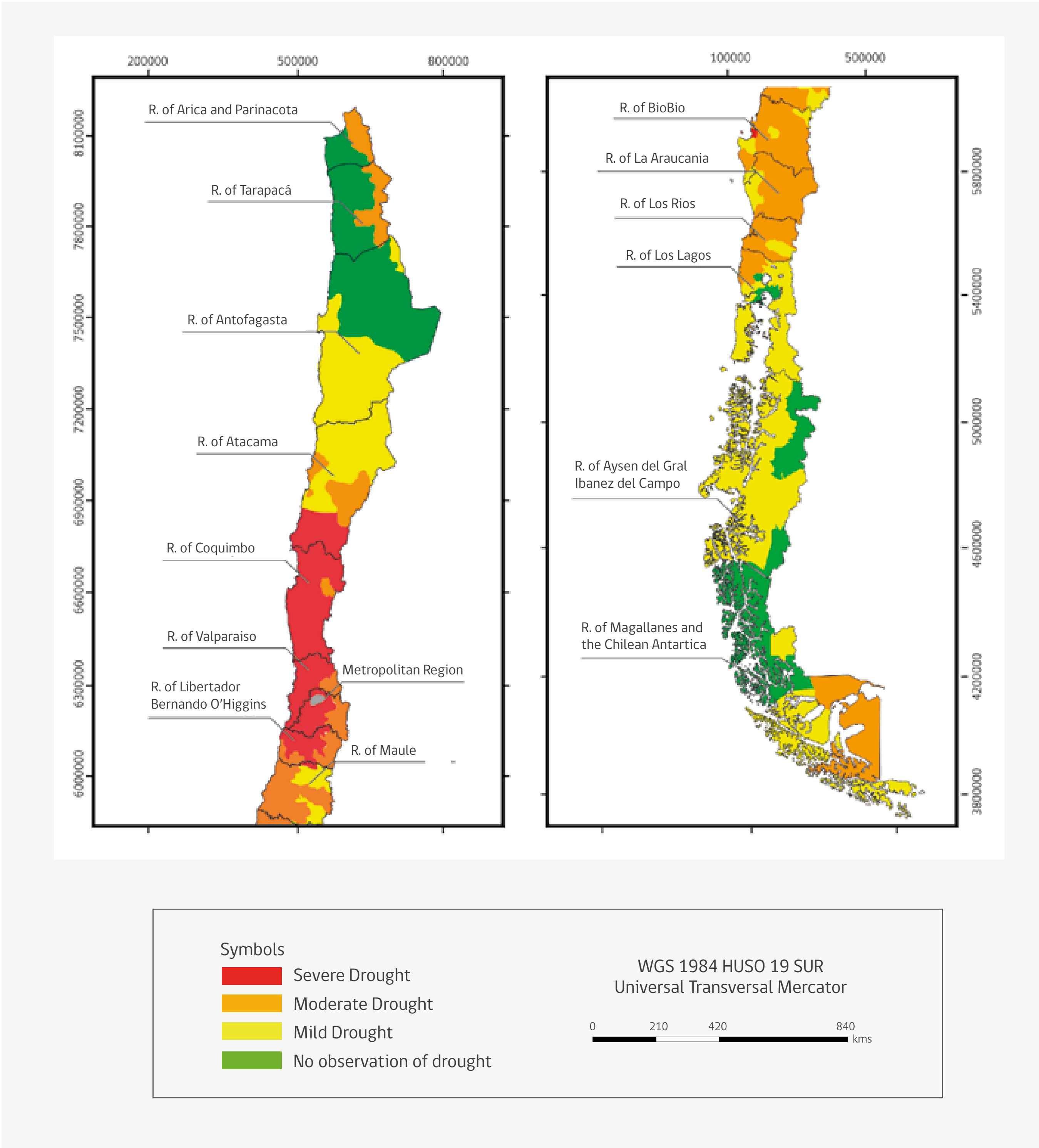



**Figure 9.** Index of drought at a regional level in Chile

# Integration of the risk of Desertification, Land Degradation and Drought (DLDD)

Once desertification, land degradation and drought are integrated by communes at a national level, we conclude that 57.5 million hectares, which account for 76% of Chile, are affected in some of the DDLD categories (severe, moderate, mild). The population affected at a national level amounts to 11.6 million inhabitants, accounting for 65% of Chile's inhabitants, who are distributed in 295 communes at a national level (Table 12; Figure 10; for regional information, see Annex 1).

It is worth noting that approximately 5.5 million inhabitants located in 32 communes classified as being of urban use, are not considered in terms of accounting statistics. Communes with urban use are those where over 90% of their area is occupied by urban infrastructure, and are located in the Metropolitan Region of Santiago.

**Table 12.** Number of communes according to their DLDD Risk category at a national level.

| DLDD Category | No. of communes | % of communes | Population | % of population | Area (ha) | % of area |
|---|---|---|---|---|---|---|
| Severe DLDD | 101 | 29% | 5.587.491 | 31% | 7.171.631 | 9% |
| Moderate DLDD | 114 | 33% | 3.375.636 | 19% | 16.326.477 | 22% |
| Mild DLDD | 80 | 23% | 2.719.967 | 15% | 34.052.822 | 45% |
| Null/low DLDD | 18 | 5% | 815.839 | 5% | 17.889.910 | 24% |
| *Urban use* | *32* | *9%* | *5.507.282* | *31%* | *203.047* | *0%* |
| **Overall Total** | **345** | **100%** | **18.006.215** | **100%** | **75.643.887** | **100%** |

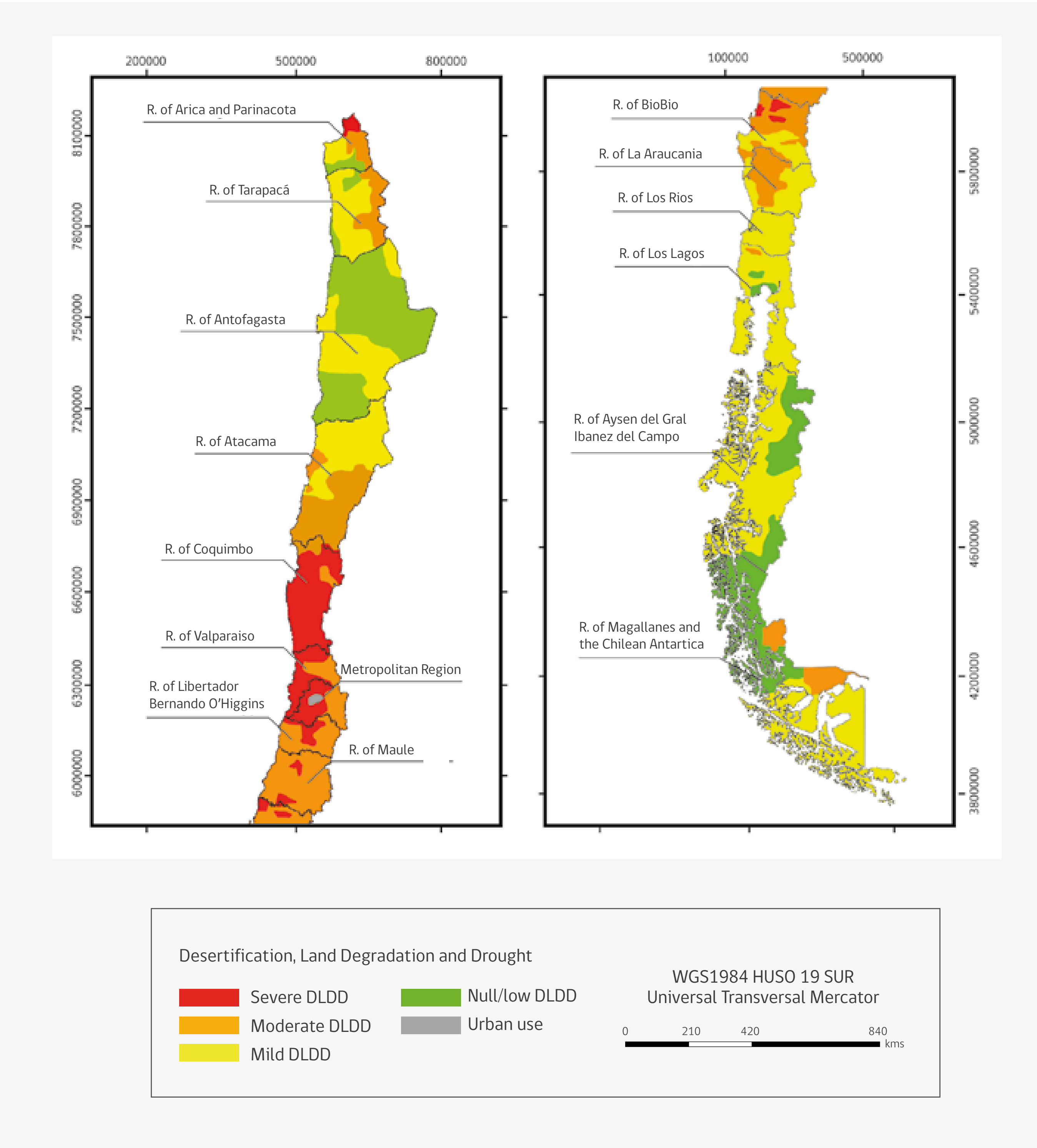



**Figure 10.** Risk of Desertification, Land Degradation and Drought (DLDD) by regions of Chile.

# Conclusions

## Risk of desertification

**1.**

The risk of desertification at a national level, quantified in terms of surface area, reflects that approximately 21.7% of Chile has some level of risk of desertification, based on its different categories (mild, moderate and severe); this accounts for 16,379,342 hectares. The affected population that poses some level of risk of desertification amounts to 6,816,661 inhabitants.

**2.**

At a national level, the population with risk of severe desertification accounts for 2,227,604 inhabitants, which is equivalent to 13% of Chile's total population.

**3.**

Chile's north zone, mainly the Region of Coquimbo, is the region with the greatest surface area with risk of severe desertification, which amounts to approximately 2,243,834 hectares, affecting 438,638 inhabitants.

## Risk of Land Degradation

**1.**

The risk of land degradation at a national level, expressed in terms of surface area, reflects that approximately 79.1% of Chile has some level of risk of land degradation in their different categories (mild, moderate and severe). These figures account for approximately 59,863,662 hectares. The affected population with some level of land degradation accounts for approximately 12,064,099 inhabitants, which is equivalent to 67.1% of Chile's inhabitants.

**2.**

At a national level, the population with a severe risk of land degradation accounts for 3,829,624 inhabitants, which is equivalent to 21% of Chile's total population.

**3.**

The 'severe' land degradation category includes, in the first place, the Region of Coquimbo (2.2 million hectares) and accounts for 50% of the national area within this condition.

# Drought

**1.**

The effect of drought at a national level, expressed in terms of the affected surface area, reflects that approximately 72% of Chile's lands have some level of drought in their different categories (mild, moderate, severe). These figures account for approximately 55 million hectares. The affected population with some level of drought amounts to approximately 16 million inhabitants, which is equivalent to 90% of Chile's inhabitants.

**2.**

The region with the largest number of population affected by drought in the severe category is the Metropolitan Region of Santiago, with 6.7 million inhabitants, followed by the region of Valparaiso, with 1.7 million inhabitants.

**3.**

The regions that have the greatest amount of land areas affected by severe drought are, first of all, the region of Coquimbo, with approximately 3.9 million hectares, followed by the region of Atacama, with 1.8 million hectares.

# Integration of the risk of desertification, Land degradation and drought (DLDD)

**1.**

57.5 million hectares - which account for 76% of Chile- are affected in some of the DLDD categories (severe - moderate - mild). The affected population at a national level amounts to 11.6 million inhabitants, accounting for 65% of Chile's inhabitants.

**2.**

The risk of DDLD in the 'severe' category prevails in the regions of Coquimbo, Valparaiso, O'Higgins and the Metropolitan Region.

**3.**

The regions that predominate in terms of area, with a 'moderate' risk of DDLD, are the Region of Atacama (3.3 million hectares), Maule (2.9 million hectares), and the Region of Biobio, with 2.4 million hectares; together, they account for 53% of the national area affected with moderate DDLD.

**4.**

With regard to mild DDLD, the first place goes to the Regions of Aysen, Magallanes and Los Lagos; which together add up to 19.0 million hectares with 720,497 inhabitants.

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# Definitions

### Desertification

Land degradation that occurs in arid, semi-arid and sub-humid areas as a result of various factors, including climatic variations and human activities. When land degradation occurs in drylands, conditions similar to a desert are created.

### Drylands

Arid, semi-arid or dry sub-humid areas in which the proportion of the average annual precipitation and the average annual potential evapotranspiration accounts for between the indexes 0.05 and 0.65. Areas with a proportion lower than 0.05 are considered deserts.

### Land degradation

Reduction or loss of biological or economic productivity and the complexity of rain-fed agricultural land, irrigated land for cultivation or grazing ground, pastures, forests and wooded land, which occurs in in arid, semi-arid or sub-humid dry areas due to land-use systems or a process or combination of processes, including those that result from human activities and population guidelines, such as (i) erosion caused by wind or water; (ii) the deterioration of physical, chemical and biological properties or the economic properties of soil, and (iii) the sustained loss of natural vegetation.

### Drought

Phenomenon that naturally occurs when precipitation is considerably lower than the normal levels recorded, causing serious water imbalances, adversely affecting land resource production systems.

### Aridity Index

Aridity indexes consider -as fundamental data- precipitation that has fallen throughout the year (as a water source) and temperatures (as an indicator of the climate's capacity to evaporate). There are several ways to calculate an aridity index, such as: the De Martonne Aridity Index (), the UNEP Aridity Index (UNESCO, 2010), Water Regimes (Santibanez *et al*., 2008)

### Evapotranspiration

Set of physical (evaporation) and biological (plant transpiration) losses of soil in water vapor. It is expressed in millimeters (mm) per unit of time. Evapotranspiration depends on climate (radiation, air humidity, wind), plant (vegetation cover) and edaphic factors (soil type, state of humidity of soil).

### Potential Erosion

The capacity of soil to erode from the effects of water, considering intrinsic soil variables, topography and climate. Potential erosion is the maximum ratio of erosion that can occur, which, in turn, gives an idea of what the maximum loss that could occur when vegetation disappears is.

### Current risk of erosion

Considers the risk of potential erosion and adds the level of protection of soil provided by current vegetation. In this sense, the current risk of erosion would be subject to vegetation currently covering the ground.

# Acronyms

| | |
|---|---|
| **EDA** | Exploratory data analysis |
| **CASEN** | National Socio-economic characterization survey |
| **CAZALAC** | UNESCO Water Center for Latin America and the Caribbean |
| **CIAT** | International Center for Tropical Agriculture |
| **CIREN** | Natural Resources Information Center |
| **CONAF** | National Forestry Corporation |
| **CDB** | Convention on Biological Diversity |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **CONAMA** | National Environment Commission |
| **UNCCD** | United Nation's Convention to Combat Desertification |
| **DDLD** | Desertification, Land Degradation and Drought |
| **ENCCRV** | National Strategy on Climate Change and Vegetation Resources |
| **ETP** | Potential Evapotranspiration |
| **FAO** | Food and Agriculture Organization |
| **GHCN** | Global Historical Climatology Network |
| **GLASOD** | Global Assessment of Soil Degradation |
| **IGM** | Military Geographic Institute |
| **IREPOT** | Index of Potential and Current Risk of Erosion |
| **IRC** | Near infrafred |
| **LADA** | Land Degradation Assessment in Drylands |
| **MINAGRI** | Ministry of Agriculture |
| **NDVI** | Normalized Difference Vegetation Index |
| **PAN** | National Action Program |
| **PANCD** | National Action Program to Combat Desertification |
| **UNEP** | United Nations Environment Program |
| **SUBDERE** | Under-Secretariat of Regional and Administrative Development |
| **UTM** | Universal Transverse Mercator |
| **WGS** | World Geodetic System |
| **WMO** | World Meteorological Organization |

# ANNEX 1

**Table 1.** Distribution of **Surface Area** by Categories of Risk of Desertification, Land Degradation, Drought and the indicator that integrates DLDD. Information obtained from a study conducted by CONAF (2016).

| Region / Risk of Desertification | Arica and Parinacota | Tarapaca | Antofagasta | Atacama | Coquimbo | Valparaiso | Metropolitan |
|---|---|---|---|---|---|---|---|
| Severe | 228.032 | | | | 2.243.834 | 112.671 | 69.062 |
| Moderate | 591.826 | 399.444 | 285.196 | | 1.251.564 | 1.020.491 | 926.264 |
| Mild | | 895.728 | | | 150.090 | 397.765 | 341.242 |
| No Desertification | | | 2.366.930 | | | 68.365 | |
| Total Desertification | 819.858 | 1.295.172 | 285.196 | | 3.645.488 | 1.530.927 | 1.336.568 |

| Region / Risk of Land degradation | Arica and Parinacota | Tarapaca | Antofagasta | Atacama | Coquimbo | Valparaiso | Metropolitan |
|---|---|---|---|---|---|---|---|
| Severe | 228.032 | | | | 2.243.834 | 643.259 | 359.927 |
| Moderate | 1.076.177 | 3.762.855 | 285.196 | 5.038.478 | 1.669.957 | 790.152 | 976.641 |
| Mild | 390.270 | 465.427 | 12.325.829 | 2.526.975 | 150.090 | 202.265 | |
| No land degradation | | | | | | | |
| Total land degradation | 1.694.479 | 4.228.282 | 12.611.025 | 7.565.453 | 4.063.881 | 1.635.676 | 1.336.568 |

| Region / Risk of Drought | Arica and Parinacota | Tarapaca | Antofagasta | Atacama | Coquimbo | Valparaiso | Metropolitan |
|---|---|---|---|---|---|---|---|
| Severe | | | | 1.819.545 | 3.913.791 | 1.338.118 | 1.036.389 |
| Moderate | 819.858 | 1.295.172 | | 1.497.346 | 150.090 | 261.174 | 498.913 |
| Mild | | | 3.738.394 | 4.248.562 | | | |
| No observations of drought | 874.70 | 2.933.230 | 8.872.600 | | | 36.390 | 4.330 |
| Total Drought | 819.858 | 1.295.172 | 3.738.394 | 7.565.453 | 4.063.881 | 1.599.292 | 1.535.302 |

| Region / Risk of DDLD | Arica and Parinacota | Tarapaca | Antofagasta | Atacama | Coquimbo | Valparaiso | Metropolitan |
|---|---|---|---|---|---|---|---|
| Severe | 228.000 | | | | 3.495.300 | 1.269.723 | 837.689 |
| Moderate | 591.800 | 1.295.100 | 285.200 | 3.317.100 | 568.500 | 329.570 | 498.900 |
| Mild | 484.400 | 2.467.830 | 3.453.600 | 4.248.800 | | 25.670 | |
| Null/Low | 390.300 | 465.400 | 8.872.600 | | | 10.720 | |
| Total DDLD | 1.304.200 | 3.762.930 | 3.738.800 | 7.565.900 | 4.063.800 | 1.624.963 | 1.336.589 |

| Lib. Bernardo O'Higgins | Maule | Biobio | La Araucania | Los Rios | Los Lagos | Aysen del General Carlos Ibanez del Campo | Magallanes and the Chilean Antarctica | National Total |
|---|---|---|---|---|---|---|---|---|
| 8.063 | 46.944 | | | | | | | 2.708.606 |
| 891.467 | 1.435.502 | 1.049.447 | | | | | 1.000.503 | 8.851.704 |
| 667.376 | 1.547.671 | 130.905 | | | | | 688.256 | 4.819.033 |
| 67.557 | | | | | | | 1.146.623 | 3.649.475 |
| 1.566.906 | 3.030.117 | 1.180.352 | | | | | 1.688.759 | 16.379.343 |

| Lib. Bernardo O'Higgins | Maule | Biobio | La Araucania | Los Rios | Los Lagos | Aysēn del General Carlos Ibanez del Campo | Magallanes and the Chilean Antarctica | National Total |
|---|---|---|---|---|---|---|---|---|
| 144.305 | 46.944 | 498.576 | 327.274 | | | | | 4.492.151 |
| 1.317.354 | 2.742.248 | 2.581.617 | 1.378.616 | 75.520 | 63.065 | | 1.688.759 | 23.446.635 |
| 172.803 | 240.925 | 632.413 | 1.476.416 | 1.762.673 | 2.209.075 | 5.533.431 | 3.836.283 | 31.924.875 |
| | | | | | 2.576.016 | 5.146.928 | 7.853.558 | 15.576.502 |
| 1.634.462 | 3.030.117 | 3.712.606 | 3.182.306 | 1.838.193 | 2.272.140 | 5.533.431 | 5.525.042 | 59.863.661 |

| Lib. Bernardo O'Higgins | Maule | Biobio | La Araucania | Los Rios | Los Lagos | Aysēn del General Carlos Ibanez del Campo | Magallanes and the Chilean Antarctica | National Total |
|---|---|---|---|---|---|---|---|---|
| 867.074 | 87.995 | 39.373 | | | | | | 9.102.285 |
| 767.388 | 2.102.741 | 3.130.210 | 2.831.669 | 1.661.754 | 736.958 | | 3.278.549 | 19.031.822 |
| | 839.382 | 543.024 | 350.637 | 176.439 | 3.802.182 | 7.988.433 | 4.949.781 | 26.636.834 |
| | | | | | 308.990 | 2.691.900 | 5.150.000 | 20.872.140 |
| 1.634.462 | 3.030.118 | 3.712.607 | 3.182.306 | 1.838.193 | 4.539.140 | 7.988.433 | 8.228.330 | 54.770.941 |

| Lib. Bernardo O'Higgins | Maule | Biobio | La Araucania | Los Rios | Los Lagos | Aysēn del General Carlos Ibanez del Campo | Magallanes and the Chilean Antarctica | National Total |
|---|---|---|---|---|---|---|---|---|
| 871.139 | 134.940 | 334.840 | | | | | | 7.171.631 |
| 763.360 | 2.895.040 | 2.422.337 | 1.532.180 | 75.520 | 63.070 | | 1.688.800 | 16.326.477 |
| | | 955.442 | 1.650.250 | 1.762.460 | 4.475.870 | 7.988.400 | 6.540.100 | 34.052.822 |
| | | | | | 308.990 | 2.691.900 | 5.150.000 | 17.889.910 |
| 1.634.499 | 3.029.980 | 3.712.619 | 3.182.430 | 1.837.980 | 4.538.940 | 7.988.400 | 8.228.900 | 57.550.930 |

**Table 2.** Distribution of **Population** by Categories of Risk of Desertification, Land Degradation, Drought, and the indicator that integrates DLDD. Information obtained from a study conducted by CONAF (2016).

| Risk of Desertification \ Region | Arica and Parinacota | Tarapaca | Antofagasta | Atacama | Coquimbo | Valparaiso | Metropolitan |
|---|---|---|---|---|---|---|---|
| Severe | 594 | | | | 438.638 | 541.026 | 994.355 |
| Moderate | 2.077 | 1.696 | 313 | | 323.333 | 1.094.497 | 396.268 |
| Mild | | 6.639 | | | 4.492 | 154.642 | 416.271 |
| No Desertification | | | 7.418 | | | 28.365 | |
| N/A | 236.455 | 328.434 | 614.909 | 312.486 | 4.622 | 7.227 | 5.507.282 |
| Total Desertification | 2.671 | 8.335 | 313 | 0 | 766.463 | 1.790.165 | 1.806.894 |

| Risk of Land degradation \ Region | Arica and Parinacota | Tarapaca | Antofagasta | Atacama | Coquimbo | Valparaiso | Metropolitan |
|---|---|---|---|---|---|---|---|
| Severe | 594 | | | | 438.638 | 1.356.670 | 1.241.486 |
| Moderate | 237.754 | 137.353 | 313 | 290.957 | 327.955 | 371.824 | 565.408 |
| Mild | 778 | 199.416 | 622.327 | 21.529 | 4.492 | 97.263 | |
| No Land Degradation | | | | | | | |
| Total Land Degradation | 239.126 | 336.769 | 622.640 | 312.486 | 771.085 | 1.825.757 | 1.806.894 |

| Risk of Drought \ Region | Arica and Parinacota | Tarapaca | Antofagasta | Atacama | Coquimbo | Valparaiso | Metropolitan |
|---|---|---|---|---|---|---|---|
| Severe | | | | 76.570 | 766.593 | 1.732.009 | 6.720.595 |
| Moderate | 2.671 | 8.335 | | 34.736 | 4.492 | 86.521 | 15.003 |
| Mild | | | 389.866 | 201.180 | | | |
| No observations of drought | 236.455 | 328.434 | 232.774 | | | 7.227 | 578.578 |
| Total Drought | 2.671 | 8.335 | 389.866 | 312.486 | 771.085 | 1.818.530 | 6.735.598 |

| Risk of DDLD \ Region | Arica and Parinacota | Tarapaca | Antofagasta | Atacama | Coquimbo | Valparaiso | Metropolitan |
|---|---|---|---|---|---|---|---|
| Severe | 594 | | | | 761.971 | 1.703.644 | 1.791.891 |
| Moderate | 2.077 | 8.335 | 313 | 111.306 | 9.114 | 114.886 | 15.003 |
| Mild | 235.677 | 129.018 | 389.553 | 201.180 | | 6.370 | |
| Null/Low | 778 | 199.416 | 232.774 | | | 857 | |
| Total DDLD | 238.348 | 137.353 | 389.866 | 312.486 | 771.085 | 1.824.900 | 1.806.894 |

CONAF (2016). 2016-2030 National Action Program to Combat Desertification, Land Degradation and Drought: PANCD-Chile. Climate Change and Environmental Services Unit (UCCSA), Forest Development and Promotion Management Department (GEDEFF), National Forestry Corporation (CONAF), Ministry of Agriculture, Chile.

| | Lib. Bernardo O'Higgins | Maule | Biobio | La Araucania | Los Rios | Los Lagos | Aysén del General Carlos Ibanez del Campo | Magallanes and the Chilean Antarctica | National Total |
|---|---|---|---|---|---|---|---|---|---|
| | 20.318 | 282.673 | | | | | | | 2.277.604 |
| | 318.186 | 500.707 | 277.225 | | | | | 1.319 | 2.915.621 |
| | 563.517 | 259.609 | 217.666 | | | | | 600 | 1.623.436 |
| | 16.730 | | | | | | | 8.705 | 61.218 |
| | | | 1.619.395 | 989.798 | 404.432 | 841.123 | 108.328 | 153.845 | 11.128.336 |
| | 902.021 | 1.042.989 | 494.891 | 0 | 0 | 0 | 0 | 1.919 | 6.816.661 |

| | Lib. Bernardo O'Higgins | Maule | Biobio | La Araucania | Los Rios | Los Lagos | Aysén del General Carlos Ibanez del Campo | Magallanes and the Chilean Antarctica | National Total |
|---|---|---|---|---|---|---|---|---|---|
| | 88.207 | 282.673 | 355.202 | 66.154 | | | | | 3.829.624 |
| | 791.294 | 721.945 | 1.442.028 | 729.446 | 5.756 | 10.490 | | 1.919 | 5.634.442 |
| | 39.250 | 38.371 | 317.056 | 194.198 | 398.676 | 586.259 | 68.504 | 11.914 | 2.600.033 |
| | | | | | | 244.374 | 39.824 | 150.636 | 434.834 |
| | 918.751 | 1.042.989 | 2.114.286 | 989.798 | 404.432 | 596.749 | 68.504 | 13.833 | 12.064.099 |

| | Lib. Bernardo O'Higgins | Maule | Biobio | La Araucania | Los Rios | Los Lagos | Aysén del General Carlos Ibanez del Campo | Magallanes and the Chilean Antarctica | National Total |
|---|---|---|---|---|---|---|---|---|---|
| | 712.015 | 46.743 | 162.883 | | | | | | 10.217.408 |
| | 206.736 | 744.165 | 1.829.020 | 922.768 | 393.595 | 236.586 | | 10.269 | 4.494.897 |
| | | 252.081 | 122.383 | 67.030 | 10.837 | 308.576 | 43.831 | 132.644 | 1.528.428 |
| | | | | | | 295.961 | 64.497 | 21.556 | 1.765.482 |
| | 918.751 | 1.042.989 | 2.114.286 | 989.798 | 404.432 | 545.162 | 43.831 | 142.913 | 16.240.733 |

| | Lib. Bernardo O'Higgins | Maule | Biobio | La Araucania | Los Rios | Los Lagos | Aysén del General Carlos Ibanez del Campo | Magallanes and the Chilean Antarctica | National Total |
|---|---|---|---|---|---|---|---|---|---|
| | 709.693 | 329.416 | 290.282 | | | | | | 5.587.491 |
| | 209.058 | 713.573 | 1.417.745 | 756.061 | 5.756 | 10.490 | | 1.919 | 3.375.636 |
| | | | 406.259 | 233.737 | 398.676 | 534.672 | 43.831 | 140.994 | 2.719.967 |
| | | | | | | 295.961 | 64.497 | 21.556 | 815.839 |
| | 918.751 | 1.042.989 | 2.114.286 | 989.798 | 404.432 | 545.162 | 43.831 | 142.913 | 11.683.094 |

**National Forestry Corporation**

Climate Change and Environmental Services Unit (UCCSA)
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