

❖ Standard 9: Conduct an analysis of the severity and geographic scope of threats to conservation targets/biodiversity elements, and analyze the root causes of priority threats.

Case Study: Analysis of critical threats in the Valdivian Temperate Rainforest

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Purpose and region of analysis

An ecoregion conservation team conducted a detailed analysis of pervasive threats in the Valdivian Temperate Rainforest. The five top threats to biodiversity in this region are: conversion to plantations, extraction of firewood, extraction for timber, anthropogenic fire and overgrazing. What follows is a description of the approach used to quantify each of these threats.

Criteria/Methods

CONVERSION TO PLANTATIONS

Overview

Using a matrix, the values of zones occurring near either roads or existing plantations were combined with the grid for plant impact area by intensity. In recent years, the single greatest cause of native forest loss in the ecoregion has been conversion (or substitution as it is called in Chile) to exotic timber plantations. In Chile, since the 1970s, a dynamic timber sector, aided by state subsidies and based primarily in export-oriented paper pulp production, has driven the rapid expansion of Monterey Pine (*Pinus radiata*) and eucalyptus (*Eucalyptus globulus* and *E. nitens*) plantations, which now reach nearly two million ha. in the ecoregion. This area of expansion has included a significant portion of native forest lands resulting in both direct habitat loss and extensive habitat fragmentation. Although, the significance of forest conversion as a driver of deforestation has been debated for years, the available data all support the importance of conversion as a major cause of native forest loss.

The only exact spatial data available comes from a process of monitoring of change in Chile's native vegetation. This showed that within the two regions studied in the late 1990s 81% of the forest loss in the VIII Region, and 41% of that in the X Region was caused by substitution (CONAF et al. 1999). This fact, although based on only a few years of data, supports earlier estimates of substitution. A study by the Chilean Central Bank and Universidad Austral de Chile (1995) estimated that between 48-62% of forest loss was attributable to conversion in the period from 1985-1994. Whereas CONAF

(Emanuelli 1997) attributed 63% of forest loss to conversion. As the rate of forestation with plantations has slowed in the late 1990s, it is possible that the rate of substitution is also finally slowing. Actual rates of conversion are very difficult to determine in part because this activity tends to be carried out under permits for other types of forest clearing allowed in the existing forest law, particularly management plans for agricultural clearing (*habilitación*).

Unlike most of the other threats to forests, the driving force for conversion is not demand for native forest products, but rather competition for growing space. Also unlike many other forest uses, conversion to plantations entails a relatively permanent ecological change, rendering the habitat unsuitable for a variety of forest interior and late-successional habitat dependent species in all taxa. Substitution also leaves areas susceptible to increased erosion, and severely disrupts natural nutrient and hydrological cycles (Arnold, 1998).

Most eucalyptus and nearly 90% of all the Monterey Pine plantations are located in the northern portion of the Valdivian ecoregion. For example, practically all the *roble hualo* (*Nothofagus glauca*) forests and accompanying ecotones toward sclerophyllous forests in Chile's Regions VII and VIII have been converted to pine plantations (Donoso 1993; Arnold 1999). Conversion has been primarily concentrated in certain subregions. In particular, the Northern and Southern Coastal Range, and Central Valley subcoregions have been converted in large proportions, either in a direct process, or indirectly after an earlier phase of agricultural expansion had removed the native forests. Much of the converted area, thus, lies in what were the ancient glacial refugia for the southern temperate forests (Armesto et al. 1994). The analyses carried out for the ER process found that 1,543,290 ha, or 7.3%, of what was once native forest cover in the ecoregion is now occupied by exotic tree plantations.

Data analysis

A map of conversion risk was developed in which the ecoregion was represented by a grid, and threat values, from 1 (highest) to 5 (lowest), were assigned to each grid cell based on available information for four variables thought to indicate levels of risk. Separate grids were established for each of the parameters affecting likelihood for substitution, and the resultant grids were then combined arithmetically. These were location in relation to the supply area of, and capacity of, pine/eucalyptus processing plants; proximity to existing plantations; road access; and suitability of vegetation types for conversion. These were used based on the assumption that each is an important variable considered by timber firms in the decision as to where to expand plantations. Qualitative observation of the spatial expansion of plantations over the past 30 years tends to support this assumption, though a more complete model of conversion risk would require several additional kinds of data which were not available. In particular, land tenure, land markets and site conditions, are all factors that appear to play a key role in determining the decision of firms to plant (and convert forest if necessary) in any area. In sum, the model can be summarized as follows: **suitability of vegetation type + location within area of supply/impact x intensity of demand + road access + proximity to existing plantations= risk factor for conversion.**

1) Suitability of vegetation types for substitution

A range of vegetation types run little risk of conversion either due to legal protection, as in the case of alerce and araucaria forest types, or because they occur on sites suboptimal for pine and eucalyptus, these include alto Andean vegetation, lenga, ñire and Guaitecas Cypress. Those types typically considered suitable by the industry were used in the analysis and included:

- Roble hualo
- Coihue, rauli, tepa
- Mixed sclerophyllous
- Roble, rauli, coihue
- Valdivian evergreen
- Coihue de Magallanes

2) Timber plants mapped

Using data from INFOR and other sources, all pulp mills (9); large, permanent, pine-based sawmills (74); and large woodchip and plywood mills using primarily eucalyptus and pine (34), were mapped according to general locations, totaling 117 plants from the VII to the XI Regions. Notably, these were concentrated in the VIII Region, Malleco Province in the IX Region and in the Province of Valdivia, X Region.

3) Supply areas of timber plants

In order to determine the areas of impact for each of these plants a rapid survey was conducted to determine the approximate radius of supply per plant. For this purpose, information on the farthest distances from which logs were transported was obtained for all of the pulp mills and for approximately 25% of the other plants operating in the ecoregion. Reported values were relatively uniform by type of plant. Woodchip, plywood and sawmills all were assigned an average radius of 200 km. For pulpmills the radius was substantially larger than for other types of plants, and averaged 300 km. Using the average radii of either 200 or 300 km, all plants were assigned a buffer using ArcView GIS. The surface area within each buffer was considered the area of impact by plant.

4) Use of installed capacity as a measure of intensities of pressure by area

In order to calculate the intensity of pressures within each radius, these were linked to the installed capacity of each plant mapped. As most radii overlapped, installed capacity for all overlapping radii was summed in order to determine a final value for installed capacity per grid cell within all zones serving as supply areas. Thus, the impact of a given plant was its processing capacity distributed over the grid cells of its harvest area. For example, if a sawmill with a capacity to process 150,000 m² per year will harvest up to 200 km from the plant, then the impact of the processing capacity would be divided up among all the grid cells that fell into a circle with a 200-km radius around that mill.

5) Proximity to plantations

A second important factor, based on the observed history of plantation expansion, was proximity to other plantations. The larger timber companies have each worked to

geographically consolidate holdings as a strategy for establishing management units ("timbersheds") that can be managed with relative efficiency and supply a given plant. Thus, maps of timber company holdings show a majority of planted areas either adjacent or within the same general supply zone. By contrast, significant forest conversion rarely occurs in areas distant and isolated from other plantations. The exception being areas that timber firms have identified starting points for plant construction and the development of new management units. Our view is that few or no entirely new areas remain in Chile, which in part explains the tendency of Chilean firms to invest in plantations in neighboring countries.

The following general categories were used to classify areas according to their proximity to existing plantations:

- Up to 1km -- zones of highest risk
- 1-5 km -- zones of relatively high risk
- 5-10 km -- zones of medium risk
- 10-15 km -- zones of relatively low risk

6) Road access

Given the crucial role of transport costs within the overall cost structure of the industry (Katz et al. 1998), road access and quality plays an important role in decision-making as to where to direct plantation expansion. Although in some areas plantation expansion drives the extension of new roads, these cases often imply the extension of relatively short logging road networks connected to new or existing public roads. Thus, road access is not a definitive, but rather a qualifying factor. According to this model we would expect areas close to paved routes and with a high density of secondary roads to be prioritized for firms for plantation expansion.

The following categories were used to classify risk associated with road access:

Primary roads:

- Up to 1 km from the road
- 1-5 km from the road
- 5-10 km from the road
- 10-20 km from the road

Secondary roads:

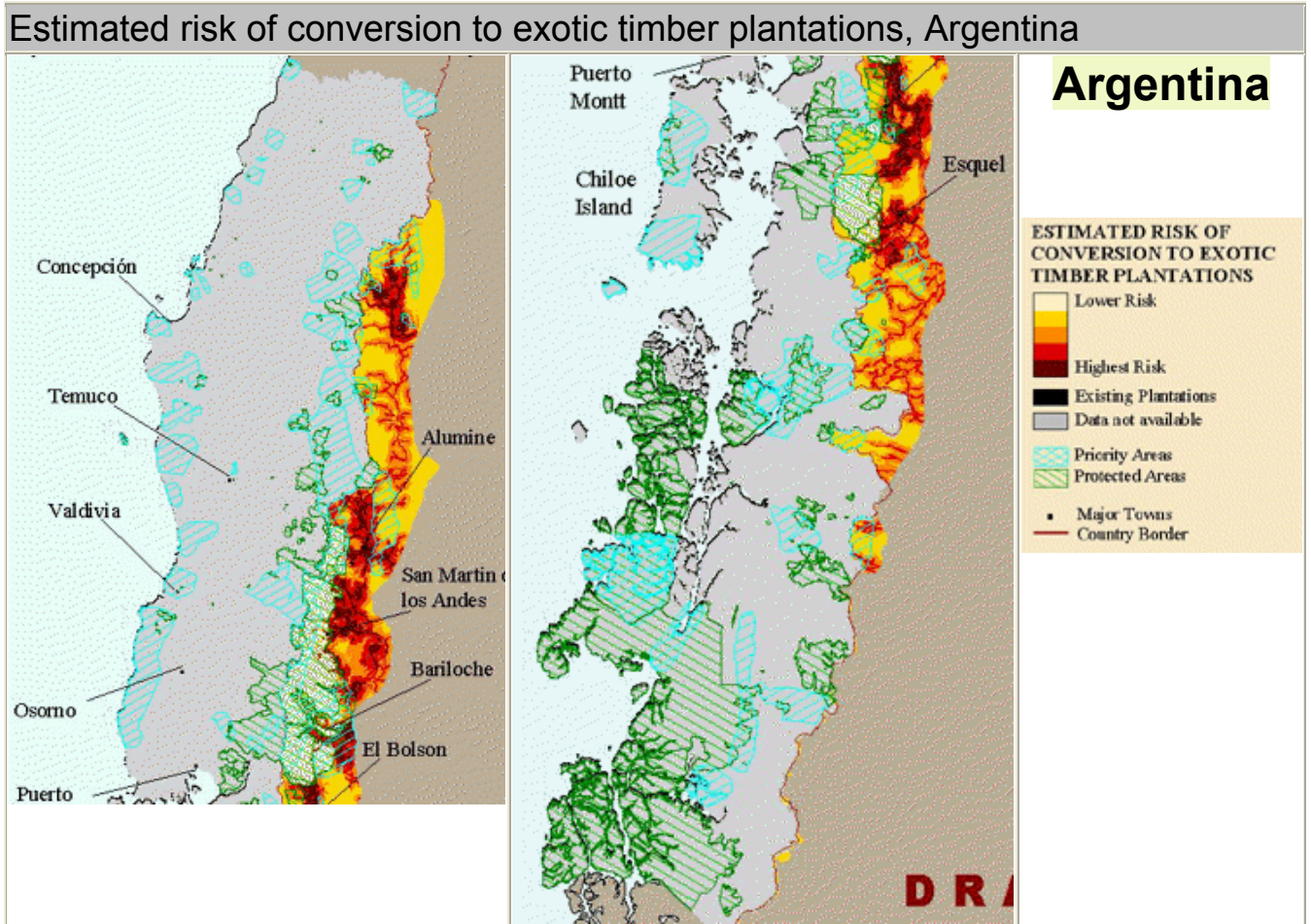
- Up to 1 km from the road
- 1-5 km from the road
- 5-10 km from the road

Areas that were farther than 20 km from a primary road, 10 km from a secondary road, and 15 km from an existing plantation were considered at relatively low risk of expansion. Areas less than 1 km from either a primary or secondary road received a total value of 1 (highest threat).

Using a matrix, the values of zones occurring near either roads or existing plantations were combined with the grid for plant impact area by intensity. The results of the combination of distance from infrastructure and mill capacity are shown in the maps below, with each grid cell in the ecoregion valued according to the likelihood of its substitution with exotic tree plantations.

As described above, the areas most likely to be converted to plantations are zones of suitable natural forest outside of existing protected areas, within the combined harvest areas or "timbersheds" of pulp plants and sawmills, relatively close to existing plantations and roads. The priority areas falling into this category included most of those in the coastal range subcoregions, as well as several in the three northernmost Andean subcoregions.

Example output



EXTRACTION OF FIREWOOD

Overview

Firewood is the primary source of heating for the majority of the population within the Chilean portion of the ecoregion. In the IX, X, and XI Regions in particular, it is a nearly universally used fuel in residences, as well as government and commercial buildings. It is also the most important energy source for many industries in these regions, including dairy and fruit processing. Official estimates identify firewood as the most important use

of native timber by volume (INFOR 1999). Within the Argentine portion of the ecoregion, logging for firewood occurs but at much lower levels, in large part due to the fact that the urban populations rely on relatively inexpensive natural gas for heating. Thus, firewood consumption was only considered a major driving force or vehicle of forest degradation and destruction for the Chilean portion of the ecoregion, and this analysis is limited to that area.

From the IX Region south, over 80% of all firewood comes from native forests, whereas in the VII and VIII regions firewood supply is divided approximately evenly between native forests and exotic plantations. Although reliable figures are lacking, INFOR (1999) estimates that approximately 60% of timber volumes logged are consumed as firewood. This concurs with Lara et al.'s (1995 cited in Lara and Cortes 2000: 143) estimate that firewood accounted for 65% of total timber volumes consumed in 1995, down from 86% in 1985. Surveys of key informants conducted for this analysis confirm the relative importance of firewood extraction as a pressure on native forests, identifying it as one of the top three pressures in every subecoregion.

Firewood extraction is a subsector of the logging industry which, in the vast majority of cases, occurs as an informal economic activity for which there is a total absence of official data. It is generally small-scale, highly decentralized and dispersed, all factors that make mapping or modeling extremely difficult. Logging for firewood tends to be selective "highgrade" (floreo) style logging, only a small proportion of which occurs within the guidelines of approved forest management plans, and practically none of which uses adequate silvicultural practices. The purpose of this analysis was to identify those areas where firewood logging occurs at important levels, recognizing that some level of firewood extraction occurs practically everywhere with minimum levels of human habitation and access. We established the following general criteria in order to consider firewood a potentially important risk factor for forests: occurs at commercial scale and is oriented toward supply of larger urban centers.

Impacts from firewood logging vary by zone. In much of the northern coastal range and central valley, logging for firewood is responsible for removal of the last remaining larger-diameter trees from small properties. In much of the Lakes (X) Region, commercial firewood logging implies the gradual removal of higher-value species such as ulmo (*Eucryphia cordifolia*) from entire landscapes that have adequate road access. On the Island of Chiloé, the vast majority of all logging and associated activities, including the construction of penetration roads, is driven by demand for firewood. In general, firewood logging is a pressure that occurs in landscapes dominated by deciduous *Nothofagus* forest types already largely given over to agricultural uses, to old growth evergreen forest areas with adequate road access, and occurs in association with larger-scale industrial timber extraction.

Data analysis

Given these general characteristics of firewood logging, and in the absence of detailed information with which to construct more adequate models, risk from firewood extraction was mapped at for the Chilean portion of the ecoregion: as "high", "medium", or "low".

Only those forest types typically subject to firewood extraction were considered in the analysis as potentially of medium and high risk. All other forest types were assigned a low risk category. Those types included were as follows:

- Roble hualo
- Coihue, rauli, tepa
- Chaparal and wetlands
- Mixed sclerophyllous
- Valdivian siempreverde
- Roble, rauli, coihue
- Coihue de Magallanes

1) Road access

As with all types of logging, proximity to roads was considered a factor that increased risk. Since margins are extremely low in this subsector, it cannot generally support the costs of road construction beyond relatively short segments. Thus, this analysis established a maximum distance of 5 km from the nearest road as the distance where this type of logging is likely to occur.

2) Supply areas of consumption centers

Nearly all heating with firewood, but only large urban markets considered to be an economic force capable of driving extraction on a scale significant to ecoregional forest habitats. This analysis thus focused on areas that concentrate extraction for the main urban markets identified in the literature and through consultation with experts as the following: Talca, Concepción, Chillan, Los Angeles, Temuco, Valdivia, Osorno, Puerto Montt, Coihaique, Ancud, Castro.

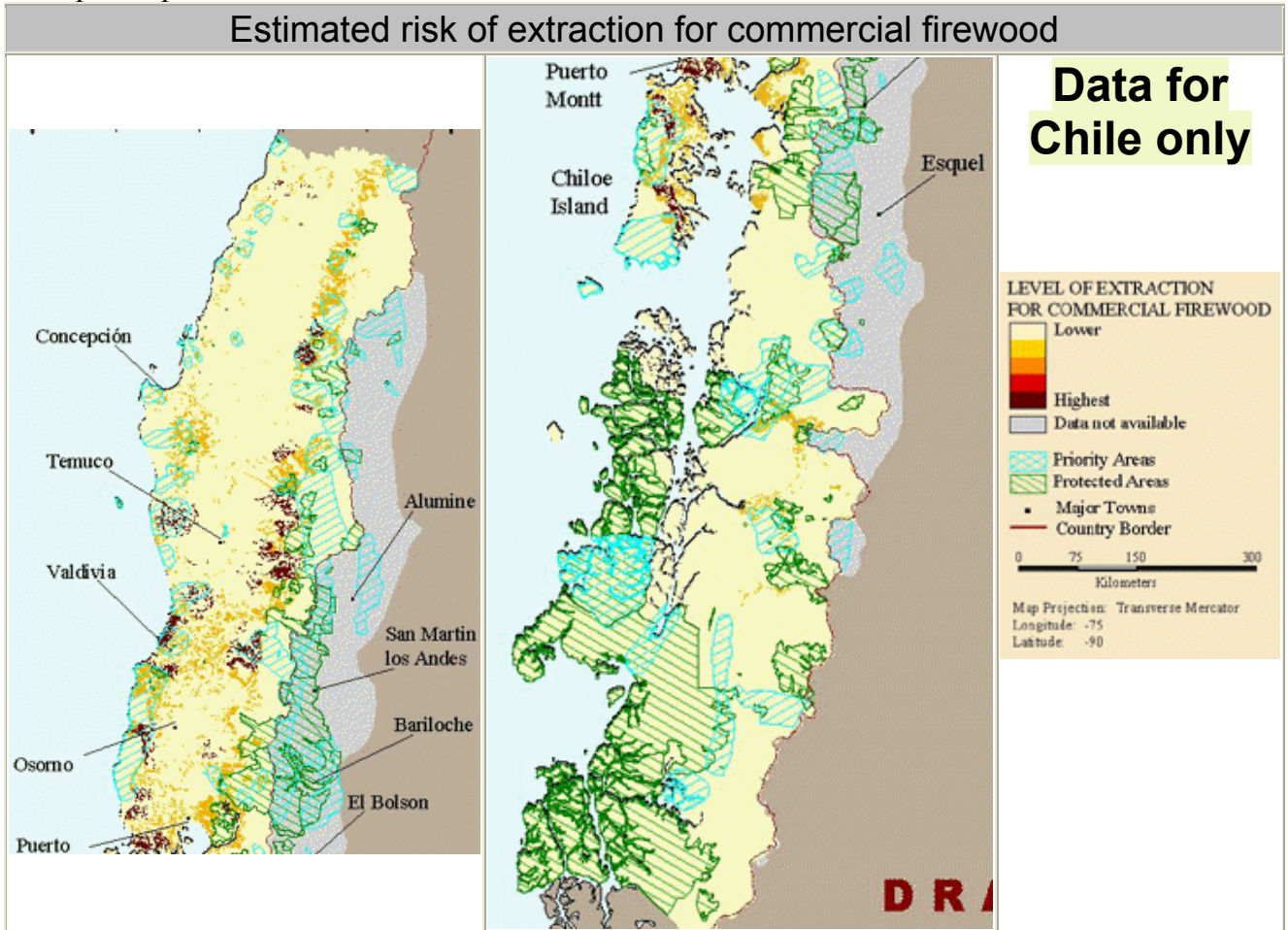
Based on surveys in the IX and X Regions, a maximum distance of 100 km was established as the radius from these urban centers within which firewood logging is normally occurs. These 11 cities were thus buffered at 100 km and the affected forest area (targeted forest type with road access) within that radius was assigned a "medium level of risk". Regions beyond 100 km from these population centers and beyond 5 km from major roads were considered of low risk for firewood extraction, as were islands south of Puerto Montt with extremely limited accessibility.

3) High risk areas identified

In addition, maps were generated of "high level risk" areas based on a mixed methodology of consultation of experts, literature review and rapid surveys of firewood distributors in urban centers, this information was then transposed onto 1:500,000 scale maps. These areas included, in particular, the area northwest of Talca; zones close to principal roads in the precordillera between Chillan and Los Angeles; the Carahue portion of the Nahuelbuta Range; the precordillera zones east of Temuco focusing on Curacautin, Melipeuco, Currarehue; the precordillera due East of Puerto Montt; all of the accessible areas of the Coastal Range in the X Region focusing on Estaquilla, San Juan de la Costa, Corral and Mariquina, and finally on the Island of Chiloe along a few penetration roads Southwest of Chonchi. Both medium- and high-level risk areas were

then converted into a grid for integration with the other threats. The firewood risk maps below presents the results of this analysis.

Example output



EXTRACTION FOR TIMBER

Overview

Adequate forest management, including silviculture, is necessarily part of an overall conservation strategy for the ecoregion. Unfortunately, most logging operations currently use very poor management practices and, in the vast majority of cases, contribute to the ecological degradation and destruction of native forests, particularly in Chile.

Despite the fact that "substantial" silviculture research that has been conducted in the *Nothofagus* forests and to a lesser extent in the other forest types, relatively little of the resulting information has been applied to forest management (see e.g., Donoso and Lara

1999; Veblen et al. 1996). CONAF has estimated that only 20% of all logging operations occur within authorized management plans (Emanuelli 1997), which in themselves do not necessarily offer ecological protections. Lara et al. (1995) found that only 5% of all operations applied adequate silvicultural techniques. In addition, there is widespread consensus that field enforcement of existing forest legislation is generally weak, and a recent study shows that effective sanctions have almost never been applied in response to forest law violations in the X Region (Ramirez et al. in press). The model developed in this analysis thus assumed a close association between the levels of logging projected for an area and the degree of forest loss and degradation.

Commercial timber extraction in the ecoregion is a marginal economic activity relative to the main sector of the industry focused on management of exotic plantations. In contrast to the export orientation of the exotic timber based industry, most native forest is logged to supply domestic demand by medium and small firms. The one major exception is the export of woodchips which has expanded rapidly since 1987 in order to supply the Japanese market. Among industrial users of native timber, the woodchip industry has been identified as the single most important cause of native forest loss both due to high volumes involved and to the intensity of site-level impacts. Whereas most extraction for timber and firewood is selective high-grade logging, much of that for woodchips uses clearcut methods. This is due to the greater capacity in this industry to process trees of varying types, diameters and grades. According to estimations by CODEFF in 1990, 88% of interventions into native forests in Chile for wood chips led to the destruction of these forests and their conversion to plantations (Arnold 1998). While other forms of logging have more extensive impacts in general, these have been particularly intense for high-value species such as rauli.

Data analysis

As with the threat of substitution, the threat of logging to priority areas was assessed by developing maps that quantified the likelihood of logging throughout the ecoregion. Again, the ecoregion was represented by a grid with values of 1 to 5 expressing decreasing likelihood that the grid cell would be logged. This grid includes all industries with large scale timber use, although the operation of these was assessed individually within the analysis. The principal factors used to classify risk were: suitability of a given vegetation type for commercial logging, location in relation to supply areas of major plants using native timber, the intensity of demand within the area as measured by the processing capacity of plants drawing supply from the zone, and road access. In sum, the model can be summarized as follows:

suitability of vegetation type + location within area of supply/impact x intensity of demand + road access = risk factor from logging

1) Relative suitability of forest types for commercial logging

Only those forest types commonly subject to commercial logging were included in this analysis. Although a few of these are rarely logged, this first minimum filter for the analysis was left as inclusive as possible so as not to underestimate threat levels. The vegetation types used included:

- Roble Hualo

- Coihue, Rauli, Tapa
- Lenga
- Mixed sclerophyllous
- Valdivian siempreverde (evergreen)
- Guaitecas Cypress
- Roble, Rauli, Coihue
- Coihue de Magallanes

All other vegetation types were excluded either because they do not contain commercially desirable species, as is the case of ñire forests, chaparral or mallines, alto-Andean and steppe vegetation, rocks and ice, agricultural and urban lands, or because they enjoy legal protection as is the case of alerce and araucaria. In the case of these two latter forest types, a certain amount of illegal logging does occur, and in particular, in the case of araucaria ambiguity as to the protection status of vegetation associated with the araucaria is opening the door to increased logging. However, these are not activities that fit well within this model which focuses on the larger commercial industry, and they were thus excluded. It is important to take into account that the vast majority of alerce forest in Chile remains highly endangered due to a variety of causes. In addition to the removal of these vegetation types, all lands within category 1, 2 and 3 protected areas were excluded based on the assumption that their officially protected status linked with a minimal level of implementation means that large-scale commercial logging is rarely a threat.

2) Timber plants mapped

All permanent sawmills (163) that use native timber, all medium and large woodchip mills (32), and all OSB and plywood mills (5), were mapped according to general locations, totaling 200 plants from the VII to the XI Regions. In addition there are approximately 500 small, mobile mills operating in the ecoregion (INFOR 1999). However, since these are highly mobile and impossible to map, they were not included in this analysis. In general, the mobile mills function to extend the resource frontier slightly beyond that mapped for large mills, but their areas of supply are thought to be generally coherent with those of the larger mills. Thus, while the inclusion of mobile mills would have extended the risk zones geographically, we do not think this would substantially alter the results of the analysis

The lists of plants operating in the ecoregion were obtained primarily from INFOR documents supplemented by other sources. While all plants were listed in the category of sawmills and plywood/OSB plants, this analysis limited inclusion of woodchip mills to those >10,000 m³ capacity. This level of capacity is generally considered a minimum for medium-sized operations, and was a necessary limit due to the large number of small woodchip operations that exist associated with sawmills or other types of plants. We decided that the impacts of these were covered through inclusion of the other mill types, and were not an essential factor to consider here.

3) Supply areas or areas of impact mapped

As with the substitution model, the areas of impact for each of these plants was determined through a rapid survey. For this purpose, information on the farthest distances

from which logs were transported was obtained for approximately 25% of all plants operating in the ecoregion. These responses spanned the full range of types of locations and plant sizes.

For sawmills, this survey determined an average supply distance of 70 km. for the Coastal Range and Andean Range and of 150 km. for those in the Central Valley. This difference is explained by the fact that central valley plants are located in zones which are largely deforested and thus depend on supply from the coastal or Andean areas that remain. In addition, the Central Valley sawmills tend to have the highest capacities and thus also the ability to support somewhat higher transport costs. The supply area of woodchip mills and plywood/OSB mills was very uniformly reported as 200 km. Thus, this distance was used as the average radius for this category. Using these average radii of 70, 150 and 200 km, all plants were assigned a buffer using ArcView GIS. The surface area within each buffer was considered the area of impact by plant.

4) Use of installed capacity as a measure of potential impact

In order to calculate the intensity of pressures within each radius, these were linked to the installed capacity of each plant mapped. As most radii overlapped, installed capacity for all overlapping radii was summed in order to determine a final value for installed capacity per grid cell within all zones serving as supply areas. In order to simplify ranking of areas, a range of four categories of installed capacity was established as follows:

- 98 – 11,752 m³/year
- 11,753-29,549 m³/year
- 29,550 – 45,843 m³/year
- 45,844 – 57,087 m³/year

Given that actual impacts are not spread uniformly throughout these radii, but rather tend to concentrate in areas relatively close to access routes, the final capacity score was summed with a ranking according to proximity to primary and secondary roads. Proximity was defined according to the following general categories from the highest to lower scores:

Primary roads:

- Up to 1 km from the road
- 1-5 km from the road
- 5. Over 5 km from the road

Secondary roads:

- Up to 1 km from the road
- 1-5 km from the road
- Over 5 km from the road

The combination of factors mentioned above resulted in six levels of risk, the results of which are shown in the maps below. Zones of highest risk were those within the radii of several large plants and less than 5 km. from roads. In general, the areas of highest risk are located north of 41° S Latitude particularly in the Coastal Range and Central Valley, though several Andean foothills areas are also under high risk. In both the conversion and logging models, the variables used change significantly over time, especially as timber

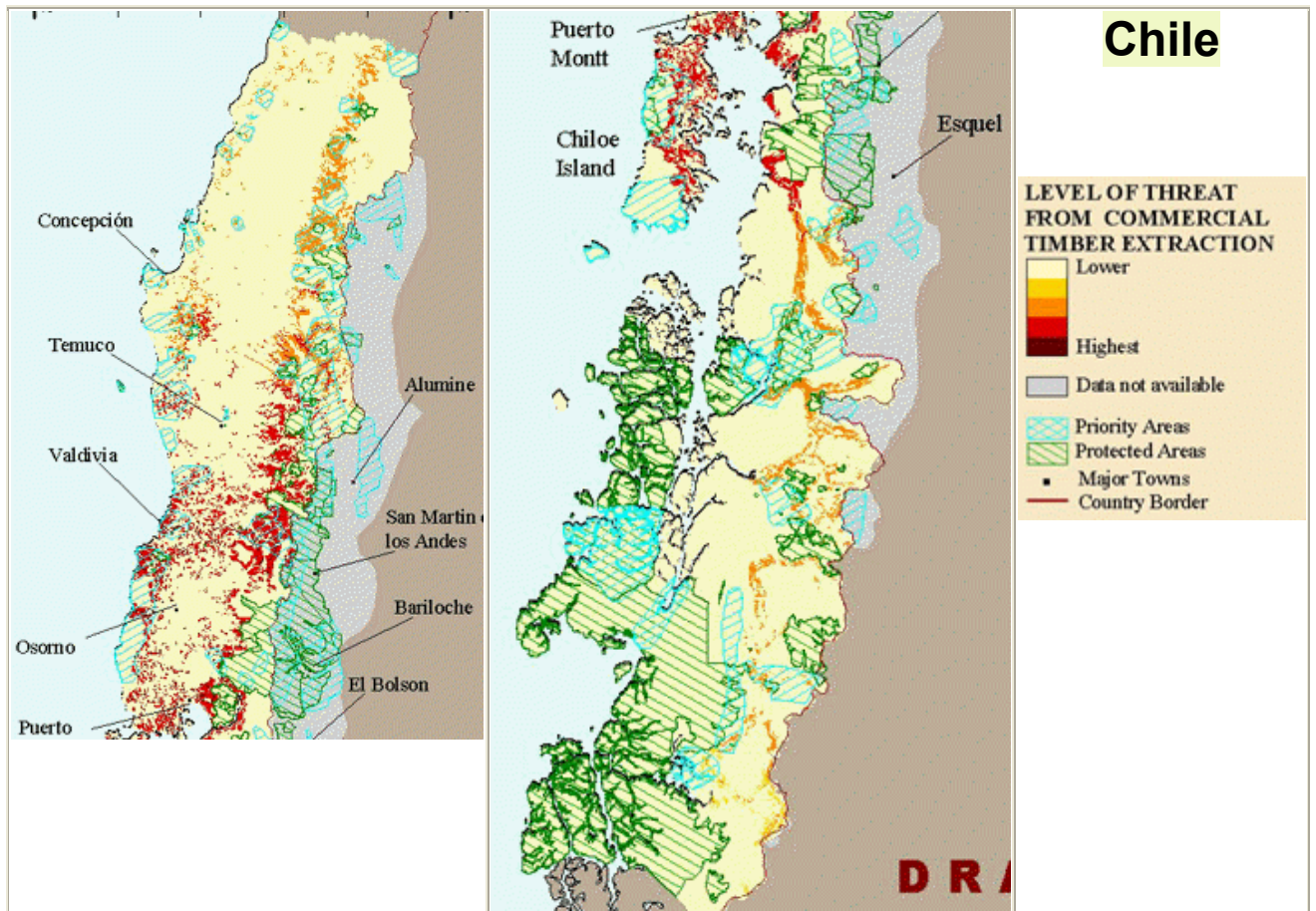
plants open and close. We tried to take this into account by including one future pulp mill (CELCO in the comuna of Mariquina) which is already driving plantation expansion in one area. In general, however, the overall spatial distribution of the industry is unlikely to undergo major shifts within the near term, and thus the general results presented here should maintain their validity even as individual situations change.

Logging risk in East-side forests

This model was only constructed for forests within the Chilean portion of the ecoregion due to data limitations for the Argentine side. While logging is not as severe of a threat on the Eastern side, it was considered one of the top 5 causes of forest loss. Additional research should be done to refine the model incorporating East-side forests.

Example output

Estimated risk of extraction for commercial timber, Chile *



ANTHROPOGENIC FIRE

Overview

Historically, forest fires have been one of the main causes of native forest loss in the Valdivian ecoregion. During the 18th century, numerous volcanic eruptions caused natural forest fires in the ecoregion. The East-side araucaria, mountain cypress forests and *Nothofagus* forests have historically been exposed to natural lightning fires. These natural fire dynamics are closely linked to spring and summer drought periods (Kitzberger et al. 1997). In addition to drought, the fire dynamics in xeric cypress forests is influenced by climatic variability over time scales of several years, caused by the Niño and Niña events, and the major fire events tend to follow the changeover from El Niño to La Niña conditions. (Kitzberger et al. 1997 and 2001; Kitzberger and Veblen). Long-term changes in fire occurrence along the rainforest to xeric woodland gradient in northern Patagonia have also been greatly influenced by human activities (Veblen and Lorenz 1988; Veblen et al. 1992; Kitzberger et al. 1997).

Changes in the intensity and frequency of fires since Spanish colonization have caused an important decline of Valdivian temperate forests (Laclau, 1997). Although indigenous populations burned forests and grasslands, anthropogenic fires- favored by environmental

conditions- have greatly increased since 1850. For example, more than 400.000 ha. were burned in 1853 during the colonization of the Lakes Region in Chile. In the "Boletín de Bosques, Caza y Pesca de 1912" (1912 Forest, Hunting and Fishing Bulletin), Albert indicates that 11.000.000 ha. of Chilean forests were burned (in: Haltenhoff, 1993) as a result of lands occupation and the expansion of the agricultural frontier. Forest fires continued in the 20th century, with a total of 5,000,000 ha. burned in the XI and XII Regions (Haltenhoff, 1993).

In Argentina, European settlement in forest areas resulted in a huge increase in the frequency of intense fires (Veblen and Lorenz, 1988). Vast areas of forest were deliberately burnt during the colonization war, as well as to increase the area for pasture and agriculture (Moreno, 1897; Willis, 1914). Rothkugel (1916) mapped 38% of the forests of the provinces of Neuquén and Río Negro as burned (Veblen and Lorenz, 1988). The phase of burning from around 1884-1915 explains the abundance of 70-100 year-old even-aged mixed *Austrocedrus* – *Nothofagus dombeyi* and pure *N. dombeyi* stands in southern Neuquén (Veblen and Lorenz 1987).

There have been major anthropogenic fires over the last several years, favored by strong seasonal droughts. For example, in the Argentinian portion of the ecoregion 1,295 fires were registered during the 1998-99 season, burning 220,000 ha. of native forests and associated ecosystems (Plan Nacional de Manejo del Fuego). Over 12,000 ha. of this was located within the national park system. Nahuel Huapi National Park was the most affected, with 7.000 ha. burned (Salguero, 1999). More than 99% of the fires in the provinces of Río Negro and Chubut were anthropogenic, while in Neuquén this figure reached 66%. Even large cities were threatened by arson fires started in their vicinity; this was the case of San Carlos de Bariloche, which registered 80% of the 706 fire focal points in the Río Negro province.

This problem was identified by local actors in a variety of workshops and national and binational ecoregional planning documents (Laclau, 1997 y 1998; Gascón, 1998; Vila et al. 1999) as an important threat to the Argentinean portion of the ecoregion, accentuated by the low resilience of communities most affected by fires, and the influence of associated erosion processes. In addition, the impact could be magnified by the effects of climate change, which, according to predictions by CRU and WWF (1999), will cause increased temperature and lower rainfall in this ecoregion.

Data analysis

Due to the lack of maps for conditions that affect fire risk and intensity, such as fuel loading, climate and topography, a simple model was developed based on proximity to roads and towns, elevation and vegetation type as important factors in determining the probability of risk for a given zone. In particular, areas around cities and roads (primary and secondary) were considered to be of high risk (value 1), while zones outside of these areas were classified as low risk (value 0). Using ArcView (ESRI 1998) procedures buffers of 1 km were used on both sides of roads and 2 km around the cities.

We also distinguished three elevation levels to evaluate the fire threat of different communities: <800 m, 800-1,200 m, and >1,200 m. Vegetation types in lower elevations were considered to be more likely to experience anthropogenic fires because human activities are concentrated within these areas. Natural habitats classified as particularly susceptible to burning were: araucaria, mountain cypress, ñire, and Patagonian steppe. Lenga and coihue-rauli-roble pellin types received medium threat scores (Table 13). Human-modified landscapes, including urban areas, agricultural zones, plantations, and pastures were all considered highly likely to be impacted by anthropogenic fire at all elevations.

Natural vegetation types categorized by level of threat from human fires depending on elevation.

Without Threat (0)	Low Threat (1) all elevations	Threat decreases with elevation (Medium to Low)	Threat decreases With elevation (High to Med/Low)	High Threat (3) all elevations
Wetlands	Alerce	Coihue, Raulí, Roble Pellín	Araucaria	Ñire
High Andean vegetation	Valdivian evergreen (Siempreverde)	Lenga	Mountain Cypress	
			Patagonian steppe	

These two grids, vegetation type classified by elevation and buffers for cities and roads, were then combined using a matrix. Highest values (4) resulted from the combination of high threat value (3) occurring near to city or road (value 1). For example, a Ñire type polygon crossed by road.

Finally, according to the specialists consulted, the threat of anthropogenic fires is greatest in the drier portions of the ecoregion. Thus, the Xeric Cypress Forest Subregion, because of its dominant vegetation and climate, was considered more vulnerable to fire than other sub-ecoregions. For this reason, if a high risk vegetation polygon (Mountain Cypress, Ñire, Patagonian steppe) or human-derived landscapes includes cities or roads in Xeric Cypress Forest Subregion, it received the highest risk value (4).

The specialists that reviewed the results obtained with this simple model considered that forest type resilience to fire should be incorporated to the model in the future. They also suggested incorporating a higher probability natural ignition factor because of lightning in the Northern and Eastern portions of Araucaria and Mountain Cypress forests.

Results

The zones with the greatest potential for being threatened by human-caused fire are indicated in the maps below. These are the areas nearest to human infrastructure within the least fire-resistant environments, such as the Patagonian steppe, Mountain Cypress and ñire in Xeric Cypress Forest Subecoregion independently of the protection status.

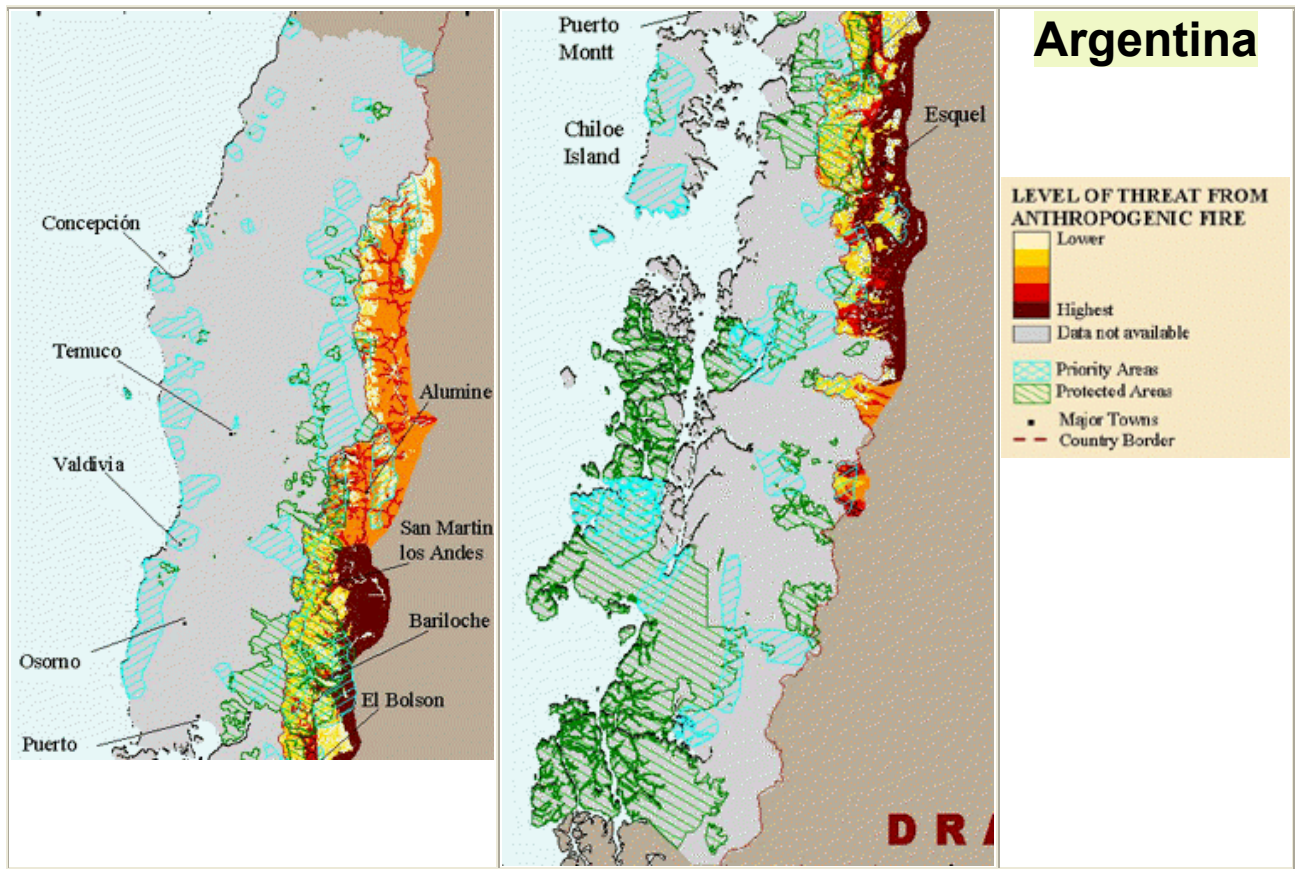
The vegetation types located in more humid areas, as well as the araucaria forests, present a high degree of threat when associated with roads or cities. Particularly, ñire forests within protected areas present average threat values even in the absence of infrastructure. In general, more humid forests (alerce, siempreverde, roble, raulí-cohiue, and lenga) present a low degree of threat, while rocky areas and Andean highland vegetation is not under threat.

It is important to point out that this model does not include factors linked to fire spread, such as winds, fuel continuity and topography. Thus, the model's results show high risk lines that accompany roads. A more realistic model, including the spread variable, would expand the high risk area beyond those sectors strictly linked to road buffers.

The fire threat in West-side (Chilean) forests

The full fire model developed for Argentina was not applied for the West-side of the Ecoregion (Chile) due to a lack of adequate information and resource limitations. Experts consulted in Chile ranked fire as a locally critical threat, and on average as one of the most important threats after forest conversion and timber and firewood extraction. West-side forests do not, with the exception of volcanism, have sources of natural ignition, and thus natural fire regimes are considered to have involved extremely long fire-free periods. Most species and habitat types are not, therefore, fire adapted and are thus have difficulty recovering after fire events. This increases the level of concern regarding fire threats in this portion of the ecoregion. In order to include the most obvious fire risk on the West-side, areas of forest types known to be targeted by intense anthropogenic fire were simply classified as highest risk (Value 4) within the overall model. This included Alerce and Guaitecas Cypress types. This classification was assigned independent of access variables, since widespread and high-intensity fires have been observed to be relatively universal for these forest types. In the future, an adequate fire model should be developed for the west-side forests as well.

Estimated risk of threat from anthropogenic fire, Argentina



OVERGRAZING

Overview

The Valdivian Ecoregion contains a variety of floristic communities with numerous plant species which are palatable to livestock (Boelcke, 1957 in: Dimitri, 1972). More than 20 of these are woody and include all large species present. According to Laclau (1997) abundant browsing by cattle, goats and sheep has been verified for the following species: Maitén (*Maytenus boaria*); Coihue (*Nothofagus dombeyi*); Ñire (*Nothofagus antarctica*); lenga (*Nothofagus pumilio*); roble Pellín (*Nothofagus obliqua*); Raulí (*Nothofagus alpina*); Radal (*Lomatia hirsuta*); Laura (*Schinus patagonicus*); Chinchín (*Azara microphylla*); Retamo (*Diostea juncea*), Caña colihue (*Chusquea culeou*); *Salix* spp; *Berberis* spp; Chacay (*Chacaya trinervis*); Maqui (*Aristotelia maqui*), etc. Moreover, there is grazing on exotic species, such as rosehip (*Rosa eglanteria*), favoring its dispersion within the native formations matrix.

Livestock activities have developed in the region for more than 150 years, since the spread of European livestock among the indigenous Mapuche. European and "criollo" colonization, towards the end of the 19th century stabilized farming activities on large properties and managed areas. The use of forests as grazing areas has developed as a function of site-specific fodder availability and climatic conditions. In a concise

synthesis, it can be said that humans carry out livestock raising activities in the following forest systems of the Argentinian portion of the Ecoregion (Laclau, 1997):

- a. Subhumid steppe (500 to 700 m.): sheep and goat raising on open shrublands (*Festuca pallescens*, *Stipa speciosa* and other pulses) alternating with grazing on humid prairies with open Chacay (*Chacaya trinervis*); Maitén (*Maytenus boaria*); Ñire (*Nothofagus antarctica*); lenga (*Nothofagus pumilio*) and *Salix* spp forests. A summer-winter rotation is practiced in these areas, with animals remaining in the steppe during 7-9 months in the cold season, and returning to mountain highlands during the summer.
- b. Forest-Steppe ecotone (700-1200 m.): sheep and goat raising with permanent grazing on open Ciprés (*Austrocedrus chilensis*) formations, sometimes accompanied by Radal (*Lomatia hirsuta*); Pehuén (*Araucaria araucana*) with lenga or Ñire, and alternating with grazing on wetlands (mallines) and prairies containing the steppe species mentioned above. In the Southern part of Neuquén province, cattle is raised in forests made up of roble Pellín, Coihue and Raulí with Caña Colihue (*Chusquea* sp). Grazing is practiced year-round in these areas, although the use of wetlands is higher in the summer, offering a partial relief to forested areas.
- c. Temperate Wet Forest (700 to 1500 m.): cattle and sheep raising, on a winter-summer rotation or continued grazing at lower elevations, where *Nothofagus* spp forests exist, sometimes associated to Ciprés and abundant bamboo as undergrowth, and araucaria forests. In some places, grazing is possible in high elevation humid prairies and shrublands of Ñire (*Nothofagus antarctica*), *Berberis* spp and others, during 3-5 months (summer season).

The negative ecological impacts of livestock on forests are directly related to the inadequate or nonexistent management of grazing, which fails to consider the forest's dissemination and regeneration cycles. These grazing systems show recent deterioration due to the following socioeconomic and environmental causes (Laclau 1997):

- Overload of wintering areas by permanent grazing or by scarce surface area per producer, combined with underuse of less accessible (seasonally or spatially) areas. This is less frequent in the case of medium to large producers.
- Deterioration of second-growth forest due to excessive browsing. Sheep have been the main cause of Ciprés forest regression in forest-steppe contact areas during the first half of the 20th century (Veblen y Lorenz 1988; Veblen et al. 1992; Villalba and Veblen 1996).
- Rural to urban emigration and decreasing prices stimulated a decrease in livestock goods, especially among small producers. As a consequence, there is a loss of the traditional move to higher elevation areas during the summer season which is necessary for allowing recovery.
- The unleashing of erosion processes, with landslides, erosion gulleys, and burning of fields and forests, favored in one way or another by overgrazing, have made the

environment more fragile and affected the resilience of the forest ecosystems under use.

In addition, it is important to point out that grazing is also practiced within protected areas. When National Parks were created within the ecoregion, valleys and lower elevations were in general occupied by indigenous and "criollo" populations, who were granted precarious occupation and grazing permits. Livestock was the main productive activity, complementing dietary needs with horticultural, fruit and cereal crops.

According to Laclau (1997) these uses have given rise to conflicts between the park administrations and the settlers, because of divergent interests. For example, Lanín National Park estimated a population of approximately 1,000 inhabitants in 1997, grouped into 230 families, many of which lived in indigenous communities (Osídala, personal communication). Approximately 15-20% of the surface of this park is under farming and livestock uses (Martín and Dedek 1985; Laclau 1992^a; 1992b). The valleys and foothills with continuous or semi-permanent grazing during the winter months show signs of overgrazing and erosion focal points, with livestock loads that often exceed the annual fodder offer by 100% or even 300% (Siffredi 1991; Laclau 1993).

Data analyses

Most of data available for mapping the potential impact from grazing for this study comes from Argentina. However due to the lack of maps for foraging resources availability and stoking rate, we develop a simple model to evaluate the grazing threats. The potential for grazing of the different land covers was ranked from 0 (no threat) to 3 (high threat) depending on vegetation types located in different elevation levels. We defined three elevation levels: <800m., 800-1,200m., and >1,200m. Lower elevations were considered to be more likely to suffer grazing. Certain vegetation types, such as araucaria and mountain cypress, were considered particularly susceptible to grazing at all elevations, while others experience a medium level of threat that increases with elevation. A third group, including alerce and siempreverde forests, was considered less vulnerable to grazing (Table 14). Human-altered areas, such as urban areas, agricultural zones and plantations weren't included in the analysis, while pastures were considered highly likely to be impacted by grazing at all elevations.

Natural vegetation types are categorized by level of threat from livestock grazing and dependant on elevation.

Low-Medium Threat at all elevations	Threat increases with elevation (Medium-to-High)	High-Medium Threat all elevations
Alerce	Coihue, Raulí, Roble Pellín	Araucaria
Siempreverde		Ciprés de la Cordillera
Lenga		Ñire

Altoandino		Patagonian Steppe
		Mallines y humedales

Using a matrix, the threat values of vegetation types by elevation were combined with existing protected areas. The protected areas were classified in two levels: strict protected (National Parks with threat value 0) and reserves that allow limited human uses (threat value 1). Protected areas reduce, but do not eliminate, the threat from grazing on all vegetation types. The protected areas poorly implemented, such as provincial parks, and areas outside of protected areas were classified as highest threat areas (2). The highest score was assigned to the most threatened vegetation types (for example, Ciprés de la Cordillera and Ñire) without protected status.

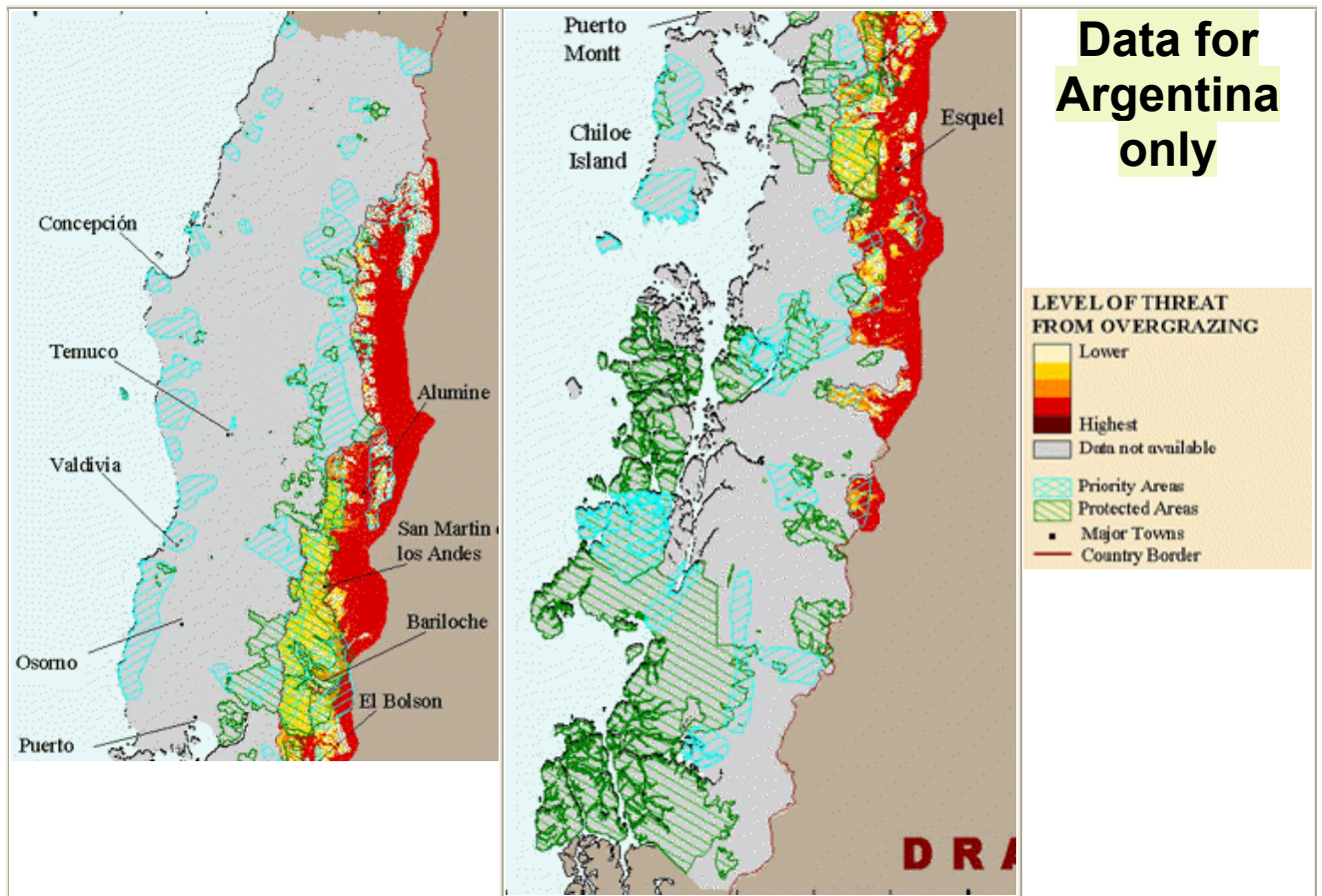
According to the specialists consulted, the results obtained with this simple model should be improved in the future, incorporating forest type resilience to grazing, and livestock load information.

Results

The threat levels from grazing are shown in the maps below, which currently include only territory in Argentina. Future versions of this document should indicate the threat from grazing of the entire ecoregion. The subregions most affected by grazing are Andean Deciduous Maulino, Andean Araucaria, and Xeric Cypress Forest sub-ecoregions despite their protection status. Nothofagus Forest with alerce and Southern Nothofagus with steppe sub-ecoregions were also highly affected out of the protected areas. The most affected vegetation types are steppe and wetlands (mallines), and all types of forested areas in low valleys or higher elevation forests outside protected areas which are used during the summer season. The eastern-most populations and high genetic value forests that border the steppe are highly threatened because of their location in areas used during both summer and winter seasons.

If the model included resilience of different plant communities when faced with this type of impact, forests of the xeric regions, mainly ciprés and araucaria, would present a higher yet degree of threat. A similar increase would occur for pastures and lenga forests at high elevations. It is clear that protected areas buffer livestock impact, but if the resilience factor was incorporated, the degree of threat to lower valleys found in these areas would also increase.

Estimated risk of overgrazing



References¹

Armesto, J.J., C. Villagrán, and C. Donoso. 1994. La historia del bosque templado chileno. *Ambiente y Desarrollo*. Vol 10. March. Arnold, 1998

Laclau, P. 1997. Los ecosistemas forestales y el hombre en el sur de Chile y Argentina. *Fundación Vida Silvestre Argentina. Boletín Técnico No. 34.*

Laclau, P. 1998. Reunión de Planificación para la Conservación de la Selva Valdiviana de Argentina y Chile: "Actividades económicas y amenazas sobre los bosques de Ecoregión Valdiviana. San Carlos de Bariloche 5-7 de mayo de 1998. FVSA, INTA y WWF: 18 pp.

Veblen, T.T., B.R. Burns, T. Kitzberger, A. Lara, and R. Villalba. 1995. The Ecology of the Conifers of Southern South America. In Enright, N.J. and R.S. Hill (eds.). *Ecology of the Southern Conifers*. Smithsonian Institution Press, Washington, DC.

¹ References from source publication were limited. See WWF 2002 for details.

Veblen, T.T., T. Kitzberger, B. R. Burns, and A.J. Rebertus. 1995. Perturbaciones y dinámica de regeneración en bosques andinos del sur de Chile y Argentina. In Armesto, J.J., C. Villagrán, M.K. Arroyo (eds.). *Ecología de los Bosques Nativos de Chile*. Chile.

Veblen, T.T., C. Donoso, T. Kitzberger, and A.J. Rebertus. 1996. Ecology of Southern Chilean and Argentinean Nothofagus Forests. In _____.

Veblen, T.T. and F.M. Schlegel. 1982. Ecological review of the southern forests of Chile. *Bosque (Valdivia)*. 4:73-116.

Veblen, T.T., F.M. Schlegel, and J.V. Oltremari. 1983. Temperate broad-leaved evergreen forests of South America. In Ovington, J.D. (ed), *Temperate broadleaved evergreen forests. Ecosystems of the World*. Vol. 10. Elsevier, Amsterdam, Cited in Arroyo, M.T.K. and A.E. Hoffmann-J. 1997. Temperate Rain Forest of Chile. In Davis, S.D, V.H. Heywood, O. Herrera-MacBryde, J. Villa-Lobos, and A.C. Hamilton. *Centres of Plant Diversity. Volume 3: The Americas*.

Veblen, T. T. and D. C. Lorenz. 1988. Recent vegetation changes along the forest/steppe ecotone of Northern Patagonia. *Annals of the Association of American Geographers*. 78 (1): 93-111.

WWF (2002) *Ecoregion Conservation: Securing Living Landscapes through science-based planning and action. A users guide for Ecoregion Conservation through examples from the field*. Washington, DC.