A VEGETATION MAP OF NEVADOS DE CHILLAN VOLCANIC COMPLEX, BIO-BIO REGION, CHILE

CARTOGRAFIA DE VEGETACION DEL COMPLEJO VOLCANICO NEVADOS DE CHILLAN, REGION DEL BIO-BIO, CHILE

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ABSTRACT

A vegetation survey of the Andean Nevados de Chillán volcanic complex, Bío-Bío Region, Chile, resulted in the preparation of a colour vegetation map, based on photo-interpretation of an aerial photograph of 1998. Classification followed a divisive method and combined physiognomic, floristic, and pedologic criteria. It resulted in eleven distinguishable vegetation units: (1) *Nothofagus dombeyi* forest, (2) *N. pumilio* forest, (3) *Nothofagus* mixed forest, (4) *N. pumilio* krummholz, (5) *N. antarctica* krummholz, assemblages of (6) *Adesmia emarginata-Pozoa coriacea*, (7) *Adesmia emarginata-Berberis empetrifolia*, (8) *Adesmia emarginata-Loasa lateritia*, (9) *Chusquea culeou*-Coirones, and (10) *Caltha sagittata-Mimulus luteus*, and the (11) *Nassauvia revoluta-Poa obvallata* assemblage which builds the upper vegetational belt. The study area´s vegetation, located in the Mediterranean-temperate transition zone, shows a higher floristic affinity to temperate regions´ vegetation.

KEYWORDS: Southern Andes, vegetation cartography, photo-interpretation, Termas de Chillán.

RESUMEN

El objetivo del trabajo fue la preparación de un mapa de vegetación del complejo volcánico andino Nevados de Chillán, Provincia del Ñuble, Región del Bío-Bío, Chile. La clasificación de la vegetación, que se basa principalmente en la fotointerpretación de una imagen aérea de 1998, sigue criterios fisonómicos, florísticos y pedológicos. Las once unidades vegetacionales son: bosque de (1) *Nothofagus dombeyi* y de (2) *N. pumilio*, (3) bosque mixto de *Nothofagus*, matorral achaparrado de (4) *N. pumilio* y de (5) *N. antarctica*, los matorrales bajos andinos de (6) *Adesmia emarginata-Pozoa coriacea*, (7) *Adesmia emarginata-Berberis empetrifolia*, (8) *Adesmia emarginata-Loasa lateritia* y (9) *Chusquea culeou*-Coirones, la unidad (10) *Caltha sagittata-Mimulus luteus* de tipo vega y la unidad (11) *Nassauvia revoluta-Poa obvallata* que forma el piso vegetacional superior. La vegetación del área de estudio, situado en la transición biogeográfica mediterránea-templada muestra mayores afinidades florísticas a la zona templada.

PALABRAS CLAVE: Andes del sur, cartografía de vegetación, fotointerpretación, Termas de Chillán.

INTRODUCTION

The southern Andean volcanic complex Nevados de Chillán is situated at 36°50´S, 71°25´W, reaching a maximum elevation of 3212 m a.s.l. (Fig. 1). It is located in the transition zone between central Chile´s Mediterranean vegetation, constituted mainly of sclerophyllous elements, and the temperate evergreen forests of southern Chile (Grau 1995; Arroyo *et al.* 2004). The combination of biogeographic situation and geomorphologic complexity leads to an exceptional degree of botanical biodiversity. Nevados de Chillán harbours 616 species of 104 families (Rodríguez *et al.* 2008).

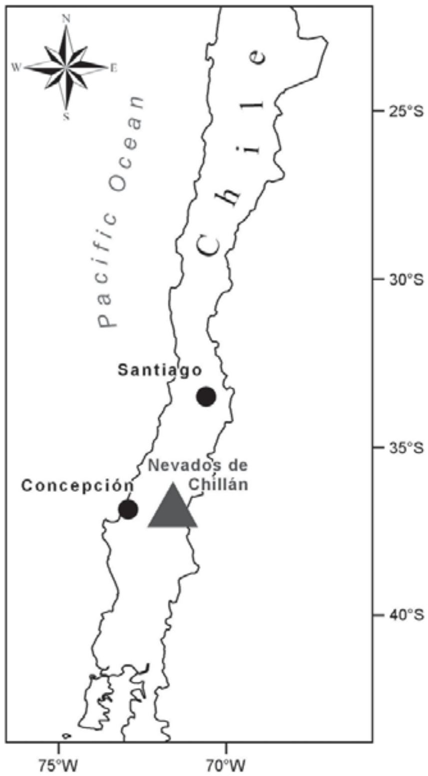

FIGURE 1. Location of Nevados de Chillán volcanic complex.

FIGURA 1. Ubicación geográfica del complejo volcánico Nevados de Chillán.

In this paper we aim to provide a large-scale color map of the spatial distribution of the vegetation of Nevados de Chillán's southern sector based on the photo-interpretation of an aerial color photograph. Due to the high rate of economic development in this area, parts of its native vegetation are critically endangered. We hope that our map will aid conservation efforts and contribute to the discussion about the spatial distribution of vegetation patterns in the Mediterranean-temperate transition zone.

The study area of 87 km^2 comprises the south-western flanks of Nevados de Chillán, the surroundings of the thermal and touristic facilities of Termas de Chillán, Nieblas Valley, Aguas Calientes Valley, Shangri-La Valley, Cerro Purgatorio plateau, Los Coltrahues and the upper basin of the Renegado River. The vegetation limit is at 2700 m a.s.l. and the tree-line at 2100 m a.s.l.

Situated at the border between temperate and Mediterranean macrobioclimates at a latitude of 37°S (Luebert & Pliscoff 2006), the climate of Nevados de Chillán is cool-temperate, with dry summers and cold winters. Decker & Boerner (2003) gives an estimation of mean annual temperature of 4-6°C for the elevational range of 1200–1800 m. More than 75% of mean annual precipitation falls between April and September (Donoso 1993). Figure 2 shows temperature and precipitation data of Diguillín (Fig. 2A) and Laguna de La Laja (Fig. 2B) climate stations, which are situated 15 km and 70 km, respectively, to the south of Termas de Chillán (Luebert & Pliscoff 2006).

The volcanic activity of Nevados de Chillán complex dates back to at least 640 000 years ago. Two eruptive centers formed 40 000 years ago, building the summit structures Nevado and the twin volcanic cone Volcán Chillán, respectively (Dixon *et al.* 1999). González-Ferrán (1995) gives a detailed description of historic eruptions. The volcanic activity resulted in a manifold topography characterized by a complex relief and geology. The diversity of geologic substrates is mirrored by the high number of different vegetation units found. The soils of the study area developed from volcanic products and belong to the order inceptisols, suborder andept (Freiberg 1984). Information about soils under *Nothofagus pumilio* forests can be obtained from Hildebrand-Vogel *et al.* (1990) and Decker & Boerner (2003).

Philippi (1862, 1892) and Reiche (1895, 1907) gave early reports of the area's vegetation. Roivainen (1933) and Jaffuel (1938) published commented lists of collected plant specimens. Recent work includes the investigation of ecophysiological aspects of the study area's *Nothofagus* forests (Decker & Boerner 2003; Fajardo & De Graaf 2004). A commented checklist of the vascular flora of Nevados is published by Rodríguez *et al.* (2008) in the same issue of this journal.

MATERIAL AND METHODS

From August 2005 to April 2006 eight field trips to Nevados de Chillán were carried out. Data of 506 waypoint sites include geographic location, elevation, aspect, vegetation physiognomy, and observations on soil condition and disturbance. Floristic information of waypoint site vegetation was obtained by recording plant species composition. The vegetation units were classified by a divisive method (Goldsmith & Harrison 1976), employing a synthesis of physiognomy (life form, structure and

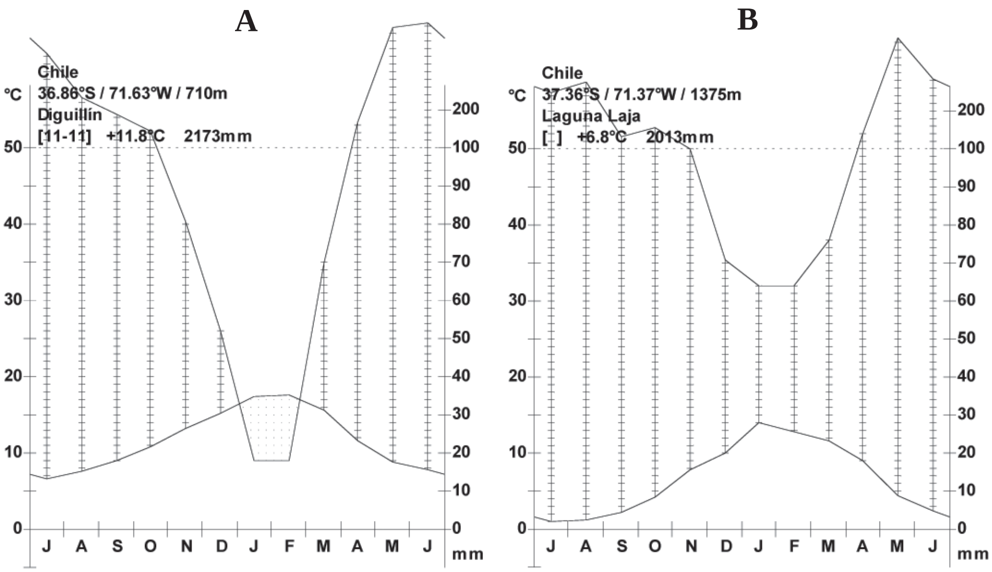

FIGURE 2. Climate data from Diguillín (A) and Laguna de La Laja (B) weather stations, from Luebert & Pliscoff (2006).

FIGURA 2. Datos climáticos de las estaciones meteorológicas de Diguillín (A) y Laguna de La Laja (B), de Luebert & Pliscoff (2006).

spacing) and floristics as divising characters to subdivide major physiognomic classes into successively smaller unites (Küchler & Zonneveld 1988, Fosberg 1967). Soil features like colour and site drainage were also taken into account.

The physiognomy, i.e. the physical appearance, of vegetation is a combination of structural and functional characters (Fosberg 1967). Whereas structure describes the spatial arrangement of the individual plants that build the vegetation, function refers to characters that fulfill purposes of maintaining life functions in a certain environment (Barbour *et al.* 1987). Functional characters are, for example, related to fire resistance or drought tolerance.

Classification and mapping of vegetation by applying purely physiognomic characteristics can be performed without much effort using air-photos (Goldsmith & Harrison 1976), but does not always satisfy the need for more detailed studies as it is suitable mainly for large areas and floristic information is lost. This generates a problem particularly in the vegetation analysis of andine enviroments (Cavieres *et al.* 2000).

Combining physiognomic, floristic, and, subordinately, pedologic criteria to classify vegetation allows a compromise between a reasonable number of distinguishable vegetation units and a useful map scale. Our map is based on photo-interpretation of an aerial colour orthophotograph of 1998, with a 4 m resolution, which was provided by Centro EULA, University of Concepción. Comparison with satellite images of December 2002 and May 2003 did not show any recognizable change of vegetation cover.

Interpretation of the photographic material, supported by the field data, led to the identification of the major physiognomic classes on the base of vegetation architecture and life form. These major classes correspond to closed woodland of phanerophytes (growth height > 2 m) and lower vegetation of the Andean belt consisting of nanophanerophytic (growth height < 2 m), chamaephytic, hemicryptophytic, cryptophytic, and therophytic plants (see Raunkiaer 1934 for life-form descriptions). We then proceeded by dividing these major categories into smaller structural subunits. Thus, closed woodland was separated into the subunits forest and krummholz; Andean belt vegetation into the subunits scrub/dwarf scrub of open spacing between individual plants and closed wet meadows. In a third step we employed floristic, and, with regards to the three floristically similar *Adesmia emarginata*-dominated assemblages, also pedologic criteria in the form of soil colour, field texture, and stone quantity to define the resulting eleven vegetation units.

The amount of the area that is directly or indirectly concerned by human activities was quantified on the base of photo-interpretation and the use of photographs and field notes made during the field trips. The geographical information system software ArcView GIS 3.2 and ArcMap 9.0 were used for data processing and management as well as for map drawing. The collected plant specimens were deposited in the herbarium of the University of Concepción, Chile (CONC).

RESULTS

Photo-interpretation resulted in thirteen cartographic units (Table I, Fig. 3). Eleven of them are proper vegetation units, i.e. with vascular plant cover. They can be divided into two physiognomically different major classes: closed woodland and Andean vegetation above tree-line.

Woodland assemblages comprise (1) *Nothofagus dombeyi* forest, (2) *Nothofagus pumilio* forest, (3) *Nothofagus* mixed forest, (4) *Nothofagus pumilio* krummholz, and (5) *Nothofagus antarctica* krummholz.

The three floristically related *Adesmia emarginata*-dominated assemblages of (6) *Adesmia emarginata-Pozoa coriacea*, (7) *Adesmia emarginata-Berberis empetrifolia*, and (8) *Adesmia emarginata-Loasa lateritia*, as well as the vegetation units of (9) *Chusquea culeou*-Coirones, (10) *Caltha sagittata-Mimulus luteus*, and (11) *Nassauvia revoluta-Poa obvallata* build the Andean vegetation.

The vegetation map also includes the cartographic units (12) Cortina Lava, and (13) rocks and ice. These bear none to very little vascular plant cover.

The vegetation units are now described in detail. Nomenclature follows Marticorena & Quezada (1985). Representative photographs of each vegetation unit are included in Pfanzelt (2007).

TABLE I. Cartographic units of Nevados de Chillán volcanic complex and their spatial distribution.

TABLA I. Unidades cartográficas del complejo volcánico Nevados de Chillán y su distribución espacial.

CARTOGRAPHIC UNIT	AREA IN HA	AREA IN %	ELEVATION IN M A.S.L.
Nothofagus dombeyi forest	360	4.2	1200-1900
Nothofagus pumilio forest	1370	15.8	1420-1860
Nothofagus mixed forest	1020	11.8	1200-1820
Nothofagus pumilio krummholz	720	8.3	1520-2050
Nothofagus antarctica krummholz	250	2.9	1200-2100
Adesmia-Pozoa assemblage	220	2.5	1530-2110
Adesmia-Berberis assemblage	750	8.7	1860-2230
Adesmia-Loasa assemblage	290	3.3	1760-2310
Chusquea-Coirones assemblage	550	6.3	1330-2020
Caltha-Mimulus assemblage	70	0.8	1640-2400
Nassauvia-Poa assemblage	1570	18.1	2120-2700
Cortina Lava	700	8.1	-
Rocks, ice, and eroded areas	800	9.2	-
Total	8670	100.0	1200-2700

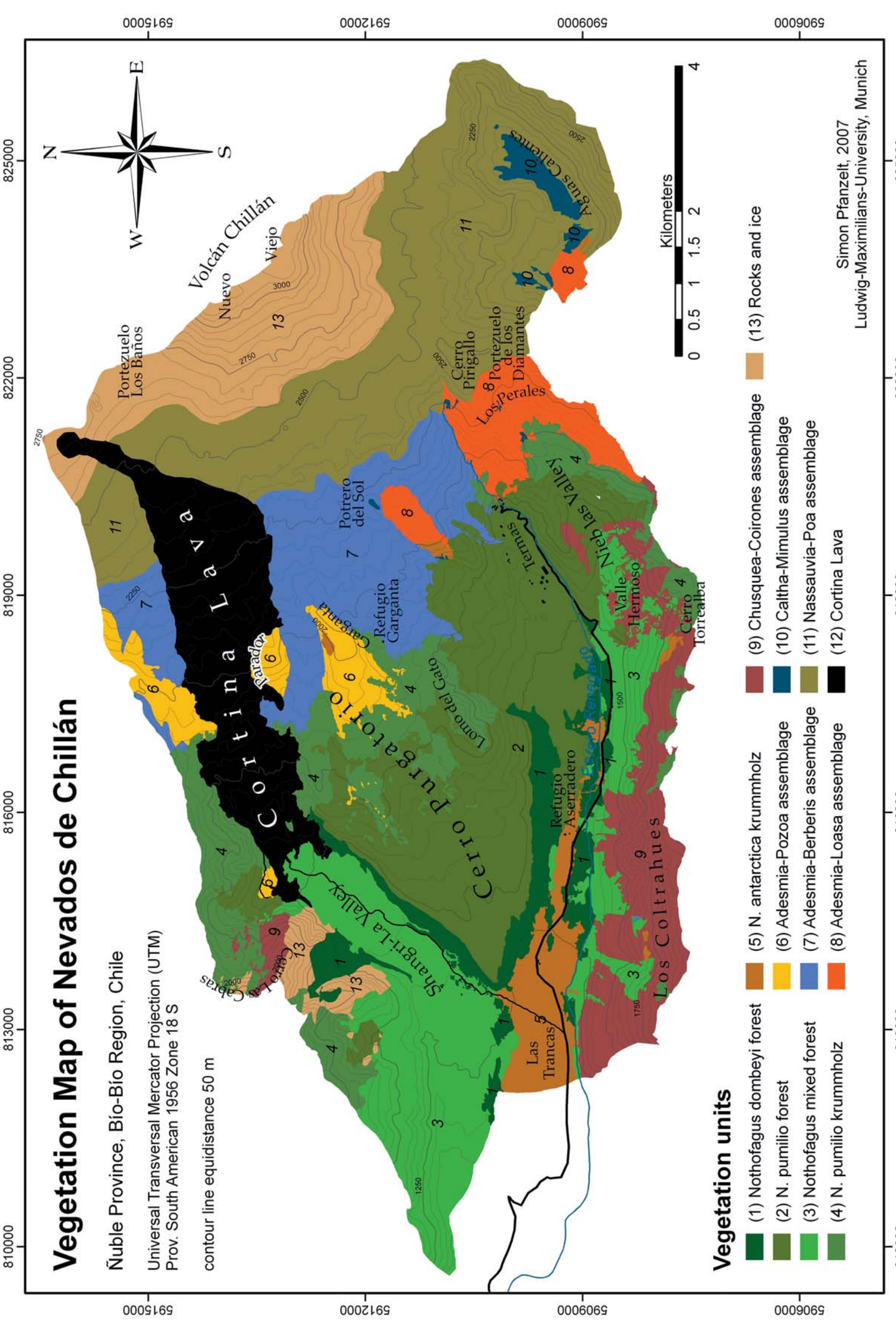

FIGURE 3. Vegetation map of Nevados de Chillán.

FIGURA 3. Mapa de vegetación de los Nevados de Chillán.

WOODLAND ASSEMBLAGES

(1) ***Nothofagus dombeyi*** **forest**

Elevation: 1200-1900 m a.s.l.; all aspects.

Description: Preferring humid localities along the riverbeds of Shangri-La Valley and the lower Renegado River, evergreen *N. dombeyi* (Mirb.) Oerst. builds old-growth forests. Truncs and branches of the tree species are covered by *Usnea* lichens. A dense understory is composed of bamboo *Chusquea culeou* E.Desv. and *Gaultheria* sp. The herbaceous layer is dominated by *Osmorhiza berteroi* DC., *Alstroemeria aurea* Graham and *Loasa acanthifolia* Desr.

Species composition: *Acaena ovalifolia* Ruiz et Pav., *Adenocaulon chilense* Less., *Alstroemeria aurea*, *A. presliana* Herb., *Azara serrata* Ruiz et Pav., *Calorezia nutans* (Less.) Panero, *Chusquea culeou*, *Dioscorea brachybotrya* Poepp., *Fuchsia magellanica* Lam., *Gaultheria phillyreifolia* (Pers.) Sleumer, *G. pumila* (L.f.) D.J.Middleton, *Hydrangea serratifolia* (Hook. et Arn.) F.Phil., *Loasa acanthifolia*, *Maytenus disticha* (Hook.f.) Urb., *Myoschilos oblonga* Ruiz et Pav., *Nothofagus dombeyi*, *N. pumilio* (Poepp. et Endl.) Krasser, *N. obliqua* (Mirb.) Oerst., *Osmorhiza berteroi*, *Ribes magellanicum* Poir., *Senecio pilquensis* H.Buek, *Tristerix verticillatus* (Ruiz et Pav.) Barlow et Wiens, *Valeriana polemoniifolia* Phil.

(2) ***Nothofagus pumilio*** **forest**

Elevation: 1420-1860 m a.s.l.; all aspects.

Description: Deciduous forest of *Nothofagus pumilio* prevails at higher altitudes and at drier sites. Its vertical stratification is less diverse than that of its *N. dombeyi* counterpart. *Nothofagus pumilio* forest covers the Cerro Purgatorio plateau and the lower Nieblas Valley. Understory species composition does not differ substantially from that of *N. dombeyi* but includes *Viola reichei* Skottsb., the orchid *Codonorchis lessonii* (d'Urv.) Lindl., as well as local abundant *Berberis rotundifolia* Poepp. et Endl. Common fungi are *Guepiniopsis alpina* (Tracy et Earle) Brasf., *Phellinus andinopatagonicus* (Wright et Desch.) Ryv., and *Hypholoma frowardii* (Speg.) Horak.

Species composition: *Acaena ovalifolia*, *Adenocaulon chilense*, *Alstroemeria aurea*, *Berberis montana* Gay, *Berberis rotundifolia*, *Chusquea culeou*, *Codonorchis lessonii*, *Escallonia alpina* Poepp. ex DC., *Fragaria chiloensis* (L.) Duchesne, *Gavilea lutea* (Pers.) M.N.Correa, *Gaultheria phillyreifolia*, *G. pumila*, *Guepiniopsis alpina*, *Hypholoma frowardii*, *Loasa acanthifolia*, *Maytenus disticha*, *Nothofagus pumilio*, *Phellinus andinopatagonicus*, *Ribes magellanicum*, *Vicia* sp., *Viola reichei*.

(3) ***Nothofagus*** **mixed forest**

Elevation: 1200-1820 m a.s.l.; aspect: N, NW of *N. obliqua*-dominated stands.

Description: The proportion of the three *Nothofagus* species *N. dombeyi*, *N. pumilio*, and *N. obliqua* varies in the *Nothofagus* mixed forest, according to moisture availability, soil, altitude, and exposure. Whereas pure *N. obliqua* stands prefer warm, N-exposed slopes, *N. pumilio* outcompetes *N. dombeyi* and *N. obliqua* at cold sites and higher elevations. Almost pure stands of mature *Nothofagus obliqua* forest with a closed canopy can be found on the lower slopes of Los Coltrahues and Cerro Las Cabras. Associated with them are shrubs like *Berberis microphylla* G.Forst., *Maytenus disticha*, and *Ribes* sp., and herbs like *Alstroemeria aurea*. Open *Nothofagus* mixed forest of Shangri-La Valley differs in spacing between individuals from the one of the locations mentioned above. On very dry, gray soils derived from volcanic sands *N. pumilio* and *N. obliqua* form an open forest with a sparse ground cover of so-called coirones (*Festuca* sp.) and the cactus *Maihuenia poeppigii* (Otto ex Pfeiff.) K.Schum.

Species composition: *Alstroemeria aurea*, *A. presliana*, *Baccharis* sp., *Berberis empetrifolia* Lam., *B. microphylla*, *B. rotundifolia*, *Chusquea culeou*, *Festuca thermarum* Phil., *F. magellanica* Lam., *Gaultheria pumila*, *Hypericum perforatum* L., *Maihuenia poeppigii*, *Maytenus disticha*, *Nothofagus dombeyi*, *N. pumilio*, *N. obliqua*, *Ribes* sp.

(4) ***Nothofagus pumilio*** **krummholz**

Elevation: 1520-2050 m a.s.l.; all aspects.

Description: At elevations of 1600 to 1800 m a.s.l. the *Nothofagus pumilio* forest gives way to a dense krummholz of up to six meter height, composed of the same species. The mechanical forces of wind pressure and invernal snow load causes *N. pumilio* to assume a bent and twisted growth form. *Chusquea culeou* and *Maytenus disticha* develop below the closed canopy. *Adesmia emarginata* Clos, *Quinchamalium chilense* Molina, and *Sisyrinchium arenarium* Poepp. grow within clearings and along footpaths. On rocky outcrops in between *N. pumilio* krummholz of upper Cerro Purgatorio *Orites* *myrtoidea* (Poepp. et Endl.) Benth. et Hook.f. ex B.D.Jacks. can be found.

Species composition: *Adesmia emarginata*, *Berberis empetrifolia*, *Chloraea nudilabia* Poepp., *Chusquea culeou*, *Empetrum rubrum* Vahl ex Willd., *Escallonia alpina*, *Euphorbia portulacoides* L., *Gaultheria pumila*, *Belloa chilensis* (Hook. et Arn.) J.Remy, *Maytenus disticha*, *Rhodophiala advena* (Ker.-Gawl.) Traub, *Nothofagus antarctica* (G.Forst.) Oerst., *N. pumilio*, *Orites myrtoidea*, *Perezia pedicularidifolia* Less., *Quinchamalium chilense*, *Senecio subumbellatus* Phil., *Sisyrinchium arenarium*, *Viola cotyledon* Ging.

(5) ***Nothofagus antarctica* krummholz**

Elevation: 1200-1820 m a.s.l.; aspects at elevations above 1800 m a.s.l.: N, NE, SW.

Description: Structurally very similar appears the study area's second krummholz assemblage, dominated by *N. antarctica*. This highly cold-resistant species grows in high density on the dry, fast draining soils of Las Trancas and the vicinity of Refugio Aserradero. Further krummholz patches, just two meters high, cover small areas of Aguas Calientes Valley´s northwestern slopes at 2100 m a.s.l., and of the northern slopes of Los Coltrahues. Frequently, *Mutisia decurrens* Cav. climbs upon the branches of *N. antarctica*.

Species composition: *Berberis empetrifolia*, *Chusquea culeou*, *Festuca* sp., *Gaultheria pumila*, *Mutisia decurrens*, *Nothofagus antarctica*, *N. pumilio*.

Assemblages of the Andean Belt

Dominance of the ubiquitous shrub *Adesmia emarginata* already indicates the floristic similarity of assemblages (6) to (8), which share common species like *Viola cotyledon*, *Euphorbia portulacoides*, and *Acaena leptacantha* Phil. as well. Nonetheless, soil conditions like colour, field texture, stone quantity, and bedrock geology differ.

(6) ***Adesmia emarginata-Pozoa coriacea* assemblage**

Elevation: 1530-2100 m a.s.l.; aspect: S, SW, W, NW; soil: gray to black, sandy, dry.

Description: This azonal vegetation unit with a low degree of coverage grows on alluvial, fast draining soils. It reaches noteworthy extensions near Garganta del Diablo, at the satellite cone Parador and on the alluvial plains north of Cortina Lava.

Species composition: *Acaena leptacantha*, *Adesmia emarginata*, *Euphorbia portulacoides*, *Hypochaeris tenuifolia* (Hook. et Arn.) Griseb., *Phacelia secunda* J.F.Gmel., *Pozoa coriacea* Lag., *Senecio chilensis* Less., *S. poeppigii* Hook. et Arn., *S. subumbellatus*, *Viola cotyledon*.

(7) ***Adesmia emarginata-Berberis empetrifolia* assemblage**

Elevation: 1860-2230 m a.s.l.; aspect: SW, W; soil: grayish-black, sandy, mixed with lava boulders.

Description: Occupying dacitic lava block landscape, this floristically diverse assemblage is dominated by *Adesmia emarginata*. Important differential species are *Berberis empetrifolia* and *Blechnum microphyllum* (Goldm.) C.V.Morton. At higher altitudes species number decreases and –marking the gradual transition into the *Nassauvia revoluta-Poa obvallata* assemblage– *Nassauvia revoluta* D.Don and *Chaetanthera villosa* D.Don appear.

Species composition: *Acaena leptacantha*, *Adesmia emarginata*, *Berberis empetrifolia*, *Blechnum microphyllum*, *Cerastium arvense* L., *Chaetanthera villosa*, *Euphorbia portulacoides*, *Festuca* sp., *Gamocarpha alpina* (Poepp. ex Less.) H.V.Hansen, *Gaultheria pumila*, *Hieracium glaucifolium* Poepp. ex Froel., *Hypochaeris tenuifolia*, *Loasa pinnatifida* Gillies ex Arn., *Nassauvia revoluta*, *Phacelia secunda*, *Poa* sp., *Senecio poeppigii*, *S. subumbellatus*, *Valeriana carnosa* Sm., *V. laxiflora* DC., *V. macrorhiza* Poepp. ex DC., *Viola cotyledon*.

(8) ***Adesmia emarginata-Loasa lateritia* assemblage**

Elevation: 1760-2310 m a.s.l.; all aspects except E; soil: brown, ochre, stony.

Description: The *Adesmia-Loasa* scree vegetation occupies the altitudinal belt from 1750 to 2300 m a.s.l. of the upper slopes of Nieblas Valley and Cerro Pirigallo. Soil physiognomy differs substantially from the one of the *Adesmia-Berberis* assemblage and is the main reason for separating these units. The dominant species is *Adesmia emarginata*. Less frequent, but nonetheless of high differential character are *Loasa lateritia* Gillies ex Arn. and *Schizanthus hookeri* Gillies ex Graham. *Festuca magellanica* and *F. thermarum* are abundant on sites where wind-accumulated sands build a finer soil substrate.

Species composition: *Acaena leptacantha*, *Adesmia emarginata*, *Berberis empetrifolia*, *Cerastium arvense*, *Euphorbia portulacoides*, *Festuca magellanica*, *F. thermarum*, *Gamocarpha alpina*, *Hordeum comosum* J.Presl, *Hypochaeris apargioides* Hook. et Arn., *Leucheria thermarum* (Phil.) Phil., *Loasa pinnatifida*, *L. lateritia*, *Nassauvia revoluta*, *N. digitata* Wedd., *Perezia pilifera* (D.Don) Hook. et Arn., *Phacelia secunda*, *Schizanthus hookeri*, *Viola cotyledon*.

(9) ***Chusquea culeou*-Coirones assemblage**
Elevation: 1330-2020 m a.s.l.; aspect: predominantly N; soil: brown, sandy at higher elevations; lighter coloured and coarser texture at lower elevations.
Description: The sun exposed north-facing slopes of Los Coltrahues and Cerro Las Cabras are covered by this assemblage. Dominant representatives are *Chusquea culeou* and elements of gramineous vegetation like *Festuca* sp. and *Poa* sp. Therefore, the vegetation cover of the gently sloped Los Coltrahues ridge shows the appearance of a typical Andean grassland community. Important components of steep and rocky slope vegetation are *Eryngium paniculatum* Cav. et Dombey ex F.Delaroche and *Puya alpestris* (Poepp.) Gay. Both reach altitudes of 1800 m a.s.l.

Species composition: *Alstroemeria aurea*, *A. ligtu* L., *A. presliana*, *Azara alpina* Poepp. et Endl., *Baccharis* sp., *Berberis microphylla*, *B. montana*, *Calceolaria cana* Cav., *C. meyeniana* Phil. subsp. *glabrata* (Phil.) C.Ehrh., *C. valdiviana* Phil., *Cerastium arvense*, *Chaetanthera chilensis* (Willd.) DC., *Chloraea bidentata* (Poepp. et Endl.) M.N.Correa, *C. magellanica* Hook.f., *C. nudilabia*, *Chusquea culeou*, *Colletia* sp., *Diplolepis nummulariifolia* (Hook. et Arn.) Liede et Rapini, *Discaria chacaye* (G.Don) Tortosa, *Ephedra chilensis* C.Presl, *Eryngium paniculatum*, *Euphrasia chrysantha* Phil., *Festuca* sp., *Gaultheria pumila*, *Haplopappus grindelioides* (Less.) DC., *Hieracium glaucifolium*, *Hypericum perforatum*, *Hypochaeris apargioides*, *Lathyrus subandinus* Phil., *Junellia* sp., *Leucheria lithospermifolia* (Less.) Reiche, *Monnina linearifolia* Ruiz et Pav., *Mulinum spinosum* (Cav.) Pers., *Mutisia ilicifolia* Cav., *M. oligodon*, *Perezia linearis* Less., *Plantago uniglumis* Wallr. ex Walp., *Poa* sp., *Polygala gnidioides* Willd., *Puya alpestris*, *Quinchamalium chilense*, *Rhodophiala advena*, *R. andicola* (Poepp.) Traub, *Ribes magellanicum*, *Rumex acetosella* L., *Senecio chilensis*, *S. polyphyllus* Kunze ex DC., *S. subumbellatus*, *Sisyrinchium graminifolium* Lindl., *S. patagonicum* Phil. ex Baker, *Solanum ligustrinum* Lodd., *Solenomelus segethii* (Phil.) Kuntze, *Stachys* sp., *Wendtia gracilis* Meyen, *Valeriana carnosa*, *V. laxiflora*.

(10) ***Caltha sagittata-Mimulus luteus* assemblage**
Elevation: 1640-2400 m a.s.l.; all aspects; soil: black, peaty, high organic content.
Description: This azonal, hygrophyllous vegetation unit depends on the availability of surface moisture that is provided by small streams of melt water. Most important species are *Caltha sagittata* Cav., *Mimulus luteus* L., and *Ranunculus peduncularis* Sm. Dominant gramineous representatives are *Carex decidua* Boott and *Marsippospermum grandiflorum* (L.f.) Hook.f. An interesting element of this assemblage is *Chillania pusilla* Roiv., which is endemic to Bío-Bío Region.

Species composition: *Anagallis alternifolia* Cav., *Calandrinia* sp., *Calceolaria filicaulis* Clos, *C. undulata* Benth., *Caltha appendiculata* Pers., *C. sagittata*, *Carex decidua*, *Cerastium arvense*, *Chillania pusilla*, *Deyeuxia erythrostachya* E.Desv., *Epilobium glaucum* Phil., *Euphrasia* sp., *Gentianella magellanica* (Gaudich.) Fabris ex D.M.Moore, *Geranium sessiliflorum* Cav., *Geum quellyon* Sweet, *Gunnera magellanica* Lam., *Hypochaeris acaulis* (J.Remy) Britton, *H. palustris* Reiche, *H. radicata* L., *Juncus stipulatus* Nees et Meyen, *Marsippospermum grandiflorum*, *Mimulus cupreus* Dombrain, *M. luteus*, *Ourisia breviflora* Benth. subsp. *uniflora* (Phil.) Meudt, *O. ruellioides* (L.f.) Kuntze, *Phleum alpinum* L., *Ranunculus peduncularis*, *Senecio fistulosus* Poepp. ex Less., *Silene chilensis* (Gay) Bocquet, *Aster vahlii* (Gaudich.) Hook. et Arn., *Trifolium* sp., *Tristagma bivalve* (Lindl.) Traub, *Valeriana fonki* Phil., *Veronica anagallis-aquatica* L., *V. serpyllifolia* L.

(11) ***Nassauvia revoluta-Poa obvallata* assemblage**
Elevation: 2120-2700 m a.s.l.; all aspects.
Description: The upper altitudinal vegetational belt consists mainly of a sparse plant cover dominated by *Nassauvia revoluta* and *Poa obvallata* E.Desv., which grow on gravel and scree slopes and between lava rocks. *Senecio portalesianus* J.Remy and *Chaetanthera villosa* reach altitudes of 2500 m a.s.l.

Species composition: *Chaetanthera villosa*, *Nassauvia revoluta*, *Olsynium frigidum* (Poepp.) Goldblatt, *Poa obvallata*, *Senecio pachyphyllos* J.Remy, *S. poeppigii*, *S. portalesianus*.

(12) **Cortina Lava**
The northern sector of the study area is covered by a postglacial dacitic lava flow, the so-called Cortina Lava, which reaches the upper Shangri-La Valley. Soil development is prohibited by the lava flow´s structure. As huge rocks are piled up with plenty of empty room between them, sediments do not accumulate. So Cortina Lava is devoid of vegetation, apart from a few individuals of *Festuca* sp., *Poa* sp., and –at lower altitudes– *Orites myrtoidea*.

(13) **Rocks, ice and eroded areas**
Rocks, ice and eroded areas bare of vascular plant cover are summarized cartographically as one category.

Human influence

Direct or indirect human activity exercises its influence on 30 km^2 of the study area.

The Cerro Purgatorio forest stands, as well as the north-facing slopes of Cerro Torrealba are used as seasonal pasture for domestic animals like cattle and horses. Grazing and trampling impedes natural forest rejuvenation and promotes soil erosion and loss of biodiversity. At Cerro Torrealba grazing-resistant species like *Rumex acetosella* and *Acaena leptacantha* are substantially more frequent than at undisturbed sites.

Skiing affects the south-western slopes of Volcán Chillán. Especially cushion plants like *Nassauvia* sp. suffer damage (Freiberg 1985). For ski runs and service roads, terrain was mechanically graded and forest was cut. As a consequence, plant species composition may change, and vegetation cover and diversity may decrease (Wipf *et al.* 2005).

Touristic activities and construction of summer cabins lead to disturbances in the surroundings of Termas de Chillán resort, in the lower Shangri-La Valley, and the Las Trancas sector, putting old-growth *Nothofagus* forest in danger.

At Valle Hermoso the alien conifer species *Pseudotsuga menziesii* (Mirb.) Franco was planted, altering the species composition of native forests. The invasive species *Verbascum thapsus* L. and *Hypericum perforatum*, both of European provenance, already reach altitudes of 2000 and 1800 m a.s.l., respectively.

DISCUSSION

In this chapter we discuss our results in the context of Nevados de Chillán's location in the Mediterranean-temperate transition zone. Besides, we comment on conservation issues.

Biogeography

Luebert & Pliscoff (2006) describe the transitional vegetation unit "Bosque caducifolio mediterráneo-templado andino de *Nothofagus pumilio* y *N. obliqua*". Its floristic composition corresponds very well to the *Nothofagus pumilio* forests found in the study area. The occurrence of *Berberis rotundifolia* and *N. obliqua* with distribution ranges from 35º-39°S (Landrum 2003) and 33º-41°S (Rodríguez & Quezada 2003), respectively, indicates the transitional character of *Nothofagus* mixed forests as well. According to Donoso (1993), Nevados de Chillán is located near the northern distribution limit of *Nothofagus pumilio* (lenga) forest type (*Tipo forestal Lenga, subtipo de Bosque de Lenga puro*) which supports a more temperate character of the study area's *Nothofagus pumilio* forests. However, Andean *Nothofagus pumilio* forests further south feature a *Drimys andina* (Reiche) R.A.Rodr. et Quez. understory (Hildebrand-Vogel *et al.* 1990), which is completely missing from *N. pumilio* forests of the study area.

Other woodland assemblages as well show temperate affinities: Gajardo (1994) places *Nothofagus* krummholz into the the sub-region "Bosque Caducifolio Alto-Andino de Chillán" of an Andean-patagonian category called "Región del Bosque Andino-Patagónico".

Nothofagus dombeyi forest stands of Nevados de Chillán are restricted to sites along water courses. Laurophyllous elements are missing. Therefore, this woodland assemblage should be regarded as azonal vegetation without a strong biogeographical connection to the temperate evergreen rainforests south of 40°S, where *N. dombeyi* forms an important element.

Prominent constituents of Andean-Mediterranean forests north of 35°S, e.g. *Austrocedrus chilensis* (D. Don) Pic.Serm. et Bizzarri, *Kageneckia angustifolia* D.Don, *Quillaja saponaria* Molina, and *Lithrea caustica* (Molina) Hook. et Arn. (Arroyo *et al.* 2004), are absent from the study area itself.

According to Luebert & Pliscoff (2006), "Matorral bajo templado andino de *Discaria chacaye* y *Berberis empetrifolia*" builds the Andean vegetation belt in Bío-Bío and Araucanía Regions. It corresponds to Gajardo's (1994) formation "Estepa Alto-Andina Sub-Húmeda". Both categories rank as temperate ones. Their floristic composition descriptions, although very general, fit well with the vegetation actually found in study area's Andean belt vegetation. Furthermore, typical cushion plants of Chile's Central Andes like *Laretia acaulis* (Cav.) Gillies ex Hook., *Azorella madreporica* Clos, and *A. monantha* Clos where not found in the study area. Two elements of the Andean belt's *Caltha-Mimulus* unit, *Calta appendiculata* and *Marsippospermum grandiflorum*, are regarded by Freiberg (1985) to represent link species to Antarctic peat bog communities.

In summary, temperate biogeographical features prevail in the study area.

Conservation

Conservation should aim at the protection of the largely undisturbed primary *Nothofagus* forests of Cerro Purgatorio, upper Shangri-La Valley, and Nieblas Valley. As great extensions of Aguas Calientes Valley with its pristine *Caltha-Mimulus* vegetation cover do not show the same luxuriance as undisturbed patches of the same vegetation due to hiking, camping, horse riding, and pasturing, it would profit substantially from conservation efforts. Still largely intact and for their exceptional number of plant species worthy of protection, are the northern slopes of Los Coltrahues.

CODEFF (Comité Nacional Pro Defensa de la Flora y Fauna) supports establishment of a biological corridor between Nevados de Chillán and Laguna de La Laja National Park to protect an enthreatened Huemul (*Hippocamelus bisulcus* (Molina) 1782, Cervidae) population of less than 60 individuals (López *et al.* 2004). The flora of Nevados de Chillán would benefit as well from the realization of this project.

ACKNOWLEDGMENTS

The authors thank Mauricio Aguayo and Andreas Langner for help in tackling software problems, Clodomiro Marticorena (CONC) for nomenclatural revision, and two anonymous reviewers for valuable comments that improved an earlier version of the manuscript.

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Recibo: 05.02.08
Aceptado: 25.08.08