Plant Ecology **136:** 9–26, 1998.

A bioclimatic classification of Chile: woodland communities in the temperate zone

Javier Amigo[1] & Carlos Ramírez[2]
[1]*Laboratorio de Botánica, Facultad de Farmacia, Universidad de Santiago de Compostela, E-15706 Santiago de Compostela, Spain;* [2]*Instituto de Botánica, Universidad Austral de Chile, Casilla 567, Valdivia, Chile*

Received 25 October 1996; accepted in revised form 30 December 1997

Key words: Bioindicators, Ombrotype, Phytosociology, Temperature belt, Woodlands

Abstract

The results of application of a global bioclimatic classification to Chile are presented. A total of 140 weather stations are assigned to bioclimatic belts on the basis of temperature and rainfall regime. In view of these assignements and of phytosociological data, a zonation of Chile into four major bioclimatic regions (Tropical, Mediterranean, Temperate and Boreal) is proposed. For the Temperate region, we discuss the distribution of the various climax forest communities with respect to bioclimatic belt. It is suggested that increased knowledge of the phytosociology of Chile will improve understanding of the climate of the different parts of the country.

Nomenclature: Plant nomenclature follows Marticorena et al. (1985) for Chilean species.

Introduction

Various authors have studied the contrasting climatic patterns of Chile, in some cases with regard to the distribution of plant and animal species, i.e. bioclimate (Fuenzalida et al. 1965; Huber 1975; Di Castri et al. 1976; Novoa et al. 1989). Indeed, a number of biogeographical maps of Chile have been published, with territorial subdivisions which vary from author to author but which in general show broad agreement. The maps of Pisano (1955) and Schmithussen (1956) are of particular interest, in view of their phytogeographical basis and coverage of the whole of Chile. Also worthy of note is the zoogeographical zonation of Artigas (1975), published together with a review of the maps of other authors.

In the present article we present a bioclimatic zonation of Chile developed following the approach of Rivas-Martínez (1981, 1987, 1993), whose phytoclimatic classification has been in use in the Iberian Peninsula and other parts of Western Europe for over fifteen years.

A fundamental element of this approach is the concept of bioclimatic belt (*piso bioclimático*), also known as temperature belt (*piso termoclimático*), since it is defined on the basis of temperature regime. The approach also involves definition of ombrotypes (*pisos ombroclimáticos*). The aim is to identify those temperature and rainfall ranges which best correspond to the limits of the major vegetation types of the region under study. The parallel delimitation of bioclimatic belts and vegetation belts (*pisos de vegetación*) thus allows a detailed analysis of the relationship between 'container' and 'contained', and constitutes a valuable basis for the use of vegetation types as indicators of climate. These advantages of the Rivas-Martínez approach are well-known (see Rivas-Martínez 1987); additionally, it is worth noting that Rivas-Martínez terminology can be readily generalized, in view of the global outlook of the approach (Rivas-Martínez 1993).

Methods

Data were compiled from weather stations located throughout Chile. These data, together with altitudes and latitudes, allowed determination of Rivas-Martínez climatic indices (see below) for each station. These indices provided the basis for a bioclimatic zonation of Chile, again following the Rivas-Martínez approach. To confirm the validity of the bioclimatic zonation thus derived, we then considered the distribution of woodland communities within the Temperate zone (which is that with the greatest diversity of woodland communities, and that in which such communities are best preserved).

Climatic data

Data were compiled from 140 weather stations. Data are in fact readily available for about 700 stations; however, about 500 of these stations have precipitation data only, and were thus not considered in the present study. Of the approximately 200 weather stations remaining, about sixty were rejected because only annual mean temperatures, not monthly mean temperatures, were available. In a small number of cases the only information available was mean temperature of the coldest month and of the hottest month; such stations were accepted since these data allow calculation of the most important Rivas-Martínez indices (i.e., I_t and I_c, and generally T_p and I_o; see below). At least 7 years of data were available for the great majority of stations (in most cases from the period 1950–1980); in a previous bioclimatic characterization of Chile (Hayek et al. 1975), 'principal' stations were likewise required to have at least 7 years of data. Stations in mountain areas are scarce, and in a few cases we accepted mountain stations with data for only 4, 5 or 6 consecutive years. Ideally, climatic data series covering at least 28 consecutive years should be used in studies of this type, and the data-collection period should be more or less the same for the different weather stations considered; however, such data are not widely available for Chile. In the classic study by Hayek et al. (1975), for example, only 34 of the 107 stations considered have temperature data for 28 consecutive years.

Monthly precipitation data are available for 111 of the 140 stations considered; in the remaining cases, P_p (see below) could still be estimated, since in none of these stations did monthly mean temperature drop below 0 °C.

Climatic indices

The indices used in the present study are discussed fully in Rivas-Martínez (1993), but will be briefly defined here.

The thermicity index (*índice de termicidad*) (I_t) is the sum of annual mean temperature (T), mean daily maximum temperature of the coldest month (M) and mean daily minimum temperature of the coldest month (m), multiplied by ten; i.e., $I_t = 10(T + M + m)$.

The corrected thermicity index (*índice de termicidad compensado*) (I_{tc}) is I_t plus a factor to correct for strongly oceanic or strongly continental climate (as indicated by I_c; see below) in the Mediterranean or Temperate macrobioclimatic territories; this correction factor is negative when $I_c < 11$ and positive when $I_c > 18$.

The index of continentality (*índice de continentalidad*) (I_c) (also known as thermal amplitude, *amplitud térmica*) is calculated as the difference between the daily mean temperatures of the hottest month and the coldest month.

The above-zero temperature index (*temperature positiva*) (T_p) is the sum of all monthly mean temperatures greater than 0 °C, multiplied by ten; this index is useful for defining bioclimatic belts in cold climates.

Precipitation (*precipitación*) (P) is mean annual precipitation in litres per square metre.

The above-zero precipitation index (*precipitación positiva*) (P_p) is the sum of mean monthly precipitation for those months in which mean temperature is greater than 0 °C.

The ombrothermic index (*índice ombrotérmico*) (I_o) is calculated as 10 (P_p/T_p), i.e., months in which mean temperature is less than 0 °C are not taken into consideration. This index provides the principal basis for defining ombrotypes.

Bioclimatic zonation

On the basis of the climatic indices estimated for each station, a bioclimatic zonation of Chile was drawn up following the world-wide classification proposed by Rivas-Martínez (1993). This classification establishes five 'macrobioclimates', namely Tropical, Mediterranean, Temperate, Boreal and Polar. On the basis of temperature regime, each macrobioclimate is divided into belts designated (hottest to coldest) by the prefixes Infra-, Thermo-, Meso-, Supra-, Oro- and Cryoro- (for example, Infratropical); note however that belt nomenclature is different for Boreal (Thermo-, Meso- and Supraboreal, plus Tundral, Cryodesertic and Pergelid) and Polar (three belts only: Tundral, Cryodesertic and Pergelid).

Each macrobioclimate is also subdivided on the basis of rainfall regime, into belts designated Ultraperarid, Perarid, Arid, Semiarid, Dry, Subhumid, Humid, Perhumid and Ultraperhumid.

Climate/vegetation relationships

In the summers of 1994, 1995 and 1996, in order to assess the validity of the bioclimatic zonation, we surveyed the climax woodland vegetation of the region between the 35th and 47th parallels, with the aim of identifying the different communities and characterizing them as regards altitudinal range. This survey was based on a series of coast-to-Andes traverses covering a total distance of over 15 000 km; note that, at these latitudes, Chile is very narrow, measuring on average about 150 km from east to west. We also took into account the previously published reviews of studies of the Chilean vegetation by Ramírez (1983) and Amigo et al. (1997?). All vegetation units considered have been defined previously in systematic phytosociological studies, notably those of Oberdorfer (1960) and Tomaselli (1981).

Results

Climatic data for the different weather stations, together with the bioclimatic belts and ombrotypes to which each station is accordingly assigned, are listed in Table 1. The location of each station, and the corresponding proposed bioclimatic zonation of Chile, is shown in Figures 5–7. Note that Chile, in view of its extreme latitudinal extent, contains regions corresponding to all five macrobioclimates (including Polar, in the Antarctic territories not shown in the figures). Recent reports have indicated that there are 'islands' of Polar climate in the extreme south of Chile; these areas are not indicated in Figure 7.

As is apparent from Figure 1, the 140 weather stations are not evenly distributed throughout the country: 52% lie between 32° and 41° S, in the region of highest population density commonly referred to as Central-Southern Chile (*Centro-Sur*).

One of the most serious obstacles to the development of an accurate classification is the scarcity of climatic data for mountainous areas. In the present study, the use of spatial interpolation techniques such as kriging was ruled out because of the topographic characteristics of Chile and the highly non-uniform altitudinal distribution of the weather stations in the Temperate and Mediterranean Zones (see Figures 3 and 4). The altitudinal distribution of weather stations in the Tropical Zone was more uniform (Figure 2), reflecting the fact that about 53% of the area of the Tropical Zone is at an altitude of 3000 m or more, and only 12% at an altitude of 1000 m or less. In the Temperate Zone, by contrast, there are no weather stations above 1000 m, despite the fact that areas above this altitude account for 18% of the total area of this zone.

As noted, all five of the Rivas-Martínez macrobioclimates are represented in Chile. Furthermore, there is high diversity within macrobioclimates. For example, five of the six bioclimatic belts of the Tropical macrobioclimate occur (Thermo-, Meso-, Supra-, Oro- and Cryorotropical); note, however, that rainfall regime in the Tropical Zone is less varied, largely ranging from Ultraperarid to Dry (though station 138 on Easter Island is Subhumid, and a few stations above 4000 m are Humid).

The Mediterranean Zone is likewise the most heterogeneous: all six bioclimatic belts are possibly present, from Inframediterranean (very probably present close to station 23, but supported by a reduced-length-of-record station, not included in Table 1) to Cryoromediterranean (station 41). In addition, eight of the nine possible rainfall regimes (Ultraperarid to Perhumid) definitely occur (e.g., stations 16 and 71).

In the Temperate Zone, the paucity of weather stations is a serious obstacle to accurate zonation. Of the six bioclimatic belts, all except Infratemperate are present. None of the weather stations fall into the Cryorotemperate Belt, but this belt certainly occurs in the Andes. Rainfall regime ranges from Dry to Ultraperhumid.

The weather station data indicate the existence of the warmer Boreal belts (Thermo- and Mesoboreal). However, since the Boreal areas of Chile reach altitudes of up to 1700 m, we can deduce the presence of at least two more belts (Supraboreal and Tundral), whose limits with and transitions to warmer belts must be inferred from phytogeographic data. Rainfall regimes in the Boreal Zone correspond to ombrotypes ranging from Ultraperhumid on the Pacific coast (e.g., station 127) to Subhumid (data from rainfall-only weather stations).

Table 1. List of the 140 weather stations; n.a.: not available. For stations in italics, monthly rainfall data are available. (+) = monthly mean temperatures only for hottest and coldest months. (* = less than 7 consecutive years' temperature data available.

	Station	Lat. S	Long.W	Alt.	T	M	m	It	Ic	Itc	P	Tp	Io	Bioclimatic Belt	Ombrotype
1	*Parinacota*	18° 12'	69° 08'	4390	**1.6**	0.0	-6.0	-44	7.1		**389**	239	16.1	Cryorotropical	Humid
2	*Putre* (+)	18° 12'	69° 35'	3530	**8.4**	n.a.	n.a.	n.a.	n.a.		**238**	1000?	2.4?	Orotropical	Dry
3	*Arica*	18° 28'	70° 20'	29	**19.1**	19.1	13.2	514	6.7		**1**	2292	0.0	Thermotropical	Ultraperarid
4	C.O.D.P.A.	18° 50'	69° 45'	1800	**16.1**	n.a.	n.a.	455	2.4		**13**	1932	0.1	Mesotropical	Ultraperarid
5	Collacagua (*)	20° 03'	68° 50'	3990	**4.6**	n.a.	n.a.	30	9.2		**159**	563	2.8?	Cryorotropical	Dry
6	*Iquique*	20° 12'	70° 11'	6	**17.6**	17.5	13.0	476	5.5		**2**	2112	0.0	Mesotropical	Ultraperarid
7	*Los Cóndores*	20° 15'	70° 07'	518	**15.5**	15.4	6.8	377	9.2		**000**	1860	0.0	Mesotropical	Ultraperarid
8	*Canchones*	20° 25'	69° 35'	960	**16.7**	29.0	-0.2	455	8.2		**1**	2004	0.0	Mesotropical	Ultraperarid
9	*Colonia Pintados*	20° 37'	69° 39'	977	**16.7**	26.2	1.8	447	6.5		**000**	2004	0.0	Mesotropical	Ultraperarid
10	*Ollagüe* (*)	21° 12'	68° 15'	3650	**6.8**	n.a.	n.a.	106	8.3		**71**	816	0.9	Orotropical	Arid
11	Linzor (*)	22° 12'	67° 59'	4096	**1.1**	n.a.	n.a.	-19	4.8		**196**	177	11.0?	Cryorotropical	Humid
12	Calama	22° 28'	68° 55'	2260	**12.2**	n.a.	n.a.	298	6.6		**4**	1464	0.0	Supratropical	Ultraperarid
13	*S.Pedro de Atacama* (*)	22° 55'	68° 12'	2450	**13.4**	n.a.	n.a.	276	11.5		**28**	1608	0.2	Supratropical	Perarid
14	*Cerro Moreno*	23° 29'	70° 26'	119	**17.0**	16.9	9.6	435	6.8	393	**2**	2040	0.0	Thermomediterranean	Ultraperarid
15	Socaire (*)	23° 36'	67° 52'	3251	**10.5**	n.a.	n.a.	227	9.0		**57**	1260	0.5	Supratropical	Perarid
16	Antofagasta-C.Moreno	23° 41'	70° 25'	35	**16.4**	n.a.	n.a.	434	6.6	390	**5**	1968	0.0	Thermomediterranean	Ultraperarid
17	*Refresco*	25° 19'	69° 52'	1850	**17.7**	23.1	5.5	463	6.6	419	**12**	2124	0.1	Thermomediterranean	Ultraperarid
18	*Tal Tal*	25° 25'	70° 34'	39	**17.4**	17.3	11.2	459	7.6	425	**25**	2088	0.1	Thermomediterranean	Perarid
19	*Chañaral*	26° 20'	70° 37'	9	**16.4**	16.3	8.8	415	7.2	377	**2**	1968	0.0	Thermomediterranean	Ultraperarid
20	*Potrerillos*	26° 30'	69° 27'	2850	**11.9**	12.9	4.9	297	5.2	239	**44**	1428	0.3	Mesomediterranean	Perarid
21	*Caldera*	27° 03'	70° 51'	14	**16.5**	16.7	9.9	431	6.8	389	**27**	1980	0.1	Thermomediterranean	Perarid
22	*Copiapó*	27° 21'	70° 21'	380	**18.0**	19.9	6.5	444	9.7	433	**22**	2160	0.1	Thermomediterranean	Perarid
23	*Lautaro Embalse*	27° 58'	70° 01'	1110	**18.6**	n.a.	n.a.	486	6.4	440	**25**	2232	0.1	Thermomediterranean	Perarid
24	*Vallenar (Campex)* (*)	28° 35'	70° 46'	470	**16.0**	19.2	5.0	402	7.7	369	**21**	1920	0.1	Thermomediterranean	Perarid
25	Conay (*)	28° 53'	70° 10'	1450	**17.9**	n.a.	n.a.	429	8.9	408	**85**	2148	0.4	Thermomediterranean	Perarid
26	El Indio, Cª Doña Ana (+)	29° 45'	69° 59'	3750	**4.3**	n.a.	n.a.	7	11.7	7	**242**	540?	1.4	Oromediterranean	Semiarid
27	*La Serena-Aeropuerto*	29° 54'	71° 15'	32	**13.5**	14.6	7.0	351	6.4	305	**104**	1620	0.6	Mesomediterranean	Arid
28	*Punta Tortuga*	29° 55'	71° 22'	25	**14.7**	15.1	9.2	390	5.6	336	**103**	1764	0.6	Mesomediterranean	Arid
29	Rivadavia (*)	29° 58'	70° 34'	850	**16.5**	n.a.	n.a.	407	8.1	378	**86**	1980	0.4	Thermomediterranean	Perarid
30	*Vicuña*	30° 02'	70° 44'	620	**15.5**	19.7	5.8	410	8.4	384	**157**	1860	0.8	Thermomediterranean	Arid
31	*Ovalle*	30° 37'	71° 01'	220	**16.6**	18.2	6.3	411	8.6	387	**126**	1992	0.6	Thermomediterranean	Arid
32	*Paloma Embalse*	30° 41'	71° 02'	430	**15.8**	n.a.	n.a.	378	9.7	365	**135**	1896	0.7	Thermomediterranean	Arid
33	Central Los Molles	30° 45'	70° 36'	1450	**14.6**	n.a.	n.a.	326	9.8	314	**138**	1752	0.8	Mesomediterranean	Arid
34	Illapel (*)	31° 38'	71° 10'	290	**15.4**	n.a.	n.a.	378	8.6	354	**177**	1848	1.0	Thermomediterranean	Semiarid

Table 1. Continued.

	Station	Lat. S	Long.W	Alt.	T	M	m	It	Ic	Itc	P	Tp	Io	Bioclimatic Belt	Ombrotype
35	*Los Vilos*	31° 52'	71° 28'	30	**13.9**	14.6	7.6	361	5.9	310	**209**	1668	1.3	Mesomediterranean	Semiarid
36	*Alicahue*	32° 19'	70° 47'	1885	**8.6**	8.8	-3.2	142	10.8	140	**324**	1032	3.1	Supramediterranean	Dry
37	*La Ligua*	32° 27'	71° 16'	58	**14.4**	16.5	4.5	354	8.0	324	**342**	1728	2.0	Mesomediterranean	Semiarid
38	*Zapallar*	32° 33'	71° 30'	30	**14.2**	14.1	8.4	367	6.5	322	**384**	1704	2.3	Mesomediterranean	Dry
39	*Baños de Jahuel*	32° 41'	70° 39'	1180	**15.6**	15.4	5.7	367	12.1	367	**305**	1872	1.6	Thermomediterranean	Semiarid
40	*Quintero*	32° 47'	71° 32'	2	**13.9**	14.5	5.2	336	6.4	290	**282**	1668	1.7	Mesomediterranean	Semiarid
41	*Cristo Redentor*	32° 50'	70° 04'	3850	**-1.4**	-4.2	-9.5	-151	10.6	-147	**902**	123	0.9	Cryoromediterranean	Semiarid
42	Los Andes	32° 50'	70° 36'	820	**15.2**	14.4	2.8	324	13.3	324	**261**	1824	1.4	Mesomediterranean	Semiarid
43	*Juncal*	32° 52'	70° 10'	2250	**9.3**	10.3	-0.3	193	10.9	192	**287**	1116	2.6	Supramediterranean	Dry
44	*Quillota*	32° 53'	71° 16'	128	**15.2**	16.8	5.5	375	8.7	352	**436**	1824	2.4	Thermomediterranean	Dry
45	*Valparaiso*	33° 01'	71° 38'	41	**14.8**	15.6	8.3	387	5.9	336	**380**	1776	2.1	Mesomediterranean	Dry
46	*El Belloto*	33° 03'	71° 24'	121	**15.5**	17.4	3.7	366	10.1	357	**334**	1860	1.8	Thermomediterranean	Semiarid
47	*Peñablanca*	33° 04'	71° 23'	154	**14.9**	16.0	5.2	361	10.1	352	**382**	1788	2.1	Thermomediterranean	Dry
48	*Colina*	33° 12'	70° 40'	542	**16.1**	14.9	1.3	323	13.7	323	**355**	1932	1.8	Mesomediterranean	Semiarid
49	*Santiago (OMC)*	33° 27'	70° 42'	520	**13.9**	14.6	3.3	318	11.8	318	**356**	1668	2.1	Mesomediterranean	Dry
50	*Los Cerrillos*	33° 30'	70° 42'	506	**13.8**	14.3	1.4	295	13.8	295	**310**	1656	1.9	Mesomediterranean	Semiarid
51	*La Platina*	33° 34'	70° 38'	625	**13.9**	14.1	2.8	308	11.2	308	**369**	1668	2.2	Mesomediterranean	Dry
52	*El Bosque*	33° 34'	70° 41'	580	**15.8**	13.5	3.3	326	13.9	326	**330**	1896	1.7	Mesomediterranean	Semiarid
53	*San Antonio*	33° 34'	71° 37'	5	**13.2**	14.1	6.2	335	6.4	289	**441**	1584	2.8	Mesomediterranean	Dry
54	*S. José de Maipo*	33° 39'	70° 22'	1060	**12.9**	15.5	2.4	308	11.2	308	**623**	1548	4.0	Mesomediterranean	Subhumid
55	El Yeso Embalse (*)	33° 40'	70° 06'	2475	**8.3**	n.a.	n.a.	113	12.2	113	**508**	996	5.1	Supramediterranean	Subhumid
56	*Quelentaro*	34° 03'	71° 35'	265	**14.9**	12.8	5.8	335	11.1	335	**439**	1788	2.5	Mesomediterranean	Dry
57	*El Teniente*	34° 05'	70° 23'	2156	**10.0**	8.7	0.4	191	13.4	191	**1051**	1200	8.8	Supramediterranean	Humid
58	*Hidango*	34° 07'	71° 44'	304	**13.6**	13.3	5.5	324	8.6	300	**898**	1632	5.5	Mesomediterranean	Subhumid
59	*Rancagua*	34° 10'	70° 45'	500	**14.7**	12.8	1.7	292	13.2	292	**563**	1764	3.2	Mesomediterranean	Subhumid
60	*Rengo*	34° 24'	70° 52'	319	**13.7**	13.2	2.9	298	11.7	298	**582**	1644	3.5	Mesomediterranean	Subhumid
61	*San Fernando*	34° 36'	71° 00'	342	**13.4**	12.2	3.7	293	12.6	293	**777**	1608	4.8	Mesomediterranean	Subhumid
62	*Curicó*	34° 58'	71° 13'	225	**14.3**	13.2	3.6	311	13.4	311	**734**	1716	4.3	Mesomediterranean	Subhumid
63	*Molina*	35° 03'	71° 16'	235	**13.2**	13.1	2.6	289	13.1	289	**921**	1584	5.8	Mesomediterranean	Humid
64	*Constitución*	35° 19'	72° 25'	12	**14.1**	14.6	6.0	347	7.9	316	**898**	1680	5.3	Mesomediterranean	Subhumid
65	*Talca*	35° 26'	71° 04'	97	**14.9**	13.6	3.8	323	13.0	323	**735**	1788	4.1	Mesomediterranean	Subhumid
66	*Punta Carranza*	35° 36'	72° 38'	30	**12.7**	13.4	7.1	332	4.7	269	**832**	1524	5.5	Mesomediterranean	Subhumid
67	Laguna Invernada	35° 44'	70° 47'	1325	**10.9**	n.a.	n.a.	185	13.9	185	**1402**	1308	10.7	Supramediterranean	Humid
68	*Panimavida*	35° 46'	71° 24'	197	**13.4**	12.6	3.5	295	12.8	295	**1107**	1608	6.9	Mesomediterranean	Humid
69	*Linares*	35° 51'	71° 36'	157	**13.9**	12.2	4.3	304	13.1	304	**1007**	1668	6.0	Mesomediterranean	Humid
70	*Cauquenes*	35° 57'	72° 19'	177	**15.2**	14.1	4.6	339	12.7	339	**642**	1824	3.5	Mesomediterranean	Subhumid

Table 1. Continued.

	Station	Lat. S	Long.W	Alt.	T	M	m	It	Ic	Itc	P	Tp	Io	Bioclimatic Belt	Ombrotype
71	Bullileo (+)	36° 18'	70° 50'	650	**14.6**	n.a.	n.a.	n.a.	n.a.	n.a.	**2006**	1752	11.4	Mesomediterranean	Perhumid
72	*Chillán*	36° 30'	72° 06'	144	**14.1**	12.4	3.5	300	12.7	300	**1025**	1692	6.1	Mesomediterranean	Humid
73	*Punta Tumbes*	36° 37'	73° 06'	120	**12.3**	13.1	6.7	321	5.8	269	**829**	1476	5.6	Mesomediterranean	Humid
74	*Talcahuano*	36° 43'	73° 07'	5	**12.7**	12.2	6.3	312	7.3	275	**1106**	1524	7.3	Mesomediterranean	Humid
75	*Concepción*	36° 50'	73° 02'	10	**13.1**	13.3	5.0	314	8.7	291	**1330**	1572	8.5	Mesomediterranean	Humid
76	*Isla Sta. María*	36° 59'	73° 32'	79	**12.2**	12.6	7.3	321	5.0	261	**876**	1464	6.0	Mesomediterranean	Humid
77	*Punta Lavapié*	37° 16'	73° 35'	46	**13.3**	13.2	7.2	337	6.2	289	**804**	1596	5.0	Mesomediterranean	Subhumid
78	*Los Angeles*	37° 28'	72° 24'	130	**13.7**	12.6	5.0	313	12.4	313	**1311**	1644	8.0	Mesomediterranean	Humid
79	*Angol*	37° 47'	72° 42'	77	**13.3**	11.8	4.3	294	11.4	294	**1054**	1596	6.6	Mesomediterranean	Humid
80	Ralco (Pangue)	37° 53'	71° 37'	550	**11.5**	n.a.	n.a.	233	11.3	233	**4080**	1380	29.6	Mesotemperate	Ultraperhumid
81	*Contulmo*	38° 02'	73° 12'	38	**12.6**	13.7	5.0	313	8.2	285	**1896**	1524	11.3	Mesotemperate	Humid
82	*Victoria*	38° 13'	72° 21'	360	**12.4**	10.1	2.1	246	11.9	246	**1329**	1488	8.9	Mesotemperate	Humid
83	*Traiguén*	38° 15'	72° 40'	170	**12.0**	11.6	4.1	277	10.2	268	**1241**	1440	8.6	Mesotemperate	Humid
84	*Isla Mocha E*	38° 22'	73° 54'	30	**12.7**	12.5	6.9	321	6.4	275	**1260**	1524	8.3	Mesotemperate	Humid
85	*Lonquimay*	38° 26'	71° 15'	900	**8.6**	6.7	-2.6	127	13.2	127	**1945**	720	27.0	Supratemperate	Ultraperhumid
86	*Cherquenco*	38° 41'	72° 01'	510	**9.7**	10.7	1.2	216	9.1	196	**2555**	1164	22.0	Mesotemperate	Perhumid
87	*Carillanca*	38° 41'	72° 25'	200	**10.0**	9.7	2.3	220	8.5	195	**1394**	1200	11.6	Mesotemperate	Humid
88	*Temuco*	38° 46'	72° 38'	114	**11.9**	n.a.	n.a.	273	9.2	255	**1270**	1428	8.9	Mesotemperate	Humid
89	*Puerto Saavedra*	38° 46'	73° 24'	5	**12.3**	12.7	6.5	315	6.2	267	**1182**	1476	8.0	Mesotemperate	Humid
90	*Puerto Dominguez*	38° 54'	73° 14'	5	**11.5**	13.0	4.5	290	6.6	246	**1581**	1380	11.5	Mesotemperate	Humid
91	*Loncoche*	39° 33'	72° 38'	115	**12.5**	11.8	3.3	276	10.8	274	**2139**	1500	14.3	Mesotemperate	Perhumid
92	Central Pullinque	39° 35'	72° 13'	145	**10.6**	n.a.	n.a.	230	9.5	215	**2096**	1272	16.5	Mesotemperate	Perhumid
93	*Valdivia*	39° 48'	73° 14'	5	**12.2**	11.0	4.7	279	9.3	262	**2532**	1464	17.3	Mesotemperate	Perhumid
94	*Punahue*	39° 51'	72° 03'	230	**10.8**	10.6	3.3	247	8.2	219	**2035**	1296	15.7	Mesotemperate	Perhumid
95	*Punta Galera*	40° 01'	73° 44'	40	**11.3**	11.3	6.4	290	4.8	228	**2077**	1356	15.3	Mesotemperate	Perhumid
96	*Futrono*	40° 07'	72° 23'	150	**13.9**	10.5	7.9	323	9.5	308	**1641**	1668	9.8	Thermotemperate	Humid
97	*La Unión*	40° 15'	73° 02'	29	**11.5**	10.8	3.6	259	9.2	241	**1267**	1380	9.2	Mesotemperate	Humid
98	*Rio Bueno*	40° 19'	72° 55'	58	**11.3**	10.8	3.6	257	9.5	242	**1235**	1356	9.1	Mesotemperate	Humid
99	*Osorno*	40° 35'	73° 09'	24	**12.5**	11.4	2.8	267	10.3	260	**1217**	1500	8.1	Mesotemperate	Humid
100	*Remehue*	40° 35'	73° 09'	73	**11.4**	11.4	3.2	260	8.9	239	**1383**	1368	10.1	Mesotemperate	Humid
101	*Purranque*	40° 55'	73° 01'	58	**10.9**	10.0	3.0	239	9.1	220	**1542**	1308	11.8	Mesotemperate	Humid
102	*Frutillar*	41° 07'	72° 59'	139	**10.3**	9.8	3.1	232	8.3	205	**1659**	1236	13.4	Mesotemperate	Perhumid
103	*Puerto Montt-El Tepual*	41° 26'	73° 07'	88	**10.7**	10.5	4.1	253	7.2	215	**2021**	1284	15.7	Mesotemperate	Perhumid
104	*Puerto Montt*	41° 28'	72° 57'	5	**11.2**	10.8	4.6	266	7.8	234	**2342**	1344	17.4	Mesotemperate	Perhumid
105	*Maullín*	41° 37'	73° 35'	47	**10.9**	11.1	4.0	260	7.2	222	**1890**	1308	14.5	Mesotemperate	Perhumid
106	*Punta Corona*	41° 47'	73° 52	56	**10.7**	10.3	5.5	265	5.5	210	**2411**	1284	18.8	Mesotemperate	Perhumid

Table 1. Continued.

	Station	Lat. S	Long.W	Alt.	T	M	m	It	Ic	Itc	P	Tp	Io	Bioclimatic Belt	Ombrotype
107	*Pudeto*	41° 54'	73° 48'	11	**11.0**	10.3	3.5	248	7.8	216	**1809**	1320	13.7	Mesotemperate	Perhumid
108	*Morro Lobos*	42° 04'	73° 24'	70	**9.5**	9.4	4.3	232	6.7	189	**2446**	1140	21.5	Mesotemperate	Perhumid
109	*Castro*	42° 29'	73° 48'	80	**11.6**	10.9	2.3	248	8.6	224	**1599**	1392	11.5	Mesotemperate	Humid
110	*Quellón*	43° 10'	73° 43'	4	**10.6**	9.2	4.3	241	7.6	207	**2048**	1272	16.1	Mesotemperate	Perhumid
111	Futaleufú	43° 12'	71° 52'	330	**9.2**	n.a.	n.a.	160	11.8	160	**2253**	1104	20.4	Supratemperate	Perhumid
112	*Isla Guafo*	43° 34'	74° 45'	140	**9.7**	9.0	5.3	240	5.3	183	**1409**	1164	12.1	Mesotemperate	Humid
113	*Melinka*	43° 54'	73° 46'	5	**10.0**	10.0	4.6	246	6.0	196	**3138**	1200	26.2	Mesotemperate	Ultraperhumid
114	*Rio Cisnes*	44° 45'	72° 00'	700	**7.6**	4.3	-4.7	72	13.1	72	**702**	912	7.7	Supratemperate	Humid
115	*Puerto Aysén*	45° 24'	72° 42'	10	**9.1**	7.3	2.4	188	8.7	165	**2973**	1092	27.2	Supratemperate	Ultraperhumid
116	*Coyhaique*	45° 29'	71° 33'	140	**9.0**	5.9	-0.2	147	10.3	140	**1164**	1080	10.8	Supratemperate	Humid
117	Coyhaique-E.Agrícola (*)	45° 34'	72° 01'	343	**8.2**	n.a.	n.a.	124	11.6	124	**1190**	984	12.1	Supratemperate	Humid
118	*Balmaceda*	45° 54'	71° 43'	520	**7.3**	3.5	-3.8	70	12.1	70	**572**	876	6.5	Supratemperate	Humid
119	Chile Chico	46° 36'	71° 43'	383	**10.0**	7,6	-1.5	161	13.5	161	**355**	1200	3.0	Supratemperate	Dry
120	Cabo Raper (+)	46° 50'	75° 36'	40	**9.0**	n.a.	n.a.	224	4.9	163	**1925**	1080	17.8	Supratemperate	Perhumid
121	San Pedro	47° 43'	74° 55'	22	**8.8**	n.a.	n.a.	206	6.4	160	**4294**	1056	40.7	Supratemperate	Ultraperhumid
122	*Puerto Edén* (+)	49° 08'	74° 25'	11	**7.1**	n.a.	n.a.	127	8.7	104	**3033**	852	35.6	Supratemperate	Ultraperhumid
123	*Cerro Guido*	50° 55'	72° 30'	815	**7.7**	4.0	-3.2	85	12.8	85	**275**	924	3.0	Supratemperate	Dry
124	Rio Paine (+)	51° 11'	72° 58'	46	**7.7**	n.a.	n.a.	137	9.0	117	**802**	924	8.7	Supratemperate	Humid
125	Puerto Consuelo	51° 35'	72° 40'	20	**7.0**	n.a.	n.a.	94	10.9	93	**605**	840	7.2	Supratemperate	Humid
126	Punta Dungenes	52° 23'	68° 25'	5	**7.2**	n.a.	n.a.	128	8.5	103	**273**	864	3.2	Supratemperate	Dry
127	*Islote Evangelista*	52° 24'	75° 06'	55	**6.2**	5.9	2.4	145	4.6		**2657**	744	35.7	Thermoboreal	Ultraperhumid
128	*Oazy Harbour*	52° 30'	70° 33'	90	**5.6**	2.4	-3.5	45	10.5	40	**255**	678	3.8	Orotemperate	Subhumid
129	*Kampenaike*	52° 41'	70° 54'	12	**6.5**	3.7	-1.4	88	10.0	78	**302**	780	3.9	Orotemperate	Subhumid
130	*Cerro Sombrero* (+)	52° 44'	69° 19'	110	**6.8**	n.a.	n.a.	84	10.5	79	**237**	816	2.9	Supratemperate	Dry
131	Chabunco (+)	53° 00'	70° 50'	33	**6.2**	n.a.	n.a.	86	9.3	69	**364**	744	4.9	Orotemperate	Subhumid
132	*Punta Arenas*	53° 10'	70° 54'	8	**6.7**	4,4	-0.3	108	9.1	89	**416**	804	5.2	Supratemperate	Subhumid
133	Porvenir Radio (+)	53° 18'	70° 23'	40	**6.4**	n.a.	n.a.	90	9.9	79	**330**	768	4.3	Orotemperate	Subhumid
134	Cameron (+)	53° 38'	69° 39'	50	**5.3**	n.a.	n.a.	73	8.7		**477**	636	7.5	Mesoboreal	Humid
135	*San Isidro*	53° 47'	70° 58'	20	**5.9**	4.6	0.1	106	6.7		**849**	708	12.0	Thermoboreal	Humid
136	Puerto Williams	54° 56'	67° 38'	36	**5.5**	n.a.	n.a.	85	7.5		**575**	660	8.7	Mesoboreal	Humid
137	*Isla Navarino*	55° 10'	67° 03'	8	**6.0**	4.8	-0.5	103	7.2		**448**	720	6.2	Thermoboreal	Humid
138	*Mataveri (I. de Pascua)*	27° 01'	109° 26'	41	**20.4**	21.3	15.0	567	5.1		**1091**	2448	4.5	Thermotropical	Subhumid
139	*Juan Fernández*	33° 37'	78° 52'	5	**15.2**	14.8	9.2	392	6.9	351	**922**	1824	5.1	Thermomediterranean	Subhumid
140	*Base Antártica Gabriel González Videla*	64° 49'	62° 52'	10	**-3.3**	-6.3	-11.7	-213	11.4		**660**	40	24.0	Cryodesertic	Perhumid

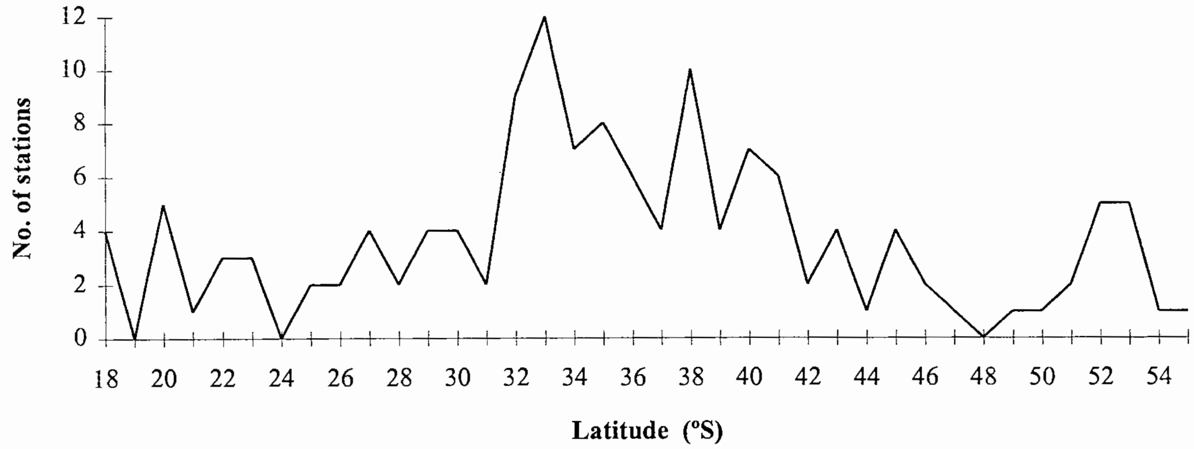

Figure 1. Plot showing variation in the number of weather stations with latitude in Chile.

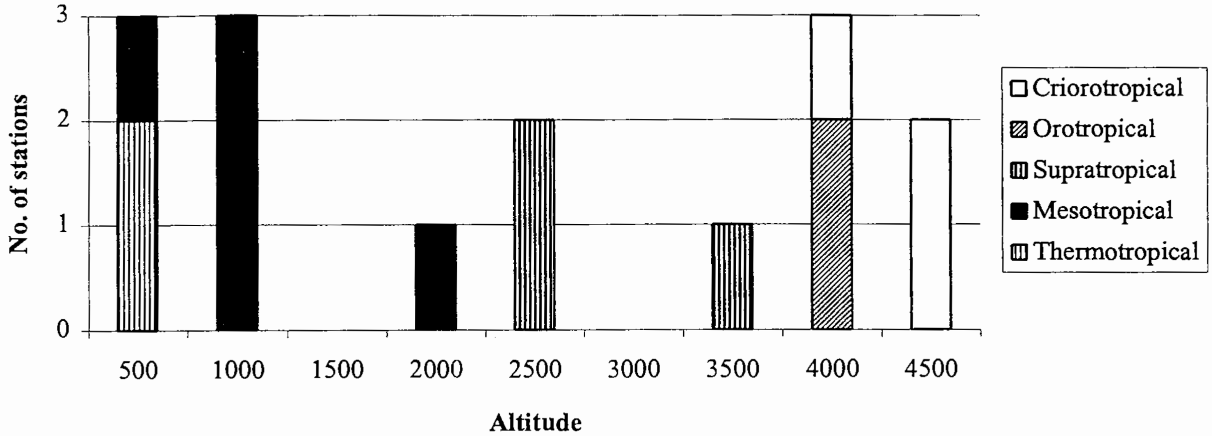

Figure 2. Classification of the 15 weather stations in the Tropical zones by altitude and bioclimatic belt. The altitude indicated under each bar is the maximum of the corresponding range.

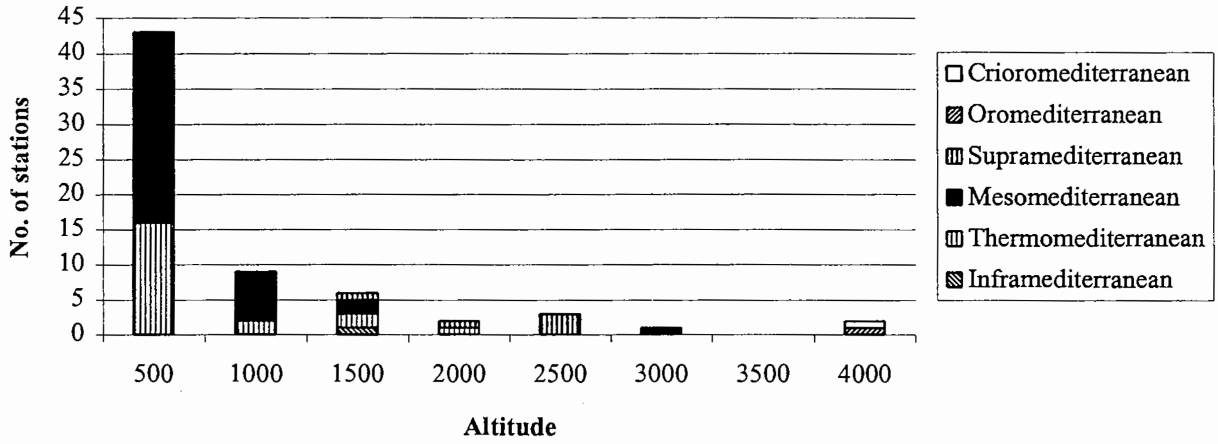

Figure 3. Classification of the 66 weather stations in the Mediterranean zones by altitude and bioclimatic belt. The altitude indicated under each bar is the maximum of the corresponding range.

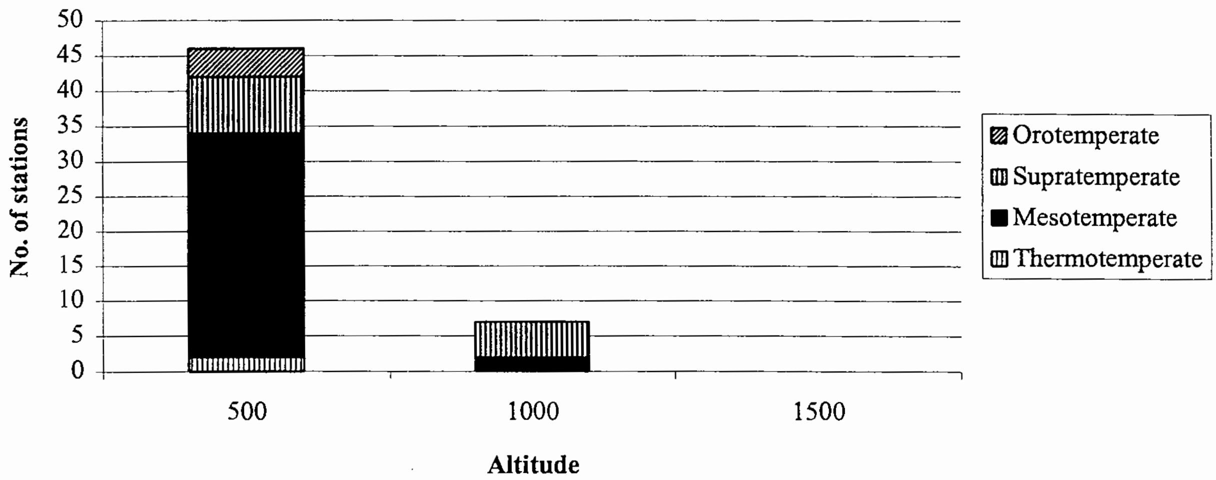

Figure 4. Classification of the 53 weather stations in the Temperate zones by altitude and bioclimatic belt. The altitude indicated under each bar is the maximum of the corresponding range.

Discussion

In what follows we focus on the Temperate Zone of Chile, since this area is that for which we have the most complete information as regards vegetation.

Tropical/Mediterranean boundaries

These two regions are basically distinguished by the rainy season, in summer in the Tropical Zone and in winter in the Mediterranean Zone. This difference is apparent even when the very arid stations of the northern coast are considered. Nevertheless, our estimate of the position of this boundary should be considered as only approximate, since there are very few weather stations between 18° and 30° S, and since we have little first-hand experience of the vegetation of this region. Recently, Squeo et al. (1994) have suggested that the summer/winter rainfall boundary lies between 24° and 25° S, though examination of their Figure 1 (Squeo et al., op. cit.: 4) in fact suggests that the boundary should be located in a similar position to that mapped in the present study (see Figure 5).

The higher-altitude areas of the Oro- and Cryorotropical Belts contain vegetation types which are probably useful discriminants with respect to the Mediterranean Zone, notably *Parastrephion lepidophyllae* of the Class *Calamagrostietea vicunarum*, and *Wernerion pygmeae* of the Class *Plantagini rigidae-Distichietea muscoides* (Navarro, 1993). Stands of these communities are known locally as 'tolares' and 'bofedales' respectively.

Temperate/Mediterranean boundaries

The fundamental difference between the Mediterranean and Temperate macrobioclimates is the occurrence in the former of a summer drought of at least two months' duration. In Chile, we have marked out the northern limits of the Temperate Zone by considering climax *Lithraeo-Cryptocaryetea* formations to be Mediterranean. On this criterion, the Mesomediterranean Belt extends south through the Intermediate Depression as far as the Bio-Bio River (in fact slightly south of this line, to the Malleco River; see Figure 8); south of this limit, the presence of *Nothofago-Perseetum lingue* as potential vegetation (currently highly degraded) indicates a Temperate bioclimate. The U shape of the Temperate/Mediterranean boundary (see Figure 6) is attributable to the northwards extension of Temperate conditions along the Cordillera de Nahuelbuta in the west and the Andes in the east, though the boundary drops southwards again on the coast, where the potential vegetation of the sandy-soiled areas around the mouth of the Bio-Bio and the Gulf of Arauco is probably humid sclerophyllous woodland of clearly Mediterranean character. Similarly, Punta Lavapié (station 77) and Santa María Island (station 76) show sufficient summer drought for classification as Mediterranean. Likewise, Lebu (a station not included in Table 1 because less than 7 years' data are available; see Hajek et al., op. cit.) should be included in the Mediterranean Zone.

Although little information is available, the coastal strip running south from Lebu to the border of Bío-

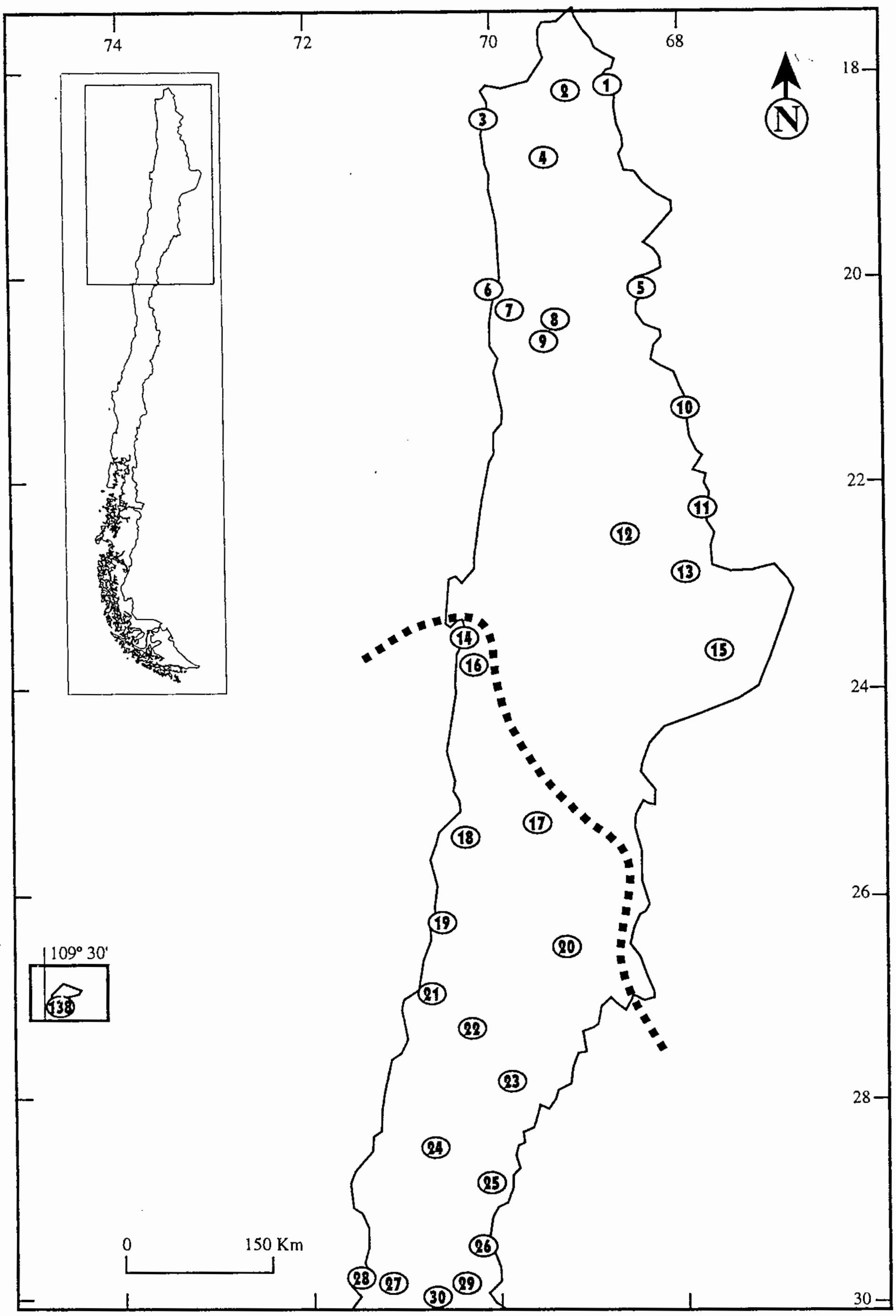

Figure 5. Map showing the locations of the 140 weather stations (see Table 1), and the Tropical/Mediterranean boundary.

Bío with La Araucanía should probably considered as Thermotemperate (I_t > 300). However, more detailed analysis of vegetation characteristics is necessary to confirm this conclusion. Certainly, *Nothofagus obliqua* formations continue to occur north of the Bio-Bio River in the Coastal Cordillera, though

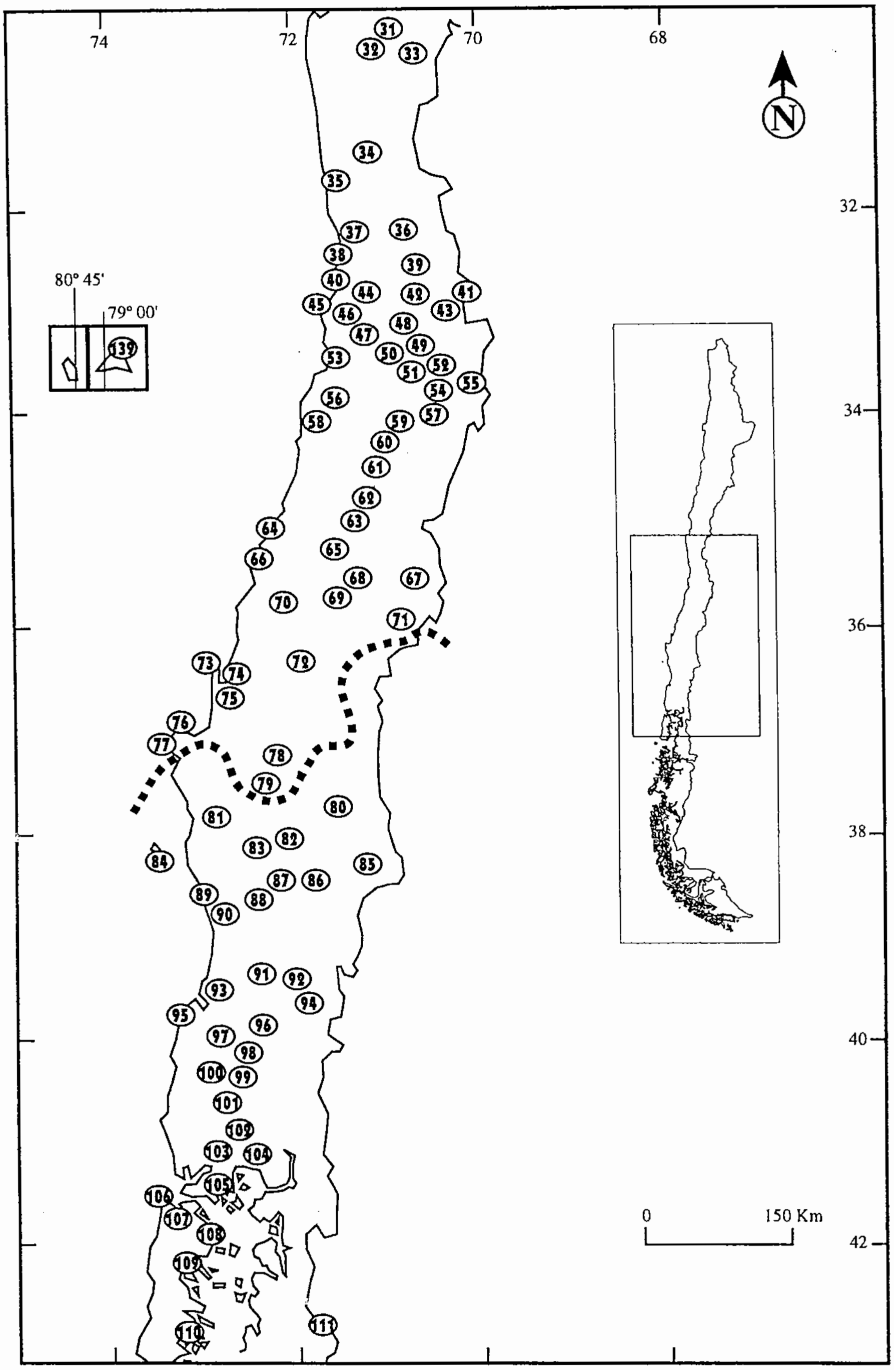

Figure 6. Map showing the locations of the 140 weather stations (see Table 1), and the Mediterranean/Temperate boundary.

the present-day landscape is largely occupied by pine and eucalypt plantations. These formations probably correspond to those described by Oberdorfer (op. cit.) as *'Nothofago-Perseetum boldetosum'*, though as we move north *N. obliqua* is increasingly restricted to habitats with high soil moisture, forming part of communities such as the Mirtaceae woodland of swampy azonal soils which is the increasingly threatened hab-

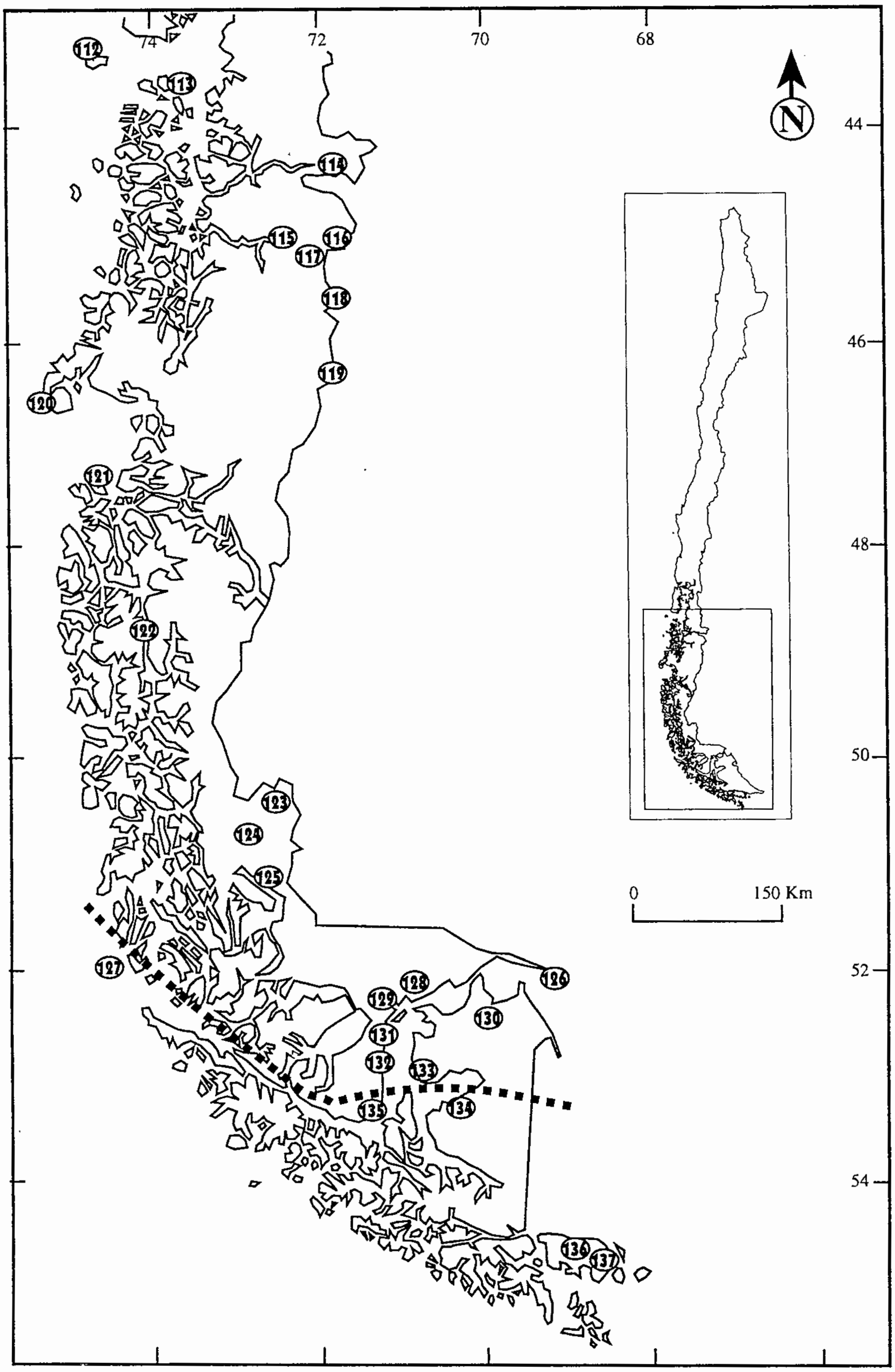

Figure 7. Map showing the locations of the 140 weather stations (see Table 1), and the Temperate/Boreal boundary.

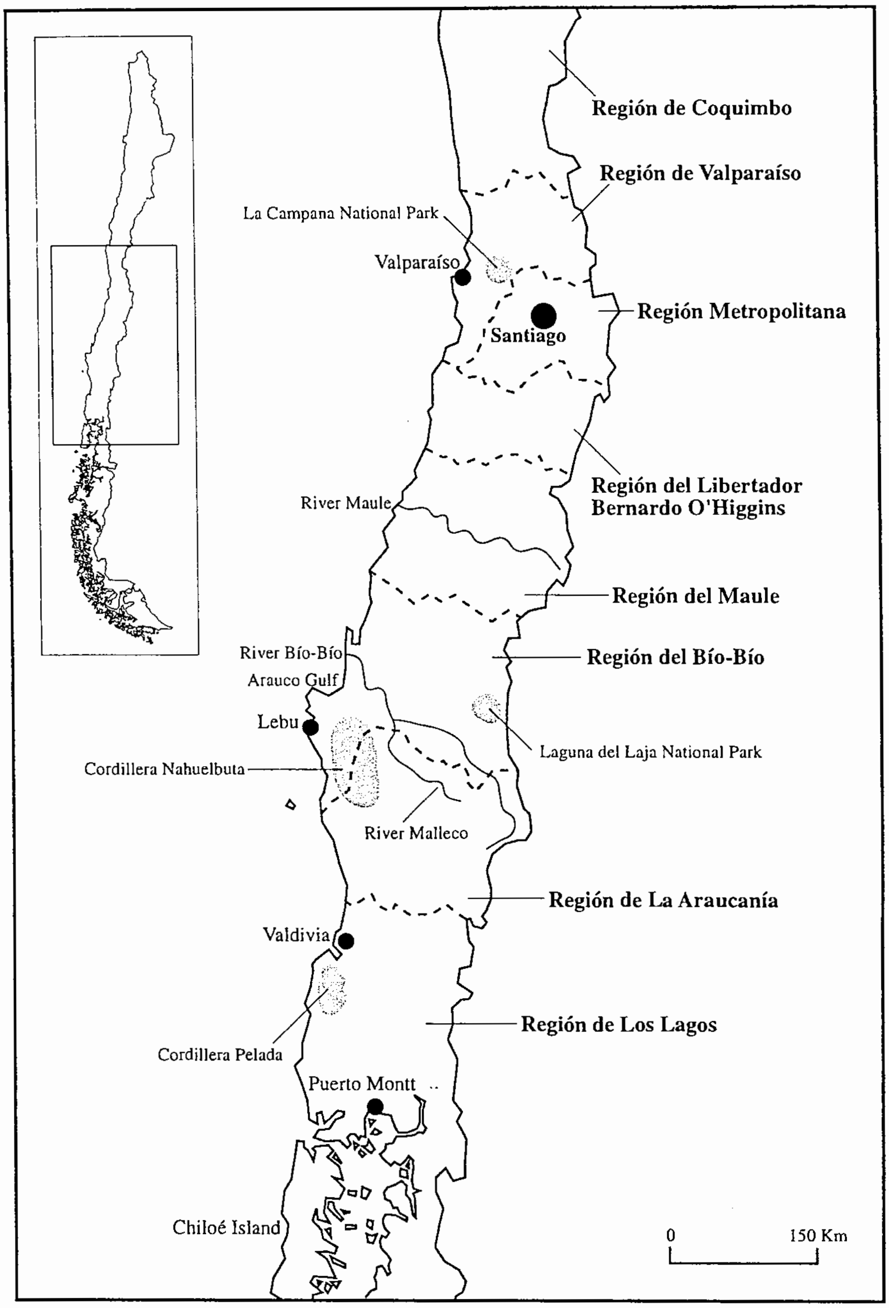

Figure 8. Map of Central-Southern Chile showing administrative regions and indicating some of the locations mentioned in the text.

itat of *Gomortega keule* (San Martín et al. 1995). Such communities should be considered as 'islands' of vegetation of Temperate-Zone origin, representing relicts of the northward expansion of Temperate-Zone vegetation during the Quaternary glaciations (Stuessy et al. 1995). The distribution of *Nothofagetum alessandri*, restricted to the Maule Region (San Martín et al. 1984) can probably be explained in the same way.

Inland, the Mediterranean-Temperate boundary extends further north than on the coast: specifically, as far as the mountainous area at the head of the River Maule. The presence of woodlands dominated by *Nothofagus obliqua*, *N. alpina* and/or *N. dombeyi*, together with other species representative of the Valdivian region (notably, species characteristic of the Alliance *Nothofago-Eucryphion*), marks the entry into first the Mesotemperate and then the Supratemperate Belts. Again, it should be stressed that the important discriminants are communities, not individual species. Woodland formations containing *Nothofagus alpina* and *N. dombeyi* are present to the north of the River Maule, but in association with more Mediterranean taxa such as *N. obliqua* var. *macrocarpa* or, at lower altitudes, arborescent species of the Alliance *Cryptocaryon albae*. These communities clearly merit further study.

Foothill communities of *Nothofagus glauca* should be considered Mediterranean, as should *ciprés* woodlands containing sclerophyllous species. Phytosociological analysis of the ecological behaviour of these species will be very important for clarifying the extent of this territory as a whole. *Ciprés* communities are without doubt Mediterranean, though communities dominated by this species extend south into the Supratemperate Belt where conditions are favourable (northerly aspect, markedly dry soils). A clear example of such behaviour is the community of *ciprés*, *radal* and *radal enano* occurring on the rocky northern slopes of the Antuco Volcano in the Laguna del Laja National Park (see Figure 8).

Nothofagus obliqua var. *macrocarpa* is a special case. *Nothofagus obliqua*, like the rest of the species of this genus in South America, is basically a Temperate taxon. Nevertheless, the variety *macrocarpa* (which in our opinion should be accorded at least subspecies status) appears to have become specialized to occupy sites in mountainous areas with high rainfall but a Mediterranean-type summer; indeed, its presence in the Supramediterranean Belt in the La Campana National Park represents the northern limit of the distribution of the genus *Nothofagus* in South America (Villaseñor et al. 1983). The community defined by Oberdorfer (1960) as *Elymo andini-Nothofagetum obliquae* (*macrocarpae*) is probably a good indicator of the Supramediterranean Belt, though note that Oberdorfer's original description was based on very few inventories, and that it is not currently clear whether this community should be considered to include all *Nothofagus obliqua* var. *macrocarpa* formations.

Temperate/Boreal boundaries

The transition from Temperate to Boreal means lower temperatures, as reflected both in the low overall temperatures for the year as a whole (T_p) and in the low temperatures reached during the summer. The analysis which follows of the vegetation at the Temperate/Boreal transition is based on information in the literature, since we ourselves have no data on the vegetation of these areas; our conclusions in this regard may thus be modified in the future as more detailed data become available. Our principal source of information on the Magellanic vegetation has been Pisano (1977, 1981).

There are no weather stations in the more westerly islands between the 48th and 52nd parallel, so that it is difficult to define the north-south limit between these two macrobioclimates. At station 121 (located at about 47°43′ S), temperature regime is very close to that defining Boreal *sensu* Rivas-Martínez (1993), while temperature regime at station 127 (52°24′ S) is clearly Boreal. Given these data and in view of the findings of Pisano (op. cit.), we consider that on Chile's western islands the peat-bog communities of the association *Donatietum fascicularidis* (which require a Perhumid or Ultraperhumid rainfall regime) should be considered indicative of Boreal conditions. Note, however, that this same association occurs in the Temperate Zone inland, at Ultraperhumid sites of the Supratemperate Belt (see Ramirez 1968).

On the other hand, it seems clear that the associations which Pisano (1977) denominated 'Turbal Juncáceo Elevado' (*Marsippospermetum grandiflori*) and 'Matorral costero de *Fuchsietum magellanici*' are Boreal. The same is certainly true of Pisano's 'Estepa Patagónica' (*Festuca gracillima-Chiliotrichum diffusum*) and 'Matorral Psammófito' (*Lepidophylletum cupressiformis*).

The woodland formations *Nothofagetum pumilionis* and *Nothofago betuloides-N. pumilio* need to be studied in greater detail, to determine whether they contain variants or subcommunities that should be defined as Boreal. The association *Nothofago betuloides-Drymidetum winteri*, reported by Pisano (op. cit.) to be the most southerly of the Magellanic woodland formations, is even more likely to contain Boreal variants.

Community diversity in the Chilean Temperate Zone

In what follows we restrict attention to climax woodland communities of the Chilean Temperate Zone. This should not be interpreted to mean that the numerous sub-climax communities described to date (such as scrub communities arising after degradation of woodland, and grassland and nitrophilous communities of anthropogenic origin) are without value as bioclimatic indicators, though in many cases a more detailed knowledge of distribution and floristic composition is necessary.

Class *Drymido winteri-Nothofagetea*

There is a reasonable amount of information available about *roble-laurel-lingue* woodland (*Nothofago obliquae-Perseetum lingue*) (see San Martín et al. 1991) and *olivillo* woodland (*Lapagerio roseae-Aextoxiconetum punctati*) (see Ramírez et al. 1985b). These communities are always Mesotemperate. The former is adapted to Humid rainfall regimes (as occurring throughout much of the Intermediate Depression in the Regions of Araucanía and Los Lagos), though it is also present in some Perhumid areas. The latter, by contrast, is restricted to Perhumid areas with precipitation of at least 1900–2000 mm per annum.

Coihue-ulmo woodlands (*Nothofago dombeyi-Eucryphietum cordifoliae*) and *raulí* woodlands (*Nothofagetum alpinae*) are probably almost exclusively Mesotemperate. The subassociation *Nothofago-Eucryphietum* subass. *saxegotheetosum conspicuae*, described by Oberdorfer (op. cit.), appears to occur in wetter areas than the typical subassociation, and is probably tolerant of a degree of continentality, since it occurs principally in the foothills of the Andes. *Nothofagetum alpinae* may occur at lower levels of the Supratemperate Belt in the Andes, and a more detailed study of this syntaxon over its entire area of distribution would probably reveal clear subdivisions.

Tepa-tineo woodland (*Laurelio philippianae-Weinmanietum trichospermae*) should be considered as Supratemperate, at least in the case of the syntaxon described as *Laurelio-Weinmanietum* subass. *phyllesietosum magellanicae*. There is however another subcommunity (only partially corresponding to *Laurelio-Weinmanietum* subass. *luzuriagetosum erectae*) which may occur in the upper Mesotemperate Belt, as on Chiloé Island and at certain sites in the coastal cordillera south of Valdivia. The subassociation *phyllesietosum magellanicae* occurs in Ultraperhumid areas (Villagran, 1980).

Coihue woodland (*Chrysosplenio valdivici-Nothofagetum dombeyii*) appears to show similar ecological behaviour to *tepa-tineo* woodland, though it extends north of the Los Lagos Region along the Andes. It typically occurs in Ultraperhumid areas of the Supratemperate Belt.

Judging by its current distribution, *alerce* woodland (*Fitzroyetum cupressoidis*) is a community of Ultraperhumid Supratemperate areas. However, it may occur in drier areas if soil moisture is sufficient, and has even been recorded from peat bogs (Veblen et al. 1976). This is probably the chief explanation for its presence in Perhumid parts of the Mesotemperate Belt, such as the Maullín Basin to the west of Puerto Montt, where it previously covered large areas but has now almost disappeared (Hildebrand-Vogel et al. 1995).

Guaitecas *ciprés* woodland (*Pilgerodendronetum uviferae*) is restricted to peat-derived soils, and its distribution thus reflects that of *Sphagnum spp.* communities. It occurs in the upper Mesotemperate or Supratemperate Belt, in Perhumid or Ultraperhumid areas. It would be of interest to compile information as regards the presence of this community in the southern part of its range, since it appears to occur right at the Temperate/Boreal boundary (Reiche 1907, in Oberdorfer 1960, Table 29).

Chiloé *coihue* woodland (*Nothofagetum nitidae*) is an association of the upper Mesotemperate Belt, though at the northern limits of its distribution (Cordillera Pelada; see Vasquez 1994) it may occur in the lower Supratemperate Belt. Judging by its present-day distribution, this association is characteristic of Ultraperhumid areas with oceanic climate.

Magellan's *coihue* woodland (*Nothofagetum betuloides*) should be mentioned, though bearing in mind that this name is currently used to refer to a number of distinct woodland communities. Woodlands of this type occur from the islands of Cape Horn in the Boreal Zone to as far north as the Cordillera Pelada (40°05′ S); a more detailed analysis is thus clearly necessary. Within the Temperate Zone, woodlands containing Magellan's *coihue* occur in Perhumid areas of the Supratemperate and Orotemperate Belts.

Class *Nothofagetea pumilionis-antarcticae*

This phytosociological class was defined by its author (Oberdorfer, op. cit.) in relation to the broad-leaved (largely deciduous) and narrow-leaved woodlands of Andean-Subantarctic regions. We have preferred not to split this class in two (to give *Nothofagetea pumilionis* and *Nothofagetea antarcticae*, as suggested by Freiberg 1985), since maintaining consistency with Oberdorfer's scheme facilitates use of his vegetation data. Throughout this article, however, we have cited syntaxon names in accordance with the International Code of Phytosociological Nomenclature (Barkman et al. 1976) (for example, *Nothofago dombeyi-Eucryphietum*, as opposed to Oberdorfer's original *Dombeyo-Eucryphietum*).

Lenga-dominated woodland (*Anemono antucensis-Nothofagetum pumilionis*) cover the greatest latitudinal range of any woodland type in the southern hemisphere. Recently, it has been suggested that *lenga* woodland should be viewed as comprising a number of separate associations (Hildebrand-Vogel et al. 1990). Within the Temperate Zone, *lenga*-dominated woodland occurs in the Orotemperate Belt; large expanses of these formations dominate the landscape to the south of the 46th parallel, and extend to the timberline in the Andes as far north as the Vilches Reserve in the Maule Region (San Martín et al. 1991). To the north of the Aysén Region, however, *lenga* may occur with other tree species characteristic of lower altitudes (such as *Nothofagus obliqua* var. *macrocarpa* in the north, or *N. dombeyi* in the Los Lagos Region). In such locations the formations in question must be interpreted as upper Supratemperate. *Lenga*-dominated woodlands are able to withstand considerable continentality, and occur in areas with rainfall regime ranging from Humid (on the leeward side of the cordillera, to the south of Coyhaique) to Ultraperhumid.

Araucaria woodland (*Carici trichodes-Araucarietum araucanae*) occurs in both the upper Supratemperate Belt and the Orotemperate Belt, where (in the Bio-Bio and La Araucanía Regions) it grades into *lenga* woodland. Along the Chilean side of the Andes and in Nahuelbuta, it occurs mainly in areas with Ultraperhumid rainfall regime, though on the Argentine side it occurs in merely Humid areas (Montaldo 1974).

Ñirre woodland (*Nothofagetum antarcticae*) is another heterogeneous grouping, and more information is needed to characterize it correctly. The ecological amplitude of this formation allows its to occupy soils ranging (in the context of the Chilean Temperate Zone) from badly drained to xeric, and to extend over an area stretching from Magellanes to the Maule Region (Ramírez et al. 1985a). *Ñirre* formations occur from the Mesotemperate to the Orotemperate Belt, in rainfall regimes ranging from Dry to Perhumid. Such extreme ecological amplitude clearly indicates the existence of various associations, and it will only be possible to discriminate these associations effectively on the basis of phytosociological, phytogeographical and edaphic data covering the full geographical range of *ñirre*-dominated formations.

Finally, *temo-pitra* woodland (*Blepharocalyci-Myrceugenietum excsuccae*) is a strictly hygrophilous community, and thus of limited value as a bioclimatic indicator; furthermore, it is clearly debatable whether this community belongs to *Nothofagetea pumilionis-antarcticae*. These communities ('hualves') are known largely from the Mesotemperate Belt (Ramírez et al. 1996), and have even been cited in the Mediterranean Zone from an area of Humid rainfall regime (between Concepción and Talcahuano; Reiche, 1907).

Conclusions

The application of the bioclimatic classification system of Rivas-Martínez (1981, 1987, 1993) to the Chilean region, as to the Iberian Peninsula, allows the identification of a series of bioclimatic belts defined by temperature and rainfall regime. The extreme latitudinal extent of Chile means that it contains all five macrobioclimates: namely Tropical (from the frontier with Peru to 23–28°S), Mediterranean (from 23–28°S to 35–38°S), Temperate (from 35–38°S to 52–56°S), Boreal (the Magellanic area, south of 52–56°S) and Polar (Antarctic territories basically).

Many associations have distributions which are closely correlated with the above zonation, and with the subzonations defined by temperature and rainfall regime. Of the fifteen climax woodland associations defined by Oberdorfer (1960) for the territory which we denominate Temperate, we consider *Lapagerio-Aextoxiconetum* and *Nothofago-Perseetum* to be indicators of the Mesotemperate Belt, *Chrysosplenio-Nothofagetum dombeyi* and *Fitzroyetum cupressoidis* to be indicators of the Supratemperate Belt, and *Anemono-Nothofagetum pumilionis* to be an indicator of the Orotemperate Belt. As regards rainfall regime, *Nothofago-Perseetum* almost always occurs in Humid areas, *Nothofagetum alpinae* and *Lapagerio-Aextoxiconetum* in Perhumid areas, and *Fitzroyetum cupressoidis* and *Nothofagetum nitidae* in Ultraperhumid areas. Other associations occur in two or more bioclimatic belts or rainfall regimes, but are still useful indicators. As more information becomes available about the plant communities of the Temperate Zone of Chile, it should be possible to develop a more complete understanding of the indicator potential of such communities. The concepts of *Nothofagetum pumilionis* and *Nothofagetum antarcticae*, for example, clearly correspond not to single associations but to various communities with a common physiognomy reflecting the dominant species.

In view of the above, it is clearly important to collect the maximum possible amount of phytosociological data, with the aim of characterizing the real diversity of Chile. The correlation between climatic conditions and plant communities is much closer than that between climate and the distribution of individual species, this being true not just of the Temperate Zone but also of the other macrobioclimatic zones of Chile.

Acknowledgements

We thank Prof. Rivas-Martínez for information and suggestions as regards the biogeography of South America in general and Chile in particular; the Meteorology Department of the *Dirección Meteorológica de Chile* for some of the climatic data; Prof. José San Martín for his company during fieldwork and generous supply of information about the vegetation of the Maule Region; Luis G. Quintanilla for his help in figures drawing; and two anonymous reviewers whose comments made a valuable contribution to the final version of this article.

References

Amigo, J. & Ramírez, C. 1997?. Bibliographia Phytosociologica et Scientiae Vegetationis Chile (1983–1994). Excerpta Botanica, Sect. B: 32(1) (in press).

Artigas, J. 1975. Introducción al estudio por computación de las áreas zoogeográficas de Chile continental basado en la distribución de 903 especies de animales terrestres. Gayana, Miscelanea 4: 3–25.

Barkman, J., Moravec, J. & Rauschert, S. 1976. Code of Phytosociological Nomenclature. Vegetatio 32: 131–185.

Di Castri, F. & Hajek, E. 1976. Bioclimatología de Chile. Universidad Católica de Chile, Santiago de Chile, 128 pp.

Freiberg, H.-M. 1985. Vegetationskundliche Untersuchungen an südchilenischen Vulkanen. Bonner Geographische Abhandlungen 70: 1–170.

Fuenzalida, H. & Pisano, E. 1965. Biogeografía. In CORFO (ed.), Geografía Económica de Chile. Texto refundido: 228–267. Santiago de Chile.

Hajek, E. & Di Castri, F. 1975. Bioclimatografía de Chile. Dirección de Investigación. Rectoría Académica, Universidad Católica de Chile.

Hildebrand-Vogel, R., Godoy, R. & Vogel, A. 1990. Subantarctic-Andean *Nothofagus pumilio* forests. Vegetatio 89: 55–68.

Hildebrand-Vogel, R., Godoy, R., Vogel, A. & Carrillo, R. 1995. *Fitzroya cupressoides* (Mol.) Johnst. Primary forest of southern Chile-Flora, vegetation and mycorrhiza. Proceedings of the 35th Symposium of International Association for Vegetation Science (I.A.V.S.). East China Normal University Press. Shangai.

Huber A. 1975. Beitrag zur Klimatologie und Klimaökologie von Chile. Disertación Mecanografiada, Munich, 87 pp.

Marticorena, C. & Quezada, M. 1985. Catálogo de la flora vascular de Chile. Gayana 42: 1–157.

Ministerio De Obras Publicas. 1987. Balance hídrico de Chile. Dirección General de Aguas: 23 pp. + mapas. Santiago de Chile.

Montaldo, P. 1974. La bio-ecología de *Araucaria araucana* (Mol.) Koch. Boletín del Instituto Forestal Latinoamericano de Investigación y Capacitación 46/48: 3–55.

Navarro, G. 1993. Vegetación de Bolivia: el Altiplano meridional. Rivasgodaya 7: 69–98.

Novoa, R. & Villaseca, S. 1989. Agroclimatología de Chile. Instituto de Investigaciones Agropecuarias, M° de Agricultura. Santiago de Chile.

Oberdorfer, E. 1960. Pflanzensociologische Studien in Chile. Ein Vergleich mit Europa. Flora et Vegetatio Mundi 2: 1–208.

Pisano, E. 1955. Fitogeografía: la vegetación de las distintas zonas geográficas chilenas. Revista Geográfica de Chile, Terra Australis 11: 95–107.

Pisano, E. 1977. Fitogeografía de Fuego-Patagonia chilena. I. Comunidades vegetales entre las latitudes 52° y 56° S. Anales del Instituto de la Patagonia 8: 121–250.

Pisano, E. 1981. Bosquejo fitogeográfico de Fuego-Patagonia. Anales del Instituto de la Patagonia 12: 159–171.

Pisano, E. 1983. The Magellanic Tundra complex. Pp. 289–323. In: Gore, A. J. P. (ed.), 'Ecosystems of the World, 4. Mires: Swamp, Bog, Fen end Moor, B. Regional Studies': Elsevier Science Publishers, Amsterdam.

Quintanilla, V. 1985. Carta fitogeográfica de Chile mediterráneo. Contribuciones Científicas y Tecnológicas, 70, Area Geociencias IV: 32 pp. + mapa, Santiago de Chile.

Ramírez, C. 1968. Die Vegetation der Moore der Cordillera Pelada, Chile. Ber. Oberhess. Ges. für Natur- und Heilkunde zu Giessen, Neue Folge, Naturwissenschaftliche Abteilung 36: 95–101.

Ramírez, C. 1983. Bibliografía vegetacional de Chile. Dirección de Investigación y Desarrollo, Universidad Austral de Chile, 76 pp.

Ramírez, C., Correa, M., Figueroa, H. & San Martín, J. 1985a. Variación del hábito de *Nothofagus antarctica* en el Centro-Sur de Chile. Bosque 6: 55–73.

Ramírez, C. & Figueroa, H. 1985b. Delimitación ecosociológica del bosque valdiviano (Chile) mediante análisis estadísticos multivariados. Studia Oecologica 6: 69–82.

Ramírez, C., San Martín, C. & San Martín, J. 1996. Estructura florística de los bosques pantanosos de Chile Central. Pp. 215–234. In: Armesto, J., Kalin-Arroyo, M. T. & Villagrán, C. (eds), 'Ecología del bosque nativo de Chile'. Editorial Universitaria. Santiago de Chile.

Reiche, K. 1907. Grundzüge der Pflanzenverbreitung in Chile. Vegetation der Erde, 8: 1–374. Leipzig.

Rivas-Martínez, S. 1981. Les étages bioclimatiques de la végétation de la Péninsule Iberique. Anales del Jardín Botánico de Madrid 37: 251–268.

Rivas-Martínez, S. 1987. Memoria del mapa de Series de Vegetación de España. Publ. del ICONA, Madrid.

Rivas-Martínez, S. 1993. Bases para una nueva clasificación bioclimática de la Tierra. Folia Geobotanica Matritensis 10: 23 pp.

Rundel, P. 1981. The matorral zone of central Chile. Pp. 175–201. In: Di Castri, F., Goodall, D. W. & Specht, R. L. (eds.), 'Ecosystems of the World. Mediterranean-type shrublands'. Elsevier Science Publishers. Amsterdam.

San Martín, C., Ramírez, C., Figueroa, H. & Ojeda, N. 1991. Estudio sinecológico del bosque de Roble-Laurel-Lingue del Centro-Sur de Chile. Bosque 12: 11–27.

San Martín, J., Figueroa, H. & Ramírez, C. 1984. Fitosociología de los bosques de ruil (*Nothofagus alessandri* Espinosa) en Chile Central. Revista Chilena de Historia Natural 57: 171–200.

San Martín, J., Solervicens, J., Ramírez, C., San Martin, C. & Elgueta, M. 1995. Estudio fitosociológico de los bosques pantanosos de Mirtáceas de la Región del Maule, Chile. Ciencias Forestales 7: 3–13.

San Martín, J., Troncoso, A., Mesa, A., Bravo, T. & Ramírez, C. 1991. Estudio fitosociológico del bosque caducifolio magallánico en el límite Norte de su área de distribución. Bosque 12: 29–41.

Schmithüsen, J. 1956. Die räumliche Ordnung der chilenische Vegetation. Bonner Geographische Abhandlungen 17: 1–89.

Squeo, F. A., Osorio, R. & Arancio, G. 1994. Flora de los Andes de Coquimbo. Cordillera de Doña Ana. Ediciones Universidad de La Serena. La Serena 168 pp.

Stuessy, T. F. & Taylor, C. 1995. Evolución de la flora chilena. Pp. 85–118. In: Marticorena, C. & Rodriguez, R. (eds.), 'Flora de Chile. I. Pteridophyta-Gymnospermae'. Universidad de Concepción, Concepción.

Tomaselli, R. 1981. The longitudinal zoning of Vegetation in the southern sector of the Andes. Stuti Trentini di Scienze Naturali. Acta Biol. 58: 471–484.

Vásquez, R. E. 1994. Estudio de la flora y vegetación boscosa potencial de la Cordillera Pelada (Valdivia, Chile). Tesis Ingeniero Forestal, Facultad Ciencias Forestales, Univ. Austral, 130 pp.

Veblen, T., Delmastro, R. & Schlatter, J. 1976. The conservation of *Fitroya cupressoides* and its environment in Southern Chile. Environmental Conservation 3: 291–301.

Villagrán, C. 1980. Vegetationsgeschichtliche und Pflanzensoziologische Untersuchungen in Vicente Pérez Rosales National Park (Chile). Dissertationes Botanicae, Band 54: 165 pp.

Villaseñor, R. & Serey, I. 1983. Estudio fitosociológico de la vegetación del Cerro La Campana (Parque Nacional La Campana), en Chile Central. Atti Istituto Botanico Reale Universita Reale Laboratori Crittogamico di Pavia, ser. 6, 14: 69–91.

Appendix 1

Origin of the data for the weather stations shown in Table 1:

Reference 7: stations 7–10, 14, 18, 19, 24, 28, 30, 38–40, 43, 46–50, 52–54, 59, 61–63, 66, 68, 69, 73, 76–78, 81–85, 90, 95, 98, 99, 102, 104, 106–110, 112–114, 116, 118, 123, 135, 140.

Reference 12: stations 4, 5, 11–13, 15, 16, 23, 25, 29, 32–34, 42, 55, 67, 80, 88, 92, 111, 117, 120, 121, 124, 126, 130, 131, 133, 134, 136.

Reference 15: stations 1–3, 6, 17, 20–22, 27, 31, 35–37, 41, 44, 45, 51, 56–58, 60, 64, 65, 70, 72, 74, 75, 79, 86, 87, 89, 91, 93, 94, 96, 97, 100, 101, 103, 105, 115, 119, 127–129, 132, 137–139.

Reference 18: additional data for stations 124, 130,131, 133,134.

Reference 20: stations122, 125. Additional data for station 120.

Reference 21: station 71.

Reference 31: additional data for station 42.

Reference 37: station 26.