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Biogeographical relationships in humid forests, based on a climatic model

Abstract

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Using a climatic model which predicts vegetation types, the relationship between characteristic taxa of different humid forests has been studied. A biogeographical assay of the origin and evolution of the vegetation, especially the Mediterranean vegetation, has also been made. To complete the biogeographical correlation between the different humid forests of the world, a comparison between their floristic composition and some subfamilies of butterflies has been made.

Introduction

The tropical humid forests are distributed throughout the world, especially in the tropics, although they can currently be found in very restricted areas of the Mediterranean Region (the Canary Islands, Madeira, northern Anatolian Peninsula, and southern Iberian Peninsula). In the present study, using a climatic model, we look for the similarity between the humid forests (rain forests and laurel-type forests), establishing a comparison between their floristic composition and some subfamilies of butterflies.

Material and methods

1- The total humidity index

The total humidity index is an algorithm composed of two sums:

$$HT = HE + HI$$

HE is the summer humidity index, which is the humidity of a determined location during the 4 months after the summer solstice. In the northern hemisphere, June, July, August and September are considered, while in the southern hemisphere December, January, February, and March:

$$HE = \Sigma\ PE + HR_E / ETP_E$$

The winter humidity index (HI) is the humidity of a determined location during the 4 months after the winter solstice. In the northern hemisphere these are December, January, February, and March, while in the southern hemisphere June, July, August, and September:

$$HI = \Sigma\ PI + HR_I / ETP_I$$

Here, P is the sum of the mean rainfall of each month considered in mm, HR is the sum of the mean relative humidity of each month, and ETP is the sum of the mean potential evapotranspiration of each month in mm.

The humidity of a territory is given by the mean circulation of the atmosphere (Weischet 1983). In this sense, the Earth is divided into several belts of high and low pressures (Medina 1984), whose direction determines the humidity. This direction is molded by the continents, originating sea currents which influence the vegetation. The constant equatorial low pressure zone (intertropical convergence zone), accented in the hottest months, induces us to consider different rainfall regimes: (1) tropical, where the high rainfall occurs in summer (PE>PI), and (2) extratropical, where the high rainfall occurs in winter (PI>PE). Both regimes may not be exclusive of the belt between the Tropics of Cancer and Capricorn. For example, in Japan and southeastern China, the hot sea currents of Kuro-Shio and of the coast of China cause a tropical rainfall regime. The opposite occurs in the Peruvian-Chilean Pacific Desert, where the cold Humboldt current brings rainfall in winter and an extratropical Mediterranean regime into the tropics. Moreover the importance of the relative humidity in the air (HR) can also be observed, because the winter humidity index (HI) is higher, and the result is therophytic vegetation with Mediterranean appearance. The same occurs in some islands of savanna inside the Amazonian Basin (Galán de Mera & al. 1995).

Potential evapotranspiration (ETP) is the most important data predicting vegetation types, because it is directly related to the humidity of the soil and the radiation of the sun. ETP includes the transpiration of plants and the evaporation from soil (Lauer & al. 1996, Schultz 1995). This means, for example, that the ETP in the Tundra is lower than in a Mediterranean forest, thus these two vegetation types can be distinguished, as the humidity (HE and HI) differs greatly.

To delimit the vegetation types, the mean annual temperature (T °C), and the number of months with absolute minimal temperatures lower than zero (nma<0) have been considered. These data enable us to determine in which month the minimal vegetation grows, and also the existing limits for the transportation of crops in different areas of the world with climatic similarity (Diemer 1996).

2- Data obtaining and processing

The data of 855 meteorological stations of the world have been obtained from Müller (1982), and 205 of these (stations with complete data), were processed with the SORT 3.3 program (Durka & Ackermann 1993) to obtain a matrix (see Appendix). This matrix was processed with the SYNTAX 5.0 statistical program (Podani 1998). Considering the similarity divergences (Gower 1966), the similarity between vegetation and climate in the same locality can be observed by dendrograms (Cluster Analysis) (Fig. 1).

In Table 1 the different vegetation types used are indicated, and also the necessary climatic conditions to predict a vegetation type. 13 tropical vegetation types have been obtained- high tropical mountain with disperse periglacial vegetation (AMT), high continental tropical mountain with disperse periglacial vegetation (AMTC), coniferous forest or espinal (BAT), laurel-type forests (BL), desert (DT), steppe with deciduous trees (ET), humid high tropical mountain with long grass 'humid puna' and 'paramo' (PH), rain forests

Table 1. Climatic conditions necessary for predicting the different vegetation types.

PE > PI	TROPICAL ZONES		
HE < 1	HI < 1		Desert with tropical character (DT)
	HI > 1	HI < 1.5	Semidesert with tropical character (SMT)
	HI > 2	T > 0, nma 7-9	Steppe with tropical character and with deciduous trees (ET)
HE > 1	HI < 1	T > 0, nma > 5	Dry savanna (SS)
		T > 0, nma > 8	Dry high tropical mountain ("dry puna")(PS)
	HI > 1	T > 20, nma < 5	Humid savanna (SH)
		T < 20, nma 0-7	Laurel-type forest with tropical character (BL)
		T < 20, nma 7-9	Steppe with tropical character and with deciduous trees ("pampa") (ET)
		T > 0, nma > 9	High tropical mountain with disperse periglacial vegetation (AMT)
		T < 0, nma > 9	High continental tropical mountain with disperse periglacial vegetation (AMTC)
HE > 2	HI > 1	T > 20, nma 0	Rain forest with palm communities (PL)
		T < 20, T > 0, nma < 4	Rain forest with arborescent fern communities (PLM)
		T < 20, T > 0, nma 4-7	Coniferous forest or espinal with tropical character (BAT)
		T < 20, T > 0, nma > 7	Humid high tropical mountain with long grass ("humid puna" and "paramo") (PH)
	HI < 1	T > 0, nma < 5	Humid savanna (SH)
PI > PE	EXTRATROPICAL ZONES		
HE > 1	HI > 1	HI > 50 HE, T < 0, nma 10-12	Tundra or high mountain grasslands (T)
		HI > 50 HE, T 0-3, nma 10-12	Wooded tundra or high mountain disperse forest (TA)
		HI > 50 HE, T > 3, nma 12	Artic and subantartic disperse scrubs (MDS)
		HI > 50 HE, T > 3, nma 10-11	Taiga or coniferous forests (TG)
		HI < 50 HE, T > 0, nma < 9	Temperate deciduous forests (BCT)
		HI < 50 HE, T > 0, nma > 9	Temperate steppe with deciduous trees (ETC)
HE < 1	HI < 1		Desert with Mediterranean character (DM)
	HI 1-1.5		Semidesert with Mediterranean character (SMM)
	HI > 1.5	HI < 50, T > 0, nma < 7	Sclerophyllous vegetation with Mediterranean character (VM)
		HI < 50, T > 0, nma 7-9	Steppe with disperse scrubs with Mediterranean character (VAL)
		HI < 50, T > 0, nma > 9	High mountain grasslands with Mediterranean character (AMM)
		HI > 50, T > 0, nma > 8	Mediterranean mixed forest with coniferous and sclerophyllous vegetation (MXCE)

with palm communities (PL), rain forests with arborescent fern communities (PLM), dry high tropical mountain 'dry puna' (PS), humid savanna (SH), semidesert (SMT), and dry savanna (SS). 13 extratropical vegetation types have also been included- high mountain grasslands with Mediterranean character (AMM), temperate deciduous forest (BCT), desert with Mediterranean character (DM), temperate steppe with deciduous trees (ETC), Arctic and Subantartic disperse scrubs (MDS), mixed forest with coniferous and decidu-

Table 2. Correlation between flowering families of plants of the laurel-type forests and mountain rain forests, and butterfly subfamilies (nutritional relationship). Symbols: ● E China, ▲ South America, ■ Tropical Africa, ★ Canary Islands, ◆ Southern Iberian Peninsula, ✚ Northern Anatolian Peninsula. (references: Ehrlich & Raven, 1964., D'Abrera, 1982., Ackery, 1984., Collins & Morris, 1985., D'Abrera, 1986., Hesselbarth *& al.* 1995., Constantino, 1998).

	Aquifoliaceae	Rosaceae	Caprifoliaceae	Lauraceae	Celastraceae	Ericaceae	Theaceae	Sapotaceae	Myrsinaceae	Rubiaceae	Labiatae	Magnoliaceae	Rutaceae	Myricaceae
Parnasiinae ●▲■	*			*								*	*	
Danainae ●▲■★◆✚		*								*			*	
Papilioninae ●▲■★◆✚	*	*		*							*	*	*	
Morphinae ●▲■				*										
Charaxinae ●▲■★◆✚				*	*	*							*	
Acraeinae ●▲■		*											*	
Lycaeninae ●▲■★◆✚	*	*	*	*		*	*	*	*	*	*		*	*
Sphinginae ●▲■	*			*										*
Macroglossinae ▲										*				
Pierinae ●▲■★◆✚		*		*		*				*				
Riodininae ●▲■★◆✚	*	*						*	*				*	

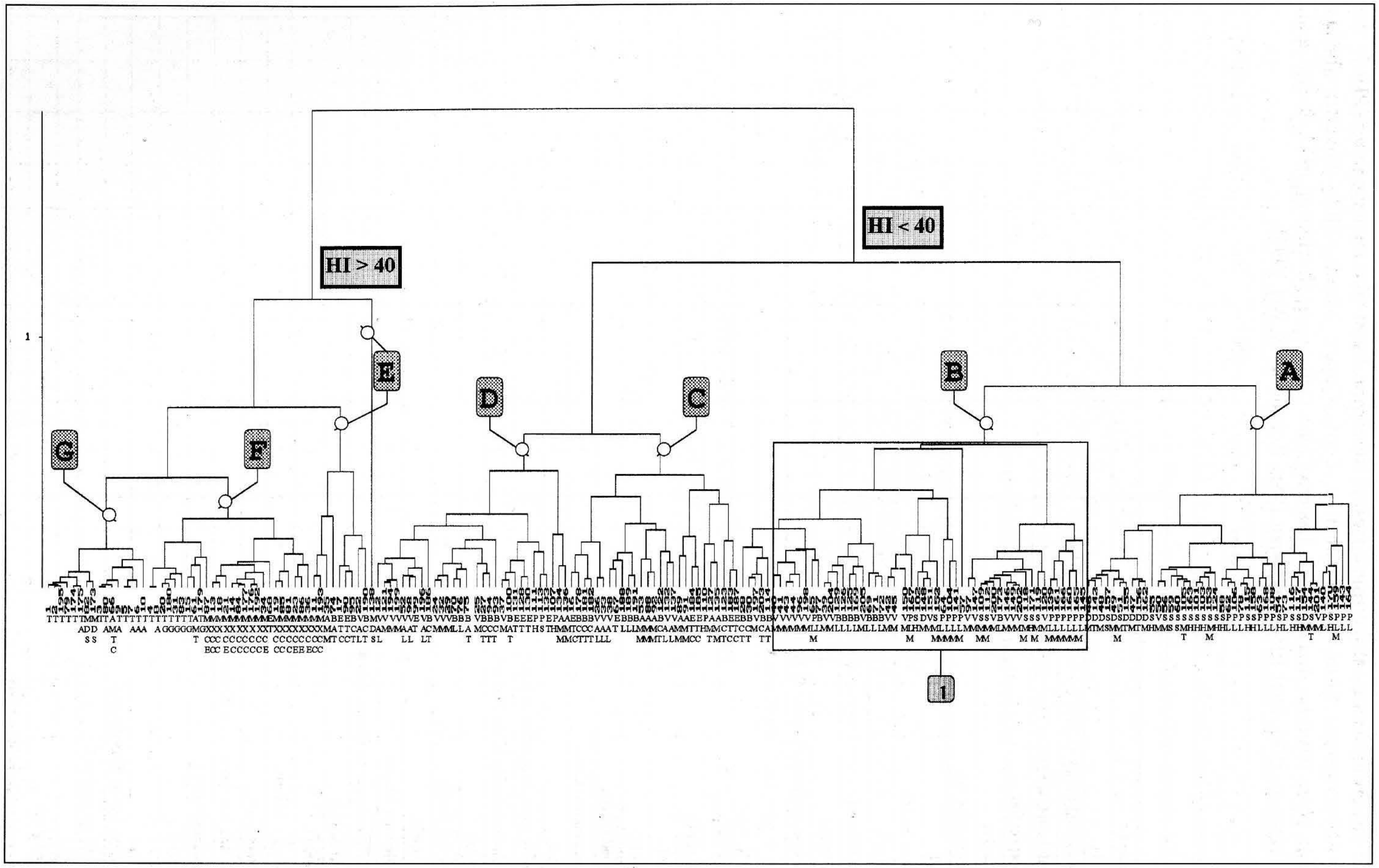

Fig. 1. Similarity dendrogram between the climate and vegetation of the meteorological stations studied. Numbers of abscissa correspond to the numbers of Appendix, and the abbreviations of the plant communities with those of Table 1.

Table 3. Presence of some characteristic taxa of laurel-type forests and montane rain forests in the world. Abbreviations: SAm- South America, CanI- Canary Islands, SPIb- Southern Iberian Peninsula, NAn- Northern Anatolia, Ech- Eastern China. (references: Hutchinson 1973, Quézel & al. 1980, Takhtajan 1981, Deil 1984, Takhtajan 1986, Hohenester & Wel 1993).

	SAm	CanI	SPIb	Aftr	NAn	ECh
Ilex L.	+	+	+	+	+	+
Prunus L.	+	+	+	+	+	+
Rubus L.	+	+	+	+	+	+
Viburnum L.	+	+	+		+	+
Myrica L.	+	+	+	+		+
Vandenboschia Copel.	+	+	+	+		+
Elaphoglossum Schott.	+	+		+		+
Woodwardia Sm.	+	+	+			+
Davallia Sm.		+	+	+		+
Hymenophyllum Sm.	+	+		+		+
Laurus L.		+	+		+	+
Diplazium Swartz	+	+	+			+
Euonymus L.			+		+	+
Rhododendron L.			+		+	+
Persea Miller	+	+				+
Polystichum setiferum (Forssk.) T. Moore		+	+		+	
Thelypteris subg. *Cyclosurus* (Link) Mort		+	+	+		
Culcita K. Presl	+	+	+			
Psilotum Swartz	+		+	+		
Ocotea Aublet	+	+		+		
Arbutus L.		+	+		+	
Begonia L.	+			+		+
Clethra Klotzsch	+	+				+
Pteris incompleta Cav.		+	+			
Visnea L.		+				+
Dryopteris guanchica Gibby & Jermy		+	+			
Polypodium macaronesicum Bobrov		+	+			
Buddleja L.	+					+
Cyathea J.E. Smith	+					+
Sideroxylon L.	+	+				
Stegnogramma Blume		+				+
Asplenium aethiopicum (Burm.) Bech.		+		+		
Rapanea Aublet	+			+		
Psychotria L.	+			+		
Bystropogon L'Herit.	+	+				
Apollonias Nees		+				
Polystichum fuscopaleaceum Alston				+		
Adiantum reniforme L.		+				
Magnolia L.						+
Citrus L.						+
Nephrolepis Schott (Davallieae)	+					
Asplenium monanthes L.		+				
Illicium L.						+
Uncaria Schreb.						+
Dryopteris oligodonta (Dsv.) Pich.		+				

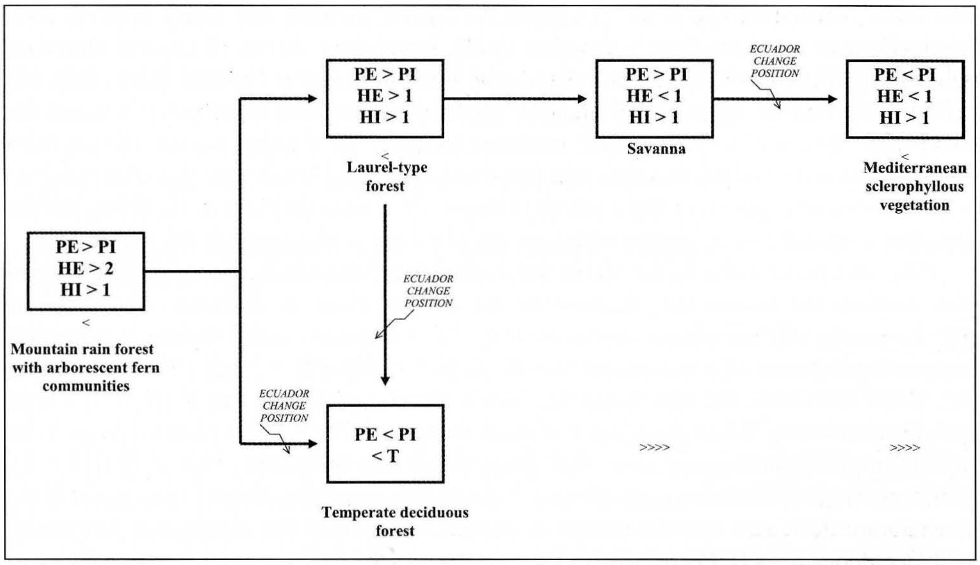

Fig. 2. Scheme of the origin of the Mediterranean sclerophyllous and temperate deciduous vegetation following the model of climatic convergence deduced from the dendrogram.

ous trees (MXCC), Mediterranean mixed forest with coniferous and deciduous trees (MXCE), semidesert with Mediterranean character (SMM), tundra or high mountain grasslands (T), wooded tundra or high mountain disperse forest (TA), Taiga or coniferous forest (TG), steppe with disperse scrubs with Mediterranean character (VAL), and sclerophyllous vegetation with Mediterranean character (VM).

Moreover, using evidence of the parallelism and coevolution between the vegetation types and groups of butterflies (Ehrlich & Raven 1964, Prance 1985), some zoogeographical relationships between the areas considered are shown (Table 2). In Table 3, there are some common genera to these forests in the different areas considered.

Results and discussion

Fig. 1 is a climatic similarity dendrogram of the meteorological stations, where the correspondence between the number of the locations used and the vegetation types of Table 1 can be observed. In this dendrogram there are two principal groups: (1) where HI > 40 (A-D) lower ETP, and (2) where HI < 40 (E-G) higher ETP. After, these branches are divided into others, considering the different thermoclimate types: *HI< 40:* A, Very hot – T 19 to 28° C, nma < 0 = 0; B, Hot – T 16 to 23° C, nma < 0 = 0 to 6; C, Fresh – T 7 to 13° C, nma < 0 = 8 to 12; D, Temperate – T 13 to 18° C, nma < 0 = 6 to 8; *HI> 40:* E, Fresh – T 5 to 12° C, nma < 0 = 7 to 12; F, Cold – T 3 to 8° C, nma < 0 = 9 to 12; G, Very cold – T –13 to 3° C, nma < 0 = 11 to 12.

What is most remarkable about the dendrogram is the convergence between climates and some vegetation types. For example, in square 1, there are many stations with Mediterranean sclerophyllous vegetation (VM), laurel-type forests (BL), and mountain rain forests (PLM), which are interrelated and found in the same thermic space, only differing in the rainfall regime. This situation allows us to establish relationship between the laurel-type forests of Eastern China, northern Anatolia, the Canary Islands, the southern Iberian Peninsula, and the montane rain forests of Africa and South America. The presence of some common species in these places is important (Galán de Mera & al. 1996), but the vicariance between some genera with laurellike biotype is more significant (Table 3).

This can give us a clue to the origin and evolution of Mediterranean vegetation, and can also explain the reason why laurel-type forests are close to savannas, and these to Mediterranean sclerophyllous vegetation (Fig. 2). A tropical rainfall regime is necessary for the development of a monuntain rain forest [(PE > PI), HE > 2 and HI > 1 (see Table 1)]. If HE decreases, the rain forest becomes a laurel-type forest, and if HE < 1, it then becomes a savanna. When the equator changes its position, PE < PI because we go far from an intertropical convergence zone. This gives origin to a sufficiently high ETP (HE < 1), which provokes a Mediterranean climate. A deciduous temperate forest is originated if the temperature decreases and the regime is extratropical. Thus, the subtropical formations with deciduous trees (ET) are close to the rain forests in the dendrogram, because they can only be distinguished by HE > 2. Here is the reason why laurel-type forests are close to savannas, and these to Mediterranean sclerophyllous vegetation.

This model agrees with Axelrod (1966) on the origin of deciduous vegetation in tropical latitudes because of the temperature drop, and also with Takhtajan (1981), who explained the similarity between the Tertiary vegetation of the Mediterranean Basin and the present one in southeastern China. In the southern Iberian Peninsula some laurel-type vegetation and some of the Tertiary savannas still persist (Schmid 1952); in deep valleys some elements of a laurel-type forest can be found (Table 3); while in the plains and mountains there is Mediterranean sclerophyllous vegetation. In the lowest zones, a clear savanna-like element still persists -*Chamaerops humilis* L.- the only natural palm in the Mediterranean Basin, which has a morphological and edaphic parallelism to *Trithrinax* C. Matius of the South America savannas, preferring limesoils. The laurel-type forests nearest to the southern Iberian Peninsula are those of the Canary, Madeira and Açores islands. Aschan & al. (1994) and Zohlen & al. (1995) have made ecophysiological studies on the laurel-type forests of Tenerife (Canary Islands). They conclude that the microclimate of these forests is comparable to that of the monuntain forests at tropical latitudes, because of the humidity of trade winds in summer which induce a low stomatal control of evaporation in plants with laurel-type leaves.

The representation of Table 2 is an example of the coevolution of communities of vegetation and butterflies. Ehrlich & Raven (1964), Castro & Vicente (1996) distinguish the preferred nutritional relationship between families of plants and families and subfamilies of butterflies, which suggest a new aspect in the evolution of humid tropical, dry and Mediterranean biomes. For example, Charaxinae can be found in all the areas considered, showing preference for botanical families which encompass relic taxa in the Mediterranean world. Thus, associations of butterflies with an ancestral aspect can also be differentiated (Downey 1962).

The total humidity index (HT) can be used for predicting biome types, including not purely physiognomic aspects, such as the significant and biogeographical relationships between the vegetal and animal constituents of tropical and subtropical humid forests.

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References

Ackery, P. R. 1984: Milkweed butterflies. — London.

Aschan, G., Jiménez, M.S., Morales, D. & Lösch, R. 1994: Aspectos microclimáticos de un bosque de laurisilva en Tenerife. — Vieraea **23:** 125-141.

Axelrod, D. I. 1966: Origin of deciduous and evergreen habits in temperature forest. — Evolution **20**: 1-15.

Castro, E. & Vicente, J. A. 1996: Algunas consideraciones sobre la taxonomía y las plantas nutricias en los *Nymphalidae* Swainson 1827, en la Península Ibérica (*Insecta: Lepidoptera*). — SHILAP Rev. Lepid. **24 (93):** 111-116.

Collins, N. M. & Morris, M. G. 1985: Threatened swallowtail butterflies of the world. The IUCN red data book. — Gland & Cambridge.

Constantino, L. M. 1998: Butterfly life history studies, diversity, ranching and conservation in the Chocó rain forests of Western Colombia (*Insecta: Lepidoptera*). — SHILAP Revta. Lepid. **26(101):** 19-39.

D'Abrera, B. 1982: Butterflies of the Oriental Region. Part 1. *Papilionidae* and *Pieridae*. — Victoria

— 1986: *Sphingidae Mundi*. Hawk moths of the world. — Oxon.

Deil, U. 1984: Zur Vegetation im Zentralen Rif (Nordmarokko). — Diss. Bot. **74**: 1-179.

Diemer, M. 1996: Microclimatic convergence of high-elevation tropical páramo and temperate-zone alpine environments. — J. Veg. Sci. **7**: 821-830.

Downey, J. C. 1962: Host-Plant relations as data for butterfly classification. — Sist. Zool. **11**: 150-159.

Durka, W. & Ackermann, W. 1993: SORT- Ein Computerprogramm zur Bearbeitung floristicher und faunisticher Artenlisten. — Natur & Landschaft. **68**: 16-21.

Ehrlich, P. R. & Raven, P. H. 1964: Butterflies and plants: a study in coevolution. — Evolution **18**: 586-608.

Galán de Mera, A., Hagen de la Cerda, M. A. & Vicente Orellana, J. A. 1995: El índice de humedad total: Un nuevo índice climático para la delimitación de la vegetación en América Latina. — Arnaldoa **3(2):** 87-98.

— , Vicente Orellana, J. A., González, J. L. & Fernández Luna, J. C. 1996: New populations of *Psilotum nudum* in SW Europe (*Psilotaceae: Pteridophyta*). — Fern Gaz. **15(3)**: 109-112.

Gower, J. C. 1966: Some distance properties of latent root and vector methods of cluster analysis. — Biometrika **53**: 315-328.
Hesselbarth, G., Van Oorschot, H. & Wagener, S. 1995: Die Tagfalter der Turkei. — Germany.
Hohenester, A. & Welβ, W. 1993: Excursionsflora für die Kanarischen Inseln. — Stuttgart.
Hutchinson, J. 1973: The families of flowering plants. — Oxford.
Lauer, W., Daud Rafiqpoor, M. & Frankenberg, P. 1996: Die Klimate der Erde. Eine Klassifikation auf ökophysiologischer Grundlage der realen Vegetation. — Erdkunde **50(4)**: 275-300.
Medina, M. 1984: Iniciación a la meteorología. — Madrid.
Müller, M. J. 1982: Selected climatic data for a global set of standard stations for vegetation science. — The Hague, Boston & London.
Podani, J. 1998: Multivariate data analysis in ecology and systematics. A methodological guide to the SYN-TAX 5.0. package. — The Hague.
Prance, G. T. 1985: The Changing forests. — Pp. 146-165 in: Prance, G. T. & Lovejoy T. E. (ed.), Amazonia (Key environments). — Oxford.
Quézel, P., Barbéro, M. & Akman, Y. 1980: Contribution à l'étude de la végétation forestière d'Anatolie septentrionale. — Phytocoenologia **8(3/4):** 365-519.
Schmid, E. 1952: Natürliche Vegetationsgliederung am Beispiel des spanischen Rif. — Veröff. Geobot. Inst. Rübel Zürich **1951:** 55-79.
Schultz, J. 1995: The ecozones of the world. The ecological divisions of the geosphere. — Berlin.
Takhtajan, A. L. 1981: Flowering Plants. Origin and Dispersal. — Koenigstein.
— 1986: Floristic regions of the World. — Berkeley.
Weischet, W. 1983: Einführung in die Allgemeine Klimatologie. — Stuttgart.
Zohlen, A., González-Rodríguez, A. M., Jiménez, M. S., Lösch, R. & Morales, D. 1995: Transpiración y regulación estomática en árboles de la laurisilva canaria medidos en primavera. — Vieraea **24:** 91-104.

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Appendix. Prediction of vegetation in the meteorological stations studied. Symbols: N- Number of station coinciding with the dendrogram, HE- Summer humidity index, HI- Winter humidity index, T- Mean annual temperature in °C, nma- months with the absolute minimal temperatures lower than 0, ve- Vegetation types.

	N	HE	HI	T	nma	ve
Ostrov Vrangel'a. Russia	1	2.3	100.0	-11.7	12	T
Dikson. Russia	2	2.4	100.0	-12.3	12	T
Bulun. Russia	3	1.3	100.0	-14.5	11	T
Archangel'sk. Russia	4	1.5	100.0	-0.6	10	T
Salekhard. Russia	5	1.5	100.0	-6.7	11	T
Murmansk. Russia	6	1.4	100.0	+0.1	11	TA
Kem'. Russia	7	1.5	100.0	+0.8	11	TA
Petrożavodsk. Russia	8	1.5	100.0	+2.6	10	TA
Vologda. Russia	9	1.6	100.0	+2.4	11	TA
Syktyvkar. Russia	10	1.4	100.0	+0.3	12	TA
Kaliningrad. Russia	11	1.6	86.1	+7.1	9	MXCC
Tbilisi. Georgia	12	0.8	12.4	+12.6	7	VAL

Tallinn. Estonia	13	1.5	100.0	+4.7	9	MXCC
Minsk. Belorussia	14	1.5	100.0	+5.3	9	MXCC
Riga. Latvia	15	1.4	100.0	+5.6	10	TG
Uzgorod. Ukraine	16	1.3	32.8	+9.3	9	ETC
Kisin'ov. Moldavia	17	1.0	49.1	+9.2	9	ETC
St. Petersburg. Russia	18	1.4	100.0	+4.2	9	MXCC
Kijev. Ukraine	19	1.2	100.0	+7.0	9	MXCC
Moskva. Russia	20	1.3	100.0	+3.6	10	TG
Kujbysev. Russia	21	0.9	100.0	+3.8	9	MXCE
Odessa. Ukraine	22	0.9	62.9	+9.6	9	VAL
Rostov-na-Donu. Russia	23	0.8	100.0	+8.4	9	MXCE
Krasnovodsk. Turmenistan	24	0.3	10.8	+14.3	6	VM
Aschabad. Turmenistan	25	0.2	11.8	+16.2	7	VM
Jerevan. Armenia	26	0.5	35.3	+11.6	9	VAL
Soci. Russia	27	1.4	12.4	+14.0	7	BCT
Zonguldak. Turkey	28	1.3	12.1	+13.0	4	BCT
Samsun. Turkey	29	0.9	8.3	+14.4	6	VM
Trabzon. Turkey	30	1.1	7.7	+14.5	5	BCT
Kars. Turkey	31	1.2	100.0	+4.2	10	TG
Bursa. Turkey	32	0.7	12.3	+14.6	6	VM
Ankara. Turkey	33	0.5	31.7	+11.6	9	VAL
Erzurum. Turkey	34	0.8	100.0	+6.2	9	MXCE
Sivas. Turkey	35	0.7	78.5	+8.1	10	AMM
Van. Turkey	36	0.4	100.0	+8.7	8	MXCE
Izmir. Turkey	37	0.4	6.7	+17.4	7	VM
Konya. Turkey	38	0.5	18.2	+11.2	8	VAL
Urfa. Turkey	39	0.2	5.9	+18.1	6	VM
Adana. Turkey	40	0.4	7.9	+19.0	4	VM
Antalya. Turkey	41	0.4	12.1	+18.9	4	VM
Hefa. Israel	42	0.4	5.9	+21.4	2	VM
Yerushalayim. Israel	43	0.4	7.8	+17.6	4	VM
Ammam. Jordan	44	0.3	6.4	+17.4	4	VM
Ha'il. Saudi Arabia	45	0.1	2.8	+21.2	2	VM
Juddah. Saudi Arabia	46	0.3	0.8	+27.7	0	DM
Kamaran Island. Yemen	47	0.3	0.6	+29.6	0	DM
Riyan. Yemen	48	0.5	0.8	+27.0	0	DM
Khormaksar. Yemen	49	0.4	0.7	+28.8	0	DM
Al-Masirah. Oman	50	0.5	2.6	+26.1	0	VM
Masqat. Oman	51	0.4	1.3	+28.4	0	SMM
Mashhad. Iran	52	0.3	11.2	+13.6	8	VAL
Kermanshah. Iran	53	0.2	22.3	+13.0	10	AMM
Lahore. Pakistan	54	0.7	3.1	+23.3	1	SH
Multan. Pakistan	55	0.3	2.3	+26.0	2	SH
Karachi. Pakistan	56	0.7	1.2	+25.9	0	SMT
Darjeeling. India	57	8.5	4.3	+11.7	4	PLM
Patna. India	58	1.9	1.3	+25.9	0	SH
Veraval. India	59	1.3	0.8	+25.8	0	SS
Pune. India	60	1.6	0.6	+25.0	0	SS
Leh. India	61	0.6	100.0	+5.6	10	AMT

Jamshedpur. India	62	2.1	1.4	+26.4	0	PL
Jagdalpur. India	63	2.6	1.0	+25.0	0	PL
Nuwara-Eliya. Sri Lanka	64	5.2	4.0	+15.3	3	PLM
Katmandu. Nepal	65	2.9	3.1	+18.7	4	PLM
Ulaanbaatar. Mongolia	66	1.1	100.0	-3.2	11	AMTC
Taiyuan. China	67	1.1	23.2	+10.0	8	ET
Wolumuqi. China	68	0.6	100.0	+5.3	8	ET
Nanjing. China	69	1.4	15.2	+15.7	5	BL
Shanghai. China	70	1.6	14.2	+15.3	6	BL
Wuhan. China	71	1.4	12.0	+16.8	5	BL
Changsha. China	72	1.4	15.8	+17.2	5	BL
T'aipei. Taiwan	73	2.1	5.5	+21.7	1	PLM
Soul. South Korea	74	2.3	76.8	+11.1	7	BAT
Pusan. South Korea	75	2.2	10.8	+13.8	6	BAT
Hiroshima. Japan	76	2.0	12.9	+14.7	6	BL
Nagasaki. Japan	77	2.5	10.3	+16.5	4	BL
Djakarta. Indonesia	78	1.1	2.7	+26.8	0	PL
Barrow. US	79	2.7	100.0	-12.4	12	T
Anchorage. US	80	1.3	100.0	+1.8	11	TA
Prince Rupert. Canada	81	2.4	100.0	+7.6	9	MXCC
Prince George. Canada	82	1.4	100.0	+3.3	12	MDS
St. John's. Canada	83	1.9	100.0	+4.7	10	TG
Saint John. Canada	84	1.8	100.0	+5.4	9	MXCC
Halifax. Canada	85	1.6	100.0	+7.4	9	MXCC
Spokane. US	86	0.6	100.0	+9.5	9	MXCE
Havre. US	87	0.9	100.0	+5.6	11	MXCE
Boise. US	88	0.4	16.2	+10.4	10	AMM
Elko. US	89	0.5	32.2	+7.4	12	AMM
Omaha. US	90	1.2	43.1	+10.8	9	ETC
Modena. US	91	0.6	24.8	+8.9	11	AMM
Denver. US	92	0.8	21.3	+10.2	10	AMM
St. Louis. US	93	1.1	24.3	+13.3	7	BCT
Cairo. US	94	1.1	14.8	+15.3	7	BCT
Indianapolis. US	95	1.2	48.8	+11.2	9	BCT
Los Angeles. US	96	0.7	3.3	+18.0	4	VM
San Diego. US	97	0.9	3.1	+17.2	1	VM
Winslow. US	98	0.4	7.3	+13.4	8	VAL
Amarillo. US	99	0.9	8.7	+14.2	8	ET
Abilene. US	100	0.7	5.0	+17.9	7	BAT
Honolulu. US	101	0.8	2.2	+23.9	0	SH
Monterrey. Mexico	102	1.1	2.1	+22.3	4	SH
La Paz. Mexico	103	0.6	2.0	+24.2	0	SH
Ciudad de Mexico. Mexico	104	2.9	1.3	+15.9	2	PLM
Guayaquil. Ecuador	105	0.7	1.0	+24.9	0	SMT
Iquitos. Peru	106	2.0	2.3	+26.5	0	PL
Cajamarca. Peru	107	1.2	2.5	+18.5	11	PH
Tingo Maria. Peru	108	2.1	3.9	+25.0	0	PL
Lima. Peru	109	1.8	0.8	+18.2	0	SMM
Huancayo. Peru	110	1.6	3.1	+11.8	12	PH

Cuzco. Peru	111	1.3	3.1	+15.6	7	PH
San Juan. Peru	112	1.6	0.7	+18.0	0	SMM
Arequipa. Peru	113	0.5	1.2	+13.8	8	PS
La Paz. Bolivia	114	1.4	2.6	+14.3	5	BAT
Manaus. Brazil	115	0.9	2.5	+26.9	0	SH
Monte Santo. Brazil	116	1.5	1.0	+23.3	0	SH
Rio de Janeiro. Brazil	117	1.9	1.6	+22.7	0	SH
Arica. Chile	118	1.5	0.6	+18.8	0	SMM
Antofagasta. Chile	119	1.7	0.7	+16.2	0	SMM
Valparaiso. Chile	120	3.9	0.9	+14.7	0	VM
Santiago. Chile	121	4.6	0.6	+14.0	7	VM
Valdivia. Chile	122	14.1	1.9	+11.9	9	BCT
Los Evangelistas. Chile	123	10.8	4.6	+6.4	9	BCT
Asuncion. Paraguay	124	2.8	1.3	+24.2	0	SH
Paso de los Toros. Uruguay	125	5.4	1.3	+17.9	5	BL
Montevideo. Uruguay	126	4.9	1.4	+16.3	6	BL
La Quiaca. Argentina	127	1.4	1.8	+9.5	12	AMT
San Juan. Argentina	128	2.2	0.5	+17.2	8	ET
Concordia. Argentina	129	4.5	1.3	+18.8	6	BL
San Luis. Argentina	130	2.6	1.1	+16.5	8	ET
Rosario. Argentina	131	4.3	1.4	+16.7	7	ET
Chos Malal. Argentina	132	4.0	0.3	+13.6	9	VAL
Mar del Plata. Argentina	133	5.0	1.5	+13.4	8	ET
Cipoletti. Argentina	134	3.9	0.5	+13.7	11	AMM
Bariloche. Argentina	135	9.2	1.0	+8.3	12	AMM
Trelew. Argentina	136	3.2	0.5	+13.5	10	AMM
Sarmiento. Argentina	137	4.3	0.5	+10.8	9	VAL
Stanley. UK	138	100.0	21.4	+5.6	12	MDS
Guatemala. Guatemala	139	3.8	1.2	+18.0	0	PLM
Tegucigalpa. Honduras	140	2.7	1.1	+21.9	0	PL
Bogota. Colombia	141	2.0	2.2	+13.2	2	PLM
Maracaibo. Venezuela	142	0.7	0.5	+27.9	0	DT
Puyo. Ecuador	143	5.5	4.9	+21.5	0	PL
Galapagos Is. Ecuador	144	1.3	0.8	+20.4	0	SMT
Quito. Ecuador	145	1.9	3.5	+13.0	0	PLM
Rabat. Morocco	146	0.7	4.3	+17.7	0	VM
Tanger. Morocco	147	0.7	5.8	+17.2	1	VM
Tamanrasset. Algeria	148	0.2	1.0	+21.2	4	DM
Tunis. Tunisia	149	0.6	5.5	+17.7	0	VM
Tarabulus. Libya	150	0.5	3.8	+19.5	2	VM
Ghudamis. Libya	151	0.2	2.8	+21.9	4	VM
Al-Kufrah. Libya	152	0.1	1.4	+22.8	3	SMM
Al-Qahira. Egypt	153	0.3	1.9	+21.7	0	VM
Nouadhibou. Mauritania	154	0.6	1.0	+22.0	0	DM
Atar. Mauritania	155	0.3	0.6	+28.1	0	DT
Nema. Mauritania	156	0.6	0.2	+30.2	0	DT
Mopti. Mali	157	1.2	0.4	+27.9	0	SS
Moundou. Chad	158	2.5	0.4	+27.6	0	SH
Harar. Ethiopia	159	2.7	1.1	+19.7	0	PLM

Addis Abeba. Ethiopia	160	5.5	1.6	+16.2	0	PLM
Jima. Ethiopia	161	4.2	1.9	+18.4	0	PLM
Berbera. Somalia	162	0.3	0.8	+30.1	0	DM
Dakar. Senegal	163	1.3	1.0	+24.7	0	SH
Monrovia. Liberia	164	6.5	1.3	+25.7	0	PL
Kisozi. Burundi	165	1.5	4.2	+16.0	0	PLM
Mbeya. Tanzania	166	1.2	3.3	+17.5	1	PLM
Cangamba. Angola	167	1.9	2.7	+21.5	2	PLM
Beira. Mozambique	168	1.6	2.1	+24.4	0	PL
Pietersburg. South Africa	169	1.7	1.4	+17.1	5	BL
Durban. South Africa	170	2.2	1.7	+21.4	0	SH
East London. South Africa	171	2.6	1.7	+18.3	0	SH
Port Elizabeth. South Africa	172	3.1	1.2	+17.6	0	BL
Hallormsstadur. Iceland	173	1.4	100.0	+3.9	12	MDS
Jan Mayen. Norway	174	2.0	100.0	-0.2	12	T
Mo i Rana. Norway	175	1.9	100.0	+2.9	12	TA
Oslo. Norway	176	1.5	100.0	+5.9	9	MXCC
Dalen. Norway	177	1.7	100.0	+5.6	9	MXCC
Goteborg. Sweden	178	1.5	33.0	+7.6	9	BCT
Malmo. Sweden	179	1.4	100.0	+7.9	10	TG
Punkaharju. Finland	180	1.4	100.0	+3.3	10	TG
Kobenhavn. Denmark	181	1.3	24.3	+8.5	8	BCT
Sanduig. Denmark	182	1.3	27.1	+8.2	8	BCT
Lerwick. UK	183	2.0	8.9	+7.2	10	ETC
Dalwhinnie. UK	184	1.9	20.7	+6.3	12	ETC
Eskdalemuir. UK	185	2.4	14.3	+7.4	12	ETC
Tynemouth. UK	186	1.6	7.3	+9.3	7	BCT
Belfast. UK	187	1.8	7.8	+9.1	10	ETC
Essen. Germany	188	1.6	13.3	+9.6	8	BCT
Kassel. Germany	189	1.4	17.6	+9.2	9	BCT
Hof. Germany	190	1.5	53.3	+6.2	9	BCT
Nurnberg. Germany	191	1.4	21.2	+8.4	9	BCT
Suwalki. Poland	192	1.5	100.0	+6.2	9	MXCC
Warszawa. Poland	193	1.2	87.8	+8.1	9	MXCC
Marseille. France	194	0.8	5.7	+14.2	7	VM
Pic du Midi. France	195	2.5	100.0	-1.2	12	T
Valladolid. Spain	196	0.7	7.4	+12.1	8	VAL
Zaragoza. Spain	197	0.7	5.3	+14.9	5	VM
Barcelona. Spain	198	0.9	4.2	+16.4	3	VM
Madrid. Spain	199	0.6	7.0	+13.9	7	VM
Almeria. Spain	200	0.6	3.2	+18.0	0	VM
Las Palmas. Canary Is. Spain	201	0.7	1.9	+20.5	0	VM
Gibraltar. UK	202	0.7	5.6	+17.8	0	VM
Genova. Italy	203	1.1	8.9	+15.6	5	BCT
Athinai. Greece	204	0.4	5.8	+17.8	6	VM
Levkosia. Cyprus	205	0.3	7.2	+16.9	5	VM