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Bioindicators and bioclimatic data as essential tools towards a consistent biogeographic district typology of Sierra Nevada National Park (Spain)

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Abstract. The relationship, through the application of robust and solvent bioclimatic indexes, between the characteristics of the natural environment (geology, orography, climate, etc.) and the recognition of species, communities, and vegetation series, has made it possible to establish in the Sierra Nevada National Park (Spain) a total of 8 homogeneous spaces (districts), included in other larger spaces (5 sectors, 2 provinces), which constitute the biogeographic typology of the territory. The consideration, of historical climatic changes and human action, among other factors, shows the necessary use of phytosociological methodology in the characterization of species, communities, and vegetation series. The application of the Aridic Index and the positive temperature, in the bioclimatic context, explains the generalized dryness in the territory and the apparent contradiction of spaces with dry and semiarid ombroclimate in the highest summits. The recognition of homogeneous territories (districts), is an essential tool for the management of this national park.
Keywords: Bioclimatology; Aridic Index; Biogeography; Districts; Frigid Territory.

[es] Bioindicadores y datos bioclimáticos como herramientas esenciales para una tipología biogeográfica distrital consistente en el Parque Nacional de Sierra Nevada (España)

Resumen. La relación, a través de la aplicación de índices bioclimáticos robustos y solventes, entre las características del entorno natural (geología, orografía, clima, etc.) y el reconocimiento de especies, comunidades y series de vegetación, ha permitido establecer en el Parque Nacional de Sierra Nevada (España) un total de 8 espacios homogéneos (distritos), incluidos en otros espacios más amplios (5 sectores, 2 provincias), que constituyen la tipología biogeográfica del territorio. La consideración, entre otros factores, de los cambios climáticos históricos y de la acción humana, demuestra el uso necesario de la metodología fitosociológica en la caracterización de especies, comunidades y series de vegetación. La aplicación del Índice Arídico y la temperatura positiva, en el contexto bioclimático, explica la aridez generalizada en el territorio y la aparente contradicción de los espacios con ombroclima seco y semiárido en las cumbres más altas. El reconocimiento de territorios homogéneos (distritos), es una herramienta esencial para la gestión de este parque nacional.
Palabras clave: Bioclimatología; Índice de Aridez; Biogeografía; Distritos; Territorio Frío.

Introduction

Sierra Nevada (Cordillera Penibética) is a mountain range in the south-eastern Iberian Peninsula. In the centre lies Sierra Nevada National Park (created on 1999), which has the highest summits of the range (Mulhacén 3479 m asl, Veleta 3396 m asl, Alcazaba 3366 m asl, etc.). It occupies 85883 ha surrounded by the Peripheral Protection Zone of Natural Park of 86355 ha. Located between 37º15'N (Lugros) and 36º55'S (Lanjarón) and between

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3º38’W (Suspiro del Moro) and 2º35’E (Terque), the total preserve area of Sierra Nevada National Park covers 172238 ha coinciding with the UNESCO Biosphere Reserve Zone (1986). Its elevation ranges between 300 m asl at the Andarax river near Terque to 3479 m on Mulhacén peak. The main rivers having their source in Sierra Nevada National Park are: the Genil, Nacimiento, Andarax, Grande de Adra, and Guadalfeo.

According to Martín & *al*. (2008), the Penibetic Range and especially its core, Sierra Nevada, belong mainly to the Nevado-Filabride geological complex. It is formed by several overlapping tectonic units (>250Myr): graphitoids and dark micaschists, prevail in the lower one, called “Veleta”, while clear micaschists predominate in the upper one, called “Mulhacén”. All of these are mixed with gneissic igneous acidic and, above all, by the basic ultramafic rocks (Vera & *al*., 2004). The Triassic Alpujarride complex (210-240 Myr), called El Calar, is located above and around the central core, in which marbles, limestones, and dolomites are common, as well as phyllites or launas at the base.

Numerous studies on the structure, composition, and distribution of plant communities have been conducted in the national park and its environment according to the phytosociological and geobotanical Braun-Blanquet method (Géhu & Rivas-Martínez, 1981; Capelo, 2003; Géhu, 2006). These include Quézel, 1953; Rivas-Martínez, 1961; Rivas Goday & Rivas-Martínez, 1968, 1971; Prieto, 1971; Martínez-Parras & Molero Mesa, 1983a, b; Valle, 1985, Losa Quintana & *al.*, 1986; Rivas-Martínez & *al.*, 1986; Martínez-Parras & *al.*, 1987a, b, c; Molero Mesa & Pérez Raya, 1987a, b; Mota & Valle, 1987; Pérez Raya, 1987; Pérez Raya & Molero Mesa, 1988a, b, 1989; Lorite & *al.*, 1997, 2003, 2007; Molero Mesa 1999; Molero Mesa & *al.*, 2001; Salazar & *al.*, 2001; Mota & *al.*, 2002; Fernández Calzado, 2007; Fernández Calzado & Molero Mesa, 2011a, b. Marfil (2017) offers an overview and includes a total of 205 plant associations, 118 alliances, and 73 orders. The syntheses of Rivas-Martínez & *al.* (2001, 2002a, b, 2011a, b), which include an exhaustive text and checklist with the description and references of all phytosociological communities known in Spain and Portugal. These papers, are the bases for arranging the hierarchical communities of the Sierra Nevada National Park.

Pollen analyses made in the Padul peatlands indicate the alternation of cold and warm-humid climatic periods in the Sierra Nevada between 46 and 4.5 ka (Flörstchütz & *al.*, 1971; Pons & Reille, 1988). Glacial events of the Holocene show a variable climatic history on the mountain. According to several authors (Gómez Ortiz & *al.*, 2002, 2012; Anderson & *al.*, 2011; Oliva & *al.*, 2010, 2011, 2014; Jiménez-Moreno & Anderson, 2012; Oliva & Gómez Ortiz, 2012, Jiménez-Moreno & *al.*, 2013; and Jiménez-Moreno, 2016), the main glacier, climatic, and anthropogenic events can be summarized in Table 1.

Table 1. Main glacial and interglacial periods in Sierra Nevada since last Würm

32-30Ka - Wurm maximum	Sierra Nevada glacial maximum
15-14Ka - Late glacial. Glaciers melting	Glaciers restricted to summits areas
11-7Ka - Old Holocene	Complete glacier melts; temperature, precipitation increase
7-4Ka - Middle Holocene. Climatic optimum	Higher temperature and rainfalls
4-2.3Ka - Anthropic impact begins	Alternation of aridic to rainy and cold to warmer periods
2.3-0.85Ka-Roman and Medieval periods	Precipitation increases moderately
0.85-0.15Ka - Little Ice Age	Temp. decreases ≥ 1.0ºC. Snowfields and glaciers in summits
21th century	One small buried rock glacier remain in “Corral del Veleta”

Material and Methods

Bioclimatology

Bioclimatology, a contemporaneous geobotanical science, studies the reciprocity between the climate and the distribution of living beings, mostly plants and their communities on Earth. The increasingly detailed data on the distribution of vegetation, as well as shifts in the appearance and composition of the natural potential vegetation and its substitution stages, caused by climatic, edaphic, geographic and anthropogenic factors, are making easier to recognize the bioclimates and the natural potential vegetation frontiers with steadily greater precision and objectivity. Once the bounds of the vegetation series (sigmetum), geoseries (geosigmetum), permaseries (permasigmetum) and geopermaseries (geopermasigmetum) are known, as well as the bioindicators (i.e. communities, soils, and plant species), it will be possible to calculate the numerical bioclimatic threshold values that distinguish them. These spaces corresponding to the bioclimatic units (bioclimates, thermotypes, ombrotypes, continentality, and isobioclimates) have been progressively delimited and adjusted. Numerous investigations have been performed in this respect (Rivas-Martínez, 1976, 1981, 1982a, b, 1983, 1984, 1988, 1991, 1994, 1996, 2004, 2005b; Loidi, 1991; Rivas-Martínez & *al*., 1991b, 2011c; Peinado & *al*., 1992; Sánchez Gómez & *al*., 1993, 1994; Del Arco & *al*., 1996, 2002; Rivas-Martínez & Costa 1998; Lousã, 2004; Mesquita & *al*., 2004; Gehú, 2006; Cantó, 2007). The synoptic table "Worldwide bioclimatic classification system", has been recently updated [13.02.2017] by Rivas-Martínez, Rivas-Sáenz & A. Penas (Table 2).

Table 3 displays the information from 34 meteorological stations inside or surrounding Sierra Nevada National Park. These data help to establish the bioclimates within the Mediterranean macrobioclimate at each station (pluviseasonal oceanic: *mepo*; xeric oceanic: *mexo*; desertic oceanic: *medo*), as well as the thermo-ombroclimatic types (isobioclimates) and to deduce the different indices that show other bioclimatic characters. The Sierra Nevada Global Change Observatory (Environmental and Regional Planning Council of the Regional Government of Andalusia-Spanish National Park Service) is currently monitoring the climatic conditions over the last 50 years (Perez-Luque & *al*., 2016a, b; Aspizua & *al*., 2012), taking into account numerous other parameters (Zamora & *al*., 2016), the results of which reveal possible climatic changes and help guide management for the conservation of the park and its sustainable future.

With the vertical zonation of vegetation series, thermotypes, ombrotypes, and altitudinal bioclimatic belts, we can also recognize and define the territory on the basis of bioclimatic indexes, such as: Thermicity Index (It = 10(T + m + M); m = mean minimum temperature of the coldest month; M = mean maximum temperature of the coldest month of the year); Annual Positive Temperature (Tp = sum of monthly mean temperature higher than 0ºC); Annual Positive Precipitation (Pp = sum of monthly rainfall for those months with mean temperature>0ºC); Ombrothermic Index (Io = 10(Pp/Tp)); Continentality Index (Ic: Annual monthly thermic interval = Tmax-Tmin); and Aridic Index (AI), which numerically expresses the aridity value lower than Io=2 (AIY = Annual Aridic Index = 200-100($Io_{1+2+...12}$)).

An initial approach to the isobioclimas (thermo- and ombrotypes), bioclimatic belts and application of the Aridic Index was found in Molero & Marfil (2015). The use of thermometric data provided by Target Region 2 in the Sierra Nevada, within the GLORIA project (Pauli & *al*., 2012; Gottfried & *al*., 2012; Fernández-Calzado & *al*., 2012; Winkler & *al*., 2016), has been useful in confirming the data of the cryoromediterranean summits, and extrapolated from the meteorological stations.

Biogeography

Biogeography is a terrestrial science concerning the distribution of species, plant communities, habitats, biocoenosis, ecosystems, biomes and bioregions on Earth, as well as the relationships between them and their conditions. It takes into account the areas of taxa and syntaxa (chorology), in addition to information from other natural sciences (Geography, Botany, Synecology, Soil Science, Bioclimatology, Geology, etc.), and attempts to establish a hierarchic biogeographic typology of the lands on Earth. The main systematic unit ranks from the higher to lower are: kingdom, region, province, sector, district, country, landscape cell, tesela, and permatesela (Rivas-Martínez & *al*., 2007, 2011b, 2014). Terrestrial biogeography has been twinned with phytogeography due to the value and information of the plant species and their communities as bioindicators, in the definition and delimitation of its units.

Table 2. Synoptic table of Worldwide bioclimatic classification system (Rivas-Martínez, Rivas-Sáenz & A. Penas). (Updated 13/02/2017)
For detailed information on indices and other features see globalbioclimatics.org

Macrobioclimate[1]	Bioclimate [5]		Bioclimatic ranges				Thermoclimatic types				Ombroclimatic types		
Tropical		Abbr.	Ic	Io	Iod2			It (Itc)	Tp[2]	Abbr.		Io	Abbr.
Zone warm: equatorial, eutropical and subtropical (0º to 36º N & S). In subtropical (23º to 36º N & S) at <200 m two values: T ≥ 25º, m ≥ 10º, Itc ≥ 580. If $Pcm_2 < Pcm_1 > Pcm_3$ y Pss > Psw, two values: T ≥ 21º, M ≥ 18º, It ≥ 470. Eurasia and Africa: 25º to 36º N >2000 m is not tropical.	**Tr. Pluvial**	trpl	-	≥ 3.6	> 2.5		1. Infratropical	690 - 890	> 2900	itr	1. Ultrahyperarid	< 0.2	uha
	Tr. Pluviseasonal	trps	-	≥ 3.6	≤ 2.5	-	2. Thermotropical	490 - 690	> 2300	ttr	2. Hyperarid	0.2-0.4	har
	Tr. Xeric	trxe	-	1.0-3.6	-	-	3. Mesotropical	320 - 490	> 1700	mtr	3. Arid	0.4-1.0	ari
	Tr. Desertic	trde	-	0.2-1.0	-	-	4. Supratropical	160 - 320	>1000	str	4. Semiarid	1.0-2.0	sar
	Tr. Hyperdesertic	trhd	-	< 0.2	-	-	5. Orotropical	< 160	600-1000	otr	5. Dry	2.0-3.6	sec
						-	6. Cryorotropical	-	1-600	ctr	6. Subhumid	3.6-6.0	shu
							7. Gelid [3]	-	0	gtr	7. Humid	6.0-12.0	hum
											8. Hyperhumid	12.0-24.0	hhu
											9. Ultrahyperhumid	≥ 24.0	uhh
Mediterranean		Abbr.	Ic	Io				It (Itc)	Tp[2]	Abbr.		Io	Abbr.
Zone warm: subtropical and temperate eutemperate (23º to 52º N & S), with aridity P < 2T, at least two months in summer: $Ios_2 \leq 2$, $Iosc_4 \leq 2$. In subtropical (23º to 36º N & S) at least two values: T < 25º, m < 10º, Itc < 580.	**Me. Pluviseasonal Oceanic**	mepo	≤ 21	> 2.0	-	-	1. Inframediterranean	450 - 580	> 2400	ime	1. Ultrahyperarid	< 0.2	uha
	Me. Pluviseasonal Continental	mepc	> 21	> 2.0	-	-	2.Thermomediterranean	350 - 450	> 2100	tme	2. Hyperarid	0.2-0.4	har
	Me. Xeric Oceanic	mexo	≤ 21	1.0-2.0	-	-	3. Mesomediterranean	220 - 350	> 1500	mme	3. Arido	0.4-1.0	ari
	Me. Xeric Continental	mexc	> 21	1.0-2.0	-	-	4. Supramediterranean	< 220	> 900	sme	4. Semiarid	1.0-2.0	sar
	Me. Desertic Oceanic	medo	≤ 21	0.2-1.0	-	-	5. Oromediterranean	-	500-900	ome	5. Dry	2.0-3.6	sec
	Me. Desertic Continental	medc	> 21	0.2-1.0	-	-	6. Cryoromediterranean	-	1-500	cme	6. Subhumid	3.6-6.0	shu
	Me. Hyperdesertic Oceanic	meho	≤ 21	< 0.2	-	-	7. Gelid [3]	-	0	gme	7. Humid	6.0-12.0	hum
	Me. Hyperdesertic Continental	mehc	> 21	< 0.2	-	-					8. Hyperhumid	12.0-24.0	hhu
											9 Ultrahyperhumid	≥ 24.0	uhh
Temperate		Abbr.	Ic	Io				It (Itc)	Tp[2 y 4]	Abbr.		Io	Abbr.
Zone warm: subtropical and temperate (23º to 66º N & 23º to 54º S). From 23º to 36º N & S, at <200 m, at least two values: T < 21º, M < 18º, Itc < 470. $Ios_2 > 2$, $Iosc_4 > 2$.	**Te. Hyperoceanic**	teho	≤ 11	> 3.6	-	-	1. Infratemperate	>410	> 2350	ite			
	Te. Oceanic	teoc	11-21	> 3.6	-	-	2. Thermotemperate	290 - 410	> 2000	tte	4. Semiarid	<2.0	sar
	Te. Continental	teco	>21	> 3.6	-	-	3. Mesotemperate	190 - 290	> 1400	mte	5. Dry	2.0-3.6	sec
	Te. Xeric	texe	≥4	≤ 3.6	-	-	4. Supratemperate [4]	< 190	> 800	ste	6. Subhumid	3.6-6.0	shu
							5. Orotemperate [4]	-	380-800	ote	7. Humid	6.0-12.0	hum
							6. Cryorotemperate	-	1-380	cte	8. Hyperhumid	12.0-24.0	hhu
							7. Gelid [3]	-	0	gte	9. Ultrahyperhumid	≥ 24.0	uhh

Macrobioclimate[1]	Bioclimate [5]		Bioclimatic ranges				Thermoclimatic types				Ombroclimatic types		
Boreal		Abbr.	Ic	Io	Tp	T			Tp	Abbr.		Io	Abbr.
Zones temperate and cold (42º to 72º N, 49º to 56º S). At < 200 m: Ic ≤ 11:T≤6º, Tp = 380-720; Tps >320; Ic = 11-21: T ≤ 5.3º, Tp = 380-720; Ic = 21-28: T ≤ 4.8º, Tp = 380-740; Ic = 28-45: T ≤ 4.3º, Tp = 380-800; Ic ≥ 45: T ≤ 0º, Tp = 380-800.	**Bo. Hyperoceanic**	boho	≤ 11	> 3.6	≤ 720	< 6.0º	1. Thermoboreal	-	> 680	tbo	4. Semiarid	<2.0	sar
	Bo. Oceanic	booc	11-21	> 3.6	≤ 720	≤ 5.3º	2. Mesoboreal	-	580-680	mbo	5. Dry	2.0-3.6	sec
	Bo. Subcontinental	bosc	21-28	> 3.6	≤ 740	≤ 4.8º	3. Supraboreal	-	480-580	sbo	6. Subhumid	3.6-6.0	shu
	Bo. Continental	boco	28-46	> 3.6	≤ 800	≤ 3.8º	4. Oroboreal	-	380-480	obo	7. Humid	6.0-12.0	hum
	Bo. Hypercontinental	bohc	>46	-	≤ 800	≤ 0.0º	5. Cryoroboreal	-	1-380	cbo	8. Hyperhumid	12.0-24.0	hhu
	Bo. Xeric	boxe	<46	≤ 3.6	≤ 800	≤ 3.8º	6. Gelid [3]	-	0	gbo	9. Ultrahyperhumid	≥ 24.0	uhh
Polar		Abbr.	Ic	Io	Tp				Tp	Abbr.		Io	Abbr.
Zones temperate and cold (51º to 90º N & S). At < 100 m: Tp < 380.	**Po. Hyperoceanic**	poho	≤ 11	> 3.6	> 0	-	1. Infrapolar[6]		380-600	ipo	4. Semiarid	<2.0	sar
	Po. Oceanic	pooc	11-21	> 3.6	> 0	-	2. Thermopolar	-	280-380	tpo	5. Dry	2.0-3.6	sec
	Po. Continental	poco	> 21	> 3.6	> 0	-	3. Mesopolar	-	100-280	mpo	6. Subhumid	3.6-6.0	shu
	Po. Xeric	poxe	≥ 4	≤ 3.6	> 0	-	4. Suprapolar[3]	-	1-100	spo	7. Humid	6.0-12.0	hum
	Po. Pergelid	pope	-	-	-0	-	5. Gelid [3,7]	-	0	gpo	8. Hyperhumid	12.0-24.0	hhu
											9. Ultrahyperhumid	≥ 24.0	uhh

(1) North and south of equatorial and eutropical latitudinal belt (23ºN & 23º S), if the locality is at 200 m altitude or higher, the thermical values at this altitude must be calculated increasing T in 0.6º, M in 0.5º, and It or Itc in 13 units, every 100 m higher than 200 m asl. But if the locality is northern 48º N or southern 51º S, the increases are T in 0.4º and Tp in 12 units, every 100 m higher than 200 m asl. (2) If Ic ≥ 21 (continental) or It o Itc < 120 the thermotype must by calculated through Tp values, and the theoric values of Tp at 200 m asl increasing 55 units every 100 m exceding that altitude. (3) In the pergelid bioclimate (polar), the upper suprapolar and the gelid thermotype on recognize the following ombrotypes (chionotypes): un-snowy (<50 mm), scanty-snowy (50-200 mm), low-snowy (200-400 mm), medium-snowy (400-600 mm), high-snowy (600-1000 mm), super-snowy (1000-2000 mm), ultra-snowy (>2000 mm). (4) The hemiboreal thermotype (hbo) is used inside the temperate macrobioclimate, north of 45ºN and south 49ºS, within the following values: Ic <21, altitude <400 m, tp 720-900; Ic 21-28, altitude <600 m, tp 740-900; Ic > 28, alt. <1000 m, tp 800-900. (5) Bioclimatic variants: steppic (stp), submediterranean (sbm), bixeric (bix), antitropical (ant), seropluvial (spl), polar semiboreal (posbo), semipolar subantarctic (sepos), tropical semimediterranean desertic (trsmd), polar euhyperoceanic (poeuhy), boreal subantarctic (bosuba) and temperte subantartic (tesuba). (6) The infrapolar thermotype (Tp: 380-600) only correspond to semipolar antarctic insular bioclimatic variant in the coast [values. Alt<100 m, T<7,5º, Tp<600, Tps<280, Tmax<10º, Ic<8, Io>10]; the polar semiboreal bioclimatic variant correspond to semicontinental-hyperoceanic hyperhumid oroboreal treeless arctic tundra territories [values: Tp 380-480, Ic<28, Tmax ≤11º, Tps≤320]. (7) In the polar pergelid bioclimate on identify three gelid thermotypes in the Antarctic Region and only two in the Circumarctic Region: hypogelid (T -10º to -25º, Tp 0, Tpmax< 30, Tpamax< 500, Twmax<-7º); hypergelid (T -25º to -45º, Tp 0, Tpmax 0, Tpamax 300, Twmax -7º to -22º); ultragelid (T <-45º, Tp 0, Tpmax 0, Tpamax 0, Twmax<-22º; only in Antarctica).

Table 3. Bioclimatic data of Sierra Nevada National Park. T: Annual Average Temperature; Tp: Annual Positive Temperature; Ts: Summer Temperature; P: Annual precipitation; Pp: Annual Positive Precipitation; Itc: Compensated Thermicity Index; Ic: Continentality Index; AI: Aridic Index; Io: Ombrothermic Index; Io6 (June); Io7 (July); Io8 (August): Monthly Ombrothermic Index; U: upper; L: lower; subhum: subhumid; sarid: semiarid; GR: Granada province; AL: Almería province.

Localities	Lat. & long.	Alt.m	Years	T	Tp	Ts	P	Pp	Itc	Ic	AI	Io	Io_6	Io_7	Io_8	Isobioclimates
Rioja, AL	36º 51’N-2º 27’W	127	55-92	18.8	2254	756	206	206	428	15.0	1143	0.9	0.74	0.06	0.07	L. thermomediterranean- U. arid
Vélez de Benaudalla, GR	36º 50’N-3º 30’W	130	51-99	18.2	1978	714	487	487	429	12.6	649	2.2	0.96	0.15	0.13	L. thermomediterranean- L. dry
Orgiva, GR	36º 54’N-3º 25’W	450	53-91	16.5	1978	701	476	476	352	15.1	652	2.4	0.54	0.13	0.18	U. thermomediterranean- L. dry
Alboloduy, GR	37º 08’N-2º 37’W	460	65-92	17.7	2119	745	241	241	389	15.4	903	1.1	0.31	0.09	0.14	U. thermomediterranean- L. sarid
Tabernas, GR	37º 03’N-2º 23’W	490	55-98	18.0	2166	774	242	242	389	16.7	916	1.1	0.37	0.06	0.12	U. thermomediterranean- L. sarid
Canjáyar, AL	36º 54’N-3º 25’W	610	51-90	17.7	2127	783	350	350	374	18.3	733	1.7	0.53	0.09	0.27	U. thermomediterranean-U. sarid
Rambla de Guadix, AL	37º 01’N-2º 40’W	616	08-14	17.2	2064	754	171	171	410	16.2	1142	0.8	0.05	0.08	0.21	L. thermomediterranean-U. arid
Granada Base Aérea, GR	37º 19’N-3º 38’W	687	61-10	15.3	1464	727	371	371	295	18.6	604	2.5	1.09	0.08	0.09	L. mesomediterranean-L. dry
Lanjarón, GR	36º 55’N-3º 29’W	710	46-99	15.0	1796	641	494	494	322	13.9	585	2.8	0.74	0.13	0.24	L. mesomediterranean-L. dry
Granada Cart, GR	37º 11’N-3º 36’W	720	61-92	15.4	1848	719	469	469	298	18.0	565	2.5	0.81	0.13	0.18	L. mesomediterranean-L. dry
Albuñuelas, GR	36º 53’N-3º 37’W	730	55-99	15.5	1857	703	496	496	309	17.0	656	2.7	0.67	0.13	0.12	L. mesomediterranean-L. dry
Padul, GR	37º 1’N-3º 37’W	753	55-99	16.0	1916	723	417	417	321	17.4	595	2.2	0.92	0.06	0.12	L. mesomediterranean-L. dry
Pinos Genil, GR	37º 9’N-3º 30’W	774	51-92	13.9	1668	653	572	572	261	16.9	518	3.4	1.16	0.14	0.25	U. mesomediterranean-U. dry
Monachil, GR	37º 8’N-3º 32’W	810	25-92	14.2	1708	661	480	480	289	17.0	544	2.8	0.91	0.10	0.22	L. mesomediterranean-U. dry
Benalúa de Guadix, GR	37º 21’N-3º 09’N	865	51-91	14.8	1702	661	289	289	276	17.9	531	1.7	1.14	0.11	0.41	U. mesomediterranean-U. sarid
Dúrcal, GR	37º 0’N-3º 33’W	890	61-92	15.3	1832	718	509	509	289	18.9	565	2.8	1.02	0.06	0.09	L. mesomediterranean-U. dry
Cádiar, GR	36º 56’N-3º 10’W	916	61-90	14.2	1708	624	607	607	282	15.7	541	2.3	0.91	0.17	0.16	U. mesomediterranean-L. dry
Laujar, AL	36º 59’N-2º 53’W	921	55-92	14.6	1753	664	531	531	294	16.0	545	3.0	0.69	0.11	1.25	L. mesomediterranean-U. dry
Fiñana, AL	37º 10’N-2º 50’W	950	66-99	14.3	1716	704	288	288	268	19.4	668	1.7	0.51	0.32	0.14	U. mesomediterranean-U. sarid
Dilar C. Eléctrica, GR	37º 04’N-3º 32’W	980	54-92	13.6	1632	647	637	637	259	17.8	522	3.9	1.07	0.20	0.19	U. mesomediterranean-L. subhum.

Localities	Lat. & long.	Alt.m	Years	T	Tp	Ts	P	Pp	Itc	Ic	AI	Io	Io_6	Io_7	Io_8	Isobioclimates
Ohanes, AL	37º 02'N-2º 44'W	1000	63-96	14.9	1794	700	385	385	294	17.6	652	2.2	0.58	0.09	0.21	L. mesomediterranean-L. dry
Pampaneira,GR	36º 56'N-3º 21'W	1060	67-92	14.5	1742	653	666	666	302	14.9	502	3.8	1.50	0.17	0.20	L. mesomediterranean-L. subhum.
Cañar Jarales, GR	36º 55'N-3º 25'W	1071	54-99	13.3	1596	591	591	591	255	17.2	521	3.7	0.80	0.13	0.30	U. mesomediterranean-L. subhum.
Jérez del M., GR	37º 11'N- 3º 9'W	1223	51-92	12.8	1531	610	377	377	236	16.3	500	2.5	1.06	0.28	0.54	U. mesomediterranean-L. dry
Huéneja, GR	37º 9'N-2º 57'W	1278	58-92	12.3	1472	614	439	439	221	17.2	511	3.0	0.92	0.30	1.48	U. mesomediterranean-U. dry
Laujar Monte.AL	37º 1'N-2º 53'W	1280	61-10	13.2	1585	639	605	605	259	16.5	446	3.8	0.92	0.22	0.42	U. mesomediterranean-L. subhum.
Bérchules, GR	36º 58'N-3º 11'W	1319	61-92	12.5	1496	613	683	683	233	16.7	480	4.6	1.25	0.17	0.22	U. mesomediterranean-L. subhumid
Robledal de Cañar, GR	36º 57'N- 3º25'W	1735	08-14	10.9	1308	566	793	793	171	15.6	524	6.1	0.44	0.14	0.18	L. supramediterranean-L. humid
Laujar Cerec., AL	37º 2'N-2º 54'W	1780	61-10	10.7	1280	559	661	661	189	16.0	349	5.2	1.43	0.47	0.61	L. supramediterranean-U. subhum.
S.de Lújar-Órgiva, GR	36º 49'N-3º 24'W	1842	65-77	8.5	1020	509	702	702	127	17.0	454	6.9	1.25	0.07	0.16	U. supramediterranean-L. humid
Piedra Soldados, GR	37º 9'N-3º 15'W	2155	08-14	7.5	899	459	516	467	73	18.3	438	5.9	1.35	0.27	0.23	L. oromediterranean-U. subhum.
Laguna Seca, AL	37º 05'N-2º 57'W	2300	08-14	6.5	780	457	519	457	66	17.8	393	5.9	1.33	0.13	0.60	L. oromediterranean-U. subhum.
S.Nevada Alb., GR	37º 5'N-3º 23' W	2510	75-14	4.9	593	414	761	307	-23	20.1	296	5.2	4.70	0.47	0.57	U. oromediterranean-U. subhum.
Veleta Peak, GR	36º 57'N-3º 25'W	3097	08-14	1.7	440	318	180	58	-110	18.1	477	1.4	0.42	0.38	0.23	L. cryoromediterranean-L. sarid

The biogeographic typology proposed to Sierra Nevada National Park is based mostly on previous geobotanic publications of flora (Molero Mesa & Pérez Raya, 1987; Rivas-Martínez & *al*., 1991; Molero Mesa & González-Tejero, 1996; Fernández Calzado & Molero Mesa, 2011b; Lorite, 2016; Marfil, 2017 in press.), vegetation, bioclimatology and biogeography, particularly in its correspondence with vegetation series and geoseries of the territory (Rivas Martínez & *al*., 1997; Molero Mesa & Marfil, 2015, 2017; Marfil, 2017 in press.), as well as on other works on vegetation, plant dynamics, and graphic representation of vegetation series, and geoseries in the area (Valle, 1985; Rivas-Martínez & *al*., 1986; Molero Mesa & *al*., 2001; Losa Quintana & *al*., 1986; Lorite & *al*., 1997; El Aallali & *al*., 1998; Fernández Calzado & Molero Mesa, 2011a). Also key have been the global studies, vegetation, maps, and the records of the vegetation series of Spain (Rivas-Martínez & Loidi, 1999; Rivas-Martínez, 1987; Valle & *al*., 2003-2005; Rivas-Martínez & *al*., 2007, 2011a, 2011b). Geobotanical data have been the essential bases to sketch the new map of the districts and biogeographic territories (Map 1).

Results and Discussion

Biogeographic districts and territories of Sierra Nevada National Park with their adjacent areas (West Mediterranean Subregion)

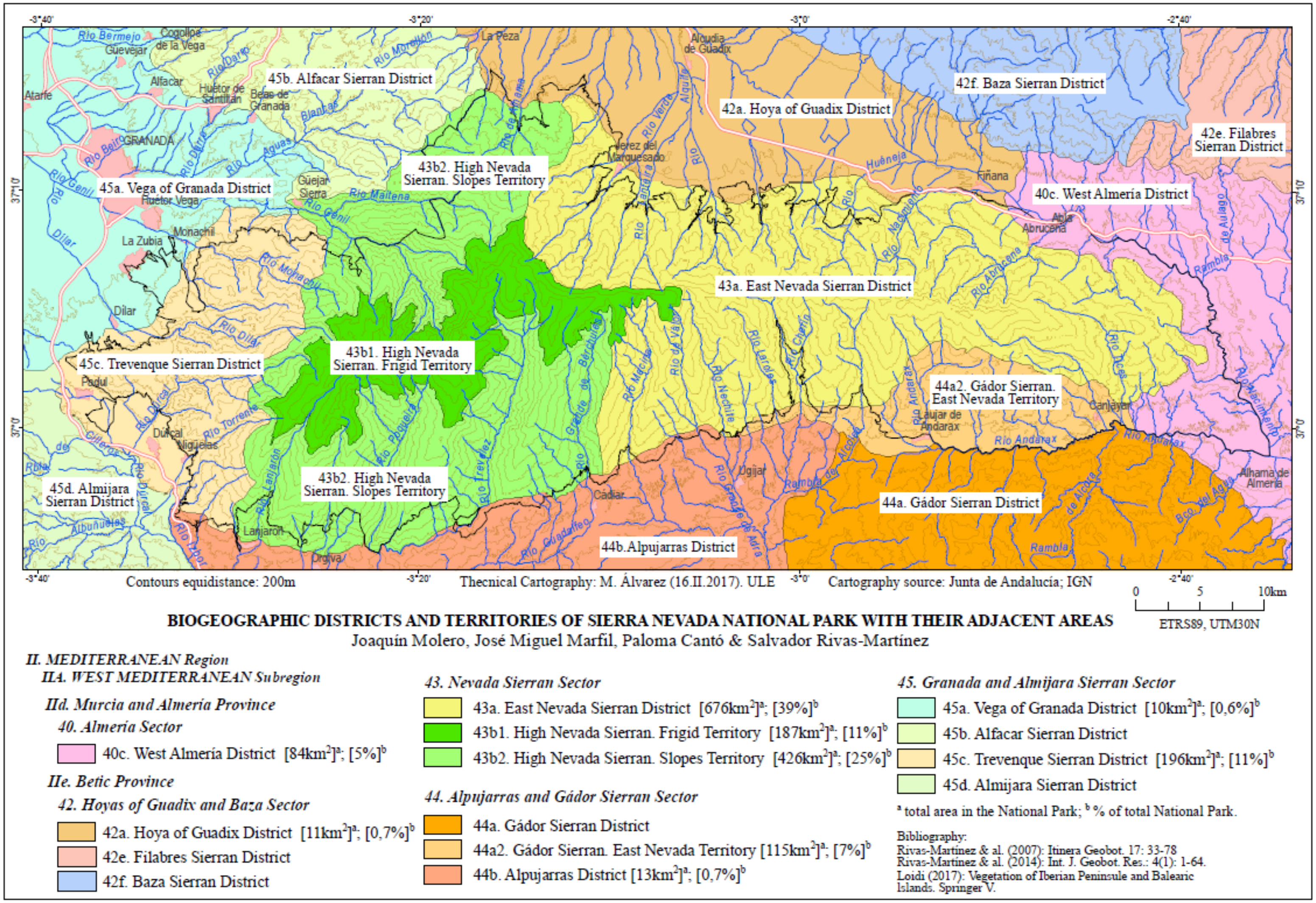
The entire National Park belongs to the Mediterranean Region and has a typical Mediterranean climate, with pronounced summer drought that can last up to 9-12 months, depending on the year, particularly in the southeast low desertic and thermic zones (West Almeria District).

The biogeographic typology recognized and accepted at the district unit rank inside the National Park includes one region, one subregion, two provinces, five sectors and eight districts (Rivas-Martínez & *al*., 2007, 2014, 2017), with two biogeographic territories (countries). Out of the National Park in adjacent areas, there are four well-represented Betic districts: 42e. Filabres Sierran District, 42f. Baza Sierran District, 45b. Alfacar Sierran District and 45d. Almijara Sierran District (Map1):

45c. Trevenque Sierran District

This district is located between the basins of the Genil, Monachil, Dílar, Durcal, and Torrente rivers, with 196 km^2, (11%), mostly on dolomites, but also on limestones, calco-dolomites and clays, sometimes vertics. Contact in height with the Nevadense sector and at the base, towards the south, with the sector Alpujarreño-Gadorense. Maximum altitude in the Loma de los Panaderos, 2350 m asl, Las Sabinas, 2215 m asl, Trevenque, 2079 m asl, and Dornajo 2075 m asl. It spans the lower mesomediterranean to the lower oromediterranean thermotypes, with ombroclimates dry, subhumid, and lower humid at the beginning of oromediterranean belt (2050 m asl).

This is a diverse, cold district with a large amount of sandy dolomitic, dolomitic, and calco-dolomitic mountains (Trevenque, Tesoro, Dornajo, Sierra del Manar, etc.) where the mesomediterranean barely reaches 1300 m asl. and the rainfall is particularly high, but with a very permeable substrate. The series of mountain conifers *Daphno hispanicae-Pino nevadensis S.*, in the upper supramediterranean and *Rhamno infectoriae-Junipero sabinae S.* in the lower oromediterranean, are good indicators of the territory, where the Holm oak series represents the largest potential area (*Berberido hispanicae-Querco rotundifoliae S.* and *Paeonio coriaceae-Querco rotundifoliae S.*). Other bioindicators are included in Table 4.



Map 1. Biogeographic districts and territories of Sierra Nevada National Park and adjacent areas.

Table 4. Trevenque Sierran District bioindicators. S: sigmetum; T: thermomediterranean; M: mesomediterranean; S: supramediterranean; O: oromediterranean; C: cryoromediterranean.

45c. Trevenque Sierran District. SNNP	Thermotypes				
	T	M	S	O	C
Sigmataxa, Syntaxa					
Daphno hispanicae-Pino nevadensis S.	-	-	●	●	-
Brachypodio boissieri-Querco rotundifoliae S.	-	●	●	-	-
Berberido hispanicae-Querco rotundifoliae S.	-	-	●	-	-
Brachypodio boissieri-Pino halepensis S.	-	●	-	-	-
Festuco hystricis-Astragaletum granatensis	-	-	-	●	-
Convolvulo boissieri-Andryaletum agardhii	-	-	●	-	-
Brachypodio boissieri-Trisetetum velutini	-	-	●	-	-
Thymo gracilis-Lavanduletum lanatae	-	●	-	-	-
Taxa					
Hippocrepis nevadensis	-	-	●	●	-
Chamaespartium undulatum	-	-	●	-	-
Rothmaleria granatensis	-	-	●	-	-
Laserpitium longiradium	-	-	●	-	-
Helianthemum pannosum	-	-	●	-	-
Erodium boissieri	-	-	●	-	-
Lomelosia pulsatilloides	-	-	●	-	-
Linaria saturejoides subsp. *angustealata*	-	●	●	-	-

The Nevada Sierran Sector covers 1290 km^2, the 75% of the total area of the park and occupies the central territory, with the highest peaks and metamorphic geological substrata (lastra). Seven large river basins (Guadalfeo, Grande de Adra, Andarax, Nacimiento, Guadix-Guadiana Menor, Genil and Dúrcal) originate in its summits. The thermotypes range from the thermomediterranean to the cryoromediterranean thermic belts, with arid to humid ombrotypes. The plant ecosystems have very high biodiversity.

In the oro- and cryoromediterránean bioclimatic belts, the special climatic conditions, high rate of endemic species and plant communities, afford strong independence to the summits. The melted deep winter snow gives rise to springs, streams, and high-altitude boggy soils, which harbour diverse hygrophilous plant communities (borreguiles). Entire months of winter registering T> 0ºC (1 to 6 months) and an aridic summer ($Io_{7-8} < 2.0$) gives rise to open, desertic-like upper oro- and cryoromediterranean vegetation. The lower oromediterranean belt, which starts at 2100-2150 m on the northern slope and at 2200-2250 m on the southern slope, rarely undergoes continuous freezes (gelid months). Before the anthropic destruction of pine forest (*Pinus sylvestris* subsp. *nevadensis*) the natural potential vegetation consisted of the dwarf hemispheric juniper communities of *Juniperus hemisphaerica*, which constituted the first seral vegetation stage of the Sierra Nevada Scots pine forest in the lower horizon. This community of junipers made up the climax vegetation in the medium and upper oromediterranean belts. The Sierra Nevada Scots pine (*Pinus sylvestris* subsp. *nevadensis*), widely cultivated, continues to be the potential vegetation particularly on shallow soils in the high levels of the upper supramediterranean horizon, where the woodlands of *Quercus pyrenaica* and *Quercus rotundifolia* as well as *Acer granatense* and *Betula fontqueri* grow well on deeper soils.

The High Nevada Sierran District (43b) is located in the central-western part of park. It contains all the forest flora and vegetation of the sector and the greatest number of ecosystems, plant communities, and endemic taxa. The marked differences between highlands (upper oro- and cryoromediterranean belts) and the lower areas make it possible to divide the area into two separate territories:

43b1. High Nevada Sierran Frigid Territory

Is the culminating zone of Sierra Nevada of (187 km^2, 11%), with a great part of the oromediterranean belt and all the cryoromediterranean belt of the national park. The upper oromediterranean horizon begins at 2500 m asl (2600 m asl south), with 3-4 months of temperatures below zero degrees and the cryoromediterranean from 2800-2850 m asl (2900-2950 m asl south), with 6 months of temperatures below zero. The series *Genisto versicoloris-Junipero hemisphaericae S.* is the climax dwarf prostrate shrubby juniper in the lower zone, mostly under 2800 m asl and in the cryoromediterranean a mosaic of perma-series occupy the different habitats of the high mountain. This belt and, in general, most of territory, is a desolate, desert-like environment with a great number of taxa endemic to Sierra Nevada and two types of characteristic ecosystems. The first is xerophytic frigid, which corresponds to associations of *Nevadension purpureae* and *Holcion caespitosi* (scree), which are extensive, while the second consists of hygrophilous peaty and boggy communities locally known as *borreguiles* (*Festucion frigidae, Plantaginion nivalis*), these being quite, scarce.

The ombrotypes range from the humid at the base south and western part of the territory changing to the dry or even the upper semi-arid as the cryoromediterranean belt ascends (>3000 m). This territory has the highest number of frosty months. Some bioindicators of the territory are included in Table 5.

Table 5. Frigid High Nevada Sierran Summits Territory bioindicators. Ps: permasigmetum, Ms: minorisigmetum; T: thermomediterranean; M: mesomediterranean; S: supramediterranean; O: oromediterranean; C: cryoromediterranean.

43b1. Frigid High Nevada Sierran Summits Territory. SNNP	Thermotypes				
	T	M	S	O	C
Sigmataxa, Permasigmeta					
Erigeronto frigidi-Festuco clementei Ps.	-	-	-	-	●
Genisto versicoloris-Junipero hemisphaericae Ms.	-	-	-	●	-
Festuco moleroi-pseudoeskiae Ps.	-	-	-	●	●
Violo crassiusculae-Linario glacialis Ps.	-	-	-	●	●
Campanulo willkommii-Polysticho lonchitidis Ps.	-	-	-	●	●
Ranunculo acetosellifolii-Vaccinio nani Ps.	-	-	-	●	●
Nardo strictae-Festuco ibericae Ps.	-	-	-	●	●
Saxifrago nevadensis Ps.	-	-	-	-	●
Taxa					
Artemisia granatensis	-	-	-	●	●
Festuca frigida	-	-	-	●	●
Ranunculus alismoides	-	-	-	●	●
Trisetum glaciale	-	-	-	●	●
Iberis embergeri	-	-	-	●	●
Pedicularis verticillata subsp. *caespitosa*	-	-	-	●	●
Vaccinium uliginosum subsp. *nanum*	-	-	-	●	●
Cerastium alpinum subsp. *nevadense*	-	-	-	-	●

43b2. High Nevada Sierran Slopes Territory

This is a large area of 426 km^2 (25%) that occupies the siliceous substrates of the high slopes of the entire western Sierra Nevada, located in the Alhama, Genil, Dúrcal, and Guadalfeo (Torrente, Lanjarón, Poqueira, Trevélez) basins. The thermotypes go from the lower mesomediterranean to lower oromediterranean, with dry, subhumid, and lower humid ombroclimates at the beginning of oromediterranean belt. The mesomediterranean boundary is situated around 1200-1300 m asl in the Genil, Alhama, and Dúrcal basins, increasing towards the south, the Guadalfeo basin, to 1400-1450 m asl. The anthropogenic climatophilic pine forests (*Avenello ibericae-Pinetum nevadensis*) mark the transit to the Frigid Territory and confirm the potentiality of this territory between bioclimatic belts. The oak, Holm oak, ash, maple, birch, and alder forests and other associations typical of high rainfall or humid soils are common. Several bioindicators are listed in Table 6.

Table 6. High Nevada Sierran Slopes Territory bioindicators. Gs: geosigmetum; S: sigmetum; T: thermomediterranean; M: mesomediterranean; S: supramediterranean; O: oromediterranean; C: cryoromediterranean.

43b2. High Nevada Sierran Slopes Territory. SNNP	Thermotypes				
	T	M	S	O	C
Sigmataxa, Syntaxa					
Genisto versicoloris-Junipero hemisphaericae S.	-	-	-	●	-
Avenello ibericae-Pino nevadensis S.	-	-	●	●	-
Berberido hispanicae-Aceri granatensis S.	-	-	●	-	-
Carici camposii-Alno glutinosae Gs.	-	-	●	-	-
Aceri granatensis-Fraxino angustifoliae S.	-	-	●	-	-
Adenocarpo decorticantis-Querco pyrenaicae S.	-	●	●	-	-
Agrostio nevadensis-Genistetum versicoloris	-	-	-	●	-
Rhamno cathartici-Loniceretum arboreae	-	-	-	●	-
Taxa					
Arabis margaritae	-	-	-	●	-
Tephroseris elodes	-	-	-	●	-
Thymus pulegioides	-	-	●	●	-
Salix caprea	-	-	●	-	-
Sorbus hybrida	-	-	●	-	-
Heracleum sphondylium subsp. *granatense*	-	●	●	-	-
Laserpitium latifolium subsp. *nevadense*	-	●	●	-	-
Quercus pyrenaica	-	●	●	-	-

43a. East Nevada Sierran District

The eastern district of the sector, with 676 km^2 (39%), presents a gradual decrease in precipitations towards the east. It is located in the Guadix, Nacimiento, Andarax, and Grande de Adra basins. The high elevation also decreases towards the east: San Juan 2781 m asl, Chullo 2612 m asl, Almirez 2519 m asl, Polarda 2253 m asl, and Montenegro 1710 m asl. This district lacks in the cryoromediterranean vegetation belt. The great extent of this territory, with N, S, and E exposures, causes appreciable changes in thermotypes, ombrotypes, and continentality. At the summits, the oromediterranean belt begins at 2200 m asl on the northern slope and at 2300 m asl on the southern one. The deep soils with large periglacial stones appear to encourage the afforested *Pinus sylvestris* subsp. *nevadensis*, at present mostly of anthropogenic character. The seral and climatic vegetation of this area belong to *Genisto versicoloris-Junipero hemisphaericae S.* with *Hieracio castellanae-Festucetum longiauriculatae* as seral grassland, and particularly at lower altitudes and in the high summits the grasslands of *Arenario frigidae-Festucetum indigestae* develop quite well.

Thermotypes go from lower mesomediterranean to the lower oromediterranean and the ombrotypes from the semiarid to the lower humid. In the south, less moisture and higher temperatures characterize the transit towards the east. The boundary between the meso- and supramediterranean thermotypes in Rio Grande basin is located at 1450-1500 m asl and at 1500-1550 m asl climbing the Andarax river. The semiarid ombrotype begins to predominate towards Montenegro peak. On the northern slopes this boundary lies at 1250-1300 m asl. It is a cold district, largely semicontinental. It shares with the western district a great number of communities, series, and species. The *Quercus pyrenaica* oak series is absent, but the *Quercus rotundifolia* xeric synvariants are significant with respect to the western series. Table 7 shows some bioindicators.

Table 7. East Nevada Sierran District bioindicators. S: Sigmetum; T: thermomediterranean; M: mesomediterranean; S: supramediterranean; O: oromediterranean; C: cryoromediterranean.

43a. East Nevada Sierran District. SNNP	Thermotypes				
	T	M	S	O	C
Sigmataxa, Syntaxa					
Genisto versicoloris-Junipero hemisphaericae S.	-	-	-	●	-
Avenello ibericae-Pino nevadensis S.	-	-	●	●	-
Dactylido hispanicae-Festucetum scariosae	-	-	●	-	-
Adenocarpo decorticantis-Querco rotundifoliae S.	-	●	●	-	-
Dorycnio recti-Salici pedicellatae S.	-	●	-	-	-
Genisto versicoloris-Cytisetum nevadensis	-	-	-	●	-
Teucrio compacti-Quercetum cocciferae	-	●	-	-	-
Thymo gracilis-Cistetum ladaniferi	-	●	-	-	-
Taxa	-	-	-	-	-
Ranunculus girelai	-	-	-	●	-
Erysimum baeticum	-	-	●	●	-
Artemisia chamaemelifolia	-	-	●	●	-
Saxifraga trabutiana	-	-	●	-	-
Pinguicula grandiflora	-	-	●	-	-
Moehringia fontqueri	-	-	●	-	-
Centaurea pulvinata	-	-	●	-	-
Sideritis luteola	-	●	-	-	-

40c. West Almeria District

This occupies an area of 83.9 km^2 (4.8%) in the low basins of the Nacimiento and Andarax rivers in the eastern limits of the National Park and reaches altitudes of close to 800 m on the slopes of the Sierra Nevada. The geological substrates are marls, sandstones, silts, alluvium materials, and calco-dolomites towards the base of the Sierra de Gádor. The territory has low continentality where it is open towards the Mediterranean. The temperatures are the highest in the park, with thermotype predominant upper thermomediterranean and with little representation of the lower thermomediterranean. Rainfall is scarce, with upper arid and lower and upper semiarid ombrotypes. The vegetation differs markedly from that of the rest of the park, with very little cover and a general absence of trees, very open, poor, desertic, where the shrubby climax vegetation, has practically disappeared and there are some stages with steppe plants. The series, *Zizipho loti-Mayteno europaei S.* is probably extinct in the park. Some of the bioindicators in this district are listed in Table 8.

44a2. Gádor Sierran East Nevada Territory

Territory with 115 km^2 (7%) in the basin of the Andarax river. Geological substrates sometimes complex, the limestones and calco-dolomites predominate and reach almost 2000 m asl on the slope of the Buitre. It presents greater oceanity, with upper thermomediterranean to the upper supramediterranean thermotypes, and with the upper semiarid to the upper subhumid ombroclimes. Contact with the Almerian sector means that the two sectors have species in common. In the mesomediterranean dry belt appears the East Penibetic calco-dolomiticolous series of the Holm oak, *Paeonio coriaceae-Querco rotundifoliae S.*, synvariant with *Phlomis almeriensis* whereas in the supramediterranean subhumid belt on similar rocky soils, but higher than 1450 m asl the synvariant of *Echinospartum boissieri* is common, with *Lavandula lanata* belonging to *Berberido hispanicae-Querco rotundifoliae S*. Some bioindicators of this territory are included in Table 9.

Table 8. West Almería District bioindicators. T: thermomediterranean; M: mesomediterranean; S: supramediterranean; O: oromediterranean; C: cryoromediterranean.

40c. West Almería District. SNNP	Thermotypes				
	T	M	S	O	C
Sigmataxa, Syntaxa					
Ephedro fragilis-Pino halepensis S. synv. with *Launea lanigera*	●	●	-	-	-
Zizipho loti-Mayteno europaei S.	●	-	-	-	-
Lonicero biflorae-Populo albae S.	●	-	-	-	-
Dactylido hispanicae-Lygeetum sparti	●	●	-	-	-
Suaedo verae-Salsoletum oppositifoliae	●	●	-	-	-
Atriplici glaucae-Hammadetum articulatae	●	●	-	-	-
Helianthemo almeriensis-Sideritidetum pusillae	●	-	-	-	-
Anabasio hispanicae-Euzomodendretum bourgeani	●	-	-	-	-
Taxa					
Hammada articulata	●	●	-	-	-
Suaeda pruinosa	●	●	-	-	-
Plantago ovata	●	●	-	-	-
Whitania frutescens	●	-	-	-	-
Euzomodendron bourgaeanum	●	-	-	-	-
Anthyllis terniflora	●	-	-	-	-
Salsola papillosa	●	-	-	-	-
Forsskaolea tenacissima	●	-	-	-	-

Table 9. Gádor Sierran East Nevada Territory. T: thermomediterranean; M: mesomediterranean; S: supramediterranean; O: oromediterranean; C: cryoromediterranean.

44a2. Gádor Sierran East Nevada Territory. SNNP	Thermotypes				
	T	M	S	O	C
Sigmataxa, syntaxa					
Berberido hispanicae-Querco rotundifoliae S.	-	-	●	-	-
Paeonio coriaceae-Querco rot. S. sinv. with *Phlomis almeriensis*	-	●	-	-	-
Rhamno almeriensis-Pino halepensis S.	-	●	-	-	-
Helictotricho filifolii-Festucetum scariosae	-	-	●	-	-
Convolvulo lanuginosi-Lavanduletum lanatae	-	●	●	-	-
Genisto retamoidis-Phlomidion almeriensis	●	●	-	-	-
Saturejo micranthae-Thymbrion capitatae	●	●	-	-	-
Lapiedro martinezii-Stipetum tenacissimae	●	●	-	-	-
Taxa					
Centaurea gadorensis	-	-	●	-	-
Teucrium bicoloreum	-	-	●	-	-
Echinospartum boissieri	-	●	●	-	-
Ephedra nebrodensis	-	●	●	-	-
Lavatera oblongifolia	●	●	-	-	-
Salvia candelabrum	●	●	-	-	-
Phlomis almeriensis	●	●	-	-	-
Lavandula lanata	●	●	-	-	-

Other small distrital territories exist in Sierra Nevada National Park:

45a. Vega of Granada District

With 10 km^2 (0.6%), it includes piedmont and meadows (vega) that converge towards the channel of the river Genil, and has heterogeneous conglomerates in the piedmont with marls and clays in the meadows area.

44b. Alpujarras District

This extends through the basin of the Guadalfeo river. In the national park, there are only fragments with 13 km^2 (0.7%). In the lower mesomediterranean dry belt, on calco-dolomitic rocky soils and launas of the Alpujarrid substrata, the natural potential vegetation correspond to a thermic microforest of *Quercus rotundifolia* that belong to *Paeonio coriaceae-Querco rotundifoliae* S. with *Rhamnus velutina* and *Phlomis purpurea.*

42a. Hoya of Guadix District

Only marginal inside the Sierra Nevada National Park, this measures 11 km^2 (0.7%) of disjointed terrain. It has poor representation in the Guadix river basin, with substrates of basic and ultrabasic (mafic) nature. The thermotypes are upper mesomediterranean and lower supramediterranean, with semiarid and dry ombrotypes.

Other adjacent districts appear on the map but not within Sierra Nevada National Park, such as 42e Filabres Sierran D, 42f Baza Sierran D, 45b Alfacar Sierran D, and 54d Almijaran Sierran D.

Conclusion

A total of 2 provinces, 5 sectors, and 8 districts (one with two territories), map 1, are established in the Sierra Nevada National Park, identified from the application of bioclimatic indices (Rivas-Martínez & *al*., 2011c), by delimitation of thermotypes and ombrotypes (bioclimatic belts), the study of the territory and the recognition and discrimination of bioindicators, using flora, plant communities, and vegetation geopermaserie, series, and geoseries. The recognition of homogeneous territories (countries) is an essential tool for the management of Sierra Nevada National Park.

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Floristic Appendix

The taxa mentioned in the text follow the nomenclature used in Flora de Andalucía Oriental (Blanca & al. (Eds.) 2009), except the following

Iberis embergeri Serve: *Iberis carnosa* Willd. subsp. *embergeri* (Serve) Moreno

Phlomis almeriensis: *Phlomis purpurea* L. subsp. *almeriensis* (Pau) Losa & Rivas Goday

Ranunculus alismoides Bory: *Ranunculus angustifolius* DC. subsp. *alismoides* (Bory) Malag.

Ranunculus girelai: *Ranunculus querubicus* (J.A. Sánchez Rodr., M.J. Elías & M.A. Martín) Fern. Prieto, Sanna, M.Pérez & Cires subsp. *girelai* Fern.Prieto, Molero Mesa, Muñoz Díaz & Sanna

Sideritis luteola Font Quer

Vaccinium uliginosum subsp. *nanum* (Boiss.) Rivas-Martínez, Asensi, Molero Mesa & F. Valle

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