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Ecological factors of biodiversity for the Mediterranean steppic grassland of Murgia (Apulia Italy)

M. Terzi[1], L. Forte[2], V. Cavallaro[2], A. Lattanzi[2], F. Macchia[2]

Summary

Murgia is a tabular mountain range of low altitude and elongated in shape stretching WNW-ESE, located in central Apulia (Italy). Its North-Western part (with maximum elevations of 700 m a.s.l.), also known as Alta Murgia or North-West Murgia, is covered by a wide steppic grassland dominated by in *Stipa austroitalica* Martinovsky and *Festuca circummediterranea* Patzke. The richness of vascular flora (more than 390 species) recorded here is related to the heterogeneous conditions of the area determined by the regional geographic context, the physiography of the range, the pedological substrate and by natural and anthropic disturbances. The vegetation and phytoclimatic analyses of this steppic grassland have allowed to evaluate the habitat heterogeneity: this study is a basic step for the working out of conservation programmes of Murgia biodiversity.

Key words: biodiversity, Mediterranean steppe, Murgia, bioclimatic indexes.

1. Introduction

Murgia is a tabular mountain range low in altitude, with a maximum elevation at Torre Disperata (686 m a.s.l.), included in the provinces of Bari, Brindisi, Taranto and, partly, Matera. The range elongated in shape and running WNW-ESE, stretches from the Ofanto river valley to the hystmus comprised between Taranto and Brindisi and bordering SW with the Bradano valley and NE with the Adriatic Sea.

Geologically, Murgia is made up of a sedimentary complex of Cretaceous age whose lithostratigraphic units fall within the group of "Calcari delle Murge" (Azzaroli *et al.*, 1968a; Azzaroli *et al.*, 1968b). Its tectonic style is represented by a wide SSW-dipping monoclinal structure characterised by small folds and direct faults, partly covered by Plyo-pleistocene sedimentary forming a horst (Ciaranfi *et al.*, 1988). The most important disjunctive structures correspond to fault systems which decompose the rigid carbonate substrate forming a horst (Ciaranfi *et al.*, *op. cit.*; Ricchetti, 1980). The major ridges of this system are NW to SE and WNW to ESE

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oriented, whereas the subordinate fault systems develop from SW to NE (Ricchetti, *op. cit.*).

The morphological structure of Murgia stems from the interaction between tectonic and geomorphologic processes. Of great importance are erosions enhanced by the *horst* structural aspect and the chemical corrosion of the carbonate substrate (karsism); sedimentary processes are definitely absent. The range physiography features the typical traits of karsic landscape, with sub-horizontal, slightly wavy and areic surfaces (Anelli *et al.*, 1973) with the formation of the so-called "functional complexes" (Sauro, 1991).

Despite the geological uniformity of the area, the high heterogeneity of the biophysical and anthropic systems allows to break down Murgia into homogeneous subunits. The "Alta Murgia" toponym identifies the North-Western part of the range (with respect to the morphotectonic depression of Gioia del Colle - Bari province) with elevations above the 350-m contour line (Rossi, 1988; Ciaranfi *et al.*, *op. cit.*).

Based on the analysis of temperatures and rainfall recorded over a thirty-year period by the climatic stations of Altamura (Bari), Castel del Monte (Andria - Bari), Minervino Murge (Ba) and Spinazzola (Ba) (Ministry of Public Works Hydrographic Service), the climate of this area is characterised by rather cold winters, warm and dry summers. Gaussen aridity index (1954), i.e. $I = 2T - P$, calculated for the above four stations, proved to be positive for at least two months and the climate is therefore Mediterranean (Gentile, 1990; Daget, 1984).

The calcareous rocky substrate outcrops and the shallow soils of Alta Murgia (Inceptisols, Alfisols and Mollisols) deepen only in case of incisions and faultings in the rock, of karst or morphotectonic depressions and along ancient torrentitial incisions locally called "lame" or "gravine". In general the soil depth, never exceeds 50 cm (Cassi *et al.*, 1999).

The vegetation is made up of three main physiognomic typologies: the steppic grassland or rocky pasture; the bushy grassland and the woodland. The steppic grassland with *Stipa austroitalica* Martinovsky, *Festuca circummediterranea* Patzke and *Asphodelus microcarpus* Salzm. et Viv., occupy the upper and south-western area of Alta Murgia. The grassland communities often take the garigue or pseudogarigue aspect for the presence of fruticose or subfruticose chamaephytes and deciduous nanophanerophytes the most frequent being *Rhamnus saxatilis* Jacq. subsp. *infectorius* (L.) P. Fourn. At lower elevations, after an ecotone belt of bushy grassland, the steppic grassland shifts to woodland phytocoenosis dominated by different species according to the side. Along the north and north-eastern sides, the dominant species in the woods are *Q. pubescens* Willd. s.l. and *Q. cerris* L.; towards south-east *Q. pubescens* and *Q. coccifera* L. with *Q. trojana* Webb, *Q. ilex* L., *Q. cerris* and *Q. frainetto* Ten. moving southwards (in the proximity of Santeramo in Colle); to the west, beyond the "Fossa Bradanica", near Gravina in Puglia (Bari), *Q. cerris*, *Q. frainetto* and *Q. pubescens* are found (Carano, 1934; Crivellari, 1950; Scaramuzzi and Lorito, 1953; Bianco, 1962; Zito *et al.*, 1975; Bianco *et al.*, 1991; Macchia *et al.*, 2001; Forte, 2001).

The steppic grassland of Alta Murgia is very rich in vascular flora with some 400 specific and subspecific *taxa;* a lot of these *taxa* are endemic, subendemic or rare. The current study was carried out with a view to probing into the diversity of this *taxocenes* with special reference to its two components: richness and equitability (Whittaker, 1965; 1972).

2. Materials and methods

The flora of the steppic grassland in the Alta Murgia area was analysed based on 24 relevés and on the data reported in the literature (Bianco, 1962). This analysis was conducted with the support of Flora d'Italia (Pignatti, 1982), Nuova Flora Analitica d'Italia (Fiori, 1923-1929) and Flora Europea (Tutin *et al.*, 1964-1980). The nomenclature followed is that by Pignatti in Flora d'Italia.

The vegetation relevés, following the phytosociological method of Zurich-Montpellier school (Braun-Blanquet, 1932), were conducted in *S. austro-italica* communities at different elevations, exposures and sloping.

On the basis of abundance-dominance data of each species, in each relevé, diversity was estimated through Shannon-Wiener (in: Kent and Coker, 1992), equitability (Pielou, 1969) and Margalef indexes (1958; 1967):

Shannon-Wiener index: $H = - \quad p_i \ ln \ p_i$; where p_i represents the *relative importance* (Whittaker, 1965; 1972) of the i-^{nth} species given by the ratio between the *importance* of the i-^{nth} species and the summation of the *importance* of all the present species;

equitability index: $J = H/H \ max$; where $H \ max$ represents the value H would take if all the species had the same *relative importance* ($Hmax = ln \ S$; where S is the total number of species);

Margalef index: $Dm = (S-1)/ln \ N$; where for N the total cover value is used as the summation of partial covers relative to each species.

These indexes were computed at two scale levels:

at a higher scale level, the three indexes were calculated for every single vegetation relevé; the relative importance value (p_i) for each species is equal to the ratio between its "coverage coefficient" (Tommaselli, 1956) and the sum of coverage coefficients of all the species registered in the relevé;

at a lower scale level, i.e. considering together all the 24 relevés, p_i was computed as the ratio between the mean value that the coverage coefficient of the i-^{nth} species takes in the 24 relevés and the summation for all the present species.

The calculation of the three indexes allowed to evaluate the impact of the two components of diversity, number of species (richness) and relative equitability, on the diversity (H) calculated for the two scale levels.

In order to correlate the data obtained to the phytoclimatic features of the area, two bioclimatic diagrammes were drawn up based on Montero de Burgos and Gonzales Rebollar (1974) method whose application fits the regional territory of Apulia (Forte and Vita, 1998), for two sites located one in a valley and at a higher elevation (600 m a.s.l.) and the other on a 23° slope at a lower altitude (460 m a.s.l.). The thermal and pluviometric regimes of these two sites were inferred by processing the daily temperature and rainfall data recorded over a thirty-year period (1962-1992) by six climatic stations in the province of Bari: Altamura, Castel del Monte, Ruvo di Puglia, Grumo Appula, Minervino Murge and Spinazzola. The estimate of the most probable mean temperatures per decade in the two sites was obtained through the double altimetry-sun radiation regression (Viola and Ducoli, 1982); for this last parameter, sun radiation without apparent contour was used (Bartorelli, 1965) in that the shadowing effect is neglectable or even null for the physiography of the studied area.

The estimate of the udometric regime for both sites was attained through the following relation (Viola and Ducoli, *op.cit.*):

$$P_x \quad \frac{\sum_{j\ 1}^{n} P_j \dfrac{1}{d_j}}{\sum_{j\ 1}^{n} \dfrac{1}{d_j}}$$

where P_x is the rainfall value looked for; P_j is the rainfall known of the j-nth station and d_j the distance between the j-nth station and the point whose rainfall is unknown.

The values of potential evapotranspiration, used for the bioclimatic diagrammes, were measured through the Turc algorithm (1961); the values concerning the available water capacity of the soil, with a maximum depth of 30 cm in both sites, were obtained through lab analyses on three soil samples taken at a depth of 0-10 cm, 10-20 cm and 20-30 cm. Soil samples were submitted to tensiometric analysis by using Richards plate method (Testini, 1989) for growing pressures of 0.3, 0.5, 1.0, 8.0 and 15.0 atmospheres. In the light of the tensiometric analyses, the water available capacity was estimated; it equals 50 mm with a mean water quantity of 1.68 mm/cm. The parameters of the water balance are quite representative of the water-temperature-plant relationship in that the geological nature of the substrate, made up of fissured limestone, excludes any water supplied by the shallow water table.

3. Results and Discussion

Shannon-Wiener diversity index, calculated for the 24 vegetation relevés, ranges between 0.87 and 2.38, with a mean value of 1.74 (Tab. 1). The relatively wide variations of the index do not show any significant correlation with the value of Margalef index and they do not seem to depend on the floristic richness of individual relevé (Fig. 1). The correlation with the equitability index (J) is much stronger: the value of the correlation coefficient (r = 0.988) is highly significant (Fig. 1 and 2). As consequence, in the steppic grassland of Alta Murgia, the level of importance of species in the community determines the diversity variations even before the specific richness. On average, the equitability index proved to equal 0.42; the extreme values are of 0.21 and 0.59 (Tab. 1).

The three indexes (Shannon-Wiener, Margalef and equitability) do not show single correlations with the altitude, exposure, the coverage level, rockiness of the surveyed areas or the presence of the major biological components. It is therefore reasonable to assume that the variations found are determined by the interaction of several environmental factors.

By comparing the mean value of the diversity index calculated for the single relevés (= 1.74) and the value of the same index computed for au the 24 relevés (= 2.56), it may be pointed up that diversity increases shifting to a lower scale level (Tab. 1 and 2). The difference between the two values cannot be attributed to the equitability since the value of the relative index for all the relevés (equalling 0.48) slightly differs from the average of those estimated for the single relevés (0.42); in contrast, it is ascribable to the great difference between the number of species registered for every single relevé (62.6 on average) and the total number of species (above 200). Margalef index, which assesses the floristic richness, is equal to 13.28 and

49.10 for the upper and lower scale level respectively (Tab. 1 and 2). It results that the relevés differ considerably in terms of specific composition although they all fall within the same physiognomic type (grassland communities dominated by *Stipa austroitalica*). This consideration is ecologically significant; if the distribution of every single species is related to the characteristics of its ontogenetic cycle, of its physiology and to the way it is related to the sequences of environmental parameters (including the interactions with the other species) (Whittaker, 1972) then, despite an apparent physiognomic uniformity, the area features a complex mosaic of micro-environments enabling the development of different species according to the site. It is just this heavy space heterogeneity, caused by several factors working simultaneously and hardly decomposing, which allows the co-existence of a high number of species, and to determine the high phytodiversity (Noy-Meir, 1998).

For low-scale levels (for a low ratio between mapped distances and effective distances), the major factors responsible for the structural macro-heterogeneity (Forman and Godron, 1986) of the habitat are represented by the regional geographic context and by the range physiography (Macchia, 1997; Macchia *et al.*, 2001). Therefore, the Mediterranean macroclimate is modified in the area by these factors.

The Adriatic side of the range is exposed to the climate of the European north-eastern sector, whereas the south-western side is influenced by the proximity of the Apennines which modifies the duration and severity of cold periods (Macchia, *op.cit.*; Macchia *et al.*, *op. cit.*).

In addition, the altimetric differences induce clear-cut variations of the duration and intensity of the growing period. The bioclimatic diagrammes, following Montero de Burgos and Gonzales Rebollar (1974), concerning two sites of Alta Murgia at elevations of 460 (Fig. 3 and Tab. 3) and 600 m a.s.l. (Fig. 4 and Tab. 4) show how at higher elevations the primary productivity of ecosystems is dramatically reduced in terms of duration and intensity, especially in the spring time. For the station at 600 m, the winter period of inactivity of plants (represented by IBLf-free Bioclimatic Intensity,cold type) starts one decade earlier and terminates two decades later (between the second and third decade of March); the summer period of inactivity, graphically represented by IBS (Dry Bioclimatic Intensity), occurs more or less simultaneously in both stations, and starts between the last decade of June and the first of July till the second decade of August. With the exception of May and of three decades between September and October, the values of IBLc (Free Bioclimatic Intensity-warm type), which represents an assessment of the net primary productivity, are always higher in the low-elevation station (Fig. 3 and 4).

The habitat macro-heterogeneity, primarily related to physiography (elevation variations and slope exposure) is overlapped by a high micro-heterogeneity (Forman and Godron, op. cit.) bound to the complex edaphic conditions and anthropic and natural disturbances.

The rocky substrate, forged by karst processes, outcrops and determines several *microhabitats* bound to the shape of rocks and to the soil thickness. Twenty to thirty centimetres of soil with rare deeper pockets were found. It is clear that the soil thickness can impact the type of vegetation and determine per se a high diversification of the specific composition.

In the dense vegetation mosaic, of relevance are the disturbances of antropic origin and in particular that bound to the pastoral activity. The influence of pasture on the specific diversity of plant communities was interpreted by Naveh and Whittaker (1979) in evolutionary terms, discriminating between the geographical environments where pasture has long been practised and those where this activity is more recent. Adaptations to community level are the evolutionary response to regular variations of environmental parameters that occurred for a sufficiently long period (Forman and Godron op. cit.); consequently, in the areas where pasture has been practised for long periods, the specific composition of communities and the functional relations (co-evolution) have been modified by the evolution of the species and the immigration of other species pre-adapted to those environmental conditions (Naveh and Whittaker, 1979; Thompson, 1996). In the Mediterranean grassland devoted to pastoral activities since time immemorial, as in Alta Murgia (Amico, 1954), the grazing pressure is a relevant ecological parameter of the system in the determination of the relative floristic richness. If the grazing pressure does not exceed (neither positively nor negatively) the range of the plant community adaptation, the floristic diversity remains high and unaltered. Conversely, species will get reduced to the most resistant and less palatable for an excessive pressure and to the most “aggressive” in case of pasture reduction.

It is therefore reasonable to admit that these communities are characterised by a metastable equilibrium, determined by competitive exclusion relations (Whittaker, 1975) and co-existence in non-equilibrium conditions (due to fluctuations of the population density) (Pickett and Thompson, 1978; Silvertown, 1978), which permit the persistence also for those populations of the less aggressive species.

This last remark paves the way to one further consideration about the heterogeneity of Alta Murgia; no doubt that the space heterogeneity shows also a basic time dimension concerning both the time variability of the climatic, edaphic conditions and, in a more overt manner, the set of antropic and natural disturbances. It results that all the aspects of the structural heterogeneity of the Alta Murgia habitat shall be related to their temporal variability and analysed based on space-time scale levels which better show the mutability of phenomena.

4. Conclusions

The high diversity of the vascular flora of the Alta Murgia steppic grassland is related to the specific richness, to the number of taxa more than to the relative equitability. The co-existence of several species depends on the space-time heterogeneity of the habitat in terms of both macro and micro-heterogeneity.

Many of the plant species registered in this grassland are endemic, sub-endemic or rare and accrue the naturalistic value of the area in terms of its biological conservation (Terzi, 2000). Conservation programmes shall be designed to safeguard diversity on a regional scale (Noss, 1983); therefore, the protection of endangered species (like the endemic ones) is a key point for the conservation of the phytogenetic resources of the area. Among them: *Stipa austroitalica* Martinovsky subsp. *austroitalica*, endemic species of the south of Italy (Moraldo, 1986) and included in the list of protected species at European level (Official Journal of the EEC, 22/7/92 Directive 92/43 EEC); *Thymus spinulosus* Ten., endemic species of Southern Italy and Sicily and in former-Yugoslavia; *Phleum ambiguum* Ten., endemic species of central, southern Italy; *Helianthemum jonium* Lacaita, endemic species of Apulia, Basilicata and Romagna; *Crocus thomasii* Ten., sub-endemic species of Apulia and Basilicata together with Dalmatia; *Centaurea deusta* Ten. subsp. *deusta*, endemic of central, southern Italy (up to Romagna); *Ornithogalum adalgisae* Groves, endemic of Apulia; *Carduus micropterus* (Borb.) Teyber subsp. *perspinosus* (Laicata) Kazmi, endemic of southern Italy, etc..Of great importance are the species of the Orchidaceae family, both for the presence of endemisms (such as *Ophrys mateolana* Medagli et al. or *Ophrys holoserica* (N.L.Burm.) Greuter subsp. *candica* Nelson) both because speciation processes are in progress in the Murgia area (Bianco *et al.*, 1991).

The high naturalistic value of Alta Murgia steppic grassland requests their protection through management plans which, on the basis of the ecology of these ecosystems, allow the protection of ecological processes upon which structure, functionality and persistence of the biological communities depend. Therefore, the plans the should be focused on the ecological processes that mantain the space-time heterogeneity and particularly on the antropogenic disturbance management

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Tab. 1. Values of Shannon-Wiener, Equitability and Margalef Indexes, and Species number for 24 relevé

Relevé Number	Shannon-Wiener Index (H)	Equitability Index (J)	Margalef Index (Dm)	Species number
1	1.82	0.43	14.36	69
2	1.62	0.38	14.43	74
3	1.44	0.35	14.10	58
4	1.64	0.40	16.17	63
5	2.38	0.59	15.17	58
6	1.61	0.39	13.86	70
7	1.68	0.42	14.42	56
8	0.87	0.21	14.88	55
9	2.13	0.51	14.24	68
10	1.67	0.43	11.09	60
11	0.95	0.24	10.92	61
12	1.96	0.51	10.46	58
13	2.28	0.55	16.25	64
14	1.49	0.38	11.55	50
15	1.90	0.45	14.32	66
16	2.03	0.51	12.61	55
17	1.50	0.36	15.73	67
18	1.86	0.44	14.51	68
19	2.11	0.49	15.51	71
20	1.44	0.35	13.23	62
21	1.82	0.43	14.15	68
22	1.91	0.49	10.93	51
23	1.92	0.45	14.97	69
24	1.65	0.40	13.79	62
Mean values	**1.74**	**0.42**	**13.82**	**62.63**

Tab. 2. Values of Shannon-Wiener, Equitability and Margalef Indexes and species number, considering together all the 24 relevés

Shannon-Wiener Index (H)	Equitability Index (J)	Margalef Index (Dm)	Species number
2.56	0.48	49.10	216

Tab. 3. Bioclimatic parameters for the site at 460 m a.s.l.

		T (°C)	Prec (mm)	PE (mm)	D (mm)	S (mm)	etr (mm)	IBP (ubc/ month)	IBR (ubc/ month)	IBLc (ubc/ month)	IBSc (ubc/ month)	IBLf (ubc/ month)
J	1°decade	5.84	10.84	10.45	57.88	47.04	2.09	-0.33	-0.33	0.00	0.00	0.33
	2°decade	5.62	26.09	10.17	73.52	47.43	2.03	-0.38	-0.38	0.00	0.00	0.38
	3°decade	6.28	13.34	11.01	63.34	50.00	2.20	-0.24	-0.24	0.00	0.00	0.24
F	1°decade	6.03	14.77	12.45	64.77	50.00	2.49	-0.29	-0.29	0.00	0.00	0.29
	2°decade	6.30	25.18	12.85	75.18	50.00	2.57	-0.24	-0.24	0.00	0.00	0.24
	3°decade	6.80	20.92	13.55	70.92	50.00	2.71	-0.14	-0.14	0.00	0.00	0.14
M	1°decade	7.52	22.58	17.68	72.58	50.00	3.54	0.00	0.00	0.00	0.00	0.00
	2°decade	8.15	17.53	18.64	67.53	50.00	3.73	0.13	0.13	0.13	0.00	0.00
	3°decade	11.10	16.94	22.52	65.83	48.89	4.50	0.72	0.72	0.72	0.00	0.00
A	1°decade	11.60	12.63	28.05	55.94	43.31	5.61	0.82	0.82	0.82	0.00	0.00
	2°decade	10.88	20.90	27.04	48.80	27.90	5.41	0.68	0.68	0.68	0.00	0.00
	3°decade	12.86	8.94	29.69	30.70	21.76	5.94	1.07	1.07	1.07	0.00	0.00
M	1°decade	14.99	13.92	35.72	14.93	1.01	7.14	1.50	0.41	0.41	0.00	0.00
	2°decade	16.89	11.59	37.85	11.59	0.00	7.57	1.88	0.25	0.25	0.00	0.00
	3°decade	18.15	15.24	39.12	15.24	0.00	7.82	2.13	0.50	0.50	0.00	0.00
J	1°decade	19.04	14.51	41.91	14.51	0.00	8.38	2.31	0.42	0.42	0.00	0.00
	2° decade	20.42	17.55	43.19	17.55	0.00	8.64	2.58	0.67	0.67	0.00	0.00
	3°decade	22.12	11.66	44.65	11.66	0.00	8.93	2.92	0.22	0.22	0.00	0.00
J	1°decade	22.46	6.86	44.92	6.86	0.00	8.98	2.99	-0.18	0.00	0.18	0.00
	2° decade	23.83	11.00	45.98	11.00	0.00	9.20	3.27	0.16	0.00	0.00	0.00
	3°decade	24.04	7.84	46.14	7.84	0.00	9.23	3.31	-0.12	0.00	0.12	0.00
A	1°decade	24.66	5.32	44.43	5.32	0.00	8.89	3.43	-0.34	0.00	0.34	0.00
	2° decade	23.95	7.99	43.94	7.99	0.00	8.79	3.29	-0.07	0.00	0.07	0.00
	3°decade	22.08	17.27	42.55	17.27	0.00	8.51	2.92	0.75	0.75	0.00	0.00
S	1°decade	20.92	21.51	37.46	21.51	0.00	7.49	2.68	1.26	1.26	0.00	0.00
	2°decade	20.31	21.71	36.99	21.71	0.00	7.40	2.56	1.24	1.24	0.00	0.00
	3°decade	19.06	15.65	35.99	15.65	0.00	7.20	2.31	0.68	0.68	0.00	0.00
O	1°decade	17.29	18.07	28.35	18.07	0.00	5.67	1.96	1.07	1.07	0.00	0.00
	2°decade	15.94	17.45	27.28	17.45	0.00	5.46	1.69	0.93	0.93	0.00	0.00
	3°decade	13.33	23.52	24.91	23.52	0.00	4.98	1.17	1.08	1.08	0.00	0.00
N	1°decade	11.95	21.51	19.26	21.51	0.00	3.85	0.89	0.89	0.89	0.00	0.00
	2°decade	10.68	25.02	18.06	27.27	2.25	3.61	0.64	0.64	0.64	0.00	0.00
	3°decade	8.87	20.51	16.14	29.72	9.21	3.23	0.27	0.27	0.27	0.00	0.00
D	1°decade	7.30	27.37	12.21	40.96	13.58	2.44	-0.04	-0.04	0.00	0.00	0.04
	2°decade	7.38	21.03	12.30	49.77	28.74	2.46	-0.02	-0.02	0.00	0.00	0.02
	3°decade	6.65	21.03	11.46	58.50	37.47	2.29	-0.17	-0.17	0.00	0.00	0.17

LEGEND:
T = Temperature; Prec =precipitation; PE = Potential evapotranspiration; D = water availability; S = storage; etr = Minimum basal evapotranspiration; IBP = Potential Bioclimatic Intensity; IBR = Actual B.I.; IBLc = Free B.I. (warm type); IBSc = Dry B.I. (warm type) IBLf = Free B.I. (cold type);

Tab. 4. Bioclimatic parameters for the site at 600 m a.s.l.

		T (°C)	Prec (mm)	PE (mm)	D (mm)	S (mm)	etr (mm)	IBP (ubc/ month)	IBR (ubc/ month)	IBLc (ubc/ month)	IBSc (ubc/ month)	IBLf (ubc/ month)
	1°decade	4.6	10.4	6.64	60.44	50.00	1.33	-0.57	-0.57	0.00	0.00	0.57
J	2°decade	4.7	22.9	6.69	72.89	50.00	1.34	-0.56	-0.56	0.00	0.00	0.56
	3°decade	5.0	14.2	7.07	64.17	50.00	1.41	-0.49	-0.49	0.00	0.00	0.49
	1°decade	4.79	12.8	8.41	62.76	50.00	1.68	-0.54	-0.54	0.00	0.00	0.54
F	2°decade	4.96	20.7	8.64	70.65	50.00	1.73	-0.51	-0.51	0.00	0.00	0.51
	3°decade	5.2	18.8	8.95	68.76	50.00	1.79	-0.46	-0.46	0.00	0.00	0.46
	1°decade	6.36	20.4	13.68	70.36	50.00	2.74	-0.23	-0.23	0.00	0.00	0.23
M	2°decade	6.99	17.3	14.60	67.34	50.00	2.92	-0.10	-0.10	0.00	0.00	0.10
	3°decade	8.45	16.8	16.55	66.83	50.00	3.31	0.19	0.19	0.19	0.00	0.00
	1°decade	10.38	11.7	24.61	61.66	50.00	4.92	0.58	0.58	0.58	0.00	0.00
A	2°decade	9.64	22.6	23.54	59.60	37.05	4.71	0.43	0.43	0.43	0.00	0.00
	3°decade	11.66	9.3	26.32	45.39	36.06	5.26	0.83	0.83	0.83	0.00	0.00
	1°decade	13.67	13.3	33.82	32.38	19.07	6.76	1.23	1.17	1.12	0.00	0.00
M	2°decade	15.79	12.9	36.38	12.88	0.00	7.28	1.66	0.32	0.32	0.00	0.00
	3°decade	17.18	17.7	37.87	17.74	0.00	7.57	1.94	0.65	0.65	0.00	0.00
	1°decade	18.28	12.6	42.24	12.56	0.00	8.45	2.16	0.26	0.26	0.00	0.00
J	2°decade	19.87	17.3	43.82	17.26	0.00	8.76	2.47	0.60	0.60	0.00	0.00
	3°decade	21.61	9.4	45.39	9.35	0.00	9.08	2.82	0.02	0.02	0.00	0.00
	1°decade	22.29	8.2	45.97	8.15	0.00	9.19	2.96	-0.08	0.00	0.08	0.00
J	2°decade	23.2	10.9	46.70	10.9	0.00	9.34	3.14	0.13	0.13	0.00	0.00
	3°decade	23.36	10.9	46.83	10.88	0.00	9.37	3.17	0.13	0.13	0.00	0.00
	1°decade	23.84	4.8	43.54	4.82	0.00	8.71	3.27	-0.36	0.00	0.36	0.00
A	2°decade	23.16	8.3	43.05	8.3	0.00	8.61	3.13	-0.03	0.00	0.03	0.00
	3°decade	21.09	14.0	41.45	14.04	0.00	8.29	2.72	0.47	0.47	0.00	0.00
	1°decade	20.2	17.4	34.54	17.35	0.00	6.91	2.54	0.96	0.96	0.00	0.00
S	2°decade	19.5	19.5	34.03	19.52	0.00	6.81	2.41	1.12	1.12	0.00	0.00
	3°decade	18.0	18.0	32.80	18.00	0.00	6.56	2.09	0.91	0.91	0.00	0.00
	1°decade	16.4	16.9	23.97	16.92	0.00	4.79	1.77	1.12	1.12	0.00	0.00
O	2°decade	14.8	16.9	22.81	16.94	0.00	4.56	1.46	0.99	0.99	0.00	0.00
	3°decade	12.11	22.0	7.91	22.04	0.00	1.58	0.92	0.92	0.92	0.00	0.00
	1°decade	11.1	18.5	7.28	32.63	14.13	1.46	0.73	0.73	0.73	0.00	0.00
N	2°decade	9.6	23.9	6.24	49.23	25.35	1.25	0.41	0.41	0.41	0.00	0.00
	3°decade	7.7	19.5	5.00	62.51	42.99	1.00	0.03	0.03	0.03	0.00	0.00
	1°decade	6.1	24.6	3.97	74.55	50.00	0.79	-0.29	-0.29	0.00	0.00	0.29
D	2°decade	5.8	18.8	3.80	68.83	50.00	0.76	-0.34	-0.34	0.00	0.00	0.34
	3°decade	5.1	21.4	3.33	71.35	50.00	0.67	-0.48	-0.48	0.00	0.00	0.48

LEGEND:
T = Temperature; Prec =precipitation; PE = Potential evapotranspiration; D = water availability; S = storage; etr = Minimum basal evapotranspiration; IBP = Potential Bioclimatic Intensity; IBR = Actual B.I.; IBLc = Free B.I. (warm type); IBSc = Dry B.I. (warm type) IBLf = Free B.I. (cold type);

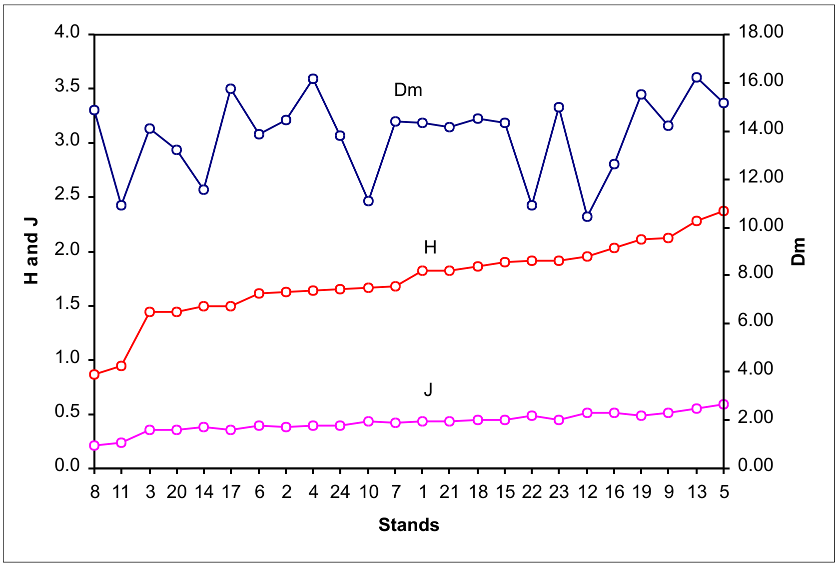

Fig. 1. Shannon-Winer (H), Equitability (J) and Margalef (Dm) indexes values for the 24 vegetation relevé

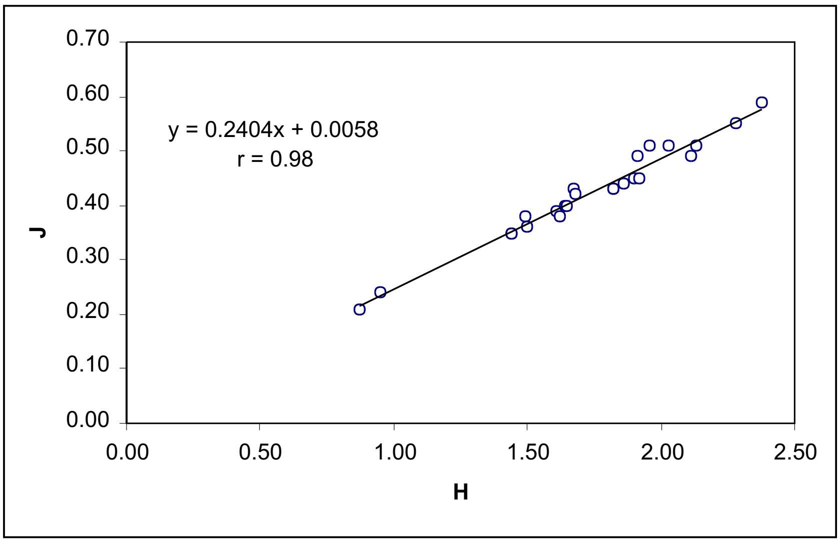

Fig. 2. Linear regression among shannon and equitability indexes values for the vegetation relevés

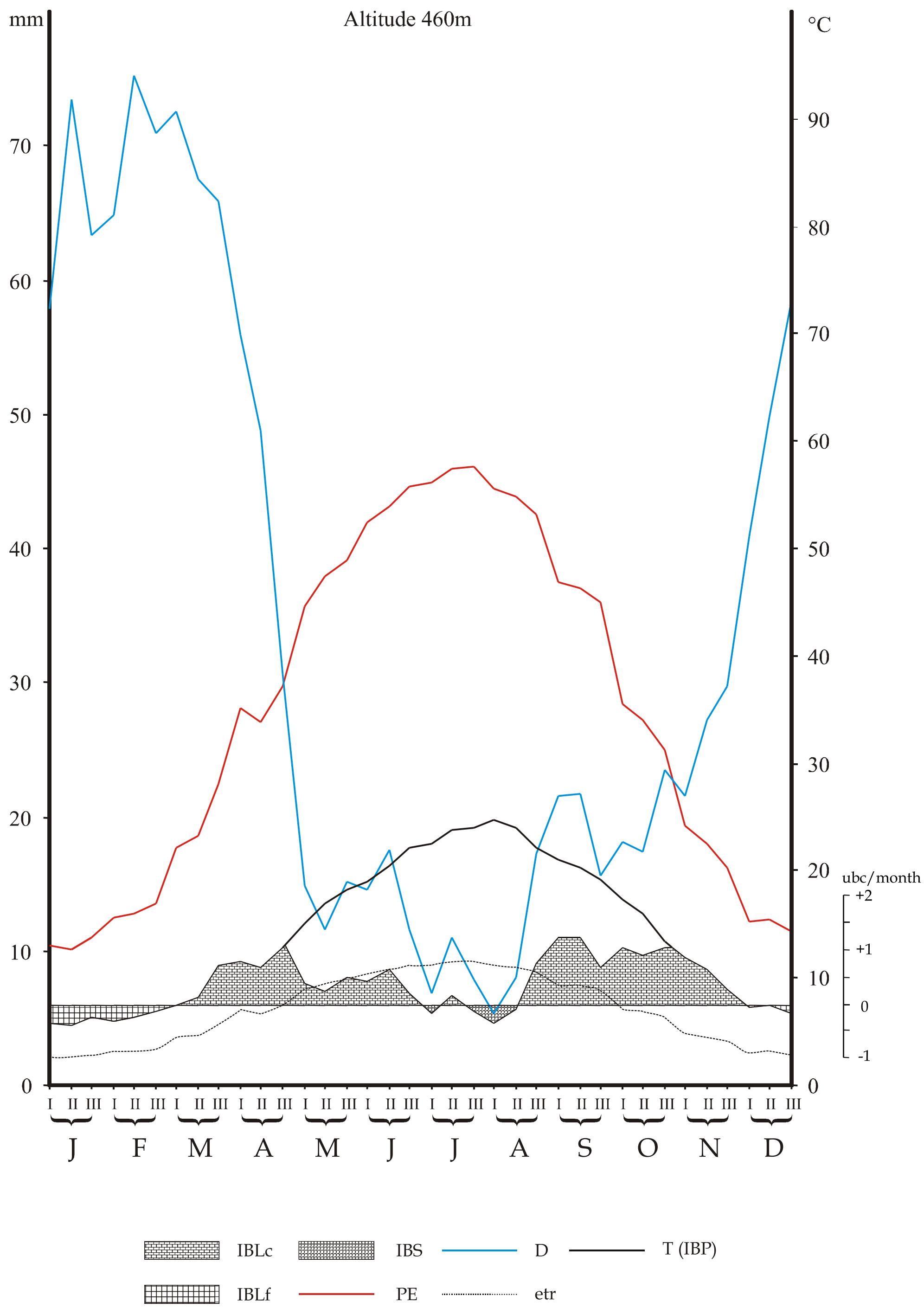

Fig. 3. Bioclimatic diagram for the site at 460 m a.s.l.

LEGEND:
PE = Potential evapotranspiration; D = water availability; etr = Minimum basal evapotranspiration; IBP = Potential Bioclimatic Intensity; IBR = Actual B.I.; IBLc = Free B.I. (warm type); IBSc = Dry B.I. (warm type) IBLf = Free B.I. (cold type);

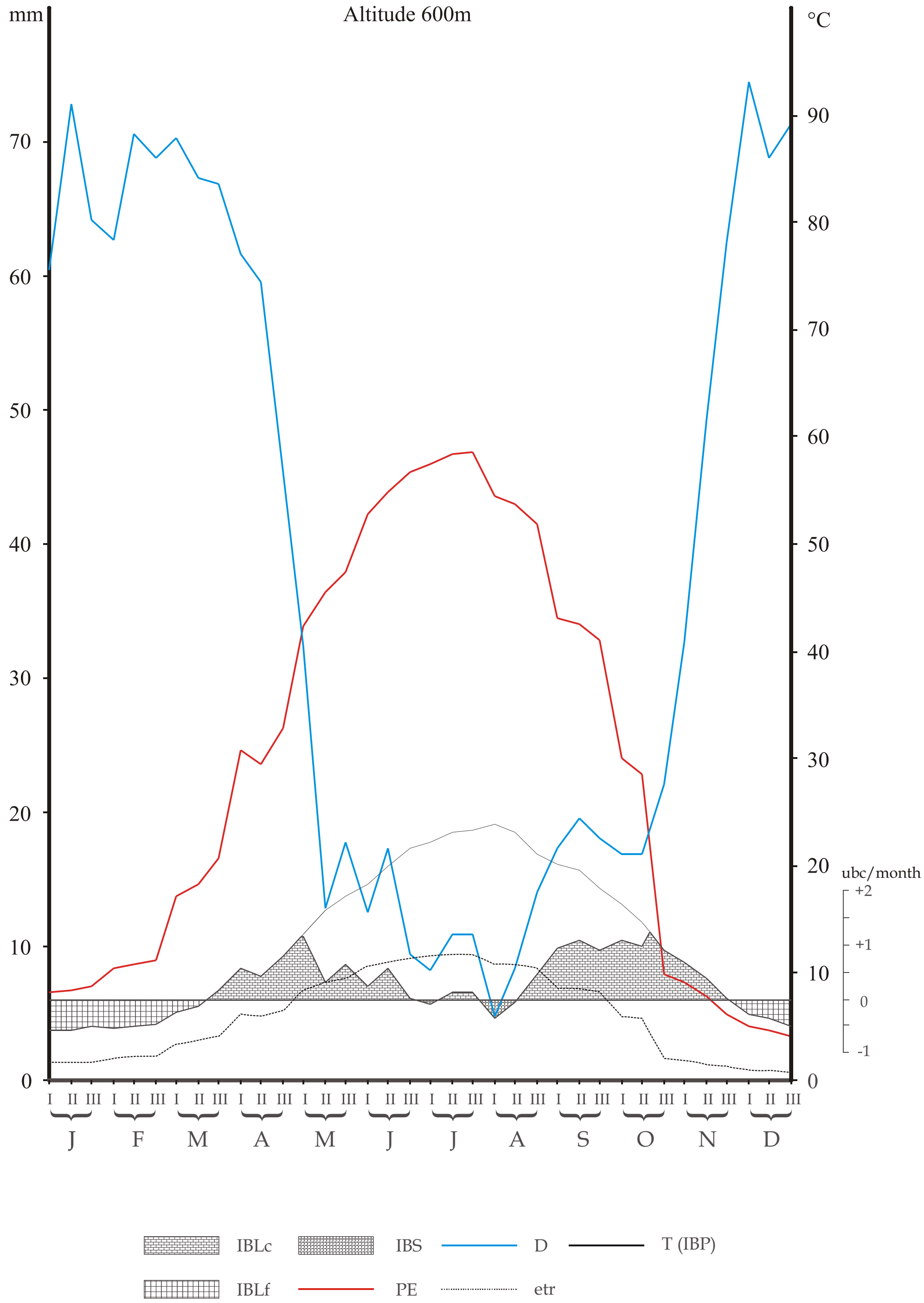

Fig. 4. Bioclimatic diagram for the site at 600 m a.s.l.

LEGEND:
PE = Potential evapotranspiration; D = water availability; etr = Minimum basal evapotranspiration; IBP = Potential Bioclimatic Intensity; IBR = Actual B.I.; IBLc = Free B.I. (warm type); IBSc = Dry B.I. (warm type) IBLf = Free B.I. (cold type);

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