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Meter scale patterns of esparto steppe vegetation and soil lichens – Experiences with the line intercept method –

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Synopsis

By surveying esparto steppe vegetation and soil-lichens with the line intercept method, it could be shown that lichens might exceed the cover of vascular plant species, *Stipa tenacissima* being the only exception. Lichens and blue algae contribute up to one quarter to the total plant cover of 37%. At investigated sites the lichen species *Diploschistes diacapsis*, *Squamarina lentigera* and *Cladonia convoluta* together contribute 11% to total plant cover.

On the chosen scale of investigation, patterning of vegetation and soil crusts could be detected. The perennial vascular plants can be considered as site-constant over decades (= vegetation matrix). Mainly soil characteristics, small scale biotic factors as debris accumulation, annual plant growth as well as growth characteristics of lichens seem most responsible for small scale dynamics and species composition. Observations were made indicating interrelationships between lichens and annual plants and lichens among themselves. Depending on growth characteristics of lichen species and cover of herbs and grasses their influence on mutual growth is considered as either positive or negative.

Keywords: South-Eastern Spain, soil lichens, line intercept method, Moran's I, *Diploschistes diacapsis*, *Squamarina lentigera*, *Cladonia convoluta*, *Stipa tenacissima*

1. Introduction

Esparto steppes (Esparto Span. = tussock forming grass species *Stipa tenacissima* and *Lygeum spartum*) are widely distributed on piedmont ramps in semi-arid South-Eastern Spain. Since antiquity these stands were used by man (FREITAG 1971; PEINADO & al. 1992) for making various fiber products and paper. Parent material of soil is rubble of conglomerate and limestone. Predominant soil types are calcaric regosols and xerosols (MINISTERIO DE AGRICULTURA, PESCA Y ALIMENTACION 1989). The vegetation type is characterized by the tufted grass species *Stipa tenacissima*. Vegetation covers soil relatively sparse and patchy, so cryptogamic crusts can develop intensively. The floristic composition (vascular plants, lichens) is well investigated but little work has been done on meter-scale distribution patterns of soil-crust organisms (GARCIA-PICHEL & BELNAP

2001). For detecting patterns on meter scale the line intercept method was applied to characterize spatial patterns of three frequent lichen species. These can be related to three following growth characteristics:

– crustose attached thallus – *Diploschistes diacapsis*
– squamulose attached thallus – *Squamarina lentigera*
– foliose, vagrant thallus – *Cladonia convoluta*

This distinction seemed necessary because one can suppose their response to and recovery from perturbation is related largely to their morphology and external appearance (ELDRIDGE & ROSENTRETER 1999). The overall pattern of these lichen species and black microphytic crusts (cyanobacteria) was analysed in order to gain a better understanding of underlying processes of lichen-spacing in this vegetation-type.

2. Material and methods

In environments where vegetation is sparsely distributed, the minimum area can be hardly reached, therefore the normal square quadrat method may not be suitable for vegetation sampling (KENT & COKER 1996; KREBS 1999). To overcome this, the line intercept method was applied. The line intercept method is ideally used for bunchgrass communities and for investigations on larger scales like canopy coverage of shrubs or geographic objects. Percentage cover data is collected by measuring the length of line touching each species present. In this case a measurement tape was used. The width of the tape (13 mm) is insignificant when regarding only one of the edges. Ten transects of 30 meters, in pairs perpendicular, were mapped. Total cover of vegetation and for single species was calculated using the formula:

$$\text{cover (\%)} = \frac{\sum \text{d} = \text{total intercepted distance}}{\text{tape length}} \cdot 100$$

Stone cover was estimated every transect-meter in 20 % steps. To test for spatial dependence of several species along single geographic axis, graphs of local autocorrelation coefficient Moran's I (MORAN 1950) were plotted against the separation distance. To test the significance of the correlograms a Bonferroni correction for multiple comparisons was applied. For 10 distance classes tested, the significance level was set at $\alpha < 0{,}005$. For individual autocorrelation statistics the progressive Bonferroni correction was used (LEGENDRE & LEGENDRE 1998). Moran's I and the standard z-variate were calculated using the freely available program Rookcase (SAWADA 1999).

On the one hand for this vegetation-type the separation-distance of one meter seems not too close to duplicate information. On the other hand the chosen transect-length of 30 meters is not far enough to increase the environmental variability which might smooth out the spatial signal of autocorrelation coefficients.

Associations between species of constancy higher than 3 % occurrence in meter-sections of transects were investigated by calculating (Systat 9) the similarity index according to JACCARD (1901) followed by additive tree-clustering (SATTATH & TVERSKY 1977).

3. Results

3.1. Importance of dominant soil lichens in the investigated vegetation type

In the investigation area, besides ascendant soil water and desiccation, mainly surface runoff leads to a hardened soil surface. Crust-forming lichens occur most likely on such hardened soil which is partly intermingled with pebbles or stones. At sites where the soil is more sandy, lichens are lacking. Here, not only the adhesive characteristic of the surfaces is different, but also the cover of herbs and grasses is higher.

Chemical soil characteristics are comparable at the five investigation-sites (Table 1). The range of pH-value in top soil measured in $CaCl_2$-suspension lies between pH 7,5–7,8. Nutrient content of dry soil is given as mean concentration ± standard deviation:

- Phosphorus (P_2O_5) 4,9 ± 2,2 mg/100g
- Potassium (K_2O) 32,3 ± 21,3 mg/100g
- Magnesium (Mg) 15,0 ± 2,2 mg/100g

Table 1
Site locations and site characteristics of vegetation transects.

Site (UTM)	Elevation (m NN)	Inclination (N-S °)	Inclination (W-E °)	Vegetation-cover (%)
A 30S0565130 4081874	170	1,5	2,5	50
B 30S0563492 4079690	80	6,0	2,0	30
C 30S0563557 4080228	150	0	0,5	30
D 30S0569400 4082196	110	0	0,5	30
E 30S0563306 4084789	270	0	0,5	40

Figure 1 illustrates cover and constancy of grasses, herbaceous species and soil lichens determined from 10 transects. Species with constancy in transects smaller than 1 %, *Asparagus albus, Asparagus stipularis, Eryngium ilicifolium, Limonium echioides, Helianthemum lavandulifolium* and *Salsola genistoides*, are not shown. On the transects lichens and blue algae contribute up to one quarter to the total plant cover of 37 %. The three lichen species under investigation contribute 11 % to total plant cover. The constancy of these three lichens is 33 % for *Diploschistes diacapsis*, 23 % for *Squamarina lentigera* and 17 % for *Cladonia convoluta*. They exceed the cover of higher plant species, *Stipa tenacissima* being the only exception.

Annual plants lead to disturbance of crust forming lichens because they break off soil crusts and substratum. Decay of lichen crusts results in colonisation of annual grasses and

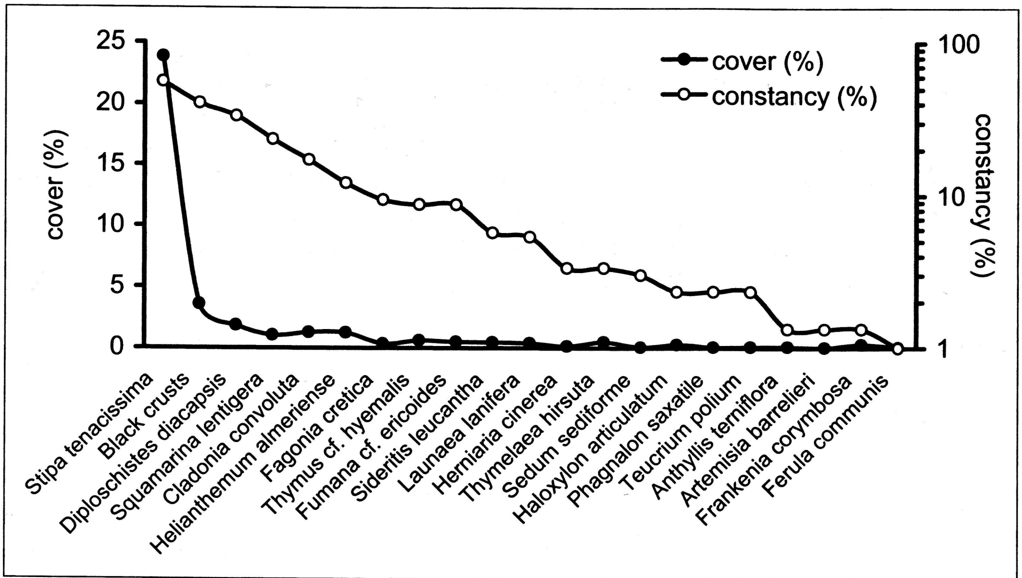

Fig. 1
Lichens, blue algae and vascular plant species of transect data in order of rank of their constancy. Species with constancy lower than 1 % are not shown.

herbs. Thus microhabitat characteristics will change totally. Woody species, Esparto-grass and lichens can be considered as site-constant. Annuals however, responding to diurnal changes, reflect only short-term site conditions.

3.2. Meter scale pattern of vegetation

Vegetation structure on investigated sites can be described distinguishing tussock areas from inter-tussock areas. On meter scale, patches and gaps are predominantly formed by the bunchgrass *Stipa tenacissima*. Other vascular species and lichens are restricted to inter-tussock areas and thus generate aggregated structures recurring at intervals. The degree of shaping is mainly dependent on vegetation cover. An example where vegetation had highest observed cover (around 50 %) is shown in figure 2.

Figure 3 shows the strength of autocorrelation as a function of lag distance of %-cover data of *Stipa tenacissima*, other vascular plant species and lichens and black crust (cyanobacteria). Data from transects A and C (fig. 3) differ markedly in plant cover (table 1). Transect data first of all reflect patterns of characteristic spacing of vegetation – very regular in transect A (N-S).

Autocorrelation of cryptogamic species is positive at distances up to approximately 3 meters indicating large flecks. This is marked along transect C where the pattern generating influence – cover and spacing – of *Stipa tenacissima* is reduced. In aggregated structures recurring at intervals, positive autocorrelation values indicate distances corresponding to the gaps between species patches (LEGENDRE & LEGENDRE 1998). The observed distribution patterns of soil lichens first of all are related to the tussocks of *Stipa*

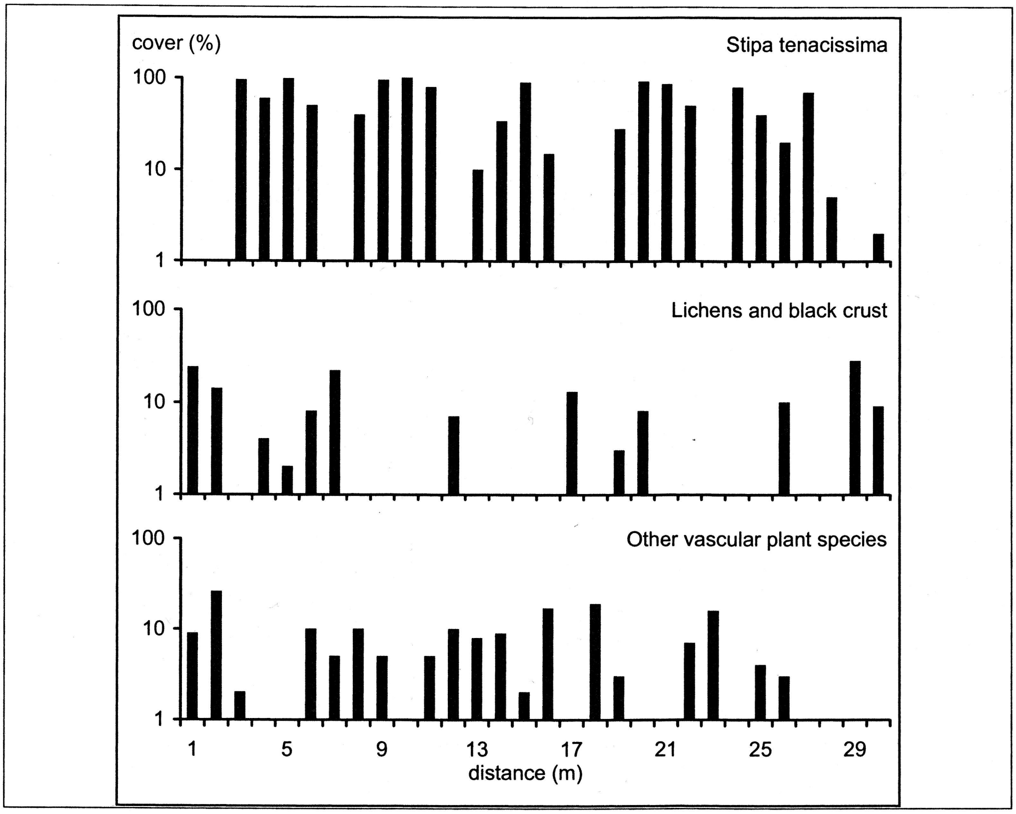

Fig. 2
Meter scale patterning along transect A (N – S). Because of an intermediate overall cover of *Stipa tenacissima* (table 1) distinct patches and gaps occur.

tenacissima repeating themselves through space. According to MAESTRE & al. (2002) and MAESTRE & CORTINA (2002) two different microsites can be distinguished: tussock microsites and open microsites. Negative autocorrelation coefficients in figure 3 are not significant and thus not interpretable. It is concluded that the dynamic processes between lichens operate at smaller scales than those analysed.

Other vascular plants did not show distinct pattern on the chosen scale and extent of investigation.

3.3. Association between vascular plants and lichens

Cluster analyses of floristic similarity leads to only one distinct group formed exclusively by cryptogams (Fig. 4). Maximum floristic similarity reaches 33 %, found between *Diploschistes diacapsis* and *Cladonia convoluta*. Probably because of different micro-habitats of both species, competition is not relevant on the investigated scale. *Stipa tenacissima*

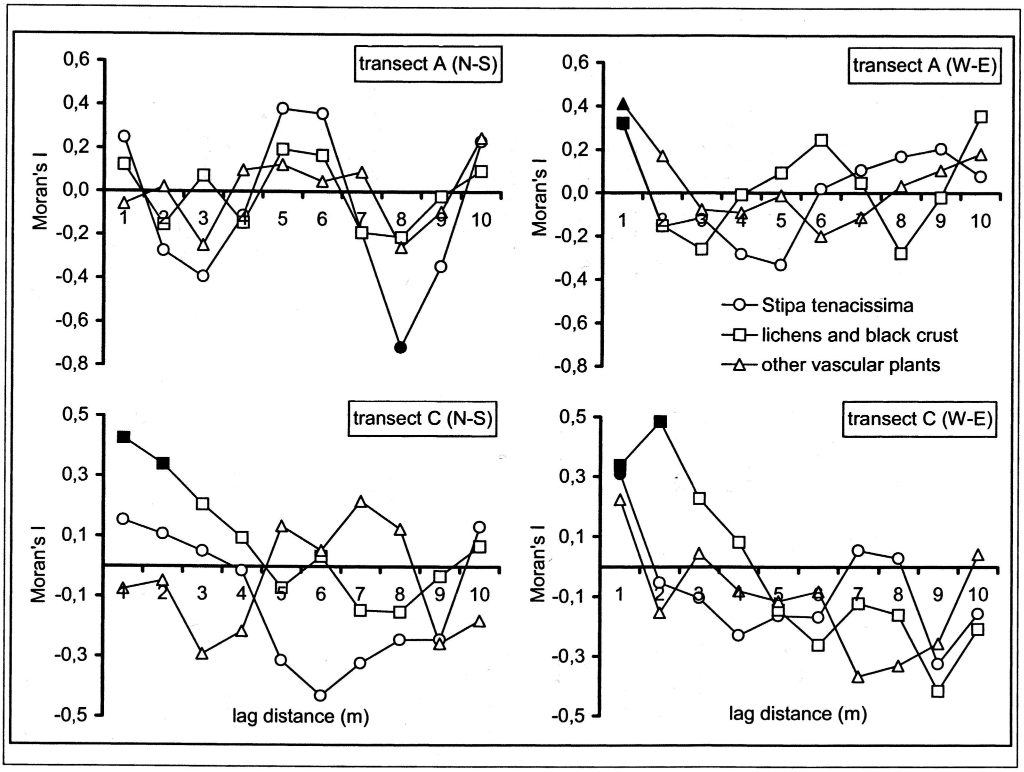

Fig. 3
Autocorrelograms based on transect cover data of *Stipa tenacissima* other vascular plants and lichens and black crust at two sites in two directions (see table 1). Globally only two correlograms – *Stipa tenacissima* site A (N-S) and lichens and black crust site C (N-S) – are significant. Solid signs indicate locally significant values of Moran's I.

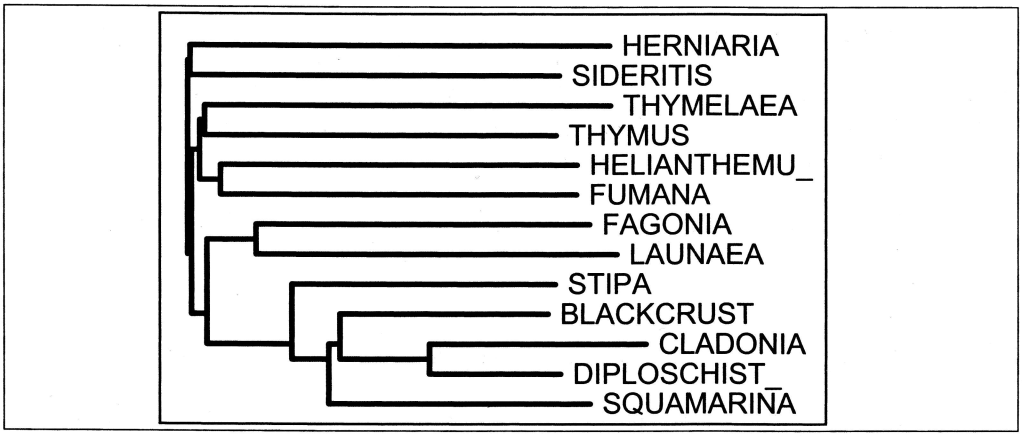

Fig. 4
Additive tree cluster diagram combining species of constancy >3 % by means of similarity coefficient after Jaccard. The only floristically distinct group is formed by lichens. Species names see figure 1.

is related closely, only indicating the overall presence of this matrix building vascular plant species. Other perennial plants (constancy >3 %) indicate no floristic similarity and seem indiscriminately scattered in this matrix.

Cladonia convoluta is often associated with annual plants. This lichen is even embedded in *Carrichtera annua*-stands. This species is fixed by setaceous leaves and becomes stationary around the tussocks of Esparto grass. Annuals often surround tussocks of this perennial grass. The reason for this is, that even when *Stipa tenacissima* is growing on conglomerate it builds up soil islands – micro structures – which allow other vascular plants and mosses to grow. Nitrophytic species like *Sonchus tenerrimus* profit from the decline of tussocks of *Stipa tenacissima.* If such sites get blocked by alluvial deposits and the surface hardens, crust-forming lichens become dominant again.

The lichen *Diploschistes diacapsis* glues stones together up to fist-size. It is also able to overgrow *Squamarina lentigera.* Overgrowing also occurs vice versa. Prerequisite is a delicate balanced equilibrium of small scale site factors. BÜDEL (2001) describes the microtopographic relief of up to 1,7 cm which is built from *Diploschistes diacapsis.* Often this stage indicates higher thallus age and/or disturbance. Quite often *Diploschistes*-thalli can be observed with holes of one to several millimeters. Here annual grasses grew through and after their dying-off, the holes in the lichen crusts kept open. The reason might be that seeds – when their diapause is prolonged – can be overgrown by lichens. The sum of cover of lichens under investigation is significantly negative correlated with stone-cover classes ($r_{Spearman} = -0{,}47^{***}$; 300; 2-sided test). It is conducted that stones – principally a suitable substrate for most investigated lichen species – alters surface run-off conditions. On such sites preferential growth of woody species was observed.

4. Concluding remarks

BELNAP & al. (2001) point out that some soil-lichens may enhance soil stability. PRASSE (1999) mentioned that competitive effects of crusts on vascular plants are most pronounced at the life history stage of seed dispersal. Generally the crusts might decrease the probability for a seed so come to rest at one place. But some exceptions exist: e.g. the adhesive seeds of *Fagonia cretica* glue very strong to crust stabilized soil surfaces. Taking in consideration the experiments of CERDÀ (1997) on the effect of patchy distribution of *Stipa tenacissima* on runoff and erosion, this patchy semiarid ecosystem can be considered as a self-sustaining system. The tussocks have a greater ability to receive water, independent of relief situation, because of the presence of bare areas in between.

Beside this general interrelationships, observations were made on interaction between lichens and annual plants and lichens among themselves.

A general positive interaction (facilitation) between *Stipa tenacissima* tussocks as mentioned by MARTINEZ-SÀNCHEZ & al. (1994) and MAESTRE & CORTINA (2002) is questioned considering the climatic gradient where this species is able to occur. It is assumed that e.g. higher precipitation affects species composition and species traits as well as tussock cover which might alter system functions and such species interrelationships.

A better differentiation of soil lichens and 'soil crusts' in dominant species with distinguishable traits might be useful for a better understanding of interrelationships of cryptogams and higher vegetation.

It could be shown that for explaining lichen patterns in esparto steppe vegetation there are likely several contributory mechanisms. Therefore it seems worth to investigate the soil-lichen-dynamics additionally in its temporal aspects.

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References

BELNAP, J., R. PRASSE & K.T. HARPER, 2001: Influence of biological soil crusts on soil environments and vascular plants. – In: BELNAP, J. & O.L. LANGE (eds.): Biological soil crusts: Structure, function and management. – Springer, New York: 281–300.

BÜDEL, B., 2001: Biological soil crusts in European temperate and Mediterrean regions. – In: BELNAP, J. & O.L. LANGE (eds.): Biological soil crusts: Structure, function and management. – Springer, New York: 75–86.

CERDÀ, A., 1997: The effect of patchy distribution of *Stipa tenacissima* L. on runoff and erosion. – Journal of Arid Environments 36: 37–51.

ELDRIDGE, D.J. & R. Rosentreter, 1999: Morphological groups: a framework for monitoring microphytic crusts in arid landscapes. – Journal of Arid Environments 41: 11–25.

FREITAG, H., 1971: Die natürliche Vegetation des südostspanischen Trockengebiets. – Botanische Jahrbücher 91(2/3): 147–308.

GARCIA-PICHEL, F. & J. BELNAP, 2001: Small-scale environments and distribution of biological soil crusts. – In: BELNAP, J. & O.L. LANGE (eds.): Biological soil crusts: Structure, function and management. – Springer, New York: 193–201.

JACCARD, P., 1901: Etude comparative de la distribution florale dans une portion des Alpes et du Jura. – Bull. Soc. Vaud. Sc. Nat. 37: 547–579.

KENT, M. & P. COKER, 1996: Vegetation description and analyses. A practical approach. – John Wiley & Sons, Chichester: 363 pp.

KREBS, C.J., 1999: Ecological methodology. – Benjamin/Cummings, Menlo Park: 620 pp.

LEGENDRE, P. & L. LEGENDRE, 1998: Numerical Ecology. – Elsevier, Amsterdam: 853 pp.

MAESTRE, F.T., M. HUESCA, E. ZAADY, S. BAUTISTA & J. CORTINA, 2002: Infiltration, penetration resistance and microphytic crust composition in contrasted microsites within a Mediterranean semi-arid steppe. – Soil Biology & Biochemistry 34: 895–898.

MAESTRE, F.T. & J. CORTINA, 2002: Spatial patterns of surface soil properties and vegetation in a Mediterrean semi-arid steppe. – Plant and Soil 241: 279–291.

MARTINEZ-SÀNCHEZ, J.J., M. CASARES-PORDEL, J. GUERRA, L. GUTIÉRREZ-CARRETERO, R.M. ROS, J. HERNANDEZ-BASTIDA & M.J. CANO, 1994: A special habitat for bryophytes and biological crusts in the arid zones of Spain. – Lindbergia 19: 116–121.

MINISTERIO DE AGRICULTURA, PESCA Y ALIMENTACION, 1989: Projecto lucdeme. Mapa de suelos, Escala 1:100000. – Almería-1045: 151 pp.

MORAN, P.A.P., 1950: Notes on continuous stochastic phenomena. – Biometria 37: 17–23.

PEINADO, M., F. ALCARAZ & J.M. MARTINEZ-PARRAS, 1992: Vegetation of Southeastern Spain. – Flora et vegetatio mundi, X. J. Cramer, Berlin: 487 pp.

PRASSE, R., 1999: Experimentelle Untersuchungen an Gefäßpflanzenpopulationen auf verschiedenen Geländeoberflächen in einem Sandwüstengebiet. – Universitätsverlag Rasch, Osnabrück: 121 pp.

SATTATH, S. & A. TVERSKY, 1977: Additive similarity trees. – Psychometrika 42: 319–345.

SAWADA, M., 1999: Rookcase: an Excel 97/2000 Visual Basic (VB) add-in for exploring global and local spatial autocorrelation. – Bulletin of the Ecological Society of America 80 (4): 231–234.

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