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Diversities of three differently used pastures in the Cserhát Mountains, Hungary.

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SUMMARY: Jákotpuszta is a so-called ETHOFARM in Hungary, and one of its aims is to help the investigation of the behaviour of sheep under environmentally sustainable conditions. The diversities of the plant communities of three differently used pastures (resting place, normally grazed pasture and site withdrawn from grazing several years before) belonging to this farm were compared with different methods in spring and autumn. In both seasons the diversity, the evenness and the species richness values were highest in the ungrazed site, whereas the values of the same characteristics were lowest in the resting place (overused site). The diversity values of the pooled samples always levelled off before reaching a total number of 50 quadrats (0.5 × 0.5 m squares), although the levelling off in the case of the species number was never reached with the same number of quadrats. Diversity ordering showed intersection between the diversity profiles of the pastures only in the case of the spring samples of the normally grazed and overused sites. In every case most diverse was the ungrazed pasture. Rank abundance plots clearly show that the decrease of diversity in the grazed sites was caused by the absence of several species with low dominance in the ungrazed site as well as by the dominance of some species tolerant of grazing, or, in the case of the resting place, presumably of trampling and increased urine as well as excrement content of the soil. On the basis of the results presented suggestions are made as to the necessary management practice of the pastures in order to maintain their sustainability in terms of diversity as well.

KEYWORDS: diversity, pasture, sheep, grazing, Hungary.

Introduction

The farm in Jákotpuszta is an ecological and landscape management example, in a few km from Bercel in Nógrád county, Hungary. Sheep grazing is the most characteristic exploitation of natural resources in the area. Jákotpuszta, having been reconstructed in its original form after the political changes in the country in 1989, lies amongst picturesque hills. Students from Hungary as well as from abroad prefer this farm as the place of their practice, and also professors visit it regularly to make scientific investigations here. One of the basic conditions of ecological sustainability of the landscape is the conservation of biological diversity.

In order to follow the trends in diversity, phytocoenological investigations were carried out in three sites of the pastures grazed with sheep. It is well documented that under extreme environmental conditions the diversity of communities decreases (e.g.: FOWLER & MOONEY 1990; DUMONT et al. 1990; NEARY et al. 1990; RABATIN & STINNER 1989). Overgrazing may also have such a diversity decreasing impact onto the vegetation of pastures (BHAT & KAUL 1989; LI 1993). In addition, grazing adversely affects many native plant species, particularly the perennial components, whereas introduced annuals are decidedly more common in grazed areas (CHEAL 1993). The effects on the long-living woody dominants are most insidious. There is generally an almost total lack of regeneration of trees and shrubs throughout grazed areas (CHEAL 1993). On the other side, mild grazing might result in an increase of the plant species diversity, richness and evenness (BHAT & KAUL 1989; LI 1993). Under European conditions abandoning of pastures in most cases resulted in a decrease in species diversity (BAKKER 1989). However, on the impact of heavy sheep grazing as well as high amount of droppings close to folds and sheep-barns the original plant communities were replaced by nitrophilous weeds, and the recovery of the vegetation took place only after more than 50 years (ROSÉN & SJÖGREN 1973; LJUNG 1970).

Although diversity is one of the central themes of ecology there is considerable disagreement about how it should be measured (MAGURRAN 1988). The index of diversity, which is most widely used by ecologists, is the Shannon-Wiener index, as it has all the desirable properties which meet the requirements of such an index (PIELOU 1975). However, diversity indices require random sampling, which results in that the probability of two successively sampled individuals belonging to the same species is dependent only on the relative abundances of species within the community (MAGURRAN 1988). With a patchy distribution of vegetatively reproducing plants, random samples are unobtainable since the contents of a randomly placed quadrat are not a random sample of the parent population. For such cases PIELOU (1966) suggests the use of the so-called pooled quadrat method. As we shall see this method can also be usefully adapted to provide a guide to sample size. Jack-knifing the estimate of the diversity index is also a robust technique against bias caused by clumping (ZAHL 1977).

In our investigations, first of all the Shannon-Wiener diversities, the species numbers and the evenness values of the pastures grazed with different intensities were established. Afterwards, the Brillouin diversities were calculated with Pielou's pooled quadrat method (PIELOU 1966) in order to control the results got with the Shannon-Wiener index, and to ascertain the necessary sample size. As a comparison, the pooled species number curves of the samples were drawn as well. Jack-knifing was also used for improving the estimate of the diversity values.

Diversity ordering is a special method for the comparison of two diversities with different scale parameters. **A** community can be considered as more divers than **B** only if its diversity profile is over **B** in the whole range of the scale parameter (TÓTHMÉRÉSZ 1994). If the curves intersect, it means that one of the communities is more diverse in respect of the rare species, whereas the other one is more diverse in respect of the dominant species. Consequently, the diversity profiles were compared as well. Further conclusions can be drawn on the basis of the rank abundance plots of the samples. These clearly show changes in the species number as well as in the dominance profile of the community as a consequence of disturbances. Changes in the dominance of species under different exploitation regimes were also suitable for the comparison of the impacts of different use. Our final aim was to draw conclusions as to the sustainability of the diversity in Jákotpuszta at the present intensity of exploitation.

Material and methods

Phytocoenological investigations were carried out on the north-western slopes of the pastures in Jákotpuszta in the spring (in the middle of June) and in the autumn (at the end of September) of 1994. According to the inhabitants one of the investigated sites has not been used as a pasture already for at least 10 years. The other investigated area was regularly grazed in the last years, whereas a third area was used as a resting place for the sheep at night. This last area was seemingly overused. The soil of all pastures was Ramann-type brown earth.

For the investigations in each of the investigated sites 50-54 0.5×0.5 m quadrats were used. The quadrats were placed randomly. The dominances of the species present in the quadrats were estimated in percentages.

For calculations of diversity, species richness and evenness values, as well as for diversity ordering and preparing rank abundance plots the program packages NUCOSA and DIVORD (TÓTHMÉRÉSZ 1994) were used. For diversity ordering Rényi's and Hill's generalised entropy plots as well as logarithmic dominance plots (see: TÓTHMÉRÉSZ 1994) were applied. Jack-knifing (QUENOUILLE 1956; TUKEY 1958) was performed on the basis of the example given by ROSS et al. (1987). In this case, diversities were estimated with the reciprocal form of Simpson's index. For the necessary calculations macros were made in the program package Excel 5.0a. Raunkiaerian life forms were also used to compare the occurrence of different groups of plants under the impact of distinct use.

Results

Both in spring and in autumn the Shannon-Wiener diversities (Tables 1-2) of the overused site were significantly (p = 0.05) lower than those of the normally grazed site, and in both seasons the diversities of the normally grazed site were significantly lower than those of the ungrazed site. Species richness and evenness, the two components of diversity had also their lowest values in the overused site, whereas the highest values of these parameters were recorded in the case of the ungrazed site.

The pooled Brillouin's diversity curves (Figures 1-2) also show that in both seasons at the points of levelling off the ungrazed sites had the highest and the resting place had the lowest diversities. Similarly, in both seasons the Jack-knifed diversities (Tables 3-4) were highest in the ungrazed pasture and lowest in the overused one. Species numbers of the pooled quadrats do not show levelling off within the range of the applied sample numbers (Figures 3-4).

Tab. 1. Shannon-Wiener diversities, evennesses as well as species numbers of the spring aspects of the ungrazed, normally grazed and overused pastures

	Ungrazed pasture	Normally grazed pasture	Overused pasture
Diversity	1.56	1.33	1.06
Evenness	0.81	0.74	0.69
Species number	85	63	35

Tab. 2. Shannon-Wiener diversities, evennesses as well as species numbers of the autumn aspects of the overused, normally grazed and ungrazed pastures

	Ungrazed pasture	Normally grazed pasture	Overused pasture
Diversity	1.47	1.25	1.05
Evenness	0.79	0.73	0.66
Species number	74	51	39

Tab. 3. Jack-knifed diversities of the spring aspects of the overused, normally grazed and ungrazed pastures

	Ungrazed pasture	Normally grazed pasture	Overused pasture
Mean diversity	25.52	11.43	8.18
Standard deviation	7.96	7.78	2.52
Standard error	1.08	1.10	0.34

Tab. 4. Jack-knifed diversities of the autumn aspects of the overused, normally grazed and ungrazed pastures

	Ungrazed pasture	Normally grazed pasture	Overused pasture
Mean diversity	17.96	10.08	6.08
Standard deviation	6.42	4.59	5.66
Standard error	0.91	0.65	0.80

Diversity ordering of the three sampling sites shows that the diversity in both seasons and in the case of all investigated scale parameters is highest in the ungrazed site (Figures 5-6). The curves of the spring dominances of the normally grazed site and the resting place, however, intersect at a high scale parameter in the case of Rényi's entropy plot and at a low scale parameter in the case of the logarithmic dominance plot. The curves of the autumn dominance values, on the other hand, do not intersect. At all scale parameters, the diversity of the normally grazed site is higher than that of the resting place. When the plots of the spring and autumn aspects are compared with Rényi's entropy function, only the curves of the overused sites intersect (Figures 7-8). However, with the logarithmic dominance plots the spring and autumn aspects of none of the differently grazed sites seem to be orderable on the basis of their diversities (Figure 9).

Rank abundance plots (Figures 10-11) show characteristic differences amongst the sites investigated. In both seasons the steepest drop of the curves was shown by the plots of the overused place, whereas most balanced curves were produced by the plots of the ungrazed site.

Changes in the species composition of the three sites were followed by the Raunkiaerian life form spectra of the pastures. Percentages of the different life forms in the differently used pastures (Table 5) show an intense decrease in the ratio of the phanerophytic and chamephytic life forms and a moderate increase in the ratio of the hemicryptophytic, geophytic and therophytic life forms under the impact of grazing. Amongst the huge number of species which disappeared as a consequence of overuse are *Anthoxanthum odoratum* L., *Astragalus glycyphyllos* L., *Bromus erectus* HUDS., *Clinopodium vulgare* L., *Campanula patula* L., *Dorycnium germanicum* (GREMLI) RIKLI, *Festuca pratensis* HUDS., *Hieracium bauhini* SCHULT. ex BESS., *Hypericum perforatum* L., *Lathyrus nissolia* L., *Medicago lupulina* L., *Picris hieracioides* L., *Plantago media* L., *Prunus spinosa* L., *Pyrus pyraster* (L.) BURGSDORF, *Ranunculus polyanthemos* L., *Rosa canina* L., *Sanguisorba minor* SCOP., *Seseli annuum* L., several *Thymus* and *Trifolium* species, *Verbascum phoeniceum* L., *Veronica chamaedrys* L. and *Viola arvensis* MURR. In addition, the presence of several other species (e.g.: *Agrimonia eupatoria* L., *Agrostis capillaris* L., *Centaurea pannonica* (HEUFF.) SIMK., *Crataegus monogyna* JACQ., *Fragaria viridis* DUCH., *Galium verum* L., *Luzula campestris* (L.) DC., *Trifolium campestre* SCHREB.) was decreased by grazing. There were some species the abundance of which was increased by overusing (e.g.: *Agropyron repens* (L.) P. B., *Convolvulus arvensis* L., *Eryngium campestre* L., *Festuca rubra* L.) or by normal grazing (e.g.: *Achillea collina* L., *Daucus carota* L., *Festuca pseudovina* HACK. ex WIESB., *Thymus glabrescens* WILLD, *Trifolium repens* L.). Some species like *Arrhenatherum elatius* (L.) PRESL, *Dactylis glomerata* L., *Leontodon hispidus* L., *Lotus corniculatus* L., *Plantago lanceolata* L., *Poa pratensis* L. and *Taraxacum officinale* WEBER ex WIGGERS did not show any clear-cut reaction.

Tab. 5. Raunkiaerian life form spectra of the pastures grazed with different intensities. Values are given in numbers of species (labels: M = Megaphanerophyte, N = Nanophanerophyte, Ch = Chamaephyte, H = Hemicryptophyte, G = Geophyte, T = Therophyte)

	Spring		
Life form	Ungrazed Site	Normally grazed site	Overused site
M	4	3	1
N	1	–	-
Ch	6	3	1
H	54	41	24
G	4	3	2
T	16	13	7
	Autumn		
Life form	Ungrazed site	Normally grazed site	Overused site
M	4	1	-
N	-	1	-
Ch	6	5	1
H	50	37	28
G	1	2	2
T	13	5	8

Discussion

Shannon-Wiener diversity and evenness as well as species richness values (Tables 1-2) of the investigated sites coincidentally show that any intensity of grazing had a degrading effect onto the pastures. This statement is confirmed by the pooled Brillouin's diversity curves (Figures 1-2) and the Jack-knifed diversities (Tables 3-4) as well. The levelling off of all curves of the pooled Brillouin's diversity curves before reaching the maximum species number (Figures 3-4) suggests that our sample size was adequate for the establishment of the maximal diversities of the investigated sites. The results were not influenced by season.

The results of diversity ordering (Figures 5-6) show that the diversity profile of the ungrazed site is in the range of all scale parameters over the normally grazed and overused sites. This proves that the ungrazed site can undoubtedly be considered as more diverse than the normally grazed site and the resting place. This contradicts with the statement of BAKKER (1989), according to which abandoning of pastures generally results in a decrease in species diversity, and may be explained either by the longer time that elapsed after abandoning in Jákotpuszta, or by the strong influence of the surrounding forest vegetation. The intersection between the curves of the spring dominance values of the normally grazed and overused sites seems to be first of all caused by the increased dominance of *Festuca pseudovina* HACK. ex WIESB. in the normally grazed pasture and the invasion of several weed species (e.g. *Agropyron repens* (L.) P. B., *Eryngium campestre* L., *Convolvulus arvensis* L.) into the overused site. This suggests that normal grazing, in spite of saving some rare species, might result in a decreased diversity as a consequence of making one species (in this case *Festuca pseudovina* HACK. ex WIESB.) highly dominant. By autumn, the relative dominance of *Agropyron repens* (L.) P. B., *Eryngium campestre* L. and *Convolvulus arvensis* L. was further increased in the overused pasture, considerably exceeding the dominance of *Festuca pseudovina* HACK. ex WIESB. in any of the grazed sites. This is why the autumn curves do not intersect. The significant difference between the plots of the autumn samples might be the consequence of the heavy grazing and in the case of the resting place of the increased trampling, defecation as well as urination by sheep during the whole year. It seems that the overused area, not serving as resting place in winter, may partially regenerate until the advent of spring, thus having an increased diversity which is thus closer to that of the normally grazed site in spring than in autumn. Presumably the spring and autumn aspects (Figures 7-9) of the overused site were not orderable on the basis of their diversities as a consequence of the increased species number in autumn.

The rank abundance plots (Figs. 10-11) show that the decrease of the species number in the normally grazed and overused sites was caused by the absence of the rare species and was accompanied by the dominance of a few species. These changes were most definite in the case of the resting place. Only the plot of the spring data shows the dominance of *Festuca pseudovina* exceeding the dominance of any species in the overused site. The ungrazed site seems to be the most balanced what is generally considered as a sign of stability.

Species composition seems to have changed in an unfavourable direction as a consequence of grazing as well as overuse. Lots of palatable species were absent from the resting place, or showed a decrease in dominance. Some weeds however, as well as red fescue (*Festuca rubra* L.) had an increased abundance on the effect of grazing. Some species had their highest dominance in the normally grazed site. As Raunkiaerian life form spectra show, most of the shrubs and trees were absent from the normally grazed site, whereas the presence of annuals and other perennials slightly increased. A decided spreading of introduced annuals, as suggested by CHEAL (1993), could not have been detected.

All this shows that in Jákotpuszta even normal grazing unambiguously decreased diversity, what might endanger sustainability. Overuse in the case of the resting place, in accordance with the establishments made by ROSÉN & SJÖGREN (1973) as well as LJUNG (1970), had a conspicuous degrading effect onto the plant community. Fortunately, the surrounding natural vegetation of the pastures seems to have a stimulating effect onto the recovery of degraded pastures. Jack-knifed diversity indices, which seem to have the best estimates of diversities suggest that differences between the overused and normally grazed sites are smaller than between the normally grazed and the ungrazed ones. Such unfavourable changes could be avoided if neighbouring parcels of pastures would be alternately withdrawn from grazing for several years. During these periods the diversity of these parcels could get recovered.

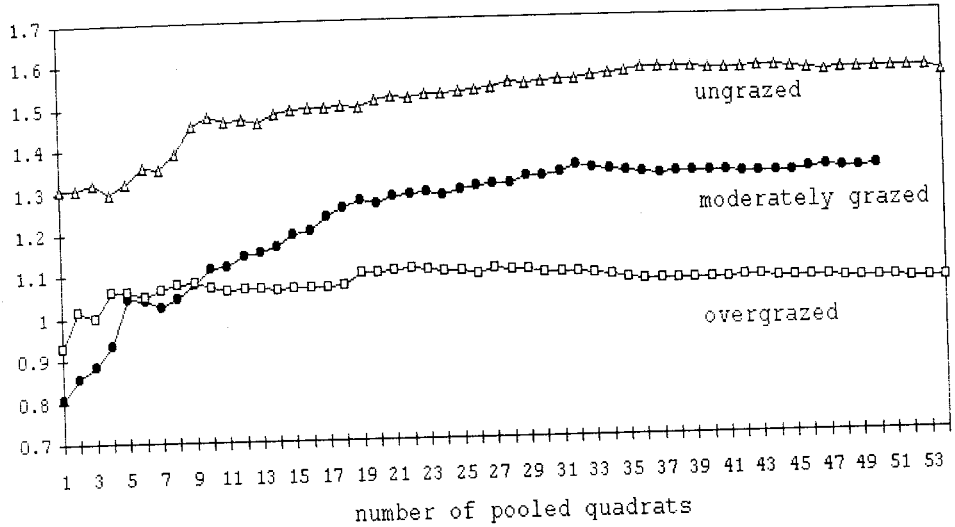

Figure 1. Diversities of the pooled 0.5 × 0.5 m quadrats used in the spring in the pastures grazed with different intensities

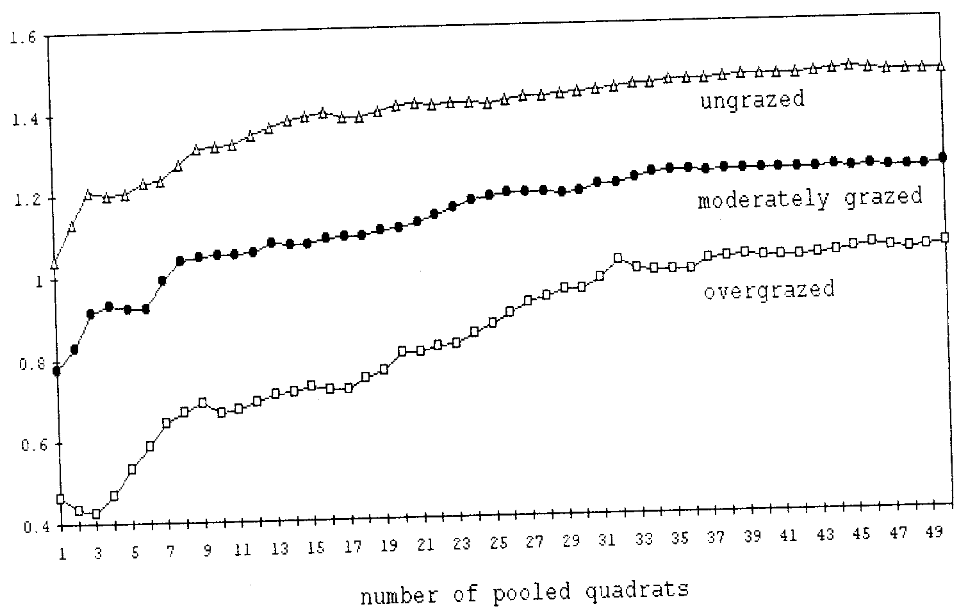

Figure 2. Diversities of the pooled 0.5 × 0.5 m quadrats used in the autumn in the pastures grazed with different intensities

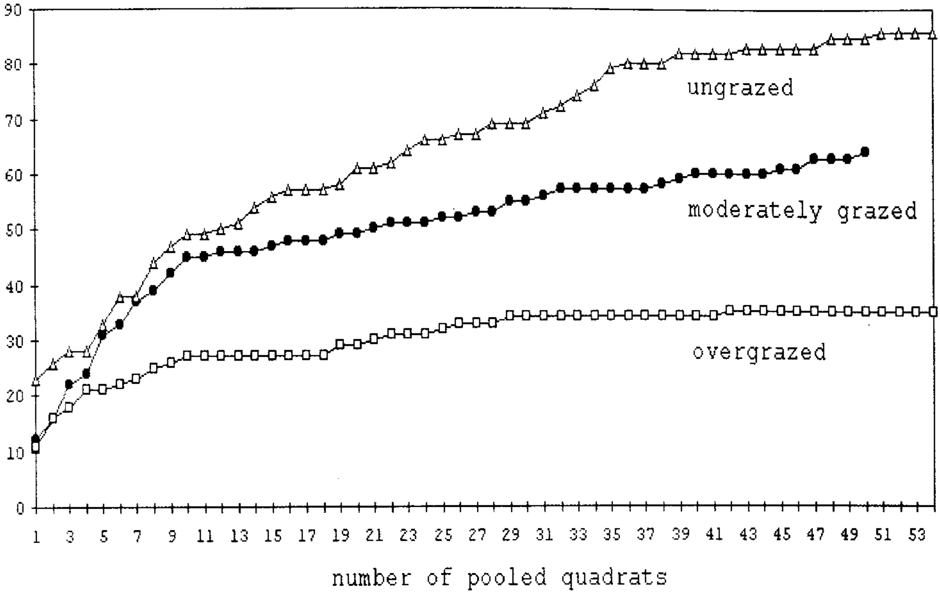

Figure 3. Species numbers of the pooled 0.5 × 0.5 m quadrats used in the spring in the pastures grazed with different intensities

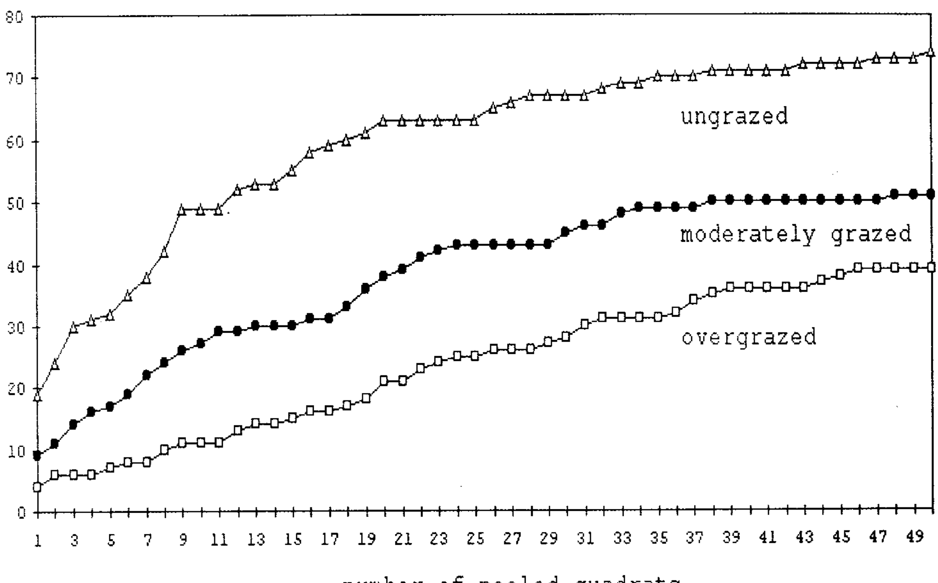

Figure 4. Species numbers of the pooled 0.5 × 0.5 m quadrats used in the autumn in the pastures grazed with different intensities

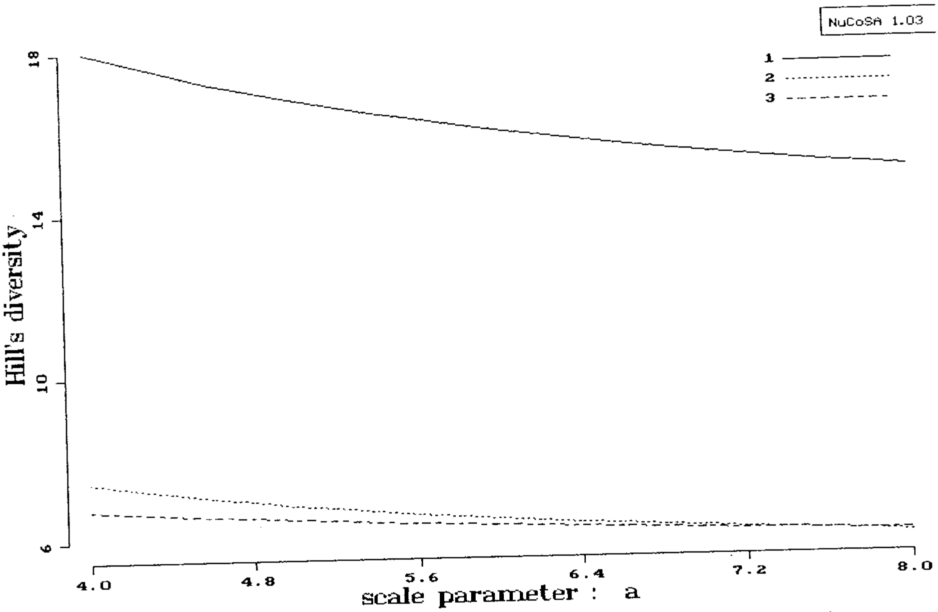

Figure 5. Diversity ordering of the ungrazed (1), normally grazed (2) and overused (3) sites of the pastures in the spring of 1994, based on their Hill's diversity values

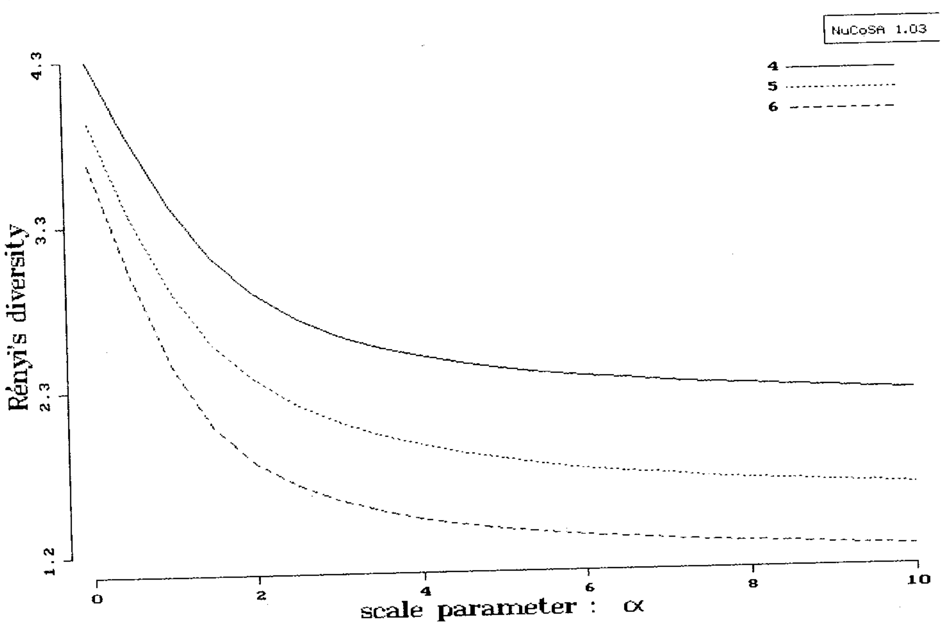

Figure 6. Diversity ordering of the ungrazed (4), normally grazed (5) and overused (6) sites of the pastures in the autumn of 1994, based on their Rényi's diversity values

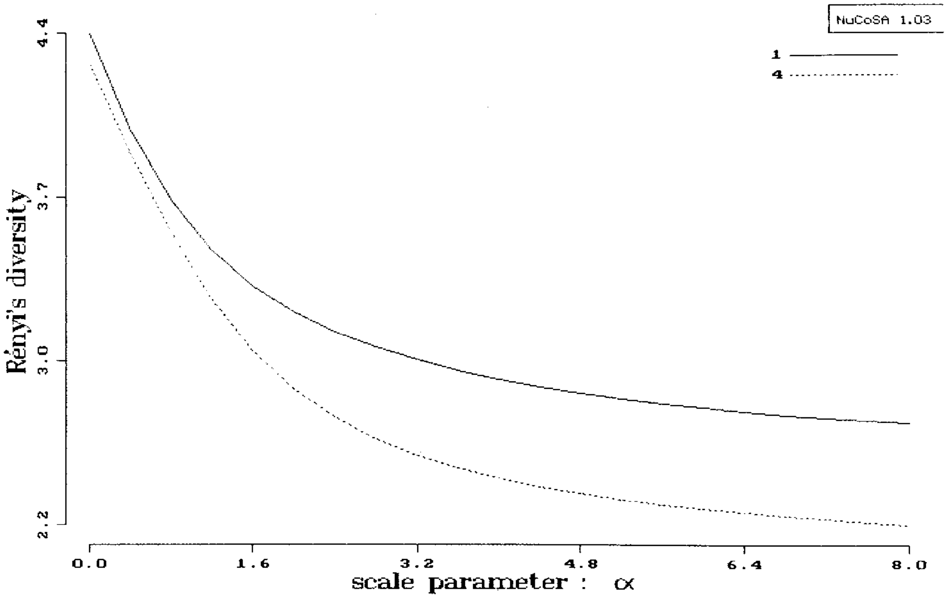

Figure 7. Diversity ordering of the spring (1), and autumn (4) aspects of an ungrazed site of the pastures in 1994, based on their Rényi's diversity values

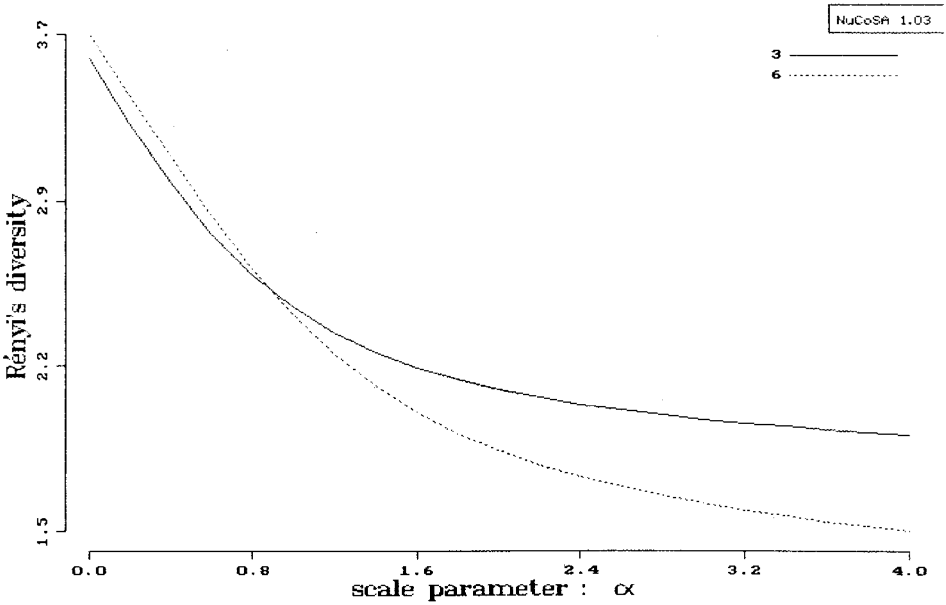

Figure 8. Diversity ordering of the spring (3), and autumn (6) aspects of an overused site of the pastures in 1994, based on their Rényi's diversity values

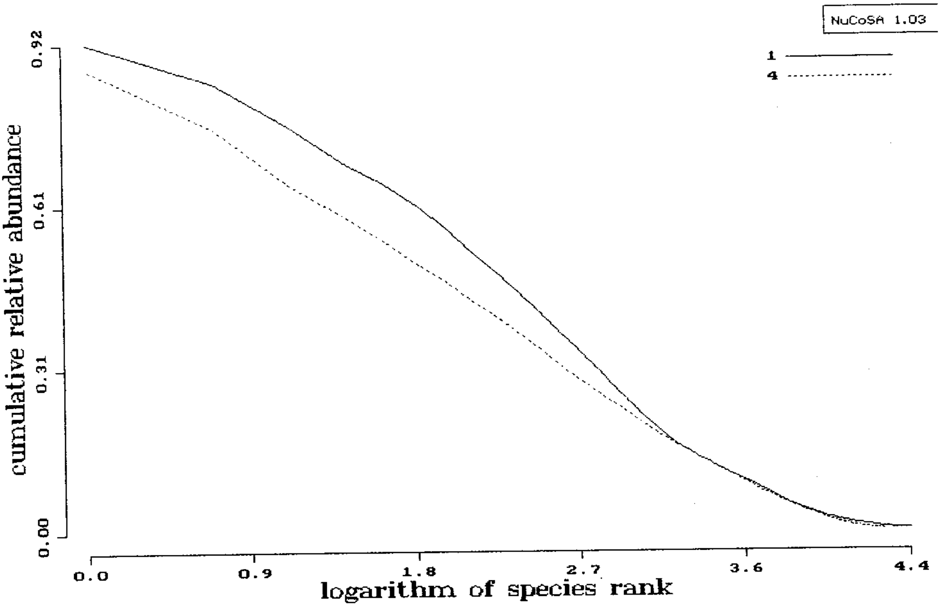

Figure 9. Diversity ordering of the spring (1), and autumn (4) aspects of an ungrazed site of the pastures in 1994, based on their logarithmic dominance values

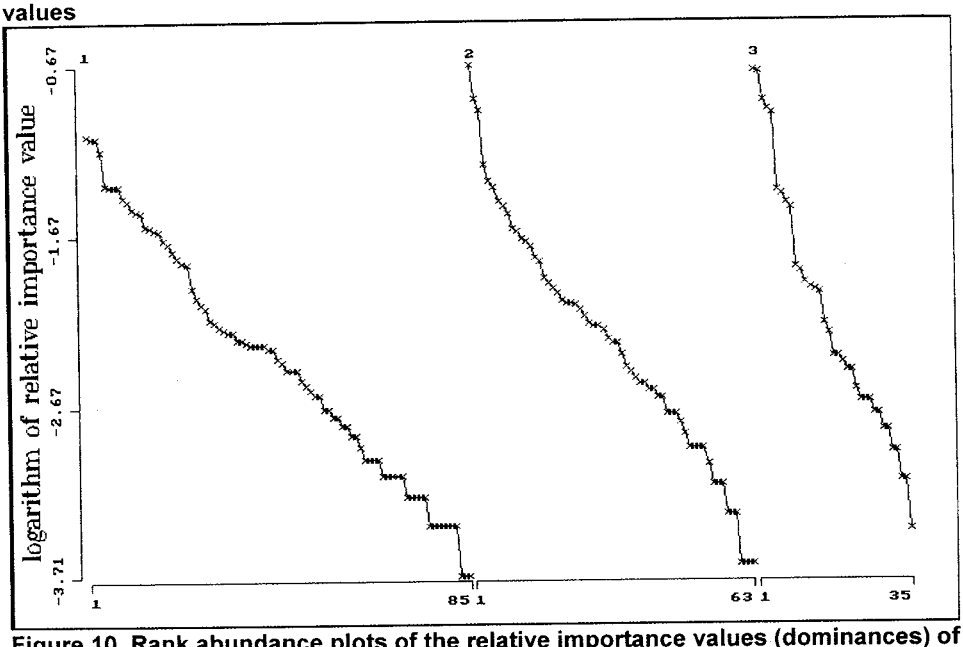

Figure 10. Rank abundance plots of the relative importance values (dominances) of the species of the ungrazed (1), normally grazed (2) and overused (3) sites of the pastures investigated in the spring of 1994

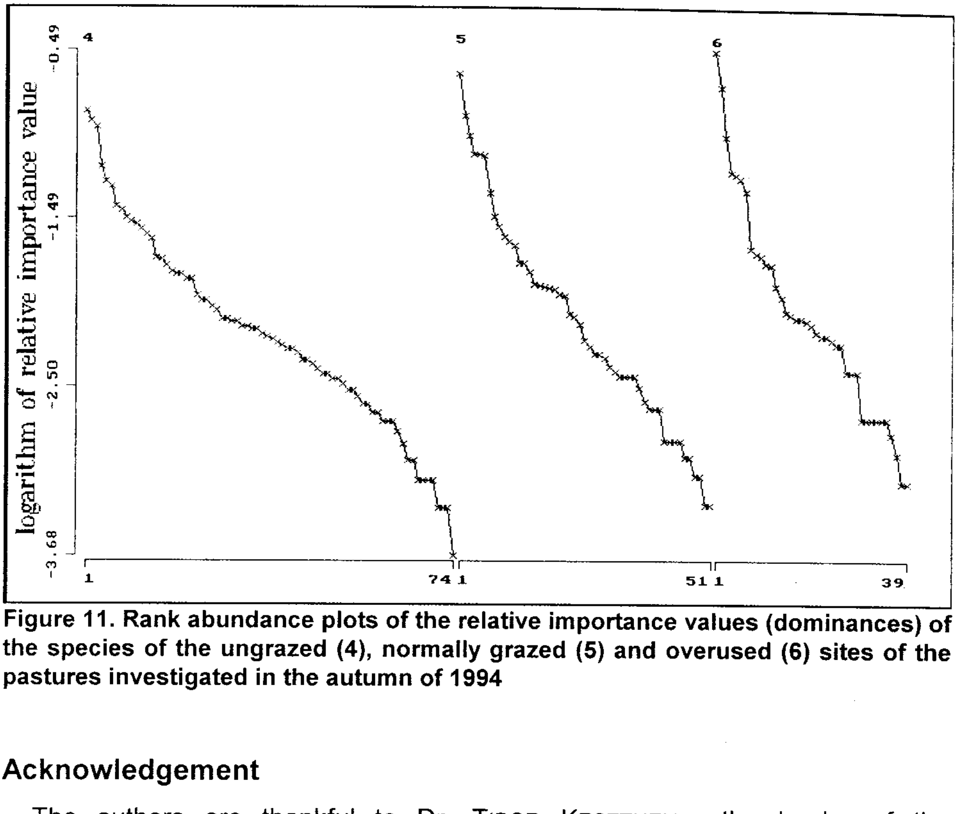

Figure 11. Rank abundance plots of the relative importance values (dominances) of the species of the ungrazed (4), normally grazed (5) and overused (6) sites of the pastures investigated in the autumn of 1994

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