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SPATIAL PATTERN ANALYSIS OF ABANDONED GRASSLANDS OF THE KARST REGION BY TRIESTE AND GORIZIA

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Keywords: Coenocline, Diversity, Gradients, Karst, Reforestation, Spatial pattern.

Abstract

We have taken in consideration grasslands on flat or slightly sloped surface surrounded or interrupted by nuclei of reforestation (NR) of different areas (10-50 square metres). The results have shown that the influence of the single NR has no great importance on the changement of vegetation along the transects, but that considerable variations are due to the mean distance of the NR all round the grassland.

Introduction

Most of the grasslands of the Karst region near Trieste and Gorizia have been no longer exploited about thirty years, for this reason there appears a progressive more or less intense process of spontaneous reforestation. The so-called Karst-Illyrian woodland is spreading on pastures by shrubs of *Cotinus coggygria, Juniperus communis, Prunus mahaleb, Cornus mas, Fraxinus ornus, Ostrya carpinifolia,* etc.

In the lands that are utilized as pastures the woodland, chiefly constituted by *Ostrya carpinifolia, Fraxinus ornus, Quercus pubescens, Quercus petraea, Acer campestre, Acer monspessulanum,* is represented by groups of trees and shrubs, usually coppiced ones, occupying areas of various extension inside the pastures. Such groups, that we have called nuclei of reforestation (N R, Feoli & Feoli Chiapella 1979), alternate to pastures giving a classical mosaic physiognomy to the landscape.

Studies on the development of reforestation of the Karst region by Trieste have been already made by Lausi, Pignatti & Poldini (1967), mainly in order to analyze the influence of the dimension of shrubs over the surrounding vegetation.

In this work we have considered the grasslands situated among nuclei of reforestation with well developed trees and shrubs on a surface ranging between 10 and 50 square metres at least 4 metres distant each other by considering the projections of the canopy on the ground (Fig. 1).

The aim of this work is the analysis of the spatial pattern of the grasslands in function of the proximity of the NR and the closeness of NR around the grasslands. In order to limit the effects of other factors we have considered grasslands on flat surfaces, on the same type of soil and all belonging to the alliance *Chrysopogoni-Satureion* Horv. et. H.ić.

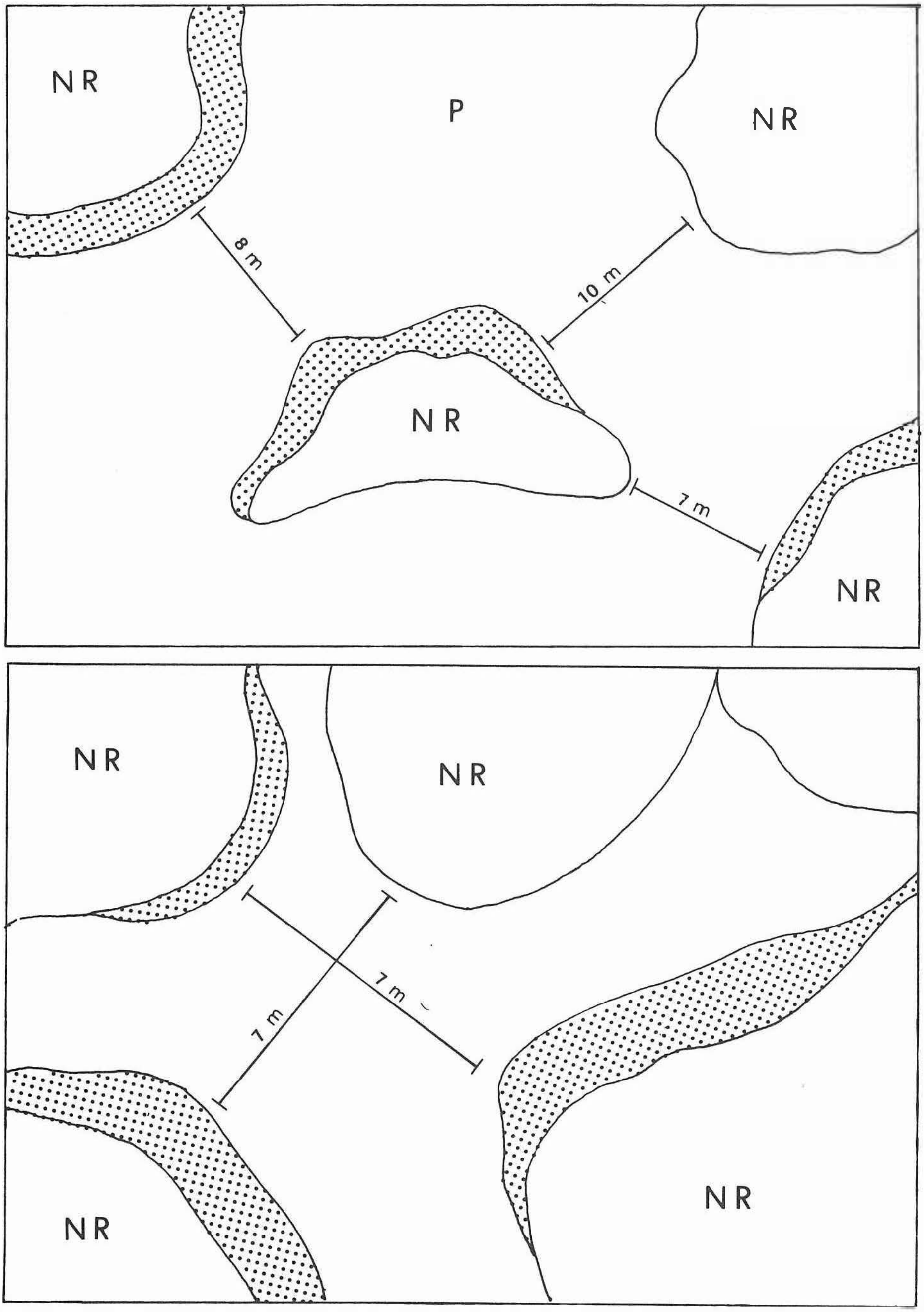

Fig. 1 — Two examples of the disposition of the nuclei of reforestation (NR) in the studied grasslands. The dotted areas present belts of *Cotinus coggygria*.

Methods

Methods and models for spatial pattern analysis have been discussed and presented recently by Goodall (1974), Pielou (1975), Juhasz Nagy (1976), Ludwig & Goodall (1978), Goodall & West (1979), Greig-Smith (1979).

In this work the relevés for pattern description have been made on the basis of a grid of 1 square metre subdivided into 25 quadrats of 400 cm^2. This basic area approximates the largest surface that can be occupied by one caespitose hemicryptophyte in the grasslands under study. For each quadrat the inventary was made of the species to each of which a cover value has been assigned. The relevés have been made along 30 transects starting from the centre of the grasslands to the projection of the canopy of trees or shrubs on the ground. The transects have been grouped in 5 groups on the basis of the mean distance of the N R around the grasslands (closeness).

group 1: at least 15 metres
group 2: between 15 and 13 metres
group 3: between 13 and 11 metres
group 4: between 11 and 9 metres
group 5: between 9 and 5 metres.

In order to test if relevés of the same transect and of the same group present significant changements towards the N R, the similarity between them has been computed by M L T A X 3 (Laagonegro & Feoli 1979). This program computes the redundancy of the matrix of species co-occurence by fusing the relevés two by two. To the redundancy matrix of all relevés it has been applied the clustering procedure by group average (Anderberg 1973, Orlóci 1978). Verified that the relevés of the same transect and the same group belong to the same cluster, for each group of relevés it has been computed the average heterogeneity of the pattern (absolute and relative) by the mutual information of the cooccurrence matrix between species. For this the program M L T A X 2 (Lagonegro & Feoli 1979) has been applied. In order to obtain species groups, the same method of clustering applied for relevés has been applied to correlation matrix between species based on the mean cover values in the relevés.

Results

The species found in the relevés are listed in Tab. 1 according to the main species groups obtained by the clustering procedures. For each of them there are indicated the life forms, the chorological types, according to Pignatti (1980), the syntaxonomical rank according to Horvat (1962), Horvatić (1963), Oberdorfer (1970), van Gils et al. (1975) and Poldini (1980), and the group of relevés in which it has been found. By considering the mean covering value of the species in all the groups the highest values are always reached by the species of *Chrysopogoni-Satureion* (about 40%). Cluster analysis applied to the redundancy matrix between the relevés has shown a perfect correspondence between the groups of transects and the clusters of relevés, this means that the influence of N R on the pattern of the same grassland is not so strong as to produce different types of vegetation along the same transect. The minimum spanning tree based on the similarity between the five groups of relevés calculated with data in Tab. 1 by Jaccard coefficient, seriates the groups quite in accordance to the mean distance between N R around the grasslands (Fig. 2).

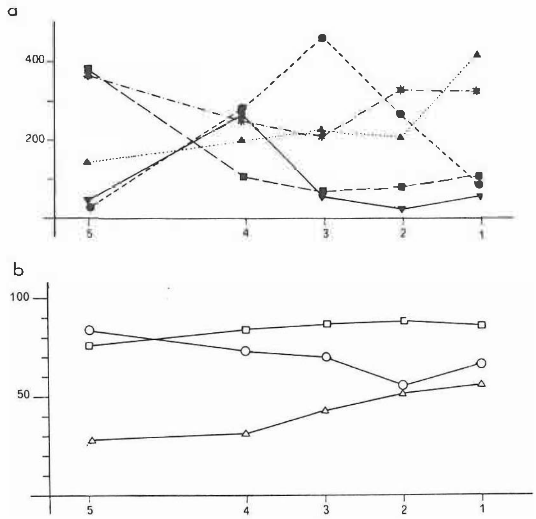

Fig. 2a — Coenocline of the dominant species in function of the closeness of NR around the grasslands. The groups of relevés are indicated on the x axis, the species response is measured by the mean sum of cover in each group of relevés. Legend to symbols:
● *Bromus erectus*, ▲ *Bromus condensatus*, ▼ *Chrysopogon gryllus*, * *Carex humilis*, ■ *Sesleria autumnalis*.

Fig. 2b — Responses to the gradient of closeness of the mean relative diversity (■), mean relative heterogeneity of spatial pattern (●), mean floristic similarity (▲).

The seriation of the groups according to a gradient of closeness produces the coenocline (cf. Whittaker, 1967) of Fig. 2. In this only the dominant species of the grasslands under study, i.e. *Carex humilis, Bromus erectus, Bromus condensatus, Chrysopogon gryllus* and *Sesleria autumnalis* are considered. From this figure each group of relevés is characterizable by a dominance of one species. In the first group,the most open, *Bromus condensatus* is the dominant species, in the second group there is not a clear dominance of one species but a certain equicover of *Carex humilis* (dominant), *Bromus erectus* and *Bromus condensatus.* The cover of this last species undergoes a drastic reduction where there is an increment of *Bromus erectus.* In the third group the dominant species is *Bromus erectus* which reaches its maximum value of cover, meanwhile there is a reduction of the cover of *Carex humilis.* In the fourth group *Chrysopogon gryllus* reaches its maximum in correspon-

Cnidium silaifolium (Jacq.) Simk.	H - SE europ.	Geranion sang., Ostryo - Carpinion			X		
Hieracium pilosella L.	H - europ. caucas.	Scorz.-Chrysopogonetalia			X	X	
Leontodon hispidus L.	H - europ. caucas.	Arrhenatheretalia			X	X	
Lotus corniculatus L.	H - SW europ.	Brometalia	X		X	X	X
Convolvulus cantabrica L.	H - euromedit.	Chrys.-Satureion				X	X
Seseli gouanii Koch	H - illirica	Chrys.-Satureion	X		X		X
Trifolium montanum L.	H - S europ. pont.	Scorzonerion vill.			X		
Globularia punctata Lapeyr.	H - S europ. S sib.	Scorzonerion vill.		X	X	X	X
Hypericum perforatum L.	H - subcosmop.	Origanetalia			X		
Polygala nicaeensis Risso ex Koch ssp. mediterranea Chodat	H - euromedit.	Scorz.-Chrysopogonetalia	X	X	X	X	X
Linum tenuifolium L.	Ch - submedit. pont.	Scorz.-Chrysopogonetalia			X		
Koeleria splendens K. Presl.	H - medit.	Chrys.-Satureion	X	X	X	X	X
Scorzonera villosa Scop.	G - illirica-appenn.	Scorzonerion vill.		X	X	X	X
Potentilla tommasiniana F.W. Schultz	H - illirica	Chrys.-Satureion	X	X	X		X
Centaurea rupestris L.	H - SE europ.	Chrys.-Satureion	X	X	X	X	X
Festuca cfr. pseudovina Hackel ex Wiesb.	H - SE europ.	Scorz.-Chrysopogonetalia	X	X	X	X	X
Allium montanum F.W. Schmidt	G - S europ. S sib.	Chrys.-Satureion			X	X	
Genista tinctoria L.	Ch - euras.	Origanetalia, Ostryo-Carpinion	X	X	X	X	
Centaurea weldeniana Rchb.	H - NE medit. mont.	Scorzonerion vill.		X			
Plantago media L.	H - euras	Brometalia			X		
Pulsatilla montana (Hoppe) Rchb.	H - SE europ.	Chrys.-Satureion			X		X
Viola hirta L.	H - europ.	Origanetalia, Ostryo-Carpinion	X		X	X	X
Dactylis glomerata L.	H - paleotemp.	Arrhenatheretalia	X		X	X	X
Bromus erectus Huds.	H - paleotemp.	Scorz.-Chrysopogonetalia	X	X	X	X	X
Ruta divaricata Ten.	Ch - subpontica	Geranion sang.				X	
Carduus nutans L.	H - W europ.	Artemisietea				X	
Botryochloa ischaemum (L.) Keng	H - cosmop.	Chrys.-Satureion				X	X
Medicago prostrata Jacq.	H - S europ. pont.	Chrys.-Satureion		X		X	
Eryngium amethystinum L.	H - NE medit.	Chrys.-Satureion		X		X	X
Koeleria macrantha (Ledeb.) Spreng.	H - orof. europ.	Brometalia, Scorzonerion vill.		X	X	X	
Thesium divaricatum Jan. ex Mert. et Koch	H - medit.	Chrys.-Satureion	X		X		X
Crepis taraxacifolia Thuill.	T - medit. atl. (euri)	Chenopodietea					X
Ferulago galbanifera (Mill.) Koch	H - SE europ. pont.	Scorzonerion vill., Geranion sang.				X	X
Asperula purpurea (L.) Ehrend.	Ch - orof. SE europ.	Chrys.-Satureion				X	X
Stachys recta L.	H - N medit. mont.	Chrys.-Satureion				X	X
Anthericum ramosum L.	G - subatl.	Scorzonerion vill., Geranion sang.					X
Daucus carota L.	H - subcosmop.	Arrhenatheretalia					X
Carex humilis Leys.	H - euras.	Chrys.-Satureion	X	X	X	X	X
Bromus condensatus Hackel	H - endem.	Chrys.-Satureion	X	X	X	X	X
Brachypodium pinnatum (L.) PB.	H - euras.	Brometalia, Geranion sang.			X	X	X
Genista germanica L.	Ch - centroeurop.	Quercion roboris-petraeae	X				X
Inula hirta L.	H - S europ. S sib.	Geranion sang., Scorzonerion vill.					X
Genista sericea Wulf.	Ch - illirica	Chrys.-Satureion					X
Juniperus communis L.	P - circumb.	Prunetalia					X
Scorzonera austriaca Willd.	H - S europ. S sib.	Chrys.-Satureion			X		X
Melampyrum carstiense (Ronn.) Fritsch	T - SE europ.	Chrys.-Satureion			X		X
Euphorbia nicaeensis All.	G - W centromedit.	Chrys.-Satureion			x		x
Hippocrepis comosa L.	H - centro S europ.	Scorz.-Chrysopogonetalia			X	X	X
Sedum sexangulare L.em.Grimm.	H - centroeur.	Sedo-Scleranthetea			X	X	X
Centaurea triumfetti All.	H - europ. caucas.	Scorzonerion vill., Geranion sang.	X		X	X	X
Thymus longicaulis K. Presl.	Ch - S europ.	Scorz.-Chrysopogonetalia	X	X	X	X	X
Salvia pratensis L.	H - eurimedit.	Scorz.-Chrysopogonetalia	X	X	X	X	X
Allium pulchellum G. Don	G - paleotemp.	Mesobromion				X	
Centaurium erythraea Rafn.	H - paleotemp.	Scorz.-Chrysopogonetalia				X	
Potentilla australis Krašan	H - illirica	Scorz.-Chrysopogonetalia			X	X	X
Chrysopogon gryllus (L.) Trin.	H - S europ. S sib.	Scorz.-Chrysopogonetalia	X	X	X	X	X
Satureja variegata Host	Ch - illirica	Chrys.-Satureion				X	X
Leontodon crispus Vill.	H - S eur. S sib.	Chrys.-Satureion				X	X
Fumana procumbens Gren. et Godr.	Ch - eurimedit. pont.	Chrys.-Satureion				X	X
Dianthus tergestinus (Rchb.) Hayek	H - illirica	Chrys.-Satureion				x	x
Leucanthemum liburnicum (Horvatić) Horvatić	H - NE medit. mont.	Scorz.-Chrysopogonetalia	X		X	X	X
Fraxinus ornus L. pl.	P - S europ. S sib.	Ostryo-Carpinion		X		X	X
Ruscus aculeatus L.	Ch - eurimedit.	Ostryo-Carpinion					X
Plantago holosteum Scop.	H - SE europ.	Scorz.-Chrysopogonetalia	X	X	X	X	X
Dictamnus albus L.	Ch - europ. S sib.	Geranion sang.		X	X	X	X
Plantago lanceolata L.	H - euras.	Brometalia					X
Paliurus spina-christi Mill.	P - SE eurog. pont.	Prunetalia					X
Campanula glomerata L.	H - euras.	Origanetalia, Bromion erecti					X
Brachypodium sylvaticum (Huds.) PB.	H - paleotemp.	Querco-Fagetea					X
Sesleria autumnalis (Scop.) F.W. Schultz	H - SE europ.	Ostryo-Carpinion	X	X	X	X	X
Geranium sanguineum L.	H - europ. caucas.	Geranion sang.	X				X
Seseli annuum L.	H - S europ. pont.	Brometalia				X	X

Silene nutans L.	H - paleotemp.	Trifolio-Geranietea			X	X	
Trifolium repens L.	H - subcosmop.	Arrhenatheretalia					
Chamaespartium sagittale (L.) Gibbs	Ch - centro S europ.	Quercion roboris-petraeae. Scorzonerion vill.					
Quercus petraea (Matt.) Liebl. pl.	P - europ.	Quercion roboris-petraeae. Scorzonerion vill.					X
Melittis melissophyllum L.	H - centroeurop.	Ostryo-Carpinion	X				
Vincetoxicum hirundinaria Med.	H - euras.	Ostryo-Carpinion	X				
Euphorbia fragifera Jan.	Ch - illirica	Chrys.-Satureion	X				X
Knautia illyrica Beck	H - NE medit. mont.	Scorzonerion vill.	X		X	X	X
Potentilla recta L.	H - NE medit. pont.	Scorz.-Chrysopogonetalia					
Dorycnium pentaphyllum Scop.	H - S europ. stepp.	Scorz.-Chrysopogonetalia	X	X		X	X
Teucrium montanum L.	Ch - orof. S eur.	Chrys.-Satureion	X	X		X	X
Prunella laciniata L.	H - eurimedit	Scorzonerion vill.				X	
Scabiosa gramuntia L.	H - S europ. S sib.	Scorzonerion vill.	x				
Euphorbia cyparissias L.	H - centroeurop.	Brometalia	X			X	X
Sanguisorba minor Scop.	H - paleocosmop.	Brometalia	X		X	X	X
Veronica barrelieri Schott ex Roem. & Schult.	H - Se europ.	Scorz.-Chrysopogonetalia	X	X	X	X	X
Genista sylvestris Scop.	Ch - illirica anfiadr.	Chrys.-Satureion	X	X	X	X	X
Plantago argentea Chaix	H - SE europ. S sib.	Chrys.-Satureion	X	X	X	X	X
Galium lucidum All.	H - eurimedit.	Chrys.-Satureion	X	X	X	X	X
Cytisus pseudoprocumbens Markgraf	Ch - illirica	Scorz. - Chrysopogonetalia	X	X			X
Asperula cynanchica L.	H - eurimedit.	Scorz.-Chrysopogonetalia	X	X		X	X
Helianthemum ovatum (Viv.) Dunal	Ch - europ. caucas.	Scorz.-Chrysopogonetalia	X		X	X	X
Betonica serotina (Host.) Murb.	H - SE europ.	Scorz.-Chrysopogonetalia	X	X	X	X	X
Pinus nigra Arnold pl.	P - NE eurimedit.	/					X
Achillea collina J. Becker ex Rchh.	H - SE europ.	Artemisietea					X
Agropyron intermedium (Host) PB.	G - S europ. S sib.	Agropyretea		X			X
Euphobia verrucosa L.	Ch - S europ. pont.	Bromion erecti	X		X		X
Teucrium chamaedrys L.	Ch - eurimedit.	Brometalia				X	X
Carex caryophyllea Latourr	H - euras.	Scorzonerion vill.	X		X	X	X
Filipendula vulgaris Moench.	H - centroeurop. S sib.	Bromion erecti				X	X
Ostrya carpinifolia Scop. pl.	P - pontica	Ostryo-Carpinion	X				
Vicia cracca L.	H - circumb.	Arrhenatheretalia	X				
Arabis turrita L.	H - S europ.	Geranion sang.. Prunetalia	X				
Lathyrus pratensis L.	H - paleotemp.	Arrhenatheretalia	X				
Mercurialis ovata Sternh. & Hoppe	G - SE europ. pont.	Ostryo-Carpinion	X				X
Thalictrum minus L.	H - euras.	Geranion sang.	X		X		X
Prunus mahaleb L. pl.	P - S europ. pont.	Prunetalia	X		X	X	X
Carex flacca Schreb.	G - europ.	Bromion erecti				X	
Onobrychis arenaria DC.	H - S europ. S sib.	Scorzonerion vill.					X
Cuscuta epithymum (L.) L.	T - euras.	Scorz.-Chrysopogonetalia					X
Cotinus coggygria Scop.	P - S europ. turan.	Prunetalia	X			X	X
Peucedanum cervaria (L.) Lapeyr.	H - eurosib.	Geranion sang.					X
Trifolium rubens L.	H - centroeurop.	Geranion sang.		X	X	X	X
Hieracium piloselloides Vill.	H - europ. Caucas.	Scorz.-Chrysopogonetalia					X
Silene vulgaris (Moench.) Garcke	H - paleotemp.	Bromion erecti					X
Quercus pubescens Willd. pl.	P - SE europ.	Ostryo-Carpinion	X	X		X	X
Peucedanum oreoselinum (L.) Moench.	H - europ. caucas.	Geranion sang.. Scorzonerion vill.	X		X		X
Chamaecytisus hirsutus (L.) Lk.	Ch - eurosib.	Origanetalia				X	X

Tab. 1 — List of species found in the relevés, ordered according to the 5 main clusters (A, B, C, D, E) obtained by group average linkage clustering, life forms, chorological types, syntaxonomical rank and presence in the 5 groups of relevés (see text).

dence of a decreasing of *Bromus erectus* and an increasing value of *Carex humilis.* In the fifth group the dominant species are *Carex humilis* and *Sesleria autumnalis* while *Bromus erectus, Bromus condensatus* and *Chrysopogon gryllus* get down to their minima. From these results we can conclude that the closeness of the N R around the grasslands is an important gradient respect to behaviour of the species.

The N R with their presence assure to the grasslands a certain degree of humidity and a certain global fertility. However if their mean distance around the grasslands is less than 9 metres the unexploited grasslands undergo a process of reforestation more evident than in the other cases. The dominance of *Sesleria autumnalis* and the high cover of species of *Geranion sanguinei* (10%) and of *Ostryo-Carpinion orientalis* (20%) in the grasslands of group 5 demonstrate clearly the tendence to a quick reforestation.

Along the coenocline of Fig. 2 the total number of species increases almost linearly from the more open grasslands to the more closed ones, while the mean species number for relevé reaches its maximum in correspondence of group 2 and another maximum in correspondence of group 5 (Tab. 2). If we consider the ratio:

$$\frac{\text{mean species number for relevé}}{\text{Total species number in the group}}$$

as a measure of floristic homogeneity within the groups, this regularly decreases from the first to the last relevés group (see Tab. 2), the mean heterogeneity of the pattern reaches its minimum in the group 2 and the maxima in groups 1 and 5. In group 2 there is also the maximum value of relative diversity; this means that in the grasslands under study when there is a certain equilibrium between the dominant species there is also a tendency to the equicover of the other species.

1	2	3	4	5	6	7	8	9	10
1	15	34	19	4.26	3.66	0.86	2.84	0.67	0.55
2	13	52	27	4.77	4.19	0.88	2.60	0.56	0.51
3	11	56	24	4.60	4.00	0.86	3.18	0.69	0.42
4	9	69	22	4.47	3.75	0.84	3.28	0.73	0.31
5	5	89	25	4.66	3.66	0.77	3.90	0.84	0.28

Tab. 2. Relevant parameters for each of the 5 groups of releves (see the text). Legend for columns: 1 = code for the releves group, 2 = class of the mean distance of NR around the grasslands, 3 = total number of species for group, 4 = mean number of species for relevé, 5 = maximal diversity (Hmax = Log_2 N), 6 = mean diversity according to the Shannon entropy based on species cover, 7 = relative diversity, 8 = mean heterogeneity, 9 = mean relative heterogeneity, 10 = mean floristic homogeneity (see text for explanations).

The facts that the mean floristic homogeneity of the relevés decreases from more open to more closed grasslands, that the relative diversity of relevés (α diversity) decreases too and that the heterogeneity of the pattern increases and finally that the total species number increases, demonstrate that along the transects of more closed grasslands there is an increment of β diversity (Whittaker 1967, 1972), i.e. the influence of N R is strongest and produces more discontinuities in the species responses along transects. What is surprising in the fact that the trend of mean heterogeneity along the gradient of closeness fits roughly the mean trend of heterogeneity along the transects (Fig. 3) i.e. firstly a decrement and then again an increment (Feoli & Feoli Chiapella 1979). The influence of N R on the pattern of grasslands is evident; they create more mesophylous conditions which favour the global productivity as indirectly proves the fact that the sum of cover of all the species is meanly lower in the more open grasslands (group 1 = 1169, group 2 = 1680, group 3 = 1180, group 4 = 1370, group 5 = 1443).

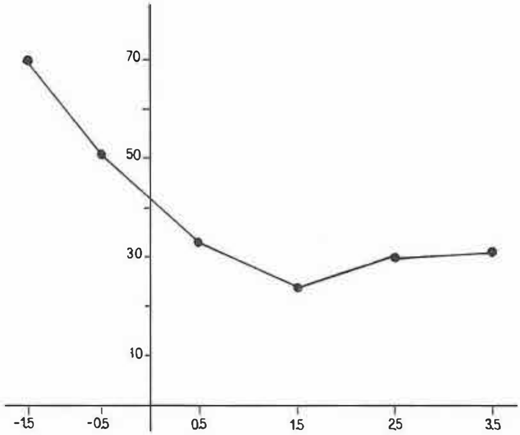

Fig. 3 — Trend of the mean heterogeneity (×10) of spatial pattern along transects towards NR. On the x axis are reported the distances in metres to the projection of the canopy on the ground, negative numbers identify relevés made under the canopy.

Conclusions

— Along transects towards the nuclei of reforestation the spatial pattern and the species composition of the grasslands don't change significantly as far as the projection of the canopy of the trees or the shrubs on the ground.

— There is a strict correlation between pattern, species composition, diversity and closeness of NR around the grasslands.

— The closeness of NR produces, after a certain limit (11 metres), the increasing of pattern heterogeneity of the grasslands and it favours the more mesophylous species of the grassland but also the species of the edge *(Geranion sanguinei)* and of the woods *(Ostryo-Carpinion orientalis)*. Under certain limits of closeness (5 metres) the high competition of *Sesleria autumnalis* produces the disappearance of the original grasslands.

Riassunto

Questo lavoro presenta i risultati dell'analisi del pattern della vegetazione dei pascoli abbandonati del Carso triestino e goriziano. I pascoli presi in considerazione si trovano su superfici piane o debolmente inclinate, circondate o interrotte da nuclei di riforestazione (NR) di varia estensione (10-51 mq). L'analisi del pattern è stata condotta rilevando la vegetazione con un reticolo di 1 mq suddiviso in 25 sottoquadrati di 400 cmq. Per ogni sottoquadrato è stato fatto l'inventario delle specie ad ognuna delle quali è stato assegnato un valore di copertura. I rilievi sono stati eseguiti lungo transetti dal pascolo aperto verso i NR. Lo scopo di questo lavoro è stato quello di valutare l'influenza dei NR sul pattern della vegetazione dei pascoli. L'eterogeneità del pattern e la somiglianza tra i rilievi sono state calcolate con funzioni della teoria dell'informazione. I risultati hanno dimostrato che l'influenza del singolo NR non ha molta importanza sul cambiamento della vegetazione lungo i transetti, bensì che variazioni considerevoli sono dovute alla distanza media dei NR attorno al pascolo.

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