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Ecological study of the vegetal component in the terrestrial ecotones of central Italy

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Abstract

Ecological analysis of the flora of central Italian terrestrial ecotones demonstrates two flows of species in opposite directions along the gradient of anthropization in order to connect the anthropized areas with the natural ones. The single species reacts to the changes of the ecological conditions with morphological and anatomical adaptations. Reduction of habitus and shortening of the life cycle took place. The flows can be identified as the results of dynamic processes of apophytization and of anthropophytization. The first assures the survival of natural ecotone species and fosters their movements towards anthropized ecotones. The second facilitates the spread of plants with wide distribution and that of species with multiple ecological strategies from strongly anthropized ecotones to seminatural and natural ones. The establishment of the latter causes the banalization of the ecotonal flora and the presence of fairly homogeneous patches dominated by some populations of the *Graminaceae* and the *Compositae* families. In the ecotones with strong human disturbance, the species with multiple strategies are selected. Continous exchanges of species between the ecotones support the connectivity among settlements exposed to different intensity of the human impact. The link between these exchanges of species and the biodiversity of the ecotones is confirmed. The greates richness in species is observed in the moderately anthropized ecotones as the result of the coexistence of plants coming from different ecosystems.

Introduction

Progressive anthropization of the environment diminishes the zones occupied by natural ecosystems in various parts of the biosphere. Their continuous fragmentation fosters the formation of ecotones, which are transitional zones between different habitats and are characterized by various levels of anthropization (Saunders *et al*., 1991). These areas control the flow of nutrients and water between aquatic and terrestrial ecosystems and attract animal and plant species deprived of primary habitats, conserving the diversity of a territory which has been strongly modified by man (Harris, 1988; Zonneveld & Forman, 1990; Farina, 1995). In terrestrial ecosystems the ecotones can be observed as soil or vegetation discontinuities. In human modified ecosystems such as in a heterogeneous environments ecotones represent the borders of patches which form the land mosaic. Ecotones created by natural processes have generally an ecological gradient, while in those caused or produced by human impact the change from one system to another is rather abrupt. These areas have frequently a high number of species, some typical of the edges, others coming from the adjacent ecosystems (Hansen *et al*., 1992). The tendency, called the edge effect is important for the preservation of the biological diversity. This characteristic affects frequently the distribution and the abbundance of different species.

Sometimes the ecotones are seen by species as a barrier which prevent their movements slowering the ecological fluxes among different ecosystems (Farina, 1995). Man's destruction of the forest ecosystem changes the ecological conditions in the natural ecotonal areas which develop on its borders. Various nemoral species move towards disturbed habitats adapting their morphology or

anatomy to the new ecological conditions. The ecological versatility of the ecotonal flora increases along the gradient of anthropization. Plants from natural ecotones colonize seminatural and anthropized habitats supporting the renewal of the ecotonal flora. The secondary habitats represent for various species the only way to persist. The possibility to survive is due, for example, to their ability to change the life form or to adapt the length of the life cycle to frequent changes of ecological conditions caused by anthropic intervention. For this reason it is ever more important to have data on ecological characteristics of the terrestrial ecotones. This need is particularly felt in studying the dynamic relationships between the city and surrounding ecosystems (Hruska, 1995), reached by particularly vital and competitive plants.

The goal of the present paper was to identify the moving of species between the ecotones along the gradient of anthropization, based on data for the territory of central Italy. The results should serve to verify the importance of the dynamic processes in improving these areas, notwithstanding the accentuated presence of the anthropic factor.

Materials and methods

Studies of the vegetation dynamics of the central Italian terrestrial ecotones were conducted from 1993 to 2002, prevalently in ecotonal areas of the hilly zone (ranging in altitude from 22 to 620 m a.s.l.) going from the Adriatic coast to the Apennine mountains (Table 1). In the zones of contact between the forest ecosystem, the agro-ecosystem and the urban one, permanent ecotonal areas were identified (about 1 m wide and 4 m long) that shared similar edaphic and topographical conditions in order to minimize any effects from exogenous factors. The study began with an inventory of the ecotonal flora in each chosen area on the basis of repeated on-site observations.

Direct evaluation of these areas and subsequent ecological analysis of the individual lists of species enabled each to be attributed with a degree of anthropization. A scale from 1 to 10 was used to indicate the progressive increase of human impact (Hruska, 1995). The use of this scale allows a comparison of the results with those already obtained in the natural ecotones (Hruska, 2001; Hruska & Markovic, 2001). Information on some general and ecological characteristics of the ecotonal areas studied here is reported in Table 1.

Lyfe cycles, biological forms, chorological types and dispersal strategies were examined, and the results of the individual analyses are reported in Table 1, 2, 3, 4. Finally, comparative analysis of the data was conducted in order to clarify the relationship between the characteristics of the ecotones and their role in the ecological processes that influence the quality of the environment.

Results

In order to confirm the presence of specific flows along the gradient of anthropization, an in-depth ecological analysis of the ecotonal flora of all the areas studied was completed. The data thus obtained were compared to identify the directions of the specific flows in relation to the intensity of the human impact.

Diversity

Table 1 reports the Shannon's index average values calculated on the basis of the estimation of the abundance of the ecotonal flora during the entire vegetative period. Comparing the data from the field samplings, one notes two seasonal increases, in spring and in autumn, caused by the territory's climatic regime. Relating the reduction in biodiversity along the gradient of anthropization to the presence of cosmopolites, one can deduce that anthropic intervention causes the disappearance of various autochtonal ecotonal species and fosters the establishment of plants with wide distributions, as already noted in the Italian urban and suburban ecotones (Hruska, 1995).

Life cycles

There is a relationship between the increase of anthropization and the reduction of the P/A ratio, as reported in Fig. 1. The percentage of perennial species (P) decreases going from less disturbed ecotones towards those intensely worked by man, while the annual therophytes (A) increased. The flow of the latter follows two principal directions. The first begins in the agro-ecosystem and reaches the moderately anthropized ecotones, involving a fairly high number of species (*Diplotaxis erucoides, Mercurialis annua, Bromus gussonei, Torilis arvensis*, etc.). The second facilitates the entrance of some urban plants such as *Linaria vulgaris*, *Conyza canadensis* and others in the seminatural ecotones.

The number of species with multiple strategies doubles along the gradient of anthropization. They are fairly abundant in the urban and suburban ecotones (Table 3). Increased anthropic disturbance favors the species capable of adapting their life cycle to the ecological conditions of the habitat. In species such as *Sonchus oleraceus* or *Stellaria media* that move from the agro-ecosystem to the seminatural ecotones, the life cycle length is inversely proportional to the intensity of the human impact.

Life forms

From Fig. 2 it can be deduced that the H/T ratio decreases in the ecotonal flora along the gradient of anthropization. The hemicryptophytes (H) with luxuriant habitus such as *Anthriscus nemorosa, Chaerophyllum aureum* or *Heracleum sphondylium*, which are important for the physiognomy of the forest ecotones (Hruska, 2001), disappear from the structure of strongly disturbed ecotones (Hruska & Markovic, 2001). The increase of species with multiple strategies regarding biological form is constant though not very marked (Table 1 C in Appendix). The abundance of species such as *Artemisia verlotorum*, *Cichorium intybus*, *Daucus carota* or *Anthemis tinctoria* depends on the type of human impact (hoeing, extirpation) as well as its duration, as has already been confirmed (Hruska, 1994 a).

In the moderately disturbed ecotones there is a more balanced relationship among the biological forms. The

Table 1. Ecological analysis of the flora of the terrestrial ecotones of central Italy: some geographical and ecological data on the ecotones studied.

N° ecotone	1	2	3	4	5	6	7	8	9	10	11
Locality	Chiaravalle	Jesi	A. di Fiastra	A. di Fiastra	A. di Fiastra	A. di Fiastra	A. di Fiastra	Matelica	Pontelatrave	Casale	Polverina
Altitude (m.a.s.l.)	22	97	182	182	182	182	182	387	409	409	620
Distance of seacoast (km)	22	32	80	80	80	80	80	63	120	100	105
Ecotone, type	field/road	urban ecotones	road/field	hedge/road	road/field	hedge/field	field/road	field/road	hedge/road	field/road	hedge/field
N° species	55	47	52	56	62	59	62	52	24	33	28
Anthropization degree	7	8	4	6	7	6.5	7	8	6.5	7	5
Shannon's index	0.9	0.96	1.01	0.9	1.03	0.88	0.86	1	0.7	0.5	0.6

Table 2. Chorological types (%) of the flora of the terrestrial ecotones of central Italy.

Ecotone	1	2	3	4	5	6	7	8	9	10	11
Annuals (%)	29.3	38.8	16.6	17.7	33.5	31.5	33.9	33.4	27.1	26.8	33.8
Biennials (%)	7.1	6	4.9	6.9	7.6	8.8	4.9	6.4	3.4	8.9	7.6
Perennials (%)	55.6	44.8	72.6	66.2	48.7	49.6	49.9	48.1	62.5	56.3	50.6
Multiple strategies (%)	8.1	10.4	6.1	9.2	10.2	10.1	11.3	12.1	7	6.2	8

Table 3. Life forms (%) of the flora of the terrestrial ecotones of central Italy.

Ecotone	1	2	3	4	5	6	7	8	9	10	11
Hemicryptophytes	44	35	46.8	41.4	43.5	45.5	38.6	40.8	43.9	43.7	42.5
Therophytes	36	38	14.5	16.5	24.2	32.8	37.2	33.4	28.7	29.2	36.8
Geophytes	8	9.4	6.1	13.8	4.8	3.8	4.9	11.6	6.8	9.7	-
Chamaephytes	-	0.74	3.1	4.5	1.6	-	1.6	-	-	-	-
Phanerophytes	1	0.86	9.1	1.7	3.4	-	1.6	0.5	4.1	4.9	4.9
Nanophanerophytes	1	-	3.8	6.9	4.8	1.3	3.2	1	6.8	4.7	5.8
Multiple strategies	10	16	16.6	15.2	17.7	16.8	12.9	12.7	9.7	8.5	10

Table 4. Dispersal strategies (%) of the flora of the terrestrial ecotones of central Italy

Ecotone	1	2	3	4	5	6	7	8	9	10	11
Anemochory	7,2	18,9	19,6	19,5	11,7	11,8	14,5	11,8	5	7,3	7,9
Anthropocory	18,2	16,4	6,1	16,1	10,1	18,1	17,7	14	11,9	17	26,3
Myrmecochory	16,8	12	16,6	12,3	11,3	19,6	16,1	11,7	20,7	18,3	18,5
Zoochory	22,3	7,7	18,5	13,4	12,9	8,8	11,3	20,1	13,7	23,2	15,8
Autochory	4,9	5,2	4,5	8,3	9,1	5,1	6,4	1,1	5	3,7	5,3
Epizoochory	4,3	2,6	16,1	15,5	14,4	8,4	6,4	16,2	5	3,7	5,3
Endozoochory	2,7	0,9	9,5	5,5	16	4,8	3,2	2,2	18,6	14,6	2,6
Idrocory	-	0,9	-	-	-	-	-	2,2	-	-	-
Polychory	23,6	35,4	9,1	19,4	14,5	23,4	24,4	20,7	20,1	12,2	18,3

chamaephytes (*Teucrium chamaedrys, Artemisia alba, Helianthemum nummularium*) and the nanophanerophytes *(Rosa sempervirens, Coronilla emerus, Rubus sp. pl.*.) are present. These species show establisment of a progressive secondary succession.

Dispersal strategies

Among the various modalities of dispersion observed in the ecotonal flora along the gradient of anthropization, one notes the prevalence of polychory, followed by myrmecochory and anthropochory. While the flow of polychorous species increases along this gradient (Fig. 3), the percentage of plants that use humans and ants as dispersal agents is moderately variable. The constant presence of myrmecochorous plants is caused by a certain edaphic homogeneity of the ecotonal areas of this study. In fact, removed and porous soil facilities the construction of ant hills (Handel & Beattie, 1990). Zoochory, and in a particular way endozoochory, is more accentuated in the ecotones that border woods and hedges (Table 4).

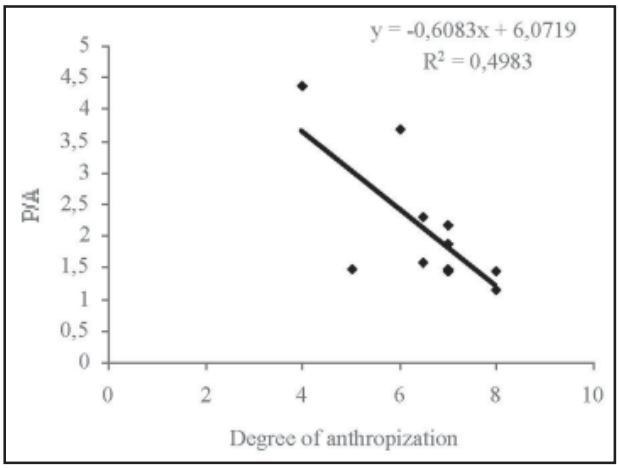

Fig. 1. Ratio between the presence (%) of perennial and annual (P/A) plants and the degree of anthropization of the terrestrial ecotones of central Italy.

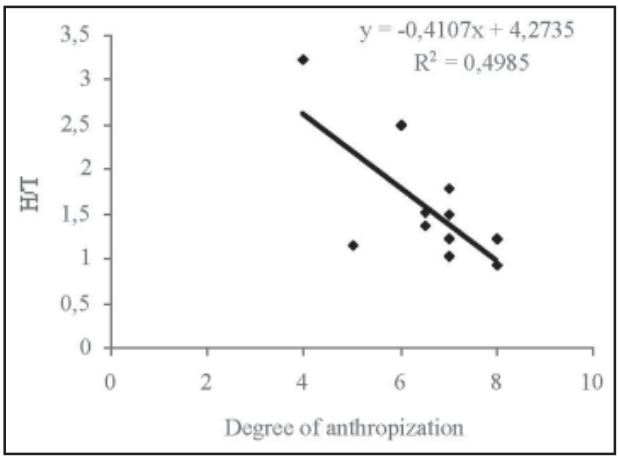

Fig. 2. Ratio between the presence (%) of hemicryptophytes and of therophytes (H/T) and the degree of anthropization of the terrestrial ecotones of central Italy.

Chorological types

The prevalence of mediterranean species is constant along the altitudinal gradient (Table 2). The distance from the coastal zone, reported in Table 1, does not significantly influence their presence. The establishment of these species in the individual areas depends above all on the local ecological conditions caused by direct anthropic intervention (extirpation, rehandling the soil), which heightens the aridity of the ecotonal physical environment.

Increased human impact provokes reduction of the total number of chorological types present in the individual ecotones, to the advantage of the cosmopolitan ones. The percentage of the latter is notable, above all in the strongly anthropized ecotones. The moving of cosmopolitans such as *Capsella bursa pastoris, Verbena officinalis* or *Convolvulus arvensis* along the gradient of anthropization leads to the structural simplification of the ecotonal vegetation. While studies on this topic are still underway, the results obtained for natural ecotones (Hruska , 2001) confirm this fact.

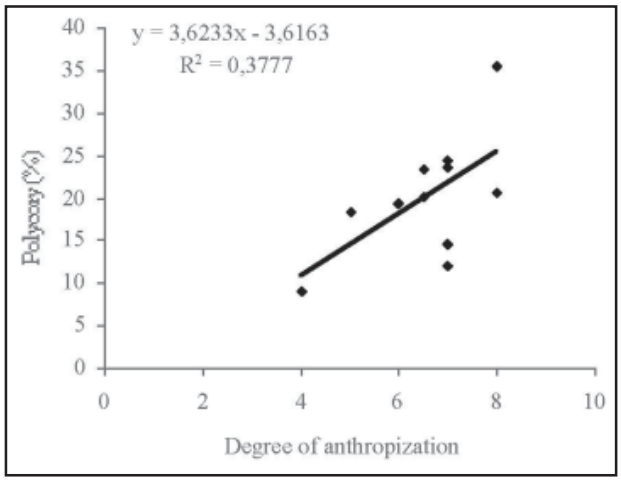

Fig. 3. Ratio between polychory (%) and the degree of anthropization of the terrestrial ecotones of central Italy.

Discussion

The studies on the ecological flows in the ecotonal flora of central Italy along the gradient of anthropization have demonstrated the particular involvement of:

- species with brief life cycle,
- euriecious species,
- species with multiple ecological strategies.

The ecological versatility of the ecotonal flora increases along this gradient, reaching maximum values in the suburban ecotones exposed to multiple disturbances.

Two specific flows moving in opposite directions have been identified. The first, which is responsible for the formation of the ecotone, develops between these and the natural ecosystems (woods, hedges), enriching them with stenoecious species. The contact with natural ecosystems increases the edge effect. The second, arising from the agro-ecosystem and from the urban ecosystem, fosters the diffusion of plants with broad ecological valence. The establishment of the latter causes the banalization of the ecotonal flora: fairly homogeneous patches form, their structure dominated by some populations of the *Graminaceae* and the *Compositae* families. Strong and constant anthropic intervention fosters the second direction. For this reason, in heavily disturbed areas the various megaforbs of the *Umbelliferae* family which are characteristic for the natural ecotones disappear and leave space for the autochthonous and alloctonous *Compositae*.

The specific seasonal movings caused by the territory's climatic regime moderately increase the biodiversity in spring and in the fall. This is more evident in the ecotones that undergo little anthropic disturbance. Roads (asphalted or dirt roads) pose considerable barriers for the specific flows in the ecotones, as has already been noted (Wiens, 1992; Farina, 1995). This effect is more accentuated in the direction from the natural ecotones towards seminatural and suburban ones. In this type of area there is a notable decrease in typical nemoral flora, which already perceives the ecotone itself as a barrier to its own spread. The works of urbanization that fragment the ecotones negatively influence biodiversity, slowing the specific exchanges.

Along the gradient of anthropization the dynamic pro-

cesses of apophytization and anthropophytization, responsible for the renewal of the ecotonal flora, have been ascertained. They connect the natural ecotones with the anthropized ones. Apophytization is the dynamic process which means the movings of plants from natural habitats to anthropized ones and depends upon the dynamic contacts between the natural ecosystem and ecotones existing in some area. Anthropophytization (*sensu* Hruska, 1994 b), causes exchanges of plants between the artificial ecosystems (city), the anthropized ones (agroecosystem) and the natural ones. This process causes a qualitative simplification of the ecotonal flora, because all over the world distributed cosmopolites become established in the natural and semi-natural ecotones. Excessive human impact temporarily blocks the processes identified.

The greatest richness in species is observed in the moderately anthropized ecotones where, notwithstanding the presence of the anthropic factor, there is co-existence of plants from the forest ecosystem, those typically ecotonal, together with a group of plants that have moved from the agro-ecosystem and the urban ecosystem. This confirms the importance of the ecotonal areas for the conservation of the biodiversity.

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