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Environmental units of the Stelvio National Park as basis for its planning

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Abstract. The Stelvio National Park (Italian Central Alps) presents a very complex landscape, due to anthropic impact and wide altitude range. Using the holistic landscape ecology approach together with synthesis cartography, the Park was divided into elementary environmental units; that is, areas of relative ecological homogeneity having a characteristic arrangement of ecosystems. Mapping of the environmental units is based on analytic data regarding lithology, morphology, pedology, climatology, vegetation, fauna, soil use and type of human establishment. The redundancy of the environmental units facilitated their reduction to only 37 types. The naturalistic-aesthetic and historical-cultural evaluation of the environmental units employed criteria (naturalness, rarity, renewability, beauty and diversity) to which were assigned ordinal scales of value. Use of binary values allowed quantification of the criteria related to the types of environmental unit and thus their division by multivariate analysis into 4 relatively homogenous groups. Cartographic rendition of these 4 groups of types led to the production of a map of preliminary Park zoning, in which it is possible to distinguish 4 functional zones, as requested by the Italian law for national parks.

Key words: Stelvio National Park, landscape ecology, synphytosociology, environmental units, preliminary zoning

Introduction

The approach of landscape ecology is defined as an integrated study of the natural environment (Troll 1966). Two aspects of landscape ecology are of special interest: the interdisciplinary approach in analyzing the landscape and the emphasis on how ecosystems relate to each other. The last-mentioned aspect differentiates landscape ecology from synecology. Naveh and Lieberman (1984) stated that "landscape ecology is presently viewed in Europe as the scientific basis for land and landscape planning, management, conservation, development, and reclamation".

On the basis of the holistic approach, the landscape units are considered as areas of relative ecological homogeneity with a characteristic arrangement of ecosystems (Vos and Stortelder 1992). The ecosystems that constitute a landscape unit may cover the whole range of naturalness, from fully man-made to natural, as defined by Maarel (1975). The concrete delineation of the land units remains subjective and artificial, since ecosystems and landscapes are open systems (Bertalanffy 1950; Chorley and Kennedy 1971). However, for practical reasons, it is justifiable to choose as a pragmatic criterion the aesthetic and cultural identity of each unit, obtained by overlapping and integrating the physical environment (ecotope), the biotic environment (biocoenosis) and the anthropic environment (Froment 1987). The degree of homogeneity and the size of the land units depend on the scale chosen for the base topographical map (Veen 1982).

Material and methods

Study area and aims

The Stelvio National Park covers 134,621 km^2 in the Italian Central Alps. Orographically, the park is made up of a fan-shaped mountain complex which spreads out from the glacialized cap of Mountain Cevedale. The minimum altitude is reached in Venosta Valley (645 m), while the maximum one on the Ortles Peak (3,905 m).

The vegetation landscape of the Park is typical of the intra-alpine zone, that is dominated by the coniferous forests and with no occurrence of beech.

The anthropic landscape is formed of permanent villages in the valley bottom and lower slopes, of temporary summer establishments ("masi") on the middle third of the slopes and of shepherd's huts at high altitude.

The aim of the present study is to make use of the landscape ecology and the synphytosociology approaches as objectively as possible, in order to establish a preliminary zoning for the territory of a national park.

Material and methods

The apparent environment is formed of geosystems with a specific physiognomic composition given by the spatial organization resultant from the interaction between biotic and abiotic components (Christofoletti 1993). Synthetic spatial units have been named environmental units inasmuch as they are not included in a hierarchic system such as land units in land systems (Mabbutt and Stewart 1962; Vinogradov 1967; Christian and Stewart 1968).

The present work employed synthesis cartography, which integrates information drawn from single thematic maps (Martinelli 1991), unlike analytic cartography which examines single landscape attributes. Identification and cartographic delimitation of environmental units was done by synoptic and analogic aggregation of the analytic data concerning lithology, morphology, pedology, climatology, vegetation, fauna, land use and type of human establishment (Patella 1969; Pedrotti 1969; Ronchetti 1969; Pedrotti *et al.* 1974; Pirola 1974; Credaro and Pirola 1975; Pedrotti and Venanzoni 1989). In particular, vegetation was used as a fundamental indicator during both the visual identification phase and that of naturalistic-aesthetic evaluation of the environmental units, inasmuch as vegetation is a tangible and integrated expression of the whole ecosystem (Küchler 1973; Küchler and Zonneveld 1988; Falinski 1990-1991; Donita and Gafta 1992). In fact, many types of environmental unit correspond to one or more contiguous sigmeta or vegetation series (Rivas-Martinez 1987; Géhu 1991), which generally belong to the same geomorphologic and elementary biogeographic unit. An up-dated list of sigmeta and their related plant associations from the Stelvio National Park is given by Pedrotti and Gafta (1994).

For environmental units mapping a 1:50,000 scale was chosen to permit a relatively detailed analysis of the landscape.

Naturalistic-aesthetic and historical-cultural evaluation of the environmental unit types was based generally on criteria reviewed by Margules and Usher (1981) and applied by Loidi (1994). To each one a scale of ordinal values was assigned, as follows:

Naturalness:
0 - without vegetation; 1 - crops or synanthropic vegetation; 2 - secondary natural vegetation; 3 - climax vegetation.

Rarity:
0 - common; 1 - rare; 2 - very rare.

Renewability:
0 - easy; 1 - difficult; 2 - almost impossible.

Beauty (aesthetic value):
0 - little; 1 - average; 2 - great.

Diversity:
0 - monotonous; 1 - modulated; 2 - heterogeneous.

Naturalness was evaluated on the basis of vegetation. A very good indicator since it reflects the state of the other biocoenotic component (zoocoenosis) and of the ecotope (humus, soil, mesoclimate). In the case of high mountain peaks (over 3,200 m), the lack of natural vegetation left only the use of ecotopic criteria.

Rarity is a more all-embracing concept because it refers not only to plant and animal species or vegetation type, but also to landscape, culture, history and so on.

Renewability refers to the possibility of reconstitution of the ecosystems, the agricultural landscape and the artistic patrimony which are part of environmental units.

Beauty considers the aesthetic value of the single plant and animal species, of the plant communities, of the natural and agricultural landscape, and lastly of historical-cultural objectives.

Diversity includes more meanings which concern the diversity of biocoenoses, ecosystem diversity and, in the case of artificial environmental units, cultural and artistic richness.

The preliminary Park zoning took into account the provisions of the Charter Law for protected areas in Italy (no. 394/december 1991). According to this one, the territory must be divided into four functional zones as follows:

Zone A - completely protected reserves;

Zone B - limited use reserves, in which natural resource management is permitted;

Zone C - protected areas, in which traditional activities involving farming, forestry or animal husbandry, and rational gathering of natural products are allowed;

Zone D - areas of economic promotion, in which the natural environment has undergone profound anthropic modifications and in which socio-economic activities compatible with the Park's institutional goals are permitted.

Division of both (semi)natural and anthropic environmental unit types into relatively homogenous groups was done by k-means clustering analysis, using the Reloc program (Podani 1990). The iterative algorithm consists in minimizing the sum of the squares by the displacement of the objects (environmental unit types) among the groups to be distinguished, in order to make them as homogeneous as possible.

Results and discussion

The following vegetation series were mainly used to distinguish the near natural environmental units:

- Alpine acidophilous series of primary meadows (*Primulo-Cariceto curvulae, Poo-Aveneto pratensis, Festuceto halleri* and *Festuceto variae* sigmeta);
- Alpine basophilous series of primary meadows (*Seslerio albicantis-Cariceto sempervirentis* and *Elyneto myosuroidis* sigmeta);
- Subalpine acidophilous series of low and dwarf shrub woods (*Vaccinio-Rhododendreto ferruginei, Vaccinio-Empetreto hermaphroditae, Arctostaphylo uvae-ursi-Junipereto nanae, Cetrario-Loiseleurieto procumbentis* and *Saliceto helveticae* sigmeta);
- Subalpine basophilous series of Swiss mountain pine scrubwoods (*Rhododendro hirsuti-Pineto mugo, Erico-Pineto mugo, Vaccinio-Pineto montanae* and *Carici humilis-Pineto engadinensis* sigmeta);
- Subalpine hygrophilous series of green alder shrubwoods (*Alneto viridis* sigmetum);
- Subalpine acidophilous series of Swiss stone pine and larch woods (*Rhododendro ferruginei-Pineto cembrae, Junipero nanae-Pineto cembrae, Rhododendro ferruginei-Lariceto deciduae* and *Junipero nanae-Lariceto deciduae* sigmeta);
- Mountain acidophilous series of spruce forests (*Homogyno alpinae-Piceeto abietis, Melampyro sylvatici-Piceeto abietis* and *Luzulo niveae-Piceeto abietis* sigmeta);
- Mountain basophilous series of spruce forests (*Adenostylo glabrae-Piceeto abietis* sigmetum);
- Mountain acidophilous series of silver fir forests (*Calamagrostio villosae-Abieteto albae* and *Luzulo niveae - Abieteto albae* sigmeta);
- Mountain basophilous series of Scotch pine

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Environmental units in Stelvio National Park

1. High peaks and rocky ridges, still glacialized or emerged from the snow, formed around glacial cirques or at the sides of valley flutes.
2. Permanent glaciers and snowfields under high rocky peaks.
3. Steep rocky slopes at high altitude with morainal and detrital deposits, more or less level, with little or no vegetation.
4. Steep or almost vertical rocky slopes in calcareous environment, generally at high elevations.
5. Glacial amphitheaters - often suspended - at the head of the valleys filled up with morainal and detrital materials from siliceous rocks, sometimes with peat bogs or small lakes edged by peaty vegetation, and covered by discontinuous primary meadows.
6. Rounded and leveled summit areas on siliceous substrata, covered by primary meadows.
7. Higher zones of the slopes with levelings, terraces and small rises above timberline formed of siliceous acid rocks and covered by primary meadows.
8. Higher zones of the slopes with levelings, terraces and small rises on the substratum of calcium rich rocks, above timberline, with primary meadows.
9. Elevated parts of the slopes with morainal deposits of little depth, in general gently steep, on prevalently silicate substrata, covered by low or dwarf shrub woods.
10. Very steep detrital deposits - boulder fields - prevalently in calcareous environments, sometimes with discontinuous vegetation of contorted shrub woods.
11. Level valley flutes shaped by glaciers and filled with alluvial cones on calcareous substratum, covered by primary meadows and erect shrub woods.
12. Gullies, small valleys and slopes with hygrophilous brushwoods.
13. High slopes on silicate substrata covered by Swiss stone pine woods, sometimes with more or less large clearings used by man, which correspond to breaks in the slope declivity.
14. Middle and low slopes interrupted by gullies with spruce forests and related secondary vegetation, sometimes with more or less large clearings used by man, corresponding to the heads of valley bottoms and to breaks in the declivity of the slope.
15. Middle third of the shaded slopes on silicate substrata with silver fir woods.
16. Middle and lower zones of the slopes, on calcareous substrata, covered by mesophilous pine woods.
17. Lower zones of the slopes with xeric pine woods.
18. Low detrital slopes, not very steep and on weakly acidic substrata, covered by deciduous woods.
19. Small alluvial cones and low slopes with infiltrations of water from higher altitude springs, which loom over the valley flutes, covered by hygrophilous woods.
20. Gravel beds of torrents with riverbank willow groves.
21. Floodplains with white alder woods.
22. Rocky outcrops, often great blocks, almost vertical, at middle and high altitude, on calcareous or metamorphic substrata, covered by casmophytic vegetation.
23. Thin plain zones formed by glacial erosion and shaped by detritus above, in cirques, on terraces and valley bottoms, with peat bogs and fens.
24. Lake basins.
25. Watercourses.
26. Terraces, small hills and slopes, with shepherd's huts circled by grazing clearings formed out of spruce forests or subalpine shrub woods.
27. Sequences of terraces on the middle third of the slopes and on valley bottoms covered by mowable grazing lands, with small hay lofts, shelters and summer establishments or shepherd's huts.
28. High glacial leveled valley bottoms with clustered villages of stone shepherd's huts and no steep slopes on the middle third of the rises with spread out villages of wood huts - blockhaus type - both temporarily inhabited and encircled by mowable grazing lands.
29. Series of terraces, on the middle third of the slope, covered by mowable grazing lands, sometimes crops, with permanently inhabited establishments which are often associated with small hay lofts, shelters, etc.
30. Sunny slopes on the middle third of the slopes, with permanently inhabited centers surrounded by mowable fields.
31. Middle and low slopes with homes, mowable fields and crops lined by hedges with frequent traces of artificial terracings.
32. Alluvial cones of valleys bottom at low altitudes with homes, mowable fields and crops lined by hedges.
33. Lower zones of the slopes and small plain areas with steppe vegetation.
34. Outskirts of rural centers, more or less urbanized, with grassy surfaces and crops.
35. Outskirts of rural centers, more or less urbanized, with surfaces used prevalently for farming and fruit growing.
36. Slopes and alluvial cones, sometimes quite steep, covered by grazing lands planted with larches.
37. More or less urbanized rural centers.

Table 1. Number code and diagnosis of the environmental unit types distinguished within the Stelvio National Park.

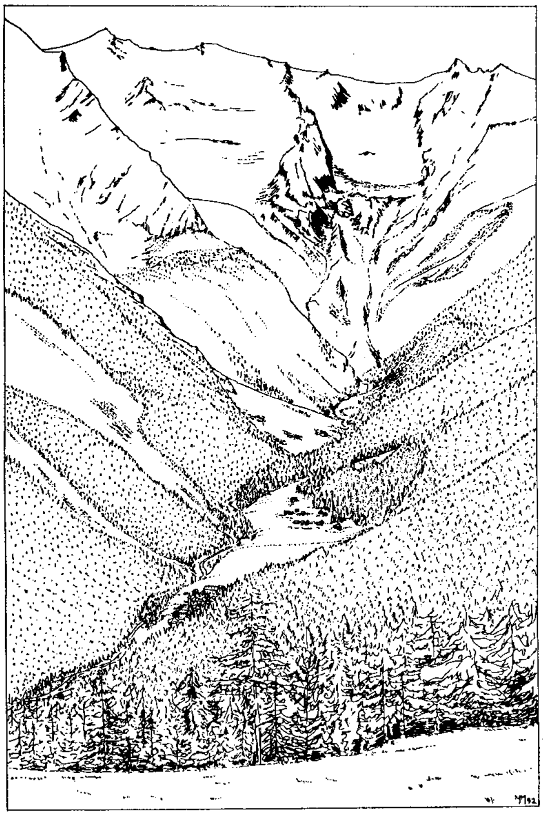

Fig. 1. Simplified drawing representing the landscape of Trafoi valley (from a color picture, by M. Martinelli).

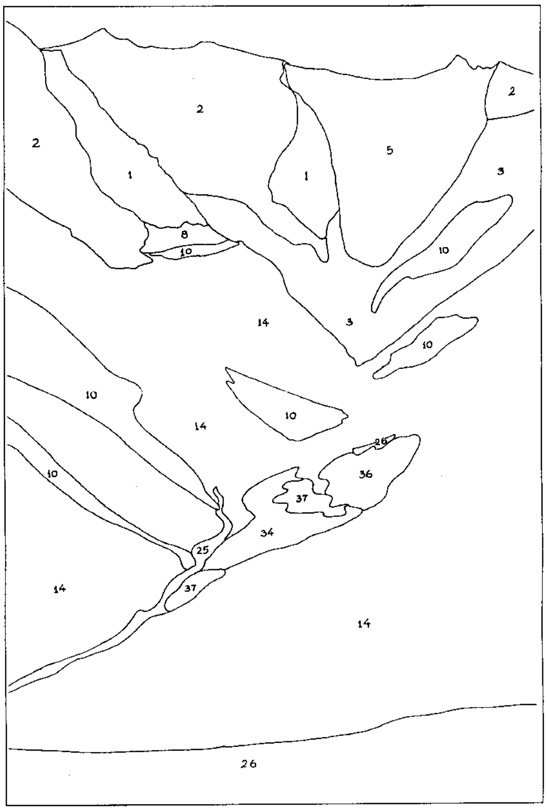

Fig. 2. Delimitation of the environmental units composing the landscape of Trafoi valley (numbers indicate the environmental unit types as in Table 1).

Variables	(Semi)natural environmental unit types																								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Naturalness 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naturalness 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naturalness 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naturalness 3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rarity 0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Rarity 1	0	0	1	0	0	1	0	0	1	1	0	1	0	1	0	1	0	0	1	0	0	1	0	0	0
Rarity 2	0	0	0	1	1	0	1	1	0	0	1	0	1	0	1	0	1	1	0	1	1	0	1	1	0
Renewability 0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	1	0	0	0	0	0
Renewability 1	0	1	0	0	0	1	1	1	1	0	1	1	1	0	0	0	1	1	0	0	0	0	0	0	1
Renewability 2	1	0	1	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0
Beauty 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beauty 1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	0	1	1	0	1	0	0	0
Beauty 2	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	0	1	0	0	1	0	1	1	1
Diversity 0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diversity 1	0	0	1	1	1	1	1	0	0	1	1	1	0	0	0	1	0	0	1	1	0	1	0	0	1
Diversity 2	0	0	0	0	0	0	0	1	1	0	0	0	1	1	1	0	1	1	0	0	1	0	1	1	0

Variables	Anthropic envir. unit types											
	26	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**
Naturalness 0	0	0	0	0	0	0	0	0	0	0	0	1
Naturalness 1	0	0	0	1	1	0	0	0	1	1	1	0
Naturalness 2	0	1	1	1	0	0	1	1	1	0	0	0
Naturalness 3	0	0	0	0	0	0	0	0	0	0	0	0
Rarity 0	1	0	0	1	1	0	0	0	1	1	1	1
Rarity 1	0	0	0	0	0	0	0	0	0	0	0	0
Rarity 2	0	1	1	0	0	1	1	1	0	0	0	0
Renewability 0	0	0	0	1	1	1	1	0	1	1	1	1
Renewability 1	1	1	0	0	0	0	0	1	0	0	0	0
Renewability 2	0	0	1	0	0	0	0	0	0	0	0	0
Beauty 0	0	0	0	0	0	0	0	0	0	1	0	1
Beauty 1	1	1	0	1	1	1	0	1	1	0	0	0
Beauty 2	0	0	1	0	0	0	1	0	0	0	1	0
Diversity 0	0	0	0	0	0	0	0	0	0	1	0	1
Diversity 1	1	1	1	1	1	0	0	0	1	0	1	0
Diversity 2	0	0	0	0	0	1	1	1	0	0	0	0

Table 2. Matrix of binary values assigned to each variable and environmental unit type.

forests (*Erico-Pineto sylvestris* sigmetum);

- Submountain xerophilous series of Scotch pine forests (*Astragalo venostani-Pineto sylvestris* sigmetum);

- Submountain series of durmast-oak/ash and maple/lime forests (*Aceri pseudoplatani-Tilieto platyphylli* and *Querco petraeae-Fraxineto excelsioris* sigmeta);

- Submountain xerophilous series of pubescent-oak forests (*Querceto pubescentis* s.l. sigmetum);

- Azonal hygrophilous series of floodplain forests and shrubwoods (*Alneto incanae, Saliceto albae* and *Hippopho rhamnoidis-Saliceto incanae* sigmeta);

- Azonal hygrophilous series of fenny woodlands and peaty meadows (*Thelypteridi-Alneto glutinosae, Saliceto caesio-arbusculae* and *Trichophoreto caespitosae* sigmeta).

Due to their redundancy, the numerous environmental units (concrete) identified in the Park were attributed to only 37 environmental unit types (Table 1). For example, the complex landscape of the Trafoi Valley was broken down into 24 cartographic units belonging to 12 environmental unit types (Figs. 1 and 2).

In this manner, the whole Stelvio National Park map of environmental unit types was produced. Single units are represented by a map code such as color, hatchure or single line (in the case of waterways). For each environmental unit type, the map legend includes a diagnosis, a specific iconography for the visual landscape and the corresponding map code.

Division of the environmental unit types into two categories can be done *a priori*, i.e. natural (seminatural) and anthropic; in this way 25 (semi)natural types and 17 anthropic types were distinguished (Table 2). Consequently, the problem is reduced to the division of each category into two groups.

To this end, each level in the evaluation criteria scale was assumed as a binary-type variable; consequently the environmental unit types are characterized by 16 variables which can have the value 0 (signifying "no") or the value 1 (signifying "yes") (Table 2).

Processing of the two matrices of binary values enabled identification of four groups of environmental unit types (Table 3). The cartographic separation of the four groups on the map of environmental unit types, by means of different colors, led to the realization of the map of naturalistic-aesthetic and historical-cultural characteristics of the environmental unit types. This document constitutes the foundation for functional zoning of the Stelvio National Park, now in progress.

Category	Cluster	Environmental unit types
(Semi)natur.	Group 1	1, 2, 4, 5, 7, 8, 9, 11, 13, 15, 17, 18, 21, 23, 24, 25
	Group 2	3, 6, 10, 12, 14, 16, 19, 20,22
Anthropic	Group 3	29, 30, 34, 35, 36, 37
	Group 4	26, 27, 28, 31, 32, 33

Table 3. K-means clustering analysis output of the environmental unit types.

Conclusions

The use of synthesis mapping has allowed the breakdown of the complex landscape of the Stelvio National Park into only 37 environmental unit types, which are operative for further processing.

The use of binary values in the evaluation of the naturalistic-aesthetic and historical-cultural qualities of the environmental unit types is an attempt at objective classification of the same, in order to produce a preliminary zoning of the Park.

The present work points out that the concepts of landscape ecology and of synphytosociology find an excellent application in the sector of land planning, conservation and management, precisely because of the integrated study of the functional, structural and temporal characteristics of the landscape.

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