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Naturalness Consumption and Biodiversity in an Ecoregion of Central Italy

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Abstract

Landscape naturalness and landscape biodiversity are closely connected with ecosystem sustainability. In this study, "naturalness consumption" and "induced biodiversity" created by human interference were evaluated in an ecoregion of Central Italy that represents a meaningful local example of land-use pattern in a Mediterranean environment. A core set of selected indicators and indexes applied to the database produced by GIS was used first to evaluate the landscape naturalness for each phyto-climatic unit and then to calculate the naturalness consumption. Moreover, the landscape biodiversity of each phyto-climate was evaluated, considering the ecomosaic space organization and taking into account the presence of some important ecological structures like ecotones and hedges.

In the naturalness analysis, the highest naturalness consumption occurred in phyto-climates with a higher presence of cultivated areas. In the biodiversity analysis, the phyto-climates with a lower naturalness and a higher presence of agricultural land showed higher values of landscape biodiversity in comparison with the other phyto-climatic units. The results suggest that biodiversity in agro-ecosystems can compensate for naturalness consumption in terms of landscape sustainability. Indeed, natural landscapes carry out a conservative role, while more bio-diverse landscapes offer a balance between human requirements and native ecosystem conditions in a frame of co-evolutionary development.

Key-words: naturalness consumption; indicators of landscape biodiversity; sustainability.

1. Introduction

Sustainability is more than a 'thing' to be measured, since it is about ecological integrity and quality of life for human development. Rather than asking how we can measure sustainability, it may be more appropriate to ask how we measure up to sustainability (Fricker, 1998). Indeed, natural environment has "psycho-spiritual values" (Callicott, 1997; Hagvar, 1999), essential to a larger ecological vision of sustainability (Caporali, 2006) transcending the "material values" usually studied.

The complex concept of natural or naturalness is of interest to a large number of scientists and currently they agree that conservation and management approaches have to be considered together (Lamb, 1996; Caporali, 2004; Siipi, 2004). With different approaches, the role of naturalness for ecosystems sustainability was addressed in many works (Anderson, 1991; Grumbine, 1994; Hunter, 1996; Comer, 1997; Haila, 1997; Angermeir, 2000; Povilitis, 2001) in which the term naturalness was defined in a variety of ways; we agree with a concept of naturalness that complies with a process of an historical independence from human actions (Siipi, 2004) and practically coincides with the climax phase of an ecological succession. Generally, human activities create a "naturalness consumption" process through biotic and abiotic resources use and land-use patterns that result in landscape changes (Angermeier, 1994; Perlman and Adelson, 1997; Caporali, 2004) and modified structure and functioning of ecosystems.

Biodiversity means variability among living organisms from all sources including, *inter alia*, diversity within species, between species and of ecosystems (UNEP, 1992). A correct management of fragmented ecosystems within a cultur-

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al landscape (agroecomosaic) is an important factor in saving biodiversity and therefore in promoting the ecosystem sustainability (Thomas et al., 1997; Stone, 2003).

In this research, the relationship between naturalness consumption and agroecosystem biodiversity was investigated at landscape level in order to highlight the implications for sustainability of the all socio-ecosystem in an ecoregion of Central Italy. An ecoregion is defined as a region of relative homogeneity in ecological systems and human factors (Omernik, 1987).

2. Materials and methods

2.1 Study area

The ecoregion is located in the Lazio Region between the Tyrrhenian Sea and the Apennine mountains (41°28'38" - 41°39'16" N and 12°55'00" - 13°09'51" E) and it is representative of a physiographic condition which is common to most of the internal rural areas of Central Italy. Its size is about 160 km^2, with an elevation ranging from 10 to 1500 m a.s.l. 24% of the ecoregion is low-land (0-200 m a.s.l.), 27% is hill (200-600 m a.s.l.) and 49% is mountain area (over 600 m a.s.l.). It includes three little towns with a total of 13,000 inhabitants, which are examples of historical rural settlements in Central Italy since medieval time. A recent land reclamation action, carried out in the 1930, allowed agriculture to expand rapidly in lowland areas. Geological and litological studies (Sevink et al., 1984) indicate that calcareous soils are the common substrate in the mountain area, while sedimentary soils are common in the lowland areas. The Italian Ministry of Environmental Protection classifies 74% of the study area as prone to hydrogeological risks; 24% of the ecoregion, prevalently in the mountain area, is protected area according to the "Rete Natura 2000" programme.

2.2 Landscape analysis

GIS technology has been used for the landscape photo-interpretation work on the base of high-resolution aerial-photograph (1 m·$pixel^{-1}$) and fieldwork validation. All data were used to classify the studied area in patches, applying the European Land Cover Classification directive (CORINE) by making reference to the ecotope concept as the smallest ecological land unit

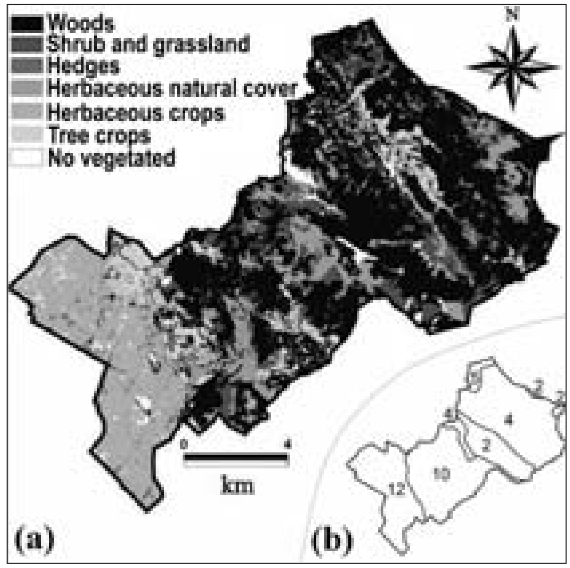

Figure 1. Ecoregion cover map (a) and phyto-climatic units (Blasi, 1994) (b).

characterized by homogeneity of at least one land attribute of geosphere – namely atmosphere – vegetation, soil, rock, water, and so on, and with non-excessive variations in other attributes (Tansley, 1939; Naveh and Lieberman 1994; Troll, 1950). Land cover classes were grouped as follows: woods (W), shrub and grassland (SG), herbaceous natural cover (HN), hedges (H), herbaceous crops (HC), tree crops (TC) and no vegetated (NV) (Fig. 1a).

The study area has been subdivided in the following 5 phyto-climatic units (P-c) as defined by Blasi (1994) according to the potential climax vegetation, reference plants and physiography (Tab. 1 and Fig. 1b).

Landscape biodiversity was evaluated using landscape metrics like ecotope number, area and perimeter (Turner, 1989; Forman, 1995; Turner et al., 2001) to produce selected indicators and indexes as reported in Table 2.

A panel of agroecologists at the Department of Crop Production of the University of Tuscia was asked to define the naturalness index (NI) for each ecotope type in the ecoregion, according to the methodology developed by Berthoud et al. (1989), which gives relative values to different classes of ecotopes (Et) ranging from 0 (minimum naturalness) to 1 (maximum naturalness). With the combined use of the Land Cover Map information and the estimated NI, values of "expressed naturalness" (EN) in each

Table 1. Characteristics of the phyto-climatics units (P-c).

P-c	Physiography	Reference plants	Range of annual precipitation (mm)
2	mountain	*Fagus sylvatica* L. *Ostrya carpinifolia* Scop. *Cornus sanguinea* L.	1247-1558
4	sub-mountain iper-humid	*Ostrya carpinifolia* Scop. *Fagus sylvatica* L. *Cornus mas* L.	1431-1606
5	sub-mountain	*Fagus sylvatica* L. *Ilex aquifolium* L. *Cistus incanus* L.	1234-1463
10	hill	*Quercus pubescens* Willd. *Quercus ilex* L. *Cistus incanus* L.	1132-1519
12	low-land	*Quercus ilex* L. *Laurus nobilis* L. *Cistus salvifolius* L.	842-966

ecotope types were calculated multiplying the ecotope surface for the respective NI. In such a way, "expressed naturalness" values derive from a combination of objective data and informed human judgment. The difference between "potential naturalness" (PN) (interested surface x 1 = maximum naturalness) and EN expresses "consumed naturalness" (CN).

Table 2. List of selected indicators and indexes of landscape naturalness and biodiversity. (s = number of ecotope types; n = number of ecotope units; a = area of each ecotope unit; e = perimeter of each ecotope unit; C = 1; p_j = ecotope type area proportion).

Name	Symbol	*Formulae*
Naturalness index	NI	$= 0 \geq NI \leq 1$ (Berthoud et al., 1989)
Expressed naturalness	EN	$= \sum_{j=1}^{s} \sum_{i=1}^{n} a_{i_j} \cdot NI_j$
Potential naturalness	PN	$= \sum_{j=1}^{s} \sum_{i=1}^{n} a_{i_j} \cdot 1$
Consumed naturalness	CN	$= PN - EN$
EN *per* unit area	ENU	$= EN \Big/ \left(\sum_{j=1}^{s} \sum_{i=1}^{n} a_{i_j} \right)$
Mean patch size	MPS	$= \left(\sum_{i=1}^{n_j} a_{i_j} \right) \Big/ n_j$
Mean ecotone length	MEL	$= \left(\sum_{i=1}^{n_j} e_{i_j} \right) \Big/ n_j$
Patch density	PD	$= n_j \Big/ \left(\sum_{j=1}^{s} \sum_{i=1}^{n} a_{i_j} \right)$
Ecotone intensity	EI	$= n_j \Big/ \left(\sum_{j=1}^{s} \sum_{i=1}^{n} e_{i_j} \right)$
Shannon-Wiever	H'	$= -C \cdot \sum_{j=1}^{s} p_j \ln p_j$

Table 3. EN *per* unit area (ENU) and relations between area extension and expressed naturalness (EN).

		ENU *(EN·ha⁻¹)*	Area extention *(%)*	EN *(%)*
Phyto-climates	2	0.773	11.6	13.3
	4	0.788	35.4	41.5
	5	0.862	2.5	3.2
	10	0.755	28.3	31.7
	12	0.312	22.2	10.3
Total area		0.673	100.0	100.0

3. Results and discussion

The results reported in Table 3, concerning the spatial distribution of expressed naturalness (ENU and EN) at the ecoregion level, suggest that EN is differently spread over the five phyto-climates, with higher unitary values in mountain phyto-climates (ENU = 0.77-0.86) and a lower unitary value in the lowland phyto-climate (ENU = 0.31). The lowland phyto-climate, which covers 22.2% of the ecoregion, is repository of only 10.3% of the EN. Phyto-climates of hilly and mountainous areas show rates of EN always greater than their share of land.

The results reported in Table 4, concerning the spatial distribution of the ecotope types in

Table 4. Land cover area, naturalness index and expressed naturalness (Et = ecotope type).

	Et	*Area*		*NI*	*EN*	
		ha	%		*global*	%
Phyto-climate 2	NV	240	*12.9*	0.00	0	*0.0*
	TC	0	*0.0*	0.17	0	*0.0*
	HC	0	*0.0*	0.33	0	*0.0*
	HN	309	*16.5*	0.50	155	*10.7*
	H	2	*0.1*	0.67	1	*0.1*
	SG	171	*9.2*	0.83	143	*9.9*
	W	1144	*61.3*	1.00	1144	*79.3*
	total	1866	*100.0*		1442	*100.0*
Phyto-climate 4	NV	181	*3.1*	0.00	0	*0.0*
	TC	325	*5.7*	0.17	54	*1.2*
	HC	273	*4.8*	0.33	91	*2.0*
	HN	887	*15.5*	0.50	444	*9.8*
	H	30	*0.5*	0.67	20	*0.5*
	SG	761	*13.3*	0.83	634	*14.0*
	W	3272	*57.1*	1.00	3272	*72.5*
	total	5729	*100.0*		4515	*100.0*
Phyto-climate 5	NV	9	*2.2*	0.00	0	*0.0*
	TC	22	*5.7*	0.17	4	*1.1*
	HC	9	*2.3*	0.33	3	*0.9*
	HN	29	*7.3*	0.50	15	*4.2*
	H	2	*0.4*	0.67	1	*0.4*
	SG	38	*9.6*	0.83	32	*9.3*
	W	288	*72.5*	1.00	288	*84.1*
	total	397	*100.0*		343	*100.0*
Phyto-climate 10	NV	62	*1.4*	0.00	0	*0.0*
	TC	430	*9.4*	0.17	71	*2.1*
	HC	173	*3.8*	0.33	58	*1.7*
	HN	874	*19.1*	0.50	437	*12.7*
	H	50	*1.1*	0.67	33	*0.9*
	SG	766	*16.8*	0.83	638	*18.5*
	W	2211	*48.4*	1.00	2211	*64.1*
	total	4566	*100.0*		3448	*100.0*
Phyto-climate 12	NV	411	*11.5*	0.00	0	*0.0*
	TC	421	*11.7*	0.17	70	*6.2*
	HC	2436	*67.8*	0.33	811	*72.4*
	HN	133	*3.7*	0.50	66	*5.9*
	H	32	*0.9*	0.83	27	*2.4*
	SG	40	*1.1*	0.67	27	*2.4*
	W	119	*3.3*	1.00	119	*10.7*
	total	3592	*100.0*		1120	*100.0*

each phyto-climate, show how the ecomosaic representing EN in each phyto-climate region dramatically changes moving from lowlands to highlands. In the low-land phyto-climate, the main contribution (72.4%) to EN comes from the dominant agricultural fields grown to herbaceous crops (HC), while in the mountain and sub-mountain phyto-climates the most important contribution (72.5-84.1%) to EN comes from the dominant wood ecotope (W). In the hill phyto-climate, the best balance of landscape elements has been recorded, as shown by the highest value (1.58) of the Shannon-Wiever index (Tab. 5). This balance is confirmed by other landscape metrics, like MPS, MEL, PD and EI that show values intermediate between those of lowland and highland phyto-climates (Tab. 5).

Due to the human pressure and its implications to land-use pattern change (agroecosystems and urban settlements), the consumed naturalness (CN) in the ecoregion (Tab. 6) is mostly a matter of the lowland phyto-climate. In the phyto-climate 12, with the highest human influence (NV = 411 ha) (Tab. 3), the presence of hedges (MEL = 0.24 km; EI = 422.95·100 km-1) and fragmented woods (MEL = 1.23 km; EI = 81.05·100 km^{-1}) (Tab. 5) certainly contribute to improving biodiversity conditions of many species, but agroecosystem sustainability depends mostly on the kind of farming system and cropping system adopted (for instance, conventional vs organic farming), especially in relation to soil fertility maintenance practices (Haber, 1990; Kuiper, 2000; Thies and Tscharntke, 1999; Caporali, 2004).

4. Conclusions

Consumed naturalness grows with landscape anthropization. The highest landscape biodiversity indicator values were recorded in the areas where the landscape has a balanced presence of natural and human structures, like in the rural hilly area. In this area, the balance of land-use patterns is a heritage of both past agriculture tradition and demographic stability. In the lowland area of more recent and intensive agriculture colonization, biodiversity promoted through hedges and ecotopes only partially compensates for the lost naturalness. Indeed a correct biodiversity-oriented management, especially in places where human activity generates high naturalness consumption, has an important role to play for keeping pace with sustainability requirements. Practices like organic agriculture can help a lot in contrasting lost naturalness while promoting biodiversity and ecosystem sustainability. Completely natural (without human interference) ecosystems no longer exist in Central Italy, but ecoregion sustainability in many places have been often guar-

Table 5. Indicators and indexes of landscape biodiversity (standard error values are reported in brackets).

	Et	MPS (ha)	MEL (km)	PD ($n \cdot 100\ ha^{-1}$)	EI ($n \cdot 100\ km^{-1}$)	H'
Phyto-clime 2	TC	-	-	-	-	
	HC	-	-	-	-	
	HN	6.58 (±1.83)	1.36 (±0.23)	2.89	73.36	
	H	0.19 (±0.04)	0.28 (±0.03)	0.68	353.48	
	SG	4.28 (±1.23)	1.23 (±0.20)	2.46	81.22	
	W	35.75 (±14.83)	3.21 (±0.91)	1.97	31.11	
	Total area	12.51 (±3.87)	1.69 (±0.26)	7.99	59.29	0.95
Phyto-clime 4	TC	2.15 (±0.36)	0.71 (±0.07)	2.72	141.61	
	HC	0.96 (±0.07)	0.49 (±0.02)	5.10	205.45	
	HN	3.74 (±0.84)	1.08 (±0.13)	4.27	92.22	
	H	0.21 (±0.01)	0.28 (±0.01)	2.67	351.59	
	SG	2.48 (±0.23)	0.86 (±0.04)	5.53	116.75	
	W	11.25 (±2.37)	1.94 (±0.21)	5.24	51.65	
	Total area	3.92 (±0.52)	0.97 (±0.05)	25.54	103.44	1.56
Phyto-clime 5	TC	1.49 (±0.59)	0.64 (±0.20)	3.86	156.94	
	HC	0.48 (±0.10)	0.34 (±0.06)	4.89	291.58	
	HN	1.26 (±0.40)	0.66 (±0.12)	5.92	150.50	
	H	0.13 (±0.02)	0.27 (±0.06)	3.60	370.00	
	SG	1.37 (±0.24)	0.63 (±0.07)	7.21	157.54	
	W	9.00 (±2.70)	2.14 (±0.56)	8.24	46.75	
	Total area	2.97 (±0.73)	0.93 (±0.15)	33.71	107.94	1.12
Phyto-clime 10	TC	2.12 (±0.28)	0.72 (±0.06)	4.51	139.80	
	HC	0.86 (±0.12)	0.44 (±0.03)	4.46	227.91	
	HN	3.67 (±0.61)	1.06 (±0.10)	5.28	94.58	
	H	0.15 (±0.01)	0.25 (±0.01)	7.35	399.20	
	SG	2.87 (±0.41)	0.86 (±0.06)	5.93	116.81	
	W	8.25 (±1.57)	1.82 (±0.22)	5.95	55.04	
	Total area	2.99 (±0.31)	0.85 (±0.05)	33.49	117.50	1.58
Phyto-clime 12	TC	1.76 (±0.21)	0.61 (±0.05)	7.51	163.81	
	HC	7.10 (±1.02)	1.22 (±0.10)	10.78	81.89	
	HN	0.90 (±0.09)	1.03 (±0.09)	4.65	97.02	
	H	0.11 (±0.01)	0.24 (±0.01)	9.40	422.95	
	SG	0.43 (±0.03)	0.45 (±0.02)	2.92	221.82	
	W	2.17 (±1.04)	1.23 (±0.20)	1.73	81.05	
	Total area	2.70 (±0.32)	0.76 (±0.04)	37.00	131.10	0.96

Table 6. Potential naturalness (PN), expressed naturalness (EN) and consumed naturalness (CN) from each phyto-climate types and for total ecoregion.

		PN		EN		CN	
		global	%	*global*	%	*global*	%
Phyto-climates	2	1867	*100*	1442	*77*	424	*23*
	4	5730	*100*	4515	*79*	1215	*21*
	5	397	*100*	342	*86*	55	*14*
	10	4566	*100*	3448	*76*	1117	*24*
	12	3592	*100*	1120	*31*	2472	*69*
	total	16152	*100*	10868	*67*	5284	*33*

antied by historical patterns of land-use that human activity has generated within its contest of life. According to Cooper (2000), an ecoregion is a 'Companion place' because symbolizes a sustainable pattern of symbiosis between man and nature at local level.

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