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The role of environmental and socio-demographic indicators in the analysis of land use changes in a protected area of the Natura 2000 Network: the case study of Lake Trasimeno, Umbria, Central Italy

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Abstract This article sets out to analyse how and to what degree land use is linked to the physical characteristics of the territory itself, and the way in which changes in land use are determined by agricultural and socio-demographic dynamics. The study was conducted within the territorial boundaries of five municipalities surrounding Lake Trasimeno and refers to the periods 1977–2000 for land use and 1971–2001 for socio-demography data. The use of environmental, social, economic and agricultural indicators demonstrates how a mix of various indicators are useful for monitoring the changes which took place. It also shows the powerful influence that socio-demographic factors exert upon land use and landscape change.

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Introduction

From a strictly ecological point of view, "*the landscape is a mosaic (a mixture of ecosystems and land uses which interact among themselves) which is repeated in a recognisable spatial configuration over a greater or lesser area*" (Forman 1995). However, with the European Landscape Convention (2000) which defines landscape as "*a given part of a territory, as perceived by the population, whose character derives from the actions of natural and/or human factors, and their interrelationship*" (article 1, letter a), http://www.coe.int/t/dg4/cultureheritage/heritage/landscape/default_en.asp), landscape has begun to be considered as an element which is closely linked to human activity, in which changes are prevalently dependent upon human actions. In the Western world, most definitions of landscape are based on soil and climatic characteristics and do not take into account the close relationship with anthropic factors (Forman and Godron 1986; Jobin et al. 2003) which often represent a valid instrument for the conservation and promotion of regional and local habitats (Steiner 2000; Swetnam et al. 1999). This study aimed at analysing the relationship between anthropic systems and land-

scape so as to define in what way, and to what degree, land use, defined as the expression of human activity on a given territory, is linked to the physical characteristics of the territory itself, and how landscape change is also determined by socio-demographic and agricultural dynamics. Numerous changes in land use have taken place over the last two decades and various studies have attempted to measure these changes (see Malaviya et al. 2010; Jobin et al. 2010; Zha et al. 2008). The phenomena which describe land use change are necessary not only to conserve biological diversity, but also to develop useful models for ecosystem management and environmental policies (Blasi and Iovino 2003; Christensen et al. 1996; Franklin 1993; Gordon et al. 1997).

Natural and semi-natural ecosystems and landscape provide numerous advantages for human society, given their great ecological, socio-cultural and economic value (see Costanza et al. 1997; De Groot 2005; De Groot et al. 2002). Various studies have shown how socio-demographic factors represent important variables for the stability of a given territory, and are often closely linked to land use changes and thus to landscape transformation (Henry et al. 2003; Lambin et al. 2001; Shen 2000; Stephenne and Lambin 2001; Verburg et al. 1999). In many cases very rapid socio-demographic dynamics have caused the creation of new landscapes whose changes have been studied by means of territorial analysis and modellistic approaches (Sui and Zeng 2001). It is also necessary to mention that landscape environmental quality often depends on the variety and dominance of land use classes (Ricotta et al. 2003).

This paper presents a new approach to multivariate analysis based on the correlation between land use changes and human activity by calculating not only environmental variables, but a mix of indicators which also include demographic, social and economic variables as well. When applied to specific time periods, this methodology is a valuable tool for studying past land use changes, but may, more importantly, also be used to monitor present land use and resultant landscape changes so as to promote sustainable landscape management.

Study area

The study was conducted in the five municipalities of the Lake Trasimeno district—Castiglione del Lago, Tuoro sul Trasimeno, Passignano sul Trasimeno, Panicale and Magione (Fig. 1). The area is of great historic value; human settlements dating back to the Etruscan period have been found (Gambini 2004). Lake Trasimeno, the fourth largest Italian lake, which is situated in the north-western part of the Region of Umbria, in Central Italy, has a surface area of about 120.73 km^2, and contains three islands (Cecchetti et al. 2005). The study covers a surface area of about 550.83 km^2 (equal to 55,083 ha), with a resident population of 40,515 inhabitants.

The area has been affected by numerous modifications to the lakeside hydrophytic vegetation due to hydrological variations which have taken place over time and which have caused continuous alterations to the habitat. The continuous water-level fluctuations have created a serious imbalance between natural/semi-natural areas and those characterised by human activity: changes in flat land with a reduction of forests, destruction of riverine vegetation, abandonment of chestnut forests, extinction of rare species and introduction of alien species in lakeside areas (Orsomando and Catorci 1991). The study area is characterised by numerous floristic emergencies, as defined in the modifications to the Province of Perugia's Land Coordination Plan (in Italian: Piano Territoriale di Coordinamento Provinciale della Provincia di Perugia, Variante di Adeguamento al P.U.T. (L.R. 27/2000)). Since March 1995, the area has become a regional nature park, which includes sites belonging to the *Natura* 2000 *Network* in which habitats and species of interest for biodiversity conservation on a European level are found (C.f. European Commission DG Environment 2003). Protected areas make up 30% of the study area which includes six sites of community importance (SCI; SCI Habitat Directive 92/43/CEE) and one special protection zone (ZPS; ZPS, Birds Directive 79/409/CEE; see Fig. 1) (Orsomando et al. 2004).

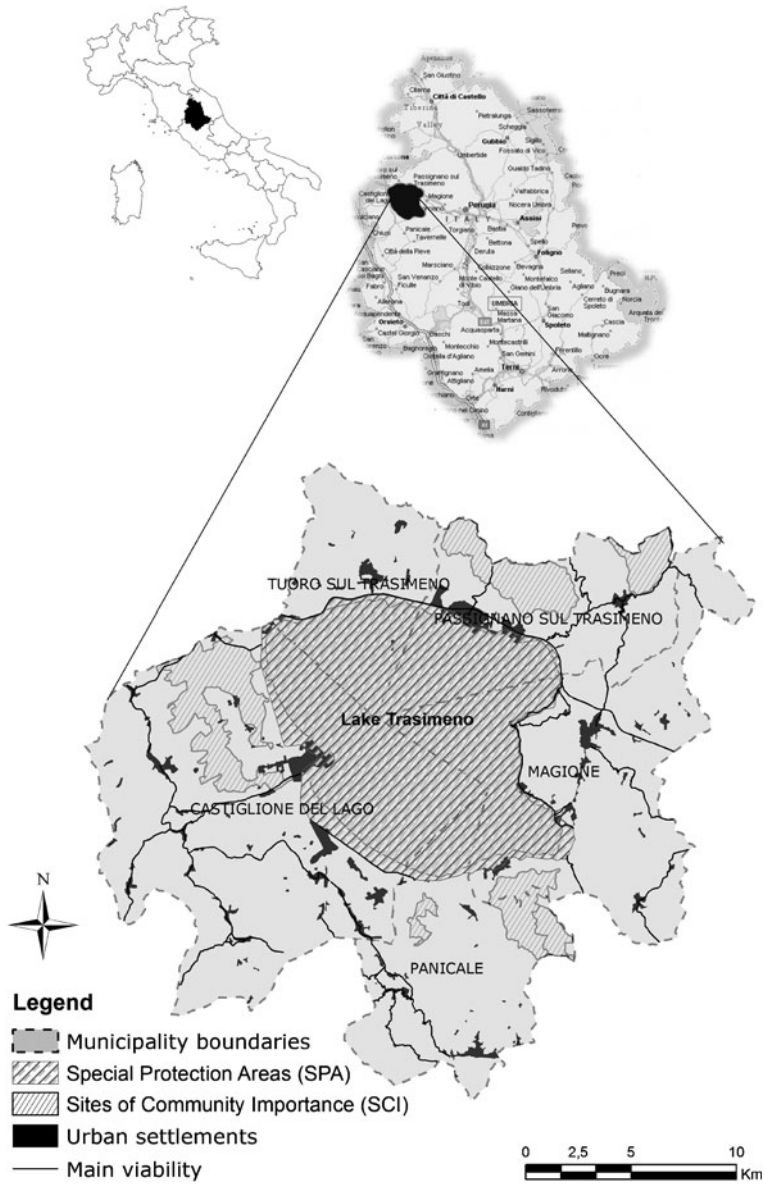


Fig. 1 Study area—the Lake Trasimeno district, north-western Umbria, Central Italy, comprising five municipalities which cover a surface area of 120.73 km^2

Materials and methods

First of all, a socio-demographic analysis was carried out by consulting ISTAT data (National Statistics Institute, /http://www.istat.it/) census data as from the 1970s as well as Unioncamere Umbria (2008) data (http://www.umbria.camcom.it/default.asp).

Population age was analysed by calculating the *Oldness index* which represents a dynamic indicator for evaluating population ageing (Eq. 1).

$$\mathrm{IV} = \frac{\mathrm{Pop} \geq 65}{\mathrm{Pop} \geq 14} \times 100 \quad (1)$$

Where Pop $\geq$ 65 represents old population (65 and over) and Pop $\leq$ 14 represents young pop-

ulation (0–14); values superior to 100 indicate a greater presence of old subjects in relation to young ones (/http://www.istat.it/).

The progressive ageing of the population was calculated by means of the *Dependence index*, a socio-economic indicator which measures the way in which the old population (65 years and over) affects the active population (15–64 years; Eq. 2)

$$\mathrm{ID} = \frac{\mathrm{Pop} \leq 14 + \mathrm{Pop} \geq 65}{15 \leq \mathrm{Pop} \leq 64} \times 100. \qquad (2)$$

The numerator is made up of the presumably non-self-sufficient population, due to age, while the denominator represents the working-age group which should support those no longer active (Fig. 2). Population trends over the last 30 years were also analysed (Fig. 3). The municipal boundaries in which businesses and institutions operate, local units, were used for the economic analysis (http://www.istat.it/; http://www.umbria.camcom.it/default.asp; Fig. 4). The agricultural analysis was based on cultivated land surface (data from utilised agricultural area (UAA)), number of agricultural holdings and main breeding activities (http://www.istat.it/).

Landscape analysis was evaluated in terms of quality by drawing up an environmental quality map (EQM) and in terms of environmental diversity by employing environmental indicators such as the landscape conservation index (LCI), the *Shannon-Wiener index* (H) (Shannon 1948; Spellerberg and Fedor 2003) and the *Evenness index* (J) (Pizzolotto and Brandmayr 1996; Shannon 1948; Spellerberg and Fedor 2003).

For environmental quality and landscape conservation evaluation, land-cover categories referring to the IV level of the 2000 CORINE Land Cover Map (2000 CLCM) (APAT 2005) were grouped into quality classes and then classified on the basis of a nine-point gradient of increasing naturality, from high human-affected struc-

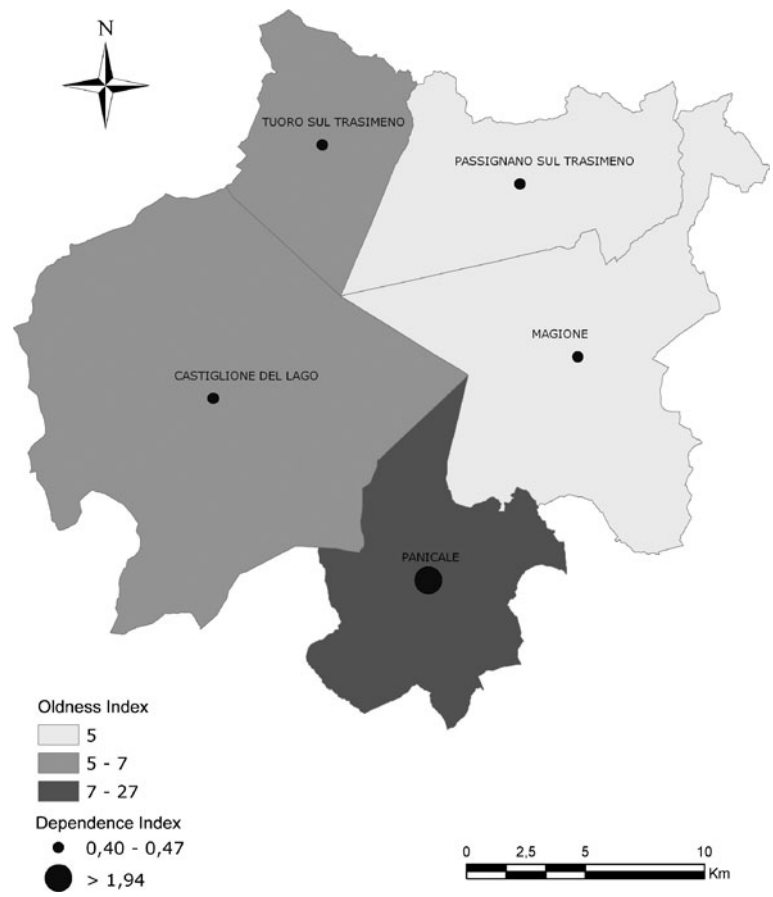
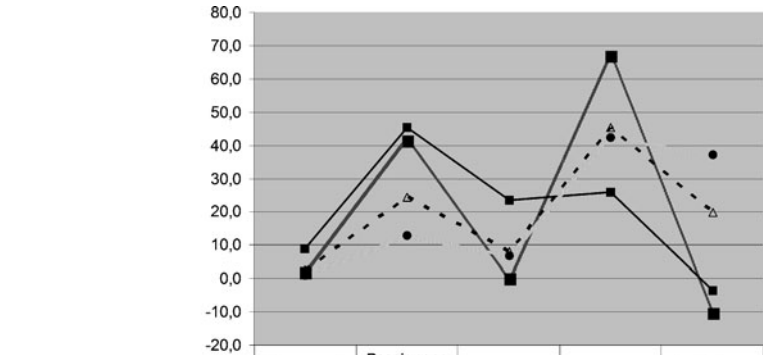


Fig. 2 Correlation between Oldness index and Dependence index in the study area—both indices show the highest values in the municipality of Panicale, where there was also a noticeable increase in old population. Passignano and Magione had the highest percentage of active population



	Tuoro sul Trasimeno	Passignano sul Trasimeno	Panicale	Magione	Castiglione del Lago
'71-'81 percentage variation	1,8	41,3	0,1	67,1	-10,4
81-'91 percentage variation	8,9	45,3	23,5	26,0	-3,7
91-'01 percentage variation	1,0	12,9	6,8	42,2	37,1
71-'01 percentage variation	2,4	24,5	7,9	45,3	19,8

Fig. 3 Percentage variation in population trends 1971–2001 (ISTAT data). The graph shows how population fluctuated over a 30-year period. From 1971–1981, in municipalities such as Castiglione del Lago, the population fell by 10% ca. while population increased by 67% in the municipality of Magione and by 41% in the municipality of Passignano sul Trasimeno. From 1981–1991, Passignano sul Trasimeno showed the greatest population increase

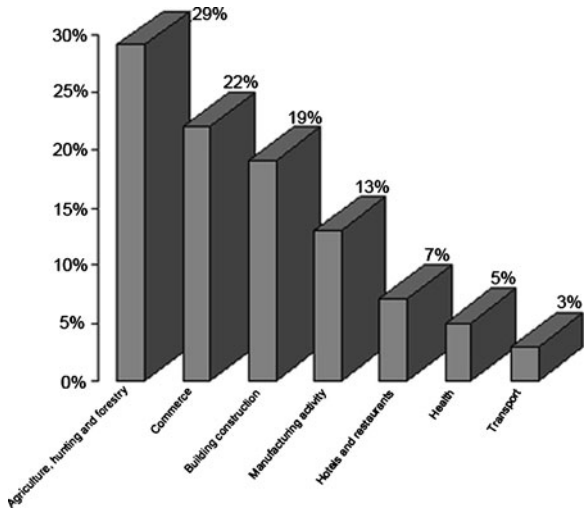


Fig. 4 Local units—agriculture, hunting and forestry was the most important productive sector (29%), followed by commerce (22%), building and construction (19%) and manufacturing (13%). Hotels and restaurants accounted for only 7%, although this is a well-known tourist area. Most of the local units were concentrated in the Castiglione del Lago and Magione areas, to a much lesser degree in the Panicale and Passignano areas, and almost none in the Tuoro sul Trasimeno area (ISTAT and Unioncamere Umbria data, 2008)

ture to high naturality. Three parameters were used to define the nine environmental quality classes Westhoff (1971): soil impermeability, i.e. the amount of original substratum occupied by urban structures, soil alteration due to agricultural activity and vegetation structure and floristic composition, i.e. the degree to which the present vegetation cover is comparable to potential vegetation cover (Table 1).

Using these three criteria, the nine classes were aligned along an increasing quality gradient, from "very low", corresponding to class 1 which includes artificial surfaces such as arable land and agricultural areas, to "very high", i.e. forests and other highly natural environments (Fig. 5).

A comparison between the 1977 land use map (source: Umbria Region) and the 2000 CLCM was used to make a diachronic analysis of land use variations so as to study landscape changes (Fig. 6). To make this possible, it was necessary to group the original legends into eight macro classes (Table 2).

Land use classes were grouped on the basis of digital maps with the help of GIS which made it possible to identify the eight macro-classes and obtain a general idea of quantitative changes in land use between 1977 and 2000.

Table 1 The CORINE land use classes to which a quality value from 1–9 was assigned, according to Westoff's three parameters

Cod_Corine	Legend	Quality qclasses
1.1.2	Discontinuous urban areas	1
1.2.1	Industrial or commercial units	1
1.3.1	Mineral extraction sites	1
1.4.2	Sport and leisure facilities	1
2.1.1.1	Arable land	2
2.4.1	Annual crops associated with permanent crops	2
2.2.3	Olive trees	3
2.2.1	Vineyards	3
2.4.2	Complex cultivation patterns	3
2.4.3	Principally agriculture with natural vegetation	4
2.3.1	Pastures	4
3.2.4	Transitional woodland shrubs	5
3.2.1.2	Discontinuous	6
3.2.3.1	Sclerophyllus vegetation	7
3.1.3.1.1	Mixed forests of coniferous and broadleaf with prevalence of deciduous oaks	7
3.1.3.1.2	Broadleaved and coniferous forests	8
3.1.1.1	Mixed coniferous and broadleaved	9
3.1.1.2	Deciduous oaks forests	9
4.1.1	Inland marshes	9
5.1.2	Water bodies	9
	Soil impermeability	
	Soil alteration due to agricultural activity	
	Vegetation structure and floristic composition	

The *index of landscape conservation* (Pizzolotto and Brandmayr 1996), which is a useful indicator of landscape quality, was calculated with the GIS maps, with particular reference to the 2000 CLCM and the categories of land use which were present in the area under study. The LCI, which supplies summarised information on the degree of landscape conservation, is formulated as follows (Eq. 3):

$$\mathrm{LCI} = 1 - (A/A\,\mathrm{max}) \tag{3}$$

A graph of the cumulative percentages of quality classes was constructed, having the environmental quality classes on the x-axis in ascending order, and the sum of the cumulative percentages of the corresponding areas on the y-axis. The area below the curve may be expressed as (Eq. 4):

$$A = \sum_{i=1}^{n} x_i \,| - 100 \tag{4}$$

where n is the number of environmental quality classes and x_i is the cumulative percentage of the ith category. A expresses the degree of human impact in the area. The higher the degree, the greater the contribution of the land categories with higher human impact.

The highest value which A can reach is expressed as follows (Eq. 5):

$$A_{\max} = 100 \cdot (n - 1) \tag{5}$$

The index value, which varies from 0 (minimum) to 1 (maximum), is proportional to the area of the Cartesian plane above the curve of cumulative percentages.

Values around 1 denote a well-preserved area while low values indicate a landscape with high human impact. Thus, the measure of the importance (in terms of surface area occupied) of the best-preserved environments may be obtained. The LCI was calculated so as to analyse the variations in landscape conservation in 1977 and in 2000 (Fig. 7).

The landscape diversity analysis was also carried out by calculating two indicators which show various environmental aspects, in particular the rich variety of land use and the relative extent of each type. These indicators were the Shannon–Wiener index (H) (Shannon 1948; Spellerberg and Fedor 2003) and the Evenness index (J) (Pielou 1966). The two indices J and H were calculated for land use in 1977 and 2000, respectively.

The H is thus formulated as follows (Eq. 6):

$$H = -\sum_{i=1}^{m} (p_i) \log_2 (p_i) \tag{6}$$

where p_i is the relative area of original land use type ith of the total area of the study and m is the total number of land types.

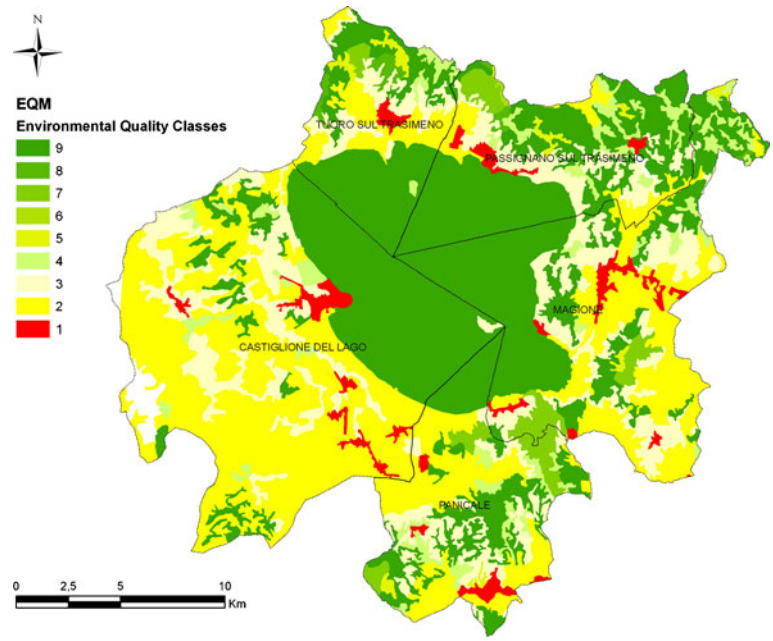


Fig. 5 EQM. The map shows environmental quality, indicated by nine classes (class 1 corresponds to a high degree of human pressure and class 9 to a high level of environmental quality). Quality was low in proximity to towns, urban areas (in *red*) and areas of extensive crops, concentrated mainly in the Castiglione del Lago municipality, while it increased towards the more natural areas, on the higher forested slopes, where pastures and forests predominated, and where human pressure was weak

The J is calculated by comparing real land patch diversity with potential diversity. It is used to evaluate landscape mosaic diversity.

J is thus formulated as follows (Eq. 7):

$$J = H/H\max \tag{7}$$

The values of both indices revealed small changes between 1977 and 2000 year (Table 3).

Then some socio-economic and agricultural variables were related to the environmental parameters by means of a correlation matrix. The analysis of the results was then used to define and describe the present situation and to predict the possible evolution of the economic, social and environmental changes that took place.

The various indicators were transformed into a matrix and then subjected to a multivariate analysis using 'Syntax 2000' (software Podani 2001). The dendrogram thus obtained was subdivided into clusters which represent groups of data with a certain affinity.

The following variables were then taken into consideration:

- *Oldness index*: relationship between population over 65 years of age and those under 14
- *Dependence index*: incidence of population over 65 and under 14
- The relationship between commuters and residents
- Depopulation: population variation rate
- LCI
- UAA
- Presence of SCI and SPA
- Percentage of agricultural holdings in the area

The analysis of the groups revealed the presence of four significant clusters (Fig. 8).

Discussion

The results showed that over a period of approximately 23 years the area of study was characterised by an ageing population and a weakening of demographic compactness, with a considerable number of residents who commuted to work. The population trend fluctuated (see Fig. 3), e.g. from 1971 to 1981, it fell by 10% in the Castiglione del Lago municipal area, while there was a significant increase in the Magione (67%) and Passignano sul Trasimeno (41%) municipal areas. From an agricultural and economic point of view, traditional

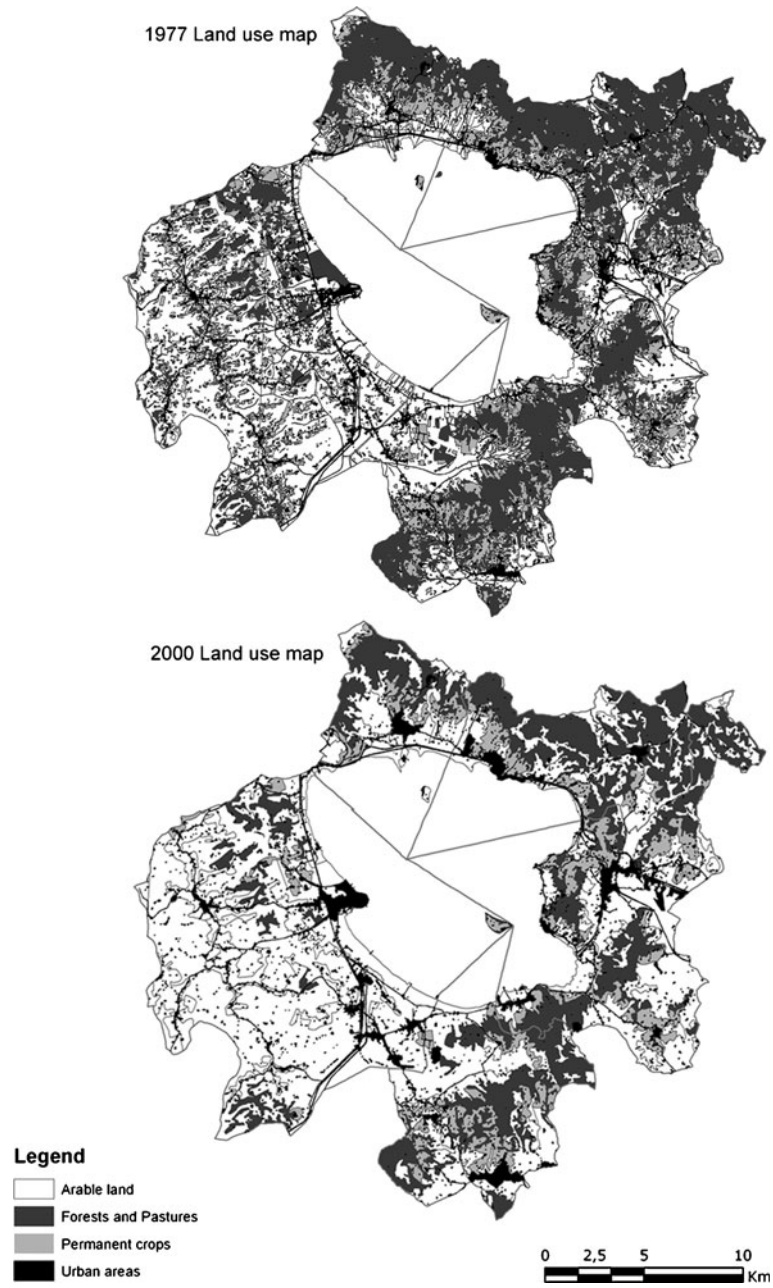


Fig. 6 Comparison between the 1997 and 2000 land use maps. Over a 23-year period, arable land and urban areas increased compared to forests and pastures, which maintained a significant presence only on the higher hills. Permanent crops gave way to extensive agricultural areas

forms of agriculture were abandoned, as can be seen from the EQM (see Fig. 5) and the comparison between the 1977 and 2000 land use maps (see Fig. 6) where a greater agricultural uniformity can be seen, at the expense of permanent crops such as olive groves, vineyards and orchards which had previously characterised the landscape (Gambini 2004).

The greater use of intensive agriculture made the area very environmentally vulnerable. This can be seen from the LCI calculations, where the reduction was caused mainly by an increase in class 2 arable land. From 1990 to 2000, the number of medium-to-small agricultural holdings (1–10 ha) increased, to the detriment of large ones.

Table 2 New land use classification

New classification	1977 land use classes	2000 CORINE land use classes
Urban areas	Urban areas, wooded arable land	1.1.2, 1.2.1, 1.3.1, 1.4.2
Arable land	Arable land	2.4.1, 2.4.2, 2.1.1.1
Olive groves	Olive groves	2.2.3
Vineyards	Vineyards	2.2.1
Pastures	Pastures	3.3.3.1
Other agricultural areas with natural areas	Orchards, poplars	2.4.3
Forests	Forests	3.2.4, 3.1.1.1
		3.1.1.2, 3.1.3.1.1, 3.1.3.1.2
Water bodies	Water	4.1.1, 5.1.2

The table shows the new land use classification obtained by combining the 1977 land use map legends and the 2000 CORINE land cover map. Thus, it was possible to confront and compare the two systems. The original legends were combined into eight macro classes

The cluster analysis provided the means to distinguish between the municipalities included in the study on the basis of demographic, economic and environmental phenomena over a 23-year period (see Fig. 8 and Table 4).

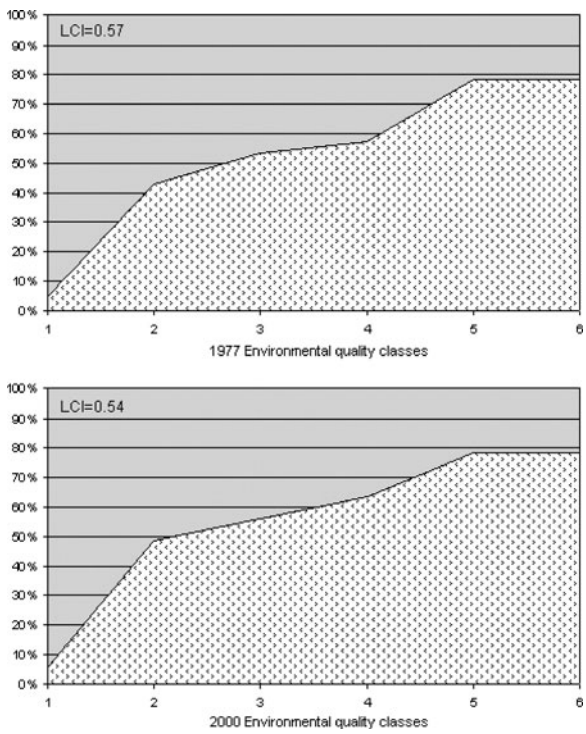


Fig. 7 Index of landscape conservation (Eqs. 3–5) values of land use 1977–2000. The decrease in LCI value which took place between 1977 and 2000 is due essentially to a decrease in natural land use typologies (classes 3–4) such as forests, and an increase in arable land (class 2)

The Castiglione del Lago area was the most intensively cultivated due to the high percentage of UAA and the number of agricultural holdings. These factors certainly influenced landscape conservation, as can be seen from the LCI, which was the lowest for the entire area. *H* shows how this municipality had the lowest value, a sign of simplification of land use.

In the Magione area, which was affected by depopulation and an increase in residents who commuted to work on a daily basis, agriculture was reasonably important, so the LCI was low.

Panicale and Tuoro sul Trasimeno were the two areas most affected by population ageing. The percentage of utilised agricultural land was very low, so agriculture was less intensive than elsewhere. Large olive groves could still be found there—a sign of continuity in traditional land use.

The Passignano sul Trasimeno area showed the largest population increase. It was also the area that retained the greatest naturality, as can be seen from the higher index of landscape conservation values and the increase in *H* from 1977 to 2000.

Although Lake Trasimeno was designated both as an SPA and an SCI, and despite the fact that 30% of the surface is one of the *Natura* 2000 *Network* sites, land use underwent changes connected with the increase of arable land, mainly for

Table 3 Values of *J* and *H* over 23 years ca.

Municipality	No. of categories of 1977 land use classes	No. of categories of 2000 land use classes	1977 H	1977 J	2000 H	2000 J
Castiglione del Lago	8	11	1.21	0.40	1.43	0.41
Magione	12	18	2.30	0.64	1.71	0.41
Panicale	12	13	1.73	0.48	1.67	0.45
Passignano sul Trasimeno	10	16	1.58	0.47	1.88	0.47
Tuoro sul Trasimeno	8	12	1.83	0.61	1.57	0.44
Lake Trasimeno	14	20	2.45	0.42	1.81	0.66

H decreased from 2.45 to 1.81 over the entire area, thus indicating increasing uniformity, while *J* increased slightly, indicating a prevalence of real over potential diversity. The Passignano sul Trasimeno municipality showed the highest increase in *H* while Magione showed a decrease

extensive agriculture, which altered the original landscape, as can be seen from the comparison between the 1977 and the 2000 land use maps. An increase in uniformity was also evident (see Fig. 6).

The calculations of *H* and *J* showed that the areas with a low environmental value were those near urban areas and along the lake shore, which over the years had been converted to arable land, due to favourable morphology. The LCI calculation confirmed the environmental quality decrease from 1977 to 2000, which can be explained by greater human exploitation. Intensive agriculture increased at the expense of natural areas, such as forests, and semi-natural areas. The natural area was well-preserved, particularly on the higher hill slopes, where there was a greater biodiversity thanks to the presence of mixed conifer and broadleaf forests. Environmental quality decreased near the areas subject to greater human pressure, where traditional permanent crops decreased and urban activity increased (see EQM, Fig. 5).

The quantitative decrease in environmental diversity was also shown by *H*, where there was a rather low level of diversity in terms of types of land use classes. This was confirmed by *J*, which showed a low level of real diversity with respect to potential diversity. With the passing of time this resulted in an increasingly homogeneous environmental mosaic.

Overall, the territory was subjected to a progressive uniformity of agricultural practices which greatly reduced qualitative and quantitative di-

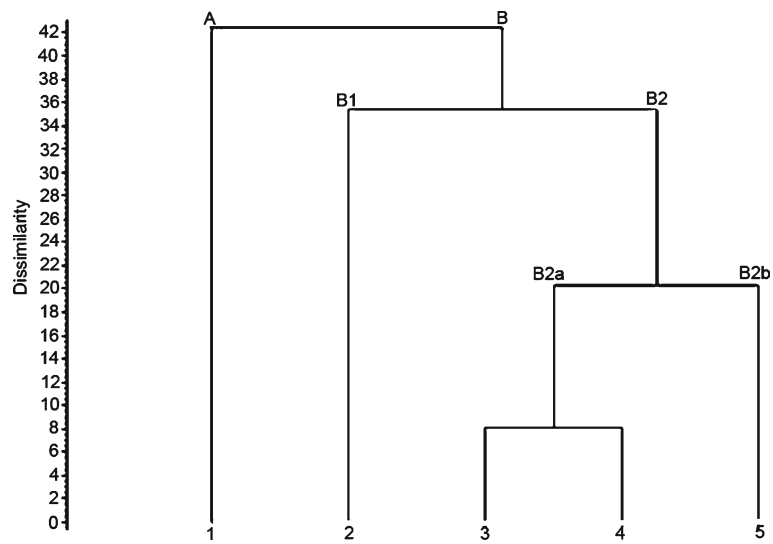


Fig. 8 The dendrogram resulting from cluster analysis of the socio-economic and agricultural variables and environmental indicators shows four principal groups where the municipalities are grouped according to common characteristics: Group A (Castiglione del Lago); group B1 (Magione); group B2a (Panicale, Tuoro sul Trasimeno); group B2b (Passignano sul Trasimeno)

Table 4 The four classes of municipality, obtained from the statistical analysis with SYNTAX 2000

Group A	
Castiglione del lago	Agriculture was still important
	Progressive population ageing
	Highest percentage in the entire study area
	A moderate trend towards depopulation
	Lowest LCI
Group B	
Magione	Municipal area where agriculture was reasonably important
	Marked depopulation
	Increase in commuting on a daily basis
	Low LCI
Group B2a	
Panicale Tuoro sul Trasimeno	Very marked population ageing, particularly Panicale
	Percentage of UAA very low
	Low level of agricultural exploitation
	The best LCI
Group B2b	
Passignano sul Trasimeno	Lowest percentage of agricultural holdings
	Greatest number of SCI and SPA

versity and widened the gap between real and potential diversity.

Conclusion

This study showed how a correlation exists between human activity and landscape, and how very often rural socio-economic policies produce positive economic results on one hand, but may have negative environmental effects on the other. The consequences of predominantly agricultural activity resulted in a marked imbalance between areas characterised by human pressure and natural and semi-natural areas. There was a reduction in areas of hydrophytic vegetation, marked simplification of the landscape and habitat fragmentation, and, as a consequence, biodiversity reduction.

The results show how the increase in extensive agriculture and the abandonment of traditional agricultural practices were similar to those taking place in other European countries over the last few decades (Forman and Godron 1986). Changes in agricultural practices influenced socio-demographic phenomena which in turn caused significant landscape changes (Paquette and Domon 2003).

It is clear that cultural identity and territory are inextricably linked, and that landscape represents the point of contact between nature, history and culture. Correct landscape management and conservation should take into consideration composition of landscape models and spatial configuration, and the way in which they are generated (Levin and Paine 1974). In recent years the need for ecological planning has become increasingly important, and is the object of continuing debate (Dal Sasso 1998). It is increasingly recognised that more sustainable approaches are needed for planning and managing landscapes worldwide and new tools are needed to effectively implement them. The spatial dimension of sustainability engages processes and relations between different land uses, ecosystems and biotopes at different scales, and over time. Therefore, ecological knowledge is essential when planning for sustainability. The study also showed that monitoring and evaluating land use change by means of GIS is indispensible for land management policy (Malaviya et al. 2010).

References

APAT (2005). La realizzazione in Italia del progetto europeo CORINE Land Cover 2000. In Rapporti 36/2005 (Ed.) APAT (p. 86), Roma.

Blasi, C., & Iovino, F. (2003). Bioclima d'Italia. In Conoscenze naturalistiche in Italia/Ecological Information in Italy. In C. Blasi (Ed.), *Società Botanica Italiana, Ministero dell'Ambiente e della Tutela del Territorio* (pp. 11–12), Roma.

Cecchetti, A., Lazzerini, G., Ficola, M., Pedini, A., & Sragentini, F. (2005). Vegetazione, habitat di interesse comunitario, uso del suolo del Parco del lago Trasimeno. Parco Regionale lago Trasimeno.

Christensen, N. L., Bartuska, A. M., Brown, J. H., Carpenter, S., D'Antonio, C., Francis, R., et al.

(1996). The report of the Ecological Society of America committee on the scientific basis for ecosystem management. *Ecological Application, 6*, 665–691.

Costanza, R., D'Arge, R., de Groot, R. S., Farber, S., Grasso, M., Hannon, B., et al. (1997). The value of the world's ecosystem services and natural capital. *Nature, 387*, 253–260.

Dal Sasso, P. (1998). Criteri di Pianificazione ecologica del territorio rurale. *Ingegneria Agraria, 2*, 97–104.

De Groot, R. S. (2005). Function-analysis and valuation as a tool to assess land use conflicts in planning for sustainable, multi-functional landscapes. *Landscape and Urban Planning, 75*, 175–186.

De Groot, R. S., Wilson, M., & Boumans, R. (2002). A typology for the description, classification and valuation of ecosystem functions. *Goods and Services Economy, 41*, 393–408.

European Commission DG Environment (2003). Natura 2000. Interpretation manual of European Union Habitats EUR25.

European Landscape Convention, Florence (2000). http://www.coe.int/t/dg4/cultureheritage/heritage/landscape/default_en.asp.

Forman, R. T. T. (1995). *Land Mosaic*. Cambridge: Cambridge University Press.

Forman, R. T. T., & Godron, M. (1986). *Landscape Ecology*. New York: Wiley.

Franklin, J. F. (1993). Preserving biodiversity: Species, ecosystems or landscapes? *Ecological Application, 3*, 202–205.

Gambini, E. (2004). La cartografia storica del Lago Trasimeno. Lo sviluppo sostenibile del Lago Trasimeno. Dipartimento di Economia, facoltà di Economia, Università degli Studi di Perugia. Sistema Informativo Territoriale, CD ROM, Parco Del Lago Trasimeno.

Gordon, D. R., Provencher, L., & Hardesty, J. L. (1997). Measurement scales and ecosystem management. In S. T. A. Pickett, R. S. Ostfeld, M. Shachak, G. E. Likens (Eds.), *The Ecological Basis of Conservation: Heterogeneity, Ecosystems and Biodiversity* (pp. 262–273). New York: Chapman & Hall.

Henry, S., Boyle, P., & Lambin, E. F. (2003). Modelling inter-provincial migration in Burkina Faso, West Africa: The role of socio-demographic and environmental factors. *Applied Geography, 23*, 115–136.

Jobin, B., Beaulieu, J., Grenier, M., Bélanger, L., Maisonneuve, C., Bordage, D., et al. (2003). Landscape changes and ecological studies in agricultural regions, Québec, Canada. *Landscape Ecology, 18*, 575–590.

Jobin, B., Latendresse, C., Grenier, M., Maisonneuve, C., & Sebbane, A. (2010). Recent landscape change at the ecoregion scale in Southern Québec (Canada), 1993–2001. *Environmental Monitoring and Assessment, 164*(1–4), 631–647.

Lambin, E. F., Turner, B. L., Geist, H., Agbola, S., Angelsen, A., Bruce, J. W., et al. (2001). The Causes of land-use and -cover change: Moving beyond the myths. *Global Environmental Change, 11*, 261–269.

Levin, S. A., & Paine, R. T. (1974). Disturbance, patch formation and community structure. *Proceedings of the National Academy of Sciences, 71*, 2744–2747.

Malaviya, S., Munsi, M., Oinam, G., & Kumar Joshi, P. (2010). Landscape approach for quantifying land use land cover change (1972–2006) and habitat diversity in a mining area in Central India (Bokaro, Jharkhand). *Environmental Monitoring and Assessment, 170*(1–4), 215–229.

Orsomando, E., & Catorci, A. (1991). Carta della vegetazione del Comprensorio Trasimeno.

Orsomando, E., Ragni, B., & Segatori, R. (2004). Siti Natura 2000 in Umbria. Regione dell'Umbria.

Paquette, S., & Domon, G. (2003). Changing ruralities, changing landscapes: Exploring social recomposition using a multi-scale approach. *Journal of Rural Studies, 19*(4), 425–444.

Provincia di Perugia (2000). Piano Territoriale di Coordinamento Provinciale PTCP. Adeguamento del PTCP al PUT, L.R. 27/2000. Provincia di Perugia.

Pielou, E. C. (1966). The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology, 13*, 131–144.

Pizzolotto, R., & Brandmayr, P. (1996). An index to evaluate landscape conservation state based on land-use pattern analysis and geographic information system techniques. *Coenoses, 11*, 37–44.

Podani, J. (2001). *Syntax 2000. Computer Program for Data Analysis in Ecology and Systematics. User's Manual* (p. 53). Budapest: Scientia Publishing.

Ricotta, C., Marignani, M., Campaiola, F., Avena, G. C., & Blasi, C. (2003). A partial order approach for summarizing landscape quality. *Community Ecology, 4*, 121–127.

Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal, 27*, 379–423.

Shen, J. (2000). Modelling national or regional grain supply and food balance in China. *Environment and Planning, 32*(3), 539–557.

Spellerberg, I. F., & Fedor, P. J. (2003). A tribute to Claude Shannon (1916–2001) and a plea for more rigorous use of species richness, species diversity and the "Shannon–Wiener" index. *Global Ecology and Biogeography, 12*, 177–179.

Steiner, F. R. (2000). *The Living Landscape: An Ecological Approach to Landscape Planning*. New York: McGraw Hill.

Stephenne, N., & Lambin, E. F. (2001). A dynamic simulation model of land-use changes in the African Sahel (SALU). *Agriculture, Ecosystems and Environment, 85*, 145–162.

Sui, Z. D., & Zeng, H. (2001). Modeling the dynamics of landscape structure in Asia's emerging desakota regions: A case study in Shenzhen. *Landscape and Urban Planning, 53*, 37–52.

Swetnam, T. W., Allen, C. D., & Betancourt, J. L. (1999). Applied historical ecology: Using the past to manage for the future. *Ecological Application, 9*, 1189–1206.

Unioncamere Umbria (2008). dati statistici. http://www.umbria.camcom.it/default.asp.

Verburg, P. H., Veldkamp, A., & Fresco, L. O. (1999). Simulation of changes in the spatial pattern of land use in China. *Applied Geography, 19*, 211–233.

Westhoff, V. (1971). The dynamic structure of plant communities in relation to the objectives of nature conservation. In E. Duffey, A. S. Watt. Blackwell (Eds.), *The scientific management of animal and plant communities for conservation* (pp. 3–14). Oxford.

Zha, Y., Liu, Y., & Deng, X. (2008). A landscape approach to quantifying land cover changes in Yulin, Northwest China. *Environmental Monitoring and Assessment, 138*(1–3), 139–147.