Mara BODESMO1*, Bruno ROMANO1, Luca PACICCO2
Mauro Roberto CAGIOTTI1, Aldo RANFA1

1 Department of Applied Biology, Applied and Environmental Botany Section, University of Perugia, Borgo XX Giugno, 74-06121 Perugia, Italy
*e-mail: bodesmo@gmail.com (corresponding author)

2 Department of Men and Territory, Agricultural and Forestry Land Planning Section, University of Perugia, Borgo XX Giugno, 74-06121 Perugia, Italy

CHANGES IN LAND USE IN AN HISTORICAL AREA OF CENTRAL ITALY OVER TWENTY YEARS: THE USE OF ENVIRONMENTAL INDICATORS

ABSTRACT: The analysis of the area of the municipality of Tuoro sul Trasimeno in Umbria, Central Italy (the historical site of the Battle of Trasimeno in 217 BC) was carried out to evaluate changes in land use from 1977 to 2000 at the land-plot level using relevant land use maps. An evaluation of the environmental quality of land use in 2000 was also made. The study involved an analysis of the environmental diversity in terms of extent and variety of land use. The Landscape Conservation Index (ILC), and diversity indicators (Shannon-Wiener Index and Eveness Index) were calculated. The study showed how landscape quality gradually declined due to an increase in agricultural areas to the detriment of natural areas. The calculation of environmental indicators, particularly the Eveness Index showed how the difference between real and potential diversity increased, in favour of real diversity. This is a symptom of increased human pressure.

KEY WORDS: landscape changes, index of landscape conservation, environmental quality, historical landscape, Umbria

1. INTRODUCTION

The analysis of temporal and spatial changes represents one of the greatest challenges in landscape ecology. Land use and cover change have been identified as one of the prime determinants of global change with major impacts on ecosystems, global biogeochemistry, climate change and human vulnerability (Foley et al. 2005).

This study aimed at using environmental indicators to evaluate environmental quality in a rural region in Central Italy, and to describe the main changes in land use between 1977 and 2000. By means of indicators, the compliance of development processes with sustainable development on a national and international level were tested (Muessner et al. 2002). Environmental indicators have many applications, including the evaluation of farming activity, of the efficacy of political decisions, of environmental conditions and of general planning (Roth and Schwabe 2003, Heyer et al. 2003, Oppermann 2003, Brand et al. 2003). For a considerable number of years environmental variables have been used to evaluate landscape quality in the ambit of local planning, and have become increasingly important following the EU Commission’s request to use them in evaluating the effects of rural planning (Osinski et al. 2003).

Landscape quality is the result of the interaction between biophysical and perceived
characteristics of the landscape. Visual rep-
resentations of the complex dynamics of ru-
ral transformation will become increasingly
useful so as to evaluate landscape quality, and
technological developments in geographical
information systems and in data modelling,
simulation and visualisation will contribute
to meet these challenges (Van Kamp et al.
2003). It has also been demonstrated that
changes in land use are closely related to the
physical characteristics of the landscape, and
that the greater the diversity of the landscape’s
physical makeup, the greater the dynamics of
land use (Hietel et al. 2004)

The necessity to develop indicators in the
fields of bio-diversity and landscape has al-
ready been sufficiently documented (OECD
1997, 2001, KOM 2001a, b, Viikari et al.
2007). Various methodological approaches
have been used to create different models for
the study of changes in land use (see reviews
by Sklar and Costanza 1991, Riebsame et
al. 1994, Lambin et al. 2000), with the aim of
demonstrating the relationship between land
use and landscape quality, and how changes
in land use determine landscape transforma-
tions.

2. STUDY AREA

The area included in the study lies within
the municipality of Tuoro sul Trasimeno, in
the Province of Perugia in Umbria in cen-
tral Italy The Region of Umbria is located
between 42°21’N and 43°36’N and between
11°53’E and 13°15’E, at 280 m a.s.l. It covers
a total surface area of 55,50 km², including a
part of Lake Trasimeno whose surface area is
120.73 km². The territory is characterised by
a high level of floristic diversity (over 2,000
vascular species), and vegetation due to the
great geological, morphological and climatic
differences within the area (Orsomando et al.
1999, 2004) (Fig. 1).

Fig. 1. Environmental Quality Map of the study area in the municipality of Tuoro sul Trasimeno (Um-
bria). The map shows how environmental quality, indicated by seven classes (class 1 corresponds to
high degree of human pressure and class 7 to a high level of environmental quality), tends to increase
moving from the lakeside area which is characterised by annual and permanent crops, towards the
northern part of the municipality where pastures and forests predominate, and where human pressure
is weak.
The study region is an area of great historical importance for our common culture as it was here, in 217 BC that the Battle of Trasimeno took place. It was the second crushing defeat suffered by Rome during the wars against Carthage. Hannibal, the Carthaginian leader, positioned his troops along the hills surrounding the lake and when the Romans marched into the narrow valley near the shore, he gave the order to attack. The Romans were taken by surprise and were unable to close ranks, so that they scattered and were easily driven down towards the lake with no way of escape. Over 15,000 Roman troops were massacred and their commander, Flaminius, was also killed (Gambini 2004).

3. MATERIAL AND METHODS

A diachronic land-use analysis for 1977 and 2000 was carried out with reference to the 1977 Land-use Map (source Region of Umbria) and the IV level CORINE Land-cover Map, updated for the reference year 2000 (APAT 2005) (Fig. 2). In order to compare both maps, it was necessary to standardise the legends and create a new classification of the land use classes (Table 1).

To minimise error deriving from the comparison of two maps based on widely differing methodologies and territorial resolutions, the original classifications were grouped into five macro-classes according to increasing human pressure:

1. Forests – mixed coniferous and broad-leaved forests, transitional woodland shrubs

2. Permanent crops – olive groves, vineyards and orchards

3. Arable land – arable land without dispersed vegetation, annual crops associated with permanent crops, vast cultivated areas

4. Pastures – pastures and sclerophyllous vegetation

5. Urban areas – discontinuous urban patches

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

In order to evaluate environmental quality and conservation of the landscape, land-cover categories referred to the IV level of the CORINE Land Cover map 2005 (APAT 2005), were grouped into quality classes and then classified according to a six-point gradient of increasing naturality, from high human-affected structure to high naturality.

The six classes of environmental quality were defined according to three parameters (Westhoff 1971): soil impermeability, i.e. the amount of original substratum occupied by urban structures, soil alteration due to agricultural activity, vegetation structure and floristic composition, i.e. the degree to which the present vegetation cover is comparable to potential vegetation cover (Table 2). On the basis of these three criteria, the six classes are distinguished along an increasing quality gradient, from ‘very low’, corresponding to class 1 which includes artificial surfaces such as roads and buildings.

Table 1. The new classification assigned to land use classes so as make land use in 1977 and 2000 comparable.

<table>
<thead>
<tr>
<th>New classification</th>
<th>Land use’77 classes</th>
<th>CLC 2000 classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forests</td>
<td>Forests</td>
<td>3.1.3.1.2 Mixed coniferous and broadleaved forests</td>
</tr>
<tr>
<td>Permanent crops (olive groves, vineyards, orchards)</td>
<td>Olive groves, Vineyards, Orchards</td>
<td>3.1.1.2 Broad-leaved forests</td>
</tr>
<tr>
<td>Urban area</td>
<td>Urban area</td>
<td>3.1.3.2 Transitional wood-land shrubs</td>
</tr>
<tr>
<td>Pastures</td>
<td>Pastures</td>
<td>2.2.3 Olive trees</td>
</tr>
<tr>
<td>Arable lands (with or without rows of trees)</td>
<td>Arable lands</td>
<td>2.4.3 Principally agriculture with natural vegetation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1.2 Discontinuous urban area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.3.1 Pastures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2.3.1 Sclerophyllus vegetation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.1.1.1 Arable land prevailingly without dispersed vegetation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.4.1 Annual crops associated with permanent crops</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.4.2 Complex cultivation patterns</td>
</tr>
</tbody>
</table>
Fig. 2. Comparison between land use in 1997 and in 2000. 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.

Fig. 3. Index of Landscape Conservation (ILC) (formula 1, 2, 3) values of land use 1977–2000. The decrease in ILC value which took place between 1977 and 2000 is due essentially to a decrease in natural land-use categories (classes 4–5) such as forests, and an increase in arable land (class 2).
Table 2. The CORINE land-use classes to which a quality value from 1–6 has been assigned, according to Westoff’s 3 parameters.

<table>
<thead>
<tr>
<th>Cod_Corine</th>
<th>Land use classes</th>
<th>Quality classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1.2</td>
<td>Discontinuous urban areas</td>
<td>1</td>
</tr>
<tr>
<td>2.1.1.1</td>
<td>Arable land</td>
<td>2</td>
</tr>
<tr>
<td>2.4.1</td>
<td>Annual crops associated with permanent crops</td>
<td>2</td>
</tr>
<tr>
<td>2.2.3</td>
<td>Olive trees</td>
<td>3</td>
</tr>
<tr>
<td>2.4.2</td>
<td>Complex cultivation patterns</td>
<td>3</td>
</tr>
<tr>
<td>2.4.3</td>
<td>Principally agriculture with natural vegetation</td>
<td>4</td>
</tr>
<tr>
<td>2.3.1</td>
<td>Pastures</td>
<td>5</td>
</tr>
<tr>
<td>3.2.4</td>
<td>Transitional wood-land shrubs</td>
<td>5</td>
</tr>
<tr>
<td>3.1.1.2</td>
<td>Broad-leaved forests</td>
<td>6</td>
</tr>
<tr>
<td>3.2.3.1</td>
<td>Sclerophyllus vegetation</td>
<td>6</td>
</tr>
<tr>
<td>3.1.3.1.2</td>
<td>Broad leaved and coniferous forests</td>
<td>6</td>
</tr>
</tbody>
</table>

Legend

<table>
<thead>
<tr>
<th>soil impermeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>soil alteration due to agricultural activity</td>
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<tr>
<td>vegetation structure and floristic composition</td>
</tr>
</tbody>
</table>

as arable land and agricultural areas, to ‘very high’ corresponding to highly natural environments such as forests. Fig. 1)

The intermediate classes include land use categories which tend gradually towards greater naturality.

The *Index of Landscape Conservation* (ILC) (Pizzolotto and Bradmayr 1996), which is a useful indicator of landscape quality, was calculated with the help of GIS maps, with particular reference to the CORINE Land Cover and the categories of land use which were present in the area under study. The ILC, which supplies summarised information on the degree of landscape conservation, is formulated as follows:

\[
ILC = 1-(A/A_{\text{max}})
\]  

(1)

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:

\[
A = \sum_{i=1}^{n} x_i - 100
\]  

(2)

where \( n \) is the number of environmental quality classes and \( x_i \) is the cumulative percentage of the \( i^{th} \) 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:

\[
A_{\text{max}} = 100 \cdot (n - 1)
\]  

(3)

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 ILC was calculated so as to analyse the variations in landscape conservation in 1977 and in 2000. The calculation is based on the definition of five environmental quality classes assigned to the new land-use classification. The comparison of the index calculation in the two study periods showed a general tendency towards a decline in landscape conservation, however of a small extent (Fig. 3).

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...
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The Shannon-Wiener diversity Index is thus formulated as follows:

\[ H = -\sum_{i=1}^{m} (p_i) \log_2 (p_i) \]  

(4)

where \( p \) is the relative area of original land use type \( i \)th of the total area of the study and \( m \) is the total number of land types.

The Evenness Index (\( J \)) is calculated by comparing real land patch diversity with potential diversity. It is used to evaluate landscape mosaic diversity.

The Evenness Index (\( J \)) is thus formulated as follows:

\[ J = \frac{H}{H_{\text{max}}} \]  

(5)

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

Table 3. The Shannon-Wiener Diversity Index (\( H \)) (formula 4) values and the Evenness Index (\( J \)) (formula 5) values of land use classes for the study area for 1977 to 2000.

<table>
<thead>
<tr>
<th>Year</th>
<th>( H )</th>
<th>( J )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>1.81</td>
<td>0.57</td>
</tr>
<tr>
<td>2000</td>
<td>0.47</td>
<td>0.12</td>
</tr>
</tbody>
</table>

The floristic relevés were taken in areas with different floristic characteristics, using the phytosociological method (Braun-Blanque 1964) later integrated according to recent phytosociological updates (Gehu and Rivas-Martinez 1981, Theurrilliat 1992, Biondi 1996, Biondi et al. 2004). The floristic relevés were transformed into a matrix and then a multivariate analysis was carried out (Westhoff 1971), using ‘Syntax 2000’ program software 2000 (Podani 2001). The phytosociological values were converted according to the Westhoff and Van der Maarel scale (1979). It was possible to order the data contained in the original tables according to degree of similarity (species in common, degree of coverage of species in common) and then to isolate homogeneous groups by the unweighted pair-group method (UPGMA). These methods take the input data and derive from them some measure of similarity between species. The dendrogram, thus obtained is subdivided into clusters which represent groups of data with a certain affinity (Fig. 4). Each group of relevés constitutes a distinct vegetational community, floristically distinct from the others.

Fig. 4. The dendrogram resulting from cluster analysis of the floristic relevés, obtained by using ‘Syntax 2000’ shows two principal groups: Cluster I (woodlands communities) and Cluster II (meadow post-cultivation communities) which clearly show two distinct vegetation types which characterise the study area.
4. RESULTS

The greatest variations in land use from 1997 to 2000 were found in arable land, followed by permanent crops (olive groves, vineyards and orchards) and forests, and, to a lesser degree, in urban areas and pastures. Over twenty years, there was an increase in arable lands (8%), mainly non-irrigate arable land, and a mosaic of small fields where a variety of annual crops were grown and also in urban areas (+2%). Permanent crops (olive groves and vineyards) (–6%) and forest areas (–5%), decreased. Pastures increased by 1% (Fig. 5).

With reference to the environmental quality map (Fig. 1) and the CORINE Land Cover (Fig. 2) it may be seen that environmental quality increased with the passage from arable land through permanent crops to forests which consisted of Quercus ilex L., Quercus pubescens Willd. subsp. pubescens, Laurus nobilis L., Juniperus oxycedrus L. and Juniper communis L.

The ILC value decreased from 0.77 in 1977 to 0.65 in 2000, with a variation of 0.12. This was mainly due to an increase of surfaces in class 2 (arable land) and a decrease of those in class 5 (forests and pastures). The presence of permanent crops (olive groves and vineyards) remained more or less stable, but although they characterise the landscape as can be seen from the eighteenth century historic maps, they do not denote an increase in environmental quality as they represent only a small percentage of the total study area.

The Shannon-Wiener Index (H) and the Evenness Index (J) for 1977 and 2000 revealed complex environmental aspects, particularly as regards types of land use and their relative extent.

The H index relative to 1977 land-use is 2.53, while for 2000 land-use – 2.86. The J index relative to 1977 is 0.75 and for 2000 land-use – 0.71. The two indices calculated, H and J, in relation to the quantitative extension of the various patches of land use reveal that over twenty years land use categories changed and produced a marked impact on the landscape. In quantitative terms there was no really significant change in the variety of land use categories, although in many cases, fields were enlarged, hedges and rows of trees were uprooted, and their place was taken by monocultures such as tobacco, maize and sunflower as can be seen by comparing the 1977 and the 2000 land use maps (Fig. 2). Furthermore, as can be seen from the Eveness Index, which underwent a slight increase, the difference between real and potential diversity increased in favour of real diversity, which shows how the territory suffered a greater human pressure over time, and was characterised by vegetation which differed increasingly from potential vegetation.

![Fig. 5. Percentage of different land cover types extracted from land use maps of the municipality of Tuoro sul Trasimeno for 1977 and 2000.](image-url)
The dendrogram obtained from the cluster analysis shows two main groups of data, each clearly subdivided into smaller groups which correspond to the different plant communities representing the categories in the area.

Two clusters, I and II were obtained from the multivariate analysis. The first cluster (I) (Fig.4) contains clusters Ia and Ib; cluster Ia is subdivided into Iaa and Iab; Iaa contains woodland communities (communities made up principally of *Quercus pubescens* Willd., *Erica arborea* L., and *Cistus creticus* L. subsp. *ericaceous* (Viv.) (Greuter et Burdet) with a low degree of dissimilarity due to the dominance of *Quercus pubescens* Willd. Cluster Iab contains woodland communities of mainly *Quercus ilex* L. with undergrowth of *Viburnum tinus* L. and *Laurus nobilis* L. Cluster Ib contains the communities bordering the forests. The second cluster (II) contains the results of the meadow post-cultivation communities in which there is a greater dissimilarity and therefore a greater species diversity. Herbaceous plants prevail, showing a greater biological diversity in subgroup II than in subgroup I, including species which are typical of abandoned or marginal agricultural areas such as *Avena sativa* L. and *Agropyron repens* L.

5. DISCUSSION AND CONCLUSIONS

It may be said that the original aspect of the traditional landscape has been modified mainly by intensive crops which now cover large areas, as shown by the percentages of land use classes from 1977 to 2000. The environmental quality analysis showed that the areas adjacent to urban areas and the lakeside areas which in the past had been converted to intensive crops, are now classified as having low environmental value. The ILC calculations confirmed the decrease in environmental quality from 1997 to 2000, due to larger areas of intensive crops, and a reduction of natural and semi-natural areas, that is to say, due to man's greater exploitation of the area.

The two indicators H and J reveal that over twenty years land use categories changed. This demonstrates how human impact has increased greatly, and how the vegetation differs notably with respect to the previous natural vegetation. It is also necessary to note that this process is closely linked to a slow but progressive abandonment of traditional crops that is taking place over vast parts of the area in question, especially marginal areas. Thus it may be seen that this is a landscape characterised by mosaic vegetation with a high degree of dynamics. The multivariate analysis, which confirms the situation, demonstrates that the areas most subject to colonisation by alien species are woodland communities because their lower level of dissimilarity makes them more susceptible to biological diversity reduction and so more sensitive to colonisation. On the other hand, meadow post-cultivation communities reveal higher levels of biological diversity and so are still characterised by environmental stability. Proper management and conservation of landscapes should consider the relationship between landscape pattern composition and spatial configuration and how they are generated (Levin and Paine 1974).

The results of the study show how the intensification of agriculture and the disappearance of traditional agricultural practices can be linked to processes which are common to many European landscapes affected by these phenomena during recent decades. (Forman and Godron 1986). The study of changes in land use is certainly a key factor in understanding a given territory, and anthropogenic changes in land use and land cover are being increasingly recognized as critical factors which influence global change. Though related, there is a clear distinction between land use and land cover. While land cover refers to the biophysical earth surface, land use is shaped by human, socio-economic and political influences on the land (Geist and Lambin 2002). (Veldkamp and Lambin 2007). Thus an understanding of the past and future impact of land use is fundamentally important for the study of environmental change (Prieler et al. 1996). To sum up, "land use links land cover to the human activities that transform the landscape" (NRC 1999).

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6. REFERENCES


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