Spatial analysis of selected biodiversity features in protected areas: a case study in Tuscany region

Abstract

The development of a strategy for biodiversity analysis is very important at different scales, in particular at the national one. Based on the World Conference on Biological Diversity held in Rio de Janeiro in 1992, and in line with most of the important actions such as the European Natura 2000 network or the Environmental Conference of the Regions of Europe (EN.CO.RE), several measures aimed at the preservation of Biodiversity were considered in Italy and more specifically in the region of Tuscany (study area).
Protected areas follow mentioned measures for biodiversity preservation, so the analysis of their degree of biodiversity is a valid tool to evaluate the effectiveness of those measures.
The present manuscript analyses the degree of some relevant features biodiversity in the region of Tuscany, through the implementation of multidimensional indicators in a Spatial MultiCriteria Analysis. After a state of the art of biodiversity definition, four indicators, have been used for the analysis. A raster map in which pixels have higher or lower values of biodiversity has been produced in order to investigate which of these values is located in protected areas. Protected areas with high value of biodiversity confirm that the adopted environmental policies, are positively related to maintenance of the biodiversity. The result of the analysis, corroborated through auto-correlational statistical analysis, has highlighted the important role of protected areas in maintaining a certain degree of biodiversity

Keywords *territorial planning; GIS; biodiversity indicators; protected areas; spatial MultiCriteria analysis*

1 Introduction

The concept of biodiversity encompasses a set of meanings, which currently converge toward the concept of conservation of species including animals, plants, and their habitats.

Article 2 of the International Convention on Biological Diversity defines "Biological diversity" as "*the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*"[1]. The Food and Agriculture Organization of the United Nations (FAO) considers that the concept of Biodiversity "***includes the variety and variability of ecosystems, animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain human life as well as the key functions of ecosystems***"[2]. The World Wildlife Fund (WWF) defines Biodiversity as "*the HUGE variety of other animals and plants on our planet, together with the places where found*"[3].

UNEP (United Nations Environment Programme-UNEP[4]) gives a clear-detailed biodiversity definition: "*The term 'biodiversity' is indeed commonly used to describe the number, variety and variability of living organisms. This very broad usage, includes many parameters, is essentially a synonym of 'Life on Earth*'". UNEP identify three levels of biodiversity:

1. Genetic diversity is all the different genes contained in all the living species, including individual plants, animals, fungi, and microorganisms.
2. Species diversity is all the different species, as well as the differences within and between different species.
3. Ecosystem diversity is all the different habitats, biological communities and ecological processes, as well as variation within individual ecosystems.

However it is important to consider that biodiversity encompasses a number of sensitive issues that are directly connected to human development. For instance, urban development is at the center of multiple spatial planning studies aiming at controlling and regulating growth to avoid the phenomenon of urban sprawl. In this case, biodiversity, as part of natural areas and habitats threatened by human activities, should be included in the decision-making processes.

A wide literature provides analysis of biodiversity (using different models) from different point of view: in 2001 there were about 547 papers from three prominent conservation journals (Fazey et al., 2005).

Dormann et al., 2008 perform a multimodel prediction to evaluate effects of climate, land-use intensity and landscape structure on species richness in some groups of

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[1] Available online http://www.cbd.int/convention/articles/default.shtml?a=cbd-02 [last accessed January 20, 2016]

[2] Available online http://www.fao.org/biodiversity/en/ [last accessed January 20, 2016]

[3] Available online http://wwf.panda.org/about_our_earth/biodiversity/ [last accessed January 20, 2016]

[4] Available online http://old.unep-wcmc.org/what-is-biodiversity_50.html [last accessed January 20, 2016]

organisms, Gotelli et al., 2009 use a mechanistic models that simulate speciation, dispersal and extinction of species in a heterogeneous landscape, Pellissier and Couteron, 2007use a multivariate linear model in order to quantify the relationship between observed species diversity and one (or a set of) external explanatory variable(s) depicting accessible information about the species' environment.

Protected areas (PA) follow special measures for environmental preservation that are correlated to biodiversity.
The emerging need for biodiversity analysis can be explained by "a shift from source-oriented to effect-oriented policy that can be recognized in environmental and nature conservation policy since the 1980's"… In the case of effect-oriented policy, the quality of the (eco)system is the starting point for the elaboration of policy and measures" (Turnhout et al., 2007).
At the same time analysis of biodiversity in protected areas (mainly represented by National, Regional, Provincial parks and Natural reverses) has always been considered area of discussion.
Based on the World Conference on Biological Diversity held in Rio de Janeiro in 1992, and in line with most of the important actions such as the "European Natura 2000" network or the Environmental Conference of the Regions of Europe (EN.CO.RE), several protected areas and measures aimed at the preservation of biodiversity were instituted in Italy. These areas/measures are:

- Sites of Community Importance (SCI) and Sites of Regional Importance (SRI)
- Protected wetlands under the "Ramsar Convention[5]",
- National Strategy for Biodiversity (active since 2010, and which development is part of Italy's commitments since the ratification of the Rio de Janeiro '92 Convention through the Act no. 124 of 14 February 1994). This act was implemented in Tuscany through the Regional Energy and Environmental Plan (Paer 2013-2015)[6].

The detail of how to measure biodiversity is an area of discussion particularly relevant at the science/policy interface (Turnhout et al., 2007). The Convention on Biological Diversity (CBD) - mandated Biodiversity Indicators partnership (BIP) promotes the development of indicators in support of the CBD and related Conventions, national and regional governments and a range of other sectors. Indicators initiated under the partnership are linked to the goals of the Strategic Plan for Biodiversity 2011-2020 and include habitat extent, protected areas and species extinction[7].

The present work analyzes the degree of some relevant features biodiversity in the region of Tuscany using specific indicators implemented through a Geographic Information System (GIS). The aim of this paper is to highlight the areas having a high value of biodiversity, and which of these areas are located into protected areas: protected areas with high value of biodiversity confirm that the adopted environmental policies, are positively related to maintenance of the biodiversity; vice versa for protected areas with low value of biodiversity. The interesting aspect of this paper is the analysis of the spatial correlation between values of relevant features of biodiversity and protected areas using a geographical dataset with high resolution. A

[5] Convention on Wetlands of International Importance, especially as Waterfowl Habitat
[6] Available online Tuscany region official website [last accessed January 20, 2016]
[7] Available online https://www.cbd.int/sp/ [last accessed January 20, 2016]

Spatial MultiCriteria Analysis has been used for the development of raster map in which the pixels (75 meters of resolution) have higher or lower values of biodiversity depending on the selected indicators (refer to section 2).
At the same time, the adopted methodology represents a tool to support territorial planning able to help stakeholders to better identify and verify the effects of the national or local environmental policies and it can be easily replicated in other contexts.
This paper is organized as follows: in Section 2 methodology is described and indicators are selected; in Section 3 case study is introduced; in Section 4 the model is implemented; in Section 5 results and discussions are provided; finally, Section 6 is dedicated to conclusions and future recommendations.

2 Definition of model and selection of indicators

Spatial MultiCriteria Analysis is a MultiCriteria decision techniques applied in Geographic Information Systems, which permits the processing of a large number of data through MultiCriteria rules.
MultiCriteria Analysis Method (MCA) was developed in the USA during the second half of the 70^{s}. It is classified as a decision support tool for decision makers or groups of decision makers (i.e. citizens, public or private bodies, investors, politicians, etc.) involved in a planning process). MCA is based on mathematical procedures that can identify the best (ideal) choice given a set of alternatives, criteria, indicators, targets and attributes related to a specific problem (target study). With reference to (Watson and Buende, 1987) statement, "*The reality in relation to which a decision maker must make a decision is a construction of the individual. Therefore, when we worry about what action to take, what is important in guiding the choice are our own mental models of the world* ", therefore, the main purpose of the MCA is to provide a decision support tool, and to select through calculations based on variables that considers human behavior, which are the best possible solution for a given problem.
Spatial MultiCriteria Analysis uses the potential of GIS to solve MultiCriteria models in order to support decision-making in spatial planning processes (Malczewski 2006a and 2006b), and to get results that are easy to interpret.
This methodology is widely adopted in the literature, "over 300 papers published between 2000 and 2009 reporting MCDA applications in the environmental field" (Huang et al., 2011). Furthermore, this analysis is appropriate for territorial analysis as confirmed by Geneletti and Van Duren, 2008; Giordano and Riedel, 2008; Riccioli and El Asmar, 2011; Chen et al., 2010; Bottero et al., 2013.
The core of the MultiCriteria analysis has represented by the definition of indicators: they are able to analize the main aspects of the target study that is represented, in this paper, by the analysis of biodiversity.
“Indicator is a simplification of nature, which is perceived to be a system characterized by high structural complexity, considerable spatial heterogeneity and temporal fluctuations” (Turnhout et al., 2007).

2.1 Biodiversity indicators

In present paper biodiversity has been analyzed and quantified by using indicators: also in this case literature provides a large number of biodiversity indicators, most part of which are proposed by Organisation for Economic Cooperation and Development (OECD, 1997 and 2005).

Ten Brick, 2000 provides a review of existing biodiversity indicators and a comparison of major indicator frameworks. In that study National Capital Index is concluded to constitute a feasible method for assessing biodiversity in a crude but comprehensive manner. Tasser et al., 2008, applied a series of indicators based on landscape heterogeneity and quality, the anthropogenic influence, naturalness of riparian area or agricultural intensity. Bulgarini et al., 2006, applied two sets of indicators for the selection of eco-regions of the Global 200 (areas to be protected, or those areas that are more representative of the various habitats: terrestrial, marine and freshwater). The first set of indicators is defined as "Biological Distinctiveness Index" (BDI) including:

- the richness of species;
- the presence of endemism;
- the particular ecological and evolutionary phenomena (migration, extraordinary adaptive dynamics, etc.);
- the rarity of habitats considered at the global level (MHT).

The second set of indicators is defined "Conservation Status Index" (CSI) including:

- habitat loss;
- large areas of virgin habitat;
- fragmentation levels of habitat;
- foreseen future threats.

Carraro et al., 2004 promoted the maintenance of the forest landscape variability, the conservation of the species-specific variability in the various ecosystems, and the creation of protected areas by studying the composition of native tree species, the anthropogenic alterations to the tree composition, and the interactions with macrofauna. Sitzia et al., 2005 used the richness of plant species, the richness of woody species, and the heterogeneity of the lower layers of vegetation, as indicators of biodiversity. Lindenmayer et al., 2000 considered the knowledge of the kind of species present in the forest, their location, and how they can respond to disturbances, as basic requirements for using the various biodiversity indicators. Rudisser et al., 2012, based their analysis on biodiversity indicators on the study of degree of naturalness, distance to natural habitat, distance to nature. Bottero et al., 2013 used 7 indicators related to some characteristics of environment (land cover, water bodies, etc.) and human pressure on territory.

As underlined before the Mandated Biodiversity Indicators Partnership promotes the development of indicators in support of the CBD that include habitat extent, protected areas and species extinction.

Therefore, as result of the previous literature review and considering the scheme about indicators of Lazarsfield (1969), analysis of relevant features of biodiversity has been addressed by considering flora, fauna and human pressure of Tuscany. Hence, we have selected the following indicators:

1. *Heterogeneity of the land use* for the analysis of flora;
2. *Distance from artificial areas* for the analysis of human pressure;
3. *Ecosystem diversity of fauna* for the analysis of fauna;
4. *Presence of ecological corridors* that represents the connection between previous features.

It’s important to underline that flora and fauna can be evaluated in innumerable ways, but in this paper are exclusively considered the different land uses e wildlife present in case study. Obviously, it is difficult to perform an exhaustive analysis of biodiversity. In fact, still, many indicators and other features (Pellissier and Couteron, 2007; Spangenberg et al., 2012; Kry et al., 2008; Fitterer et al., 2012) are not considered in this work (mainly due to lack of resources and adequate economic and ecological information). In this paper has been selected one indicator for each important issue regarding previous biodiversity definitions.
In addition to review of the existing literature, the choice of indicators has been influenced by the availability of geo-referenced data: the use of geo-referred dataset with high resolution represents new frontiers of territorial analysis (Bernetti et al., 2010, 2011; Baerenklau et al., 2010; Nelson and Kennedy, 2008; Zandersen and Tol, 2009; Bottalico et al., 2016), and represents a tool able to help decision maker to choice the right allocation of resources.

3 Case Study

Tuscany is a region located in the center of the Italian peninsula, where 1,086,000 hectares are covered by forestland: they play an important role, being equivalent to 47% of the total area of the region (nearly 2,300,000 hectares). The territory is mostly hilly (66.5%); includes some plains (about 8.4% of the territory) and major mountain ranges (25.1% of the region). The climate is characterized by average annual temperatures around 16°C, with rainfall around 600 -700 mm annually. The region is made up of 10 provinces and 287 municipalities, and has a population of about 3.7 million with a density of 160 inhabitants per sq. km.
Figure 1 shows the Tuscany region where the protected areas (highlighted in green) cover about 227,000 hectares (10% of the total area of the region). Most important of them are constituted by 3 National parks, 3 Regional parks, 2 Provincial parks and over 100 different protected areas mainly represented by Natural Reserves, Sites of Community Importance (SIC) and Special Protection Zones (ZPS).

Figure 1 Case study: Tuscany region (protected areas in green)

4 Applied methodology

According to chapter 2, the features selected for analysis of biodiversity have been evaluated through multidimensional indicators and implemented in a Spatial MultiCriteria Analysis (figure 2). Each indicator has been described in following subsections.

Figure 2 MultiCriteria analysis flowchart

4.1 Heterogeneity of land use

In order to calculate heterogeneity of land use, we considered the 2006 Corine Land Cover (CLC) developed within the CLC project as per the European Standard on

Geographic Information (ENV 12657). We modified CLC map by eliminating the artificial areas, urban residential areas, industrial areas, commercial areas and infrastructures, the mining areas, construction sites, landfills, disrupted and abandoned lands, artificial non-agricultural green areas, heavily populated agricultural areas and intensive crops.
Notwithstanding the existence of numerous indicators able to describe the heterogeneity of land use ("Relative Richness", "Edge density" analysis, see Eastman, 2009), this indicator was calculated using the Shannon index, which is considered one of the best indices to define this level of heterogeneity (Magurran, 1988; Duels and Obrist, 2003; Pellissier and Couteron, 2007).
The Shannon index is used to estimate the level of biodiversity of a determined territory. It can define the measure of how the individuals (vegetal, in our case study) could be distributed among the different species.
To estimate this first indicator the CLC was used and edited calculating the environmental diversity using an area of 3 pixels by 3 pixels (formula 1).

$$S = -\sum_{j=1}^{S} p_j \cdot \log p_j$$ **Equation 1**

S = Shannon index
p_j = surfaces in use by land use j-unit
s = number of the measured land use

Through this index it was possible to highlight the most heterogeneous areas in terms of land use (higher values), considering them as areas of high biodiversity value (figure 3). Using this indicator, the component related to flora was accordingly measured.

Figure 3. Map representing the heterogeneity of the land use

4.2 Distance from artificial areas

As per the previous index, the calculation of the distance from the artificial areas was based on the modified land use map of Corine Land Cover: in this case, artificial areas were highlighted and from these fuzzy distances were measured.
"*The fuzzy distance decay membership function is used to indicate proximity to a given feature*" (Al-Ahmadi et al. 2009). Rather than having a single crisp threshold that denotes a distance away from a feature, the fuzzy distance decay function is capable of describing the degree of biodiversity that increases far from artificial areas (highest values in figure 4). The choice of this indicator permitted us to consider the human sphere that is represented by all those critical issues that can threaten biodiversity.

Figure 4. Map representing sectors distant from artificial areas

4.3 Ecosystem diversity of fauna

The National Ecological Network (la Rete Ecologica Nazionale, REN) was used to measure this indicator. Accordingly, we analyzed the distribution of the richness of species in the area (internal polygons potential number) of amphibians, mammals, fish, reptiles and birds. This distribution is represented by the superposition of the countless networks of all animal species and is characterized by a dense fragmentation of the territory (Boitani et al., 2002). Accordingly, an ecosystem biodiversity analysis was measured; also, called gamma diversity or regional diversity. This analysis takes into account the number of species in a region, the latter defined as an area that does not include significant barriers to the dispersal of organisms. As suggested by Duelli and Obrist, 2003, this decision is due to the choice of the "relatively large" case study. In this respect, it is more effective to correlate the number of species to a larger area rather than to the individual pixels.

"*Gamma Diversity is calculated as the richness of species over a region. Thus the value recorded at any pixel represents the richness within the region to which it belongs and not the richness at that particular spot*" (Eastman, 2009).

Figure 5 shows the ecosystem diversity of fauna, where higher values correspond to a greater richness of species over a region and thus a higher value of biodiversity. This indicator allowed us to analyze the component related to fauna.

Figure 5. Map of the ecosystem diversity of fauna

4.4 Presence of ecological corridors

At this stage, we measured the Normalized Difference Vegetation Indicator (NDVI), by calculating through the application of Landsat 7 ETM+ images (year 2006) (Enhanced Thematic Mapper) that provide 7 multispectral bands covering a wavelength ranging from visible to infrared spectrum. Remote sensing has been used in biodiversity analysis (Lassau et al., 2005; Fitterer et al., 2012).

The NDVI relates the chlorophyll absorption spectrum in the red with the typical reflection in the near infrared where it is strongly influenced by the type of the leaf structure (Bocchi, Galli, Gomarasca, 1997). NDVI was obtained by processing Landsat images. Vegetation index module of IDRISI Software calculates the green vegetation indices through a combination of the visible red and the near infrared bands of any earth observation satellite images. Band 3 of Landsat was set for visible red and band 4 was set for near infrared.

To measure the ecological corridors NDVI values above 0.20 were selected. According to Agone and Bhamare, 2012 these areas are represented by scrub, grasslands and dense forest that permit wildlife movement.

Successively, an NDVI value is assigned, through a moving window centered on a pixel that is equal to the average NDVI values of adjacent pixels. These pixels define the "geographic neighborhood" made with a square grid of 7 pixels by 7 pixels (48 pixels adjacent to the reference pixel were examined). This method develops a gradient of values from one pixel to another that is useful in order to maintain the gradual changes of environmental characteristics.

Accordingly, an ecological corridor map is generated on the basis of significant movement of fauna, and where higher values correspond to the most suitable areas to such displacements (figure 6).

Figure 6. Map of the ecological corridors

4.5 Biodiversity in Tuscany region

The last step of the analysis is to aggregate indices overcoming the dilemma of indicating complexity of biodiversity with simple measures (Duelli e Obrist, 2003).
In order to generate comparable maps from numerical point of view (Ribeiro et al., 2014) each indicator was standardized using fuzzy method (Zadeh, 1965, 1997): table 1 includes the normalization parameters used for the four indicators. Each indicator has a minimum and a maximum value. The minimum value represents the worse conditions of biodiversity (control point a), in other word, areas without biodiversity of land use, areas in the proximity of artificial zones, areas without gamma biodiversity and areas with the absence of ecological corridors (maximum fragmentation of land use). The maximum value however, represents the best conditions of biodiversity (control point b) in other words maximum biodiversity of land use, maximum distance from artificial areas, maximum gamma biodiversity, and maximum presence of ecological corridors (minimum fragmentation of land use).
Many of the more pressing pressures that challenge decision makers, such as urban growth management and environmental protection, are complex and require a comparison of the several possible indicators. The attribution of weights to indicators is an important process. For this purpose, PCA (Principal Component Analysis, Eastman, 2009; Jolliffe , 2014; Cozzi et al., 2015) has been used.
PCA is a multivariate technique used for the analysis of relationship between quantitative variables (indicators in our case). A correlation matrix has been calculated in order to produce correlation coefficients: correlation coefficients with high values mean indicators strongly correlated with others (redundant). For each indicator, the cumulative contribution of the eigenvectors to the main components has been calculated. The result is multiplied by the eigenvalue reported to each component. The PCA determines, as a result, the relative importance of the indicators (weights show in table 1) not excluded from the model (Alleva et al., 2009; Sanguansat, 2012).

Indicators	**Type of normalization**	**Control point**		**Weights of indicators (w_i)**
		a	*b*	
Shannon	Linear increasing	0	1.58	0.2118
Distance from artificial areas	Linear increasing	0	12,929	0.2237
Gamma biodiversity	Linear increasing	0	177	0.2891

Ecological corridors	Linear increasing	0	0.99	0.2754

Table 1. Parameters of indicators normalization

The aggregation method chosen in this paper is the "Weighted Linear Combination" (WLC) that was already applied in other works on environmental analysis (Comber et al., 2010, Carver et al., 2012 and 2013, Orsi et al., 2013).
WLC is based on the concept of compensation and mitigation in the environmental studies as mentioned by Rajvanshi, 2007: "*mitigation and compensation in environmental assessment thus have a critical role to play in encouraging positive development planning and steering the development process in order to:*

- *enable better protection of environmental assets and ecosystem services;*
- *encourage prudent use of natural resources;*
- *avoid costly environmental damage, thus also making economic sense*".

The biodiversity map of Tuscany has been obtained by a weighted linear combination (equation 2).

$$B_j = \sum_{i=1}^{n} I_{ij} \cdot w_i$$ **Equation 2**

where
B_j = biodiversity value of a j-unit pixel
I_{ij} = value of the i-unit indicator belonging to the j-unit
w_i = i-unit indicator weight ($\sum wi = 1$)
n = number of the biodiversity indicators

Consequently, to better define the different levels (degree) of biodiversity (the goal is to highlight the areas with a high level of biodiversity), the analysis was based on the use of fuzzy logic quantifiers. To convert the verbal terms into fuzzy numbers, an appropriate scale of linguistic terms was used. Chen and Hwang, 1992, proposed eight different scale typologies varying in linguistic terms used. These scales are referred to the terms "high" and "low" with various shades in between, depending on the decision problem to be analyzed.
The scale used in this work is based on the 5-point scale that identified 5 degrees of biodiversity (high, medium-high, medium, medium-low, low): a "high" value of biodiversity corresponds to fuzzy values between 0.70 and 1 (figure 7).

Figure 7 Scale of linguistic terms

5 Results and discussion

The final aggregation map presented in figure 8, show how the high values correspond to the areas with a high degree of biodiversity: a total of 2.2 millions of hectares have been examined (about 95% of total regional surface).
Ignoring the areas with low degree of biodiversity, which could be the subject of future works, the paper has focused on areas of high biodiversity value falling in protected areas.
The areas with highest values of biodiversity (THB) are highlighted in different shades of purple and cover an area of approximately 35,867 hectares that represent about 1.6% of examined territory (table 2).

Provinces		**Biodiversity**	**High biodiversity (THB)**	**THB on Biodiversity**
Name	*Abbreviation*	*ha*	*ha*	*%*
Arezzo	AR	314,101.75	7950.94	2.53
Pisa	PI	231,711.94	5392.1	2.33
Grosseto	GR	441,594.07	9623.6	2.18
Siena	SI	373,227.17	5430.49	1.46
Massa - Carrara	MS	107,807.96	1536.28	1.43
Livorno	LI	110,476.53	1197.48	1.08
Florence	FI	332,852.60	3337.07	1.00
Lucca	LU	163,315.02	1172.51	0.72
Prato	PO	29,487.30	93.91	0.32
Pistoia	PT	89,895.93	132.62	0.15
Gran Total		**2,194,470.27**	**35,867.00**	**1.63**

Table 2 Hectares of Biodiversity in Tuscany sort by Province

Arezzo, is covered by 2.53% of high biodiversity areas (of total examined surface), followed by Pisa and Grosseto where the high biodiversity areas represent respectively 2.33% and 2.18% of examined territory.
According to fuzzy logic quantifiers, it's possible to underline that areas with high values of biodiversity (over 0.70) are located in protected areas. In particular, they are distributed essentially in three homogeneous clusters (highlighted in black in Figure 8) that are defined along the northern-east part of the region (the Apennines Mountains located in Florence and Arezzo provinces), in the south-eastern part of the territory corresponding to the Amiata Mountain (located in provinces of Siena and Grosseto) and in the central part matching with the Metalliferous hills (located in province of Pisa and Livorno).
In order to confirm the presence of geographic spatial clusters, a statistical test of spatial autocorrelation, was performed. The test consisted in calculating, on the map, the Moran indicator with high biodiversity values. "*Autocorrelation is the propensity for data values to be similar to surrounding data values. This describes the degree to which values in a cell are similar to the cells immediately surrounding it. The measure used is Moran's I, which ranges from -1 when adjacent cells are very dissimilar to +1 when they are very much alike*" (Eastman, 2009). This indicator is equal to 0.80, indicating a positive autocorrelation, thus confirming the presence of spatial clusters.

Table 3 shows distribution of high biodiversity (in hectares and percentage) of three clusters. Amiata mountain cluster covers 8,375 hectares (23% of Tuscany total surface of high biodiversity), the Apennines cluster has an area of almost 7,545 hectares (21% of total), while Metalliferous hills covers about 6,453 hectares (18% of THB).

Geographic cluster	**Cluster's High Biodiversity**	**Percentage on THB**
	ha	*%*
Amiata mountain (SI and GR)	8,375	23
Apennines mountains (FI and AR)	7,545	21
Metalliferrous hills (PI and LI)	6,453	18
Tuscany	**35,867 (THB)**	**100**

Table 3 Clusters with highest values of biodiversity

Analysing each cluster it is possible to confirm that some of the zone with highest biodiversity are included in the protected areas. Apennines cluster is close to National Park of Casentinesi Forests, Amiata cluster is near to Faunistic Park of Amiata Mountain and Metalliferous cluster is nearby Sites of Community Importance of Merse Valley (Figure 8).

Regarding the above mentioned relationship (high biodiversity zones embedded into protected areas), for each cluster, a statistical test of spatial autocorrelation was performed using a Local Indicator of Spatial Association (LISA). As suggested by Anselin, 1995, Moran indicator was used for this purpose.

Three Moran's indicators are above 0.70 indicating a positive autocorrelation: 0.71 for Apennines area and respectively 0.73 and 0.74 in Metalliferous and Amiata clusters.

Figure 8 Biodiversity and protected areas

The three underlined areas have many peculiarity related to each indicator that motivates their high values of biodiversity.

The heterogeneity of land use is an important feature of biodiversity in Casentinesi forests that represent a great floristic heritage: there are about 1357 species and 1125 of them are represented by local species. Same as previous in Merse Valley: thanks to some abandoned land, heterogeneity of land use has represented by interesting local species like Alyssum bertolonii, Centaurea aplolepa, Stachys recta Stipa Etrusca.

Also the ecosystem diversity of fauna is a relevant characteristics of Casentinesi forests where is possible to sight some rare species like wolf (Canis lupus Linnaeus), golden eagle (Aquila chrysaetos) and rare amphibians, reptiles and invertebrates (crayfish) while in Merse valley is possible to sight raptors, wolf, wildcat (Felis silvestris Schreber).

This indicator has a primary importance degree in Amiata because the aim of this park is focused on the preservation of animals at risk of extinction like some mammals like Amiatina donkey (Equus asinus).

The presence of ecological corridors is guaranteed by prevalent land use that is represented by forest (conifer and deciduous).
Finally distance from artificial areas is an important aspect in all areas, specially in Amiata park: it is involved in a Regional project called "I sentieri dell'arte" (paths of the art) and it represent one of the most relevant viewpoint concerning astronomical observations due the absence of light pollution.
The analysis of biodiversity in the three different areas has shown opposite policy solutions: nevertheless both solutions have contributed to maintain high level of biodiversity.
In Merse Valley and Amiata the anthropic pressure is relevant due to the organization of activities focused on sensitization of humans on species at risk of extinction. There are different paths aimed to the observation of wild animals, rare plants and other natural peculiarities. In particular in Merse valley some educational activities have been focused on river restoration projects (these activities are important due to presence of some amphibians rarities such as Spectacled salamander (Salamandrina terdigitata) and European green toad (Bufotes viridis).
Instead Casentinesi Forests are divided into three zones where the anthropic activities are minimized, and the forest was left to its natural evolution. Zone A also called "Riserva integrale" is related to areas without anthropic activities where the natural environment is preserved in its integrity (it cover about 930 hectares). Zone B aims at improving complexity of ecosystem and maintenance of natural balances (only human educational activities are allowed). Zone C includes areas of natural interest, characterized by human activities aimed to silvicultural planning.

6 Conclusions and future recommendations

The analysis of biodiversity has been studied for long time, through different and very subjective points of view, and often where data are available. There is no unique and accurate method or indicators to study biodiversity. Based on the literature review and indicators, the present paper tackled the different features of biodiversity.
The analysis was based on Spatial MultiCriteria Approach (MCA), a powerful and useful tool for territorial planning and for supporting decision-making process.
MCA was successfully applied to spread the spatial data management and visualization of GIS with MultiCriteria analysis capabilities and to weigh evaluation criteria relative to decision makers' preferences and priorities. Traditionally, GIS and MCA methods were integrated in a largely sequential manner with GIS used first to identify possible options, followed by MCA evaluation of each alternative's relative attractiveness and subsequent mapping of evaluation results.
Nevertheless, the approach shows classic weaknesses due to "spatial" problems associated with territorial analysis, such as the spatial resolution problem (pixel dimension), the measure unity used, the software or human errors, the approximation of errors during the conversion process from real world to pixel, the uncertainty degree due to vague environment characteristics.
Furthermore, in subsection 4.5 "global" weights are used in WLC process: one shortcoming of this approach is that it assumes implicitly that the same set of criteria and criteria weights are applicable across an entire study area. The result is a loss of details in the final map aggregation.
"*Earlier, the MultiCriteria land suitability was assessed more non-spatially, assuming the spatial homogeneity over the area under consideration. This, however, is*

unrealistic in cases like land suitability studies, where decisions are made using criteria which vary across in space” (Malczewski 1999).
Recently, researchers started to explore methods to lessen this assumption in light of the fact that people often employ localised or neighbourhood-sensitive sets of criteria and/or criteria weights in decision-making. Different approaches could be used for this type of analysis as if localized criteria weight sensitivity analysis (Feick and Hall, 2004), post-hoc geographic smoothing of evaluation results (Rinner and Heppleston, 2006), local MCA decision rules (e.g. Malczewski, 2011) and localized criteria weights (e.g. Ligmann-Zielinska and Jankowski, 2012).
Biodiversity analyzed in present paper relies on the interaction of three relevant features: fauna, flora and human pressure. The first was analyzed through the ecosystem diversity of wild animals, the second through the indicator of heterogeneity of land uses, and the third through an analysis of zones that are close to artificial areas (resulting from human activities).
The analysis links the three above mentioned features, by including, the study of the ecological corridors consisting of scrub, grasslands and dense forest (flora), used by wild animals (fauna), and threatened by human pressure (as highlighted in Fleury and Brown, 1997, Savard et al., 2000).
Obviously, depending on available data, the methodology could be implemented with other set of indicators able to analize other features of biodiversity from social, economic and environmental point of view.
A purpose of the work was to verify if biodiversity is effectively associated to protected areas: the highlighted positive relationship means that protected areas really contribute to the maintenance of biodiversity and indirectly highlight a success of environmental policies designed to the conservation of biodiversity to be adopted across Italy. The highlighted positive spatial autocorrelation shows local specific areas where it is easier to allocate resources properly. Using indicators with a strong dependency between them, in future research, could be used systematic conservation planning frameworks such as Zonation, Marxan, C-Plan (Ball et al., 2009; Watts et al., 2009; Rayfield et al., 2009; Lehtomaki and Moilanen, 2013).
Definitely, this study aimed to be a tool to support territorial planning (using a geographical dataset with high resolution), and therefore help stakeholders to better identify and verify the effects of the national or local environmental policies.
It is also a tool able to classify specific areas according to their several degrees of biodiversity and it can be easily replicated in other contexts.
As Turnhout et al., 2007 suggest, through data analysis (provided by our methodology), policy-makers can adopt new policy rules or verify if existing ones are well structured.
Indeed the result of the analysis, corroborated through auto-correlational statistical analysis, has highlighted the important role of protected areas in maintaining a certain degree of biodiversity, by promoting indirectly environmental policies oriented towards its conservation.

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