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An Estimation of Urban Fragmentation of Natural Habitats: Case Studies of the 24 Italian National Parks

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Italy is a densely populated country, where most of the land is actively used by its human population. As a result, many of the remaining natural areas are subject to different typologies of human pressures that generally cause habitat fragmentation. Habitat fragmentation, unanimously considered as one of the greatest threats to biodiversity conservation, is due to a variety of factors related to land use changes, such as urban sprawl, increasing of transport infrastructures, and the intensification of agriculture and forestry practices. The main purpose of this paper was to investigate levels of natural habitat fragmentation due to the presence of human settlements in the Italian National Parks through the use of the Urban Fragmentation Index (UFI). All the results were recorded in a GIS database (Geographic Information System), elaborating a new method for a comparative spatial analysis of these records in order to achieve a critical scale of the habitat fragmentation levels in each of the 24 Italian National Parks.
The results represent an important indicator for the prioritization of biodiversity conservation interventions in the Italian National Parks.

1. Introduction

This paper presents one of the results of the multi-year collaboration in environment planning and management between the General Directorate for Nature and Sea Protection of the Italian Ministry for the Environment, Land and Sea, and the Sapienza University of Rome Interdisciplinary Centre for Landscape, Building, Conservation, Environment (CITERA).
The main aim of the project was to analyze impacts on biodiversity due to the human settlements in the Italian National Parks (INP_S), in order to facilitate an environmentally sound management and planning of the natural protected areas.
According to the Millennium Ecosystem Assessment (MEA, 2005), Europe is the most urbanized continent and has the highest level of habitats and ecosystems fragmentation. A recent European study (EEA, 2006) shows a continuing and rapid spatial development of urban areas. More than a quarter of the European Union territory is directly earmarked for urban uses and most of its land is actively used. As a result, many of the remaining natural areas are subject to pressure and risk fragmentation. The areas where the urban sprawl impact is most visible are located in countries or regions with high population density and intense economic activities. Among European countries, Italy is one of those with the greatest land consumption rate. According to UN-HABITAT (2012), in Italy 67.9 % of the population lives in urban areas. In 2030 the level of urbanization will be equal to 74.6 %. Italy is also, in terms of biodiversity (both species and habitat), one of Europe's richest countries. In order to protect all this biological diversity, 24 National Parks that cover about 5 % of the whole national area (15500 km^2) have been established in Italy. As recognized by the DG Environment of the European Commission (2009), urban sprawl affects land change elsewhere through the transformation of urban-rural linkages with significant consequences on natural areas. Moreover, this massive concentration of people has a huge impact on ecosystems and natural resources. In fact, the fragmentation phenomenon and the progressive isolation of natural areas alters the structure and dynamics of animal and plant species. In fact, this high urbanization rate produces direct

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consequences like the habitat fragmentation process and soil sealing, with multiple effects on species survival, average temperatures rising, hydro-geological structures, etc. These processes generally cause an ecological resilience loss through the destruction and degradation of habitat. In particular, fragmentation of natural habitats is considered a serious threat to the main ecological processes (Lindenmayer and Fisher, 2006), biological diversity (McKinney, 2002) and endangered species (Burkey and Reed, 2006). Furthermore, the International Union for Conservation of Nature (IUCN) considers habitat fragmentation the major menace for biodiversity preservation (Graham, 2004). This situation undermines the ecosystems functioning, which need space to thrive and deliver their services. This makes it necessary to manage the urban development through a sustainable integrated approach that takes into account the environmental, energy and economic variables specific to each territory (Cumo et al., 2012). With this theoretical background, the main aim of this paper is to analyze the fragmentation level due to artificial areas within each of the 24 INP_S. This investigation will allow the development of an integrated and sustainable spatial planning strategy for the INP_S.

2. Methodology

The whole analysis process was based on the use of GIS (Geographic Information System) software. The GIS mapping software made it possible to apply calculation models for assessing levels of habitat fragmentation and environmental damages (Mattia et a., 2012) in order to obtain a set of territorial results useful for planning management and conservation strategies. The obtained results include queried thematic maps which express the urbanization level in each INP_S, highlighting the most critical areas.

2.1 Assessment of artificial surfaces within the 24 Italian National Parks

In order to assess the level of habitat fragmentation due to the presence of urbanization, the first step was to identify the land use typology using the CORINE Land Cover (CLC) 2006: through the use of GIS software, all areas classified as 'Artificial surfaces' by the CLC 2006 have been identified for each INP_S (Heymann et al., 1994). Consequently, from the preliminary study of these cartographic data, it was noted that the detail level of the CLC 2006 was not sufficiently accurate for the assessment of habitat fragmentation associated with the urban presence in areas generally considered to be at high environmental value, such as National Parks. In fact, several urban settlements present in the parks were not recognized as artificial surfaces. Therefore, a readjustment of the CLC data was necessary, in order to obtain a more detailed identification of artificial areas otherwise classified. In particular, this specific territorial analysis was carried out using high quality satellite images and local cartography of the Italian Military Geographical Institute. Figure 1 shows as example the CLC modifications produced in the Orria municipality area, with a resident population of about 1500 inhabitants, located within the National Park of Cilento and Vallo di Diano. Using CLC classification, this area has been identified as forests and semi-natural areas, while our revision classifies it as an artificial surface.

After identifying all the CLC 2006 classification divergences, overlaying different layers, both raster (cartographies and satellite images) and vectors (shapefiles), it was possible to reshape all artificial areas and calculate the percentage of each land use category for all the INP_S. This land use analysis shows that only 4 of 24 INP_S did not need any changes to the CLC 2006. Artificial surfaces previously unreported were identified in the other 20 parks by 1 (Dolomiti Bellunesi National Park) to 84 (Cilento and Vallo di Diano National Park). Thanks to this new CLC database, it was possible to quantify the effective presence and pressure of artificial surfaces and urban areas within the 24 INP_S. For the purpose of UFI index elaboration, in the first two columns of Table 1 the percentage of artificial surfaces and urban areas are reported.

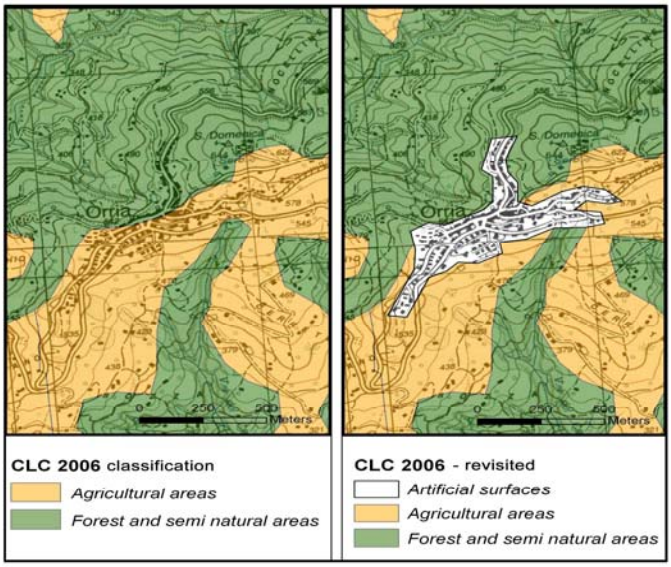

Figure 1: Difference between CLC 2006 land use classification and the revised version

2.2 Urban fragmentation Index (UFI) assessment

With regard to habitat fragmentation analysis due to the presence of urban areas, many indices and numeric models have been developed. In this analysis, the UFI index (Urban Fragmentation Index), elaborated by prof. Romano (2002) at the University of L'Aquila was used. This index was already used and validated in several scientific studies (Biondi et al., 2003; Romano and Tamburini, 2006). This index represents a useful criterion for evaluating the fragmentation degree within a National park, as it allows a numerical comparison between several parks, or between different areas within the same park, and thus identifies the most critical zones. The UFI index value is obtained for each territorial unit using the following equation:

$$UFI = \frac{\left(\sum_{i=1}^{i=n} L\max_i \cdot S_i \cdot O_i \right)}{At} \qquad (1)$$

where:
L max_i: maximum length of the *i-th* urban barrier inside the territorial unit (m);
S_i: area of the *i-th* urban barrier (m^2);
O_i: obstruction coefficient of the *i-th* urban barrier;
At: territorial unit area (m^2).

This equation was applied to each natural surface territorial unit within the INP_S, analyzing all the polygons that fall in 'Class 3' of the CLC 2006: Forest and semi natural areas.
The obstruction coefficient values have been assigned classifying the different types of settlements as reported by Romano (2002). In order to use a universally recognized classification to assign the O_i coefficient values, CLC 2006 codes were used. In particular, all land typologies in Class 1 'artificial surfaces' have been considered. As reported in Table 2, for each of these, a specific O_i value was used.

Table 1: O_i values according to CLC 2006 classification (Level 3)

O_i value	CLC 2006 settlements typology
1	Industrial or commercial units; Road and rail networks and associated land; Port areas; Airports; Mineral extraction sites; Dump sites; Construction sites
0.8	Continuous urban fabric
0.6	Discontinuous urban fabric
0.4	Green urban areas; Sport and leisure facilities

After identifying the percentages of artificial surfaces for each park, it was possible to evaluate the level of urbanization of each National park through the percentiles calculation, outlining three urbanization levels: INP_S with low level of urbanization are those with a percentage degree below the first percentile (≤ 0.2%); parks with medium level of urbanization are those between the first and the third percentile (≥ 0.21% and ≤ 0.875%); and finally, in the last level (high urbanization) are parks with a percentage higher than the third percentile (> 0.875%). In order to perform a comparison between the fragmentation values obtained in the various National parks, the following equation was used, weighting each UFI value on the land surface characterized by that value:

$$\overline{UFI} = \frac{\sum_{i=1}^{i=n} V_i \cdot S_i}{\sum_{i=1}^{i=n} S_i} \quad (2)$$

where:
$\overline{UFI}$: UFI weighted mean;
V_i: *i-th* value of UFI index;
S_i: surface characterized by V_i UFI index.

The same procedure used for evaluating the level of urbanization of each National park was also utilized for classifying the 24 $\overline{UFI}$ values.

Table 2: Percentage of artificial surfaces, urban areas and weighted means of the UFI for each INP_S

National Parks	Artificial surfaces (%)	Urban areas (%)	$\overline{UFI}$	Fragmentation level
Abruzzo, Lazio and Molise	0.3	0.2	1.3	Medium
Alta Murgia	0.3	0.2	0.2	Low
Appennino Lucano - Val D'Agri - Lagonegrese	0.7	0.6	2.1	High
Appennino Tosco-Emiliano	0.2	0.2	0.2	Low
Arcipelago La Maddalena	15.9	14.1	6.7	High
Arcipelago Toscano	4.0	0.7	20.6	High
Asinara	0.5	0	0.5	Medium
Aspromonte	0.6	0.5	1.4	High
Cilento and Vallo di Diano	1.4	1.4	0.8	Medium
Cinque Terre	1.7	1.7	0.3	Low
Circeo	6.5	6.5	0.2	Low
Dolomiti Bellunesi	0.001	0.001	0.03	Low
Foreste Casentinesi, Monte Falterona, Campigna	0.3	0.3	0.5	Medium
Gargano	1.2	1.1	3.8	High
Golfo di Orosei and Gennargentu	0.2	0.2	0.6	Medium
Gran Paradiso	0.1	0.1	0.02	Low
Gran Sasso and Monti della Laga	0.5	0.5	1.1	Medium
Majella	0.4	0.4	1.1	Medium
Monti Sibillini	0.9	0.8	0.8	Medium
Pollino	0.7	0.5	1.8	High
Sila	0.7	0.5	1.3	Medium
Stelvio	0.5	0.5	0.01	Low
Val Grande	0.2	0.2	0.6	Medium
Vesuvio	8.1	6.7	0.6	Medium

3. Results and Discussion

Analyzing the data reported in the first and second columns of Table 2, it emerges that the percentage of urban areas in the 24 INP_S is approximately 108 km^2 which corresponds to 0.7 % of the INP_S territory. Moreover, the average percentage of urban areas for a single National park is 1.58, while the percentage of artificial surfaces is equal to about 125 km^2 which corresponds to an average percentage of 1.91 % for a

single National park. Thanks to the artificial surfaces data, it was possible to calculate the UFI values in each INP_S. All results obtained from the calculation of the UFI values were then included in a cartographic database developed using a GIS software. The results of this elaboration are thematic maps that highlight the UFI values within each INP_S. An example of these maps is shown in Figure 2.

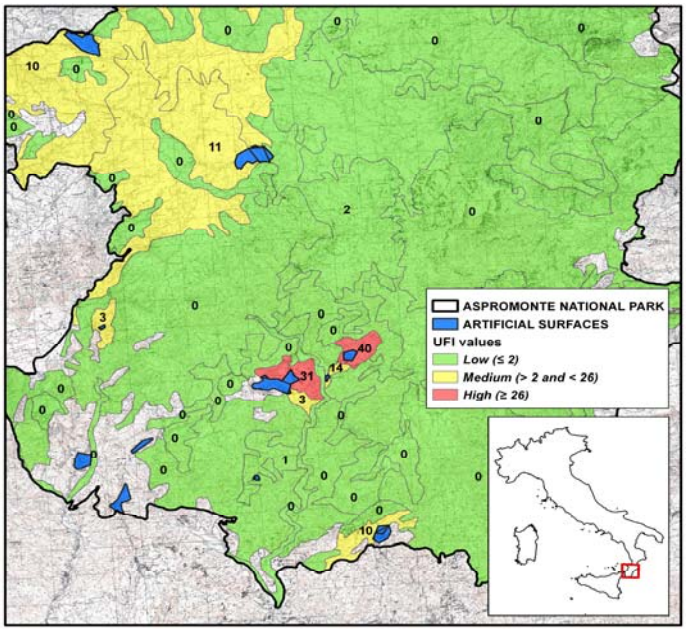

Figure 2: UFI values within the Aspromonte National Park

The third column of Table 2 shows the values related to the weighted mean of the UFI calculated, while the fragmentation levels (high, medium or low) are expressed in the last column.
According to the data reported in Table 2, Figure 3 graphically shows the fragmentation level for each INP_S.

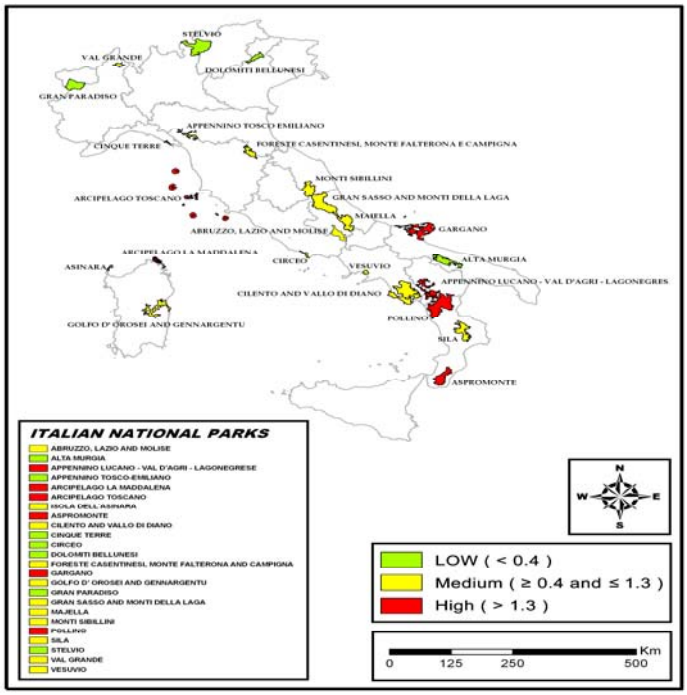

Figure 3: INP_S fragmentation level due to artificial surfaces

Interesting data emerge when comparing artificial surface presence and the fragmentation level for each INP_S. Considering the five INP_S with the highest values in both categories, it emerges that there is no correspondence: only two parks with a high presence of artificial surface present a high fragmentation level. In the light of these data, it emerges the importance of UFI analysis. In fact, it allows to estimate the effective natural habitats fragmentation levels, that do not depend only on the artificial surfaces extension.

4. Conclusions

The results of this paper represent a first step for the development of a sustainable and integrated spatial planning strategy for the INP_S. The next research step will be to analyze the pressure of the transport infrastructures (roads and railways) on natural habitat through the use of the Infrastructural Fragmentation Index (IFI). The integration of the results of the two indices (UFI-IFI) will ensure the development of methodologies and design tools consistent with the objectives of eco-compatibility respecting the local landscape values. As INP_S are important touristic sites, to reduce the habitats fragmentation risk ensuring at the same time touristic activities, it is necessary to develop sustainable local planning which take into account eco friendly infrastructures to ensure human needs (Astiaso Garcia et al., 2012).

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