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A GIS methodology for assessing ecological connectivity: application to the Barcelona Metropolitan Area

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Abstract

We developed a new methodology for the assessment of landscape and ecological connectivity at regional scale. This method has been entirely formalized using mathematical language, is supported by a topological analysis of a 1:25,000 scale land use map, and has been developed using Geographic Information Systems (GIS). The method allows the elaboration of a diagnose of the connectivity of terrestrial landscape ecosystems, on the basis of a previously defined set of ecological functional areas, and a computational cost-distance model which includes the barrier effect. This last component takes into consideration the type of barrier, the distance impact, and the adjacent land use and vegetation type. We defined two new compound indices: one for ecological connectivity and another for the barrier effect. The practical interest of our model is that it not only allows a cost-effective assessment of the current situation, but it has predictive capabilities, allowing the quantitative assessment and comparison of the impacts resulting from different planning scenarios or different infrastructure alternatives on the landscape and ecological connectivity.

The application of this model to the Barcelona Metropolitan Area (BMA), 16% of which is currently classified as urban, showed that 65% of the BMA area is currently occupied by functional ecological areas, and that 18% is covered by artificial barriers, although they have a direct negative impact on 56.5% of the area. The model also allowed the identification of vulnerable spots, including 1.7% of the BMA that has a critical importance for ecological connectivity, as well as the network of landscape linkages and ecological corridors that offer a high restoration potential. Further applications of this methodology assessing the impacts of regional and urban plans on ecological connectivity, suggest than it could easily be extrapolated to other regions.

Keywords: Barcelona; GIS; Metropolitan area; Ecological connectivity; Regional planning

1. Introduction

Since the 1990s, scientific concerns for habitat and ecosystem fragmentation and landscape and ecological connectivity has entered the political arena, as can bee seen the Global Strategy for Biodiversity (1992), the Habitat Directive (1992), the Paneuropean Strategy of Biological and Landscape Diversity (1995) or the Biodiversity Strategy of the European Community (1998). The EECONET (European Ecological Network) declaration, endorsed by the European Union Treaty (1991) has fostered a gradual development of ecological networks in many European countries (Jongman, 1995; Kubes, 1996). The principles

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suggested by the EECONET framework include that the network: (1) must encompass the places of greatest importance for the conservation of the biological and landscape related diversity, (2) must guarantee the keeping of the ecological processes and the connectivity of the territory, (3) must be incorporated into the planning of the territory, and (4) must promote sustainable development (Bennet, 1991).

The analysis and modeling of ecological permeability or connectivity has been the goal of several methodological developments in different countries, usually based on landscape ecology principles (Beier and Noss, 1998; Gustafson and Gardner, 1996; With and Crist, 1995; Forman, 1990; Schreiber, 1987) such as in the Netherlands or Denmark (Brandt, 1995), although in some cases, such as the Estonia ecological network (Sepp et al., 1999) or the Territorial System of Ecological Stability developed in Slovakia and the Czech Republics (Kubes, 1996) combine these principles with planning pragmatic approaches.

However, there is a lack of quantitative methods of landscape ecology to cost effectively assess ecological connectivity or ecological fragmentation at regional scale, in a way that can be easily incorporated into the planning processes and the strategic environmental assessment. A difficulty that most existing methodologies have for assessing ecological connectivity is that they are very data demanding, including distribution of linear features and movement requirements for key species (Múgica et al., 2002). As suggested by Gardner and O'Neill (1990) the simplest model that can adequately explain the observed phenomena is the most useful.

This paper has a double purpose; first, to present a new Geographic Information Systems (GIS) quantitative methodology, based on landscape ecology principles, for assessing several aspects related with landscape and ecological connectivity, that could be applied either to regional planning or to strategic environmental impact assessment. And second, to show the performance of this methodology in a case study, the Barcelona Metropolitan Area (BMA), in Catalonia, Northeastern Spain, displaying some preliminary results, and discussing its implications. Since our methodology was developed in the BMA, we first present some key characteristics of this area.

2. The Metropolitan Area of Barcelona

The Barcelona Metropolitan Area is one of the most densely populated areas of Europe. With a surface of 3200 km^2 and 4.2 million people, it currently has a density of 1300 inhabitants/km^2. However, BMA also maintains natural areas of great value, with a high landscape and biological diversity, from Mediterranean sierras and cliffs, extensive agrosystems, to sandy, rocky coastal areas and deltas, totaling over 40 habitats of European significance, to be included within the Nature 2000 network. No wonder, therefore, that the BMA has been identified as one of the European regions with the highest concentration of pressures and impacts on the environment (European Environmental Agency, 1999).

Since the establishment of the first Natural Park of Spain in Sant Llorenç del Munt (1972), local and regional governments have been working to provide legal protection to the most significant natural sites, creating a system that, nowadays, almost covers 20% of the BMA (Fig. 1). Most of this system is located on mountain forested areas, which are becoming increasingly isolated by the expansion of urban areas and traffic infrastructures spreading over the valleys and plains. Traffic and energy infrastructures combined cover some 20,000 ha (6% of the BMA).

Typically, municipal land use and urban plans do not take into consideration functional ecological processes, and, as a result, most protected areas located on littoral sierras, such as the Parks of Collserola and Serres de Montnegre-El Corredor, had already become biological islands, surrounded by a sprawl of urban, industrial, commercial areas, and highways.

It is well known that a set of natural areas, even when they are properly designed and managed—which is uncommon—are not sufficient to provide for long term protection of biodiversity, not to mention to perform many other important ecological functions (Forman and Godron, 1986; Noss and Coperrider, 1994). Moreover, recent studies in the BMA have revealed that some components of biodiversity, such as a large number of endangered o threatened bird species, are concentrated outside protected natural areas, specially in agricultural mosaic landscapes, such as the Vallès plains (Pino et al., 2000).

The main cause of habitat and landscape fragmentation in the BMA has been rapid urban and industrial