



Research article

The agri-environmental footprint: A method for the identification and classification of peri-urban areas



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ABSTRACT

The aim of this research is to define and test a methodology for an articulated and systematic analysis of the countryside, which can lend support to urban and landscape planning processes in addition to improving knowledge of the landscape, and for the implementation of agricultural and rural development policies. We have conceived a multi-criteria and multilevel methodology that was integrated into a geographic information system (GIS) and is based on clustering and maximum likelihood classification algorithms. The proposed method focuses on various agri-environmental and socio-economic components, whose synthesis is performed by means of an interpretative key that was developed by the authors, the “Agri-Environmental Footprint”, to quantify the impact of rural areas on urban systems. In particular, this paper presents the general framework of the methodology, a set of indexes that are defined for its first-level analyses, and the results of their implementation through a case study in the Emilia-Romagna Region (Italy). The method is based on the IsoCluster technique, which is associated with statistical analyses of criteria, such as the Principal Component Analysis and different data standardisation algorithms (min–max and z-score). The case study has allowed an iterative calibration of both the methodological framework and indexes.

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1. Introduction

The lack of harmonious relationships between the urban, rural and natural components of landscape mosaics has led to a loss of the local identity values of many places. In particular, the mutual impacts between urban and rural systems have become dramatically evident in peri-urban areas. The iconic concept of *footprints* is often used in the scientific literature to describe the transformations of such contexts. The *urban footprint* (Socco, 2004; Angel et al., 2007) and the *ecological footprint* (Rees and Wackernagel, 1996; Eaton et al., 2007; Muñoz and Galindo, 2005) address the assessment of the negative impacts of human actions on ecosystems in terms of resource consumption and habitat alteration.

This paper presents the first part of a research that focuses on peri-urban contexts to analyse the potential roles and key functions of non-urbanised areas that are located close to residential and production spaces. The manifold functions of the agricultural sector can substantially contribute to the overall balance of these hybrid

urban-rural spaces (La Greca et al., 2011) and thus to their potential of favouring a systemic landscape balance (Donadieu, 1998). Moreover, the preservation and enhancement of the agricultural characteristics of peri-urban areas through suitable rural development policies and tools (Ministry of Cultural Heritage and Activities, 2004; Commission of the European Communities, 2001) prove fundamental for the protection of landscape identity, a priority goal that was issued by the European Landscape Convention and various national and regional land-use management laws (Commission of the European Communities, 2001; Ministry of Cultural Heritage and Activities, 2004; Ministry of Environment of Denmark, 2007; Priore, 2008; Gibelli, 2008; Emilia-Romagna Region, 2009). This framework calls for the implementation of actions to preserve typical landscape features and properly conduct landscape management for the social, environmental and economic sustainability of landscape changes (Gibelli, 2008). Standard landscape analysis procedures that lend support to urban and rural planning usually consist of a decomposition and subsequent synthesis of the various landscape components, which are identified and inventoried in knowledge frameworks that focus on socio-economic and landscape systems (Romano and Ciabò, 2008; Gambino, 2011). Such analyses classify

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urban and rural systems into homogeneous spatial units in terms of characteristics and change trends. The synthesis, interpretation and evaluation phases of those analyses prove crucial because their approaches can deeply influence the quality of the results.

The general goal of our research is the development and validation of an innovative quantitative and multi-criteria methodological approach to classify the countryside that is based on its agricultural, environmental, and socioeconomic profiles, with a particular focus on the aggregation of landscape features. In particular, this study uses a model to characterise peri-urban areas. The proposed method can improve the knowledge of various landscape systems and lend support to the integrated implementation of spatial planning and agricultural and rural development policies.

2. State of the art

2.1. Urban sprawl and new urban-rural spaces

In recent decades, international, national and regional policies as well as studies and scientific research works have been paying increasing attention to the efficiency of settlement systems in relation to soil sealing, thus encouraging multidisciplinary approaches that cover the urban planning, agricultural, and landscape ecology fields, etc. (Zeng et al., 2005). The lack of proper planning and monitoring of land-use changes is likely to lead to a progressive increase in the erosion of the countryside because of urban growth, resulting in agronomic, environmental, economic and social problems. Moreover, fringe areas that are created by urbanisation processes (Antrop, 2000; Antrop and Van Eetvelde, 2000) are characterised by different land uses and high morphologic and functional fragmentation (Díaz-Palacios-Sisternes et al., 2014).

2.2. Methods and tools for the analysis of peri-urban areas

The scientific language, definitions, indexes and methodologies that are used in various research works about landscape processes are not uniform. First, no unique definition exists for the *urban* and *rural* land typologies themselves (Organisation for Economic Co-Operation and Development, 1994). Therefore, no established criteria for the classification of *peri-urban* landscapes exist. Moreover, no homogeneous codification of spatial information exists at the national and regional levels. This often does not allow a comparison of the various classifications, definitions and interpretations of rural landscape changes. Many studies have addressed such issues and developed indexes, parameters and methods to describe urban sprawl and countryside trends. Many scholars have used landscape metrics (Antrop and Van Eetvelde, 2000; Croissant, 2004; Ramachandra et al., 2015) that were computed by means of a geographic information system (GIS) to describe the complexity and structure of landscapes and assess their changes. Several authors (Cooper and Murray, 1992; Reger et al., 2007; Wade et al., 2009; Purvis et al., 2009; Styers et al., 2010; Vizzari, 2011) have used clustering techniques (Ball and Hall, 1965) for systematic landscape characterisation and the creation of classes of homogenous spatial data. The analytical and integrated study of landscape trends is also the subject of initiatives such as IRENA's "Indicator Reporting on the Integration of Environmental Concerns into Agricultural Policy" (Commission of the European Communities, 2001, 2006; European Environmental Agency, 2006) and related projects, which specifically identify sets of agri-environmental indicators that are useful for monitoring the integration of environmental issues and EU agricultural policies and focus on farm management practices and production systems, pressures and risks on an environment, and natural resources

conditions. The *Agri-Environmental Footprint Index*, or *AFI* (Purvis et al., 2009), is the result of an interdisciplinary research project that was carried out by seven Member States to develop a common methodology to assess the farm-scale effects of CAP agri-environmental measures. This study was based on comparisons between measured values and indexes that were related to natural resources, biodiversity and landscape quality. The *urban footprint* is an aggregate index that consists of a set of indicators that were conceived to assess the impact of urban systems on peri-urban agricultural areas and to evaluate the quality of urban growth based on the ability to protect natural resources (Socco, 2004). Several institutions and agencies, such as the Organisation for Economic Cooperation and Development (OECD), the Joint Research Centre (JRC), and the European Environmental Agency (EEA), have developed extensive literature for the description of specific phenomena, such as soil sealing, urbanisation, and landscape fragmentation, which are caused by the growth of infrastructures and sprawled built-up areas to assess and mitigate their impacts on the countryside and ecosystems (Piorr et al., 2011; European Environmental Agency, 2011; Prokop, 2011; Commission of the European Communities, 2012; Organisation for Economic Co-Operation and Development, 2009, 2012).

Multi-criteria land analyses can significantly benefit from the use of GIS tools, which allow a combined reading of spatial information and spatialised data, by using both geometrical properties and feature attribute data (Malczewski, 1999). Moreover, GIS can integrate subjective and objective approaches during the selection of analysis rules and in land classification, respectively (Brabyn, 2005).

The short review above shows how an increasing amount of quantitative tools have become available over time, allowing us to measure the conditions and dynamics of the countryside with reference to various specific elements. Therefore, developing analysis models that are well-suited to real applications in the urban and rural planning process by means of an objective and transparent integration of huge amounts of information from various subject categories is topical. These models should allow us to safeguard the complexity and richness of input data.

3. Materials and methods

3.1. Methodological approach and case-study area

The basic assumptions for the development of this methodological approach are a renewed concept of the peri-urban space, which is based on its potentials and vulnerabilities, and the related "Agri-Environmental Footprint" (AEF) postulate, which introduces a new point of view with reference to the established concept of *footprint* that is described above. This new perspective, which is defined by means of an in-depth analysis of the scientific literature and a study of the critical issues and challenges of rural landscape (see the following section), refers to the potential positive impacts of non-urbanised spaces on urban systems depending on the former's agricultural, environmental, landscape and socio-economical profiles. Therefore, this approach benefits from the scientific literature in the footprint sector; however, we have interpreted this background through an original and opposite perspective.

In this paper, we present the general framework (Fig. 1) of the proposed methodology and a set of indexes that are defined and validated for its first-level analyses. Moreover, we present the results of their first implementation through a case study in a region of the Po Valley (Italy), where the centuriated landscape pattern is still well preserved and the agricultural sector is mainly represented by small and medium-sized farms, whose farmsteads form a scattered rural settlements system. This case study, in addition to advancing the knowledge of this specific geographic context, allows

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