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Characterization of non-urbanized areas for land-use planning of agricultural and green infrastructure in urban contexts

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HIGHLIGHTS

- Non Urbanised Areas (NUAs) have a crucial role in ecosystem service provision.
- NUAs are endangered by urban sprawl processes in metropolitan areas.
- A method for NUAs characterization based on 5 different analytical phases is proposed.
- Results from the method are used to define a new scenario of land uses for NUAs.
- This scenario is aimed at the protection and enhancing of urban ecosystem services.

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ABSTRACT

Non-urbanized areas (NUAs) are outdoor places with significant amounts of vegetation. They are mainly semi-natural patches that represent the last remnants of nature in metropolitan areas. As part of the agricultural and green infrastructure they provide ecosystem services, such as purification of air and water, mitigation of floods and droughts, re-generation of soil fertility, moderation of temperature extremes and enhancing of landscape quality. Like all natural ecosystems, NUAs today are endangered by urban sprawl, which is the main cause of their fragmentation and loss of evapotranspiration features. For these reasons, the protection of these areas is a fundamental issue for land-use planning, and it requires appropriate strategies for their management. We propose a land-use suitability strategy, based on five different analytical phases, to address the land-use of NUAs: (1) land-use and land cover analysis quantifies the percentage of evapotranspiring surface for each land-use; (2) fragmentation analysis assesses the size and density of NUAs; (3) proximity analysis takes into account the degree to which NUAs are close to residential areas; (4) the results from these analyses are integrated in a land-use suitability matrix, which produces as output a new scenario of prospective land-uses for NUAs; (5) a compatibility matrix verifies the correspondence of these new land-uses with the current ones to confirm or modify the proposed land-uses. The resulting scenario allows to enhance the production of ecosystem services and define new appropriate land-uses for NUAs within the agricultural and green infrastructure. The method is tested on three municipalities within the Catania metropolitan area (Italy), characterized by a considerable urban sprawl.

1. Introduction

Ecosystem services are the conditions and processes through which natural ecosystems and the species that compose them sustain and fulfill human life (Daily, 1997). These services include, among others, purification of air and water, mitigation of floods and droughts, detoxification and decomposition of waste, generation and renewal of soil fertility, regulation of climate, moderation of temperature extremes, provision of aesthetic beauty and intellectual stimulation (Bolund & Hunhammar, 1999).

The relationship between ecosystems and urban settlements is complex and multifaceted. A conceptual framework for analyzing these interactions has been proposed by Tzoulas et al. (2007), and many studies have addressed these issues on a global scale. Among these studies, the following issues have been examined: a definition of green infrastructure (Sandström, 2002), an assessment of the economic value (Costanza et al., 1997) and a definition of planning and design criteria (Walmsley, 2006).

Non-urbanized areas (NUAs) are part of the agriculture and green infrastructure that produce ecosystem services (La Greca, La Rosa, Martinico, & Privitera, 2011). They are outdoor places with significant amounts of vegetation, mainly semi-natural areas that,

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especially in urban contexts, represent the last remnants of nature (Jim & Chen, 2003). In urban areas NUAs provide multiple services: they preserve biodiversity (Dinetti, Cignini, Fraissinet, & Zapparoli, 1996; Kowarik, 2011), sequester CO_2 (McHale, McPherson, & Burke, 2007), produce O_2 (Jo, 2002), reduce air pollution (Yang, McBride, Zhou, & Sun, 2005) and noise (Fang & Ling, 2003), regulate microclimates, reduce the heat island effect (Shin & Lee, 2005), affect house prices (Kong & Nakagoshi, 2006), have recreational value (Tarrant & Cordell, 2002) and are useful for health, well-being and social safety (Groenewegen, Berg, Vries, & Verheij, 2006).

The consequences of climate change in urban areas (IPCC, 2007) also heighten the importance of ecosystem functions; therefore, mitigation and adaptation actions should be used to maintain the provision of ecosystem services. From this perspective, NUAs play an important role in reducing the consequences of climate change and are particularly important in urban heat islands. Urban greening is the most commonly used strategy to fight against the increasing risk of urban heat waves in cities (Bowler, Buyung-Ali, Knight, & Pullin, 2010).

For agricultural systems, among the many provided services, cultural benefits (e.g., open-space, rural landscape and the cultural heritage of rural lifestyles) are those that can be especially difficult to evaluate. Moreover, other socio-economic values can come from the new forms of urban agriculture, such as community-supported agriculture, which represent a partnership of mutual commitment between farms and communities of supporters and which provide a direct link between the production and consumption of food (Van En, 1995). Community-supported agriculture can also provide environmental benefits due to an environmentally friendly production process as well as reduced 'food miles' thanks to the proximity between production and consumption (Bougherara, Grolleau, & Mzoughi, 2009). Allotment gardens can provide other important social values, including the active participation of particular social groups such as young children, retired people or un-employed (Rubino, 2007).

Although many ecosystem services are essential for sustaining the long-term well-being of societies (Foley et al., 2005), the degradation of the quantity and quality of these services is expected to continue over the next decades (Millennium Ecosystem Assessment, 2005). Urban sprawl is strictly related to this degradation and it represents the main threat to NUAs in European metropolitan areas. Sprawl is characterized by a mix of low density urban settlements, primarily on the urban fringe, and it is often the result of the lack of a planning strategy. Urban areas at risk of sprawl diffusion are common in southern, eastern and central Europe (EEA, 2006).

As urban areas are expected to keep growing in the future, planners and political decision makers should carefully consider the role of NUAs that provide ecosystem services. Better understanding of the different features of NUAs would allow us to identify the more suitable land-uses to fulfill the aims of conservation and leisure as well as the promotion of new forms of agriculture (La Greca et al., 2011).

This paper proposes a method to characterize the patches of NUAs, in order to identify new land-uses to conserve and enhance the provided ecosystem services. The method is composed of five different phases, all performed with GIS: (1) a land cover analysis (LCA) is used to evaluate evapotranspiration of the different land-use types based on their land cover composition; (2) with a fragmentation analysis (FA), every patch of NUAs is assigned a value of fragmentation, taking into account its dimension and density; (3) a proximity analysis (PA) is conducted to evaluate the proximity of residential parcels to NUAs and to quantify the number of people that have access to NUAs; (4) combining these sets of results, a first option for new land-uses of NUAs is proposed in a land-use suitability matrix; (5) the last analytical step verifies the correspondence of proposed new land-uses with the current ones, using a compatibility matrix.

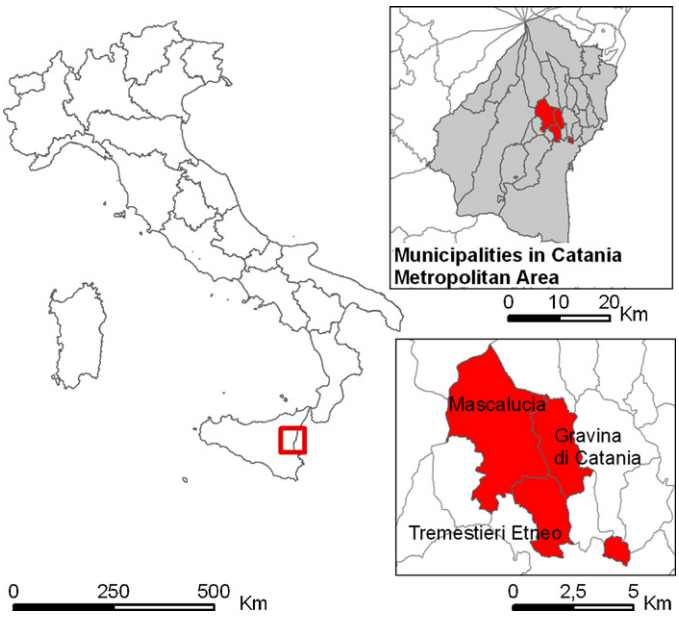

Fig. 1. The study area of the three municipalities of Mascalucia, Gravina di Catania and Tremestieri Etneo in the Catania metropolitan area (Italy).

The work is partially based on a previous model developed by La Greca et al. (2011) that has been improved with the introduction of the proximity analysis and compatibility matrix. The methodology has been applied in three municipalities of the Catania metropolitan area (Italy).

2. Data and methods

2.1. The study area

The case study presented here includes the municipalities of Mascalucia, Tremestieri Etneo and Gravina di Catania (Fig. 1), the most urbanized part of the Catania metropolitan area, in Sicily (Italy). The settlement system is characterized by considerable urban sprawl. In the 27 municipalities included in the official designation of the metropolitan area, the total population had experienced a growth of more than 27% in forty years (1961–2001).

The three municipalities considered are small agricultural towns on the Mt. Etna slopes that have been absorbed into the expanding urban area of Catania. In the late 19th century they had slightly more than 6000 inhabitants and they cover about 2700 ha, with an height range from 200 m to almost 700 m a.s.l.

Economy once dominated by agriculture (wine and oranges), was completely wiped out, first, by holiday houses developments in the 1960–1970s. In the following 20 years these houses became stable dwellings and in 2008 the population of the three municipalities reached more than 77,000 inhabitants.

2.2. Land-use and land cover analysis

The first step has been the construction of a detailed land-use map for the study area, based on vector cartography (1:10,000) produced by regional authorities, municipal vector cartography (1:2000), field surveys and 2008 regional high-resolution orthophotos (0.25 m). Land-uses are mapped in Fig. 2 and summarized in Table 1. It can be seen that built-up areas cover almost half of the municipality. The rest is distributed among farmlands and abandoned farmlands, woods & shrubs, parks & public gardens. Roads cover almost 10% of the total.