Ecological Indicators 108 (2020) 105694

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original Articles

The role of green infrastructures in Italian cities by linking natural and social capital

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ARTICLE INFO

Keywords:
Urban well-being
Social capital indicators
Natural capital indicators
SLOSS debate

ABSTRACT

Urban growth causes numerous threats to human well-being, as a consequence of the loss and degradation of urban and peri-urban green spaces. This research aims to investigate the possible role of green infrastructures (GIs), as providers of ecosystem services, in enhancing urban well-being in the 116 Italian provincial capital cities. The analysis has been based on the conceptual model proposed by the Millennium Ecosystem Assessment (MEA) (2005) to explain how the four categories of ecosystem services (supporting, provisioning, regulating, and cultural) and the components of human well-being are interrelated. In order to perform the assessment, the most suitable indicators of social capital and green infrastructures have been identified from the panel of indices and indicators provided by national official statistics. The corresponding analysis has highlighted that northern Italian cities are characterized by simple but well-managed green infrastructures and wooded areas, with the highest level of social cohesion and inclusion associated with a high value of Gross Domestic Product (GDP) per capita. The southern part of the country is characterized mainly by "Historical greens" and high levels of health and social security but low levels of income, social inclusion and cohesion. This research represents a first attempt to link the different typologies of green infrastructures with the provision of ecosystem services. Given the recognized contribution of GIs in preserving natural habitats in an urban context, the SLOSS (single large or several small) debate, typically applied for conservation purposes, could also be appropriate for GIs. Therefore, it could be necessary to investigate whether fewer large nature preserves (large urban parks), or a patchwork of smaller green areas can better enhance human well-being in an urban context.

1. Introduction

Rapid urbanization and globalization have become important issues in the urban development process (Gong and Hu, 2016) marking them as two of the greatest threats to global biodiversity (Seto et al., 2012). The world's urban population, in fact, is expected to increase by more than two-thirds by 2050, from 3.9 billion in 2014 to 6.3 billion in 2050 (United Nations, 2014) and, at the global scale, the general level of human well-being, as measured by Human Development Index, has been steadily rising in spite of (not because of) the widely acknowledged declining trend in ecosystem services during the past several decades (Wu, 2014). This appears even more worrying considering that climate change will have a significant impact on city environments. Urban growth, by changing urban and peri-urban areas, causes numerous threats to human well-being, due to the loss and degradation of urban and peri-urban green spaces (Tzoulas et al., 2007; Lin and Fuller, 2013; Haaland and Konijnendijk van den Bosch, 2015).

1.1. Green infrastructures and wellbeing

Cities as complex socio-ecological systems (Elmqvist et al., 2004; Cook et al., 2012; McHale et al., 2015) represent the correct context where natural and social dimensions can be studied simultaneously (McPhearson et al., 2016; Pickett et al., 2016). In this context, urban green infrastructures can play a crucial role in promoting the reciprocal connections between natural and social capital in sustaining human well-being (Gómez-Baggethun et al., 2010, 2013) due to their capacity to promote urban quality of life (de la Barrera et al., 2016).

In general, the term green infrastructures refers to "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services" within urban areas (Naumann et al., 2011; European Commission, 2013) and at different spatial scales (Tzoulas et al., 2007), some of which have not long been recognized by planners or social scientists. Recently, there has been a rapid increase in research focused on urban ecosystem services, and most studies so far have

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https://doi.org/10.1016/j.ecolind.2019.105694
Received 11 June 2019; Received in revised form 10 August 2019; Accepted 3 September 2019
Available online 10 September 2019
1470-160X/

focused on green spaces (Wu, 2014). A large number of studies have highlighted that green infrastructures as green spaces in the urban context can be positively related to human well-being (Dunn, 2010; Naumann et al., 2011; Young, 2011; MacKerron and Mourato, 2013; Shanahan et al., 2015; Hartig and Kahn, 2016; Bauduceau et al., 2015; WHO, 2015a; WHO, 2015b; EEA, 2016; WHO, 2016), and have documented that urban green (vegetation) and blue (water) spaces provide several ecological, environmental, economic, and socio-cultural benefits (Bolund and Hunhammar, 1999; Morris, 2003; Tratalos et al., 2007; Termorshuizen and Opdam, 2009; Barton and Pretty, 2010; Lundy and Wade, 2011; Pataki et al., 2011; MacKerron and Mourato, 2013).

Thus, the integration of the concept of green infrastructures into the urban planning process can preserve natural capital, through the mitigation of human pressures (Pakzad and Osmond, 2016; Ives et al., 2016), and sustain social capital, allowing people to live in contact with nature. There are several regulating services related to urban green infrastructures. It is possible to list the regulation of air quality in urban areas (Dunn, 2010; Al-Dabbous and Kumar, 2014; Gallagher et al., 2015), the mitigation of urban heat island effects (Dunn, 2010; Vaz Monteiro et al., 2019) and the regulation of runoff and flooding (Pearlmutter et al., 2017). Green infrastructures can be associated with a wide range of different functions that allow for the improvement of urban aesthetics (Dunn, 2010; Young, 2011), biodiversity conservation (McDonald et al., 2005; Kambites and Owen, 2006; Naumann et al., 2011; European Commission, 2013), water management (Kambites and Owen, 2006; Dunn, 2010; Naumann et al., 2011; Young, 2011; European Commission, 2013), sustainable land management (McDonald et al., 2005; Naumann et al., 2011), climate change mitigation and adaptation (Naumann et al., 2011; Young, 2011; Moore and Hunt, 2013), and urban regeneration (Kambites and Owen, 2006; Dunn, 2010; Wright, 2011).

From the social capital perspective, the research indicates several human benefits that, among others, include positive psychological, cognitive (Pretty et al., 2005; WHO, 2016), physiological and social impacts (Romanelli et al., 2015; Sandifer et al., 2015) the promotion of physical activity (Bowler et al., 2010; Claessens et al., 2014; Hartig and Kahn, 2016), the enabling of stress reduction (MacKerron and Mourato, 2013; Hartig et al., 2014) and the encouraging of socially cohesive communities (e.g. White et al., 2013; van den Berg et al., 2015; Alaimo et al., 2016; Al-Delaimy and Webb, 2017). The social capital associated with green infrastructures is mainly related to intangible and non-material benefits, since they are considered ideal places for promoting healthy practices (Lee and Maheswaran, 2011; Dobbs et al., 2014; Marselle et al., 2015), relaxation and nature contemplation (Chiesura, 2004; Larondelle et al., 2014; Carrus et al., 2015), or, spaces where it can be possible to value natural beauty, to learn about nature and to practice sport (Lindholst, 2009; Hofmann et al., 2012).

Assessing how urbanization affects biodiversity and ecological functions and processes has been a major research focus in most ecological and environmental studies of cities during the past several decades (Wu, 2014). In this context, this research aims to investigate the possible role that green infrastructures, by supporting urban biodiversity and provisioning ecosystem services, can play in enhancing urban well-being. For this purpose, the conceptual model proposed by the Millennium Ecosystem Assessment (MEA) (2005) has been applied to urban green infrastructures, to explain how the four categories of ecosystem services, supporting, provisioning, regulating, and cultural ecosystem services intended as natural capital, and the components of human well-being (social capital) are interrelated. In order to perform the assessment, the most suitable indicators of social capital and green infrastructures have been identified from the panel of indices and indicators provided by the national official statistics.

2. Materials and methods

2.1. Study area

The study area is represented by the 116 Italian provincial capital cities (Fig. 1), which should be representative of the other cities in those provinces. They vary greatly in terms of the number of inhabitants, area of the city (in km2), and population density.

2.2. Conceptual model, data acquisition and methods

The conceptual model used in this research is based on the MEA framework that links natural capital with the different components of human well-being. In particular, green infrastructures are intended as ecosystem services providers and, therefore, can support the constituents of urban well-being (Fig. 2). Specifically, Fig. 2 represents the most suitable indicator or index available from the database of the National Statistics Institute (Istituto Nazionale di Statistica – ISTAT – www.istat.it) to estimate the contribution of green infrastructures (by supporting ecosystem services) towards each component of human well-being in an urban context.

The green infrastructures considered in this study are listed below:

- “Historical greens”, i.e. villas, gardens and parks that are of interest because of their landscapes, are of artistic, historical or cultural interest, or are notable for their uncommon beauty according to Legislative Decree n. 42 of 2004 and subsequent amendments.
- “Large urban parks”: parks over 5000 m^2.
- “Equipped green areas”: small parks and gardens.
- “Urban greenery”: permeable and unpaved green areas created for aesthetic or functional purposes, such as for example bicycle lanes, road roundabouts, street trees.
- “Urban forestation”: areas characterized by urban forests.
- “Wooded areas”: landscape context of the cities
- “Gardens”: school, botanical and urban gardens”.
- “Outdoor sports areas”: outdoor areas for sporting activities.
- “Uncultivated green areas”: natural urban green areas with spontaneous vegetation.
- “Other green areas”: other types of urban green areas.

As regards the constituents of well-being associated with green infrastructures, the most suitable indicator(s) refer to different components of urban well-being. In particular, for the topic “Security”, the “Micro-criminality index” has been selected, which is given by the % of total crimes related to micro-criminality over the total crimes in an urban context. It can give specific indication about the level of urban security. For the topic “Health”, two indicators have been chosen: (1) the “Urban air quality – PM10”: given by the number of days when the limit value of PM10 concentration (50 $\mu g/m^3$) is exceeded. It gives an indication of the quality of the air with potential effects on residents’ health. (2) The availability of drinking water given by the percentage of “Resident population served by the drinking water distribution network in the provincial capital city”. Even if this indicator is crucial for human health, in the analyzed case studies it is not a discriminating indicator given the high percentages of residents with access to the drinking water service.

As regards the “Basic material for good life” topic the “Gross per capita income” has been chosen to give an idea of the economic wealth of the various cities under study. This is the most used economic indicator and suitable to represent the ability to access to the basic material for a good life.

Finally, to estimate the topic “Good social relations” two indicators

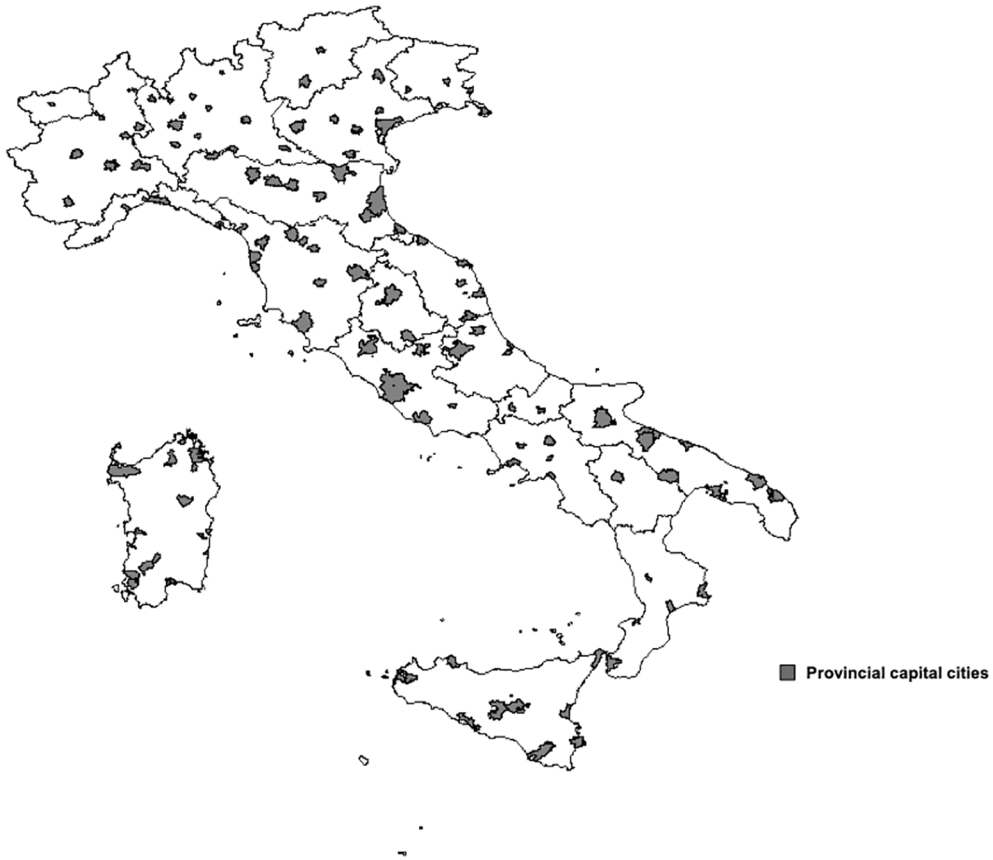

Fig. 1. Study area representing the 116 provincial capital cities in Italy.

have been selected: (1) "Number of non-profit institutions per provincial capital cities" as indicators of social cohesion, and (2) "Percentage of women in decision-making bodies", which gives an indication of social inclusion. Social cohesion and inclusion are two of the main components of social capital. High number of non-profit institutions could mean high availability of local community to be of help for residents in difficulty, which express the level of social cohesion. On the side, the inclusion of women in the decision-making bodies could represent the level of gender equality.

All indicators have been statistically analyzed through Correspondence Analysis using the software "Multi-Variate Statistical Package" (MVSP, Kovach Computing Service, 2018), which is able to explore relationships among qualitative variables (or categorical data) in cross tabulations, and to provide a solution for summarizing and visualizing data set in two-dimension plots. The data satisfied the requirements of Correspondence Analysis: no missing data, no negative values, and all the data had the same scale.

3. Results

3.1. The ecological role of green infrastructures

The results of the correspondence analysis between urban green infrastructures (green squares) and the 116 Italian provincial capital cities (blue triangles) are shown in Fig. 3. The first three components explain almost 68% of the overall variance. In particular, Axis 1 gives

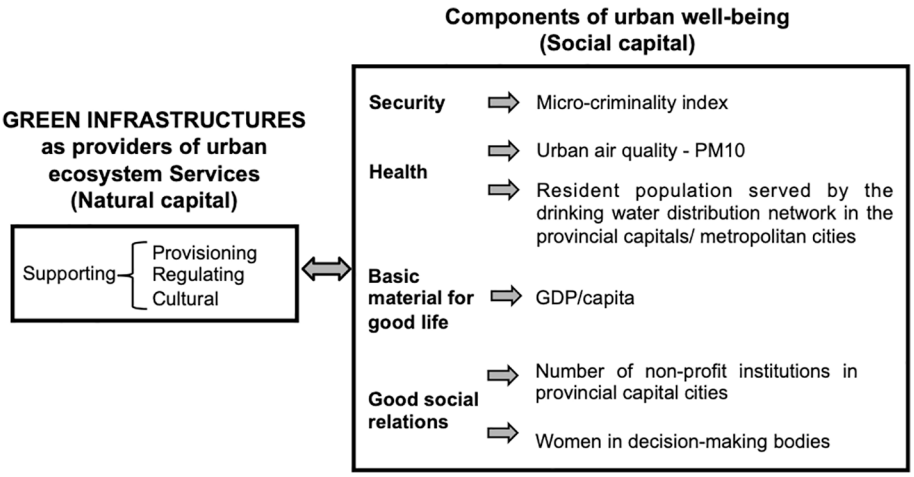

Fig. 2. The conceptual model proposed by the MEA (2005), adapted to the description of the relations between the green infrastructures as providers of ecosystem services and the components of urban well-being. For each component of well-being, the most suitable indicator(s) acquired from the National Statistics Institute (Istituto Nazionale di Statistica - ISTAT) are listed.

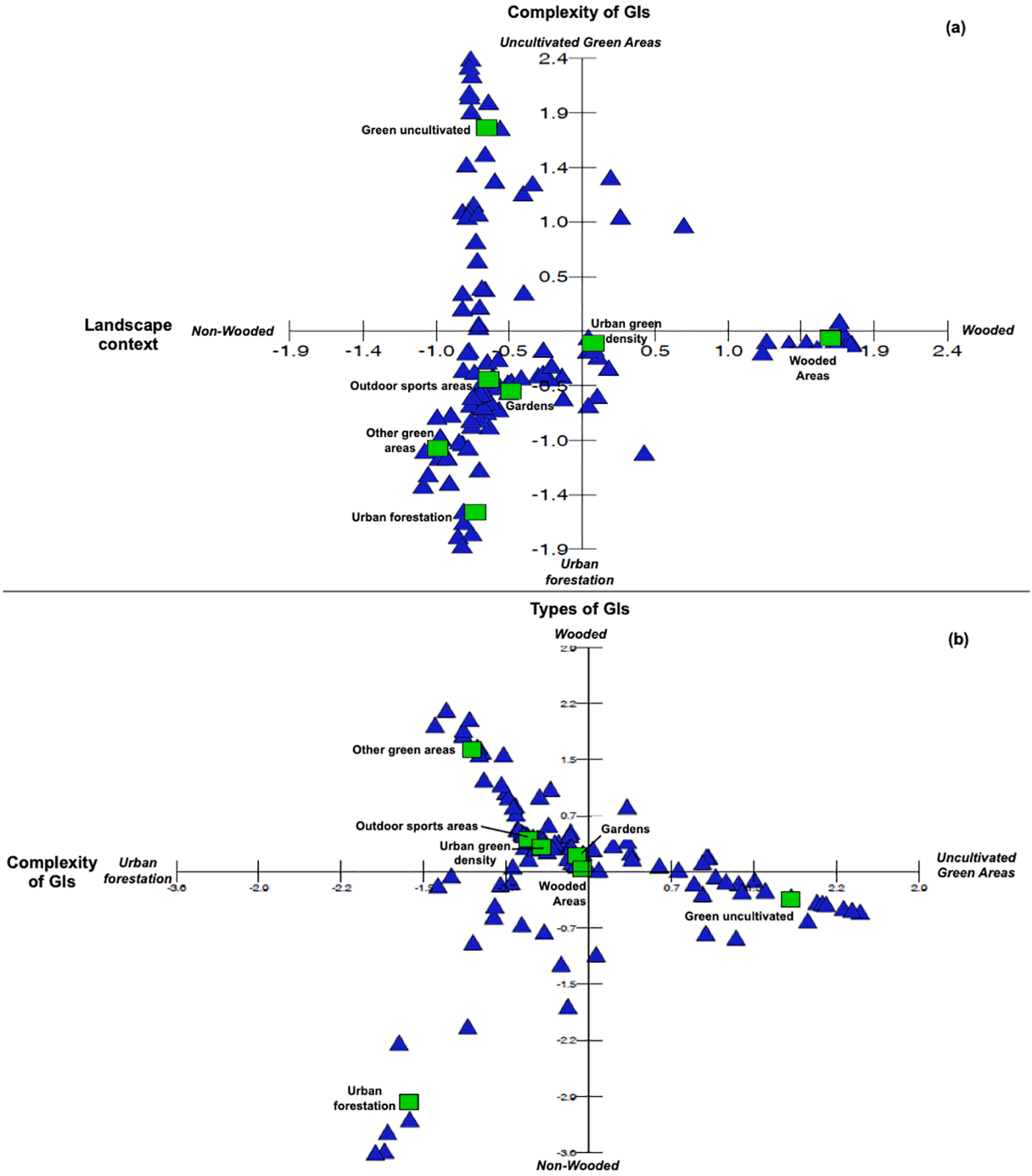

Fig. 3. Correspondence analysis between Natural Capital variables (green squares) and 116 provincial capital cities (blue triangles): (a) Axis 1 (Landscape context of the provincial capitals) and Axis 2 (Complexity of GIs); (b) Axis 2 (Complexity of GIs) and Axis 3 (Types of GIs).

indications about the landscape context of green infrastructures that characterize the cities under study, moving along a gradient from not forested to ever-increasing forested, up to totally forested landscapes. Axis 2 represents the level of complexity of GIs, ranging from simple "green areas not cultivated" to "gardens" up to "Urban forestation" areas, which represents a more complex ecosystem in an urban context. The general complexity of the different green infrastructures is related to the overall complexity of the ecosystem they resemble and can give an insight into the potential flow of ecosystem services provided.

Finally, Axis 3 is based on the typology of green infrastructures. It is possible to observe that northern Italian cities are mainly characterized by simple green infrastructures, namely "Other green areas", with the exception of cities already localized in wooded regions, where the forested landscape context affects the cityscape. In general, more complex green infrastructures can characterize cities localized along the whole national context. The southern part of the country is characterized mainly by "Historical green" areas, while "Forested and wooded areas" interest the islands, specifically the region of Sardinia (Fig. 4).

A first attempt to link the different typologies of green infrastructures with the provision of ecosystem services is based on a short literature review. In particular, it is possible to associate "Wooded areas" with a wide variety of ecosystem services: regulation of water runoff, regulation of air and water quality, microclimate regulation

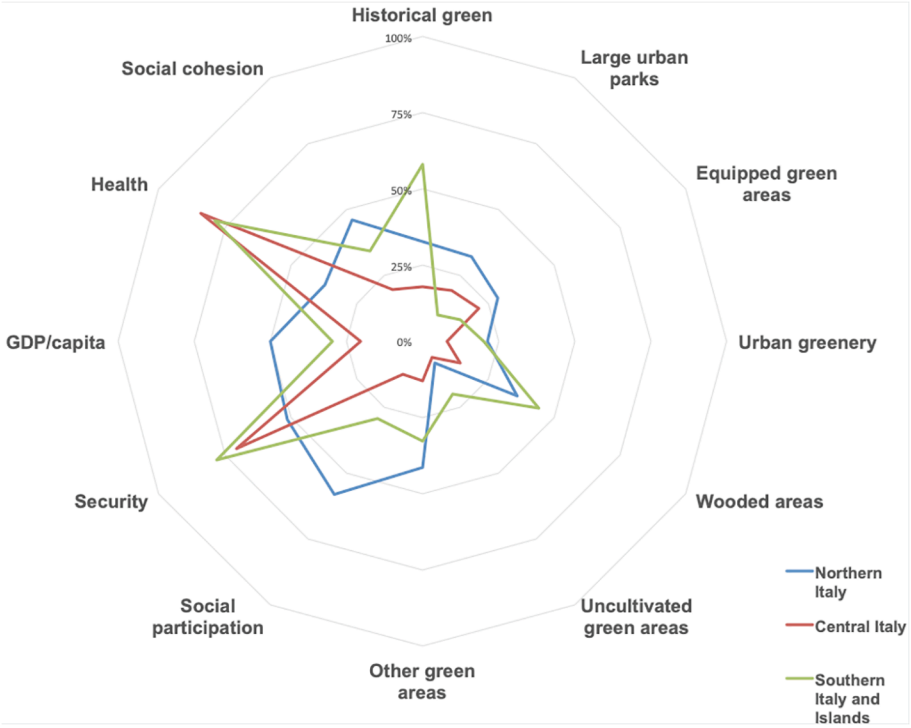

Fig. 4. Graphical representation of the interplay between green infrastructures and the indicators of social capital (social cohesion, health, GDP per capita, Security, and social participation).

(mitigation of urban heat islands), increase of natural habitats in urban context (Abhijith et al., 2017; Barron et al., 2016; Buccolieri et al., 2018; Eisenman et al., 2019; Grote et al., 2016; Livesley et al., 2016; Marando et al., 2019; Nowak et al., 2006; Salmond et al., 2016; Siriwardena et al., 2016; Talarchek, 1990). In addition, by making the urban environment a more pleasant place to live, the wooded areas can increase human health as in the case of southern Italy (Fig. 4), providing numerous health benefits (Akpinara et al., 2016; Payton et al., 2008; Ulrich, 1986; Van den Berg et al., 2015).

Several authors have connected the benefits of large urban parks with aesthetics (Vaz et al., 2018), noise reduction (Cohen et al., 2014) and habitat for small animals and insects (MacIvor et al., 2017), identifying the many social, environmental and economic services they are responsible for (Buchel and Frantzeskaki, 2015; Mellino et al., 2015). For instance, Lin et al. (2011) have related green urban areas to the sequestration or storage of atmospheric carbon and the reduction of temperatures in the neighborhood of the park.

In general, green infrastructures are critical resources since they satisfy the human need for environmental experience (Romolini et al., 2019). However, some GIs provide crucial cultural ecosystem services. The cultural role of some typologies of green areas affects what it is known as “place attachment”, even if not all green areas produce this kind of feeling (Scannell and Gifford, 2017). Historical green, urban parks, and wooded areas seem to be the best candidates for providing cultural ecosystem services.

3.2. The social role of green infrastructures

The correspondence analysis between the variables used as indicators for social capital characterizing the 116 provincial capital cities under study is shown in Fig. 5. The first two components explain almost 94% of the overall variance and, taken together, can give an indication of urban well-being. In particular, Axis 1 represents social security in terms of access to resources, with the “Resident population served by the drinking water distribution network”, on one side, and the “Micro-criminality index” on the other. These two aspects are inversely proportional: it is possible to increase the availability of urban services in contrast with the level of micro-criminality, while the offered services can decrease in the presence of high levels of micro-criminality (low well-being). This tendency is also confirmed by the second axis that shows micro-criminality in opposition to social participation and gender equality (”Number of non-profit institutions “ and ”Women inclusion in the decision-making bodies“) (Fig. 5).

Given the available indicators used in this study, it is possible to see that the northern part of the country shows the highest level of social cohesion and inclusion associated with the high value of GDP per capita, at the expense of human health and urban security. The situation is inverted in central and southern Italy, where levels of health and security are high, but levels of income, social inclusion and cohesion are low (Fig. 4). Therefore, neither northern neither central and southern Italy seem to guarantee all the components of human well-being as identified by MEA. Finally, the economic prosperity given by high value of GDP per capita appears not enough to assure human well-being.

4. Discussion

This research represents a first attempt in linking GIs, as providers of ecosystem services, with the components of human well-being as identified by MEA. Given the recognized interplay between natural and social capital in supporting quality of life (Petrosillo et al., 2013), the results have shown how different typologies of GIs interact with different components of social capital in 116 cities, which represents a good sample of the total Italian cities.

In literature there is the recognition that most commonly used socio-economic and environmental indicators are either difficult to use in policy or fail to comprehensively reflect social well-being and environmental sustainability (Bagstad and Shammin, 2012). In the national statistics the indicators available at the urban level have not been perfectly suitable for the aims of this research, however they can give some indications that can be a starting point to propose new and more targeted indicators. On the other hand, the available indicator for social cohesion (the number of non-profit organizations) is not really suitable

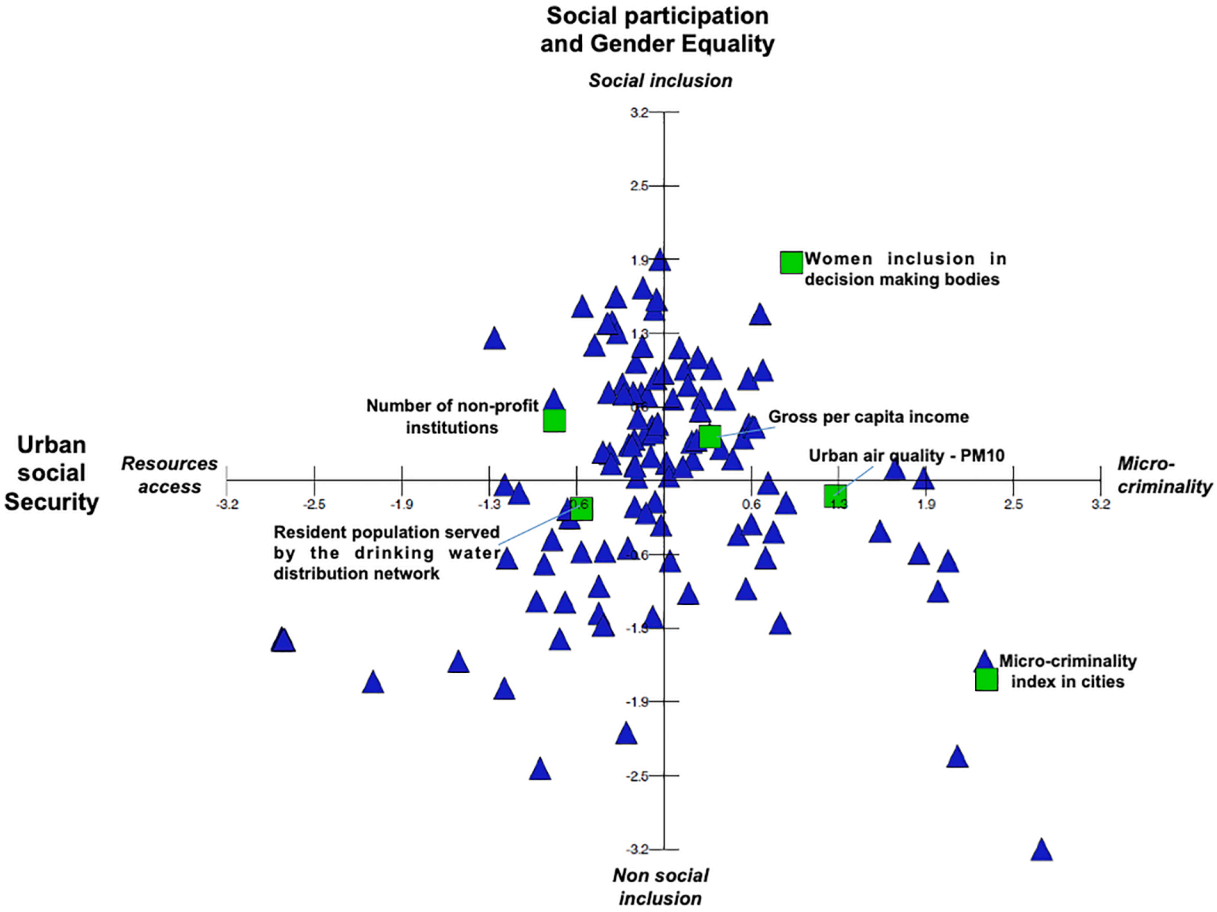

Fig. 5. Correspondence analysis between Social Capital variables (green squares) and 116 provincial capital cities (blue triangles): Axis 1(Resources access and micro-criminality) and Axis 2 (Social inclusion).

to capture the widespread social inclusion, characterizing southern Italy, where it is possible to guarantee a good quality of life despite low income levels (Fig. 4).

In a recent study, Calcagnini and Perugini (2019) analyzed the well-being of the Italian provincial capital cities by elaborating a well-being index, which highlighted a discontinuity across Italy with differences between Northern-Central and Southern regions. However, the approach used in the present study enlarges the perspective to include the ecological aspects, relying on the well-known MEA framework.

What it is still missing regards the perception of the role of GIs in supporting human well-being. The subjective perspective can complete the general picture of GIs in urban context by analyzing the perception and the value assigned to the GIs by people. Citizens are active participants in the cityscape. They think, feel and act, so they attribute a value to specific places where they live, work, visit, for different reasons. Therefore, from the urban planning viewpoint could be relevant to assess not only the beneficial effects related to the presence of GIs (objective assessment), but also the benefits perceived by residents (subjective assessments). It could be possible to verify which typologies of GIs are better perceived as beneficial in comparison with the other, both from the natural and the cultural point of view.

5. Conclusions

GIs play an important role in complex urban ecosystems and provide significant ecosystem services with environmental, aesthetic, recreational and economic benefits.

According to the World Health Organization the urban environment plays a key role for guaranteeing the well-being of its inhabitants, bringing to a considerable effort on urban green space planning to enhance the quality of life. Therefore, the challenge to link natural and social capital in this research represents a novel approach to deal with GIs, encouraging urban planners to increase their extent in the cityscapes.

According to the European Commission (2012), green infrastructure has benefits beyond protecting biodiversity. It also promotes ecosystem services and the well- being of people and has been attributed a role in the development of a green economy and sustainable land management.

The different levels of environmental naturalness linking the concepts of Natural and Social capital together with GIs emphasize the important role of human societies in the maintenance of environmental assets and the ecosystem services they provide. The Green Infrastructure Strategy proposed by the European Commission promotes the development of Green Infrastructure across the EU to deliver economic, social and ecological benefits and contribute to sustainable growth.

Urban green spaces can have many positive effects on human well-being and life satisfaction (Bertram and Rehdanz, 2015) since there are strong linkages between natural capital provided by GIs and social capital in the urban context.

Clearly, the role played by GIs in different cities country-wide depends on the social context. Therefore, to evaluate the double value (social and natural) of GIs in supporting human well-being, it is necessary to take into account the users' perception (Bertram and Rehdanz, 2015; Vierikko et al., 2016; Aronson et al., 2017; Fischer et al., 2018).

Effective planning at the urban level should take into account the

optimal size as well as the most effective spatial allocation of GIs. Given the recognized contribution of GIs in preserving natural habitats in an urban context, the SLOSS (single large or several small) debate, typically applied for conservation purposes, could be appropriate also for GIs. The SLOSS debate is a typical ecological topic applied to biodiversity conservation to discuss if it is better to protect single large or several small hot-spots of biodiversity. This concept is translated to single large or several small GIs in urban context to protect the provision of ecosystem services. Therefore, it could be necessary to investigate whether fewer large nature preserves (large urban parks), or a patchwork of smaller green areas can better enhance human well-being in an urban context.

Acknowledgement

We strongly thank the anonymous Reviewers for their comments and suggestions on the original version of the manuscript.

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