Antonio Leone Carmela Gargiulo
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Environmental and territorial modelling for planning and design

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Environmental and territorial modelling for planning and design

Antonio Leone   Carmela Gargiulo

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This book collects the papers presented at the 10th International Conference INPUT 2018 which will take place in Viterbo from 5th to 8th September. The Conferences pursues multiple objectives with a holistic, boundary-less character to face the complexity of today socio-ecological systems following a systemic approach aimed to problem solving. In particular, the Conference aims to present the state of art of modelling approaches employed in urban and territorial planning in national and international contexts.

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This book is the latest scientific contribution of the "Smart City, Urban Planning for a Sustainable Future" Book Series, dedicated to the collection of research e-books, published by FedOAPress - Federico II Open Access University Press. The volume contains the scientific contributions presented at the INPUT 2018 Conference and evaluated with a double peer review process by the Scientific Committee of the Conference. In detail, this publication, including 63 papers grouped in 11 sessions, for a total of 704 pages, has been edited by some members of the Editorial Staff of "TeMA Journal", here listed in alphabetical order:
- Rosaria Battarra;
- Gerardo Carpentieri;
- Federica Gaglione;
- Rosa Anna La Rocca;
- Rosa Morosini;
- Maria Rosa Tremiterra.

The most heartfelt thanks go to these young and more experienced colleagues for the hard work done in these months. A final word of thanks goes to Professor Roberto Delle Donne, Director of the CAB - Center for Libraries "Roberto Pettorino" of the University of Naples Federico II, for his active availability and the constant support also shown in this last publication.

Rocco Papa
Editor of the Smart City, Urban Planning for a Sustainable Future" Book Series
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INTRODUCTION

Between 5th and 8th September 2018 the tenth edition of the INPUT conference took place in Viterbo, guests of the beautiful setting of the University of Tuscia and its DAFNE Department.

INPUT is managed by an informal group of Italian academic researchers working in many fields related to the exploitation of informatics in planning.

This Tenth Edition pursed multiple objectives with a holistic, boundary-less character, to face the complexity of today socio-ecological systems following a systemic approach aimed to problem solving. In particular, the Conference will aim to present the state of art of modeling approaches employed in urban and territorial planning in national and international contexts.

Moreover, the conference has hosted a Geodesign workshop, by Carl Steinitz (Harvard Graduate School of Design) and Hrishi Ballal (on skype), Tess Canfield, Michele Campagna.

Finally, on the last day of the conference, took place the QGIS hackfest, in which over 20 free software developers from all over Italy discussed the latest news and updates from the QGIS network.

The acronym INPUT was born as INformatics for Urban and Regional Planning. In the transition to graphics, unintentionally, the first term was transformed into "Innovation", with a fine example of serendipity, in which a small mistake turns into something new and intriguing. The opportunity is taken to propose to the organizers and the scientific committee of the next appointment to formalize this change of the acronym.

This 10th edition was focused on Environmental and Territorial Modeling for planning and design. It has been considered a fundamental theme, especially in relation to the issue of environmental sustainability, which requires a rigorous and in-depth analysis of processes, a theme which can be satisfied by the territorial information systems and, above all, by modeling simulation of processes.

In this topic, models are useful with the managerial approach, to highlight the many aspects of complex city and landscape systems. In consequence, their use must be deeply critical, not for rigid forecasts, but as an aid to the management decisions of complex systems.

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ECOSYSTEM SERVICES FOR SPATIAL PLANNING

A REMOTE-SENSING-BASED MAPPING APPROACH

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ABSTRACT

The role of sustainability is becoming even more important in the framework of urban and spatial planning since human well-being is strictly correlated to environmental health. At the same time, new technologies are spreading and permit to have even more spatial information, also thanks to the open access to several satellite images. The topic of ecosystem services mapping, useful to provide an overview of the relationship between the environmental and the territorial and human dynamics, today is still under discussion since it is highly dependent on the type and availability of data, which is not always homogeneous for all the areas. Satellite data can be considered a solution since, in addition to providing homogeneous, continuous and real-time data, they provide quantitative and spatially explicit information that are currently spatialized for ecosystem services assessments with land use land cover maps. Vegetation indices not only are able to identify the distribution of vegetation, but also act as a proxy for mapping and quantifying different ecosystem services linked to biomass provision. A methodology of ecosystem services mapping and assessments on the basis of satellite data is presented in a case study. Through a multi-temporal series of Landsat 8 satellite images collected for the year 2016, the distribution and the magnitude of the ecosystem services associated to biomass provision are mapped using the SAVI (Soil Adjusted Vegetation Index). Such information is subsequently spatialized in relation to a land use land cover map. Finally, results are discussed on the basis of the spatial distribution of ecosystem services and their relationship with different land uses.

KEYWORDS

Ecosystem Services Mapping; Satellite Images; Soil Adjusted Vegetation Index; Plant Biomass; Land Uses

1 INTRODUCTION

The role of sustainability is becoming even more important in the framework of urban and spatial planning since human well-being is strictly correlated to environmental health. At the same time, new technologies (Information and Communication Technology – ICT) are spreading and permit to have even more spatial information, also thanks to the (relatively new) open access to several satellite images, which provide consistent and continuous series of real-time, spatially homogeneous and free of charge data. Even though Remote Sensing (RS) technologies are not that recent, their use has been spreading only in the last period, also thanks to the increasing number of free of charge satellite data provided by non-commercial satellites (e.g. Modis, Landsat, Sentinel). Data coming from satellite images have the potential to be related with other relevant spatial and non-spatial data in order to obtain different data and information products, using methods and tools regarding image analysis techniques, spatial and geo-statistical analysis within GIS-based frameworks. More relevant data coming from satellite images are Vegetation Indices (VIs). Furthermore, the management and analysis of geospatial data from multi-source databases provide important and complex information that can be used in the monitoring, analysis and assessment of environmental concerns, coping with current global challenges such as Climate Change (CC) and environmental sustainability of our cities and territories, which in turn can be communicated to decision-makers to drive and support the development of appropriate strategies and policies.

In this framework, the application of Ecosystem Services (ES) helps to increase awareness that natural ecosystems provide the basis for human well-being, which is a core advantage of this concept (Koschke et al., 2013). Furthermore, ES will have a challenging role in reducing the vulnerability of society to CC (Vignola et al., 2009). ES are the benefits, like services and goods, people obtain from ecosystems (MA, 2005) and are distinguished in four categories: supporting services (services that are necessary for the production of other ES, e.g. nutrient cycling, primary production, soil formation), provisioning services (products obtained from ecosystems, e.g. food, fuelwood, fresh water), regulating services (benefits obtained from the regulation of ecosystem processes, e.g. climate regulation, water regulation, pest and disease control) and cultural services (nonmaterial benefits people obtain from ecosystems, e.g. aesthetic, spiritual, educational values). Because of the spatial peculiarity of ES, mapping their distributions and changes over time has the potential to aggregate complex information (Burkhard et al., 2012), e.g. for ES trade-offs analysis (Gissi et al., 2014, 2016, 2017). This visualization of ES can be used by decision-makers, e.g. land managers, as a powerful tool for the support of landscape sustainability assessments (Swetnam et al., 2011). As a supporting tool it can assist stakeholders and decision-makers (land managers, local or regional planning authorities) in developing sustainable land use strategies (de Groot et al., 2010; MA, 2005; Koschke et al., 2013; Swetnam et al., 2011; TEEB, 2010) and toward a specific policy goal (Gissi et al., 2015). RS supplies consistent time series and real-time data for monitoring ES (Ayanu et al., 2012), providing more accurate and up-to-date information than land use land cover data. It allows not only the description of landcover spatial patterns but also a direct estimation of functional attributes of the ecosystems (Paruelo et al., 2016; Pettorelli et al., 2005), providing quantitative, spatially explicit, and (in some cases) physically based estimates of a number of the biophysical parameters that are currently spatialized for ES assessments with Land Use Land Cover (LULC) maps (Andrew et al., 2014). In particular, VIs can be used as an indicator of productivity during the vegetation growing season (De Araujo Barbosa et al., 2015), since they are able to define phenological variations and photosynthetic potential of crops, allowing to identify crops' growth cycle and process (Brown & de Beurs, 2008; De Araujo Barbosa et al., 2015; Muukkonen & Heiskanen, 2005;

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Prabakaran et al., 2013; Wall et al., 2008; Wardlow & Egbert, 2008). Thus, VIs not only are able to identify the spatial distribution of vegetation, but act as a proxy for mapping and quantitatively assessing the plant biomass provided by ecosystems (De Araujo Barbosa et al., 2015) and several ES linked with its provision. As reported in literature, these services – and the related biophysical processes generating them – are: climate regulation, through the process of carbon sequestration and storage by vegetation (Atzberger, 2013; De Araujo Barbosa et al., 2015; Egoh et al., 2007; Feng et al., 2010; Pettorelli et al., 2014; Rembold et al., 2013; Zurlini et al., 2014;); soil erosion regulation, occurring thanks to the vegetation cover of soil (Andrew et al., 2014; Ayanu et al., 2012; De Araujo Barbosa et al., 2015; Kandziora et al., 2013), which helps to reduce the water and wind erosion; natural hazard regulation, through the process of mass stabilisation fostered by the vegetation cover of soil (De Araujo Barbosa et al., 2015); water cycling and regulation, through the structural and functional properties of vegetation (Zurlini et al., 2014), which feed this cycle, filtering and purifying the water; maintenance of soil fertility, through the structural and functional properties of vegetation (Ayanu et al., 2012; Zurlini et al., 2014), which establish a mutual relationship with the soil, feeding the nutrient cycle; net primary productivity, through the process of capture of the solar energy from the chlorophyll (Zurlini et al., 2014).

A methodology of ES mapping and assessment on the basis of satellite data is presented in a case study, by analysing the distribution and the magnitude of ES linked to the provision of biomass, mapped using a VI as a proxy, in relation to a LULC map. Results are discussed on the basis of the spatial distribution of ES and their relationship with the different land uses and territorial dynamics.

2 METHODOLOGY OF ECOSYSTEM SERVICES MAPPING USING SATELLITE DATA: A CASE STUDY

The case study area corresponds to the Province of Rovigo (Veneto Region, Northern Italy). A multi-temporal series of eight satellite images (Landsat 8) at 30m spatial resolution have been collected for the year 2016, so as to cover all the seasons and, consequently, all the stages of the vegetation growing cycle. The use of the multi-temporal series of satellite images, not only provide a more accurate classification (Prishchepov et al., 2012), but also allows to map the seasonal vegetation (located especially in agricultural crops) that otherwise, using a single image, is unlikely to be identified if the date of acquisition does not cover the vegetation/crop growing season. For each one of the eight images, the VI called Soil Adjusted Vegetation Index (SAVI) was obtained through the calculation of the ratio between two spectral bands (red band and NIR – near-infrared – band) [1]. Then, the annual average value of the SAVI was calculated from the eight images. From the SAVI annual average value image, wherein to higher SAVI values it corresponds a greater presence of plant biomass throughout the year, it was possible to obtain the spatial and quantitative distribution of ES linked to biomass provision, mapped using the VI as a proxy.

Subsequently, in order to understand the relationship between these ES and the territorial and human dynamics, the SAVI annual average value image has been associated with the regional LULC map of Veneto Region (level III of the Corine Land Cover classification). The method is based on the overlapping of the SAVI annual average value image on the LULC map, computing a geo-statistical calculation which combines to each object of the LULC map the corresponding SAVI average value of all the pixels located within the

[1] Formula of the SAVI: (1 + L) * (NIR band – RED band) / (NIR band + RED band + L), where L is the correction factor for the soil brightness, defined as 0.5 to accommodate most land cover types.

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perimeter of the object itself [2]. In this way, it is possible to know the capacity of the territory and different land uses to provide ES linked to biomass provision.

3 RESULTS

Fig. 1 shows the map related to the spatial distribution of the SAVI annual average value within the territory of the province of Rovigo, obtained from the eight satellite images of the time series.

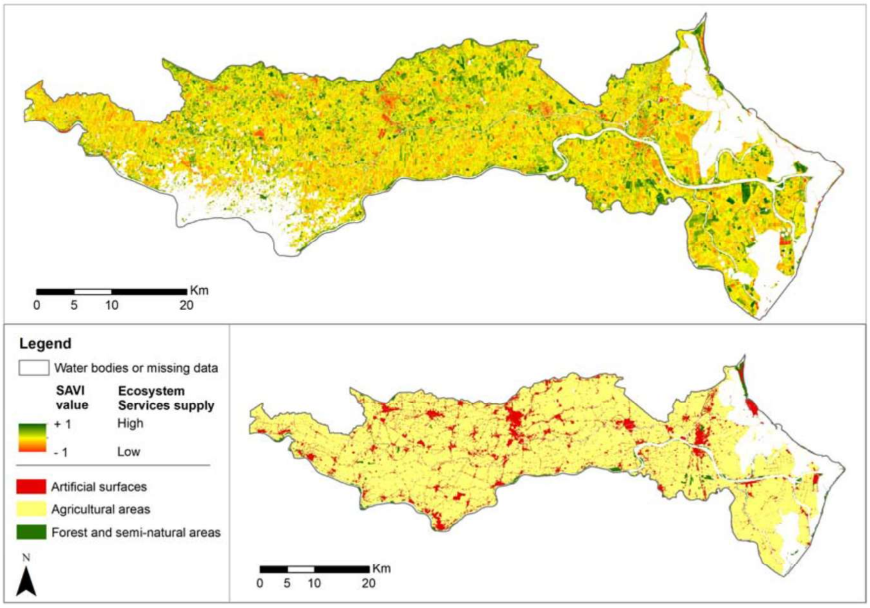

Fig. 1 Map of the SAVI annual average value for the year 2016 (up) and map of the regional LULC – only terrestrial ecosystems – (down)

Associating the map of the SAVI annual average value with the LULC map shown in Fig. 1, by applying the method previously described, three maps related to the capacity of the territory (and of each object and LULC class) of the province of Rovigo to provide ES linked to biomass provision has been elaborated, according to the different terrestrial ecosystems: artificial surfaces (Fig. 2), agricultural areas (Fig. 3) and forest and semi-natural areas (Fig. 4). In addition, for each one of the three maps, the SAVI average value of the objects located within each LULC class was calculated (Tables 1, 2, 3).

The LULC classes related to the artificial surfaces having the higher SAVI values, besides the class "airports" (it's about an herbaceous airfield), are the ones related to the "green urban areas" and "sport and leisure facilities", followed by "soil with special uses (under transformation)" and "widespread urban fabric". The classes having lower SAVI values are the ones related to the "continuous urban fabric", "port areas" and "Industrial or commercial units".

[2] The analysis has been carried out on the terrestrial ecosystems, corresponding to the LULC classes related to 1. Artificial surfaces, 2. Agricultural areas and 3. Forest and semi-natural areas.

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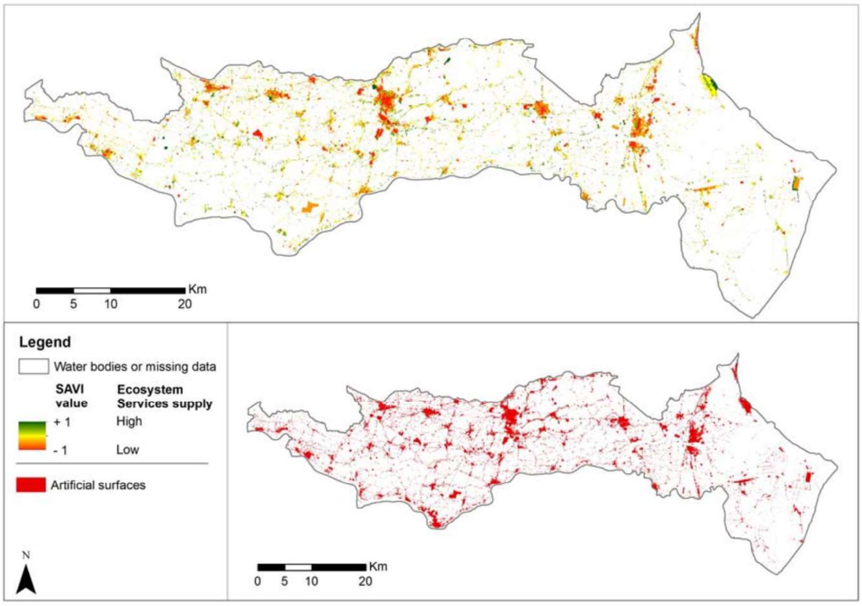

Fig. 2 Map of the capacity of the territory, related to the artificial surfaces, to provide ES linked to biomass provision

LULC CLASSES (ARTIFICIAL SURFACES)	SAVI VALUE	AREA (HA)
1.1.1. Continuous urban fabric	0.14	77
1.1.2. Discontinuous urban fabric	0.29	6,417
1.1.3. Widespread urban fabric	0.32	2,956
1.2.1. Industrial or commercial units	0.24	3,554
1.2.2. Road and rail networks and associated land	0.28	2,274
1.2.3. Port areas	0.14	55
1.2.4. Airports	0.45	8
1.3.1. Mineral extraction sites	0.29	69
1.3.2. Dump sites	0.28	41
1.3.3. Construction sites	0.29	271
1.3.4. Soil with special uses (under transformation)	0.33	269
1.4.1. Green urban areas	0.34	723
1.4.2. Sport and leisure facilities	0.35	725
1. ARTIFICIAL SURFACES	0.30	17,439

Tab. 1 SAVI average value of the objects within LULC classes related to the artificial surfaces

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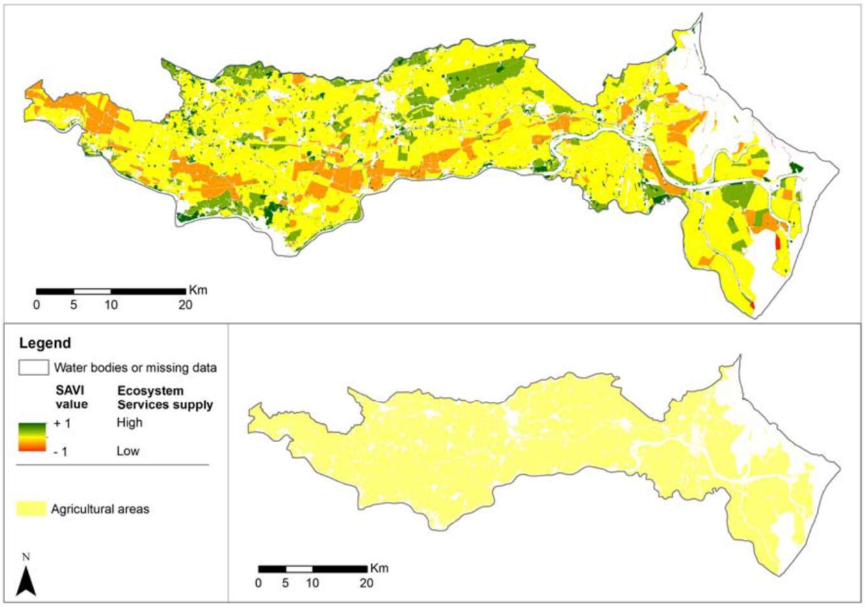

Fig. 3 Map of the capacity of the territory, related to the agricultural areas, to provide ES linked to biomass provision

LULC CLASSES (AGRICULTURAL AREAS)	SAVI VALUE	AREA (HA)
2.1.1. Non-irrigated arable land	0.34	1,363
2.1.2. Permanently irrigated land	0.32	124,959
2.2.1. Vineyards	0.37	548
2.2.2. Fruit trees and berry plantations	0.38	2,202
2.2.4. Other permanent crops	0.38	1,274
2.3.1. Pastures	0.36	2,350
2.3.2. Permanent grassland	0.33	2,584
2.4.1. Annual crops associated with permanent crops	0.33	6
2.4.2. Complex cultivation patterns	0.36	500
2. AGRICULTURAL AREAS	0.35	135,786

Tab. 2 SAVI average value of the objects within LULC classes related to the agricultural areas

All the LULC classes related to the agricultural areas have similar SAVI values. The ones related to the "fruit trees and berry plantations" and "other permanent crops" have slightly above SAVI values, while the class related to the "permanently irrigated land" has a slightly below SAVI value.

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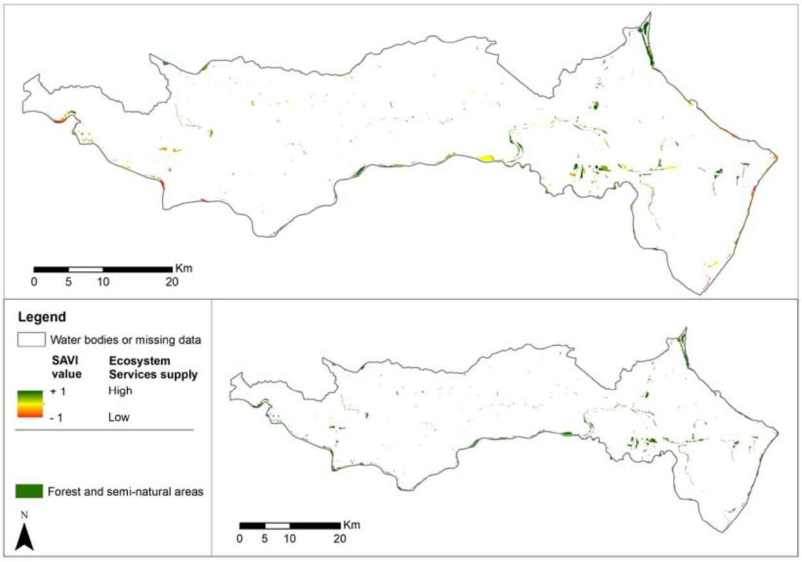

Fig. 4 Map of the capacity of the territory, related to the forest and semi-natural areas, to provide ES linked to biomass provision

LULC CLASSES (FOREST AND SEMI-NATURAL AREAS)	SAVI VALUE	AREA (ha)
3.1.1. Broad-leaved forest	0.37	2,210
3.1.2. Coniferous forest	0.41	233
3.2.1. Natural grasslands	0.27	2
3.2.2. Moors and heathland	0.37	95
3.2.3. Sclerophyllous vegetation	0.41	39
3.3.1. Beaches, dunes, sands	0.14	712
3.3.2. Bare rocks	0.17	4
3. FOREST AND SEMI-NATURAL AREAS	0.34	3,295

Tab. 3 SAVI average value of the objects within LULC classes related to the forest and semi-natural areas

The LULC classes related to the forest and semi-natural areas having the higher SAVI values are the ones related to the "coniferous forest" and "sclerophyllous vegetation", followed by "broad-leaved forest" and "moors and heathland". The classes having lower SAVI values are the ones related to the "Beaches, dunes, sands" and "bare rocks".

4 DISCUSSION

The analysis of the capacity to provide ES linked to biomass provision of each LULC class allows to identify the role of the different land uses, which lie behind the territorial and human dynamics, in supplying such

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ES, in coping with the sustainability and resilience of our society and territories. In the case study area of the province of Rovigo, the SAVI mean value of all the objects related to the terrestrial ecosystems is 0.32. In general, the artificial surfaces, as expected, show a lower SAVI mean value (0.30), demonstrating a lower capacity to provide ES linked to biomass provision than the agricultural areas and the forest and semi-natural areas, which show similar SAVI mean values (respectively 0.35 and 0.34). Analysing single LULC classes, it results that the "coniferous forest" and the "sclerophyllous vegetation" (both related to forest and semi-natural areas) are the ones with the highest capacity to provide such ES, followed by the classes related to the "fruit trees and berry plantations", "other permanent crops" and "vineyards" (related to agricultural areas), and "broad-leaved forest" and "moors and heathland" (related to forest and semi-natural areas). All these classes are marked by a common factor: they are all characterized by trees, shrubs or woody crops, emphasizing the importance of providing ES of such vegetation types. The area covered by these classes (6,601 ha) is only the 4% of the whole case study area (156,520 ha). Other classes with a higher than normal (SAVI value > 0.32) capacity to provide ES linked to biomass provision are the ones related to the other types of cultivation in agricultural areas (except "permanently irrigated land") and the artificial surfaces related to "sport and leisure facilities", "green urban areas" and "soil with special uses (under transformation)". "Permanently irrigated land" is the most common LULC class within agricultural areas (92% of the whole agricultural surface), while simultaneously is the LULC class within agricultural areas with the lower capacity to provide ES linked to biomass provision. Concerning the artificial surfaces, of great importance for the provision of ES are the areas for sport and leisure activities and the urban green spaces (1,448 ha), covering the 8% of the whole artificial surfaces (17,439). Most of the artificial surfaces (87%) are covered by classes related to "discontinuous urban fabric" (6,417 ha), "widespread urban fabric" (2,956 ha), "industrial or commercial units" (3,554 ha) and "road and rail networks and associated land" (2,274). All these classes have a lower than normal (SAVI value < 0.32) capacity to provide ES linked to biomass provision, except "widespread urban fabric". It is worthwhile underlining that this latter class has the highest capacity to provide ES between all the classes related to urban fabric, even though the urban sprawl is considered to produce environmental degradation (Johnson, 2001). It is also true that, if "widespread urban fabric" class covered less areas, it could be room for LULC classes with higher capacity to provide ES (e.g. forests).

5 CONCLUSION

This study presents a methodology of ES mapping using a multi-temporal series of satellite data and a LULC map, suggesting an innovative spatial approach for the analysis of the relationship between the territorial and human dynamics and the provision of ES, which could support a better and more sustainable management of the territory. Such methodology can be easily replicated in other case studies because of the intrinsic characteristics of (non-commercial) satellite data: large spatial coverage, timely availability, temporal continuity and free access. The case study of the province of Rovigo shows, once again, the important role in providing ES played by forests and vegetated semi-natural areas, as well as by the urban green spaces and recreational areas within the urban settlements. However, they cover only a small part of the case study area. Moreover, it shows that most of the agricultural lands is cultivated with crop types and cultivation techniques that do not allow a high provision of ES. This analysis wants to stimulate further remarks and insights about the relationship between the provision of ES and the territorial and human dynamics, in order to support a better planning and management of the territory for the enhancement of the environmental sustainability and human well-being.

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