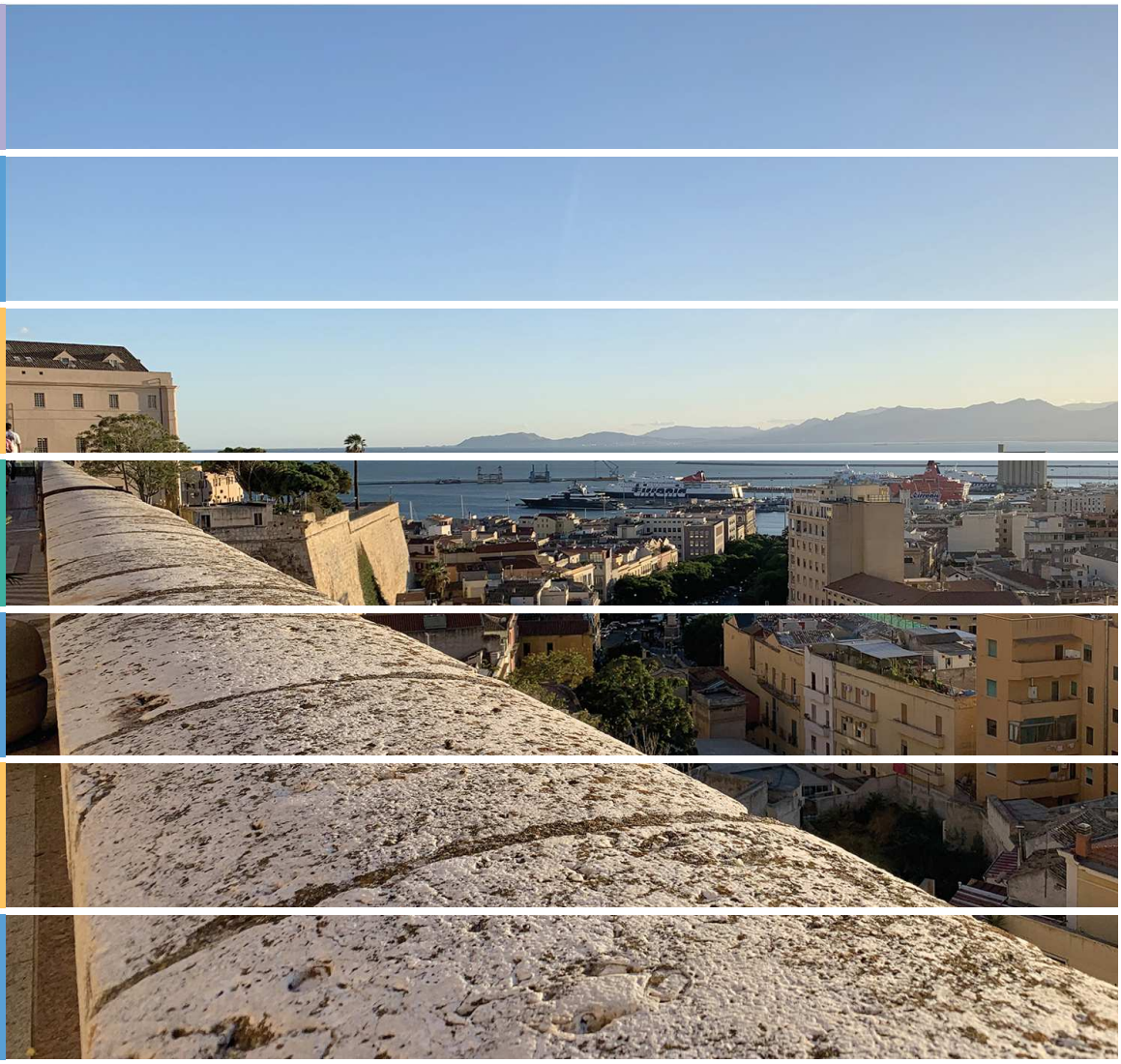
Carmela Gargiulo Corrado Zoppi
Editors

Planning, Nature and Ecosystem Services



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Smart City, Urban Planning for a Sustainable Future

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Carmela Gargiulo Corrado Zoppi

Editors

Planning, Nature and Ecosystem Services

INPUT aCAdemy 2019

Conference proceedings

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This book collects the papers presented at INPUT aCAdemy 2019, a special edition of the INPUT Conference hosted by the Department of Civil and Environmental Engineering, and Architecture (DICAAR) of the University of Cagliari.

INPUT aCAdemy Conference will focus on contemporary planning issues with particular attention to ecosystem services, green and blue infrastructure and governance and management of Natura 2000 sites and coastal marine areas.

INPUT aCAdemy 2019 is organized within the GIREPAM Project (Integrated Management of Ecological Networks through Parks and Marine Areas), co-funded by the European Regional Development Fund (ERDF) in relation to the 2014-2020 Interreg Italy – France (Maritime) Programme.

INPUT aCAdemy 2019 is supported by Società Italiana degli Urbanisti (SIU, the Italian Society of Spatial Planners), Istituto Nazionale di Urbanistica (INU, the Italian National Institute of Urban Planning), UrbIng Ricerca Scientifica (the Association of Spatial Planning Scholars of the Italian Schools of Engineering) and Ordine degli Ingegneri di Cagliari (OIC, Professional Association of Engineers of Cagliari).

This book is the most recent 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 aCAdemy 2019 Conference. In detail, this publication, including 92 papers grouped in 11 sessions, for a total of 1056 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;
- Carmen Guida;
- Rosa Morosini;
- Floriana Zucaro.

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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Table of contents

Session: 2 - Integrated management of marine protected areas and Natura 2000 sites

ISBN: 978-88-6887-054-6
DOI: 10.6093/978-88-6887-054-6

Session 3 - Rural development and conservation of nature and natural resources

Session 4 - Geodesign, planning and urban regeneration

ISBN: 978-88-6887-054-6
DOI: 10.6093/978-88-6887-054-6

Session 5 - Green and blue infrastructure

Session 6 - Smart city planning

ISBN: 978-88-6887-054-6
DOI: 10.6093/978-88-6887-054-6

Session 7 - Water resources, ecosystem services and nature-based solutions in spatial planning

ISBN: 978-88-6887-054-6
DOI: 10.6093/978-88-6887-054-6

Session 8 - Conservation and valorisation of architectural and cultural heritage

Session 9 - Accessibility, mobility and spatial planning

ISBN: 978-88-6887-054-6
DOI: 10.6093/978-88-6887-054-6

Session 10 - Tourism and sustainability in the Sulcis area

Special session 1 - Ecological networks and landscape planning

ISBN: 978-88-6887-054-6
DOI: 10.6093/978-88-6887-054-6

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INTRODUCTION

This e-book contains the Proceedings of the INPUT aCAdemy 2019 Conference held at the University of Cagliari on 24-26 June 2019, titled "Planning, nature and ecosystem services."
Input aCAdemy follows the tenth INPUT Conference, held in September 2018 at Tuscia University, in Viterbo and, in some way, it breaks the biennial tradition of the INPUT Conferences. The reason for the frequency increase of the INPUT Conferences is that the Department of Civil and Environmental Engineering and Architecture of the University of Cagliari is involved in a project funded by the Programme INTERREG Marittimo–Italia France–Maritime 2014–2020, Axis 2.
In the context of the project, entitled "GIREPAM–Integrated Management of Ecological Networks through Parks and Marine Areas", the Department and the Office for Nature Protection and forest policies of the Regional Autonomous Administration of Sardinia are studying and defining an experimental methodology to integrate conservation measures concerning Natura 2000 Sites into marine protected areas regulations. The methodology is implemented to build the new regulations of two marine protected areas of Sardinia, namely the Island of Asinara and of the Island of Tavolara and Cape Coda Cavallo.
Since GIREPAM allocates a considerable amount of funds to the organization of an international conference on protection of nature and natural resources, ecosystem services and their relationship with spatial planning processes and practices, green infrastructure, and integrated management of protected areas and Natura 2000 Sites, and these funds must be spent by December 2019, the research group at the Department proposed to the INPUT Community, during the 2018 Viterbo Conference, a 2019 INPUT Conference focussing on these themes. The INPUT Community responded enthusiastically and, that being so, the research group has made every effort to make the event come true.
The Conference develops through plenary sessions and parallel tracks. The scope of the plenary sessions is to propose distinguished points of view concerning research and implied planning ideas and policies on important and significant issues which feature the ongoing scientific and technical debate on nature and natural resources.
The questions proposed and discussed in the Conference are three central topics which are characterized by several studies available in contemporary literature, and by vibrant debates as well, both from the theoretical and technical points of view. These questions are presented and discussed in the three plenary sessions which are the starting points of the three days of the Conference. Each plenary session is organized as follows: first, a speaker, a distinguished scholar, proposes the findings of his theoretical and/or applied research work and derived implications for spatial policy; secondly, a discussant, a distinguished

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scholar as well, critically analyzes the positions expressed in the first place and identifies open or unresolved questions and outstanding issues; thirdly, the public enters the discussion, through questions, observations, critical positions. Finally, the speaker replies to the discussant's and to the public's statements.

The first plenary session is on "Valuing ecosystem services in money: A necessary evil for protecting biodiversity?"; the speaker is Erik Gomez-Baggethun (Faculty of Landscape and Society, Norwegian University of Life Sciences); the discussant is Andrea Arcidiacono (Department of Architecture and Urban Studies, Polytechnic University of Milan).

The second plenary session concerns "Managing urban ecosystems for goods and services"; the speaker is Kevin Gaston (Environment and Sustainability Institute, University of Exeter); the discussant is Bernardino Romano (Department of Civil, Building-Architecture and Environmental Engineering, University of L'Aquila).

The third plenary session is related to "Mapping and modeling ecosystem services: A cascade ES modeling approach applied to the Flemish Natura 2000 Network"; the speaker is Jan Staes (Department of Biology, University of Antwerp); the discussant is Beniamino Murgante (School of Engineering, University of Basilicata at Potenza).

The topics presented in the plenary sessions are the background of the discussions which characterize the parallel tracks. These tracks are featured by studies which consider protection of nature and natural resources, ecosystem services and their relationship with spatial planning processes and practices, as regards the following topics:

1. Ecosystem services and spatial planning;
2. Integrated management of marine protected areas and Natura 2000 sites;
3. Rural development and conservation of nature and natural resources;
4. Geodesign, planning and urban regeneration;
5. Green and blue infrastructure;
6. Smart city planning;
7. Water resources planning, ecosystem services and nature-based solutions in spatial planning;
8. Conservation and valorisation of architectural and cultural heritage;
9. Accessibility, mobility and spatial planning;
10. Tourism and sustainability in the Sulcis area;
11. Ecological networks and landscape planning.

The closing plenary session of the Conference proposes a roundtable discussion on "Planning Nature 2000 Network and protected areas: The integration of conservation measures into regulations." The roundtable will involve panelists from several institutions who participate in the GIREPAM Project.

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DOI: 10.6093/978-88-6887-054-6

Carmela Gargiulo is full professor of Urban Planning Techniques at the University of Naples Federico II. Since 1987 she has been involved in studies on the management of urban and territorial transformations. Since 2004, she has been Member of the Researcher Doctorate in Hydraulic, Transport and Territorial Systems Engineering of the University of Naples "Federico II". She is Member of the Committee of the Civil, Architectural and Environmental Engineering Department of the University of Naples "Federico II". Her research interests focus on the processes of urban requalification, on relationships between urban transformations and mobility, and on the estate exploitation produced by urban transformations. On these subjects she has co-ordinated research teams within National Project such as Progetto Finalizzato Edilizia - Sottoprogetto "Processi e procedure" (Targeted Project on Building – Subproject "Processes and procedures), from 1992 to 1994; Progetto Strategico Aree Metropolitane e Ambiente, (Strategic Project Metropolitan Areas and Environment) from 1994 to 1995; PRIN project on the "Impacts of mobility policies on urban transformability, environment and property market" from 2011 to 2013. Principal investigator of the Project Smart Energy Master for the energy management of territory financed by PON 04A2_00120 R&C Axis II, from 2012 to 2015. Scientific Responsible Unit Dicea Project by Fondazione Cariplo "MOBILAGE. Mobility and aging: daily life and welfare supportive networks at the neighborhood level" 2018-2020. Scientific Responsible Unit TeMALab Dicea ERASMUS+ Key Action2: Project "Development of a Master Programme in the Management of Industrial Entrepreneurship for Transition Countries" (MIETC), partners: University of Santiago de Compostela (leading organization), University of Ljubljana, Academy of Science of Turkmenistan, Karaganda Economic University of Kazpotrebsouz (2020-2022). Author of more than 130 publications. Since 2008 Associate Editor of TeMA Journal of Land Use, Mobility and Environment.

Corrado Zoppi, Civil engineer, is Doctor of Philosophy in Economics (Northeastern University, Boston, Massachusetts, United States, 1997), Doctor of Research in Territorial Planning (University of Reggio Calabria, 1992), and Master of Science in Economic Policy and Planning (Northeastern University, 1990). Since October I 2015 he is Professor (Full Professor, Scientific Disciplinary Sector ICAR/20 Urban and Regional Technique and Planning)) at the Department of Civil, Environmental Engineering and Architecture. In the past, he taught at the Faculty of Engineering of the University of Cagliari, and at the Faculties of Architecture of the Universities of Rome "La Sapienza" and Sassari-Alghero. He is presently the Official Professor of the Module of Strategic Planning of the Integrated Course of Strategic Environmental Planning and of the Course of Regional and Urban Planning at the Faculty of Engineering of the University of Cagliari, and the Coordinator of the Undergraduate and Magisterial Degree Programs at the Faculty of Engineering and Architecture of the University of Cagliari. He was the Coordinator of the Panel for the Assessment and Evaluation of Public Investments of the Sardinian Regional Administration in the period 2007-2013. He was the Coordinator of the Graduate Committee of Environmental and Territorial Engineering of the University of Cagliari in the period 2012-2015. He is the President of the Faculty Committee of Engineering and Architecture of the University of Cagliari.

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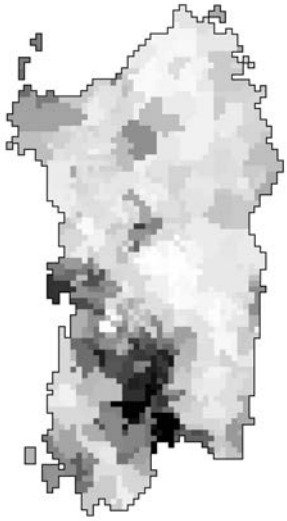

CARBON SEQUESTRATION AND LAND-TAKING PROCESSES

A STUDY CONCERNING SARDINIA (ITALY)

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ABSTRACT

According to the European Commission's "Roadmap to a Resource Efficient Europe," the annual land take in the countries of the European Union should amount at most to zero by 2050. This entails that planning practices should focus on ecological objectives, which should be prioritized over other current issues, such as land values' and uses' regulations, spatial market processes and real estate. Land take and related urban development not only implies decline in the availability of land able to sequestrate carbon, but also an increase in emissions. That being so, innovative ecological policies are necessary in order to mitigate or eliminate land-taking processes. This study analyzes the interdependence between land take and carbon capture and storage, identified as an ecosystem service, and proposes an interpretive approach, which is implemented into the Sardinian regional context, that is, a spatial context concerning one of the two insular regions of Italy. CORINE Land Cover nomenclature is used to identify the land cover characteristics. The European Environment Agency makes data available as regards the time series of land cover types. Carbon capture and storage is defined through the NDVI (normalized difference vegetation index) concerning semi-natural and natural zones. By means of the NDVI, an approximation of carbon sequestration distribution and a spatial relation between carbon capture and storage capacity and land-taking processes are detected. The outcomes imply relevant consequences with reference to the implementation of planning measures concerning mitigation of land take and preservation and improvement of carbon capture and storage.

KEYWORDS
Land Take; Ecosystem Services; Carbon Sequestration; Normalized Difference Vegetation Index (NDVI)

1 INTRODUCTION

This study analyzes the interdependence between land take and carbon capture and storage. The research goal is to assess the evidence of a relationship between carbon sequestration by the soil and land-taking processes, and to estimate the quantitative profile of this relationship. The assessment is implemented as regards a spatial context concerning Sardinia, one of the two insular regions of Italy. The results are relevant in terms of further research developments. Carbon capture and storage is a phenomenon, based on photosynthesis, which characterizes peat swamps, forests and grasslands, and other similar ecological systems and consists in carbon dioxide removal from the air by its sequestration by soil and plants (Lal, 2008). The interaction involving air composition and soil has a strong influence on climate regulation (Jobbagy & Jackson, 2000) and is strictly correlated to changes in land cover. Moreover, land condition and green areas play an important role in regulating the carbon cycle since they provide carbon capture and storage as an ecosystem service (European Commission, 2012; Millennium Ecosystem Assessment, 2005). The EEA (European Environment Agency, 2013a) provides the following definition of land take: "Change of the amount of agriculture, forest and other semi-natural and natural land taken by urban and other artificial land development." This is a relevant reference for the ongoing discussion on spatial planning since, according to the European Commission's "Roadmap to a Resource Efficient Europe" (Communication COM(2011) 571 of 20 September 2011), the annual land take in the countries of the European Union should amount at most to zero by 2050. Furthermore, a medium-term goal is established by 2020 with reference to the 2014-2020 cohesion policy, which states that direct and indirect impacts of this policy on land cover have to be carefully monitored and assessed. The structure of this study consists of three sections. The next section discusses the methodology concerning the definition of the taxonomies of normalized difference vegetation index (NDVI) and carbon sequestration related to the Sardinian regional context. The results of a multiple linear regression used to assess the relation between carbon storage and capture and land-taking processes are described in the third section. In the conclusions, a discussion related to the outcomes is proposed as regards implications and suggestions concerning planning measures and further research developments.

2 METHODOLOGY

The relation between carbon capture and storage and land-taking processes is studied on the basis of spatial units represented by the 377 municipal administrations of Sardinia,

ISBN: 978-88-6887-054-6
DOI: 10.6093/978-88-6887-054-6

which are the lowest layer of the regional public administration framework. A linear regression is estimated according to specification shown in Tab. 1. Carbon sequestration is the dependent variable, whereas the explanatory variables are the level of land take and the land take change occurred between 1990 and 2018, the most recent data concerning the number of residents and the area of the land administered by a municipality. The last two variables are used as control variables to check for: i. the presence of a concentration factor, namely, the lower the number of residents the highest the capacity of capturing and storing carbon dioxide (Sklenicka et al., 2013; Zoppi & Lai, 2015); and, ii. the effect on carbon capture and storage capacity caused by the size of the municipal area, which, ceteris paribus, can possibly positively influence carbon sequestration.

VARIABLE	DEFINITION; SOURCE	UNIT	MEAN	ST. DEVIATION
C_SEQ	Carbon capture and storage capacity; estimated through the NDVI, see Subsection 2.1	Stored carbon dioxide per ha of municipal land, Mg/ha	89.40	22.00
L_TAKE	Size of uptaken land; Copernicus Database	Percentage ratio of land uptaken per km^2 of municipal land, km^2/km^2, %	3.41	5.29
ΔL_TAKE	Change in uptaken land; Copernicus Database	Percentage ratio of the 2018-1990 change in land uptaken per km^2 of municipal land, %	0.99	1.29
RESIDS	Resident people in 2016; the *Comuni Italiani* (Italian municipal administrations)	Number of resident people	4,385.01	12,199.99
ML_AREA	Area of the land administered by a municipality; the Region Sardinia's Geoportal	km^2	63.92	61.76

Tab. 1 Statistics of the variables included in regression model C_SEQ = β0 + β1 L_TAKE + β2 ΔL_TAKE + β3 RESIDS + β4 ML_AREA

The next subsection presents the methodological approach implemented to define the spatial taxonomy of carbon sequestration, whereas a discussion proposed in a previous study (Zoppi & Lai, 2014, Section "What is land take?") is assumed as reference for characterizing the spatial distribution of land take. As per Zoppi and Lai (2014), the spatial taxonomy of land take implemented in this study is based on the land cover classification of the COoRdination de l'INformation sur l'Environnement (CORINE) Land Cover vector map

ISBN: 978-88-6887-054-6
DOI: 10.6093/978-88-6887-054-6

(CLC) of the European Environment Agency (EEA) of the EU (European Environment Agency, 2013a). In the CLC classification, non-artificial surfaces are classified into four classes (at Level 1): i. agricultural areas; ii. forests and semi-natural areas; iii. wetlands; and, iv. Waterbodies. The land-taking process is identified in this study as the change of status of areas from non-artificial classes to the artificial land-cover class. Sardinia has experienced an increase in artificial land from 2.26% in 1990 (54,443 hectares) to 3.14% in 2018 (75,718 hectares).

2.1 CARBON CAPTURE AND STORAGE

A number of studies propose combinations of carbon dioxide- and remote sensing-related data to represent spatial taxonomies of carbon pools (Lee et al., 2016; Sun et al., 2019; Rao et al., 2013; Raciti et al., 2014). NDVI indexes biomes' levels of greenness, on the basis of their reflectance spectrum. Late in the 1970s, it was discovered that the quantity of radiation active in photosynthetic terms absorbed by the plants is positively correlated to net photosynthesis. The remote sensors of satellites provide quantitative information concerning the absorbed radiation active in photosynthetic terms. The NDVI is computed through the following formula:

$$\mathrm{NDVI} = \frac{(\mathrm{NR}-\mathrm{RD})}{(\mathrm{NR}+\mathrm{RD})}, \quad (1)$$

where NR is the near-infrared reflectance and RD is the red reflectance. The spatial distribution of the NDVI taxonomy reveals values included in the interval -0.60 - 0.96, as shown in Tab. 2.

Based on the NDVI distribution, a spatial taxonomy is mapped which associates groups of types of land cover, featured by similar characteristics, to NDVI intervals. This is implemented on the basis of the authors' expertise and of on site survey.

Carbon capture and storage capacity associated to land cover types as regards the pools of carbon is determined on the basis of the spatial data provided by a project funded by the Autonomous Region of Sardinia[1].

[1] The spatial database is based on the surveys implemented in the Project "Charter of the land units and land use capability of Sardinia – First part (2011-2013)." The Project was funded by the Department of Local public administrations, Finance and Spatial planning of the Autonomous Region of Sardinia (ARS). The surveys were implemented by the following public bodies: (i) AGRIS (the Agency of the ARS for theoretical and experimental research concerning agriculture, agri-industrial production and forestry) for the Muravera-Castiadas area (South-eastern Sardinia); (ii) LAORE (the Agency of the ARS for the implementation of the regional projects concerning agriculture and rural development), and the University of Sassari, for the Arzana and Nurra areas (Central and North-western Sardinia); and, (iii) the University of Cagliari for the Pula-Capoterra area (Southern Sardinia).

ISBN: 978-88-6887-054-6
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The InVEST[2] model uses the carbon pools provided by the Project quoted above to estimate the carbon capture and storage capacity for each land cover type (Nelson et al., 2008).
Three NDVI-related intervals are determined in this study with reference to the Sardinian region, which are characterized by soil features and by the estimated mean carbon capture and storage capacity defined through InVEST (Tab. 2).

NDVI INTERVAL	CLASSIFICATION	CARBON SEQUESTRATION CAPACITY (Mg/ha)
-0.5981 – 0.2659	Soils with no vegetation, bare rocks, built areas, water bodies	0
0.2659 – 0.4890	Soils with sparse vegetation, grass or medium-density vegetation	104.50
0.4890 – 0.9597	Soils with dense vegetation; forests	117.39

Tab. 2 Stored carbon and land uses

3 FINDINGS

The findings concerning the implementation of the proposed methodology are proposed in the following paragraphs. The first two subsections describe the spatial distributions of carbon capture and storage and land-taking processes, whereas the last shows the results of the multiple regression model defined by the variables reported in Tab. 2.

3.1 SPATIAL DISTRIBUTION OF CARBON CAPTURE AND STORAGE

The spatial taxonomy of carbon sequestration belongs to the interval 4.30-115 Mg/ha. The carbon sequestration capacity of about 37% of the municipalities is below 90 Mg/ha. The towns of South Sardinia reveal values comparatively lower than the others. Municipalities located around the SE-NW line which connects Cagliari to Oristano (from South to Central Sardinia) are particularly characterized by a low sequestration capacity. About 4% of the towns, mostly located in the central and northern areas of the Island, show values belonging to the interval 109-116 Mg/ha.
The Metropolitan City of Cagliari, whose administration extends over seventeen municipalities, shows a relevant decrease in carbon capture and storage capacity caused by

[2] InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) is a free of cost software product, licensed under the BSD open source licence. InVEST is developed by the Natural Capital Project (NCP), whose partners are: the Woods Institute for the Environment and Department of Biology of Stanford University; the Institute on the Environment of Minnesota University; the Nature Conservancy; and, the World Wildlife Fund (WWF). http://data.naturalcapitalproject.org/nightly-build/investusers- guide/html/index.html.

ISBN: 978-88-6887-054-6
DOI: 10.6093/978-88-6887-054-6

intensive land artificialization generated by heavy urban expansion, which is as high as 10,700 Mg. This outcome implies that the density of carbon sequestration capacity decreases as urban transformation increases (Sun et al., 2019).

Even higher is the loss in carbon sequestration which is shown by the coastal towns, whose a share of about 35.5% reveals an increase in land take in the interval 0.96-10.80 km2 as a consequence of pressures generated by tourist enterprises, which put at risk coastal and marine environments and their provision of ecosystem services (Lai, Zoppi, 2010). A share of around 38% of the coastal municipalities shows a carbon sequestration capacity ranging between 4.3 and 70.6 Mg/ha.

Fig. 1 reports the spatial distribution of carbon capture and storage in the Sardinian Island.

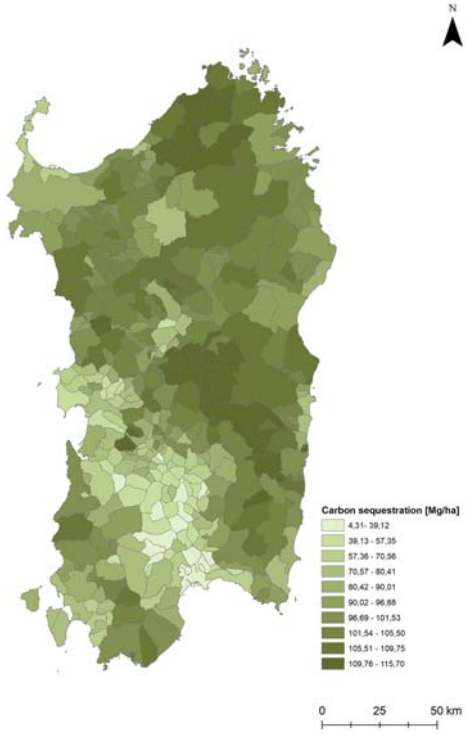

Fig. 1. Taxonomy of carbon sequestration

3.2 SPATIAL DISTRIBUTION OF LAND TAKE

The regional land which changed its status from non-artificial to artificial amounts to about 215 km2 in the period 1990-2018. Its spatial distribution is not homogeneous, and it shows the highest values in the most populous cities, such as the Metropolitan City of Cagliari (5.6

ISBN: 978-88-6887-054-6
DOI: 10.6093/978-88-6887-054-6

km2) and the urban areas of Olbia (9.4 km2), Sassari (10.8 km2) and their surroundings, and in the costal tourist settlements.

Nevertheless, more than 33% of the municipal administrations reveal an increase in land take less than 0.09 km2, whereas less than 18% reveal an increase in land take more than 0.98 km2. The towns which are included in the Cagliari metropolitan administration, Olbia, Sassari and a small number of costal settlements belong to this set.

The highly populated and urbanized consolidated tissues of Sassari and Cagliari reveal values of land take which amount to 5% and 2.5%. The two contexts are examples of two different types of urban expansion, namely land sharing and land sparing (Soga et al., 2014).

Cagliari shows a density of 1,801 residents/km2, and, that being so, a compact tissue3 and a relevant concentration of green spaces within it, which makes the Sardinia's capital city a land sparing urban context, while Sassari, which shows a density of 234 residents/km2, characterized by less concentrated green spaces within the compact tissue, can be identified as a land sharing urban context (Lin & Fuller, 2013). The density of green areas within the compact urban fabrics is positively correlated to protection of biodiversity and supply of ecosystem services and, as a consequence, planning and decision-making processes should focus on land sparing-based policies (Soga et al., 2014), whose Cagliari is an important point of reference. Tab. 3 reports the comparison of the cities of Cagliari and Sassari in terms of their land-sparing and land-sharing attitudes.

CITY	GREEN SPACES (km^2)	COMPACT TISSUE (km^2)	GREEN AREAS IN THE COMPACT URBAN TISSUE (km^2/km^2; percentage of green spaces within the compact urban tissue to the area of the compact tissue)
Sassari	0.5	15.7	2.8%
Cagliari	2.8	54.7	4.9%

Tab. 3 Analysis of green spaces within the compact urban tissue

3.3 RESULTS OF THE REGRESSION MODEL

The outcomes of the regression model are consistent with expectations on signs and significant in terms of p-values (always lower than 2%) as regards the estimates of the explanatory variables' coefficients (Tab. 4).

[3] Compact urban fabric is identified within a municipal area by the "artificial surfaces" of the CORINE Land cover (European Environment Agency, 2013b).

ISBN: 978-88-6887-054-6
DOI: 10.6093/978-88-6887-054-6

Explanatory variable	Coefficient	Standard deviation	t-statistic	p-value
L_TAKE	-0.716	0.300	-2.395	0.0180
ΔL_TAKE	-4.370	1.126	-3.879	0.0002
RESIDS	-0.0003	0.0001	-2.559	0.0110
ML_AREA	0.092	0.019	4.910	0.0001

Dependent variable: C_SEQ - Adjusted R-squared: 0.289

Tab. 4 Results of the regression model

The estimate of the land-take coefficient entails that, everything else being equal, an increase of 1% in land take implies a decrease of about 700 kg/ha in carbon capture and storage. This also implies that the total land-taking process related to Cagliari4 in 2018 reveals that about 40% of the municipal land is artificialized, which determines a loss of about three million Mg in carbon capture and storage.

Furthermore, the estimates of the regression model reveals that between 1990 and 2018 the change in land take (variable ΔL_TAKE) causes a negative impact on carbon capture and storage, in addition to variable L_TAKE, which represents the level of land take. As a consequence, the results show that carbon capacity decreases not only in correlation with an increase in the land take level, but also in connection with an increase in the change rate of land take. Taking into consideration Cagliari, an increase of 6.5% in the level of land take5 is correlated to an additional decline of around 235,000 Mg in carbon capture and storage.

The estimated coefficients of the control variables RESIDS and ML_AREA are significant and present negative and positive signs respectively, as was expected.

The concentration effect of RESIDS is a decrease of 5.6 kg/ha in carbon capture and storage related to an increase of 20 residents. This entails that, ceteris paribus, Sassari (127,533 residents) reveals an additional capacity of 399,000 Mg compared to Cagliari (154,083), as a consequence of less residents.

Lastly, carbon capacity is positively correlated to the size of the municipality (ML_AREA), because the estimate of the correspondent coefficient is positive, and, as a consequence,

[4] Cagliari is the capital city of Sardinia and the most populous municipal area. Data drawn from Copernicus, see Tab. 1.

[5] Data drawn from Copernicus, see Tab. 1.

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the impact on carbon capture and storage of an additional 1-km2 of municipal area is connected to an increase of around 90 kg/ha in carbon sequestration.

4 CONCLUDING REMARKS[6]

The outcomes of the regression model show an important and significant correlation, at the municipal level, between carbon sequestration and land take, and indicate that NDVI is a very effective proxy for carbon sequestration capacity, since it identifies the size of carbon captured and stored, and provides a way of measuring this capacity as a phenomenon independent from land take, and, in so doing, it makes it possible to estimate the regression model in stochastic terms. Moreover, since the coefficients of the variables representing the factors that were tentatively assumed as determinants of carbon sequestration are significant and the goodness of fit of the model is relatively high (adjusted R-squared is about 30%, see Tab. 4), it can be concluded that our research perspective is effective in explaining, in quantitative terms, the relationship between carbon sequestration and land take.

Our study puts in evidence a number of important implications concerning the relationship between carbon sequestration capacity and land-taking processes. First, our estimates highlight a robust negative influence of land take (level) and land-taking dynamics, that is, increase in land take through time, on carbon sequestration capacity, which is a finding consistent with Stakura et al.'s (2015) outcomes related to expansion of urban areas (sprawl). This implies that, everything else being equal, the presence, size and dynamics of land take are correlated to a decrease in carbon sequestration capacity.

Second, the reduction in capacity as a consequence of land-taking process is significant in quantitative terms. From this standpoint, our results imply that the presence and size of protected areas, which limit urban expansion and, in so doing, land-taking processes (Hazeu et al., 2009; Martínez-Fernández et al., 2015), are important factors to conserve and possibly enhance carbon sequestration capacity.

This entails that land saving and, as a consequence, conservation of carbon sequestration capacity spreads over the whole municipal land area in correlation with the presence and size of protected areas. An important type of protected areas are the Sites of the Natura 2000 Network (SN2Ns), established under the provisions of the Habitats (no. 92/43/EEC) and Birds (no. 2009/147/EC) Directives. According to the Habitats Directive, an Appropriate

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assessment procedure7 must be applied not only in case of plans and projects concerning land parcels located within SN2Ns, but also in case of plans and projects related to areas outside the SN2Ns' boundaries, if such plans and projects may possibly damage habitats and species within the SN2Ns.

A third important policy implication, related to the positive impact of Natura 2000-related policies on the conservation of the non-artificial status of land, is that, because the impact of Natura 2000-based environmental protection on land take is not related to other conservative planning rules, there is no need for severely restrictive planning codes, if SN2Ns are properly established. Indeed, the establishment of SN2Ns does not imply that there are land uses or developments which are forbidden in general terms. However, the mere presence of a SN2N entails that developers, public administrations, planners, and practitioners, have to show that their projects or planning proposals will not damage or generate loss of habitats and/or species, which, according to the outcomes of our analysis, significantly reduces land-taking processes.

Finally, an important implication of this study is the following. Municipal masterplans should state, as regards new development proposals, that such proposals should describe their impacts on existing land uses and demonstrate that artificialization processes are minimal, if any, as for the Appropriate assessment procedure, in case of plans and projects that may possibly generate negative impacts on habitats and species of the SN2Ns. The four points highlighted above entail important implications for planning policies, both at the local (municipal) and regional levels. A first consequence is that policies aiming at reducing land take and at preserving carbon sequestration capacity, should imply the establishment of new protected areas, or the enlargement of existing ones. Both policies need effective and continuous cooperation involving the local and regional administrations, since the complex and long-lasting time period concerning the establishment of new or enlarged protected areas needs a substantial integration of planning visions on behalf of the local and regional authorities. Cooperation is necessary since the identification of conservation objectives and the subsequent establishment of conservation measures entail that the local authorities propose these measures, possibly in the context of a management plan, and the regional administration approves them and, in some cases, brings them to the attention of national

[7] Paragraph 3, art. 6, of the Habitats Directive establishes that "Any plan or project not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, either individually or in combination with other plans or projects, shall be subject to appropriate assessment of its implications for the site in view of the site's conservation objectives," and that "the competent national authorities shall agree to the plan or project only after having ascertained that it will not adversely affect the integrity of the site concerned and, if appropriate, after having obtained the opinion of the general public."

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administrations. Cooperation and integration of the local and regional planning processes would imply an important enhancement in the quality of Sardinian public planning, which has been characterized by a lack of coordination in recent years (Zoppi & Lai, 2010). A second significant implication is that in public planning processes, especially at the municipal level, experts in nature conservation should systematically participate and cooperate with spatial planners and developers in the process of definition and approval of local plans, in order to support the identification of sites to be proposed for the establishment of protected areas and, in so doing, to define policies aimed at limiting land take and at preserving carbon sequestration capacity. At present, this expertise is not considered as a necessary component of local planning teams (Leone & Zoppi, 2016). Thirdly, attention should be paid to the possibility of proposing new protected areas in the strategic environmental assessment processes of local plans. These processes entail the inclusion of objectives related to the protection of environmental resources and to the sustainability paradigm into the definition of spatial plans, which implies the possibility of the integration of such goals into the plans, even though they were not considered in the first place (Zoppi & Lai, 2014). Moreover, since the presence and size of protected areas are effective against land take and in support of preservation of carbon sequestration capacity, conservation measures consistent with those adopted for the protected areas could be extended over areas located outside the boundaries of protected areas. From this perspective, complete and detailed maps concerning the spatial distribution of natural resources are needed. A fifth point is related to the necessity of a comprehensive coordination of conservation measures between plans of cities and towns whose municipal areas are adjacent to each other. From this point of view, a fundamental role should be played by the planning office of the regional administration, which coordinates local plans under the provisions of the Sardinian rules concerning the approval of regional and local plans. Finally, as widely recognized in the literature, conservation measures may prevent the implementation of traditional land uses related to urbanization, agriculture and pastures, and, by doing so, they may possibly generate conflicts between local communities and municipal authorities (Kovács et al., 2015; Leone & Zoppi, 2016). The issues of information, participation and consensus-building should not be undervalued in the definition and implementation of local plans that entail conservation measures and policies against land take and in support of carbon sequestration capacity, and inclusive participatory processes should be carefully designed in detail long before plans are discussed and approved. Our methodology and results are based on a regression model that assesses the relation between carbon capture and storage capacity, defined on the basis of the NDVI spatial taxonomy, and land-taking processes. The model considers the municipalities of Sardinia as spatial units. From this perspective, it has to be

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intensive land artificialization generated by heavy urban expansion, which is as high as 10,700 Mg. This outcome implies that the density of carbon sequestration capacity decreases as urban transformation increases (Sun et al., 2019).

Even higher is the loss in carbon sequestration which is shown by the coastal towns, whose a share of about 35.5% reveals an increase in land take in the interval 0.96-10.80 km2 as a consequence of pressures generated by tourist enterprises, which put at risk coastal and marine environments and their provision of ecosystem services (Lai, Zoppi, 2010). A share of around 38% of the coastal municipalities shows a carbon sequestration capacity ranging between 4.3 and 70.6 Mg/ha.

Fig. 1 reports the spatial distribution of carbon capture and storage in the Sardinian Island.

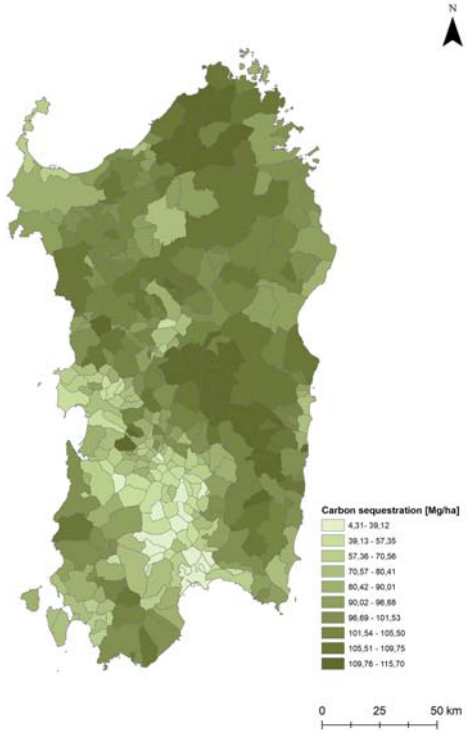

Fig. 1. Taxonomy of carbon sequestration

3.2 SPATIAL DISTRIBUTION OF LAND TAKE

The regional land which changed its status from non-artificial to artificial amounts to about 215 km2 in the period 1990-2018. Its spatial distribution is not homogeneous, and it shows the highest values in the most populous cities, such as the Metropolitan City of Cagliari (5.6

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km2) and the urban areas of Olbia (9.4 km2), Sassari (10.8 km2) and their surroundings, and in the costal tourist settlements.

Nevertheless, more than 33% of the municipal administrations reveal an increase in land take less than 0.09 km2, whereas less than 18% reveal an increase in land take more than 0.98 km2. The towns which are included in the Cagliari metropolitan administration, Olbia, Sassari and a small number of costal settlements belong to this set.

The highly populated and urbanized consolidated tissues of Sassari and Cagliari reveal values of land take which amount to 5% and 2.5%. The two contexts are examples of two different types of urban expansion, namely land sharing and land sparing (Soga et al., 2014).

Cagliari shows a density of 1,801 residents/km2, and, that being so, a compact tissue3 and a relevant concentration of green spaces within it, which makes the Sardinia's capital city a land sparing urban context, while Sassari, which shows a density of 234 residents/km2, characterized by less concentrated green spaces within the compact tissue, can be identified as a land sharing urban context (Lin & Fuller, 2013). The density of green areas within the compact urban fabrics is positively correlated to protection of biodiversity and supply of ecosystem services and, as a consequence, planning and decision-making processes should focus on land sparing-based policies (Soga et al., 2014), whose Cagliari is an important point of reference. Tab. 3 reports the comparison of the cities of Cagliari and Sassari in terms of their land-sparing and land-sharing attitudes.

CITY	GREEN SPACES (km^2)	COMPACT TISSUE (km^2)	GREEN AREAS IN THE COMPACT URBAN TISSUE (km^2/km^2; percentage of green spaces within the compact urban tissue to the area of the compact tissue)
Sassari	0.5	15.7	2.8%
Cagliari	2.8	54.7	4.9%

Tab. 3 Analysis of green spaces within the compact urban tissue

3.3 RESULTS OF THE REGRESSION MODEL

The outcomes of the regression model are consistent with expectations on signs and significant in terms of p-values (always lower than 2%) as regards the estimates of the explanatory variables' coefficients (Tab. 4).

[3] Compact urban fabric is identified within a municipal area by the "artificial surfaces" of the CORINE Land cover (European Environment Agency, 2013b).

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Explanatory variable	Coefficient	Standard deviation	t-statistic	p-value
L_TAKE	-0.716	0.300	-2.395	0.0180
ΔL_TAKE	-4.370	1.126	-3.879	0.0002
RESIDS	-0.0003	0.0001	-2.559	0.0110
ML_AREA	0.092	0.019	4.910	0.0001

Dependent variable: C_SEQ - Adjusted R-squared: 0.289

Tab. 4 Results of the regression model

The estimate of the land-take coefficient entails that, everything else being equal, an increase of 1% in land take implies a decrease of about 700 kg/ha in carbon capture and storage. This also implies that the total land-taking process related to Cagliari4 in 2018 reveals that about 40% of the municipal land is artificialized, which determines a loss of about three million Mg in carbon capture and storage.

Furthermore, the estimates of the regression model reveals that between 1990 and 2018 the change in land take (variable ΔL_TAKE) causes a negative impact on carbon capture and storage, in addition to variable L_TAKE, which represents the level of land take. As a consequence, the results show that carbon capacity decreases not only in correlation with an increase in the land take level, but also in connection with an increase in the change rate of land take. Taking into consideration Cagliari, an increase of 6.5% in the level of land take5 is correlated to an additional decline of around 235,000 Mg in carbon capture and storage.

The estimated coefficients of the control variables RESIDS and ML_AREA are significant and present negative and positive signs respectively, as was expected.

The concentration effect of RESIDS is a decrease of 5.6 kg/ha in carbon capture and storage related to an increase of 20 residents. This entails that, ceteris paribus, Sassari (127,533 residents) reveals an additional capacity of 399,000 Mg compared to Cagliari (154,083), as a consequence of less residents.

Lastly, carbon capacity is positively correlated to the size of the municipality (ML_AREA), because the estimate of the correspondent coefficient is positive, and, as a consequence,

[4] Cagliari is the capital city of Sardinia and the most populous municipal area. Data drawn from Copernicus, see Tab. 1.

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put in evidence that it would be interesting to detect what would happen if spatial units, different from the Sardinian municipalities and related to more detailed spatial taxonomies, were considered, especially with reference to the most relevant conurbations, such as Cagliari and Sassari. The comparative assessment of the relationship between carbon sequestration and land take related to different areas identified within the fabric of the main Sardinian conurbations would help to improve the goodness of fit of the estimated model, its explanatory power, and the quality of its implications in terms of the definition and implementation of policies to preserve and enhance carbon sequestration capacity and to limit or prevent land-taking processes.

NOTES

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Maddalena Floris and Corrado Zoppi have made substantial contributions to the study's conception, background and design remarks (Section 1), and to discussion and concluding remarks (Section 4). Subsections 2.1, 3.1 and 3.2 are by Maddalena Floris. The introductory paragraph of Section 2, and Subsection 3.3 are by Corrado Zoppi.

REFERENCES

European Commission (2012). *Guidelines on Best Practice to Limit, Mitigate or Compensate Soil Sealing*. Luxembourg: Publications Office of the European Union. ISBN: 9789279262104.

European Environment Agency (2013a). Land take. http://www.eea.europa.eu/data-and-maps/indicators/land-take-2/.

European Environment Agency (2013b).
CORINE Land Cover. http://www.eea.europa.eu/publications/COR0-landcover.

Hazeu, G.W., Mücher, C.A., Swetnam, R., Gerard, F., Luque, S., Pino, J, & Halada, L. (2009). Historic land cover changes at Natura 2000 sites and their associated landspaces across Europe. In: D. Maktav (Ed), *Remote Sensing for a Changing Europe - Proceedings of the 28th Symposium of the European Association of Remote Sensing Laboratories, Istanbul, Turkey, 2-5 June 2008* (pp. 226-231). Amsterdam, The Netherlands: IOS Press. ISBN: 9781586039868.

Jobbagy, E.G., Jackson, R.B. (2000). The vertical distribution of soil organic carbon and its relation to climate and vegetation. *Ecological Applications, 10*, 423-436. doi: https://dx.doi.org/10.1890/1051-0761(2000)010[0423:TVDOSO]2.0.CO;2

ISBN: 978-88-6887-054-6
DOI: 10.6093/978-88-6887-054-6

Kovács, E., Kelemen, K., Kalóczkai, A., Margóczi, K., Pataki, G., Gébert, J., Málovics, G., Balázs, B., Roboz, A., Krasznai Kovács, E. & Mihók B. 2015. Understanding the links between ecosystem service trade-offs and conflicts in protected areas. *Ecosystem Services, 12*, 117–127. doi: https://dx.doi.org/10.1016/j.ecoser.2014.09.012

Lai, S. & Zoppi, C. (2017). The influence of Natura 2000 Sites on land-taking processes at the regional level: An empirical analysis concerning Sardinia (Italy) *Sustainability, 9 (259)*, 26 pp. doi: https://dx.doi.org/10.3390/su9020259

Lal, R. (2008). Carbon sequestration. *Philosophical Transactions of the Royal Society B, 363*, 815–830. doi: https://dx.doi.org/10.1098/rstb.2007.2185

Lee, J.H., Ko, Y., McPherson, E.G. (2016). The feasibility of remotely sensed data to estimate urban tree dimensions and biomass. *Urban Forestry & Urban Greening, 16*, 208-220. doi: https://dx.doi.org/10.1016/j.ufug.2016.02.010

Leone, F. & Zoppi, C. (2016). Conservation measures and loss of ecosystem services: A study concerning the Sardinian Natura 2000 Network. *Sustainability, 8 (1061)*, 15 pp. doi: https://dx.doi.org/10.3390/su8101061

Lin, B.B. & Fuller, R.A. (2013). FORUM: Sharing or sparing? How should we grow the world's cities? *Journal of Applied Ecology, 50*, 1161–1168. https://dx.doi.org/10.1111/1365-2664.12118

MacCallum, S.H. (2003). The enterprise of community: Market, competition, land and environment. *Journal of Libertarian Studies, 17*, 1-15.

Martínez-Fernández, J.M., Ruiz-Benito, P. & Zavala, M.A. (2015). Recent land cover changes in Spain across biogeographical regions and protection levels: Implications for conservation policies. *Land Use Policy, 44*, 62–75. doi: https://dx.doi.org/10.1016/j.landusepol.2014.11.021

Millennium Ecosystem Assessment (2003). Ecosystems and Human Well-being: A Framework for Assessment. Washington, DC: Island Press. ISBN: 1559634030.

Nelson, E., Polasky, S., Lewis, D.J., Plantinga, A.J., Lonsdorf, E., White, D., Bael, D. & Lawler, J.J. (2008). Efficiency of incentives to jointly increase carbon sequestration and species conservation on a landscape. *Proceedings of the National Academy of Sciences, 105*, 9471-9476. doi: https://dx.doi.org/10.1073/pnas.0706178105

Raciti, S.M., Hutyra, L.R. & Newell, J.D. (2014). Mapping carbon storage in urban trees with multi-source remote sensing data: Relationships between biomass, land use, and demographics in Boston neighbor-hoods. *Science of the Total Environment, 500-501*, 72-83. doi: https://dx.doi.org/10.1016/j.scitotenv.2014.08.070

Rao, P., Hutyra, L.R., Raciti, S.M. & Finzi, A.C. (2013). Field and remotely sensed measures of soil and vegetation carbon and nitrogen across an urbanization gradient in the Boston metropolitan area. *Urban Ecosystems, 16*, 593-616. doi: https://dx.doi.org/10.1007/s11252-013-0291-6

Sklenicka, P., Molnarova, K., Pixova, K.C. & Salek, M.E. (2013). Factors affecting farmlands in the Czech Republic. *Land Use Policy, 30*, 130-136. doi: https://dx.doi.org/10.1016/j.landusepol.2012.03.005

Soga, M., Yamaura Y., Koike, S. &. Gaston, K.J. (2014). Land sharing vs. land sparing: does the compact city reconcile urban development and biodiversity conservation? *Journal of Applied Ecology, 51*, 1378–1386. doi: https://dx.doi.org/10.1111/1365-2664.12280

ISBN: 978-88-6887-054-6
DOI: 10.6093/978-88-6887-054-6

Stachura, J., Chuman, T. & Sefrna, L. (2015). Development of soil consumption driven by urbanization and pattern of built-up areas in Prague periphery since the 19th century. *Soil and Water Resources, 10*, 252-261. doi: https://dx.doi.org/10.17221/204/2014-SWR

Sun, Y., Xie, S. & Zhao, S. (2019). Valuing urban green spaces in mitigating climate change: A city-wide estimate of aboveground carbon stored in urban green spaces of China's Capital. *Global Change Biology, 00*, 1-16. doi: https://dx.doi.org/10.1111/gcb.14566

Zoppi, C. & Lai, S. (2010). Assessment of the Regional Landscape Plan of Sardinia (Italy): A participatory-action-research case study type. *Land Use Policy, 27*, 690–705.
doi: https://dx.doi.org/10.1016/j.landusepol.2009.09.004

Zoppi, C. & Lai, S. (2014). Land-taking processes: An interpretive study concerning an Italian region. Land Use Policy, 36, 369–380. doi: https://dx.doi.org/10.1016/j.landusepol.2013.09.011

Zoppi, C. & Lai, S. (2015). Determinants of land take at the regional scale: A study concerning Sardinia (Italy). *Environmental Impact Assessment Review, 55*, 1–10.
doi: https://dx.doi.org/10.1016/j.eiar.2015.06.002

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Maddalena Floris graduated in Architecture at the University of Cagliari, Italy (2013). She is presently a graduate student in the doctoral program in Civil Engineering and Architecture at the University of Cagliari. Her research areas are sustainable urban and regional planning, and environmental policy-making. Her research studies focus on the relationships between ecosystem services and spatial planning, and, in particular, on the issue of carbon sequestration enhancement.

Corrado Zoppi, Civil engineer, is Doctor of Philosophy in Economics (USA, 1997), Doctor of Research in Territorial Planning (Italy, 1992), and MSc in Economic Policy and Planning (USA, 1990). He is a Professor at the University of Cagliari (Sector ICAR/20 – Spatial planning). He is presently teaching at the Department of Civil and Environmental Engineering and Architecture of the University of Cagliari in the Undergraduate and Graduate Programs in Environmental and Territorial Engineering and in Sustainable Tourism Management and Monitoring (Regional and Urban Planning, Strategic Planning and Environmental planning).

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