ECOSYSTEM SERVICES AS SUPPORT TOOL OF URBAN PLANNING ACTIVITIES IN COASTAL AREAS

Annunziata Palermo, Lucia Chieffallo, Natalia Rispoli

Abstract: In coastal areas, increased climatic and anthropogenic pressures contribute to the reduction of ecosystem services related to the biodiversity of natural capital. These dynamics make the coastal areas one of the most complex contexts in which to combine the needs of environmental protection and those that characterize the government of the territory. Given these assumptions, this research activity intends to define the "Blue Community" model. It is aimed at directing planning processes in the definition of the rules of local resources' use increasing coastal ecosystem services. In order to guide this research, a Systematic Literature Review (SLR) on the role of ecosystem services in urban planning was conducted. The paper presents the first results of the SLR. In particular, quantitative analysis has made it possible to derive information relating to sources, authors and keywords, highlighting the growing recent interest on the research topic. Instead, the qualitative analysis based on the adoption of a technique of cluster analysis has favoured the study of the interrelations between planning activities of the coastal settlements and the ecosystem services.

Keywords: coastal areas, ecosystem services, urban planning

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Introduction

Starting from the commonly recognized definition of ecosystem as a system characterized by the biotic component and the abiotic component, Morri and Santolini (2013) state that "ecosystems have in themselves the potential to preserve life, stabilize soils, control the cycles of the elements (atmospheric and water), buffer extreme phenomena (temperature, humidity, precipitation, etc.). This dynamism, characterized by cyclicity and reciprocal subsidiarity with the neighbouring ecosystems, allows a better adaptation to the global factors of change and makes natural and anthropic systems less vulnerable and more resilient" [17].

Sharing this position, it is evident how the anthropogenic pressure and all the activities that interact with the ecosystem balances determine a reduction in the number of species and habitats and, therefore, a progressive loss of natural capital, which forms the basis for social welfare and sustainable economic development. In this regard, the term "capital" demonstrates how, alongside the intrinsic value of the environment, some aspects related to its economic importance can be identified. Indeed, the notion of natural capital has been instrumentally borrowed from the economic sector to indicate the value in physical, monetary and welfare terms offered by biodiversity to humanity, also in order to guide the choices of public decision-makers with specific regard to urban and spatial planning activities.

Among the natural elements that play an important role in meeting the needs of citizens, the coastal system is considered to be one of the main, as it favours the extension of trade and human settlement, as well as numerous indirect ecosystem-related functions. Therefore, the coastal system represents a strategic resource in the experimentation of new territorial policies and planning that bring advantage to the settled population keeping the ecosystems in an efficient ecological state. Specifically, the benefits of the coastal system can be classified according to the ecosystem services categories [6, 11] proposed by the Millennium Ecosystems Assessment (MEA) [16].

MEA is an international research project, undertaken in 2000 and concluded in 2005, which proposes a classification of ecosystem services in four categories: provisioning, regulating, supporting and cultural service. Among these, the categories regulating and cultural services are of particular interest for the research, including benefits that concern, for example, environmental protection and climate regulation [2, 10, 14, 15] and the intangible benefits that people obtain from ecosystems such as tourism, seascapes, health and well-being, creativity and art [4, 9, 13, 21].

With regard to the coastal areas, which offer innumerable benefits in terms of quality of life, it should be stressed that they are characterised by specific elements of complexity and present numerous challenges, for example, due to the presence of fragile ecosystems, different intensive socio-economic activities, inadequate anthropogenic processes of urbanization, as well as natural dynamics of climate-related erosion. In particular, in recent years, the alteration of marine and coastal ecosystems is internationally growing because of the complex interaction between anthropogenic and climatic pressures, such as rising sea temperatures that can cause waves of sea heat, increasing frequency of extreme weather events and

acidification of the oceans. Therefore, the international scientific community is progressing in designing and testing different approaches and methodological tools for a solid assessment of the impacts arising from the action of these multiple pressures that simultaneously affect coastal zones and related ecosystem services. These efforts are aimed at finding the right balance between the actions of environmental protection of the coastal areas and those of settlement and redevelopment of urban infrastructure and services, favouring an integrated and sustainable territorial planning.

In particular, sharing these aims, this research activity is oriented to the definition of the "Blue Community" model. It looks at coastal areas as a place of experimentation of innovative planning strategies, the integrated and sustainable management of the urban-maritime and local environmental heritage. Therefore, the following are the first results preparatory to the definition of the above model. They regard the definition and application of a Systematic Literature Review study to investigate the interrelationships between coastal settlement planning and design activities and ecosystem services. This deductive approach makes it possible to define a theoretical framework on the research topic, which is the essential reference point for the future development of the research, also in order to take account of any empirical aspects.

Materials and Methods

Intercepting the scientific research carried out at the international level through the application of a Systematic Literature Review is useful in order to deepen the definition and methods of measurement and evaluation of coastal ecosystem services. In fact, it is a technique that allows to identify, select, critically evaluate and summarize current knowledge in a research field.

Therefore, the Systematic Literature Review provides a theoretical framework for identifying trends in existing literature and for identifying gaps and inconsistencies in research on the issues under consideration at the same time. To conduct an accurate Systematic Literature Review and minimize the risk of distortion, undertaking a standardized and reproducible scientific methodology recognized at the academic level is crucial. It is divided into the following phases.

The first phase concerns the identification of the research topic that concern the issue of ecosystem services in urban planning, with particular reference to coastal services.

The next step is the definition of the research question, ensuring that it is clear, targeted, concise, complex and questionable. In this case, the following research question is considered: "What are the main lines of research on ecosystem services in the context of urban planning?".

From the above research question, it is possible to extract the keywords in order to form the query string and start the search of documents on the selected database, which is Scopus. In the query string "ecosystem service AND urban plan", the operator "AND" allows to connect the two concepts, so that the database returns in response all indexed documents that contain both words entered.

In order to refine the research, Scopus offers a wide range of useful options to further narrow the list of results. Therefore, it is possible to set criteria to include-exclude documents. In this case, only articles in English and open access format are chosen.

The next step is to extract the relevant data from the selected publications, which in this case consist of 757 documents.

After that, the eligibility of the data is assessed by submitting the documents to a first review through the reading of the abstracts and of the main contents.

The last phase consists in the bibliometric analysis of the relevant data characterizing the documents, to obtain a complete overview of the scientific research carried out on the topic.

In the end, this study made it possible to summarize the quantitative and qualitative information of the publications collected, through a series of maps, tables and graphs.

Results

The results of the bibliometric analysis may be divided into quantitative and qualitative data.

The quantitative ones, deduced thanks to the use of the Rstudio's Biblioshiny package, have allowed to summarize the distribution models of publications over the years and explore their impact on the scientific community. In particular, 757 documents published in the period 2005 to 2023 were collected. Figure 1 shows the time course of publication of these documents.

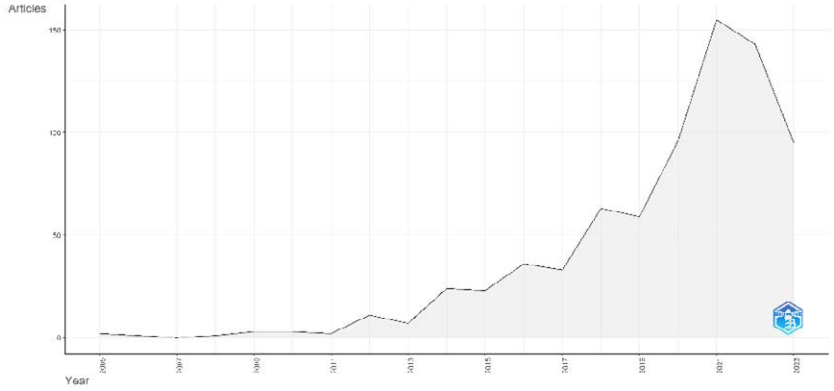

Figure 1 – Time course of publication of the selected documents.

In general, the graph shows a curve with increasing trend, so the scientific documents related to the topic have increased with time and consequently also the interest on the role of ecosystem services in urban planning. The peak of the chart was reached in 2021 with a number of publications exceeding 150 articles. In the

following years, despite the curve shows a slight decrease, the articles published are in high numbers: just under 150 in 2022 and 2023 are about 100.

The documents are derived from 206 sources and have an average citation of 30.98, while the total references amount to 47 290. The authors of the documents are 2659 and most have worked in collaborations, which for 33.16% are international. The documents come from 88 countries, although most of the publications were produced in China and in the United States. The European countries that exceed 100 publications are the United Kingdom, Italy, Germany, Sweden and Austria.

3276 keywords plus have been identified, that is keywords that appear frequently inside the documents, while the sum of the keywords identified by the authors is equal to 2330.

Subsequently, a qualitative analysis was launched to gather information on the content of the documents. Qualitative analysis is a process of study of publications through techniques of correlation and co-occurrence between keywords, aimed at obtaining significant results of synthesis represented by thematic clusters.

This type of analysis was carried out using the VOSviewer software, a tool for building and displaying bibliometric networks. In particular, the network extrapolated from the selected literature is the "Network Visualization", reported in the following Figure 2.

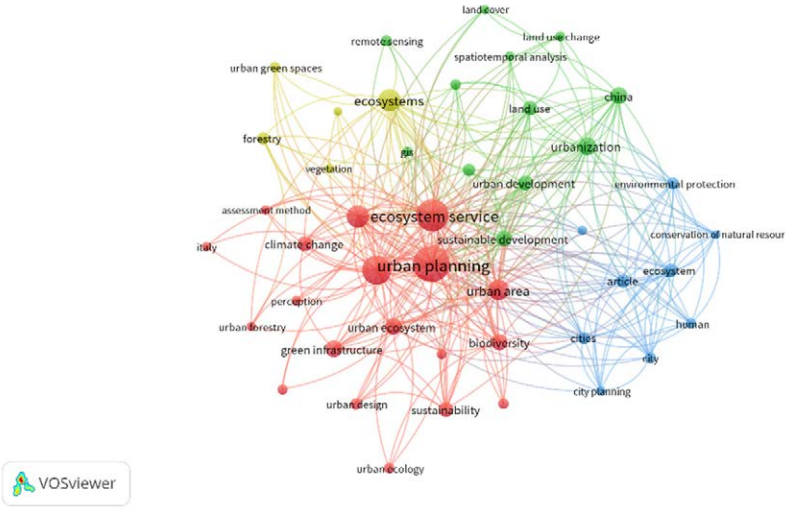

Figure 2 – Network Visualization.

The Network Visualization is composed by a series of nodes on which the major keywords from the 757 documents downloaded by Scopus are labelled. The size of the nodes reflects the frequency of presence of keywords in the documents and the proximity of terms in the map is directly proportional to their correlation.

Therefore, the closer the terms are to each other, the greater the frequency with which they occur simultaneously in the documents.

The main feature of Network Visualization is the colour subdivision that allows you to visually define thematic clusters. In Figure 2, clusters are distinguished by four different colours:

- the red cluster is called "assessment methods of urban ecosystem service" [18, 20];
- the green cluster is called "spatio-temporal analysis of land use and urban growth" [1, 24];
- the blue cluster is called "conservation of natural resource and environmental protection" [3, 12, 22, 23];
- the yellow cluster is called "ecosystems in urban green spaces" [5, 8, 19].

Discussion

The quantitative results of the Systematic Literature Review revealed a strong increase in interest in the research on ecosystem services in the context of urban planning, although the number of documents focused on coastal areas is quite small. Nevertheless, the same have been used to carry out an analysis on the link between the same and the different clusters emerged.

Considering the first cluster, in particular the study of Portman *et al*. (2016) proposes to identify the level of protection of coastal areas in order to ensure the effective management of ecosystem services. The classification is carried out by combining two values. The first one is obtained from questionnaires administered to stakeholders, who have assigned a score in relation to the value of the landscape and activities. The second one is obtained from the quality of the physical attributes of the areas, based on biotic and abiotic elements. Based on the data obtained, the authors define three protection scenarios highlighting the need for stricter procedures within the areas closest to the coast because of the presence of more ecosystem services [18]. The assessment of such ecosystem services may be carried out through software. Among these, the most widely used internationally is "Integrated Valuation of Ecosystem Services and Tradeoffs" called InVEST. In fact, it is used in most of the articles aimed at quantification and mapping of ecosystem services, as well as comparison of scenarios, economic evaluation, land and resource management, impact assessment and policy development [7]. A sample application of InVEST models is presented by Salata and Arslan (2022). Their research aims to demonstrate how digital modelling of ecosystem services can be used practically to design sponge districts and measure the benefits of performance-based solutions. In fact, the first important step of the research was to measure the risk of floods in the area, through the InVEST's model called "Urban Flood Risk Mitigation model". The results of this modelling are used to assess the biophysical distribution of the outflow and its retention throughout the city of Izmir, Turkey [20].

Considering the second cluster, in particular Zhanget *et al*. (2022) propose a mapping of land use change and spatial distribution of ecosystem services values from 1989 to 2018 in the six districts of the coastal city of Xiamen, China. The

results of the research show the conversion of agricultural land and river basins into built-up areas, especially in the period between 2000 and 2010. In this period, the authors highlight a loss of about 70 million CNY of river basins followed by the loss of about 50 million CNY of agricultural land, aggravating urban challenges such as the heat island effect, traffic congestion, housing strain, environmental pollution and lack of urban greenery [24]. The increase in urbanisation at the expense of ecosystem services is also addressed in the article proposed by AlQahtany *et al*. (2022). The case study analysed concerns the metropolitan area of Dammam, located along the east coast of Saudi Arabia. Here the extent of coastal land reclamation is assessed through the use of satellite imagery to compare the coastline boundary of the study area from 2000 to 2020. The analysis of five major reclamation projects showed that the total surface area of water and marine vegetation is between 66.5 % and 100 %, for a total of 6081 hectares of reclaimed land in the Arabian Gulf. The research focuses on the importance of these practices to highlight the implications in terms of sustainability, namely the loss and damage to biodiversity and ecosystem services. The article concludes by highlighting the need to undertake sustainable coastal environmental management through the regeneration of wetlands in coastal areas to restore lost ecological services. Although, according to the authors, it may be difficult to reduce the degradation of marine habitat and ecosystem if coastal remediation continues [1].

Considering the third cluster, some documents propose the combination of urban planning and ecosystem services generated by the species to be safeguarded. For example, Thomson *et al*. (2022) deal with the regeneration of the city of Perth, located on the Swan Coastal Plain in Western Australia, which is a hot spot for the biodiversity it hosts. The authors, based on some examples, developed principles of urban design, called “cockatoo friendly”, with the objectives of increasing the city’s ability to support endemic species, improve associated ecosystem services, increase urban resilience to climate change to strengthen community and institutional support for nature-positive design and development [23]. Likewise, Brodie *et al*. (2020) propose the analysis of coastal planning of the vulnerable area of developing States of the small islands of the Pacific, to reduce anthropogenic pressures that threaten local biodiversity. The latter provides a wide range of ecosystem services, including food supply, water purification and coastal protection. Therefore, a number of priority actions are proposed in the document with a view to improving the conservation of the marine habitat, enhancing climate change resilience and the related ecosystem services [3]. In addition, Sutton-Grier and Sandifer (2019) analyse the value of conservation of coastal ecosystems for the protection of biodiversity, for the reduction of impacts and for the promotion of human health and well-being. Specifically, the authors identify a range of ecosystem services provided by coastal areas, focusing on the significant role of coastal ecosystems in reducing the risk of storms, floods and erosion, highlighting how these benefits turn into substantial economic value for coastal communities. To confirm this theory, the study published in 2017 [22] highlights how coastal wetlands had avoided direct damage for 625 million dollars during Hurricane Sandy. Therefore, the authors recommend to act in the pre-disaster phase by adding a section Nature-Based Solutions (NBS) to the emergency preparedness plans. The NBS contribution is also analysed in Hughes *et al*. (2022). These authors also

provide the definition of NBS by the International Union for Conservation of Nature (IUCN), or "actions to protect, sustainably manage and restore natural or modified ecosystems that address social challenges effectively and sustainably in an adaptive manner, while providing benefits to human welfare and biodiversity". On the basis of this definition, three types of NBS are proposed for marine environments: the improvement of the use and preservation of protected natural aquatic ecosystems; the active restoration of degraded habitats; the creation of new ecosystems regulating nutrients through aquaculture [12].

Considering the fourth cluster, Chen *et al*. (2002) propose a study to verify the direct and indirect effects of urbanization on vegetation productivity. At the centre of their research are 48 cities located along the coastal zone of eastern China. The results showed that the direct effects relate to the significant loss of urban vegetation areas as the intensity of urbanisation increases in all cities examined. In contrast, indirect effects of urbanisation on the productivity of urban vegetation vary between cities depending on local climatic conditions [5]. The relationship between urban greenery and climate in coastal areas is also analysed by Rodrigues *et al*. (2023). Specifically, the study proposes a methodology for the implementation of green infrastructure with the aim of offering ecosystem services that mitigate the impacts caused by climate change in the districts of Pirambu, in the Brazilian city of Fortaleza. Four types of green infrastructure have been proposed combining decision-making analysis for the choice between different types of green infrastructure and spatial analysis of data through geoprocessing software. They are multi-purpose roads, rainforests, Permeable flooring and soil bioengineering.

The location of each of them has resulted in benefits for the environment and for the ecosystem services offered linked to global warming [19]. The importance of green and blue spaces for biodiversity and human welfare is analysed in Fisher *et al*. (2021). The document examines how the diversity of animal species in the coastal green and blue space in Georgetown (Guyana) is associated with people's welfare, through questionnaires and point counts [8].

Conclusion

At the international level, the debate on the ecological transition alludes to a process of technological innovation and environmental revolution, aimed at encouraging socio-economic development also in terms of territorial governance while respecting natural balances. Therefore, one of the most concrete areas of experimentation of the ecological transition is urban and territorial planning. It fosters the sustainable and resilient development of territories through a balanced management of their natural resources. In this regard, ecosystem services have long been insufficiently targeted by sectoral programmes and policies. However, they have recently been rediscovered, especially in the field of sustainable planning, as confirmed by the results of the quantitative analysis of the proposed Systematic Literature Review.

In particular, this study analysed the relationship between ecosystem services and urban planning in coastal areas that are subject to processes of urban expansion

on average more intense than internal areas. This study was carried out in order to orient the first phases of the authors' research aimed at defining a planning model, called "Blue Community". It supports the integrated management of ecosystem services and urban heritage to improve the sustainability and coherence of urban and spatial planning choices. This aim is particularly relevant because of the recognition of ecosystem services as a dominant issue in the policies of mitigation and adaptation to climate change, the protection of ecosystems and biodiversity and socio-development of the established communities.

Going into the merits of the discussion of the results obtained, compared to the 757 documents analysed, it emerged that a small number deepens the research topic with reference to coastal areas. Specifically, the qualitative analysis allowed to deepen the content of these documents, also through the application of a cluster analysis technique, from which four thematic clusters emerged.

The first cluster showed a growing interest in new methods of evaluating ecosystem services, or, on the one hand, the combination of socio-economic and environmental aspects in the analyses and, on the other hand, the utility of mapping ecosystem services through open-source software InVEST.

The issue of mapping ecosystem services is also addressed in the second cluster, which focuses on spatial-temporal analysis of land use and urban growth, highlighting the importance of this type of study to point how the urbanization of territories translates also in losses of the values of ecosystem services in economic terms and not only into almost irrecoverable loss of biodiversity and habitats.

The third cluster focuses on the activities of conservation of natural resources and protection of the environment by addressing in an integrated way studies that concern the protection of habitats and biodiversity typical of marine territories that can be implemented with different types of NBS.

Finally, the fourth cluster includes studies that highpoint how ecosystems in urban green spaces within coastal areas are important because they can contain the negative effects of urbanization, and combating the consequences of climate change, including by providing benefits for habitats and in terms of quality of life.

From a more general point of view, the study summarised here raised awareness of the need to integrate environmental issues into territorial policies. In particular, it allowed to identify definitions and methodologies for measuring existing coastal ecosystem services, quantitative benchmarks, access to platforms and software implemented for this purpose, and to start an initial analysis of the main intervention tools characterizing these contexts and aimed at combining conservation and development needs. These elements underline the importance of taking a multidimensional approach to assessing ecosystem services, with regard to urban and spatial planning activities in coastal areas, that is both necessary and strategic in terms of sustainability and resilience.

From an operational point of view, for example, the importance of using geospatial data from satellite applications and digital instruments has emerged. They produce information layers that can be easily imported into the GIS environment to evaluate the state and evolution of the inhibitory and driving factors of ecosystem services and, consequently, address data-based urban planning applications. These applications, aimed at the integrated and sustainable management of the coastal strip, can be oriented, based on local needs, for example,

to the protection and enhancement of natural emergencies, the recovery of urban and economic decommissioning and greater cohesion between local government and coastal communities. In this regard, although studies on the assessment and mapping of ecosystem services are numerous, they do not seem to find a stable and codified place in the processes of planning of local scale and large area to date. Recognising this gap, the future developments of this research will be aimed at supporting planners in defining rules for the ecosystem use of coastal areas also on the basis of the studies summarized in this contribution, for example by providing them with an integrated information base through the implementation of a GIS geo-database fed by updated and interoperable data at the appropriate geographical scale from which to deduce appropriate ecosystem indices.

In conclusion, there is a need on the part of urban and territorial planners not to confine the assessment of ecosystem services to the sphere of pure environmental accounting, but to consider it as a tool to support the definition of new development models, preserving the environmental components and triggering ecosystem dynamics of territorial rebalancing. In this sense, coastal ecosystem services represent a driver of sustainable and compatible development with the ability of ecosystems to preserve themselves over time.

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