Ecosystem Services and Rural Innovation: The Liguria Region Case Study

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Abstract. The exploitation of environmental resources and the growth of urbanization significantly altered natural ecosystems, turning over time into socio-ecological systems strongly influenced by urban regions. Spatial structures and ecosystems are required to address a mutually reinforcing symbiosis with environment and natural resources that can no longer be postponed, so as to combine the conservation needs with the reduction of socio-economic inequalities. The case study concerns the Liguria Region, characterized by a strong polarization between linear coastal conurbation and hinterland. This territorial structure is responsible for the mismatch between areas that provide most of Ecosystem Services (ES) and those with the highest population and urbanization density, which, on the other hand, are configured as major demand poles. This paper therefore aims to analyze the relationship between environmental values, in terms of ecosystem multifunctionality, and forms of rural innovation that contribute to support territorial competitiveness. The aim is to explore how a systemic approach can foster opportunities for integration between inner and coastal areas, qualifying the valley systems as new components of the anthropic-environmental structure of the region.

Keywords: Rural innovation · Ecosystem Services · ecosystem multifunctionality

1 Introduction

On our rapidly urbanizing planet, there is a need for planners to rethink human components and natural resources no longer as separate units but as part of a large socio-ecological system [1]. It represents a highly interconnected relationship between society and ecosystems [2] and is useful to jointly pursue natural resource conservation imperatives, economic development needs and the reduction of socio-economic inequalities, increasingly linked to differential access to ES [3]. The search for territorial structures suited to this new paradigm can no longer be postponed and must instead be seized as an opportunity to enhance those innovative characteristics of rural systems that stand as interface between anthropic and purely environmental systems [4].

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This paper focuses on the case study of the Liguria Region (Italy), whose anthropic-settlement structure is essentially made up of the most important urban centers and the coastal conurbation, developing mainly along the east-west axis [5].

While showing a high potential in terms of natural capital and ecosystem multifunctionality [6, 7], this structure produces a significant spatial mismatch between the inner areas that provide most ES and the main demand poles represented by areas with the highest population and urbanization density.

According to a *bioregional* approach, based on the concept of urban bioregion that underpins balanced polycentric spatial patterns and supports self-reliant and fair local development [8], our research question is: can a systemic approach offer opportunities for integration between inner areas and coastal strips, qualifying the valley systems as new components of the regional anthropic-environmental structure?

The purpose of this paper is hence to investigate the relationship between ecosystem multifunctionality, defined as the capacity to simultaneously deliver several ES [9–11], and different forms of rural innovation that contribute to support territorial competitiveness and strengthen resilience [12, 13].

This work is organized as follows. Section 2 presents the overall methodology and describes methods used to assess the degree of rural innovation and the multifunctionality indicator. Section 3 illustrates the result of the comparison between spatial distributions of the two indicators and highlights correspondences interpreted in the light of territorial policies implemented and on-going settlement dynamics. Finally, the conclusions highlight a reciprocal multiplier effect between ES provision and the development of innovative contributions in rural systems.

2 Methodology

In order to analyze the relationship between innovation of rural systems and multifunctionality of ecosystems, two different spatially explicit indicators were calculated.

The first expresses the ability of ecosystems to provide multiple goods and services essential for human well-being. As part of this work, it was computed as the sum of 7 ES normalized with respect to time series.

The second measures rural systems' innovation degree and is representative of a set of characteristics of both socio-economic and political-technological dimensions.

With the aim of investigating the mutual relationship between these two indices, an autocorrelation analysis was performed to define innovation territorial cluster. They were then overlayed to ecosystem multifunctionality variation over the period 2000–2018.

The following paragraphs illustrate the methods used to calculate the two indices.

2.1 Ecosystem Multifunctionality

For the purpose of this study, we selected a set of 7 ES (Table 1) based on two criteria:

– relevance with respect to the study area;

– input dataset and layer availability to implement the calculation models, considering the 2000–2018 time series.

According to the Common International Classification (CICES v5.1) [14], they are included in two sections "Provision" and "Maintenance and regulation".

Table 1. Set of ES considered

Section	Class	Method/Model
Provision	Crop Production	InVEST
	Water yield	Budyko equation
Regulation and Maintenance	Regulation of chemical composition of atmosphere	InVEST
	Pollination	InVEST
	Maintaining nursery populations and habitats	InVEST
	Control of erosion rates	InVEST
	Regulation of the chemical condition of freshwaters	InVEST

The aforementioned ES were assessed and mapped for each available Corine Land Cover chrono sequences (2000–2006–2012–2018). The multifunctionality index used was calculated in the GIS environment by normalizing the current value compared to the historical series. This index was calculated with reference to 2000 and 2018. The difference between these two layers returns the spatial distribution of its variations over the period considered.

2.2 Rural Innovation

The second indicator was used to analyze sustainable territorial innovation processes and quantitatively measure the organizational characterizations of socio-economic structures.

For the purpose of computing this index, 7 indicators were selected, relating to aspects linked to the socio-economic dimension (multifunctional agriculture and agro-productive circuits; social and cultural actions; sustainable tourism) and 4 indicators describing political-technological aspects (governance policies; energy systems; digital networks).

By geolocating the presence of aforementioned innovation components over the regional territory, a regular hexagonal grid (size 500 m) was created in order to have a synthesis representation. Each grid cell shows the degree of innovation, i.e. the mean number of innovation components included within it.

3 Results and Discussion

This section illustrates the result of the cluster analysis carried out to define area where a more evident rural innovation is occurring. Then it shows the results from overlapping of rural systems innovation clusters with respect to the variation of ecosystem multifunctionality index.

To identify local clusters in the Innovation Degree (Fig. 1) we performed an autocorrelation analysis by the Univariate Local Moran's I index (LISA) [15] using the software GeoDa [16].

Results from this kind of geo-statistical analysis allow to identify *High-High* and *Low-Low* spatial clusters and, on the other hand, to classify *High-Low* and *Low-High* spatial outliers.

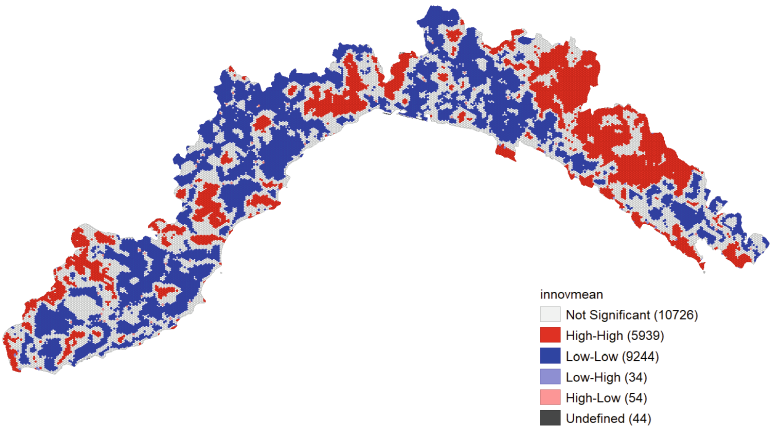

Fig. 1. Results of the cluster analysis performed to identify innovation clusters in rural systems

These results confirm that different innovative actions create a field of mutual attraction, so they tend to have a tendency to have a certain degree of spatial concentration.

The representation of the clusters defined by the analysis is accompanied by the corresponding Significance Map (Fig. 2) that shows the locations with a significant local statistic ($p < 0.05$).

Results deriving from autocorrelation analysis were therefore used to extrapolate the areas of the regional territory that qualify as innovation clusters (*High-High* cluster) and to overlay them with the variation of the ecosystem multifunctionality index.

The highest values of multifunctionality are distributed in the inner part of the region near the mountainous areas characterized by predominantly forested and highly vegetated land covers, low anthropic pressure and geomorphological factors that have contributed to limiting the spread of urbanization processes.

On the other hand, the lowest values are found along the coastal strip in the most densely urbanised areas, where the highly fragmented settlement and production system, the massive adoption of intensive cultivation practices and the high density of road infrastructures contribute to low environmental performance.

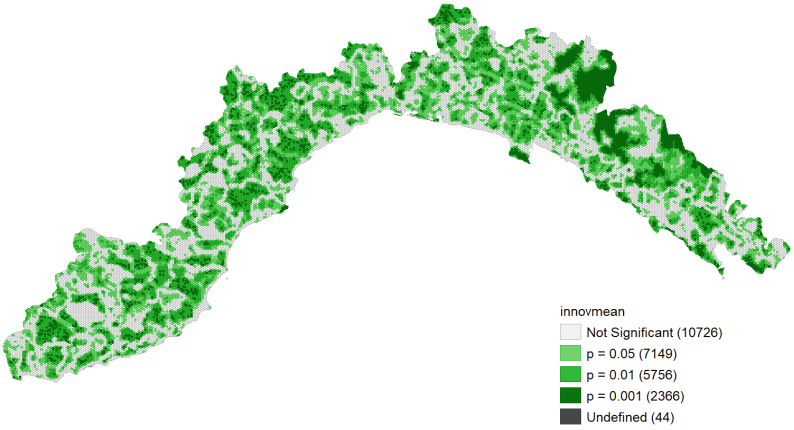

Fig. 2. Significance Map

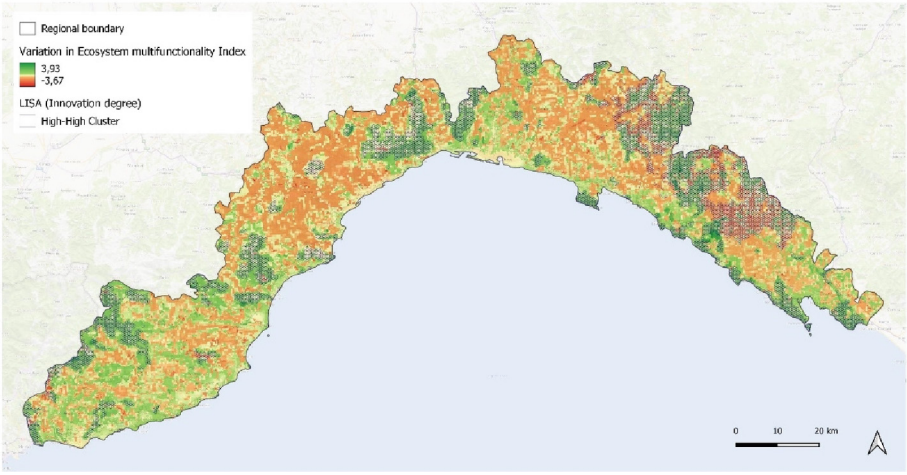

Fig. 3. Overlay between the rural systems innovation clusters and the spatial distribution of the variation of ecosystem multifunctionality index.

The overall picture shows a high variability of environmental performances as a function of urbanization intensity, with correspondences emerging between areas characterized by low to medium values and the main coastal conurbations.

The degree of innovation also takes on a rather fragmented distribution, assuming greater intensity where a multiplicity of innovative actions related to the tourism-accommodation, hiking and agro-production sectors are concentrated. A first level of innovation is also detected along the eastern coastal strip, linked to the initiation of regeneration projects and the presence of biodiversity in protected park areas.

The overlap between innovation clusters and the variation in ecosystem multifunctionality (Fig. 3) shows some correspondences: in fact, most innovation clusters correspond to areas where multifunctionality increased over the period 2000–2018.

It can also be seen that the major innovation hubs fall within the 4 regional Inner Areas. Also evident in the west part of the Region is the increase in ES where the Alta Valle Arroscia Inner Area and the Ligurian Alps Regional Natural Park are located. Thus, the synergy existing between innovation and protection actions through the creation of park areas that significantly affect regional environmental quality is evident.

4 Conclusions

To correctly interpret the innovation characteristics of a territory, it is necessary to consider their dynamic nature. These in fact are distributed over space and time in relation to a series of intrinsic factors such as contextual preconditions, resources, situational variables, capacity to accept risk and change, socio-cultural values and interests, absorption capacity [8, 17].

From a purely environmental point of view, the set of these factors can be summarized in the multifunctionality of ecosystems, i.e. the overall ES supply, which can thus be taken as a measure of territorial environmental performance [7].

It is therefore important to pursue a systemic approach and deepen the link established between the set of environmental values and innovation factors, which in turn is representative of the functional relationship between natural capital production sites and forms of innovation in rural systems [18].

It is clear from the overlay maps that innovative actions play an active and dynamic role in promoting ES production [19]. On the other hand, it is evident that areas with better predisposition to ecosystem service provision attract innovative actions.

Since inner areas could play an important role in promoting ecosystem multifunctionality for coastal areas [20–22], this work shows how a symbiosis of rural space and innovative actions can be an opportunity for integrated regional spatial development.

Research developments will be aimed at deepening and characterizing the relationship between rural systems' innovation degree and ecosystems multifunctionality in order to verify the opportunity to promote policies that enhance the conservation of natural resources as elements of competitive advantage for local development.

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