Regulation and Maintenance Ecosystem Services (ReMES): A Spatial Assessment in the Basilicata Region (Southern Italy)

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Abstract. The current spatial planning system in Italy demonstrates its lack of a data infrastructure so robust, flexible and adaptive to provide adequate performance in the capacity to support the decision-making process. This weakness is manifested even more in the management of the territorial transformations under the pressure of rapid changes involving social, environmental and economic dimensions. The ecosystem services (ES) approach constitutes a robust framework to contribute to the renewal of the planning system by making explicit complex dynamics until now considered only marginally and by introducing spatially explicit knowledge as an effective decision support system (DSS). This work focuses on the class of Regulating and Maintaining Ecosystem Services (ReMES) as it is considered particularly relevant with respect to the ecosystems' potential of expressing environmental performance and contributing to human well-being. A further characteristic of this class is the often significant mismatch between the spatial scale of the territorial transformations and the (larger) scale at which changes in ES supply are measured.

The aim of this work is therefore to represent the spatial distribution of a relevant set of ES in the Basilicata Region (Southern Italy) thus contributing to the development of a cross-sectoral spatial knowledge infrastructure with respect to components still managed within the planning processes in a sectoral and fragmented way. The results highlight the usefulness of such a tool for the comparison between different planning scenarios including both environmental conservation issues and socio-economic development strategies.

Keywords: Ecosystem services · Regulation and Maintenance Ecosystem Services (ReMES) · Territorial specialization · Territorial transformations

1 Introduction

The rapid changes occurred in recent decades from the environmental, social, and economic perspectives revealed some limits of traditional approaches of the planning discipline and in the management of territorial transformations and land use changes.

The planning system showed structural weaknesses from both a regulatory and informative perspective. The first concerns the un-adaptive nature of traditional zoning and of

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the regulatory models applied in urban and regional planning; the second relates to the provision of spatial data infrastructures capable to support decision making accounting the three components of sustainability (environmental, social and economic) [1] and the human well-being [2, 3].

We need to make the planning processes more comprehensive and integrated [4] since they still do not fully meet the demand for tools to support policy making and the development of alternative transformation scenarios [5, 6].

In this regard we refer to the "*ultimate goal of spatial planning"* [7] that should be improving the decision-makers' territorial knowledge about current and future issues of the contexts where the plan will be implemented.

The Ecosystem Services (ES) Approach proved to be a robust framework for territorial analysis [8] and for spatially explaining the trade-offs associated to different land use patterns [9] and transformations [10], improving the communication and the debate among the stakeholders [8] involved in the different levels of governance.

The aim of this work is to contribute to building territorial knowledge by mapping a relevant set of Regulation and Maintenance Ecosystem Services (ReMES) at the regional scale of the Basilicata Region (Southern Italy) referred to the year 2018.

According to the CICES classification [11], they have a strong influence on the ability of the environment to contribute to the quality of human life even if they are not directly consumed. Furthermore, belonging to the Division of "Regulation of physical, chemical, biological conditions", they are relevant for express a measure of the ecosystems quality [12].

For the purposes of this work, we selected the following 5 classes [13]: i) Regulation of chemical composition of atmosphere; ii) Pollination; iii) Maintaining nursery populations and habitats; iv) Control of erosion rates; v) Regulation of the chemical condition of freshwaters.

We developed this data infrastructure as a baseline of reference to encourage the comparison between alternative development scenarios in an ex-ante evaluation of the planning process. Our results are also useful to monitor the transformation and the relative environmental performances following the implementation of territorial policies [14].

The conclusions highlight the contribution that a data infrastructure based on ReMES mapping as a crosscutting informative layer useful in different planning processes, from the urban to the regional scale.

2 Materials and Methods

According to the CICES classification, five ES classes were selected in relation to their significance for the assessment of the current status of ecosystems in the Basilicata Region.

Most of them were assessed by the means of the InVEST models, a set of spatial-explicit software widely used to map not belonging to traditional markets [15].

The basic spatial information layer necessary for all of the ES assessed, was the "land use map", i.e. the CORINE Land Cover (year 2018) made available as part of the Copernicus program.

The results are maps representing the spatial distribution of the ES supply to be intended as a baseline of reference to compare alternative development scenarios. This data layers constitute the basis for future territorial analysis oriented to explicate the relations between multiple ES and to support the development of win-win solutions in both land use management and territorial planning [16–18].

A methodology is finally applied in order to define "areas of specialization" and identify part of the regional territory actually performing better in terms of ES multifunctionality.

2.1 Carbon Storage

The assessment of Carbon storage constitutes an increasingly relevant layer for the design of policies defined into strategies for climate change adaptation and mitigation.

The recent classification of the CICES v.5.1 [11] consider Carbon stock an ecosystem function [19] but allows its assessment as a proxy of the regulatory effect that the ecosystem provides with respect to all atmospheric components [20].

For the purposes of this work, we considered the Carbon stock strictly related to the land use pattern [21] so we employed the InVEST Carbon Storage and Sequestration Model to map the spatial distribution of carbon stock extending previous case studies [22] and referring to biophysical tables depending on the Land Use/Land Cover class [23].

The processing results (Fig. 1) still have the resolution of the CORINE land-use map. According to the nature of the implemented model, the values are distributed among discrete ranges varying from 0 t/ha for "urbanized areas" to 168 t/ha for "forests" that corresponds to the maximum pixel value.

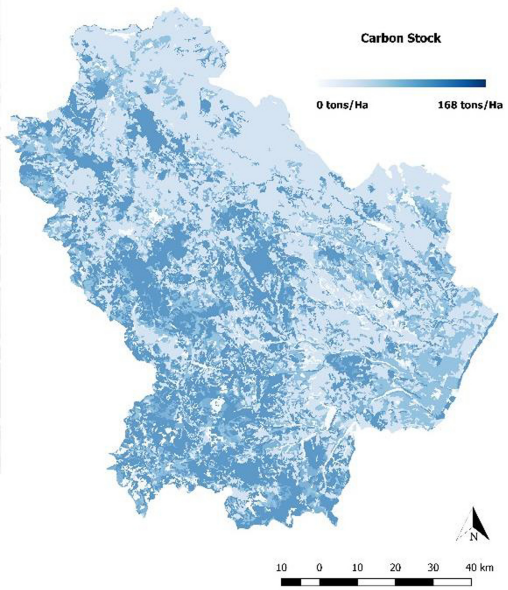

Fig. 1. Carbon stock

The carbon stock map shows that the most significant reservoirs in the Region are located along the Apennine chain in the western part of the regional territory.

2.2 Crop Pollination

The pollination is recognized as a fundamental ReMES since its importance is linked to both the protection of biodiversity and to agricultural productivity related to the food security.

At the European level, there is an explicit policy demand for the protection of the pollinators habitats: the EU Biodiversity strategy [24] for example explicitly requires the Member States to map spatial distribution of pollination services and to evaluate their economic value.

In this work we used the InVEST Crop pollination tool based on the territorial availability of suitable nesting grounds and food considered as necessary conditions to provide pollinators' habitat.

Input data required are: the potential availability of nesting sites and floral resources, the flight range of pollination species and their seasonality [25].

Basing on land use classes [26], the model uses expert estimations about nesting and floral resources to give as results two maps: the "pollinator supply" describing the availability of pollinators; the "pollinator abundance" representing the potential presence of pollinators, i.e. the area where pollination services are delivered.

The results thus depend not only on the land cover class but also on the pattern of land uses.

Literature dataset for each Land Use Class [27] were used to derive information about floral availability and nesting suitability as well as data concerning the flight range and seasonality of pollinators [28].

The results' resolution is the same of the Corine Land Use Map (Fig. 2).

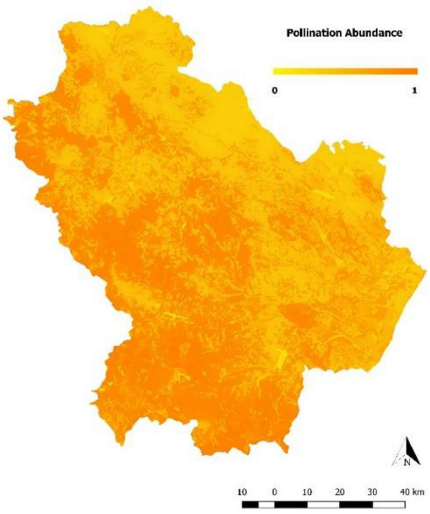

Fig. 2. Pollination abundance

Being significant of an observation probability, both maps vary between 0 and 1.

As can be seen, the areas where the pollination service is provided with a greater intensity correspond to "forestlands" and vegetated areas in which the herbaceous and shrub cover is intermixed. The pollinator supply distribution assumes its maximum value in correspondence of "transitional woodland shrub", "forests" and "sparsely vegetated areas".

The pollination abundance is relevant in those areas where the regulating services are delivered and its intensity reaches the maximum where extensive "natural grasslands" are present (Fig. 3).

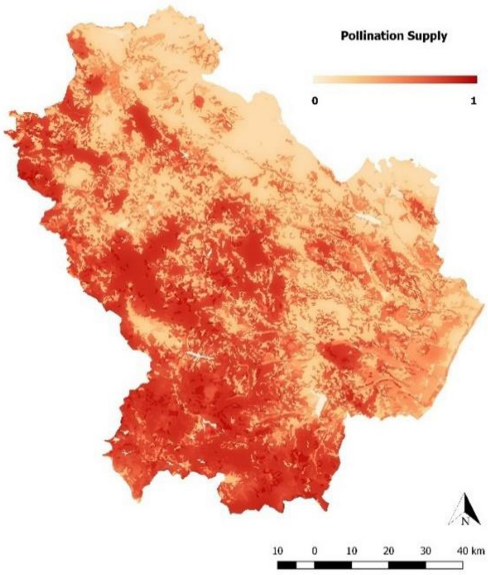

Fig. 3. Pollination supply

2.3 Habitat Quality and Degradation

Habitat quality and degradation was assessed as a proxy of the CICES class "Maintaining nursery populations and habitats". We used InVEST 'Habitat Quality and Degradation' [25] module that combines information on habitat suitability, depending from the land use, and different threats deriving from anthropic activities.

The model is sensitive to the spatial distribution of habitat and pressures and it can support the monitoring of the interactions between natural and anthropic components.

The results are two maps: "habitat degradation" resulting from the cumulative effects of anthropic pressure that contribute to degradation; "habitat quality", ranging from 0 (low habitat quality) to 1 (high habitat quality) and derived from the combination of the overall impact and the habitat suitability.

Data needed are: (1) land use map (2) a table describing the weight (in a range between 0 and 1) and the radius of influence where the threat generates an impact (expressed in km) of each threats; (3) a binary raster map for each threats; (4) the sensitivity matrix for each land use class.

In our case, dataset were derived from the literature for both the threats [61–63] and the sensitivity matrix [64–66].

For the Basilicata Region, the degradation map (Fig. 4) varies between 0 and 0.24, with the lowest values corresponding to the higher zones of the Apennines Chain.

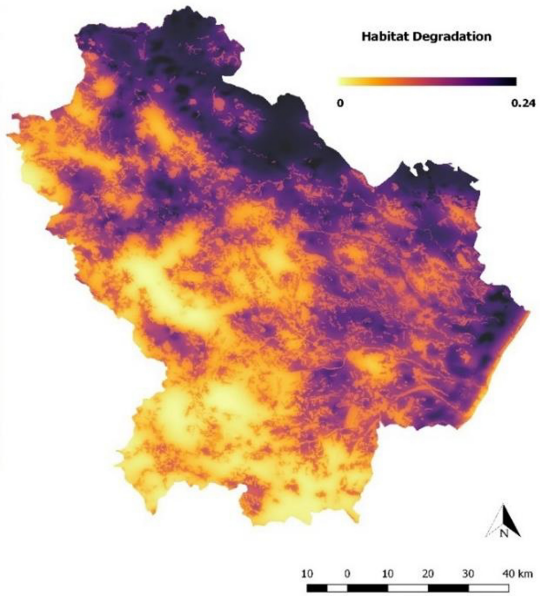

Fig. 4. Habitat degradation

As can be seen from Fig. 4, the highest values of habitat degradation occur in correspondence of the main agricultural areas. The north-eastern part of the Region is in fact characterized by intensive cereals production and very homogeneous land cover.

Habitat Quality (Fig. 5) ranges between 0 and 1, with the null values corresponding to the major urban and industrial centers. Apart from artificial surfaces, the lowest value can be observed in the eastern part of the Region, where an intensive agriculture is practiced. The values closest to one are observed in correspondence of wetlands along the coast strip which have been assigned a very high naturalness value, and in the more remote wooded areas where the distance from the sources of threat is higher.

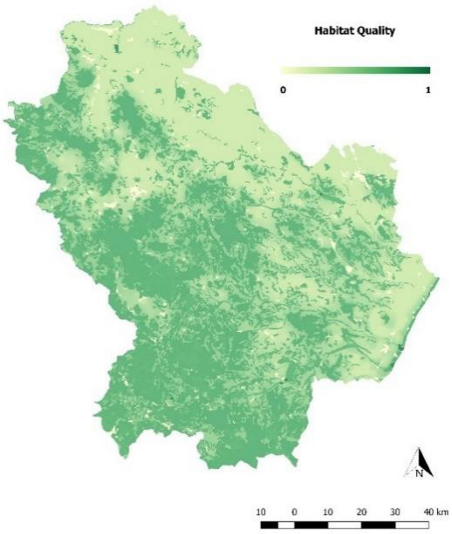

Fig. 5. Habitat quality

2.4 Control of Erosion Rates

There's a general agree about the need to conserve the soil since it is one of the main provider of ES [29] being essential for agricultural productivity, for the carbon cycle regulation [30] and the biodiversity preservation [31] and a key component to pursue sustainable development objectives [32].

In this work we used Sediment Delivery Ratio (SDR) InVEST module [33], a spatially-explicit software able to model erosive phenomena and to represent the spatial variability of soil loss [34]. It is based on the Revised Universal Soil Loss Equation (RUSLE) [35] that allows to map the distribution of the annual average soil loss (tons/ha/yr).

Data required are: (1) the Land Use Map; (2) a table of the values of the crop management (C) and support practice (P) parameters assigned to each Land Use Class; (3) the Digital Elevation Model (DEM); (4–5) two raster dataset for the rainfall erosivity (R) and the soil erodibility (K).

The "crop management factor" (C) represents the capability of land use cover to limit the rainfall impact [36]; we used the dataset developed by Panagos et al. [37].

The support practice (P) accounts for agricultural management practices that contrast erosive phenomena; for these values, we referred to datasets available in the literature [38].

The "rainfall erosivity" (R) is a measure of the rainfall energy [39] expressed in [MJ $\cdot$ mm $\cdot$ ha^{-1} $\cdot$ hr^{-1}] and it depends from the total kinetic energy, the duration and the intensity of a rainfall [40]. We used available dataset with 1 km resolution and based on the Rainfall Erosivity Database on the European Scale (REDES) [39].

The "soil erodibility factor" (K) (Mg$\cdot$h$\cdot$MJ$^{-1}\cdot$mm^{-1}) represents the susceptibility of soil particles to be detached and transported by rainfalls and runoff [40]. In this work,

we used the dataset derived from the JRC's European Soil Data Centre (ESDAC) [41] with 1 km resolution.

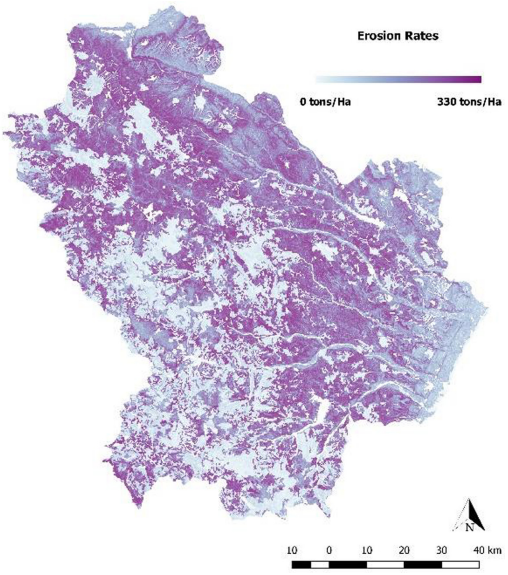

Fig. 6. Erosion rates

The result of this elaboration is a map (Fig. 6) representing the phenomenon of soil loss: the highest value thus characterize the area where the provisioning of the ES is minimum. As can be seen, in the Basilicata Region the most intensive erosive phenomena occur in the central part of the territory, in particular along the western slope of the Apennine Chain where morphological characteristics significantly influence hydrogeological processes.

2.5 Regulation of Freshwaters' Quality

Mapping the Regulation of freshwaters' quality as ReMES constitute a useful data layer because it supports the interpretation of the interactions occurring between: land uses representing a source of pollution (e.g. agricultural uses); land use representing a potential filter to mitigate contamination (e.g. areas covered by riparian vegetation); water bodies. The results are thus support the design for action aimed at improving the surface water quality [42].

The model applied, the InVEST Nutrient Delivery Ratio, simulates the movement of pollutants (Nitrogen and Phosphorus) by computing a mass balance combined with the territorial morphology. It can model both the components transported through surface and subsurface flows. Input data required are: (1) The land use map; (2) the Digital elevation model (DEM); (3) the nutrient runoff proxy representing the capacity to transport pollutants downstream; (4) the watersheds vector layer; (5) a biophysical table summarizing the nutrient loading (kg/Ha/yr).

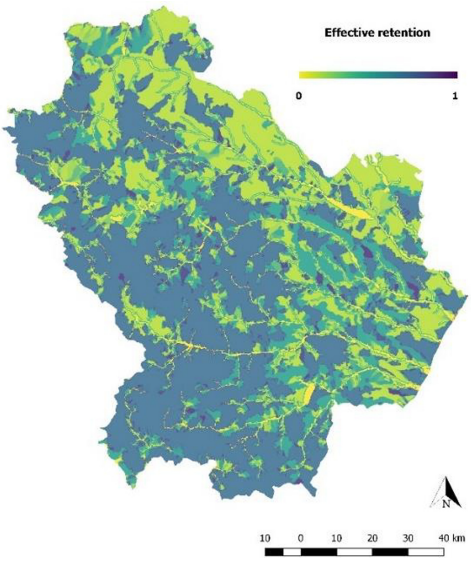

Fig. 7. Nutrients effective retention

For the biophysical table the data used in this work were collected by Salata et al. [42].

Among the outputs of the model, we considered the layer called "effective nutrients retention" (Fig. 7) as the most relevant output for the purposes of this work since it represents the filtering potential of each territorial unit. This layer is indeed a function of land use and the runoff pattern depending on territorial morphology.

The value of Effective Retention varies between 0 and 1, in our application it is 0, in correspondence with watercourses, and goes up to the maximum values where vegetated areas are located in proximity to watercourses.

3 Results and Discussion

Basing on the results obtained following the software implementation, we identified for each of the ReMES considered an "area of specialization" that is the area of the Regional territory were the supply of each ES reach its maximum values. The criteria used for this identification was a simple classification, based on the third quantile of the overall raster values distribution.

The ultimate goal is defining some area of the Region that are specialized in the ES multifunctionality provision. For this reason, the results (Fig. 8) allow to highlight the areas that play a relevant role in the provision of ReMES, that doesn't mean that only a single ES is supplied in a specific area, but several ES show a relevant magnitude in that area following to different site characteristics.

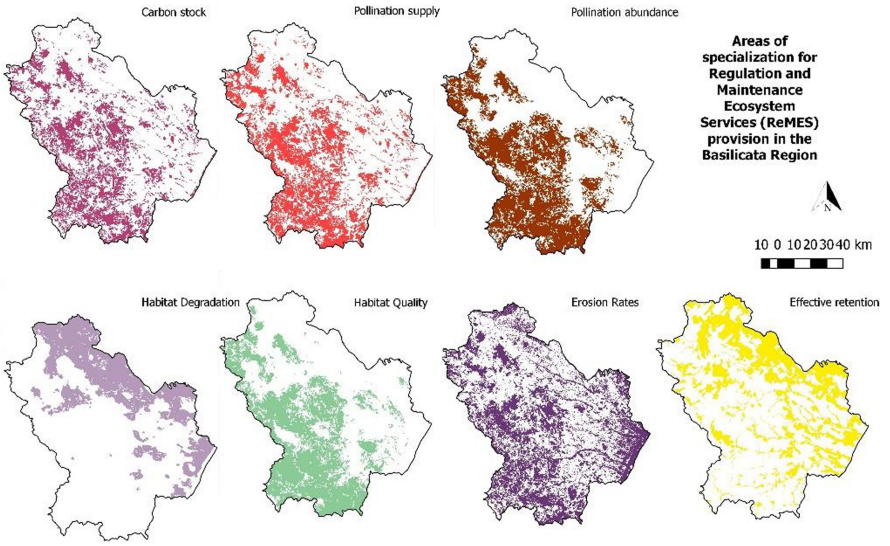

Fig. 8. Areas of specialization for ReMES in the Basilicata Region

Some comprehensive consideration arise: for example the relevance of woods and forests in eastern part of the Region, along the Apennines Chain, emerges. The value of carbon stored ranges from 168 tons/ha for forests, to 125 tons/ha for shrubland and sclerophyllous vegetation. These areas occupy a relevant extension and are characterized by a significant spatial continuity along the entire regional territory. This is a necessary precondition to reinforce biodiversity conservation objectives.

The habitat degradation map highlights the areas where the anthropic pressure is more intense due to the wide presence of anthropic areas and industrial centers, a branched network of transport infrastructures and, above all, the prevalence of intensive agricultural activities. This consideration supports the need to prioritize in territorial governance policies actions and measures that encourage the differentiation of agricultural production and greater ecosystem multifunctionality.

The issue of habitat degradation linked to the intensive agriculture can be furtherly investigated including in the evaluation of the environmental quality, the component related to the freshwaters' quality. As can be seen, in fact, the water component of the environmental matrix is not so affected by the pollution generated by agricultural activities because the advantagious morphological conditions aloow a good degree of natural filtration by soil.

Finally, the pollination abundance and supply are useful if compared with other specialization areas since pollinators' demand and supply can be compared and assessed in function of a comprehensive and systemic environmental quality evaluation. Pollination is in fact essential for agricultural productivity, and the individuation of new ecotonal areas that ensure the sufficient presence of suitable sites for nesting and foraging pollinators and an higher sustainability of current agricultural practices may reinforce the ES multifunctionality supply.

4 Conclusions

The traditional planning system showed to be weak in governing territorial transformations and land use changes according to sustainable principles, especially in view of the growing pressures due to ongoing climate change [43–48].

To tackle these structural challenges, we need to overcome the contraposition between the protection of the natural capital and the sicio-economic development [49, 50].

The main assumption by the authors is that the ES approach can support decision making and the planning processes by enhancing the comparison among different scenarios and thus allowing the formulation of win-win governance solutions.

This work was aimed at propose a methodology oriented to reinforce the knowledge building process, making explicit complex dynamics between ES and anthropic land-uses currently not fully integrated within the plan evaluation process.

Our results highlight the potential of mapping ES multifunctionality in terms of areas of specialization for the supply of multiple ES. Assessing and representing the spatial distribution of this areas are useful to define territorial complementarity among areas of provisioning and areas of major demand. Furthermore, such methodology could support the definition of supplementary measures for example for designing green infrastructures [51, 52].

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