Sustainable Cities and Society 56 (2020) 102082

Contents lists available at ScienceDirect

Sustainable Cities and Society

journal homepage: www.elsevier.com/locate/scs

Comparing the territorial performances of renewable energy sources' plants with an integrated ecosystem services loss assessment: A case study from the Basilicata region (Italy)

Francesco Scorza, Angela Pilogallo*, Lucia Saganeiti, Beniamino Murgante, Piergiuseppe Pontrandolfi

Laboratory of Urban and Regional Systems Engineering (LISUT), School of Engineering, University of Basilicata, Viale Dell'Ateneo Lucano 10, 85100 Potenza, Italy

ARTICLE INFO

Keywords:
Performance based planning
Ecosystem services
RES
Cumulative effect
InVEST

ABSTRACT

Territorial transformations are currently influenced by the combination of multi-scale processes that generate complex change dynamics. In particular, we focus on the emerging conflicts between CO_2 reduction policies and the preservation of natural and ecosystem values on a the local scale. Global policies stimulate a generalized effort in promoting the transition towards a low carbon economy, and a relevant component of such a development process is connected with Renewable Energy Sources (RES). Such technological settlement processes in low density areas generate relevant impacts.

This paper discusses an ex-post-impact assessment methodology based on cumulative ecosystem services losses in a specific study area: the Melfi municipality in the Basilicata region (Italy).

The proposed methodology, starting from a temporal evolution of RES plants, considers the ecosystem services estimation based on InVEST tools in order to deliver spatial multicriteria maps of the resulting territorial impacts. These results allowed to clarified the limits of a local sectorial planning approach and highlighted the opportunities offered by performance-based planning in assessing alternative transformation scenarios.

The conclusions regard policy implications towards a multidimensional performance-based planning system where alternative low carbon transition scenarios could be compared in order to take into account territorial specializations and identity assets as a tool to drive decision-making in a sustainable planning perspective.

1. Introduction

Although the need to perform an energy transition from fossil to renewable sources is widely shared and well-established, increasing attention is being paid in assessing the degree of sustainability of energy landscapes (Stremke, 2015) thus created.

It is indeed clear that we are facing a complex process of territorial transformation promoted under the global flagship of clean energy production, but not supported by an accurate monitoring system able to identify broad impacts on other territorial values. This general consideration represents a critical issue in those contexts where the territorial planning system showed structural weaknesses both from a normative and an informative perspective. The normative perspective includes the structure of responsibilities articulated per territorial authorities (mainly public) that operate in planning elaboration and management. The informative perspective deals with the availability of effective data infrastructures that serve the modelling and assessment capacity so as to support decision-makers in managing territorial development. This critical remarks refer to the wide literature of complexity in planning and decision-making (Batty, 2013; Friedmann, 2019; Healey, 2003). The focus on Renewable Energy Sources (RES) is representative of the lack of managing technological innovations in planning. Such is the case of the diffusion of new technology characterized by spatial footprint rapidly coming out (mainly under financial speculative rules) without an effective reaction of the normative planning framework. Consequently, public interest oriented towards facilitating benefits that derive from such technological innovation and to avoid impacts and negative effects on sensible territorial values, might not be achieved. Therefore, the research questions at the bases of this work are: how to improve the territorial monitoring system so as to achieve an appropriate landscape and environmental assessment in RES planning? Consequently, how to develop effective innovations in the

* Corresponding author.
E-mail addresses: francesco.scorza@unibas.it (F. Scorza), angela.pilogallo@unibas.it (A. Pilogallo), lucia.saganeiti@unibas.it (L. Saganeiti), beniamino.murgante@unibas.it (B. Murgante), piergiuseppe.pontrandolfi@unibas.it (P. Pontrandolfi).

https://doi.org/10.1016/j.scs.2020.102082
Received 11 June 2019; Received in revised form 3 February 2020; Accepted 3 February 2020
Available online 05 February 2020
2210-6707/ © 2020 Published by Elsevier Ltd.

normative planning framework in order to improve long-term sustainability for territorial transformation on a local scale?

Our research hypothesis is to consider the process of RES settlement as a planning research domain where a performance-oriented assessment could reveal un-sustainable features of territorial transformation leading to a loss in ecosystem values.

With this view, RES global campaigns i.e. Europe 202020 EU, 2008)) might not be considered as a fully sustainable transition. The territorial changes provided, widely affected the provision flow of the Ecosystem Services (ES) and such a trend will not be reverted without a comprehensive territorial planning approach based on effective tools oriented towards a Performance Based Planning (PBP) framework.

In PBP literature (Baker, Sipe, & Gleeson, 2006; Faludi, 2000; Frew, Baker, & Donehue, 2016; Geneletti, La Rosa, Spyra, & Cortinovis, 2017; Haller, 2014) this approach is often mentioned as an alternative to the rigidity of prescriptive zoning regulations and it represents a valid methodological tool to overcome urban planning regulations formulated on the concept of land classification, in favour of a management system of urban transformation impacts based on performance standards. If the zoning approach led to an a-priori design of the plan aimed at 'conforming' forthcoming projects to the pre-established strategy (cfr. (Janin Rivolin, 2008)), the practice of a slow implementation of this strategy (where private development capacity prevailed over the public development), created in the end, an un-effective system where the fulfilment of quality objectives of territorial transformation could only be partially verified after decades from the adoption of the plan. The urban system changes so rapidly that such an old strategy (vintage) becomes inadequate without a flexible procedure in place to improve the plan under the traditional normative framework. A way to monitor such rapid changes is to consider land use classification holding the tools sensible to verify linkages between specific territorial transformations and the nearest surrounding territorial features.

We agree with the formulation proposed by Baker et al. (2006) (Baker et al., 2006) that links PBP to the assumption that impacts of anthropic land uses are a function of intensity, physical characteristics and functions. In our case, the definition of 'performance of territorial transformations' (in terms of expected results) takes into account objectives of renewable energy development compared with the complex system of territorial values to be preserved: agriculture, wooded areas, naturalness and landscape. The PBP approach is composed of two main components: i) criteria describing desired results and ii) methods to define standards used to measure acceptable impacts (Baker et al., 2006).

Wishing to follow up on the questions posed above and considering what has emerged from the analysis of literature, we identified the following research gaps:

a) Lack of detailed spatial data availability on RES plants
b) Weakness of spatial indicators describing comprehensive effects of RES settlement on territorial values/components
c) A "Vintage planning" (Romano, Zullo, Marucci, & Fiorini, 2018) system structured on traditional zoning and anthropic land use categories that are unable to react to intensive RES sprawl in order to guarantee sustainable performances of territorial management for citizens.

With a view to filling these gaps, we propose a methodology aimed at characterizing the effects of widespread RES settlement throughout an ecosystem services based procedure implemented on a specific territorial system: the Melfi municipality in the Basilicata region.-.

Accordingly, although our results are limited by case study features, the applied model represents a transferable and innovative methodology that could be able to produce a sensible evaluation scenario in contexts that are characterized by different territorial structures.

The issue of the rapid evolution of RES is a relevant process throughout the entire Basilicata region. Without a doubt, in recent decades, the Basilicata region has experienced a rapid growth and a scattered settlement of RES installations in a context of weakly regulated territorial planning context. In 2010, the Regional Environmental Energy Plan (PIEAR) (Consiglio Regionale Di Basilicata, 2010), adopted a stimulated electricity production from renewable sources. Consequently, the number of RES plants in the Basilicata region rapidly increased in the last decade, reaching 25.1 % of the total national amount in 2018 (GSE, 2018). A shattering effect in terms of CO_2 reduction objectives achievement, but also a tremendous process of territorial transformation occurred in the absence of a Regional Landscape Plan and therefore without any rules of protection and preservation for the territorial landscape, and natural and cultural values.

Our approach selected ES as a territorial assessment framework in the absence of a more specific way to detect the impact on ecological components and, in other words, the ecological footprint (Danish, Hassan, Baloch, Mahmood, & Zhang, 2019), of such settlement process at the most adequate scale. Moreover we affirm that ES constitute an innovative approach since they are based on the idea that decision making processes should consider services provided to humans, according to a comprehensive scenario analysis. This could reinforce the capacity of rational 'decision-makers' to take 'better' decisions (Owens, 2005; Sanderson, 2002; Scorza, Murgante, Las Casas, Fortino, & Pilogallo, 2019; Weiss, 1979) by developing an assessment framework oriented towards overcoming a radical approach in ecological protection issues that constitute a value for human life and a component of human well-being, not only a way to protect one (or a selected group of) specific (flora/fauna) species (Arico et al., 2020).

The first section of the paper describes the study area by highlighting the components of anthropic, natural and semi-natural systems. It also includes a detailed description of the evolution of RES installations and infrastructures that provided a distinguishable energy landscape in the Melfi municipality.

The second section illustrates the methodology used both for the assessment of single ES and for the formulation of three scenarios.

Results are discussed highlighting differences and similarities among structured scenarios.

Finally, the conclusions critically discuss the results obtained from the integration between an ecosystem service approach and a multicriteria analysis. We explored a procedure that is worthwhile developing as a decision support system in order to promote innovation for effective PBP on a regional level.

2. Materials and methods

2.1. Study area

The study area corresponds to the Melfi municipality, located in the Basilicata region in southern Italy (Fig. 1). Melfi is the third largest municipality in the region for both resident population and territorial extension. It has 17,878 inhabitants (2017) on a territorial area of about 205 km^2 (Istat n.d., 2020). The territory is characterized by a settlement structure based on two main components: the main town, including a historic settlement and post-World War II residential expansions, and a huge industrial area, "San Nicola", where the most important car plant of Fiat Chrysler Automobiles group (FCA) was established in the 1990s. The remaining municipal area is characterized by a strong agricultural vocation, together with widespread areas with considerable naturalistic and environmental values. The territory is also crossed by three railway lines and a high-speed suburban road, which serves as the main link between Melfi and the regional capital, Potenza.

The area was selected due to the coexistence of a wide variety of natural and semi-natural land uses, with residential (urban and rural) and industrial settlements. This area is representative of landscape features characterizing the northern part of the Basilicata region and some neighbourhood areas in the Apulia and Campania regions. Since

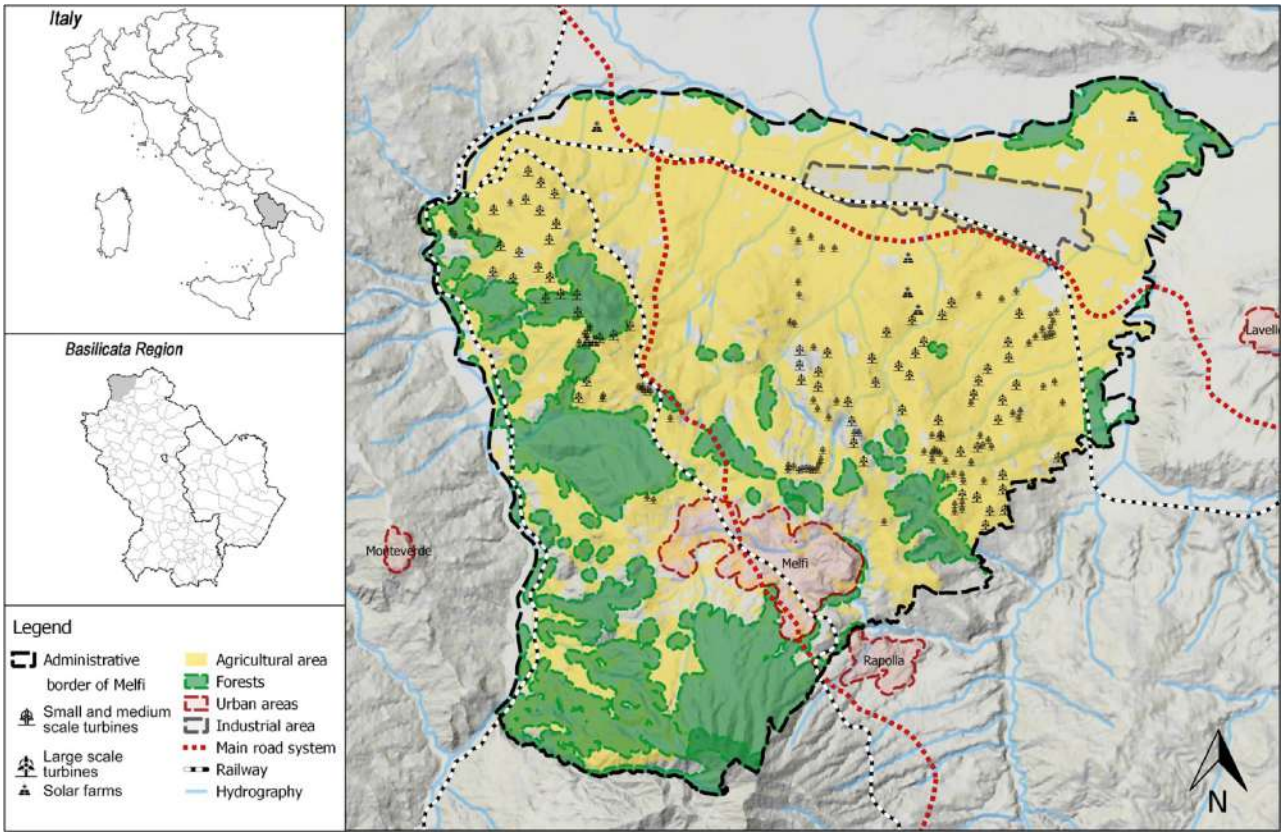


Fig. 1. The study area.

2010 (year of the Basilicata PIEAR adoption) this territory has been one of the most favourite sites for RES plant installation. Such process attracted numerous and relevant investments by big players in the RES sector. In 2018, in the study area, the number of RES installations reached 186 plants, divided between 179 wind turbines and 7 solar farms. The estimated installed electricity production capacity is close to 200 MW.

2.2. Authorization procedures and boosting policies for Solar and wind farms in the Basilicata Region

The reform adopted with Constitutional Law 3/2001 defined the energy sector as an area of concurrent legislative competence between State and Regions. This means that while the central government determines general provisions, the Regions set out detailed regulations, including location, construction and authorisation rules and procedures to be respected in order to set up energy production plants. The administrative decentralisation objective looks at encouraging private investments in order to achieve EU targets in clean energy production.

The regulatory reference framework for renewable energy transition in the Basilicata Region is the Regional Environmental Energy Guideline Plan (PIEAR), approved in 2010. PIEAR contains the energy strategy of the Basilicata Region that is to be implemented until 2020 according to four main objectives: i) Reduction in consumption and energy bills; ii) Increase of the electricity production from renewable sources; iii) Increase in thermal energy from renewable sources; iv) Creation of an energy district in the Val D'Agri area.

The role taken on by the Region for the implementation of the plan regards the identification of suitable areas for installations and renewable energy exploitation measures The municipalities are directly responsible for the authorization cycle of small-scale RES plants.

The stated purposes of PIEAR to support and encourage the development and diffusion of RES, is conditioned by the adoption of specific criteria for location, construction and management. However according to the evidence of our research, the results were un-effective

Wind-power plants are defined in the PIEAR as “large-scale” if their power output exceeds 1 MW; as “small-scale” according to the following conditions: (a) maximum total nominal power output under 1 MW; (b) 5 wind turbines maximum. The authorisation process concerning “large-scale” plants is based on the Unified Environmental Authorisation (UEA) to be carried out in accordance with Legislative Decree 387/03 (environmental act) through a Services Conference (a technical board involving all the Administrations with specific competences in the area of RES plants’ construction and operation). UEA constitutes a unique authorisation measure and is therefore an administrative simplification instrument oriented towards guaranteeing environmental protection and reducing the bureaucratic burden on private and public operators. Small-scale farms are instead subject to Commencement of Activity Report (DIA), which must be submitted to the competent municipality. Recently this authorization was replaced by the Certified Start of Activity Notification (SCIA): it is a declaration that allows private operators to start, modify or cease a production activity (handcraft, commercial, industrial), without having to wait for the duration and the implementation of preliminary checks and inspections by cognizant authorities. Additionally, for the installations with a power output that varies between 200 kW and 1 MW, the private operator is required to demonstrate the financial capacity for the complete implementation of the project. The Environmental Impact Study is compulsory only if plants fall within 1 km (for large-scale farms) and 500 m (for small scale farms) of Natura 2000 Network sites.

Solar farms are classified as small-scale if they meet one of the following conditions: a Integrated under Ministerial Decree of 19 February 2007; b non-integrated as per DM 19.2.2007 with a maximum power output not exceeding 1,000 KWp; c self-production plants pursuant to Article 2 of Legislative Decree 79/99. For the construction, extraordinary maintenance and refurbishment of these types of

installations, a DIA is requested. In the case of non-integrated plants with an installed capacity of more than 200 KW, the authorisation procedure is the same as that of" large-scale" wind plants but further documentation regarding the availability of the necessary financial resources is required of the private operators. Large-scale solar farms, i.e. those with a power output that exceeds 1 MW, have to obtain Unified Environmental Authorisation in order to be set up and the Environmental Impact Study is compulsory if they fall within 500 m of Natura 2000 Network sites.

The policies encouraging RES technologies are based on financial incentives and are articulated on several levels from national to regional. In Italy, electricity from RES is promoted through value added tax (VAT) and real estate tax deductions and it can be sold on the free market or to the Energy Provider at a guaranteed minimum price. Alternatively, renewable energy producers can opt for net-metering which provides economical compensation for the electricity fed into the grid. In addition to these, further forms of incentives are provided at a regional level. The Basilicata Region, during the last EU programming cycles relating to the European Regional Development Fund (ERDF) and the Rural Development Programme (EAFRD), has financed RES plants installation supporting the following groups of beneficiaries: private citizens, small and medium enterprises but also for local authorities and administrations.

Concerning the spatial assets of RES development, PIEAR turned out to be weak. For all types of plants, installations within the Natura 2000 sites and national and regional parks are banned. Unsuitable sites for large-scale plants were: WWF Oases; archaeological, historical-monumental and architectural sites; conservation areas included in the Wide Area Landscape Plans; wooded areas; areas affected by fires in the last 10 years; coastal areas; rivers, wet areas, lakes and artificial dams; urban centres; altitude areas above 1,200 m, and ridge areas identified by Wide Area Landscape Plans. Such restrictions didn't produce an effective system oriented towards controlling and regulating the RES plants scattered over the whole regional area. Fig. 2 represents how critical can be the landscape impacts generated by such a de-regulating framework can be.

Table 1
Wind plants classification.

	Power output	Radius of influence
Small-scale turbines	0 – 200 kW	15 m
Medium-scale turbines	200 – 999 kW	25 m
Large-scale turbines	> 1 MW	50 m

2.3. Data source and processing

The basic geographical information structure includes two main datasets: (1) TRC land use dated 2013 (Technical Regional Cartography produced by the Basilicata Region and distributed via OGC standards in RSDI (RSDI – Geoportale Basilicata, 2019)); (2) RES plants dataset.

We referred to the following Land Use/Land Cover (LULC) classes: (a) Residential buildings in compact urban centres; (b) Residential buildings in dispersed urban centres; (c) Buildings for industrial and commercial use; (d) Roads and railways;(e) Caves and dumps;(f) Gardens and urban green areas; (g) Orchards; (h) Gardens; (i) Arable land; (l) Olive groves; (m) Vineyards; (n) Pastures or uncultivated areas; (o) Mixed forests; (p) Conifer woods; (q) Broadleaf forests; (r) Watercourses.

The RES plants datasets come from the combination of different official information sources: TRC and GSE (National Energy Provider) (GSE, 2018) and the digitalization of plants from an aerial photogrammetric survey on different dates: Ortho-photo and Google Earth images.

RES database includes, among other information, attributes concerning the installed generation capacity measured in [kW] or [MW] of individual wind turbines.

This dataset has been used as a basis for the development of the territorial evaluation model presented in this research.

Geo-processing operations have been applied to the layer of RES plants in order to integrate computational hypotheses into the evaluation model for the estimation of occupied/transformed surfaces by the

Fig. 2. Energy landscape from the Basilicata region.

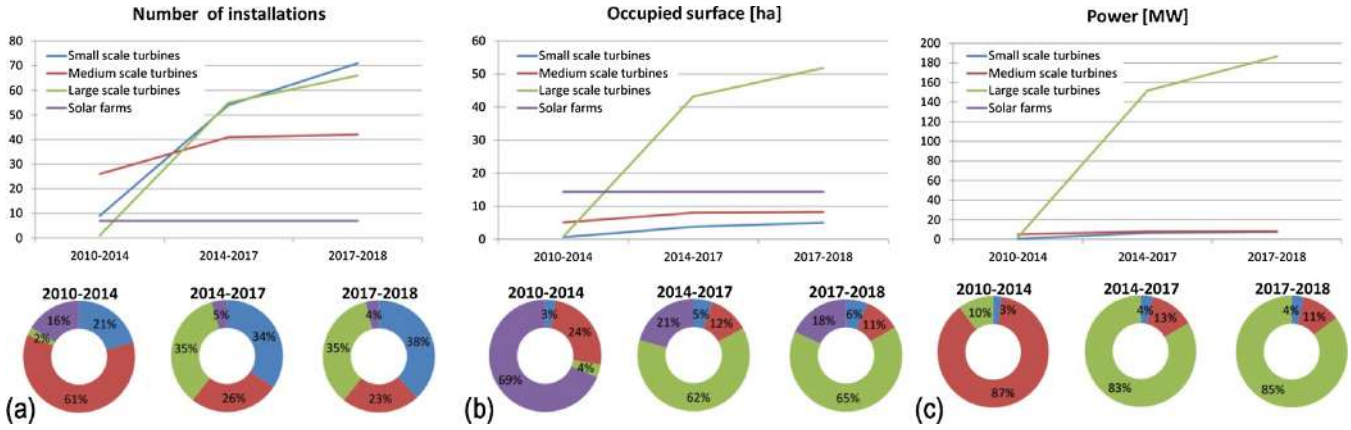


Fig. 3. Graphs representing (a) the number, (b) the area occupied [ha] and (c) the power [MW] of RES plants in the study area.

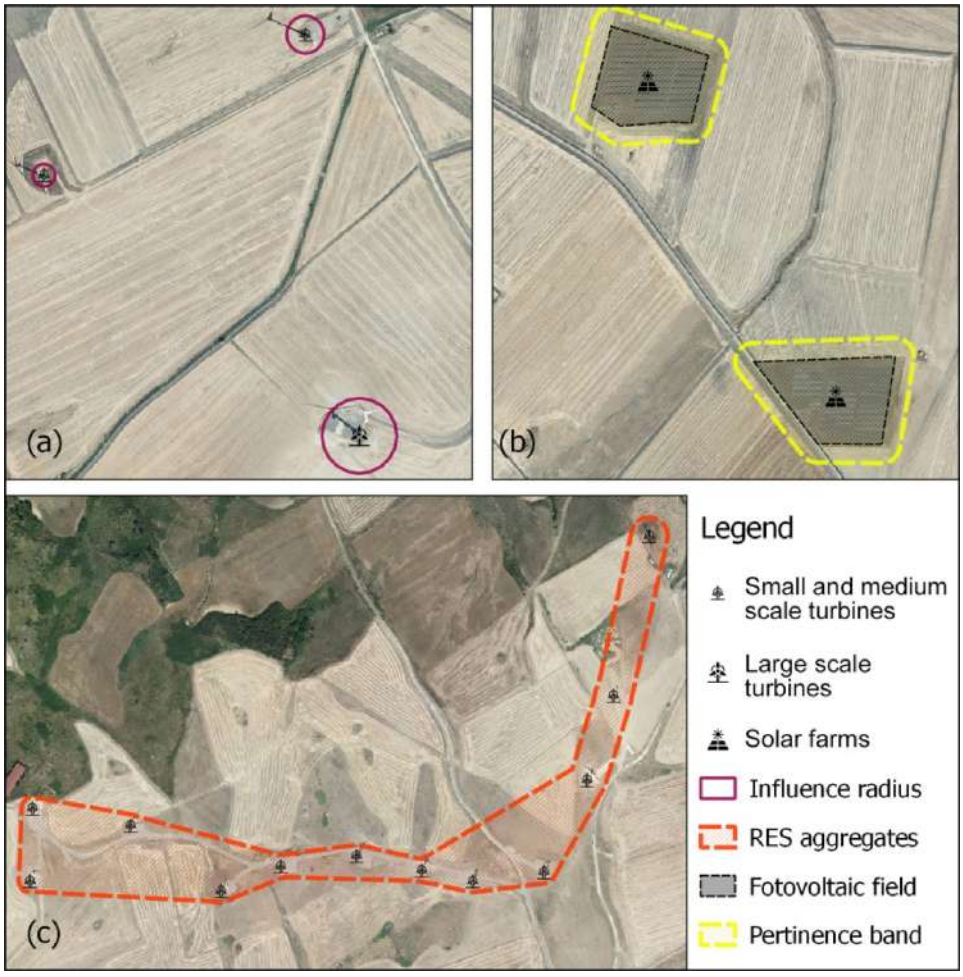


Fig. 4. Example of influence radius (a), photovoltaic pertinence band (b) RES aggregates (c).

process of RES plants settlement. Therefore, we need a way to include the amount of land-taken areas into our model.

With reference to the structure of the evaluation approach, we have defined categories for wind plants according to the 'installed power' (Table 1). Hypotheses for the estimation of altered surface in terms of land use and ecosystem services provisioning correspond to each category. The "Influence Radius" allows to approximate, through a buffer process, the total area of land transformed by wind turbine installation, including fields, access road and technical services.

The values used for the three influence radii result from previous elaborations (Saganeiti, Pilogallo, Faruolo, Scorza, & Murgante, 2019) carried out on a sample of wind farms in the Basilicata region.

For solar farms, a pertinence band, equal to 25 m from the perimeter of the installation area, was considered. In this case, the installation area includes structures and photovoltaic modules, technical services, access roads and internal circulation areas, security fences.

The graph in Fig. 3 shows the temporal evolution of RES plants with respect to: the number of installations (divided in power classes); occupied area; power production capacity. In the first time interval (2010–2014), medium-size turbines (26 turbines)were the largest

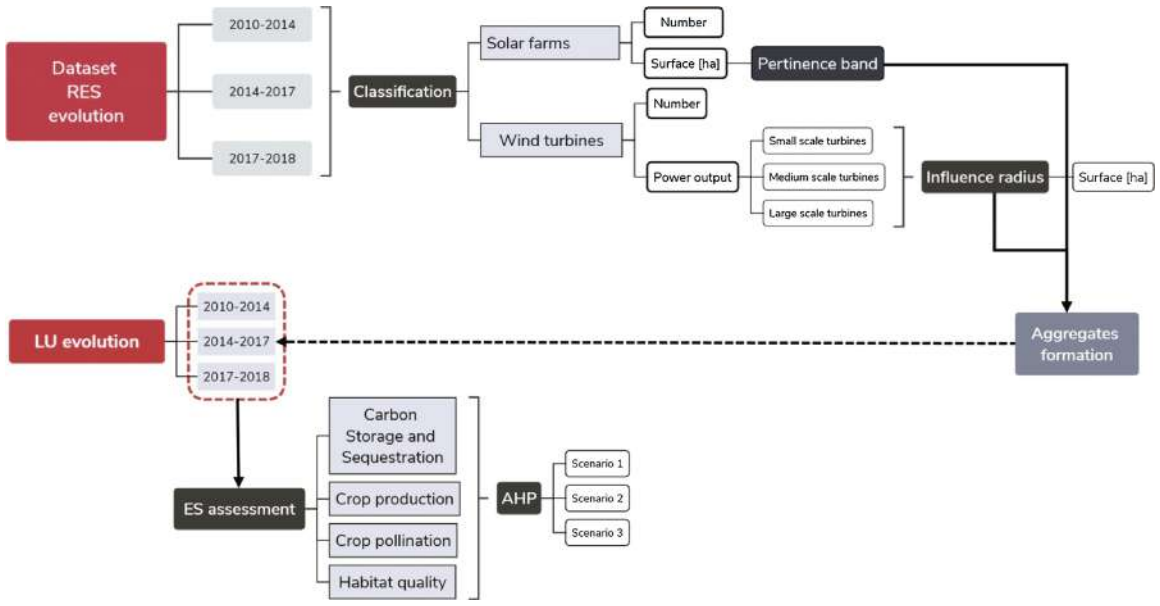


Fig. 5. Flow chart of methodological framework.

Table 2
Summary table of fertilizer compound values (kg/ha) used for the study area.

crop_name	nitrogen_rate	phosphorous_rate	potassium_rate
wheat	110.0	35.0	30.0

percentage of installations, whereas between 2014 and 2017 the number of large-scale wind farms increased (54 turbines) and, in the last time interval (2017–2018) the number of small-scale turbines was the largest class (71 turbines). In the same way, the area transformed by RES plants increased over time. The big turbines are responsible for the wider process of land-take with a total surface of 52 ha transformed in the period 2017-2018. Other classes contributed with a smaller share (around 40 %) with a total transformed area of 13 ha.

In terms of power capacity, it is clear how big wind turbines contributed almost entirely to the total electricity production capacity.

Saganeiti et al. (2018), aimed towards the analysis of building aggregations in urban areas, for the identification of RES clusters that should be treated not as an individual installation but as more complex settlement systems for the estimation of the impacts.

An aggregate is considered to be a polygon containing two or more RES plants whose distance between the influence rays is below a predetermined threshold. This aggregation allows to compute the amount of surface area taken up after a RES system installation. The area includes not only the field, the access road and the technical rooms of the plant itself, but also a measure of the total area removed from its natural vocation. This is mostly due to the proximity/aggregation of the RES plants to each other than because of the direct presence of a single RES plant. Small RES plants placed at a short distance from each other will constitute an aggregate, while large plants that are placed at greater distances will be considered individually.

The aggregates of RES plants have been computed for three time intervals: (1) 2010–2014, (2) 2014–2017, (3) 2017–2018. The threshold distance has been set at 250 m (Fig. 4). It is selected to be the most suitable threshold to represent plants aggregation in the study area.

2.4. Methodology

The transition to RES is considered inevitable in order to pursue sustainable development goals (Pachauri et al., 2015; UNFCCC, 2016) even if their territorial impact can be critical. They have a spatial footprint, alter landscape perception, involve change in land use and are responsible for the fragmentation of the ecosystems in which they are located. In other words, they affect the ES delivery (Akella, Saini, & Sharma, 2009; Alsema & Nieuwlaar, 2000; Chiabrando, Fabrizio, & Garnero, 2009; Saidur, Rahim, Islam, & Solangi, 2011; Tsoutsos, Frantzeskaki, & Gekas, 2005).

Although increasing renewable energy production infrastructures affects the ES trade-offs (Picchi, van Lierop, Geneletti, & Stremke, 2019; Stremke & van den Dobbelsteen, 2013) (as a matter of fact, according to the Common International Classification of ES (CICES) energy production is in itself a provisioning ecosystem service (Haines-Young & Potschin, 2011)) the most appropriate way of approaching an integrated impact assessment of low carbon energy transition might benefit of a process evaluation.

Table 3
Table of threats acting on the territory with their weights and distances of impact. Each threat represents a single class of land use (lucode) or an aggregation of several classes.

lucode	Threat	Threat code	Max distance [km]	Weight [0–1]
From 511 to 515	Agriculture	AGRI	0.30	0.40
11–12	Residential buildings in compact urban centers and scattered urban centers	BUILD	1.00	0.85
13	Buildings for industrial and commercial use	IND	1.50	1.00
3	Caves and dumps	CADI	1.50	0.65
7	Wind and photovoltaic systems	RES	1.50	1.00
2	Main high-speed link roads and railways	BROAD	2.00	1.00
2	Local roads	SROAD	0.40	0.30

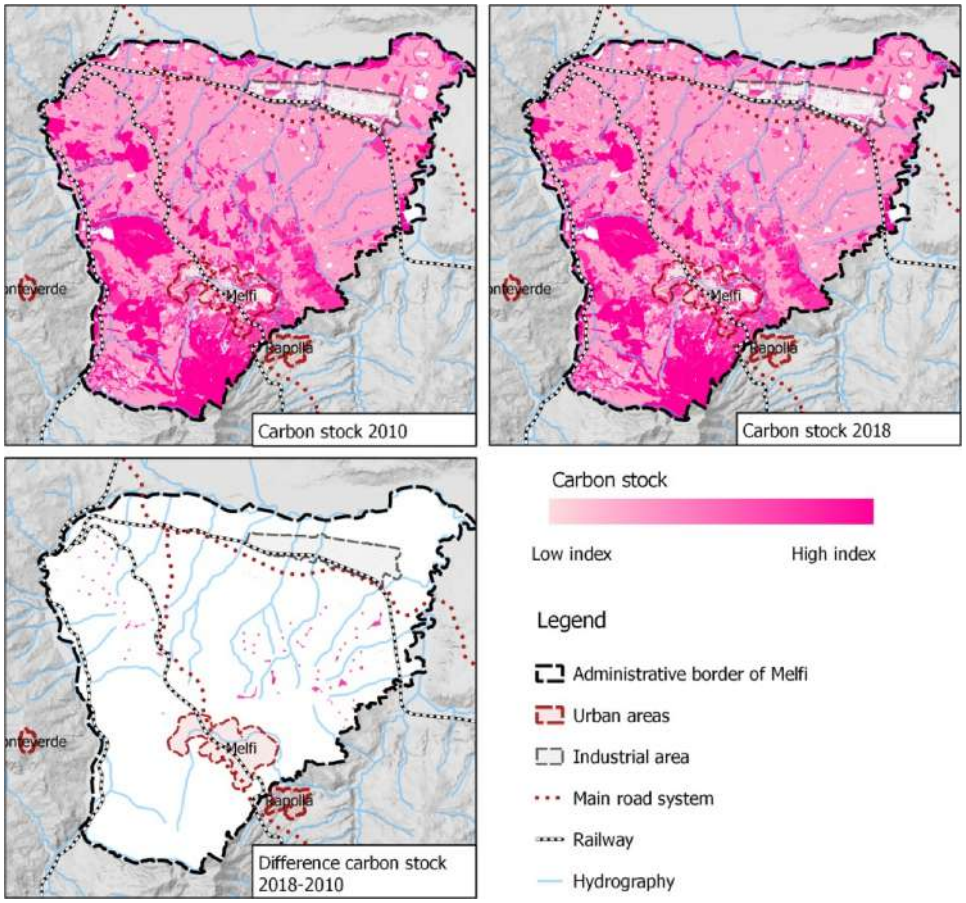


Fig. 6. Carbon storage and sequestration maps.

Oudes and Stremke (2018) have already tried to propose a framework to measure the sustainability of energy landscapes based on four types of criteria: environmental, socio-cultural, economic and technical. This approach, although worthy of support, has to be adopted in a circular process (called evaluation cycle (Las Casas and Scorza, 2016, 2016; Las Casas & Scorza, 2017; Scorza et al., 2017)) analysing ex-ante, on-going, final and ex-post stages of RES plants settlements. Moreover, a detailed territorial information system (Amato, Pontrandolfi, & Murgante, 2015; Murgante, Tilio, Lanza, & Scorza, 2011; Saganeiti et al., 2018) is needed to support a circular assessment process, according to a matrix of pre-defined performance indicators and furthermore, a ES thresholds approach promoted by the United Nations through the Millennium Ecosystem Assessment (MEA) (Alcamo & Bennett, 2003) is proposed in this research as a tool to support the decision-making process so as to conduct an adequate and effective scenario analysis (Owens, 2005), where the value of the ecosystem is proportional to the services provided to foster human well-being. Therefore, our purpose was to characterize the effects of a widespread RES settlement in terms of ES loss. Four ecosystem services have been selected as they are considered to be most significant for the study area: Carbon Storage and Sequestration, Crop pollination, Crop production and Habitat Quality.

Each of the ES considered was evaluated in the three time intervals considered: 2010–2014; 2014–2017; 2017–2018. For each of them it was therefore possible to calculate the difference between the last year taken into consideration (2018) and the period before the installation of the RES systems (2010). In order to integrate these assessments into a decision support system able to take into account policy hypotheses, the results obtained for each ES have been spatially aggregated through a multi-criteria analysis conducted by means of the Spatial Analytical Hierarchy Process (AHP) method. This last step was carried out for three different scenarios in order to simulate different policy priorities.

The analytical model used to assess and to represent ES is incorporated in the suite powered by InVEST (Integrated Valuation of Ecosystem service and trade-offs) (Nelson et al., 2018); further analyses were carried out in the GIS environment in order to obtain the overall cumulative impacts based on the spatial AHP method.

AHP (Saaty, 1980) is indeed a traditional way to approach complex decision-making by formulating scenarios based on weighting different alternatives. By reducing complex decisions to a series of pairwise comparisons, it constitutes both a powerful and flexible tool so much so that it has found applications in multi-criteria decision-making processes, in planning and resource allocation and in conflict resolution (Grimm et al., 2008; Mishra, Deep, & Choudhary, 2015; Saaty, 1987).

With AHP, the decision maker selects the alternative that best matches his decision criteria by means of a numerical score that classifies each decisional alternative according to how well each alternative meets them. In AHP, preferences between alternatives are determined by comparing them in pairs (matrixes). In a pair comparison matrix, the decision-maker examines two alternatives by considering a criterion and indicates a preference. These comparisons are made using a preference scale, which assigns numerical values to different levels of preference (Taylor III, 2010). The preference scale used values from 1 to 5: from equal importance to extreme importance. Value 5 indicates that one factor is far more important than another, value 1/5 indicates that one factor is far less important than the other, and the value 1 indicates the same importance (Özdağoğlu & Özdağoğlu, 2020). The comparison scale has been built on the basis of the technical judgement from the authors without any involvement of other key stakeholders.

The benefit of using AHP when building the pairwise comparison matrices involved in the process, consists in incorporating an effective technique to check the consistency of the evaluations, thus reducing the

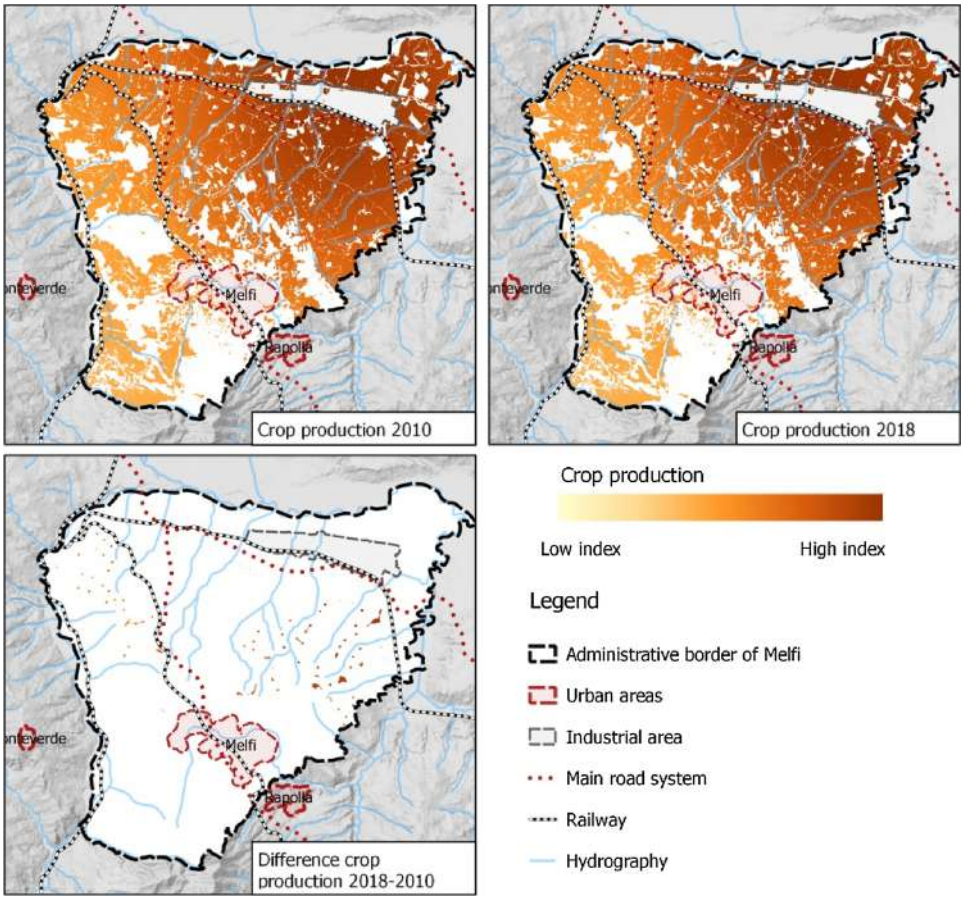


Fig. 7. Crop production maps.

bias in the decision making process (Moreno-Jiménez, Aguarón, & Escobar, 2008; Saaty, 2003).

AHP allowed us to compute the weighted vector of criteria regarding three scenarios: the first aim at highlighting the importance of biodiversity conservation; the second prioritizes carbon storage; the third t emphasizes the agricultural vocation of the Melfi territory.

Fig. 5 represents a synthetic view of the whole methodological framework starting from data collection and processing to the AHP scenario assessment.

2.4.1. Carbon storage and sequestration

The assessment of the quantity of carbon stored was carried out using the InVEST tool "Carbon Storage and Sequestration". The result is a raster map that represents the total value of carbon stored in t/ha, pixel by pixel.

This value is the result of the aggregation of carbon stored in four large tanks, defined 'pools': i) Aboveground biomass, which includes carbon stored in foliage and wood (the herbaceous cover is not considered a long-term carbon source); ii) Belowground biomass, mainly carbon inside root systems; iii) Soil, defined as organic carbon (SOC) stored by the mineral layer of the soil; iv) Dead organic matter, consisting of the carbon inside the litter and dry biomass on surface soil.

As input data, the software requires, a LULC map and a corresponding table with the four values of each carbon pool. The resulting raster maintains the same resolution as the input cover map. We selected a resolution (pixel size) of 5 × 5 m in order to obtain a high spatial accuracy, thereby also ensuring computation of the contribution provided by urban green areas.

The main criticality of this analytical stage concerns the lack of data on carbon pools on a regional level. No on-site studies are available for the Basilicata Region apart from the report from the National Inventory of Forests and Forest Carbon Sinks (INFC) (Gasparini, Di Cosmo, Pompei, & TEMI, 2013) with specific data for wooded areas. We took into consideration the Guidelines for national greenhouse gas inventories published by the Intergovernmental Panel on Climate Change (IPCC) in 2006 (IPCC Guidelines for National Greenhouse Gas Inventories, 2020) as reference values to complete the carbon tanks matrix for the analysis. The summary table of the values of the carbon pools for each LULC class used for the study area is attached in the Appendix. Land use classes also include those relating to RES plants (lucode 7), to which a zero contribution in terms of carbon pools corresponds. The working hypothesis is to assimilate the areas occupied by RES plants to the urban environment or, more generally, to a process of land take that cancels ES contribution.

2.4.2. Crop production

The "Crop production-percentile" was developed to carry out trade-off analyses where the transformation hypotheses concern changes in land use 'in favour of' or 'starting from' agricultural uses. Based on a global scale climate model, it is possible to make productivity estimates of 175 kinds of crops. Data used by the model come from the FAO database supplemented by national and regional datasets. In order to assess trade-offs between an increase in agricultural profitability and the expected loss of ES, calculations make it possible to predict the productivity of an area in relation to specific crops and their relative economic benefits, while neglecting the impact of different agricultural management practices.

This work, in aiming at estimating the impacts of territorial transformation on agricultural productivity, is based on the assessment of loss in agricultural production according to a transition of extensive portions of agricultural yields from crop production to RES plants LULC, expressed in tons per pixel.

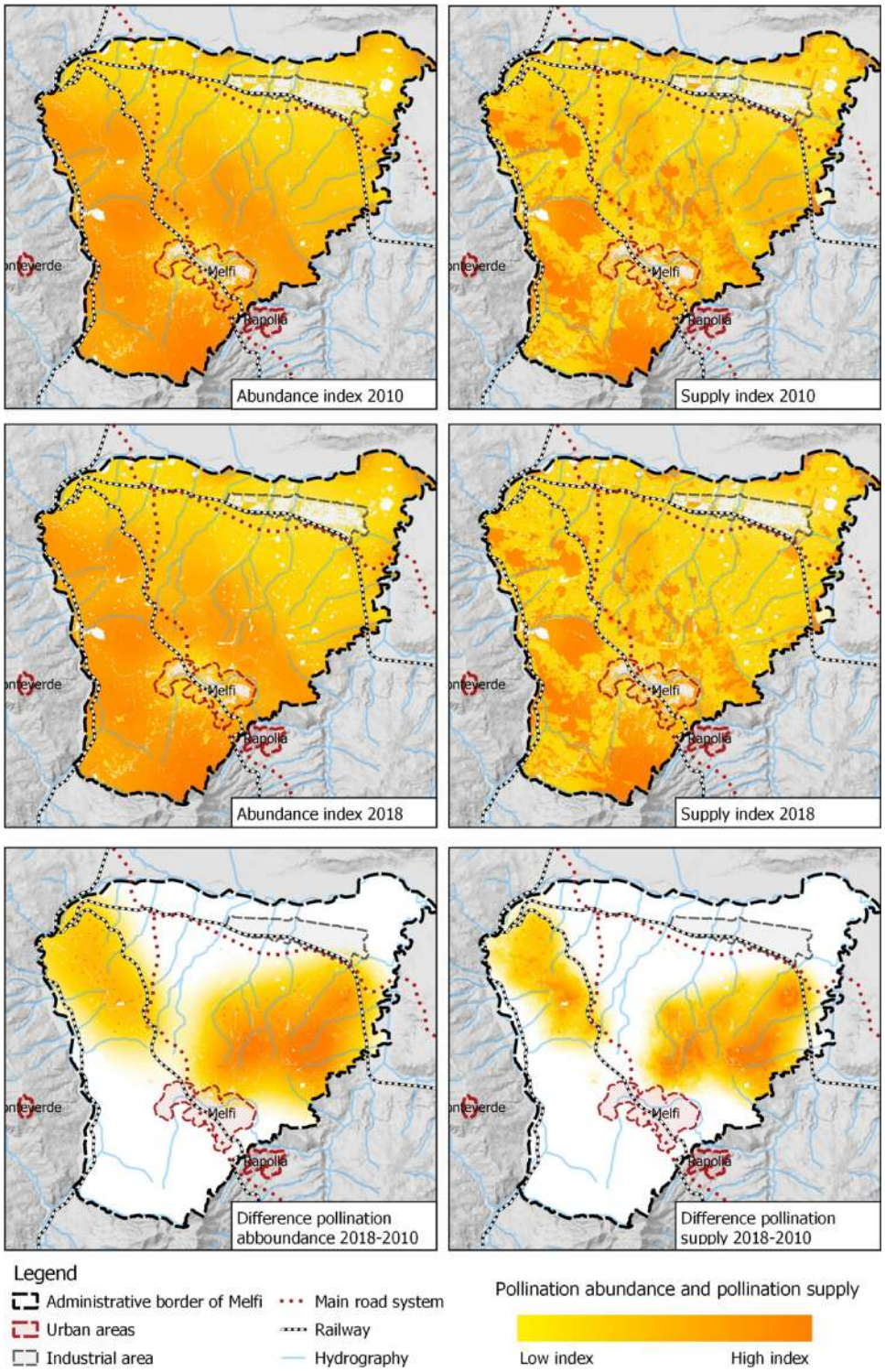


Fig. 8. Pollination abundance and supply indexes maps.

The required input data consist of a land use map and a corresponding 'table of crops'. Furthermore, average values in kg/ha of nitrogen, phosphorus and potassium compounds used throughout the study area are required. We derived such values from the Integrated Production Disciplinary of the Basilicata Region (Basilicata, 2010) for wheat production (Table 2).

Without a doubt, wheat production has been selected as a representative crop for extensive arable land in the study area, the total extension of which is about 20,174 ha.

2.4.3. Crop pollination

In the ES regulation, the aptitude of the study area to hosting pollinating species was investigated using the InVEST "Crop pollination" tool. It elaborates maps of the potential presence of pollinating species based on a model that evaluates appropriate environmental conditions in terms of the presence of suitable nesting grounds and food availability. The necessary data consist in: LULC map; indicators of nesting suitability and/or distribution of floristic species (food sources for pollinators) for each lucode; a table summarising the main

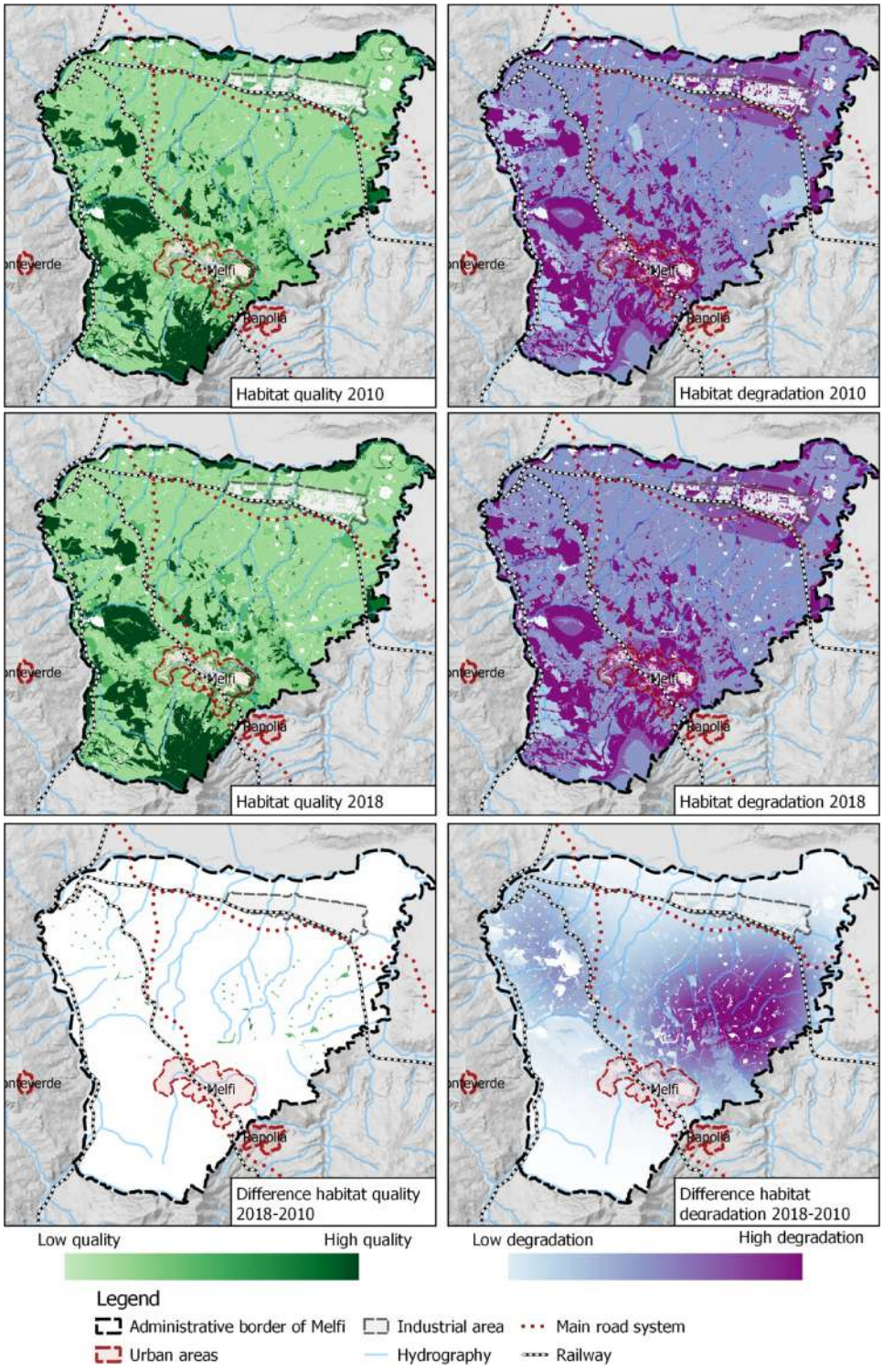
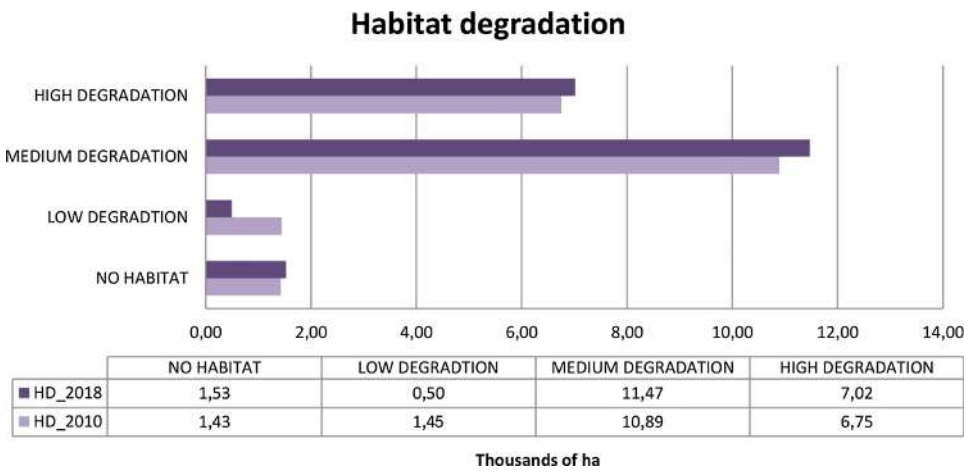


Fig. 9. Habitat quality and degradation maps.

characteristics of each pollinator species (maximum range, seasonality, food preferences).

Elaboration results consist in two maps for each pollinator species and for each season. The first map represents an index of "pollinator supply" that expresses a measure of the availability of pollinator species considering both accessibility to food resources and usability of nesting sites. The second is a "pollinator abundance" map, i.e. the potential presence of pollinators per pixel. In other words, while the first map represents sites where pollinators originate, the second map indicates the sites where pollinators carry out their activity.

Since the purpose of this work is not to refer to a specific species, we applied the InVEST model considering a generic pollinator species and assigned the maximum values for the availability of suitable nesting sites and food resources to wooded areas and uncultivated pastures (corresponding to the highest natural degree of LULC in the study area). Intermediate values were considered for the agricultural LULC, favouring the role of orchards, olive groves and vegetable gardens, arable land. Minimum values (but not null) were assigned along the riparian



	NO HABITAT	LOW DEGRADTION	MEDIUM DEGRADATION	HIGH DEGRADATION
HD_2018	1,53	0,50	11,47	7,02
HD_2010	1,43	1,45	10,89	6,75

Fig. 10. Graph of habitat degradation representing the total surface area in percentage, on the abscissas axis, and the level of identified habitat degradation on the ordinate axis. The table below shows the percentage value for the two time intervals.

S1	Carbon storage and sequestration	Crop production	Pollination	Habitat degradation
Carbon storage and sequestration	1	1/2	1/5	1/3
Crop production	2	1	1/3	1/5
Pollination	5	3	1	1
Habitat degradation	3	5	1	1

Matrix scenario 1

S2	Carbon storage and sequestration	Crop production	Pollination	Habitat degradation
Carbon storage and sequestration	1	4	5	3
Crop production	1/4	1	2	2
Pollination	1/5	1/2	1	1
Habitat degradation	1/3	1/2	1	1

Matrix scenario 2

S3	Carbon storage and sequestration	Crop production	Pollination	Habitat degradation
Carbon storage and sequestration	1	1/3	2	3
Crop production	3	1	4	5
Pollination	1/2	1/4	1	1
Habitat degradation	1/3	1/5	1	1

Matrix scenario 3

ES	S1	S2	S3
Carbon storage and sequestration	8,8%	55,3%	23,6%
Crop production	12,4%	20,4%	54,5%
Pollination	39,0%	11,2%	11,7%
Habitat degradation	39,7%	13,1%	10,2%

Weights

Fig. 11. Pair-wise matrixes for each scenario and resulting weights summary table.

strips and within green urban areas.

The assigned values are based on the hypothesis that wooded areas are those characterized by a higher degree of naturalness, and therefore more suitable to hosting pollinating species. The minimum value assigned to the riparian strips is instead given by the presence along the valley of productive and industrial settlements and sometimes main roads that undermine the naturalness of these areas.

2.4.4. Habitat quality

The ecosystem service related to habitat quality is considered as an index of overall biodiversity and falls within the category of supporting services. It has been estimated using the InVEST 'Habitat Quality' tool. It returns two raster maps: one related to habitats quality and the other (complementary map) to habitat degradation. These maps are created by combining information on LULC and biodiversity threats. Therefore, the tool allows to geographically model the variations of habitat quality and evaluate interactions between the natural environment and anthropic activities.

It estimates the effect of each threat on the analysed habitats, the indirect effects induced by the combination of threats. These are to be considered as explicit spatial variables that could potentially cause local extinction of one or more species. To better explain the spatial variability of effects induced by the threats, the distance between habitats and degradation source has been considered. Finally, the model assesses the sensitivity of each LULC class to each threat according to different weights.

The Habitat Quality tool allows to evaluate the spatial distribution of changes that a territory has undergone as a result of the exposure to threats that may affect a specific species or biodiversity in the broader sense of the term. It assumes that threats are additive and do not account for connectivity, patch size or habitat resilience characteristics. Furthermore, threats as well as habitats are to be set by a well-defined geometric object.

Input data are: (1) LULC Map (raster); (2) Threats table: containing

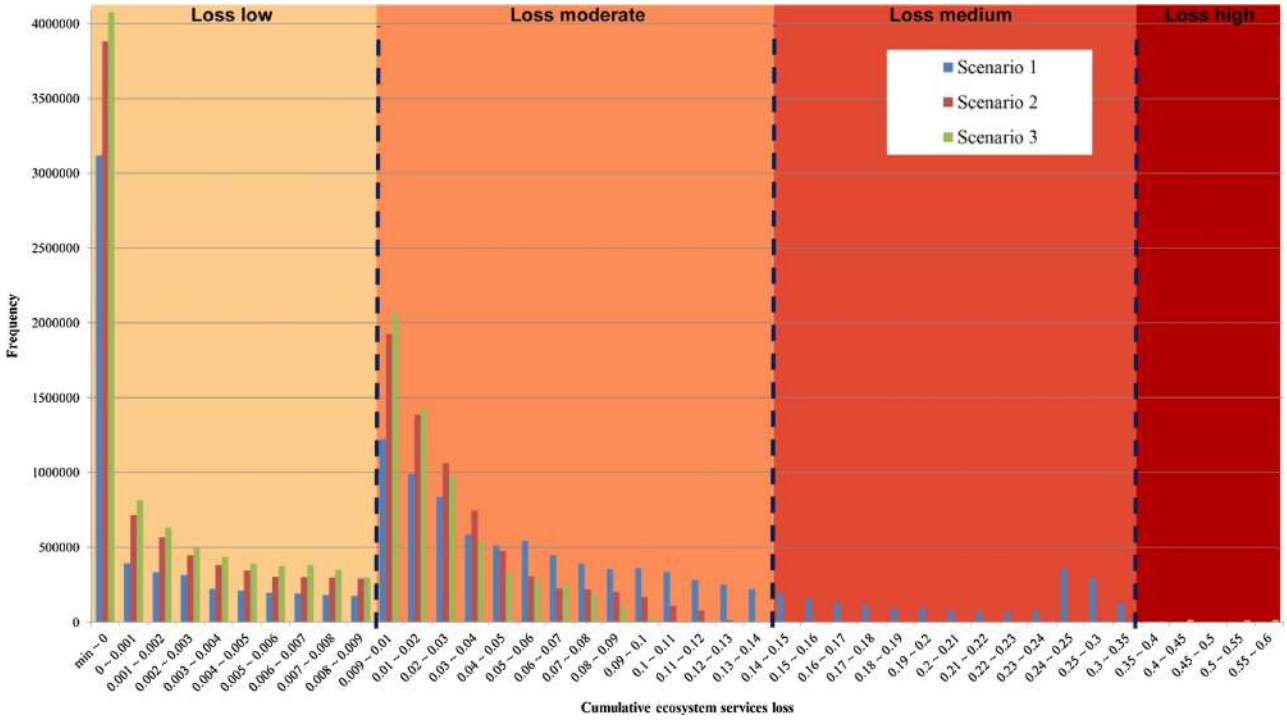


Fig. 12. Cumulative loss distribution of ecosystem services.

all the threats that the model must take into account with relative weight (in a range between 0 and 1) and space impact (expressed in km); (3) Threats maps: binary type 0–1 raster maps where the value 1 indicates the presence of the threat in a specific pixel and value 0 indicates no-threat; (4) Sensitivity matrix: for each LULC the suitability to be a habitat (accounted in a range between 0 and 1) and the sensitivity to each threat is reported.

The model therefore assumes that biodiversity (Baral, Keenan, Sharma, Stork, & Kasel, 2014), intended as a greater number of species and individuals of flora and fauna, is proportional to the size of the areas characterized by the highest degree of habitat quality, considered indeed as a biodiversity proxy (Bai, Zhuang, Ouyang, Zheng, & Jiang, 2011).

Categories set out in Table 3 have been taken as threats on the basis of scientific literature (]; Salata & Ronchi, 2017; Sharma et al., 2018).

For the sensitivity matrix, maximum habitat values were assigned to forests and watercourses, and zero values were assigned to anthropic land use classes (buildings and RES installations). The sensitivity values are presented in Table B1 (see the Appendix B) according to main literature references Polasky, Nelson, Pennington and Johnson (2011), Salata, Ronchi, Arcidiacono and Ghirardelli (2017), Sallustio et al. (2017), Terrado et al. (2016).

The model returns a habitats quality value ranging between 0 and 1. In particular, the result assumes zero value in correspondence to "NO HABITAT", i.e. those classes of anthropic land use in which biodiversity is assumed to be negligible. It also increases as the habitat suitability parameter grows and where degradation takes on lesser values. This means that the outcome will be influenced not only by the extent to which several threats act simultaneously, but also and significantly, by the initial degree of naturalness.

3. Results

In order to demonstrate the share of interaction between territorial transformations induced by the realization of RES plants and the capacity of ES provisioning, the results obtained in the analytical stage are presented in this section.

The amount of carbon stored, totals 10.3 kt in the first period. This value, considering the transformations induced by RES energy production plants, remains almost unchanged compared to previous stock (Fig. 6). Indeed, only a decrease of 0.31 % (32 t) was assessed. It is relevant to highlight how an increase in the installations of large-scale wind farms is responsible for the greater share of this variation (see Fig. 3).

Agricultural productivity is extensively affected by the settlement of RES plants. Results show the presence of three climate zones within the study area, which implies the division into three classes of productivity. The area of greatest concentration of RES plants is the central part of the municipal territory characterized by ‘Non-irrigated crops’. Such area covers about 20,174 ha with an average productivity of 2.07 t/ha (with 0.31 t/ha in the northern part of the municipality). Fig. 7 clearly shows how RES plants overlap agricultural areas with a consequent reduction of production capacity of more than 163.00 t per year comparing to 2010 and 2018 scenarios.

Concerning crop pollination, we recognized the major effect of RES settlement in terms of ‘supply index’(Fig. 8). Comparing results from 2010 and 2018, it is clear how the concentration of RES plants induced a generalized decrease of pollination supply in those areas where wheat production is concentrated.

Fig. 9 shows the maps of habitat quality and degradation. The white areas indicates the classes of land use considered in the analysis’ no-habitat ‘(urban and anthropic areas) in the analysis.

In order to represent the quantitative estimation of habitat degradation, we classified the results into 4 macro-classes: ‘no-habitat’, ‘low degradation’, ‘medium degradation’ and ‘high degradation’. The comparison between the extension (in ha) of each class allows to understand how RES settlement widely affected the overall habitat quality of the study area. In Fig. 10 it is obvious how, even in the presence of a small increase of no-habitat share (depending on the transition towards an anthropic land use of RES plant settlements sites), a huge amount of low degradation areas in 2010 turned into ‘medium degradation’ and ‘high degradation’ classes in 2018. It means that the impacts of RES plants have to be assessed not only on the installation site but on a wider scale where habitat degradation effects can be measured.

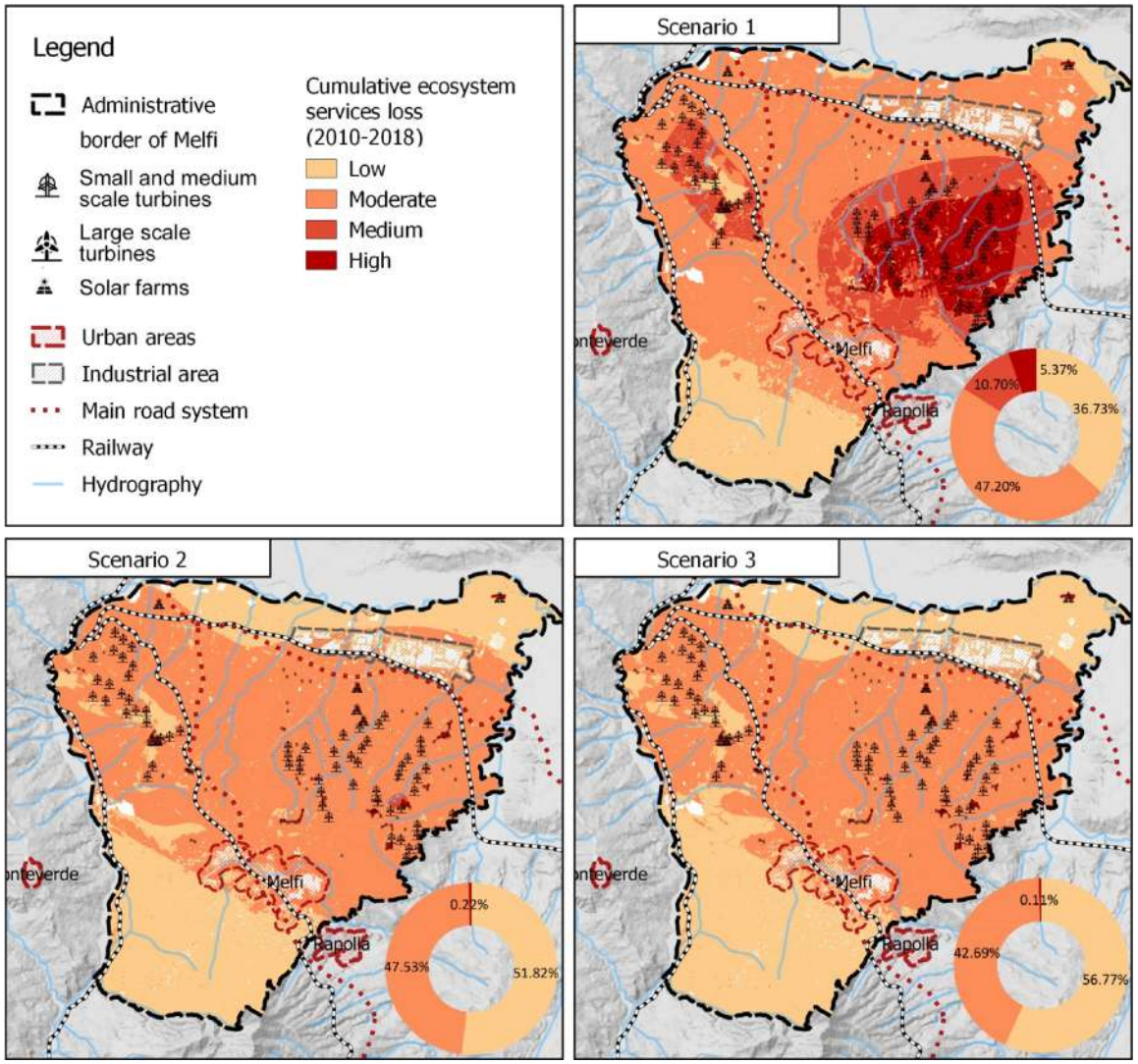


Fig. 13. Results obtained for three different scenarios: spatial distribution and percentage area classes for cumulative ES loss.

4. Cumulative effects and impact scenario discussions

A critical remark for ES estimation is that the results deriving from a single tools application are mostly thematic and scarcely integrable in a comprehensive territorial assessment. As a matter of fact, from the previous discussion we verified a local loss in carbon stock concerning a very small territorial share (0.3 %), while we computed a widely distributed effect in terms of habitat quality. Such output could be tentatively included in a systematic interpretation.

Looking for a way to achieve a significant cumulative estimation of territorial effects according to the set of selected ES is the major requirement in order to provide an effective decision support system (DSS) in policy-making framework.

A way we tackle this challenge in a tentative approach is based on the spatial AHP method (Bathrellos, Kalivas, & HS-E, 2009; Omar et al., 2014). The maps obtained for the selected 4 ES have been normalized in order to make the losses comparable, enhancing the role of the effects of territorial distribution more than the specific values computed by InVEST tools. In order to deliver a significant estimation of the cumulative effects, three pair-wise comparison matrices were created (Fig. 11). Each matrix refers to a different scenario: the first emphasizes impacts on biodiversity (emphasising the contribution of habitat degradation and crop pollination); the second is oriented towards comparing carbon stock loss by CO_2 emission reduction accompanied by RES settlement; lastly, the third, aims at highlighting impacts on agricultural productivity which has to be considered also as an irreversible loss for future capacity of food provisioning.

We chose the ES approach because it allows for the consolidated environmental impact assessment procedures to be overcome and gives the analysis a more holistic approach. In this perspective, the three scenarios were formulated considering all selected ES at the same time, but giving them a different weight depending on the priorities that could characterize a potential policy design or decision-making process. Undeniably, this could be aimed at achieving results in the short and medium term, for example by prioritizing to the role of agricultural productivity, or at pursuing long-term sustainability objectives by favouring the role of habitat quality and therefore biodiversity conservation.

AHP Vectors (S1, S2, S3) allowed to calculate the cumulative ES loss for the three scenarios in the GIS environment. As shown in Fig. 12, the results have been plotted considering the respective frequency in order to identify suitable thresholds to represent the spatial distribution of cumulative degradation classes.

Fig. 13 shows that the most critical scenario is the first one regarding the effects on biodiversity. More than 15 % of the total area falls without a doubt into the highest loss classes. In actual fact, in giving greater importance to those ES (habitat degradation and crop pollination) whose effects are distributed within a certain distance from

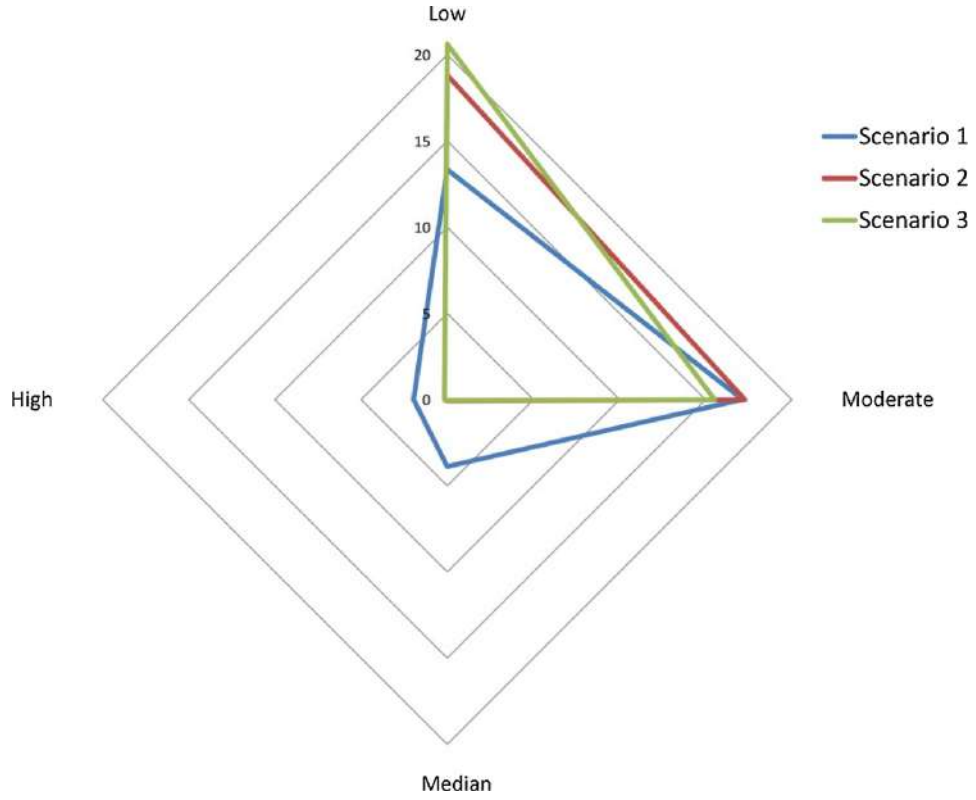


Fig. 14. Distribution of area between the four cumulative loss classes.

the degradation source according to a given intensity function, the overall loss is spatially distributed starting from areas with a higher density of RES plants. Only 37 % of the territorial area is classified as LOW Cumulative ES loss. In scenarios 2 and 3, this area exceeds 50 %.

Scenarios 2 and 3 present a similar distribution of cumulative effects in comparison with higher values in local hot spots on RES plants.

The spider graph (Fig. 14) represents the distribution of areas (in thousands of hectares) among the 4 classes of cumulative loss in relation to the three scenarios. Scenarios 2 and 3 appear to be similar, while scenario 1 shows a different behaviour.

5. Conclusions

Fast and far-reaching changes in the energy landscape of the Basilicata region highlight the weakness of current urban and regional planning tools. This evidence is part of the broader framework that concerns the capability of the planning discipline to manage the complexity and the multidimensional facets of sustainable development (Sala, Ciuffo, & Nijkamp, 2015).

While urban plans still focus on traditional urban functions (residence, commerce, industries and services) and promote a conformational approach, rural areas rapidly change under un-regulated settlement processes, based on different settlement categories that derive from technological innovations and are promoted in the global framework of climate adaptation policies.

If we refer to urban sustainability (Kremer, Haase, & Haase, 2019), our starting hypothesis, which has been partially confirmed by this research, is that we are not in a win-win process. In other words, set before the achievement of EU 2020 (EU, 2008) targets in RES production, with consequent benefits for small groups of operators, different territorial values are neglected and local conflicts arise (see also (Las Casas & Scorza, 2017; Las Casas, Scorza, & Murgante, 2018)). The implementation of energy and climate policies needs new models of multilevel governance (Betsill & Bulkeley, 2006) in which local authorities play a key role in managing both energy and environmental issues (Fudge, Peters, & Woodman, 2016; Melica et al., 2018).

The instance of PBP is confirmed as a necessary innovation to be promoted under normative and methodological bases, supported by the effective spatial assessment tools directly connected with the current issues of land take which are useful for the innovation of environmental assessment procedures.

According to our case study evidences, the effort to develop place based methodology, tailored to local needs and data availability, is a way to reinforce environmental assessment practices as a tool for both decision-makers and stakeholders (Las Casas & Scorza et al., 2016). Energy and urban planning has to be integrated in a multidisciplinary perspective (Allam, 2019), thus the proposed methodology is a way to improve territorial PBP by optimizing sustainable energy scenarios (under technological, spatial, availability and safety criteria (Botelho, Pinto, Lourenço-Gomes, Valente, & Sousa, 2016)).

The ES framework is a challenging domain to promote innovation for effective PBP. Such approach is linked to the demand by decision-makers to hold new reliable assessment tools in order to develop a comprehensive scenario analysis reinforcing 'decision-making' processes (Owens, 2005; Sanderson, 2002; Weiss, 1979).

Acknowledgements

This research has been partially developed within the MEVCSU and INDICARE projects supported by the Environmental Observatory Foundation of the Basilicata Region (FARBAS).

Appendix A

Table A1

Table A1
Summary table of carbon pools values used for the study area.

lucode	Description	C_above	C_Below	C_Soil	C_Dead
11	Residential buildings in compact urban centres	0.00	0.00	0.00	0.00
12	Residential buildings in dispersed urban centres	0.00	0.00	0.00	0.00
13	Buildings for industrial and commercial use	0.00	0.00	0.00	0.00
2	Roads and railways	0.00	0.00	0.00	0.00
3	Caves and dumps	0.00	0.00	0.00	0.00
4	Gardens and urban green areas	15.00	0.00	0.00	0.00
511	Orchards	63.00	7.85	1.00	0.00
512	Gardens	0.00	4.7	62.57	0.00
513	Arable land	0.00	4.7	62.57	0.00
514	Olive groves	63.00	7.85	1.00	0.00
515	Vineyards	63.00	7.85	1.00	0.00
53	Pasture or uncultivated areas	0.00	4.7	64.50	0.00
54	Mixed forests	160.00	58.00	64.50	20.50
541	Conifer woods	160.00	52.00	64.50	20.50
542	Broadleaf forests	160.00	59.80	64.50	20.50
62	Watercourses	0.00	0.00	0.00	0.00
7	RES plants	0.00	0.00	0.00	0.00

Appendix B

Table B1
Sensitivity matrix where the habitat grade [0–1] is reported for each land use class (or group of classes) and the sensitivity of each habitat to the individual threat [0–1]. Abbreviations: AGRI agriculture, BUILD residential building, IND industrial building, CADI caves and dumps, RES renewable energy system, BROAD high velocity roads, SROAD low velocity roads.

		Habitat suitability [0–1]	Sensitivity of habitat types to threats						
lucode	Habitat type		AGRI	BUILD	IND	CADI	RES	BROAD	SROAD
11; 12; 13; 2; 3; 4.	Anthropized urban area	0	0	0	0	0	0	0	0
4	Gardens and urban green areas	0.3	0.3	0.4	0.4	0.1	0.3	0.3	0.5
511	Orchards	0.5	0	0.3	0.5	0.2	0.5	0.4	0.5
512	Gardens	0.5	0	0.3	0.5	0.2	0.5	0.4	0.5
513	Arable land	0.4	0	0.5	0.6	0.2	0.8	0.4	0.5
514	Olive groves	0.5	0	0.3	0.5	0.2	0.5	0.4	0.5
515	Vineyards	0.5	0	0.3	0.5	0.2	0.5	0.4	0.5
53	Pasture or uncultivated areas	0.6	0.4	0.7	0.6	0.3	0.9	0.6	0.4
54	Mixed forests	1	0.8	0.8	0.7	0.5	0.5	0.7	0.5
541	Conifer woods	1	0.8	0.8	0.7	0.5	0.5	0.7	0.5
542	Broadleaf forests	1	0.8	0.8	0.7	0.5	0.5	0.7	0.5
62	Watercourses	1	0.5	0.4	0.8	0	0.3	0.8	0.4
7	Renewable energy production plants: Wind and Photovoltaic	0	0	0	0	0	0	0	0

References

Chu, L., Sun, T., Wang, T., Li, Z., Cai, C., Chu, L., et al. (2018). Evolution and prediction of landscape pattern and habitat quality based on CA-Markov and InVEST model in hubei section of three gorges reservoir area (TGRA). *Sustainability, 10*, 3854. https://doi.org/10.3390/su10113854.

Bai, Y., Zhuang, C., Ouyang, Z., Zheng, H., & Jiang, B. (2011). Spatial characteristics between biodiversity and ecosystem services in a human-dominated watershed. *Ecology Complex, 8*, 177–183. https://doi.org/10.1016/J.ECOCOM.2011.01.007.

Akella, A. K., Saini, R. P., & Sharma, M. P. (2009). Social, economical and environmental impacts of renewable energy systems. *Renewable Energy, 34*, 390–396. https://doi.org/10.1016/J.RENENE.2008.05.002.

Alcamo, J., & Bennett, E. M. (2003). *Millennium Ecosystem Assessment (Program). Ecosystems and human well-being : A framework for assessment.* Island Press.

Allam, Z. (2019). Enhancing renewable energy adoption in megacities through energy diversification, land fragmentation and fiscal mechanisms. *Sustain Cities Society*101841. https://doi.org/10.1016/J.SCS.2019.101841.

Alsema, E., & Nieuwlaar, E. (2000). Energy viability of photovoltaic systems. *Energy Policy, 28*, 999–1010. https://doi.org/10.1016/S0301-4215(00)00087-2.

Amato, F., Pontrandolfi, P., & Murgante, B. (2015). Supporting planning activities with the assessment and the prediction of urban sprawl using spatio-temporal analysis. *Ecological Informatics, 30*, 365–378. https://doi.org/10.1016/j.ecoinf.2015.07.004.

Arico, S., Bridgewater, P., El-beltagy, A., Harms, E., Program, S., Hepworth, R., et al. (2020). *Ecosystems and human well-being.* n.d..

Baker, D. C., Sipe, N. G., & Gleeson, B. J. (2006). Performance-based planning. *Journal of Plan Education Research, 25*, 396–409. https://doi.org/10.1177/0739456X05283450.

Baral, H., Keenan, R. J., Sharma, S. K., Stork, N. E., & Kasel, S. (2014). Spatial assessment and mapping of biodiversity and conservation priorities in a heavily modified and fragmented production landscape in north-central Victoria, Australia. *Ecology Indic, 36*, 552–562. https://doi.org/10.1016/J.ECOLIND.2013.09.022.

Basilicata, R. (2010). *Disciplinari di produzione integrata - regione basilicata*.

Bathrellos, G., Kalivas, D., & HS-E, G. (2009). *Undefined. GIS-based landslide susceptibility mapping models applied to natural and urban planning in Trikala, Central Greece.* AcademiaEdu n.d.

Batty, M. (2013). *The new science of cities.* Cambridge: The MIT Press.

Betsill, M. M., & Bulkeley, H. (2006). Cities and the multilevel governance of global climate change. *Global Health Governance : the Scholarly Journal for the New Health Security Paradigm, 12*.

Botelho, A., Pinto, L. M. C., Lourenço-Gomes, L., Valente, M., & Sousa, S. (2016). Social sustainability of renewable energy sources in electricity production: An application of the contingent valuation method. *Sustain Cities Society, 26*, 429–437. https://doi.org/10.1016/J.SCS.2016.05.011.

Chiabrando, R., Fabrizio, E., & Garnero, G. (2009). The territorial and landscape impacts of photovoltaic systems: Definition of impacts and assessment of the glare risk. *Renewable and Sustainable Energy Reviews, 13*, 2441–2451. https://doi.org/10.1016/J.RSER.2009.06.008.

Consiglio Regionale Di Basilicata (2010). *Piano di indirizzo energetico ambientale regionale. (PIEAR)*.

Danish, Hassan, S. T., Baloch, M. A., Mahmood, N., & Zhang, J. (2019). Linking economic growth and ecological footprint through human capital and biocapacity. *Sustain Cities Society, 47*, 101516. https://doi.org/10.1016/J.SCS.2019.101516.

EU (2008). *The climate action and renewable energy package, Europe's climate change opportunity*. https://ec.europa.eu/clima/.

Faludi, A. (2000). The performance of spatial planning. *Plan Practice Reseach, 15*, 299–318. https://doi.org/10.1080/713691907.

Frew, T., Baker, D., & Donehue, P. (2016). Performance based planning in Queensland: A case of unintended plan-making outcomes. *Land Use Policy, 50*, 239–251. https://doi.org/10.1016/J.LANDUSEPOL.2015.10.007.

Friedmann, J. (2019). Thinking about complexity and planning. *International Planning Studies, 24*, 13–22. https://doi.org/10.1080/13563475.2018.1517594.

Fudge, S., Peters, M., & Woodman, B. (2016). Local authorities as niche actors: The case of energy governance in the UK. *Environ Innovation Society Transitions, 18*, 1–17. https://doi.org/10.1016/J.EIST.2015.06.004.

Gasparini, P., Di Cosmo, L., Pompei, E., & TEMI, T. (2013). *Il contenuto di carbonio delle foreste italiane : Inventario nazionale delle foreste e dei serbatoi forestali di carbonio INFC2005 : Metodi e risultati dell'indagine integrativa.* Roma.

Geneletti, D., La Rosa, D., Spyra, M., & Cortinovis, C. (2017). A review of approaches and challenges for sustainable planning in urban peripheries. *Landscape and Urban Planning, 165*, 231–243. https://doi.org/10.1016/J.LANDURBPLAN.2017.01.013.

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., et al. (2008). Global change and the ecology of cities. *Science, 319*, 756–760. https://doi.org/10.1126/science.1150195.

GSE 2018. https://www.gse.it/ (Accessed July 8th, 2019).

Haines-Young, R., & Potschin, M. (2011). *Common international classification of ecosystem services (CICES): 2011 update european environment agency*.

Haller, A. (2014). The "sowing of concrete": Peri-urban smallholder perceptions of rural–urban land change in the Central Peruvian Andes. *Land Use Policy, 38*, 239–247. https://doi.org/10.1016/J.LANDUSEPOL.2013.11.010.

Healey, P. (2003). Collaborative planning in perspective. *Planning Theory & Practice, 2*, 101–123. https://doi.org/10.1177/14730952030022002.

Chapter 2: Generic Methodologies Applicable to Multiple Land-Use Categories 2006 IPCC Guidelines for National Greenhouse Gas Inventories 2.1. n.d.

Istat n.d. http://dati.istat.it/# (Accessed March 8th, 2019).

Janin Rivolin, U. (2008). Conforming and Performing Planning Systems in Europe: An Unbearable Cohabitation. *Plan Practical Research, 23*, 167–186. https://doi.org/10.1080/02697450802327081.

Kremer, P., Haase, A., & Haase, D. (2019). The future of urban sustainability: Smart, efficient, green or just? Introduction to the special issue. *Sustain Cities Society, 51*, 101761. https://doi.org/10.1016/J.SCS.2019.101761.

Las Casas, G., & Scorza, F. (2017). *A renewed rational approach from liquid society towards anti-fragile planning. Lect. Notes comput. Sci. (including subser. Lect. Notes artif. Intell. Lect. Notes bioinformatics), vol. 10409 LNCS.* Cham: Springer517–526. https://doi.org/10.1007/978-3-319-62407-5_36.

Las Casas, G. B., Scorza, F., & Murgante, B. (2018). From the rules to the models and vice-versa for a new planning rationality. In A. Leone, & C. Gargiulo (Eds.). *Environ. Territ. Model. Plan. Des.* (pp. 499–508). FedOApress. https://doi.org/10.6093/978-88-6887-048-5.

Las Casas, G., Scorza, F., et al. (2016). Sustainable planning: A methodological toolkit. In O. Gervasi, B. Murgante, S. Misra, A. M. A. C. Rocha, C. Torre, & D. Taniar (Eds.). *Lect. Notes comput. Sci.* (pp. 627–635). Springer International Publishing. https://doi.org/10.1007/978-3-319-42085-1_53.

Melica, G., Bertoldi, P., Kona, A., Iancu, A., Rivas, S., & Zancanella, P. (2018). Multilevel governance of sustainable energy policies: The role of regions and provinces to support the participation of small local authorities in the Covenant of Mayors. *Sustain Cities Society, 39*, 729–739. https://doi.org/10.1016/J.SCS.2018.01.013.

Mishra, A. K., Deep, S., & Choudhary, A. (2015). Identification of suitable sites for organic farming using AHP & GIS. *Egypt Journal of Remote Sensor Sp Science, 18*, 181–193. https://doi.org/10.1016/j.ejrs.2015.06.005.

Moreno-Jiménez, J. M., Aguarón, J., & Escobar, M. T. (2008). The core of consistency in AHP-Group decision making. *Gr Decision Negot, 17*, 249–265. https://doi.org/10.1007/s10726-007-9072-z.

Murgante, B., Tilio, L., Lanza, V., & Scorza, F. (2011). Using participative GIS and e-tools for involving citizens of Marmo Platano-Melandro area in European programming activities. *Journal of Balk Near East Studies, 13*, 97–115. https://doi.org/10.1080/19448953.2011.550809.

Nelson, E., Ennaanay, D., Wolny, S., Olwero, N., Vigerstol, K., Penning-ton, D., et al. (2018). *InVEST 3.6.0 user's guide.* The Natural Capital Project.

Omar, N. Q., Ahamad, M. S. S., Wan Hussin, W. M. A., Samat, N., Binti Ahmad, S. Z., & Markov, C. A. (2014). Multi Regression, and Multiple Decision Making for Modeling Historical Changes in Kirkuk City, Iraq. *Journal of Indian Society Remote Senssor, 42*, 165–178. https://doi.org/10.1007/s12524-013-0311-2.

Oudes, D., & Stremke, S. (2018). Spatial transition analysis: Spatially explicit and evidence-based targets for sustainable energy transition at the local and regional scale. *Landscape and Urban Planning, 169*, 1–11. https://doi.org/10.1016/J.LANDURBPLAN.2017.07.018.

Owens, S. (2005). Making a difference? Some perspectives on environmental research and policy. *Transactions (Institute of British Geographers : 1965), 30*, 287–292. https://doi.org/10.1111/j.1475-5661.2005.00171.x.

Özdağoğlu, A., & Özdağoğlu, G. (2020). *Comparison of ahp and fuzzy ahp for the multi-criteria decision making processes with linguistic evaluations.* n.d..

Pachauri, R. K., Meyer, L., Hallegatte France, S., Bank, W., Hegerl, G., Brinkman, S., et al. (2015). *IPCC, 2014: Climate change 2014: Synthesis report. Contribution of working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change*Geneva, Switzerland: IPCC.

Picchi, P., van Lierop, M., Geneletti, D., & Stremke, S. (2019). Advancing the relationship between renewable energy and ecosystem services for landscape planning and design: A literature review. *Ecosystem Services, 35*, 241–259. https://doi.org/10.1016/j.ecoser.2018.12.010.

Polasky, S., Nelson, E., Pennington, D., & Johnson, K. A. (2011). The impact of land-use change on ecosystem services, biodiversity and returns to landowners: A case study in the state of Minnesota. *Environmental & Resource Economics, 48*, 219–242. https://doi.org/10.1007/s10640-010-9407-0.

Romano, B., Zullo, F., Marucci, A., & Fiorini, L. (2018). Vintage urban planning in Italy: Land management with the tools of the mid-twentieth century. *Sustainability, 10*, 4125. https://doi.org/10.3390/su10114125.

RSDI – Geoportale Basilicata 2019. https://rsdi.regione.basilicata.it/ (Accessed July 8, 2019).

Saaty, T. L. (1980). *The analytical hierarchy process.* McGraw – Hill.

Saaty, R. W. (1987). The analytic hierarchy process—What it is and how it is used. *Math Model, 9*, 161–176. https://doi.org/10.1016/0270-0255(87)90473-8.

Saaty, T. L. (2003). Decision-making with the AHP: Why is the principal eigenvector necessary. *European Journal of Operational Research, 145*, 85–91. https://doi.org/10.1016/S0377-2217(02)00227-8.

Saganeiti, L., Favale, A., Pilogallo, A., Scorza, F., Murgante, B., Saganeiti, L., et al. (2018). Assessing urban fragmentation at regional scale using sprinkling indexes. *Sustain, 10*, 3274. https://doi.org/10.3390/SU10093274 2018;10:3274.

Saganeiti, L., Pilogallo, A., Faruolo, G., Scorza, F., & Murgante, B. (2019). *Energy landscape fragmentation: Basilicata region (Italy) study case.* Cham: Springer692–700. https://doi.org/10.1007/978-3-030-24302-9_50.

Saidur, R., Rahim, N. A., Islam, M. R., & Solangi, K. H. (2011). Environmental impact of wind energy. *Renewable and Sustainable Energy Reviews, 15*, 2423–2430. https://doi.org/10.1016/J.RSER.2011.02.024.

Sala, S., Ciuffo, B., & Nijkamp, P. (2015). A systemic framework for sustainability assessment. *Ecological Economics : the Journal of the International Society for Ecological Economics, 119*, 314–325. https://doi.org/10.1016/J.ECOLECON.2015.09.015.

Salata, S., & Ronchi, S. (2017). *U. Mapping habitat quality in the Lombardy Region, Italy.* OneecosystemPensoftNet n.d.

Salata, S., Ronchi, S., Arcidiacono, A., & Ghirardelli, F. (2017). Mapping Habitat Quality in the Lombardy Region, Italy. *One Ecosystem, 2*, e11402. https://doi.org/10.3897/oneeco.2.e11402.

Sallustio, L., De Toni, A., Strollo, A., Di Febbraro, M., Gissi, E., Casella, L., et al. (2017). Assessing habitat quality in relation to the spatial distribution of protected areas in Italy. *Journal of Environmental Management, 201*, 129–137. https://doi.org/10.1016/J.JENVMAN.2017.06.031.

Sanderson, I. (2002). Making sense of "What works": Evidence based policy making as instrumental rationality? *Public Policy Adm, 17*, 61–75. https://doi.org/10.1177/095207670201700305.

Scorza, F. (2016). Towards self energy-management and sustainable citizens' engagement in local energy efficiency agenda. *International Journal of Agriculture Environment Information System, 7*, 44–53. https://doi.org/10.4018/IJAEIS.2016010103.

Scorza, F., Santopietro, L., Giuzio, B., Amato, F., Murgante, B., & Las, C. G. (2017). *Conflicts between environmental protection and energy regeneration of the historic heritage in the case of the city of Matera: Tools for assessing and dimensioning of sustainable energy action plans (SEAP).* Cham: Springer527–539. https://doi.org/10.1007/978-3-319-62407-5_37.

Scorza, F., Murgante, B., Las Casas, G., Fortino, Y., & Pilogallo, A. (2019). *Investigating territorial specialization in tourism sector by ecosystem services approach.* Cham: Springer161–179. https://doi.org/10.1007/978-3-319-99444-4_7.

Sharma, R., Nehren, U., Rahman, S. A., Meyer, M., Rimal, B., Aria Seta, G., et al. (2018). Modeling land use and land cover changes and their effects on biodiversity in Central Kalimantan, Indonesia. *Land, 7*, 57. https://doi.org/10.3390/land7020057.

Stremke, S. (2015). *Sustainable energy landscape: Implementing energy transition in the physical realm (Encyclopedia of environmental management) energy potential mapping*

view project DEESD: Sustainable energy landscapes and ecosystems services (2013) view project. https://doi.org/10.1081/E-EEM-120053717.

Stremke, S., & van den Dobbelsteen, A. (2013). *Sustainable energy landscapes : Designing, planning, and development.* Taylor & Francis.

Taylor III, B. W. (2010). *Introduction to management science* (tenth edit.). Prentice Hall.

Terrado, M., Sabater, S., Chaplin-Kramer, B., Mandle, L., Ziv, G., & Acuña, V. (2016). Model development for the assessment of terrestrial and aquatic habitat quality in conservation planning. *The Science of the Total Environment, 540*, 63–70. https://doi.org/10.1016/J.SCITOTENV.2015.03.064.

Tsoutsos, T., Frantzeskaki, N., & Gekas, V. (2005). Environmental impacts from the solar energy technologies. *Energy Policy, 33*, 289–296. https://doi.org/10.1016/S0301-4215(03)00241-6.

UNFCCC, S. (2016). *Report of the Conference of the Parties on Its Twenty-First Session, Held in Paris from 30 November to 13 December 2015. Addendum. Part Two: Action Taken by the Conference of the Parties at Its Twenty-First Session*.

Weiss, C. H. (1979). The many meanings of research utilization. *Public Administration Review, 39*, 426. https://doi.org/10.2307/3109916.