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Comparison between Demand and Supply of Some Ecosystem Services in National Parks: A Spatial Analysis Conducted Using Italian Case Studies

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Abstract: In recent decades, modeling approaches of ecosystem services (ES) have been used extensively at the international level, providing useful tools during the decision-making process by integrating both physical and economic information, thus improving its management. The relationship between supply and demand may impact social welfare: for example, a deficit in ES could negatively influence demand (either potential or effective). For this reason, the relational study between supply and demand is necessary for the sustainable management of natural resources; particularly since the demand for some ES must be fulfilled not only on a local scale but also globally (as in the case of regulatory ES). This paper proposes an ES analysis framework that links the flow of services (supply) generated by the interaction between natural, human and social capital with consumption (demand) connected to potential beneficiaries. Specifically, we analyze three ES: Forage production, regulation of local climate (PM_{10}), and carbon sequestration in three national parks (Aspromonte National Park, Circeo National Park, and Appennino Tosco Emiliano National Park). The use of synthetic (biophysical) indicators, on a spatial basis, made it possible to quantify the supply and demand of specific catchments with the aim of accounting for the surplus/deficit through the calculation of the ES supply and demand ratio (ESDR). In fact, sustainable land management requires a balance between supply and demand in relation to the different needs of the stakeholders and local community. The relationship between supply and demand of ES can help identify resource use trade-offs, thus rendering the achievement of management and protection objectives more efficient. Lastly, through the use of monetary coefficients, it was possible to calculate the benefits of increasing the awareness of public decision-makers of ES's value and the importance of implementing integrated strategies for environmental protection and enhancement.

Keywords: protected areas; economic valuation; biophysical assessment; mapping ecosystem services

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1. Introduction

Economic growth has led to an increase in ecosystem services (ES) demand worldwide, to cope with societal production and consumption patterns. This is causing a depletion of natural resources which is reflected in the ability of ecosystems to provide goods and services to society itself.

The need to quantify ES, and include them in decision-making policies, is highlighted in the Biodiversity Strategy for 2030 and in the "EU guidance on integrating ecosystems and their services into decision-making" (SWD (2019) 305 final). This document is aimed at achieving the goal of restoring and protecting ecosystems by 2050. Integrating natural capital into the decision-making process already in the planning and programming phases of sector policies would make it possible to improve the management of the ES for the benefit of the community in terms of food safety, public health, disaster risk reduction, etc. [1].

International and national scientific studies have highlighted the inextricable link between economic wellbeing and natural capital from which ES are generated [1–7]. The concept of ES is therefore closely connected to utility, i.e., the fulfillment of human necessities, and, in this perspective; it becomes an important tool for the improvement of environmental management [8].

At the international level, there is no common methodology for quantifying the demand and supply of ES [9]. Based on most of the studies listed in the bibliography [6,10,11] the supply of ES can be defined as the component of an ecosystem based on biophysical properties, ecological functions, and social characteristics of a specific area and over a given period [9]. The provision of ES reflects the ability of ecosystems to provide services for human beings, irrespective of effective consumption [12].

The demand for ES is regarded as a prerequisite for obtaining effective benefits from ecosystems [5,6,13]. Among the various definitions reported in the bibliography [10–14], this paper will refer to that proposed by Burkhard et al. [6] defining the demand as ecosystem goods and services currently consumed or used in a given area over a given period of time.

Some ES, such as those of support which include the processes of soil formation, photosynthesis, etc., are rarely evaluated. Furthermore, the quantification of cultural and regulatory ES is more challenging because it requires extensive detailed knowledge [9]. The choice of the most suitable indicators for assessing supply and demand depends on the availability of basic data. For example, biophysical indicators are mainly used to evaluate supply, while consumption indicators (such as water consumption, energy per capita) are used to evaluate demand. To map the demand and supply of the ES, remote sensing data are mainly used, while in other cases empirical data and statistical data are used [15].

Furthermore, most studies focus on spatial analysis of supply [12–16] whereas the quantification of demand remains less studied [6,17–20]. Currently, the analysis of supply mainly reflects the ability of ecosystems to provide effectively delivered and used ES, while the analysis of demand is strictly related to the beneficiaries [21,22]. This may also vary between stakeholders and the community in relation to the location, type, and intensity of the ES request [23].

Scientific literature highlights the absence of a univocal method that connects the point of ES supply to the beneficiaries [9].

The spatialization of ES demand and supply is vital as it facilitates the collection of useful information, which in turn helps to direct and improve the governance of the territory [14,24]. ES maps are important tools for decision-makers, making it possible to spatially identify which areas should be maintained due to their high potential to deliver ES [25].

In today's society, the gap between ES supply and demand is widening [9]. Supply and demand can, in fact, be influenced by natural dynamics (drought, floods, etc.) and socio-economic dynamics. For instance, a change in the conservation status of habitats could decrease the flow regime and the relative water quality and therefore have an impact on the supply of ES and on its beneficiaries [26]. Similarly, the consumption of resources by the socio-economic system could lead to a change in land use and the provision of the related supply of goods and ES.

In recent years, several studies have been carried out [27–29] with the purpose of analyzing the surplus/deficit of ES. Assessing the deficit/surplus of ES on a spatial and temporal scale is important because it allows public decision-makers to define strategies and implement interventions for sustainable economic growth.

For example, Nedkov and Burkhard [30] produced a map of the balance between supply and demand for the regulation of flooding of the Malki Iskar river basin in northern Bulgaria. Burkhard et al. [31] developed a matrix linking the ecosystem service potentials and ecosystem service flows with a budget matrix between ecosystem service flows and demand for ES. Li et al. [32] formulated two indicators, i.e., "supply rate" and "supply-demand ratio", to compare the status of some ES in the Taihu River Basin. Guan et al. [33] elaborated two ecological indices to assess the degree of correspondence between supply and demand (MD-demand-supply), and the degree of coordination between supply and demand (CD-supply-demand) in the Quzhou Region, China. Chen et al. [34] calculated ES supply and demand ratio (ESDR) to evaluate the balance between supply and demand of some ES in the Shanghai municipality. In this study, we calculated the ESDR index based on the study of Chen et al. [34].

The supply-demand analysis and the identification of spatial and temporal mismatches allow us to identify the social-economic impacts on the ecosystem [35] and help policy-makers to manage the territory in order to allow a sustainable use of resources [36]. In order to evaluate and integrate ES in decision-making processes, several methodologies have been developed, for example, multi-criteria analysis and performance-based planning [37,38].

Protected natural areas are important for biodiversity conservation because they can counterbalance the loss of ES [39,40] not only internally but also externally [41,42].

The creation of protected areas represents a useful instrument of territorial governance. It ensures the conservation of biodiversity in situ and promotes the integration between human beings and the natural environment [43,44], through the safeguarding of anthropological, archaeological, historical, and architectural values, as well as of agroforestry-pastoral and traditional activities.

Including the ES and their value in the planning and programming tools of protected areas would allow reducing the risk of a decrease in the stock of natural capital and the flow of goods and services [45,46].

Protected areas can also be integrated into broader social, economic, and political contexts, which in turn can affect ES provision.

In this perspective, the ES become the result of the interaction of three forms of capital, namely natural capital (NC), social capital (SC), and economic capital (EC) which, in various combinations, have the ability to generate different benefits [7] (NC, i.e., ecosystems whose creation does not require human intervention [47], social or cultural capital (SC, including human capital), consisting of social networks and norms that facilitate cooperation; this includes culture, institutions [48]; economic capital (EC), including capital produced by man, regardless of whether they are final consumer goods or intermediate goods used for the production of other goods, but also financial capital), the utility flows of which may be perceived at different space-time scales [49]. Particularly in Europe, protected areas are included in social contexts where the interaction between natural processes and human activities creates a Socio-Ecological System—SES [50]. This concept was developed to increase the understanding of the relationship between the natural and social and economic system [51], improving conservation efforts and restoration of natural capital in protected areas [50]. For this reason, the understanding, modeling, and enhancement of ES require an integrated and transdisciplinary approach [52].

In order to evaluate the SES, the following article reports the results based on the application to three national parks (Figure 1) of a methodological process (Figure 2) which involves an analysis of the qualitative and quantitative status of the ES, the attribution of an economic value and the demarcation of the catchment area. In this study, we analyzed the ES forage production, regulation of local climate (PM_{10}), and carbon sequestration in the Circeo National Park, Aspromonte National Park, and Appennino Tosco Emiliano National Park in Italy. The calculation of the ecological supply-demand ratio (ESDR), makes it possible to analyze the impact of consumption activities on the ability of NC to offer goods and services.

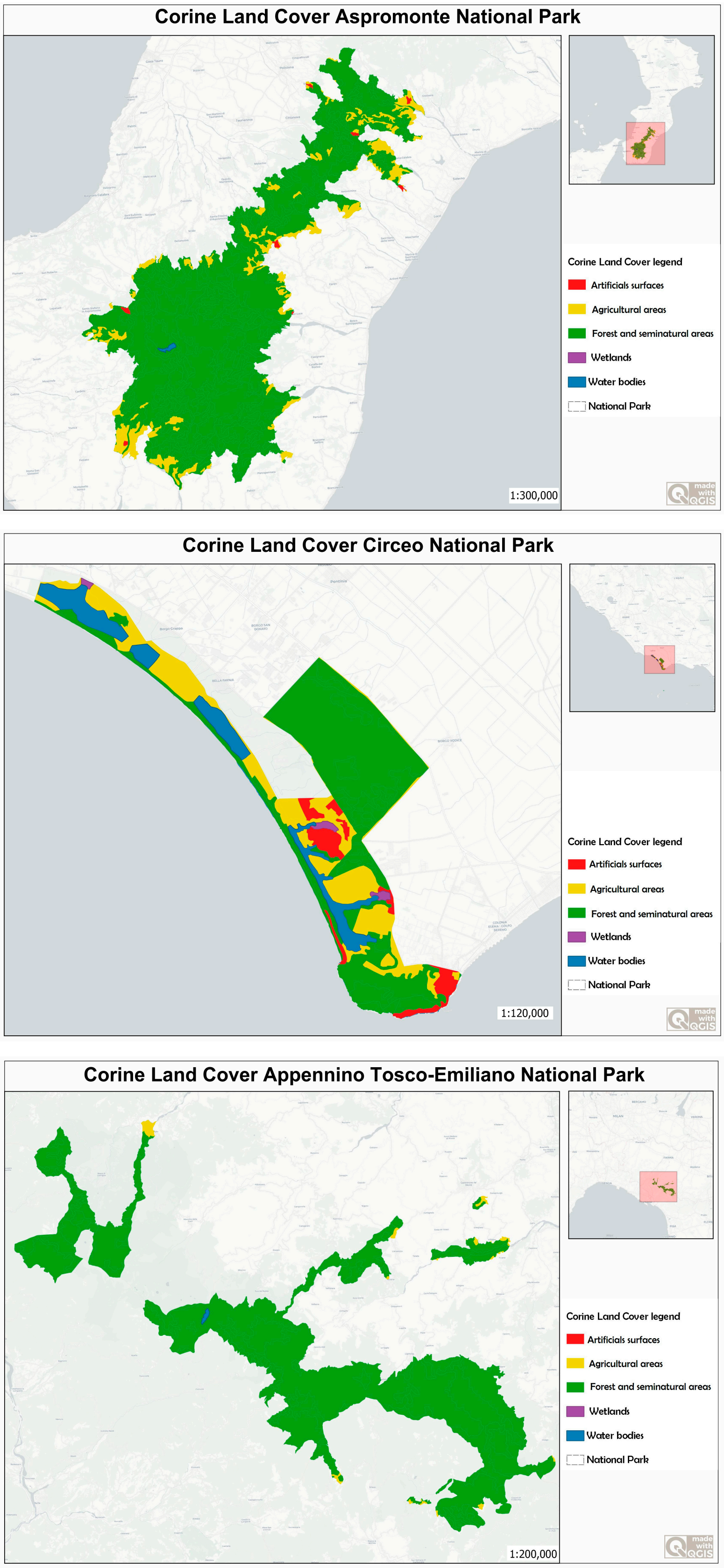

Figure 1. Land use of national parks, 2012.

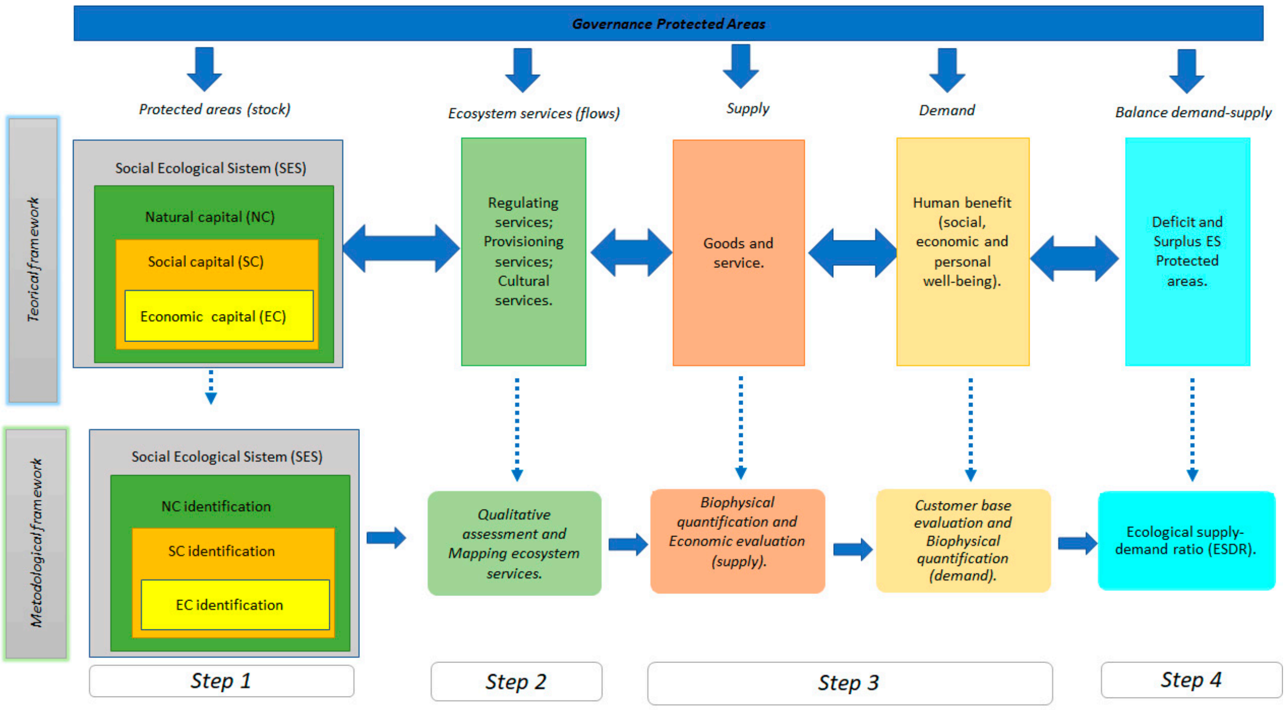

Figure 2. Frameworks of ecosystem services (ES) valuations of protected areas. Sources: Based on various sources [6,7,53,54].

2. Materials and Methods

2.1. Case Studies

The framework illustrated in Figure 2 was applied to three national parks in Italy: the Appennino Tosco Emiliano National Park, the Circeo National Park, and the Aspromonte National Park. The choice of the three case studies fell on three areas distinguished by localization, environmental and socio-economic context (Table 1), and land use (Figure 1).

Table 1. Territorial characteristics of the case studies. N.B. the resident population refers to the perimeter of the catchment area.

UEPA Code	Name	Region	Biogeographical Region	Extend (ha)	Main Land Cover (%)	City (n.)	Population (2015) (n. inhabitants)
EUAP1158	Appennino Tosco Emiliano National Park	Emilia-Romagna, Tuscany	Continental	22,800	78.5 forest; 17.5 pastures	13	5,600
EUAP0004	Circeo National Park	Lazio	Mediterranean	5,620	47.5 forest; 19.4 arable; 12.5 water basins	4	20,400
EUAP0011	Aspromonte National Park	Calabria	Mediterranean	64,150	62.9 forest; 4.6 pastures; 16.6 agricultural land	37	18,050

The Appennino Tosco Emiliano National Park extends along the ridge of the Apennines and is mainly characterized by a hilly-mountainous landscape. It is mainly characterized by wooded areas and semi-natural environments (Figure 1). The Circeo National Park, one of the first parks to be established in Italy (in 1934), develops mainly along the coastal stretch of the Tyrrhenian coast. In addition to the forest areas within the park, there are agricultural and artificial areas (Figure 1). The artificial areas include the urbanized center (i.e., the town of Sabaudia), the marina, and the accommodation facilities located along the coast.

Lastly, the Aspromonte National Park is characterized by wilderness/mountainous areas and agricultural areas mainly linked to agroforestry-pastoral activities (Figure 1).

The most important economic activities are the retail sector (ATECO class 47) and the agricultural sector (ATECO class 01) equating to 18.97% and 13.79% respectively of the number of companies in the area (Unioncamere, 2015). ATECO is a type of classification adopted by the Italian National Statistical Institute (ISTAT) for national statistical surveys of economic nature All three sites investigated conform to the "Plan of Park" (a legal strategy concerning protected natural, environmental, historical, cultural, and anthropological assets); in addition, the Aspromonte National Park also conforms to the Park regulation and Multi-year economic and social plan, as required by the Framework Law on Protected Areas 394/91.

2.2. Theoretical and Methodological Framework

In this study, the analysis of the demand and supply of ES in protected areas is based on the framework shown in Figure 2. The framework consists of a theoretical part "theoretical framework" and of an application part "methodological framework".

In the theoretical framework, the links between the various components are bidirectional as the change in the state of one component can affect the state of the others.

Within the Social-Ecological System (SES) of protected areas, NC generates ES (Figure 2) through its interaction with other forms of capital such as human, social, and built capital [7,53]. NC includes processes and functions which generate resources, later extracted by the economic system and transformed into goods and services and utilized by the social system in the various forms of traditional use. EC is largely the result of traditional economic activities and practices (The concept of traditional in this chapter refers primarily to the material culture (traditional knowledge) with which local populations have co-evolved with the natural and semi-natural environment, still evident in rural areas, particularly in the Mediterranean [55]), which are the result of a long co-evolutionary path, of anthropogenic adaptation and the transformation of specific ecosystems. The livelihood of local communities depends mainly on traditional economic activities and practices (agriculture, grazing, fishing, forestry, harvesting of non-wood products, etc.) which are typical of rural environments [53]. Accordingly, as in most protected areas, the landscape is the result of a long evolutionary process that has seen the interaction between humans and nature, and its utmost expression is illustrated by distinctive cultural and landscape features.

The goods and services provided by the NC are seen as public goods and therefore their benefits are very often not internalized in economic markets and thereby are excluded from public investments. It is, therefore, possible to ascribe a value of direct and indirect use to these goods and services. This value can be expressed in different forms using monetary, non-monetary, or qualitative criteria [5,8,56,57]. Hence the need to ascribe an economic value to these services and, at the same time, to understand consumption in order to implement a model of economic and sustainable growth in compliance with the ecological balances generated by ecosystems.

Consumption of ES, represented by demand, is closely related to the other components of the SES (Figure 2) [19]. Demand can be influenced by various factors, such as socio-economic conditions, demographic changes, and technological innovations [10]. Growth and changes in population composition can influence patterns of consumption or use, as well as individual preferences [19]. Furthermore, demand is also influenced by the individual needs of potential beneficiaries, their awareness, opportunities, and costs of using specific ES (e.g., access, availability) [14].

Our research considers the balance (deficit/surplus) between supply and demand with respect to a specific catchment area. The analysis of the budget in terms of deficit/surplus becomes important in an effort to redeploy governance processes for the protection of biodiversity both upstream, for better management of protected areas and therefore of the Social-Ecological System (stock), and on production models (flows) and consumption (demand) of natural resources by the SES.

The methodological approach (Figure 2), based on the acquisition of useful information to describe the stocks (the different forms of capital investigated) and the flows (the ES that originate from the latter), was developed in accordance with the theoretical approach (Figure 2). The methodological process follows a sequential and parallel approach to the theoretical one and includes; an understanding of the reference context through the analysis of stocks; the identification and quantification of ES; the estimation of benefits; the identification of beneficiaries in the catchment area and the balance between supply and demand obtained through the calculation of the ecological Supply-Demand ratio (ESDR).

Biophysical analysis is relevant for the assessment of capital stocks (natural, social, and economic), flows of ES (supply), and impacts on resources caused by consumption (demand). The economic valuation can affirm the importance of ES and assist communication with policy-makers responsible for the implementation of adaptive land management.

2.2.1. Step 1. Capital Identification

The first step identifies the different forms of capital for each protected area investigated, starting from the analysis of the area of reference. The NC includes ecosystems that do not require human intervention for their formation [47]. In this paper, natural capital is analyzed according to the community habitats identified by Directive 92/43/EEC. Each community habitat is able to provide more ES [57]. The establishment of these habitats in the European Union makes it possible to reduce the pressures on the environment from the Socio-Economic System, which can alter the supply of ES. Social capital (SC) constitutes the social networks and norms which facilitate cooperation, including human capital, culture, and institutions [48]; economic capital (EC) is the built capital produced by people, represented by final consumer goods or intermediate goods used for the production of other goods, and also financial capital. For the analysis of the SC and of the EC, we herein refer to data from statistical sources in order to investigate the territorial scope both in reference to economic activities and to public and private subjects which distinguish the community of the investigated areas.

2.2.2. Step 2. Valuation and Mapping of ES

Mapping the areas that provide ES is an important aspect as it allows for the development of strategies that will ensure the supply of ES in the future [12]. According to De Vreesea et al. [58], the mapping of the most used ES supply in scientific studies is mainly based on land use and land cover and the spatial distribution of biophysical/abiotic resources and flows [59–63]. In this study, the mapping of the ES was based on land cover and use (Corine Land Cover, 2012), which allowed the identification of the most relevant ES for protected areas. For the qualitative assessment, each Corine Land Cover class was assigned a relevance class (3-very relevant, 2-moderately relevant, 1-with some relevance, 0-no significant relevance) which indicates the land use capacity to provide different SE [57]. The relevance classes were assigned by Schirpke on the basis of some parameters (density of function, potential distance from demand, intrinsic biodiversity). In our study, we used these relevant classes because the Circeo National Park, the Aspromonte National Park, and the Appennino Tosco Emiliano National Park include Natura 2000 sites with territorial characteristics and Community habitats (Directive 94/43/EEC) similar to those investigated by Schirpke [57]. The classification adopted for the ES is the one presented in the LIFE + MGN project (http://www.lifemgn-serviziecosistemici.eu/IT/Documents/doc_mgn/LIFE+MGN_Report_A2.4.pdf, accessed on 25 November 2020).

2.2.3. Step 3. Biophysical Quantification (Supply-Demand) and Economic Evaluation

The supply of ES is influenced by natural factors (habitat, fauna, flora, vegetation, latitude, altitude, etc.) as well as by anthropogenic factors: for example, the variation in land use and land cover affects the ability of ecosystems to provide goods and services and consequently of meeting the needs of society. Biophysical quantification methodologies of the supply may vary according to the type of ecosystem service being analyzed. For example, supply ES can be investigated through biophysical indicators (quantity of forage produced), cultural ES by taking into consideration a set of biophysical and social aspects, and lastly regulatory ES can be quantified through the analysis of ecosystem processes (e.g., carbon sequestration [10]). The indicators used to quantify supply must be sensitive to changes in land cover and land use at both spatial and temporal scales [64]. The demand for ES can be traced back to different scales [65] as it is functional to the very nature of ES. For example, the demand for carbon sequestration and climate regulation can be analyzed on a global scale, while forage production can be analyzed on a local scale [31]. In this paper, the analysis of the demand was carried out by identifying the potential consumers of ES within the area of impact of the benefits induced by the ES themselves. The catchment area includes municipalities with a minimum surface share of 45% within the investigated national parks [66], thereby focusing on the network of areas immediately gravitating around each park, rather than on the phenomena observed within the perimeter of the park.

The aim is to quantify the demand from potential consumers such as local communities, stakeholders, and economic activities (tourism, agriculture, livestock, commercial establishments, etc.), which benefit from the flow of goods and services generated by ecosystems. An economic valuation of the ES is important as it allows the ascription of a price to goods that are not traded on the market. Ignoring the economic value of a resource can lead to the damage and impoverishment of ES. The economic valuation of the ES supply takes place through monetary techniques belonging to both traditional valuation and consumer surplus (preferences expressed and detected) [67]. The choice of the most appropriate economic technique depends on biophysical quantification which makes it possible to define the economic features ((non) rival and (non) excludable) of the investigated ES. Moreover, as highlighted by various studies [68,69] the attribution of the values of use and non-use of the ES must be carried out through an interdisciplinary approach, which takes into account, in addition to the biophysical analysis, the spatial scale of reference, the perception of the benefits by the local community correlated to territorial dynamics, as well as from the institutional context of reference. The present study utilized methods of economic valuation which belong to the market price and to the avoided costs selected according to the ES analyzed.

Forage Production

The average productivity values of forage available at the regional level were used for the biophysical quantification of supply ES [70]. These values were multiplied by the

Extension of grassland and pastures for each protected area, thus obtaining the average productivity values.

Supply = Average regional forage production (t/ha) * national park grassland and pastures area (ha).

The economic valuation was carried out taking into consideration the forage price in Italy (between 100 and 150 euro per tonne) multiplied by the average production of each site.

Economic value = average forage production (t) * average market price (€/t).

The ES demand was evaluated considering the average consumption per capita by type of livestock within the catchment area.

Demand = average consumption of forage per capita (t/year/head) * head of cattle/sheep/buffalo (n. of heads).

Carbon Sequestration

The biophysical quantification of carbon sequestration can be carried out by estimating stored carbon in the wood mass (carbon stock) and/or processed (carbon sink). In this study the quantity of carbon processed was estimated considering the epigeal component of the forests, taking into account the increment as a function of the arboreal phytomass of each forest type, as distinguished by region. Phytomass is converted into carbon at a general carbon/phytomass ratio (0.5) and a fresh weight/dry weight ratio which varies according to the forest type. The dataset took into account the National Inventory of Forests and Forest Reservoirs of Carbon Forests INFC (Forestry National Inventory on Carbon Reservoirs) in Italy.

The formula used to measure supply is the following:

$$\text{Supply (tC/year (site-s, region-s))} = \text{Incr} \times \text{BEF} \times \text{WBD} \times 0.5.$$

where:

Incr = Current increment in epigeal tree volume per hectare, by region, and by forest type [Table 1].
BEF = BEF conversion factor (epigeal biomass/growing stock, Biomass Expansion Factor).
WBD = basal density of wood dry weight/fresh weight (t/m^3) (Table 2).

There are two approaches for the economic valuation of ES carbon sequestration: one is based on the Social Cost of Carbon (SCC), and the other on the market value of emission permits. Specifically, the social cost takes into account the damage avoided, at a global level, through the sequestration of CO_2. This calculation is rather mutable as both value and price per tonne of carbon are subject to considerable fluctuations on the international market. For example, different estimates have led to very heterogeneous values: between 32 $ tC and 326 $ tC. [71]. Otherwise, the market value is the price established by the market for emission permits, and according to the European Climate Exchange, the price ranged from 153 $ tC in 2008 to 12 $ tC in 2012. In this paper, the social cost, in reference to the value estimated by Ricke and colleagues [72] of 417 $/t CO_2 (approx 374.89 €/t CO_2), as well as the price of a tonne of carbon on the emission allowance market were considered (https://ember-climate.org/data/carbon-price-viewer/ accessed on 31 December 2018). These values were multiplied by the equivalent tonnes of CO_2 captured by each of the parks investigated.

$$\text{Economic value (€)} = CO_2 \text{ captured by forest biomass (t/year)} * \text{social cost (€/t)}.$$

$$\text{Economic value (€)} = CO_2 \text{ captured by forest biomass (t/year)} * \text{market price (€/t)}.$$

The demand for CO_2 storage was assessed with reference to local anthropogenic emissions, taking into account the number of employees of economic enterprises in the catchment area. The type and number of economic enterprises in the catchment area were identified and provided by Unioncamere (Italian Union of Chambers of Commerce, Industry, Crafts and Agriculture). The Italian Statistical Institute (ISTAT) classifies economic enterprises into the ATECO categories (i.e., economic activities), recording the total number of employees per enterprise. To estimate the CO_2 emissions of each enterprise the ATECO categories have been reclassified into a macro category known as Selected Nomenclature for Air Pollution (SNAP 97) (The SNAP 97 classification (Selected Nomenclature for Air Pollution), which identifies 11 macrosectors of pollutant emissions, was defined within the Corine air project, promoted and coordinated by the European Community DG XI as part of the Corine experimental program (Coordinated Information on the Environment in the European Community), undertaken by the Commission of the European Communities following the decision of the Council of 27 June 1985. Each SNAP 97 category is also reclassified within the respective emission sources established by the IPCC). The process of reclassification was complex as it was not always possible to find a direct correspondence between the ATECO categories and the macro sectors of polluting activities into which the SNAP 97 classification is divided. Reclassification made it possible to estimate the CO_2 demand in the catchment area of each national park investigated, according to the number of employees per economic enterprise. Estimates of carbon emissions by the energy services sector only concern the combustion of non-renewable energy sources.

Demand (tCO_2) = CO_2 emissions (t/no. of employees per economic enterprise) * employees per economic activity national park (n).

Regulation of Local Climate (PM_{10})

The ES supply was based on the ability of protected areas to capture PM_{10} particles (<10 µm). The amount of PM_{10} in the atmosphere is influenced both by the vegetation present in an area and by rainfall and temperatures [73,74].

The annual capture coefficients of PM_{10}—by type of vegetation extrapolated from the scientific literature—were used to calculate supply [75–77] and assigned according to the Corine Land Cover classification (Table 3). The formula used to calculate the ES supply is the following:

Supply = capture coefficients by type of forest (t/ha/year) * type of forest (ha).

A rough estimate of the capture potential of PM_{10} is obtained by multiplying the surfaces of each Corine Land Cover cover of the national parks investigated by the relative capture coefficient.

The monetary value was calculated by taking into account the avoided costs (social damage) as a result of the capture function of PM_{10} by plants, which is equal to €5484.61 for each tonne of PM_{10} absorbed [78] (converted from 2008 to 2018 € value).

Economic value (€) = PM_{10} captured (t/year) * social cost (€/t).

The calculation of PM_{10} demand is complex as it requires precise data on emissions (from environmental monitoring) or potential emissions by surface category or production activities (factories, roads, agriculture, etc.). In order to overcome the difficulties in obtaining data or lack thereof, we estimated PM_{10} emissions relating to employees by following the same methodology used to estimate the demand for carbon absorption. Therefore, having reclassified the ATECO classes in SNAP 97 categories and calculated the relative PM_{10} emissions per employee at the national level, the latter was multiplied by the number of employees per service area. PM_{10} emissions at the national level were calculated by dividing the PM_{10} emissions of the individual SNAP 97 classes by the relative total number of employees.

The formula used to measure demand is as follows:

Demand (tonnes PM_{10}) = PM_{10} emissions (t/n employees in economic enterprise)* employees in economic enterprise (n.).

2.2.4. Balance Demand-Supply

The ecological supply-demand ratio (ESDR) was calculated from the biophysical data obtained through the application of the methodological procedure. In the bibliography, this indicator is mainly used for a space-time comparison of site-specific supply and demand [34]. In this study, the balance between supply and demand focused instead on a spatial comparison to verify the state of ES in the areas investigated. For this purpose, the actual supply and the effective demand calculated for each ecosystem service in each park area were compared using the following equations (modified from Chen [34]):

$$\text{ESDR} = \frac{supply\ actual\ ES\ -\ demand\ ES}{(supplyactualES\ +demand\ ES)/2}$$

where *supply actual ES* represents the biophysical supply of each ecosystem service investigated in the study areas and *demand ES* the consumption of *ES* by potential resident consumers in the catchment area. Values above zero represent a surplus of *ES*, whereas < zero represents a deficit and equal to zero a balance between supply and demand [32].

3. Results

For each protected area, the contribution of NC, SC, and CE to the supply of ES was identified [53] (Table 2). As Table 2 illustrates, the three national parks investigated show an evident heterogeneity of Natura 2000 habitats which testifies to the biodiversity richness at the community level. Conversely, the social and economic fabric presents some differences between the parks. The Aspromonte National Park and the Appennino Tosco Emiliano National Park, being predominantly rural areas, have similar SC and NC. What sets them apart is the variety of products grown, processed, and marketed in relation to the peculiarities of the territory. The Circeo National Park is a coastal park and its SC and EC are linked to seaside tourism and to the production and processing of wine and oil products. Public human capital depends on the political-administrative division of the Italian territory.

Figure 3 shows the qualitative mapping of ES in the studied areas. Most of the territories of the Appennino Tosco Emiliano National Park and the Aspromonte National Park provide ES that are very relevant to society. This result is mainly due to the coverage of forest and vegetation and to the reduced surface of urbanized areas. In fact, if on the one hand urbanized areas do not provide SE, on the other hand, the forest areas perform relevant functions including climate change mitigation (carbon sequestration) and air purification (PM_{10}) on a local scale. The two parks constitute territories with a significant supply of ES and low demand.

The Circeo National Park is also characterized by artificial areas dislocated along the coast. The areas that provide the most SE are the Circeo Promontory, the Circeo state forest (Biosphere reserve Man and the Biosphere – MAB Programm), and water bodies and wetlands near the coastal dunes (very relevant areas Figure 3). From the spatialization of the demand (Figure 4) it is evident that the potential catchment area of the analyzed ES corresponds to densely populated areas and agricultural areas. The data of biophysical quantification of supply and demand and economic value by ES are shown in Table 3.

As Figure 5 shows, the ESDR of ES is not always positive. This depends on the one hand on the capacity of the land to provide ES (supply) and on the other on the economic and social fabric that distinguishes the catchment area (demand). The Circeo National Park shows a deficit in the ES of forage production and regulation of local climate (PM_{10}) (Figure 5). The negative ESDR values for the forage production ES are due to a reduced cover of the grassland and pasture areas used for forage production. The production of forage (5250 t) does not satisfy the demand (25,282 t). As for the ES regulation of local climate (PM_{10}), the results also show that compared to PM_{10} emission into the atmosphere of approximately 13,518 t/year, only 65.30 t/year PM_{10} is deducted by the forest constituent. For the Aspromonte National Park as well, the spatial comparison of demand and supply of the ES forage production shows a deficit. Despite 4.6% of the territory being allocated to grazing (Table 1), it fails to meet the demand of approximately 46,930 t of forage per year required by 36,681 heads of cattle (bovine, buffalo, goat, sheep). Conversely, the relationship between supply and demand for the carbon sequestration ES is positive, which is a common trend for the investigated parks. This highlights the importance of the contribution made by forest cover to the mitigation of climate change on a local scale.

Table 2. Relationship between different types of capital and potential beneficiaries of ES: forage production, regulation of local climate (PM_{10}), and carbon sequestration, identified in the protected areas investigated. * Priority habitat Natura 2000.

National Park	Natural Capital Habitat N2000	Social Capital			Economic Capital	Beneficiaries
		Built Capital	Human Capital			
			Private	Public		
Appennino Tosco Emiliano	3140; 3150; 3240; 3250; 3260; 3270; 4030; 4060; 5130; 6110; 6170; 6210; 6230; 6410; 6430; 6510; 6520; 7140; 7210; 8110; 8130; 8220; 9110; 9150; 9180; 91E0; 9210; 9220; 9260; 92A0	Companies: agri-food, agricultural, zootechnics. Activities: commercial, tourist. Rural settlements housing.	Operators in the agricultural, livestock, trade, and tourism sectors. Local population.		Pastoralism and breeding, agriculture, harvesting and processing of undergrowth products, beekeeping, fruit and vegetable activities, tourism.	
Circeo	1150 *; 1210; 1240; 1310; 1410; 1420 1510 *; 2110; 2120; 2190; 2210; 2230; 2240; 2250 *; 2270 *; 3170 *; 5210; 5320; 5330; 6220 *; 6420; 8210 9180 *; 9190; 91B0; 91M0; 9280; 9330; 9340	Companies: zootechnics, viticulture, oil producers, agricultural. Activities: tourism, commercial. Seaside resorts, housing.	Farmers, breeders, tour operators, trade operators. Local population.	Managing bodies, Local Authorities.	Farming agriculture, tourism, trade, production, processing, and marketing of agricultural products (oil, wine), seaside tourism.	Local population; breeders, farmers, tourists, urbanized areas
Aspromonte	3150; 3170 *; 3270 3280; 4090; 5330; 5332; 5430; 6175; 6220 *; 6420; 6430; 6431; 7110 *; 7220 *; 8210; 8220; 9110 *; 9180 *; 92A0; 92D0; 9210 *; 9220 *; 9260; 9280; 9330; 9340; 9510 *;9530 *; 9560 *	Companies: horticultural, fruit and vegetable. Craft activities, rural, and pastoral settlements.	Farmers, Breeders, Operators in the agri-food sector, craft activities workers. Local population.		Oil production, Pastoralism, and breeding, production, processing, and marketing of agricultural products (fruit, vegetables, oil, wine), artisanal production, tourist activities.	

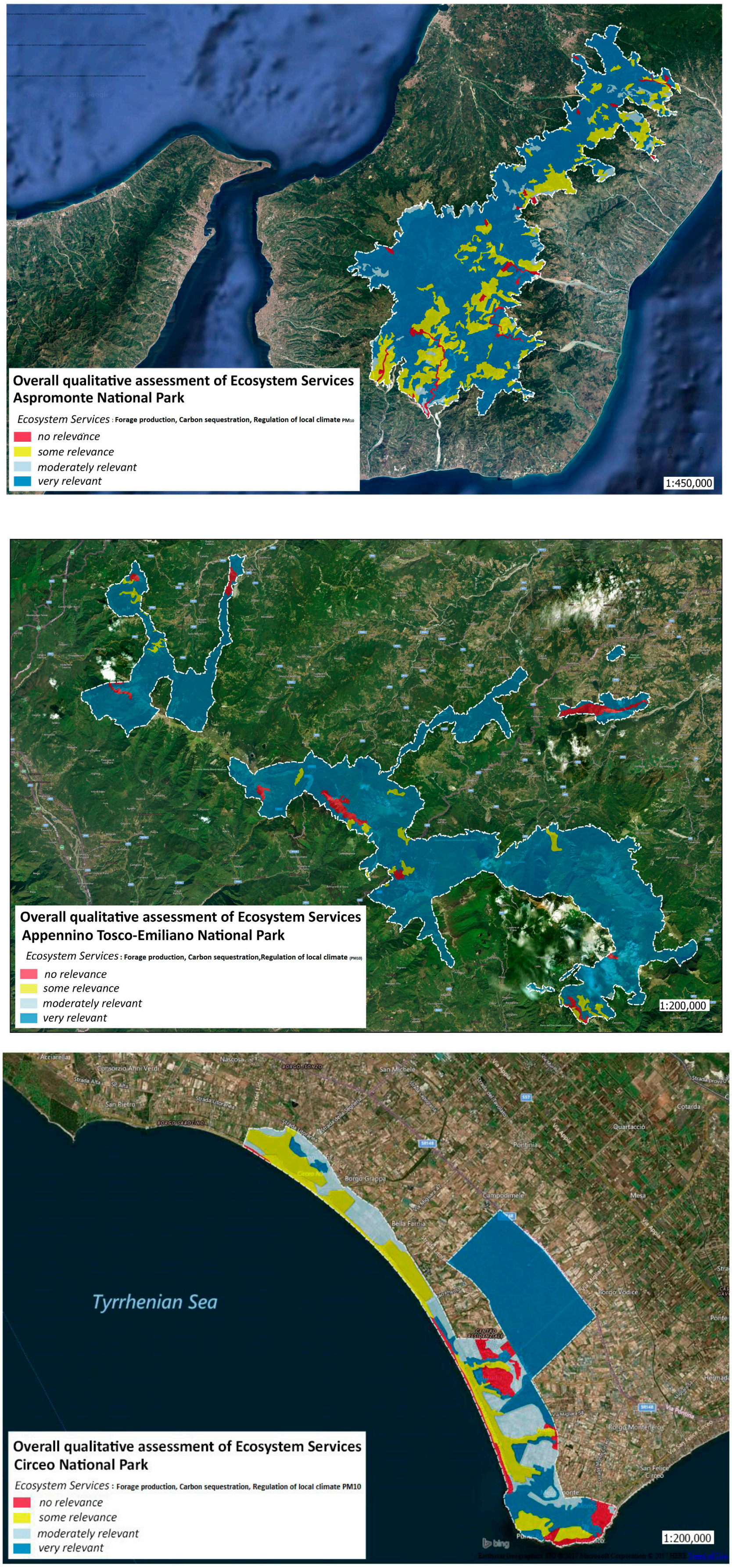

Figure 3. Qualitative analysis of the ES investigated in the case studies.

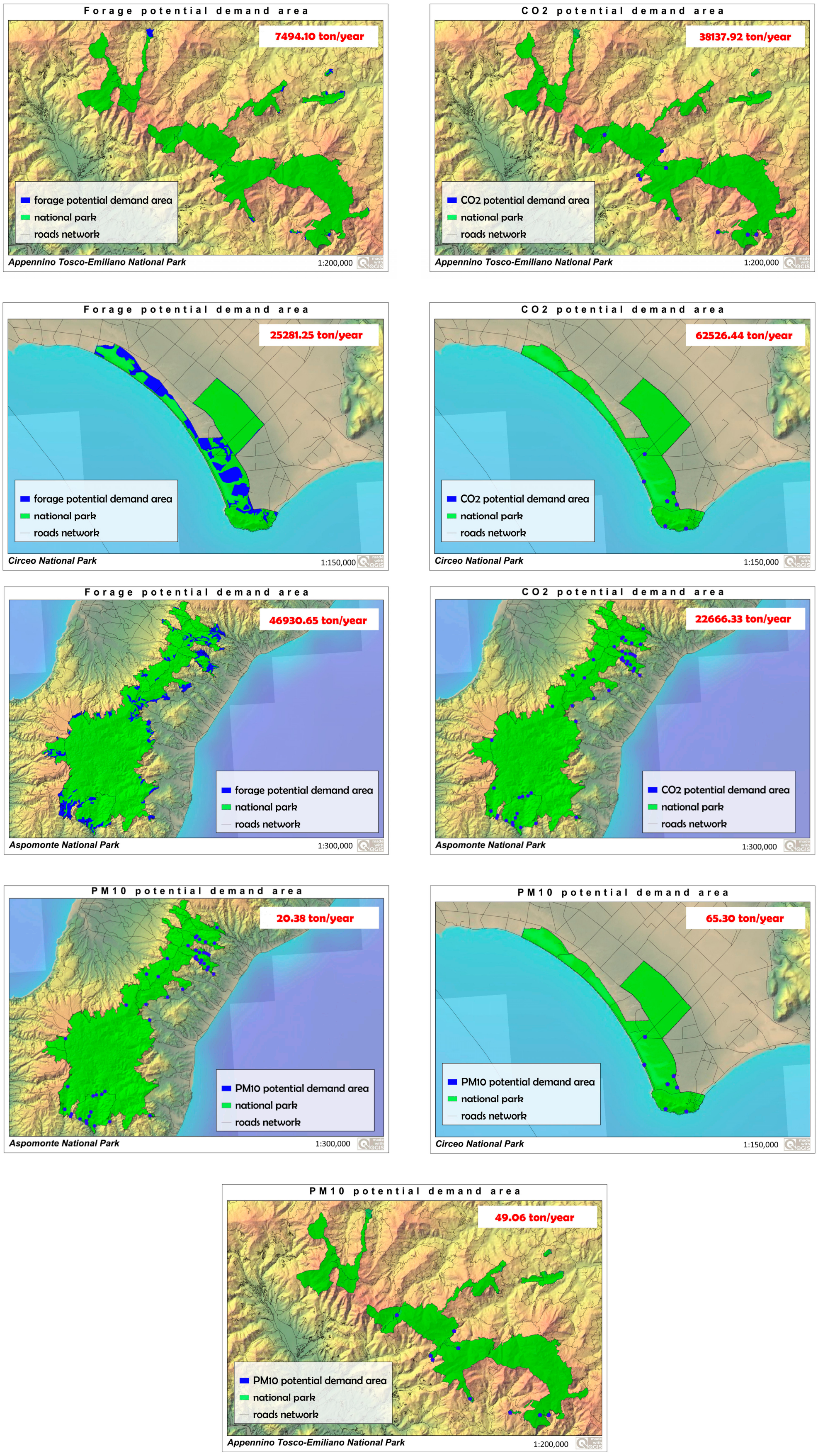

Figure 4. Demand of ES in National Parks.

Table 3. Biophysical quantification of supply and demand and economic value by ES. * social cost ** market price.

ES	National Parks	Demand (t/year)	Supply (t/year)	Economic Value (€)
Forage production	Appennino Tosco Emiliano	7494.10	99,409.76	12,426,219.56 **
	Circeo	25,281.25	5252.92	656,615.24 **
	Aspromonte	46,930.65	37,147.66	4,643,457.03 **
Carbon sequestration	Appennino Tosco Emiliano	38,137.92	333,280.04	124,943,354.20 * 8,042,047.37 **
	Circeo	62,526.44	21,619.9	8,105,110.55 * 521,689.88 **
	Aspromonte	22,666.33	491,589.16	184,291,860.19 * 11,862,046.43 **
Regulation of local climate (PM_{10})	Appennino Tosco Emiliano	49.06	52,066.08	285,562,143.03 *
	Circeo	65.30	13,518.00	74,140,957.98 *
	Aspromonte	20.38	111,770.97	613,014,697.90 *

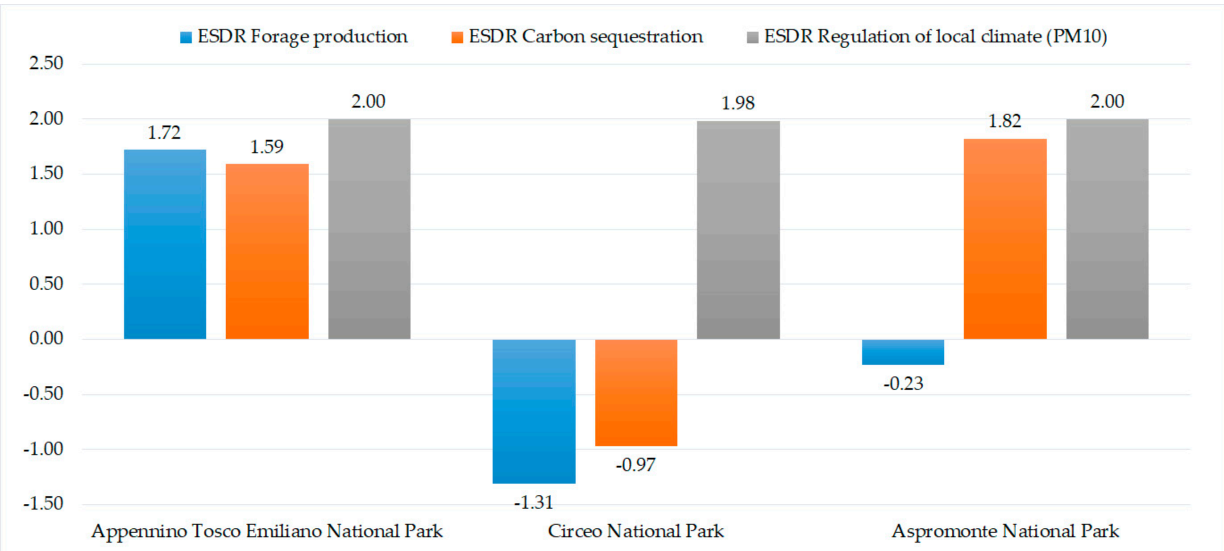

Figure 5. Ecological supply–demand ratio (ESDR) of National Parks.

The ESDR calculated at the system level of the protected areas investigated (Figure 6) acquire positive values for all three ES. This highlights how, overall, the benefits of establishing protected areas are linked to the protection of the supply areas of ES. The supply balances the demand not only at the catchment level but also at a regional and global scale. As the investigated ES have a higher value than 1328 billion euro, the estimated benefits (Table 3) are higher than management costs: for each euro invested there is a return of around 228 euro.

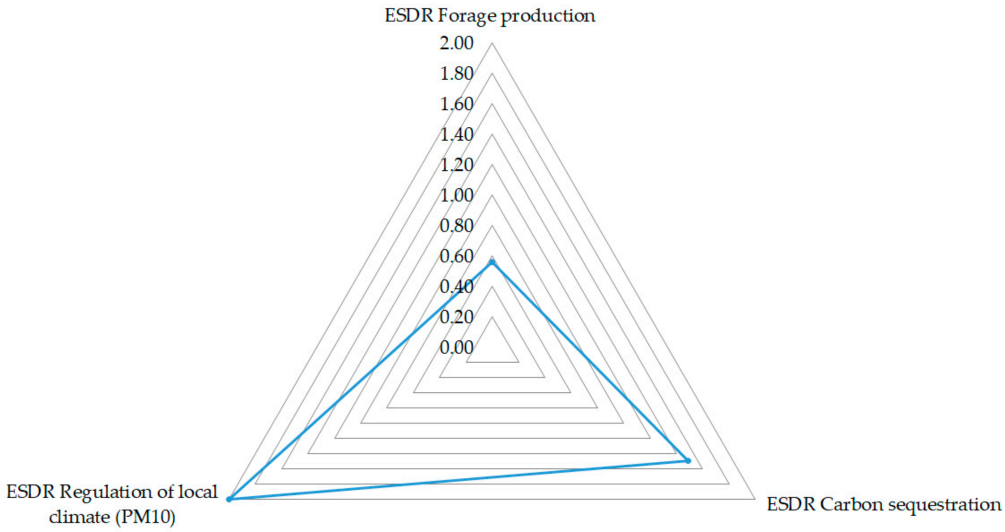

Figure 6. Ecological supply–demand ratio (ESDR) of National Parks.

4. Discussion

Studies with a focus similar to ours have found it challenging to deal with the different scales between social and ecological systems. In fact, socio-economic data are usually made available on administrative surveys and it is necessary to georeference them so as to relate them to the scale of the survey [79,80]. In addition, many ES (support services, nutrient cycle, etc.) are absent from the market. They require indirect methods, such as avoided cost, to be economically quantified. Our research used two estimation methodologies, one based on the market price to value the ES of forage production and the other based on social costs for the regulatory ES intrinsic to carbon sequestration and the regulation of local climate (PM_{10}).

The results reported in this study consider the need to improve the conservation of natural capital by taking into account the spatial relationship between the supply and demand of ES. Improving the understanding of the relationship between supply and demand of services in different areas is recognized as a fundamental aspect that must take into account the ES framework [81].

The analysis, conducted through the use of ESDR, is important as it provides an opportunity to understand the socio-economic context (for example ATECO economic activity) that can change the ability of NC to provide ES.

The ESDR index has highlighted a different contribution made by national parks to the provision of ES, in response to social and economic demand. The ESDR index shows, to varying degrees, that the Circeo National Park is unable to compensate for the CO_2 emissions from anthropogenic activities. The results reveal the need to undertake a policy of conversion of energy policies aimed at reducing emissions at the local and global levels.

There is also an imbalance between the supply and demand of fodder for the Circeo National Park as the agricultural areas are mainly used for the cultivation of vines and olive groves (Table 3).

Air pollution due to PM_{10} represents one of the main health risks for citizens. In our study, the ESDR value is positive in the three parks analyzed (Figure 5). This is due not only to the ability of the forest component to absorb PM_{10} but also to the characteristics of the socio-economic context. The ESDR shows that the parks are able to absorb part of the PM_{10} emitted by economic activities also present in the neighboring areas (catchment area). The capture of PM_{10} by vegetation can produce economic benefits such as, for example, the reduction of health costs related to air pollution.

The economic benefit of the three parks relative to the social costs avoided thanks to the capture of PM_{10} is approximately 973 million euros. If we add up the avoided costs due to carbon sequestration, the total economic benefit is 1290 billion euro.

Therefore, an effective assessment of ES requires an analysis of the actual needs of society in relation to the supply of services and their ability to reach the areas of demand through service flows [82].

This paper highlights how the flow of goods and services depends on the synergy of the environmental, social, and economic capital while the demand depends on the economic activities falling within the catchment area.

To calculate supply and demand it is necessary to analyze the social and economic drivers [83] responsible for inducing variations in the flow of goods and services [84]. It is important to understand the spatial relationships among the areas in which ES originate (supply) and those that benefit from them (demand), correlating the calculation of supply and demand to the reference scale, in order to implement effective policies [85,86].

Furthermore, the ecological and economic processes from which the different ES emerge and the utility flows may not match their point of origin [49,86,87].

For example, the place of ES forage production and the benefitting areas can be in situ (Services Providing Units (SPU) and Services Benefiting Areas (SBA) are realized in the same location) and decoupled from the point of supply as these goods/services can also be exchanged over long distances [31]. The benefitting areas of the ES carbon sequestration and ES regulation of local climate (PM_{10}) are localized not only at the point of origin (in situ) but also in an omnidirectional way, as the benefit expands from the point of production (SPU in one location, SBA in the surrounding landscape without directional bias) [31]. Adequate levels of governance of park areas would guarantee the continuous flow of goods and services by limiting the externalities of the production and consumption of resources at the system level [44]. Taking the work of Burkhard et al. [31], and Kettunen [88] as reference, the benefits (ES) provided by the three protected areas can be felt at different scales (Table 4).

Table 4. The spatial relationship between demand and supply of the investigated ES. Based on Burkhard [31] and Kettunen [88].

ES	Indicator Flow	Indicator Demand	Service Providing Units (SPU) (Hotspots)	Service Benefiting Areas (SBA)	Spatial Relation SPU-SBA	Governance Protected Areas Benefits
Forage production	Average forage production	Consumption of forage on farms	Areas of grassland and pastures	Head of cattle	In situ; Decoupled	Regional Private
Carbon sequestration	CO_2 captured by forest biomass	PM_{10} per employee per economic enterprise	Forest cover	Employees per economic enterprise	In situ - omnidirectional	Global
Regulation of local climate (PM_{10})	PM_{10} captured by forest biomass	PM_{10} per employee per economic enterprise	Forest cover	Employees per economic enterprise	In situ - omnidirectional	Global

The benefits provided by regulation ES such as carbon sequestration and regulation of local climate (PM_{10}) exceed the boundaries of the protected area and reach society as a whole, while the benefits deriving from the ES supply of forage and grazing mainly concern the local scale.

5. Conclusions

The objective of the present paper was to evaluate the application of a method for calculating the flows of ES which would highlight, on a physical-spatial, social and political basis, the relationships established between the areas in which such flows originate and the areas that benefit from them. Specifically, the supply areas investigated were three Italian national parks and the beneficiaries were the respective areas from which the demand for three indicative ES originates.

Ultimately, through the mapping of supply and demand of ES, studies such as this one provide an opportunity to identify the economic value of the services themselves, and also to map the different stakeholders and their roles, facilitating the identification of management tools (regulatory, planning or market-based tools such as payments for ES) aimed at preserving natural capital, maintaining the flow of ES, and therefore social welfare. In this context, the application of the ES supply and demand ratio (ESDR) can potentially improve the application of management tools. In the event of a surplus in the supply, it is, in fact, possible to identify ex-ante the service use limit, or alternatively, policies aimed at increasing conservation and natural capital to increase supply levels, in order to avoid the over-exploitation of resources.

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Appendix A

Table 1. Values per unit of surface area of the epigeal arboreal phytomass for the forest categories of high woods (m^3/ha) [75].

INFC Categories	Regions			
	Emilia Romagna	**Toscana**	**Lazio**	**Calabria**
Spruce woods	13.2	13.3	20.2	0
white spruce woods	12.4	12.3	0	8.6
Scots pine and Mountain pine	3.9	8.7	0	0
Black pine forests, laricio pine forests	6.3	8.7	5.5	8.6
Mediterranean pines	4.3	4.2	3.4	4.7
Other coniferous forests, pure or mixed	4.8	7.8	8.3	10.3
Beech woods	6.2	8.1	3.5	6.4
Oak wood, Downy Oak Woods, English oak woods	2.2	1.9	1.5	2.3
Sessile oak and other oaks	4.7	2.9	3.1	4.8
Chestnut groves	5.3	6.4	6.6	6.2
Hornbeams	3.2	3.8	2.2	1.8
Hygrophilous woods	3.4	4.6	3.3	4.5
Other deciduous forests	3.4	4.3	2.7	3.4
Holm oak woods	5.2	2.3	1.9	3.7
Cork oak woods	0	2.3	2.1	2.7
Others broadleaves	0	2.1	1.1	3

Table 2. Biomass expansion factor (BEF) and basal density of wood (WBD) values [75].

INFC Categories	WBD	BEF
Spruce woods	0.38	1.29
white spruce woods	0.38	1.34
larch woods and stone pine woods	0.56	1.22
Scots pine and Mountain pine	0.47	1.33
Mediterranean pines	0.53	1.53
Other coniferous forests, pure or mixed	0.43	1.37
Beech woods	0.61	1.36
Sessile oak and other oaks	0.69	1.45
Chestnut groves	0.49	1.33
Hornbeams	0.66	1.28
Oak wood, Downy Oak Woods, English oak woods	0.65	1.39
Holm oak woods	0.72	1.45
Cork oak woods	0.72	1.45
Other deciduous forests	0.53	1.47
Black pine forests, laricio pine forests	0.52	1.44
Hygrophilous woods	0.41	1.39
Others broadleaves	0.63	1.49

Table 3. PM_{10} sequestration coefficients for Corine Land Cover class (III level) [75].

Corine Land Cover Class	Coefficient *	Approach
3.1.1. Broad-leaved forest	0.16 t/ha/year	data 1/3 of the value for coniferous
3.1.2. Coniferous forest	0.49 t/ha/year	average approx. of the highest values of Escobedo and Nowak [76], Nowak et al. 2006 [77], compared to fully wooded areas (x 4)
3.1.3. Mixed forest	0.325 t/ha/year	average of the previous values

* The coefficients do not consider the contribution of shrubs and grassy surfaces.

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