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Ecosystem Services Multifunctionality: An Analytical Framework to Support Sustainable Spatial Planning in Italy

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Abstract: A growing demand at several levels of territorial government concerns the need for tools to support policy-making oriented towards sustainable planning. That of Ecosystem Services (ES) represents a well-structured and robust methodological framework for developing tools to assess environmental performances and territorial transformations linked to different development needs. The paper fits into this frame by proposing an analytical framework based on the ES multifunctionality approach, i.e., the joint provision of multiple ES, and applying it to the Italian national context. The methodology defines a spatial model based on three aggregate indices (abundance, diversity and richness) assessed considering the Provinces as reference territorial units. Derived from ecological disciplines, these three dimensions of ES multifunctionality describe the variability with which territorial units deliver multiple services for community well-being and support the analysis of the relationships between anthropic components of territorial systems and the ecosystems' multifunctionality. The evaluation of how the three indices' spatial distribution varied as a result of land use changes in the period 2000–2018 allows us to highlight specific aspects of territorial units useful to improve the knowledge framework from a sustainable planning perspective. The results highlight its potential to support decision-making processes and formulate recommendations for sustainable spatial planning.

Keywords: Ecosystem Services (ES); ES multifunctionality; sustainable spatial planning; Dcision Support System (DSS)

Citation: Pilogallo, A.; Scorza, F. Ecosystem Services Multifunctionality: An Analytical Framework to Support Sustainable Spatial Planning in Italy. *Sustainability* **2022**, *14*, 3346. https://doi.org/10.3390/su14063346

Academic Editor: Stefano Salata

Received: 8 February 2022
Accepted: 10 March 2022
Published: 12 March 2022

1. Introduction

Current issues for urban studies are focused on implementing sustainable principles and addressing spatial demands related to the needs of modern society, maintaining environmental quality, protecting biodiversity and managing the increasingly urgent issues of climate change adaptation and mitigation [1].

These issues globally depend on the unsolved conflict between anthropic systems and environmental components [2]. The need for tools to support policy-making oriented to sustainable planning arises at several levels of governance. In this regard, the Ecosystem Services (ES) approach represents a structured dimension in which to develop new effective tools for the assessment of environmental performance [3].

More specifically, the ES multifunctionality approach [4,5], intended as the opportunity to compute the joint supply of multiple ES, is promising. Recently, in fact, ES multifunctionality is gaining interest among planners [6–9] because it allows them to make the three principles of rational planning [10] explicit and operative: equitable access to opportunities and services for people, natural resources' use efficiency [11] and sustainability [9,12,13]. It supports, in fact, a renewal in the evaluation of land use change processes more oriented to the assessment of systemic performances than to the estimation of specific variables depending on territorial transformations (i.e., land take). It also contributes to the construction of an integrated knowledge system that offers decision-makers the opportunity to appropriately relate planning tools, different environmental components and several strategic development alternatives.

In this respect, there is a growing body of work in the scientific literature that refers to the concept of ES multifunctionality to account for synergies and trade-offs [14,15], to tackle the challenge of fair distribution of costs and benefits by different stakeholders [16], to compare scenarios in a frame of rationality and efficiency [17,18] and to enhance coherence between context-based measures and global instances [19–21].

The aim of this work is to provide an interpretative model of the effects of land use change on ES multifunctionality. As expressed by the same authors in a previous work, ES multifunctionality constitutes an innovative and comprehensive way to analyze and interpret different land use patterns, considering further territorial features linked to the fragmentation of urban settlements [22] and multiple facets of human well-being [23,24]. A deeper insight into the spatial distribution of ES multifunctionality could indeed underpin the prediction of how targeted policies or land use change might affect ecosystem delivery and the subsequent capacity of ecosystems to meet multiple human demands.

This model was applied to Italy as a case study. The minimum statistical units for ES multifunctionality appraisal are provinces that represent Nomenclature of Territorial Units for Statistics (NUTS) level 3 units. The input data related to land use changes that occurred in the time period considered (2000–2018) were obtained from CORINE Land Cover (CLC) maps. These also represent the core information layers for the spatial assessment of the ES considered. These features make the analytical approach transferable to other EU countries in order to compare results and characterize trends.

Within the wide variety of conceptualizations and methods [25] available in the scientific literature, we chose to express ES multifunctionality in terms of integrated indices that constitute combined measures of ES indicators.

Aggregate indices constitute a useful method for effectively representing the synthesis of complex dynamics related to the capacity of ecosystems to provide multiple services useful for human well-being. They are therefore recognized as having great communicative potential, even considering non-expert stakeholders and decision-makers. Several authors also highlight their role as tools for increasing public awareness of sustainability issues [26] and for making an immediate comparison between different territorial units on the basis of their environmental performance [27].

In the context of planning practice, Staiano et al. [28] outline that aggregate indices can support several steps in the planning process, from context analysis, to the comparison of alternative development scenarios, up to effectiveness monitoring of different environmental policies. Finally, other authors [29–31], in order to improve the degree of stakeholder involvement in participatory decision-making processes, propose an integration of multifunctionality ES and multi-criteria analysis. This makes it possible to assign a weight to needs expressed by stakeholders, which vary according to their actual demand.

As the ES provision depends on a mix of environmental (including land use patterns and characteristics of urbanization processes) and socio-economic (including implementation of conservation policies and management of transformation processes) factors, at the national scale we find it useful to provide a joint analysis of transformation phenomena and consequent changes in different dimensions of ES multifunctionality, as described by Holting et al. [32]. They argue that borrowing the concepts of abundance, diversity and richness from ecological disciplines in the ES framework allows the assessment of multifunctionality across scales, differentiating territorial units that provide ES with the greatest intensity (abundance), that contribute most to the maintenance of national multifunctionality (richness) or that provide the greatest ES variety (diversity). This contributes to a better understanding of the effects of spatial transformations and land use changes in terms of the supply capacity of multiple ES [33]. Analyses related to the monitoring of land use and urbanization processes are currently limited to the perspective of increasing artificial surfaces. However, several authors highlight the importance of better characterizing these processes e.g., in terms of spatial fragmentation [22,34,35], social [36] and/or environmental costs [37–39]. Extending the classification by Holting et al., this research defines a spatial model to assess these three indexes (that in our view represents the three dimensions of ES multifunctionality) deriving from ecological disciplines to characterize the ES multifunctionality of the case study area. The novelty of the research, therefore, lies in the integration of indices formulated in the field of ecology and the ES framework in order to obtain a synthetic spatial representation of the complex dynamics underlying ES multifunctionality, able to support sustainable planning thinking and to inform thoroughly decision-making processes concerning territorial governance.

The analysis of the spatial distribution of the three indices allows us to detect critical issues in terms of ES multifunctionality in areas characterized by a high degree of anthropization, the presence of a dense network of transport infrastructure and management models of agricultural areas marked by intense agricultural systems [40,41].

On the other hand, mountain and inland areas emerge as hotspots of ES provision and as an hotspot of multifunctionality relevant to the entire national context, confirming the findings of previous work [1,3]: the role of natural areas as specialized providers for multiple ES.

Furthermore, the variation analysis allows us to differentiate the effects of urbanization processes on the three indices.

The paper is structured in four parts: the description of the study area with particular reference to land use change and urbanization dynamics of occurred in the twenty years examined; the description of our spatial analytical model that is the foundation of the analytical methodology; the discussion of the main results; the conclusions that highlight the potential of the analytical framework presented to support decision-making in sustainable land use planning.

2. Area of Study

The study area for the application of the analytical framework of ES multifunctionality is the whole Italian territory, taking NUTS3 areas as territorial units of reference.

Consistent with the European context where the urban conversion rate in the period 2000–2018 was 1790 km^2/year [42], and according to the Italian Institute for Environmental Protection and Research (ISPRA) [43], the study area is characterized by relevant criticalities in terms of land take trends [34,35,44], especially in peri-urban and urban areas, where artificial surfaces are increasing to the detriment of natural and semi-natural areas.

The analysis of land use changes and urbanization dynamics were derived from information layers made available within the Corine Land Cover (CLC), a project started in 1985 (with the first map produced referring to 1990) and then regularly updated (2000, 2006, 2012 and 2018). The layers, available on the Copernicus project website, are the result of land cover/land use classification from remotely sensed imagery using semi-automated procedures. The product provides a standard division into 44 classes, divided into three levels with the minimum mapping unit (MMU) equal to 25 ha for areal phenomena and 100 m for linear phenomena (MMW).

In order to synthesize the main changes in terms of land cover that occurred between 2000 and 2018, we considered the first level of the CLC.

As shown in Figure 1, artificial surfaces (corresponding to *class 1*, the first level of the CLC), have significantly increased (+16.33%) at the expense of agricultural areas (*class 2*) and forests and seminatural areas (*class 3*). This increase, equal to about 2350 km^2, is slightly higher than the entire territorial extension of the Province of Mantua.

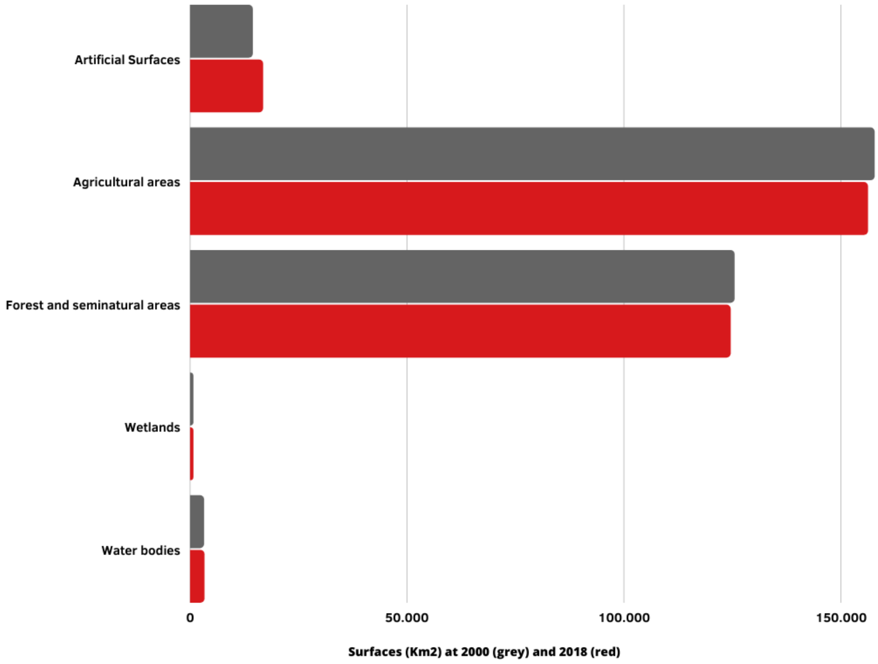

Figure 1. Comparison between areas for each class of CLC I level referring to 2000 (grey) and 2018 (red).

In addition to the intensity of the land consumption phenomenon, other critical issues concern the ways in which infrastructurization processes, urban settlements expansion and transformations took place.

Looking at Figure 2, which shows the increase in artificial surfaces in 2018 compared to those already existing in 2000, it is possible to recognize different dynamics.

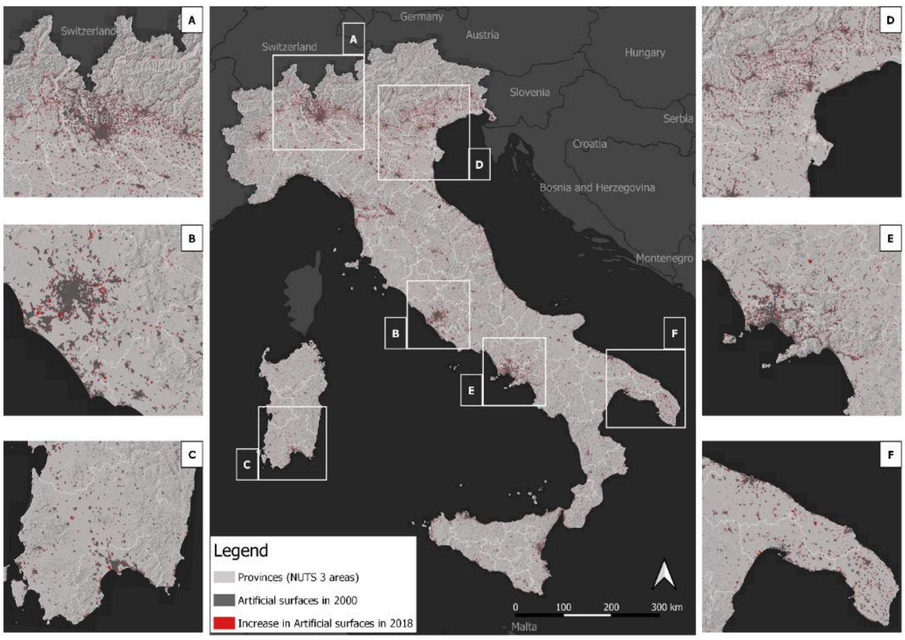

Figure 2. Increase in Artificial surfaces over the period 2000–2018. (**A**–**C**,**E**) the surroundings of main metropolitan areas; (**D**) southern "Triveneto"; (**F**) the peninsular part of Apulia.

In fact, a high rate of land conversion can be noted in the surroundings of main metropolitan areas (Figure 2A–C,E), which act as poles for the provision of services at a territorial scale and act as drivers for new urbanization for residential and productive/commercial use.

On the other hand, urban development processes involving polycentric territorial systems are more widespread. Examples are the southern "Triveneto" (Figure 2D), a geographical area including the Regions of Veneto, Trentino Alto-Adige and Friuli Venezia Giulia, and the peninsular part of Apulia (Figure 2F), between which however there are differences in terms of population density and spatial continuity of settlement system.

In addition to these, there are further settlement dynamics typical of low-density contexts, which happen as part of the "sprinkling" process [45], characterized by spontaneous urban development and featured by a building density of about 0.1 building/ha and concerning also inner areas where processes of depopulation, marginalization and land abandonment have been occurring for several years [22,46]. Due to its geometric/spatial characteristics, which cannot be captured by the CLC's minimum mapping units, this phenomenon is currently underestimated at the European level [47].

Considering that urban growth processes in Italy occurred as described by Romano et al. [46,48,49], we highlight that they are still ongoing, and we also point out the lack of both an adequate monitoring system and an effective interpretative framework of the effects that these transformations exert on environmental and territorial components.

Several studies [50–53] proposed a critical review of the Italian planning system, underlining the delay in upgrading its regulatory framework in order to be effective in the governance of territorial processes and able to cope with the emerging social, technological and environmental demands related to territorial transformations.

The inefficiency of the Italian planning system in governing and monitoring these urbanization processes [50,54] resulted in a distribution of the settlement system and infrastructure network that entails considerable social and environmental costs [36], and is difficult to manage, especially with a view to achieving zero net land take by 2050 [55]. In a nutshell, this is the European Commission's ambitious objective to propose an approach to the issue of soil consumption that goes beyond the limitation of entrusting monitoring of such processes to a single variable of increase in artificial surfaces. Focusing on how natural resources could be efficiently used to provide ES for next generations, it published guidelines for limiting, mitigating and compensating for soil sealing.

The recommended reference framework to apply to territorial transformations and land use changes is based on the impact mitigation hierarchy [56]: negative impacts on ES and biodiversity should be avoided as far as possible; the effects that cannot be completely avoided should be minimized by jointly considering their duration, intensity and extent. Ecosystems subject to impacts that cannot be avoided and/or minimized should be restored with actions aimed at recovering their structure, composition or function. Finally, residual impacts should be addressed through appropriate compensation mechanisms.

In this perspective, our work proposes an analytical framework based on ES multifunctionality indices aimed at interpreting urbanization and the land use change dynamics described above in terms of the spread and intensification of threats to natural ecosystems [57] and the subsequent depletion of ES and decrease in ES multifunctionality [58].

3. Methodology

The proposed methodology is aimed at evaluating the effects of the spatial distribution of urbanization and land use change processes that occurred in the period 2000–2018 in terms of ES multifunctionality.

Following the methodological flowchart represented in Figure 3, the first step was the selection of ES most relevant for the case study and the work scale (summarized in Table 1), and their subsequent assessment for the whole Italian territory.

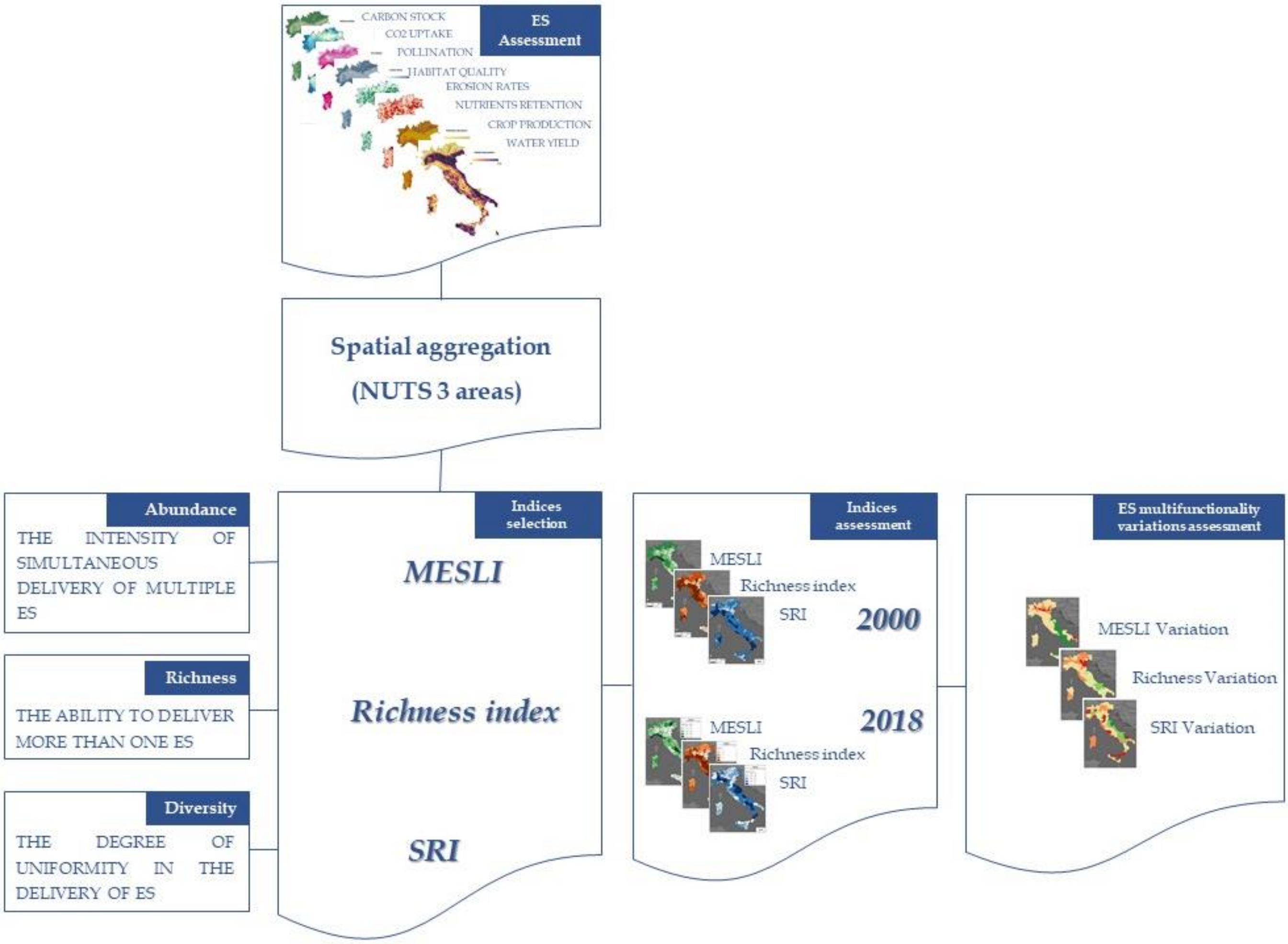

Figure 3. Methodological flow chart: from the national scale assessment of ES, indices of abundance, richness and diversity were obtained with reference to two years (2000 and 2018). Their variation was then calculated for each territorial unit (NUTS 3 areas).

Table 1. Indicators, methods and units used to quantify different ES.

Class *	Indicators	Methods	Unit
Regulation of chemical composition of atmosphere	Carbon stock	InVEST	Tons/Ha
	CO_2 Uptake	Eq. by Clark	g/m^2/year
Pollination	Pollination Abundance	InVEST	Index **
Maintaining nursery populations and habitats	Habitat Quality	InVEST	Index **
Control of erosion rates	Erosion Rates	InVEST	Tons/Ha
Regulation of the chemical condition of freshwaters	Effective nutrients retention	InVEST	Index **
Cultivated terrestrial plants grown for nutritional purposes	Crop production	InVEST	q/Ha
Ground (and subsurface) water for drinking	Water Yield	Eq. by Budyko	mm/year/Ha

* according to CICES v.5.1 [59]; ** dimensionless.

Their assessment is essentially based on CLC land use maps and additional information layers necessary for the implementation of each of the specific models belonging to the InVEST suite. Details of input data and models used are described in previous works [1,2].

To trace a trend of ES multifunctionality in recent decades, all the ES were assessed and mapped for the years 2000 and 2018.

The next step was the spatial aggregation of results obtained by considering the provinces as territorial units. To this end, we considered the average value of data distribution relative to the specific province.

Extending the conceptualization by Holting et al. [32], we defined the three dimensions of multifunctionality (abundance, richness and diversity), and for each of them, we selected an index.

Abundance is a measure of the intensity of simultaneous supply of multiple ES. Some work assesses abundance by considering the average (for example [60]) or summed values of ES (for example [61]) after appropriately normalizing them. In both cases, there are opportunities for misinterpretation: while the average is insensitive to the number of ES considered, the sum is very sensitive to it. In addition, the balance in the provision of different ES is not captured by these indicators, and they may be inflated by the increased provision of only some ES. To address these issues, some authors (for example [62]) use thresholds to limit the number of ES considered to only those whose intensity exceeds a threshold. The limitation of this approach, however, lies in the discretion with which to define the threshold value.

We assumed the Multiple Ecosystem Services Landscape Index (MESLI) [23] as relevant to ES abundance. Being suitable for different work scales [63], it is considered effective in providing a comprehensive overview of environmental performances [27].

It can be considered as the ability of different ecosystems to supply multiple services simultaneously [64], and it is equal to (1):

$$\text{MESLI} = \sum_{i=1}^{n} \frac{\text{Observed value}_i - \text{Low performance benchmark}_i}{\text{Target} - \text{Low performance benchmark}_i} \quad (1)$$

For ES providing a positive contribution to the territorial performance.

Benchmarks for low and high performance can be defined by biological thresholds, expert judgement in light of ecosystem ecology, or even policy objectives. In the absence of clearly defined thresholds, these values can be set on the basis of minimum and maximum observed values in a time series.

In this work, all ES were assessed for the whole country for each CLC date in the period 2000–2018 (i.e., 2000, 2006, 2012, 2018). The minimum and maximum threshold values were assumed to be equal to the minimum and maximum values of the resulting time series.

Richness constitutes the ability of an ecosystem to simultaneously deliver more than one ES [65], and it is usually computed as the number of ES delivered in the territorial unit [66]. In order to consider the intensity with which each province (NUTS3 areas) contributes to the national multifunctionality, we defined a threshold value and decided to include in the richness index only the number of ES exceeding the first quartile of the national data distribution, according to the following formula:

$$\text{Richness} = \sum_{0}^{N} i : n_{ij} \geq Q_1(n_i)$$

where i is the number of ES ranging from 0 to N, n_{ij} is the intensity of the i-th ES at the location j and $Q_1(n_i)$ is the first quartile of the entire national data distribution for that i-th ES.

In this work, the richness index allows the identification of those territorial units which, by delivering several ES simultaneously and with an intensity equal to the value of the first quartile with respect to the whole national context, constitute the main pillars of multifunctionality in Italy.

The third ES multifunctionality dimension is constituted by diversity, which blends the two concepts of richness and abundance by considering the intensity of the delivery of each ES in proportion to the total supply [24]. It, therefore, provides information on the evenness of provision across several ES (higher values) or the dominance of a specific ES over others (lower values). We used the Simpson's reciprocal index (SRI) [67], recognized as useful to evaluate whether ES are equally supplied or whether a few dominant ones are delivered [29].

Considering N as the total number of ES supplied and n_{ij} the intensity of the i-th ES at the location j, the SRI is calculated as:

$$\text{SRI} = \frac{1}{\sum \left(\frac{n_{ij}}{N} \right)^2} \tag{2}$$

This index, originally formulated as a measure of biodiversity (i.e., species diversity), has recently found useful applications within the ES methodological framework [29]. As highlighted by Raudsepp-Hearne et al. [68], a high diversity value occurs where the trade-offs between ES are smaller and the territorial performance in terms of ES delivered is such that it satisfies a greater diversity of human demands, contributing overall to greater system resilience [69].

4. Results

Comparing the three ES multifunctionality indices reinforces the analysis of the relationships between the anthropic components of territorial systems and the capacity of ecosystems to provide multiple ES. As can be seen in Figure 4, the overall spatial distribution of MESLI does not change significantly. In both years considered, in fact, the distribution of the abundance index highlights the importance of areas located along the Apennine Chain and the Alps characterized by wide wooded areas. Areas corresponding to the lowest values, coinciding with the Po Valley and central-southern part of the Apulia Region, increase in extension during the period considered. The processes of urbanization and changes in land use have therefore contributed to increasing the depletion of natural resources and the decrease in ES.

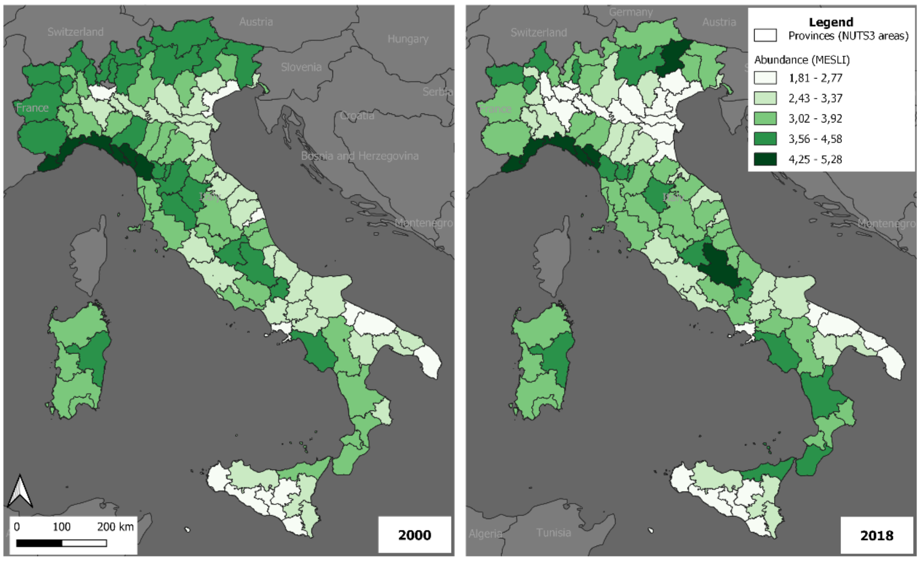

Figure 4. Comparison between the Abundance Index (MESLI) in 2000 and 2018.

The territorial performance, while remaining in the lower range, does not further decline in the Province of Naples and Southern Sicily.

The richness index (Figure 5) confirms what was found in the observation of the MESLI spatial distribution, highlighting in an even more marked way the contribution of ES in the central Apennines. The "backbone" of the Alpine and Apennine Chains is therefore confirmed as an area of priority interest for maintaining the multifunctionality of the entire national territory. In this respect, in 2018, it shows an enhancement of its spatial continuity, with increasing values in the central-southern part of the Apennines. This is probably linked to the phenomenon of agriculture abandonment, which is widespread in inner areas, and the consequent process of renaturalization of agricultural areas.

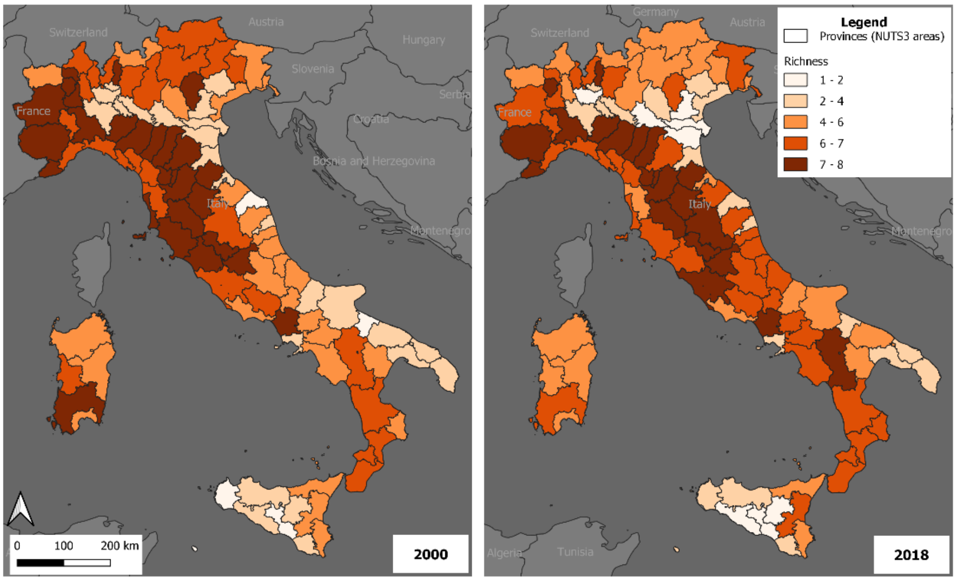

Figure 5. Comparison between the Richness Index in 2000 and 2018.

The Simpson's index (Figure 6) illustrates diversity as a measure of the balance between the different ES provided: where it assumes the lowest values, a small number of ES prevail over the total supply; where it assumes high values, the level of supply among ES is evenly distributed. This, in the Italian context, occurs in correspondence with the most densely populated provinces or the main metropolitan areas and in areas where there is a marked presence of intensive agricultural systems. Here, in fact, the contribution of ES relating to agricultural productivity and control of erosive processes is markedly dominant.

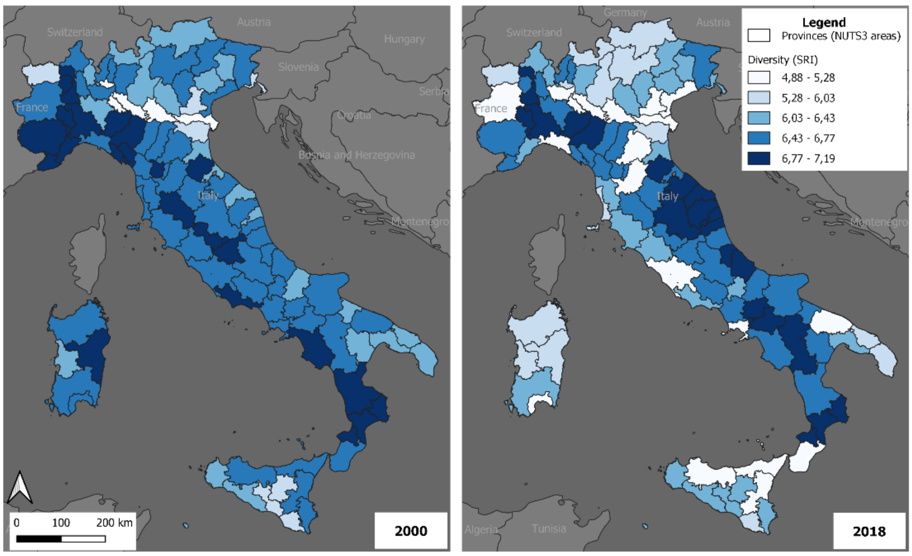

Figure 6. Comparison between the Diversity Index (SRI) in 2000 and 2018.

Again, areas along the Po Valley where the lowest values are found in 2018 are larger than in 2000.

Rather than land use conversion, this index shows that it is more influenced by urbanization and land consumption. Its spatial distribution, in fact, changes heterogeneously along the peninsula, decreasing in correspondence with metropolitan areas.

Processes linked to land use changes and urbanization occurred in the time period between 2000 and 2018 have sharpened existing differences in the spatial distribution of ES multifunctionality. Figure 7 shows in fact that both abundance and richness increased along the Apennine areas of central and southern Italy. The Po Valley is instead characterized by a decrease in both abundance and richness, thus widening the existing ES supply gap between the most industrialized territories and the inner areas of the Apennine Chain. On the other side, the diversity index's spatial distribution changed in a more heterogeneous way, decreasing with greater intensity in correspondence with the metropolitan areas.

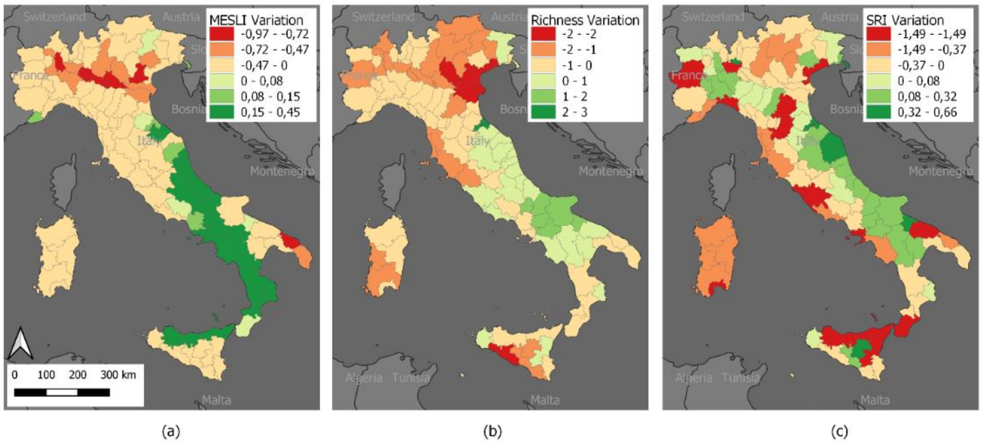

Figure 7. Variations in the three dimensions of ES Multifunctionality over the period 2000–2018: (**a**) Abundance (MESLI); (**b**) Richness; (**c**) Diversity (Simpson's reciprocal index).

The differences between maps shown in Figure 7 also underline the extent to which the choice of ES multifunctionality index affects the interpretation of results in terms of comparing the environmental performance of different territorial units.

In order to deepen the interpretation of the distribution of indices and of their variations over time, we considered it useful to report some illustrative cases that jointly show the indices' trends with respect to the variations undergone in the same time interval.

Figure 8A refers to the Province of Naples. In this case, there is a discrepancy between the increase in MESLI and the decrease in diversity. In fact, the increment in CO_2 uptake and Habitat Quality lead to an 11.7% increase in the abundance index (from 2.23 to 2.49), even if the other six ES indicators decrease. However, these increases do not imply a change in richness, which remains stable at 3.

The second case refers (Figure 8B) to the Province of Rome, one of the largest metropolitan cities in Italy. Compared to the national context, the abundance index is in the lower-middle class in both years considered, with a slight decrease in value (−0.6%) even though the richness index increased. Thus, although the intensity of most of ES decreased, the values in 2018 are such that they exceed the first quartile of the national data distribution. Diversity also decreases as the predominance of two ES increases with respect to the distribution of supply values.

The Province of L'Aquila (Figure 8C) is reported to be representative of a typically Apennine context characterized by a high degree of naturalness and a settlement system that does not compromise the ES multifunctionality. For all three indices, it falls between the medium and high classes, with an upward trend over the period. The largest contributions come from increases in CO_2 uptake, habitat quality and nutrients' retention capacity, which induce an increase in homogeneity between ES supply with a consequent increase in SRI (from 6.44 to 6.49).

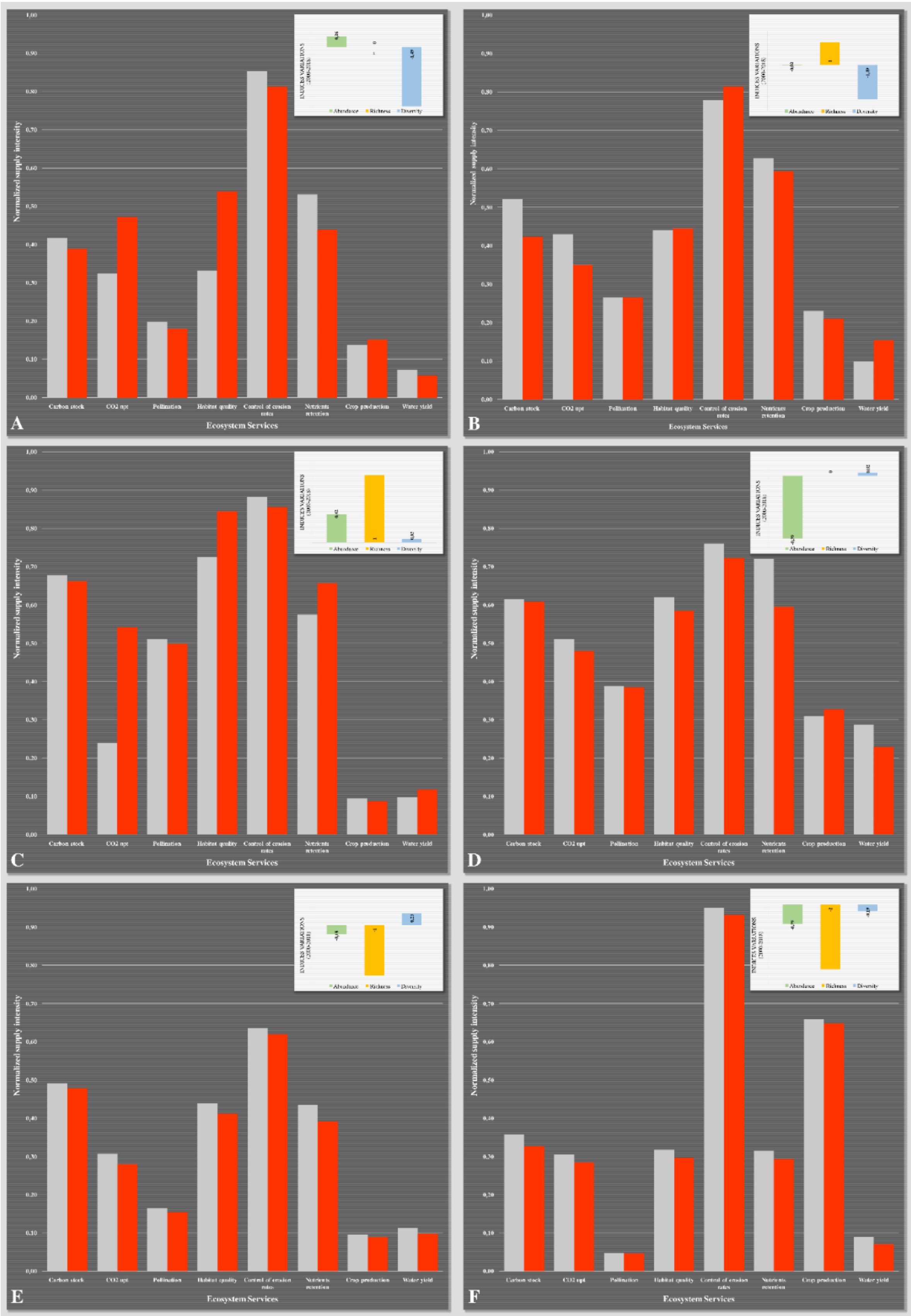

Figure 8. Variation in ES and consequent changes in ES multifunctionality indices for the Provinces of (**A**) Naples, (**B**) Rome, (**C**) L'Aquila, (**D**) Parma, (**E**) Caltanissetta and (**F**) Rovigo.

This situation is similar to that observed in the Province of Parma (Figure 8D), which, while seeing a decrease in the MESLI index (from 4.06 to 3.67) due to slight variations in several ES, shows high values of ES multifunctionality both in terms of richness and diversity. Indeed, the graph shows that in 2018 the intensity of provision among several ES is more homogeneous than in 2000.

Finally, the last two cases refer to territorial units that do not perform well in terms of ES multifunctionality: the Provinces of Caltanissetta (Figure 8E) and Rovigo.

The former, located in the southern part of the Region of Sicily, shows a decreasing trend in both abundance (from 2.53 to 2.35) and richness (from 2 to 1). On the other hand, the diversity index increases (from 5.86 to 6.09) as the distribution of intensity values tends to flatten out.

The Province of Rovigo (Figure 8F), on the other hand, is representative of the Po Valley area, which expresses low values of multifunctionality regardless of the index considered, and for all three indexes a decreasing trend over time. Both abundance and richness decrease to the lowest class. The diversity value, while diminishing, ranks the area in the lowest range as early as 2000. As can be seen from the graph, values for ES delivery intensity are low and tend to decrease over the time period. The low value of the SRI index is, in fact, justified by the prevalence of ES "Control erosion rates" to which the flat territorial morphology contributes significantly, and "Crop production".

5. Conclusions

Multi-functionality assessment is an innovative and integrated approach to interpreting different land use patterns and analyzing land use changes in relation to multiple components of human well-being [23,69]. The analysis of the spatial distribution of ES multifunctionality, including its different facets, is effective in supporting the understanding of how local policies or territorial transformations might affect the overall ES provision and the consequent capacity of ecosystems to meet several human needs.

In this work, we propose an analytical framework based on three different dimensions of ES multifunctionality: abundance, richness and diversity.

Results show that the same territorial transformations affect differently aspects related to provision intensity, the ability to contribute to overall multifunctionality ES and the degree of uniformity between the delivery of different ES.

In particular, MESLI assumes high values both if multiple ES are delivered with low intensity and if few ES are delivered with high intensity. It can therefore be considered as a tool for comparing overall environmental performance, but it does not provide a univocal interpretation of the characteristics of the human–nature system that affect the ES multifunctionality of that specific territorial unit. Its variations also seem to provide a localized picture of ES multifunctionality capable of expressing a trend over time.

The index chosen for richness and its mean depend on threshold definitions to determine ES effectiveness in contributing to national multifunctionality. The threshold assumed in this work, equal to the I quartile of national distribution, gives results suitable for identifying territorial units that show greater criticality (e.g., Caltanissetta). On the other hand, it affects consistency with the index of abundance: its value is, in fact, variable both where MESLI is high (e.g., L'Aquila) and where it is low (e.g., Rome).

The interpretation of the diversity index, which some authors identify as the most significant dimension of multifunctionality [24], is sufficiently variable to distinguish areas where ES provision is more uniform from those where the occurrence of trade-offs means that a small number of ES markedly prevail over others. While, in fact, high diversity can be considered an indicator of regulating ES provision [68], the second situation occurs where there arises what Shen [64] calls "the food–environment dilemma", that is the prevalence of agricultural productivity under intensive practices that conflict with the maintenance of biodiversity and the provision of additional ES (e.g., Rovigo).

Our findings confirm the relevance of the proposed approach in interpreting the impacts of complex transformation dynamics on ES delivery and in identifying strategies to maximize synergies and minimize losses. In the literature, however, there is no unambiguous definition of multifunctionality and there is also a lack of agreement on which ES territorial components should express in order to be considered "multifunctional" [63].

This thus also constitutes a limitation of this work, which is subject to the authors' discretion in the choice of ES to be considered in the assessment of ES multifunctionality.

This represents a research question and a perspective towards orienting further developments. For the planning discipline, in fact, the multifunctionality approach is useful to the extent that it helps to provide support for formulating policies and actions aimed at meeting as many human needs and demands as possible [68].

Author Contributions: Conceptualization, A.P. and F.S.; methodology, A.P.; software, A.P.; validation, A.P. and F.S.; formal analysis, A.P.; investigation, A.P.; resources, A.P.; data curation, A.P.; writing—original draft preparation, A.P.; writing—review and editing, A.P. and F.S.; visualization, A.P.; supervision, F.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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