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ASSESSMENT OF ECOLOGICAL CAPACITY FOR URBAN PLANNING AND IMPROVING RESILIENCE IN THE EUROPEAN FRAMEWORK: AN APPROACH BASED ON THE SPANISH CASE

RAFAEL CÓRDOBA HERNÁNDEZ[1]*, FEDERICO CAMERIN[2]

[1] *Departamento de Urbanística y Ordenación del Territorio, Escuela Técnica Superior de Arquitectura, Universidad Politécnica de Madrid, Spain.*

[2] *Departamento de Urbanismo y Representación de la Arquitectura, Escuela Técnica Superior de Arquitectura, Universidad de Valladolid, Spain.*

ABSTRACT: The basic idea underlying this research is that urban planning is one of the main causes of environmental degradation. Despite its relevance in impacting ecosystems, the current methodological assessments across Europe still fail to include spatial planning as a relevant factor. This paper aims to formulate an innovative methodology for the evaluation of ecosystems for protecting land at risk of degradation. This methodology is exemplified by the case of Spanish spatial planning applied in the Community of Madrid, being also capable to be employed in other European State Members after a cartographic adaptation. The proposed methodology specifically implements a European approach to the scale of regional and local spatial planning based on the "Mapping and Assessment of Ecosystems and their Services" (MAES) project. Among the main results, four outcomes stand out. The first is the novelty to provide a methodology capable of dealing with natural values at regional and municipal levels based on a spatial-planning-based scale (1:20,000). The second result regards the incorporation of new attributes tied to existing ecosystems during the drafting of spatial plans, thus improving the quality of the information to make better decisions in terms of environmental protection. The third result is the more accurate environment assessment due to the inclusion of a new element of direct pressure on ecosystems, while the fourth outcome is that the proposed methodology detects the impacts of the drivers of change in the Community of Madrid. Although the cartographic information is defined at the regional scale, the results obtained can be linked to the municipal planning scale. The proposed methodology can be a much more useful tool for regional spatial planning for three main reasons: it works at the same scale as regional planning (1:20,000), it incorporates the environmental information necessary for the correct identification of natural values and impacts at the municipal level, and it works with geographic information systems. These reasons allow an easier and quicker incorporation of ecosystems in spatial planning tools by simultaneously interpreting and comparing different land protection issues such as ecosystem loss and ecosystem services.

Evaluación de la capacidad ecológica para la planificación urbana y la mejora de la resiliencia en el contexto europeo: un enfoque basado en el caso español

RESUMEN: La principal idea que subyace en esta investigación es que la panificación urbana es una de las principales causas de la degradación medioambiental. Sin embargo, pese a la importancia de su impacto en el medio natural y en los ecosistemas, las evaluaciones metodológicas actuales en toda Europa siguen sin incluir la ordenación del territorio como un factor relevante. Por ello, el documento pretende formular una metodología innovadora de evaluación de los ecosistemas para la protección del territorio en riesgo de degradación. Esta metodología se ejemplifica con el caso de la planificación territorial española aplicada en el caso concreto de la Comunidad de Madrid, siendo también susceptible de ser empleada en otros Estados Miembros europeos tras una adaptación cartográfica. En concreto, la metodología propuesta implementa un enfoque europeo a escala de planificación territorial regional y local basado en el proyecto "Mapping and Assessment of Ecosystems and their Services" (MAES). Entre los principales resultados ligados a esta propuesta, cabe destacar cuatro resultados. El primero es la novedad en el tratamiento de los valores naturales a escala regional y municipal a partir de una escala basada en la planificación urbana y territorial (1:20.000). Como segunda cuestión destaca la incorporación de nuevos atributos ligados a los ecosistemas existentes en la elaboración de los planes de ordenación del territorio, mejorando así la calidad de la información para tomar mejores decisiones en materia de protección del medio ambiente por el planificador. El tercer resultado es una evaluación más precisa del medio ambiente debido a la inclusión del concepto de presión directa sobre los ecosistemas, mientras que la cuarta consecuencia sería que la metodología propuesta detecta los impactos de los motores del cambio en la Comunidad de Madrid. Además, aunque la información cartográfica viene definida a escala regional, los resultados obtenidos pueden vincularse a la escala de planificación municipal. La metodología propuesta puede ser una herramienta mucho más útil para la ordenación del territorio municipal por tres razones principales: trabaja a la misma escala que el planeamiento general (1:20.000), incorpora la información ambiental necesaria para la correcta identificación de los valores e impactos naturales a escala municipal, y trabaja con sistemas de información geográfica. Estas razones permiten abordar con mayor facilidad y rapidez la inclusión de los ecosistemas en la formalización de la ordenación del territorio, interpretando y comparando simultáneamente diferentes aspectos de la protección del territorio como la pérdida de ecosistemas y los servicios ecosistémicos.

Keywords: Sustainable development, Ecosystem Services, environmental impact, regional planning, resilience.

Palabras clave: Desarrollo sostenible, ecosistema, impacto ambiental, planeamiento territorial, resiliencia.

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*** Corresponding author:** Rafael Córdoba Hernández, Departamento de Urbanística y Ordenación del Territorio, Escuela Técnica Superior de Arquitectura, Universidad Politécnica de Madrid, Spain. E-mail address: rafael.cordoba@upm.es

1. Introduction

The increasing pace of massive global urbanization is generating a variety of socio-environmental pressures and impacts that are clearly going beyond the physical boundaries of cities and are consequently having negative impacts even beyond their administrative boundaries. These dynamics include changes in land-use and land-cover (Baveye *et al.*, 2016; Keesstra *et al.*, 2016), which affect ecosystem functions and services, such as water regulation and retention (Stürck *et al.*, 2014), climate regulation (Ghaley *et al.*, 2014), and biomass production (Larondelle and Haase, 2012). Whereas the importance of ecosystems and the associated benefits are attested by the European Union (EU), national, and regional policies and the different tools for their assessment and mapping, the integration of environmental aspects into spatial planning is a major challenge for planners (Hurlimann and March, 2012).

As advocated by the United Nations (United Nations Habitat, 2015), the integration of ecosystem service (ES) knowledge into spatial and land-use planning – especially if promoted from the early stages of the planning processes – could support decision-making in formulating more sustainable economic, social, cultural, and environmental goals and decisions (Longato *et al.*, 2021). The integration of ES assessment and monitoring tools in spatial planning processes could help to address the serious issues affecting our territories such as sprawling urbanization (Córdoba Hernández, 2021; Maruna *et al.*, 2019; Ronchi *et al*., 2019; Thoidou, 2021) or flood risks (McGranahan *et al*., 2007) by promoting policies and actions aimed at protecting, enhancing, and restoring ecosystems.

Scholars have identified the following main benefits of integrating ES knowledge into spatial planning management processes: i) a broader inclusion of relevant issues to address during the management process (Masoudi *et al*., 2023; Veidemane *et al*., 2017), ii) a synthesizing perspective to interpret multiple data and information (Arkema *et al*., 2015; Verutes *et al*., 2017), and iii) effective stakeholder involvement with a higher degree of participation (Adem Esmail and Geneletti, 2017; Spyra *et al*., 2019). Overall, these benefits can make a contribution to legitimate decisions on more sustainable spatial allocation of uses and management options (Longato *et al*., 2021).

1.1. The role of ecosystem preservation in territorial resilience

The starting point of this research is the concept of 'territorial resilience', that is, the capacity of positive adaptation shown by some cities or regions to face crises stemming from external events or processes and to emerge stronger after a process of internal transformation (Méndez, 2012). As highlighted by Hamilton (2009) and Pickett *et al*. (2004), this definition shows the contradictions and complexity of the urban and territorial land system. A good quality of biological, physical, and chemical characteristics of ecosystems is fundamental to mitigate shocks and increase resilience. These three factors are the pillars of the capacity of the ecosystems to generate ES. However, these qualities are often under threat from a variety of sources.

The Millennium Ecosystem Assessment (2003) identified five main pressures on ecosystems: land cover change; climate change; overexploitation of resources (e.g., through irrigation and harvesting); the introduction of alien invasive species; and the use of fertilizers, and air and water pollution. These processes affect the integrity of ecosystems and, consequently, disrupt their contributions to society and the environment (Büttner *et al*., 2017; Kramer and Verkaar, 1998), contributing thus to a decrease in territorial resilience.

The frequency of events that put pressure on ecosystems can have low or high impacts on them. Low-impact events are integrated into ecosystems, e.g., through interactions between natural hazards and ecosystem characteristics, leaving existing biodiversity and ES functioning largely intact. However, when these changes are more significant, such as those associated with climate change, an ecosystem may lose its capacity to recover and may even disappear, favoring the substitution with a new ecosystem. Fragmentation is also a significant factor affecting the vulnerability of ecosystems: a small disturbance may have the same or even a greater impact on fragmented ecosystems than a larger disturbance on well-connected ecosystems (Urban *et al*., 1987).

Therefore, the design and implementation of biodiversity strategies and action plans, and the use of evidence-based planning tools to design networks of protected areas, ecosystem connectivity and biodiversity conservation are fundamental tasks for achieving an integrated ecosystem management. Fulfilling these tasks would increase the resilience of cities and territories in dealing with climate change, natural disasters, and disturbances.

Reducing or at least not increasing the existing vulnerability of the ecosystems and the environment in general is a primary goal of various ES assessment frameworks such as 'TEEB - The Economics of Ecosystems and Biodiversity' (Kumar, 2012) or 'CICES – Common International Classification of Ecosystem Services' (United Nations, 2017). These assessment frameworks sometimes lack providing arguments to promote land conservation against urban development. Ecosystem assessment, in turn, can lead to the identification of the most important ecosystem goods and services and thus to appropriate land-use regulations.

International scholars recognize that mapping these issues makes it possible to reflect on how spatial planning and land-use management can incorporate and integrate these aspects into practical experience (Burkhard and Maes, 2017; Verhagen *et al*., 2015). However, these frameworks fall short without a regulatory framework that should help technicians evaluate land protection and conservation. The Spanish legislation has begun to address this issue with the approval of the Law 7/2021 on Climate Change and Energy Transition. This Law integrates the existing Law 7/2015 on Land-Use and Urban Regeneration – "Ley de Suelo y Rehabilitación Urbana" in Spanish – by establishing that climate change-related risks must be taken into account in land-use planning, in particular the "risks associated with the loss of ecosystems and biodiversity and the deterioration or loss of essential ecosystem goods, functions, and services" (Jefatura del Estado, 2021a, Disposición final cuarta).

1.2. The contextualization of the ecosystems preservation in the Spanish and EU policy system

At the European level, the loss of ecosystems and their goods and services has been recognized by the "EU 2030 Strategy on Biodiversity"(European Commission, 2020). This strategy aims to halt biodiversity loss and degradation of ES and to restore them as far as possible, being closely related to the European Environment Agency's (EEA) recommendation to integrate the results of the ES assessment into spatial planning. This recommendation is essential as it can identify areas with high and very high capacity to provide ES (European Environment Agency, 2014).

In line with the EU strategy and recommendation, the Spanish government approved the "National Strategy for Green Infrastructure and Ecological Connectivity and Restoration" in 2021. This document establishes the future provision of a specific cartographic planning-support tool that will allow the spatially explicit mapping of national ecosystems based on elements defined as "green infrastructure" (Jefatura del Estado, 2021b). These elements refer to the list provided by the Law 33/2015 on Natural Heritage and Biodiversity (Article 15.3): "Protected areas; endangered habitats and species; mountain areas; river courses; wetlands; livestock trails; ocean currents; submarine canyons; migratory routes that facilitate connectivity; systems of high natural value created as a result of good practices applied by different economic sectors; priority habitats to be restored; areas affected by nature conservation banks; and the instruments used by administrations in the application of the European Landscape Convention signed in Florence on 20 October 2000" (Jefatura del Estado, 2015). The release of this new tool is expected in three years after the approval of the Law 7/2021, i.e., in 2024.

One year before, the EU Biodiversity Strategy to 2020 proposed to the Member States to develop a mapping and assessment of ecosystems and their services. To do so, an EU-wide ecosystem assessment has been introduced to provide harmonized information on the state of ecosystems and biodiversity, and their capacity to provide ES. The European Commission supports Member States by providing useful data and guidelines for the mapping (e.g., a report with a list of possible indicators to assess and map ES), along with the release of new and updated data (e.g., through the Copernicus service portfolios and the habitat classification of the European Nature Information System EUNIS). This work formed the basis for the mapping and assessment of ecosystems and their services at EU level following the MAES (Mapping and Assessment of Ecosystems and their Services) analytical framework (European Environment Agency, 2018).

The European Commission is developing MAES to identify ecosystems in collaboration with many entities, such as the Member States and the EEA based on thematic pilot projects focusing on nature, agriculture, forests, freshwater, marine, and urban and terrestrial ecosystems. The first reports resulting from MAES consist of an analytical framework that provides common typologies of European ecosystems to be mapped and a typology of ES to be considered (Maes *et al*., 2013). This typological classification takes into account regular cartographic aspects by using data from the CORINE Land Cover (CLC) project for its design, and allows the comparison of different sectors of the European territory and the maintenance of a pan-European scale (Büttner *et al*., 2021; Heymann *et al*., 1994).

Recognizing what services – and to what extent –the ecosystems of a territory provide to society requires an understanding of the number of ecosystems in a given territory that are affected by spatial planning. This information can be obtained through an updated map of vegetation or habitat, with a resolution appropriate to the scale of the spatial plan (regional or municipal).

The quality requirements for cartography are limited by the availability of resources and the risk of decisions based on them. On the one hand, the upper limit of the requirements is set by the philosophical-logical principle known as Ockham's razor – i.e., of two competing theories, the simpler explanation of an entity is to be preferred. This approach emphasizes the need to use as few resources as possible to solve a problem. The methodology proposed by this paper does not require a new cartography, but starts from an existing one that has the necessary standard for this purpose. On the other hand, the lower limit of the requirements is determined by the social impact of map-based decisions. Uncertainty or lack of social impact can lead to a social risk of adverse outcomes if decisions are based on incorrect data.

The Driver-Pressure-State-Impact-Response (DPSIR) framework used by the proposed methodology stems from DPSIR's first report. DPSIR is a theoretical framework used to systematically classify the information needed to analyse environmental problems and to identify actions to solve them. (Turner *et al*., 2010) Drivers of change (D) exert pressures (P) on the state of ecosystems (S) at any given time, affecting habitats and biodiversity (I) across Europe at all combinations of intensities and, consequently, affecting the number of services they can provide. If these impacts are not eliminated, policy makers should implement appropriate responses (R) by taking measures to address the negative impacts. These drivers are referred as pressures to adapt the terminology to the DPSIR framework applicable to European policy framework.

1.3. Goals and hypothesis

This work aims to propose a methodological assessment for ecosystems and their services that can be used to support spatial planning at the regional level. The specific objectives are: i) to propose a high-resolution mapping method to assess and map ecosystems and their services, as well as their vulnerability to degradation or loss of essential ecosystem goods, functions, and services at the local level; and ii) to analyze/compare the extent to which the results of the assessment are or not aligned with current regulations establishing ecosystem protection regimes, and how they can support the development of better protection regulations.

The research hypothesis is that the European Ecosystem Assessment Methodology provides important keys to understand the main stressors acting on ecosystems but, by not considering spatial planning, it neglects one of the main causes of environmental degradation. The methodology aims to overcome this situation by making a comparison between the protection derived from spatial planning and the ecosystems.

2. Methods and materials

The European Environment Agency's (EEA) methodology still does not consider spatial planning as a complementary tool capable to address the pressures on ecosystems and their services, although EEA claims that spatial planning can support policy decisions for the environmental conservation and protection (European Environment Agency, 2015b, 2015a). Implementing the methodology and integrating spatial planning into the Strategic Environmental Assessment (SEA) requires working at a scale where spatial planning and SEA can work together and with accessible information. Although this task is quite complex at the European or national level, the regional land legislation in Spain – the case study choses is the Community of Madrid – may be the appropriate level to implement the methodology.

To achieve the aforementioned objectives, the proposed methodology is based on four levels of work – or steps. Thus, Steps 1 and 2 are performed to obtain a high-resolution cartographic method for assessing and mapping ecosystems and their services, as well as their vulnerability to degradation or loss of essential ecosystem goods, functions, and services at the local scale (Fig. 1 left):

- **Step 1. Homologation of the initial information with the necessary scale adaptation**. For this purpose, the case study uses the information available from the Spanish National Geographic Institute (IGN) and the Madrid Spatial Data Infrastructure Server (IDEE-Madrid). Both IGN and IDEE-Madrid provide open information that can be processed using Geographic Information Systems (GIS) applications.
- **Step 2. Identification of the main direct drivers of change**. Once the main ecosystems have been detected using the European Nature Information System (EUNIS), they are grouped for characterization according to the main impacts identified by the Millennium Ecosystem Assessment. This step is performed through the Mapping and Assessment of Ecosystems and their Services (MAES), which identifies the impacts of habitat change, climate change, overexploitation of resources, introduction of invasive species, and pollution and nutrient enrichment.

Steps 3 and 4 are devoted to analyze/compare the extent to which the results of the assessment do or do not match existing spatial planning regulations and how they can support the development of better protection regulations (Fig. 1 right):

- **Step 3. Identification, assessment, and relevance of ecosystem services**. Based on the general classification of ecosystem inputs used by the Common International Classification of Ecosystem Services (CICES), the main ecosystems identified are characterized according to the MAES grouping. A total of 5 provisioning, 13 regulating, and 7 cultural ESs are identified. These ESs are valued independently and considering the interactions between each of the inputs to obtain a more complex qualification of these inputs.
- **Step 4. Introduction of spatial planning as a factor in the ecosystem assessment**. Once the plan for the provision of services has been drawn up, it is possible to compare it with the existing land-use plan or to identify the areas that could suffer a major ecosystem transformation as a result of the land-use plan proposals. Based on the previous considerations, there is the need to distinguish transformations associated with the loss of ecosystems and those related to biodiversity loss. This distinction is performed by considering the direct drivers of change associated with the degradation or loss of essential ecosystem goods, functions, and services, as described below. This comparison requires to overlay and/or cross-reference the studies carried out in the four steps with the land-use plan.

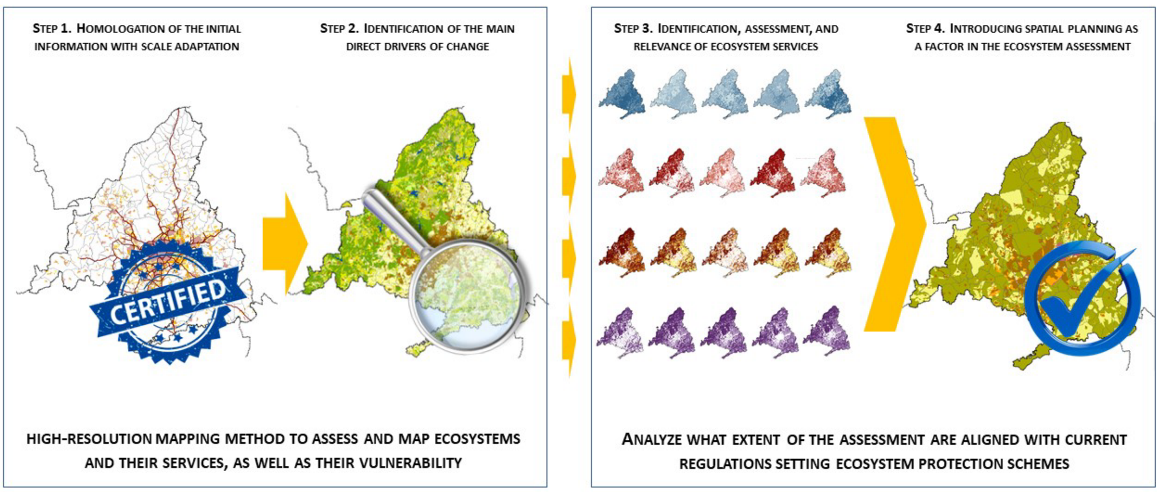

Figure 1. Diagram of the main research phases and objectives.

The implementation of this methodology, especially between steps 2 and 4, relies on the increasing use of remote sensing tools and Geographic Information Systems (GIS), together with the improved accessibility of satellite images and open classification methods from multiple sources. The cartographic management carried out on the different thematic aspects has been essential for their analysis, evaluation, and presentation. Free access to land use information was performed on the basis of the European Inspire Directive. The latter establishes the general guidelines for the proper functioning and service of the European Community's spatial information infrastructure and makes the information provided by the different Member States compatible. The use of regional sources is necessary to cross-reference the results of the assessment of the direct drivers of change and the loss of ecosystem services to modify the existing spatial planning tools.

The main functions performed by GIS enable to detect the different issues either by assessing the different ecosystems according to MAES's conceptual framework for assessment (Step 2) or by the SEEA Ecosystem Accounting assessment (Step 3). A series of maps are then used to create new thematic maps as developed in sections 2.2 and 2.3. These new maps are then processed to derive hazard zones which are overlaid on the spatial planning information to identify areas where specific problems overlap and to define the risks in these areas.

2.1. Step 1. Homologation of the initial information with the necessary scale adaptation

As suggested by MAES framework, the mapping and assessment of ecosystems and their services proposed in this study is mainly based on land cover data (i.e., CLC data). CLC-based maps can be produced repeatedly by the territorial administration at relatively low cost in terms of time and money, being sufficiently suitable for most purposes and with a higher level of detail than necessary. However, maps with more reliable data (e.g., at a scale greater than 1:20,000) can be produced at excessive cost or with complex assumptions. Depending on the time required to produce them, maps would not be commensurate with the urgency of the objective. Therefore, the proposed mapping method is in line with the MAES method promoted at the European level, mainly by refining it and adapting it to the scope and scale of the work.

The CLC data supporting ecosystem assessment in spatial planning can be summarized in the following five conflicts, which the proposed mapping method aims to overcome:

- Reference scale. Due to its European dimension, the CLC provides consistent land and land use and land cover information at a detailed scale (1:100,000), which is however not accurate for a more regional scale (Fig. 2). This element creates a conflict with the Royal Decree 2159/1978 on "Planning Regulations for the development and application of the Law on Land Regime and Spatial Planning". This Decree only establishes the minimum scales at which "urban land" and "land for development" must be represented (respectively 1:2,000 and 1:5,000). Instead, the Decree leaves the Autonomous Communities (i.e., the Spanish Regions) free to interpret the regional scale. In fact, Article 39.2 states that the regional spatial plans "shall affect the entire territory included in their scope at an appropriate scale" (Jefatura del Estado, 1978).
- Minimum mapping unit. CLC updates (1990, 2000, 2006, 2012, and 2018) record land, land use, and land cover information using 5 ha as the minimum mapping unit for change. However, the minimum unit of the CLC is 25 ha, which is more appropriate to the territorial scale of other Spanish national documentary sources, such as the Information System on Land Occupation (*Sistema de Información sobre Ocupación del Suelo* de España – SIOSE).
- Hierarchical simplification. The CLC is the basis for ecosystem coverage at the European level, but there is a serious knowledge gap at the regional level. CLC provides information and, according to its third level of hierarchical aggregation, generates a classification of up to 44

ecosystem types. However, this classification cannot be useful at the regional scale where certain types are more relevant for the EU inventory.

- The CLC does not include certain types of natural information that are instead provided by the Spanish Autonomous Communities and the General State Administration, such as the forest map. Many Spanish Regions provide these maps at a scale of 1:10,000, including information on the type of vegetation, type of use, and classification. Such maps can provide more detailed information in relation to CLC.
- Raster representation of freely available information. The open-access MAES documentation on the European Nature Information System website is in raster format. This is a problem because the raster format makes the adaptation to the local vectorial cartography unfeasible in different regions or areas where the resolution of the cell size is not suitable for the analysis with spatial planning tools.

These conflicts may require adaptation of the data source to achieve greater precision regarding CLC in terms of mapping resolution and ecosystem type's information.

The resolution of these conflicts implied the decision to reclassify the categories of the SIOSE database to integrate it into the Spanish National Plan for Territory Observation (*Plan Nacional de Observación del Territorio* – PNOT). The output has a larger scale of definition (1:25,000) than the CLC (1:100,000) for the classification of ecosystem types and meets the European requirements established by the INSPIRE Directive (Infrastructure for Spatial Information in the European Community).

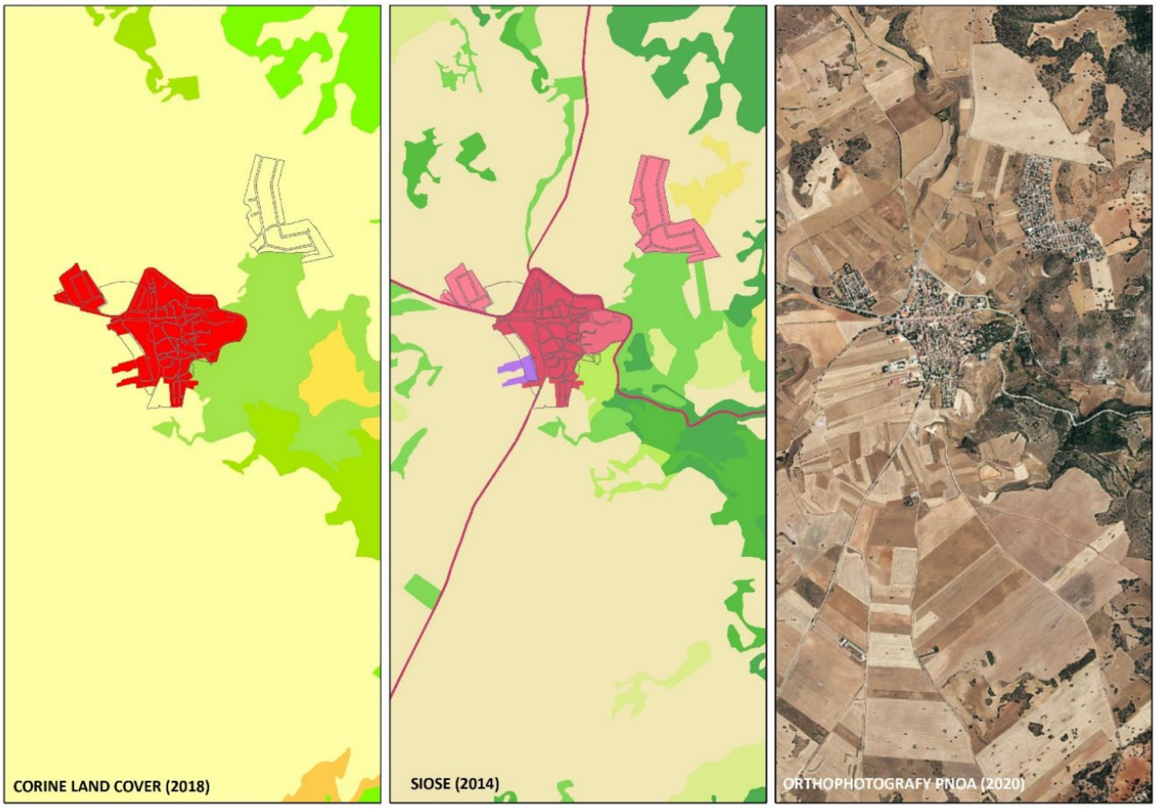

Figure 2. Degree of definition of the minimum mappable unit in the Pezuela de las Torres area (Madrid). Source: Authors' elaboration based on CLC 2012, SIOSE 2014 and orthophotography 2018.

The better definition of SIOSE is achieved through the incorporation of data produced by the Autonomous Communities at 1:10,000 and 1:5,000. The result is the definition of a series of surface coverages with a minimum surface of representation area of 0.5 ha for water, crops, wetlands, beaches, riparian vegetation, and sea cliffs, 1 ha for urban areas, and up to 2 ha in agricultural, forestry and natural areas. In the case of CLC, instead, the minimum representation area was 25 ha by default. This greater precision not only results in a more accurate delineation of ecosystems, but also incorporates with greater approximation the elements that divide habitats, such as communication or energy infrastructure.

This adapted information is approached with the methodological proposal of this study (Fig. 3) and compared it with the similar process followed by the identification and grouping of ecosystems by the EUNIS. The result is a map with the same information as it would have been obtained by using the EUNIS methodology, but with greater definition and updated to the latest monitoring date of the SIOSE national project. The resulting map – which can be called an "adapted EUNIS regional map" – could be continuously upgraded in the future by following the same steps to integrate updated data.

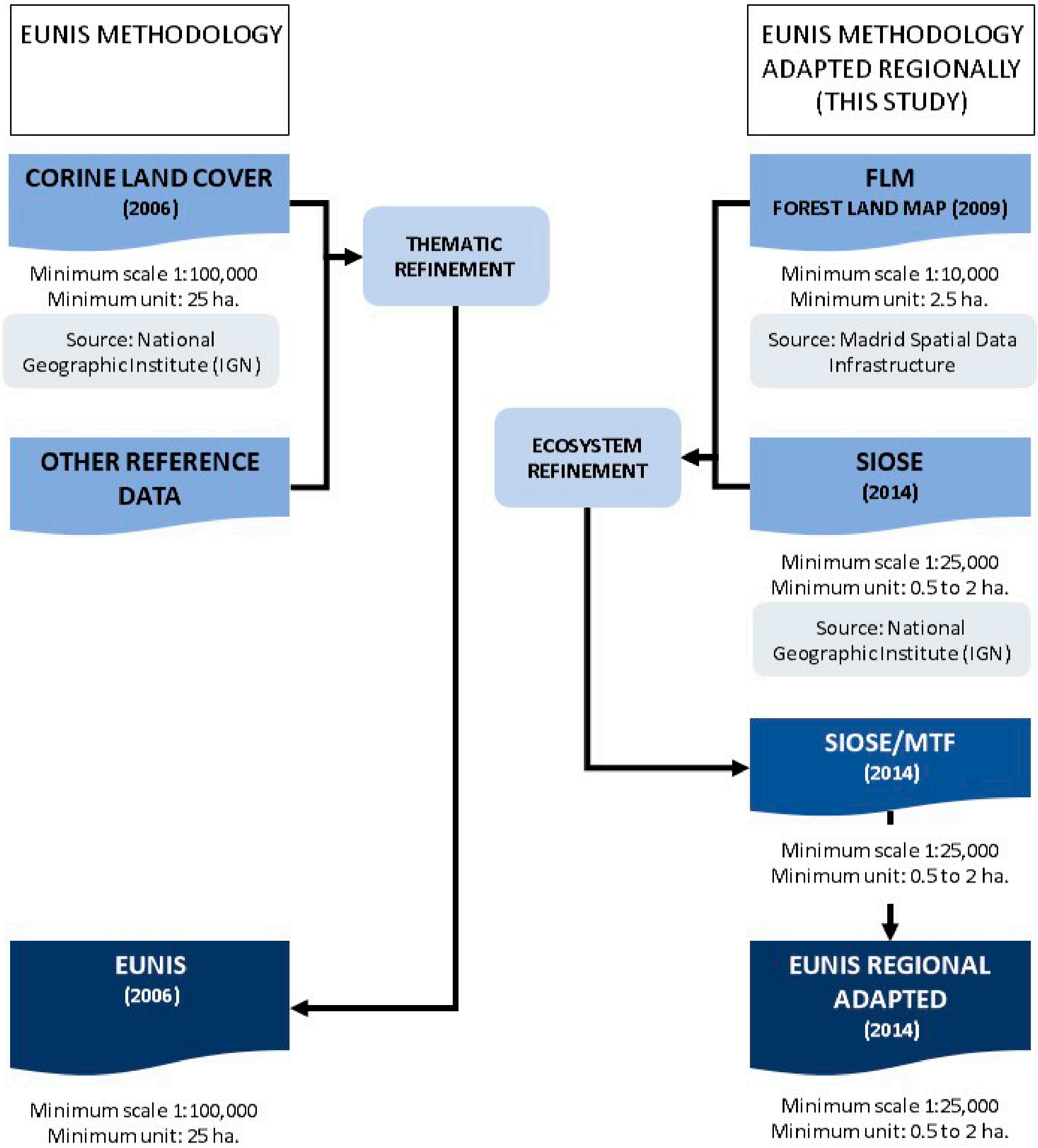

Figure 3. Comparison of EUNIS methodology with EUNIS methodology adapted regionally (this study).

Identifying the ES of a particular territory is the next step: the resulting information needs to be adapted to the regional scale. Although EUNIS is based on information provided by the CLC, the information supplied by the Spanish SIOSE is used as the basis for this study for the abovementioned reasons.

In this way, the ecosystems identified in the European Nature Information System (EUNIS) habitat groupings (Davies *et al*., 2004) can be unambiguously recognized in the study area. These ecosystems are divided into marine and/or coastal habitats; surface water areas; wetlands; grasslands, herbs, mosses or lichens; heathlands, scrub and tundra; forests, woodlands and wooded areas; habitats with very little or no vegetation; agricultural, horticultural and domestic habitats; and artificial habitats.

The application of this method to the Community of Madrid (Fig. 4) shows that the main ecosystem is "forests, woods and other wooded land" (28.81%). Deciduous, coniferous, mixed, and transitional woodland cover slightly more than half of this ecosystem, being located in between northern and southern Sierra. The ecosystem "regularly or recently cultivated agricultural, horticultural, and domestic habitats" occupies a slightly smaller area (27.79%), being mainly located on the *meseta*, in the southern and eastern sectors of the region: it includes rainfed arable land, permanent irrigated land, and agroforestry systems.

"Built-up, industrial, and other human-made habitats" (15.07%) is the fourth largest ecosystem after "heathland, scrub and tundra" (17.34%), but its territorial distribution significantly fragments the regional territory, creating a central strip that clashes head-on with attempts to create ecological corridors or other nature-based solutions. Finally, the ecosystem "lodazales, peat bogs, and fens" occupies a small area within the Community, with only 61.77 ha (0.01%).

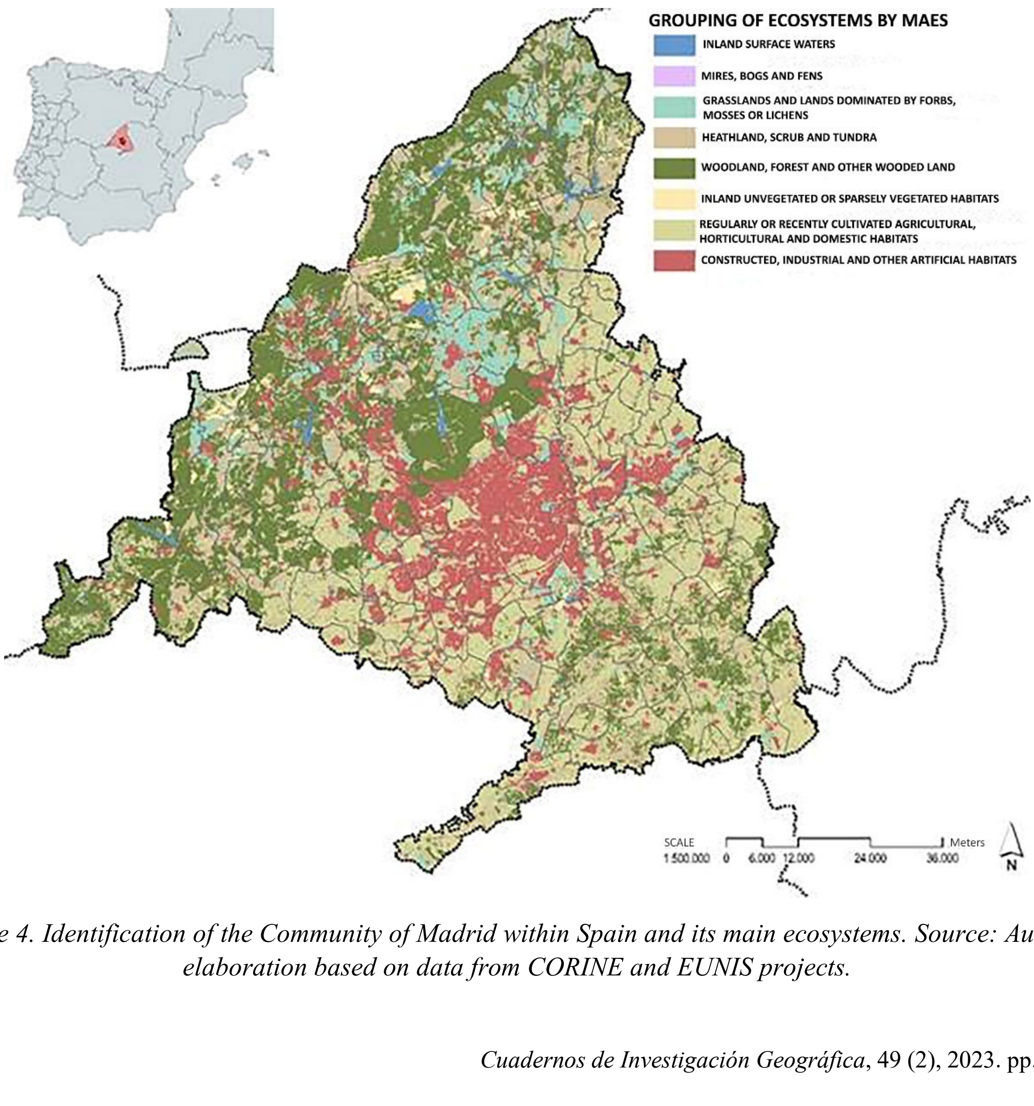

Figure 4. Identification of the Community of Madrid within Spain and its main ecosystems. Source: Authors' elaboration based on data from CORINE and EUNIS projects.

2.2. Step 2. Identification of the main impacts on ecosystems

Once the ecosystems have been grouped, the next step of the methodology is assessing the human impacts on ecosystems and their effects on the capacity to provide services. This assessment takes into account the difficulties in assessing the different pressures, trends, and impacts corresponding to each ecosystem due to the lack of specific data. Therefore, the five main drivers of change identified by the Millennium Ecosystem Assessment (2003) (i.e., land cover change, climate change, overexploitation of resources, introduction of alien invasive species, and use of fertilizers and air and water pollution) are linked to the ecosystems for their assessment. These drivers create environmental pressures that can alter the condition of habitats and the species composition of ecosystems, thereby reducing their resilience and affecting their ability to provide services (European Environment Agency, 2016). Based on these results, it is possible to identify the ecosystems that could undergo high pressure in the future.

Pressures, trends, and impacts on the ecosystems are challenging to assess. However, the combined effect of all the pressures over time results in the severity and extent of changes affecting an ecosystem and its ability to provide its services to natural and human systems. Therefore, the second step of the methodology is to assess these ecosystems using the MAES's conceptual framework for assessment. This approach consists of describing the different ecosystems from a qualitative assessment and establishing different relative scales according to the major pressures of the Millennium Ecosystem Assessment (2003). These scales are relative in the sense that all ES must be assessed at a specific geographical scale. In this case, the assessment provides the different levels of risk in reducing ES in an area by classifying potential future impacts as "very high" (VH), "high" (H), "moderate" (M) and "low" (L) based on the main direct drivers of change identified by the Millennium Ecosystem Assessment (Table 1).

Table 1. Intensity of the impact of direct drivers of change on ecosystems at the territorial level. Source: Mapping and assessing the condition of Europe's ecosystems: progress and challenges (European Environment Agency, 2016). Urban -URB; cropland -CR; grassland -GR; forest -FR; heathland and shrubland -H&S; sparsely vegetated land -S&V; wetlands -WET; freshwater (rivers and lakes -R&L) and marine -MAR. very high (VH), high (H), moderate (M) and low (L).

	MAES's conceptual framework for assessments								
Main direct drivers of change	URB	CR	GR	FR	H&S	S&V	WET	R&L	MAR
Habitat transformation	VH	VH	M	H	M	H	VH	VH	VH
Climate change	M	M	M	L	M	L	M	M	M
Overexploitation of resources	L	H	L	M	L	M	H	H	H
Introduction of invasive species	H	M	M	M	M	L	M	M	H
Pollution and nutrient enrichment	VH	VH	L	M	L	L	VH	VH	H

This second step develops an analytical assessment methodology based on the DPSIR framework (drivers, pressures, state, impact, and response model of intervention) which aims to establish a cause-effect relationship between human actions on the ecosystem. This methodology groups habitats into 12 ecosystem types, being divided into terrestrial (urban -U; cropland -CR; grassland -GR; forest -FR; heathland and shrubland -H&S; sparsely vegetated land -S&V; and wetlands -WET), freshwater (rivers and lakes -R&L) and marine (marine estuaries and transitional waters; coastal, continental shelves; and open ocean -MAR) ecosystems.

These ecosystems are not the same everywhere but adapt themselves to the climatic conditions of each location, so not all stressors affect similar ecosystems in the same way. As a result, similar ecosystems in different bioclimatic zones of Europe may respond differently to climate change and ecosystem responses to natural hazards are specific to each bioclimatic zone. Neither the application of the proposed methodology at regional scale nor the MAES allow for a precise assessment of pressures and future trends for all ecosystems taking into account the abovementioned specificities. Despite these limitations, a territorial diagnosis based on ES can identify their goods and services and assess their relevance with the aim of analyzing future urban pressures and the ways they affect the provision of ES.

The identification of the ecosystems is performed through the CLC grouping based on the categories developed by MAES and adapted territorially through SIOSE. In this way, the risk assessments of ecosystem loss and the ecosystem goods and services can be assigned to each of the polygons that make up each ecosystem (Fig. 5).

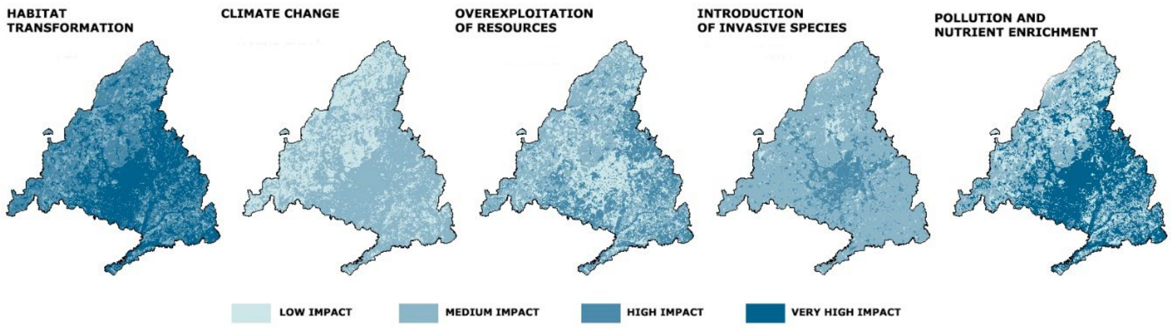

Figure 5. Assessment of the main drivers of ecosystem change. Source: Authors' elaboration based on SIOSE14 data.

The identification of effects is based on observing the effects of each driver on the different ecosystems. The effects can be observed in isolation – when considering only the effects of habitat transformation – or jointly – in the case of simultaneous analysis of the synergistic effects of the five actions. For instance, half of the Community of Madrid's surface is currently at very high risk due to cumulative impacts. The areas most affected by habitat transformation are urban ecosystem types, crops, wetlands, and rivers.

On the contrary, the effects of climate change would be moderate or low in the Community of Madrid, with urban areas, croplands, wetlands, and rivers suffering most from changes in temperature and precipitation, and rural areas from extreme events and fires.

The areas where overexploitation of resources could be most pronounced are croplands, wetlands, lakes, and rivers, i.e., where intensive agriculture through the overexploitation of crops and groundwater are already having their primary effects.

In terms of the potential risks associated with the introduction of exotic plant and animal species, the greatest risk lies in urban areas, i.e., where invasive species are being introduced into public and private gardens and parks. The mitigation of impacts in the rest of the regional territory shows a great homogeneity, except for the abovementioned areas. Only grassland ecosystems would have low impacts.

The effects of pollution and nutrient enrichment would particularly affect urban ecosystems, cultivated ecosystems, wetlands, lakes, and rivers. Soil contamination by heavy metals from industrial activities, air pollution, and critical ozone levels, and water pollution from poor management of sewage, sludge, and waste are particularly noticeable.

2.3. Step 3. Identification, assessment, and relevance of ecosystem services

The *Common International Classification of Ecosystem Services* (CICES) considers ES to arise from living organisms (biota) or from the interaction of biotic and abiotic processes. The classification identifies three families of ES: provisioning, regulating, and cultural.

The values of the three families of ES are obtained using a variety of economic valuation techniques. These techniques do not assign a price on nature, but simply estimate the economic value of a limited number of services at a time. Despite limitations in certain contexts, an economic assessment can help to put nature conservation on an equal footing with urban development, and thus help decision-makers to better understand their trade-offs. Conducting this assessment is controversial as it raises a number of significant ethical and cultural considerations (Brand, 2009; Saner and Bordt, 2016).

The proposed grouping of Step 3 is the same that the work carried out in Step 2 on the cartographic basis of the MAES ecosystem groupings. Therefore, the most sensitive ecosystems are identified to subsequently outline the "ecosystem vulnerability associated with the degradation or loss of essential ecosystem goods, functions, and services". The aim is to detect ecosystems with high or very high values in their contribution of goods and services that make them worthy of special protection to prevent their disappearance or degradation.

The SEEA Ecosystem Accounting (SEEA EA) offers a territorial approach to the problem of measuring the flows of ES and calculating their condition in terms of capacity to provide services. SEEA EA adopts a spatial approach because of the benefits that the society receives from ecosystems depend on the relationship between ecosystems and the location of the beneficiaries (United Nations, 2017).

The territorialization of these aspects involves the identification of ecosystems, but also the recognition and assessment of the ES and the interactions between them (Ruhl *et al*. 2008; Bagstad *et al*. 2013). These assessments come from various academic papers that, while presenting different degrees of territorialization, are carried out on a European-continental basis (Córdoba Hernández and Martí Guitera, 2022; Fernández de Manuel *et al*., 2020; Henderson, 2015; Jacobs *et al*., 2013). For instance, a negative interaction between the services provided by an ecosystem occurs when trade-offs arise. Such a dynamic may occur when a grassland ecosystem has a high input of food, but a low input of raw materials. These two ESs are mutually exclusive in a trade-off, so as the ecosystem provides both ESs independently, when combined they cancel each other out.

The biophysical assessment of ESs requires an assessment of both the capacity of ecosystems to provide relevant services and the estimation of their demand. The resulting cartography paves the way for understanding the distribution and importance of each contribution in the territory, as ecosystems take values for each contribution. The relationship with the capacity of ecosystems to provide services is presented in three areas to facilitate the understanding of the spatial distribution of each service.

As it happened in Step 2, a qualitative assessment is performed by introducing a new relative scale. The new scale ranges are established taking into account the assessments provided by different sources at international (Henderson, 2015; Longcore and Rich, 2004) and national levels (Fernández de Manuel *et al*., 2020). The different inputs on ecosystems are identified as "low" (L), "medium" (M) or "high" (H) regardless of the documentary sources used.

This identification should be carried out for each of the 25 ESs grouped according to the CICES methodology. In this way, the ES can be mapped independently to obtain results at other levels such as the groupings of ESs by families of contribution (supply, regulation, and cultural) or by their overall territorial relevance. According to the European Environment Agency, regulation is the most remarkable contribution of ESs. Up to 13 different ESs can be distinguished and assessed differently depending on the ecosystem that produces them. (Table 2).

Table 2. Biophysical assessment of the different contributions of each service family. Green area – GA; cropland –CR; grassland -GR; forest -FR; heathland and shrubland -H&S; sparsely vegetated land -S&V; wetlands -WET; freshwater (rivers and lakes -R&L) and marine -MAR.

		MAES's conceptual framework for assessments								
	Ecosystem services	GA	CR	GR	FR	H&S	S&V	WET	R&L	MAR
REGULATION	Habitat maintenance	M	M	H	H	H	H	H	H	H
	Climate	M	L	M	H	M	L	M	M	M
	Noise reduction	H	-	-	H	L	-	-	-	
	Thermal buffering	H	L	M	H	M	L	A	A	L
	Air quality	H	L	M	H	M	L	A	A	L
	Hydrological cycle	M	-	H	H	H	L	A	A	M
	Erosion control	-	-	H	H	H	M	-	-	H
	Soil fertility	-	-	H	H	H	L	-	-	M
	Natural disturbances	-	-	H	H	H	-	H	H	H
	Biological control	H	M	H	H	H	H	H	H	M
	Pollination	M	H	H	L	H	M	-	-	
	Endemic species conservation	-	M	H	H	H	H	H	H	H
	Soil production	-	-	M	H	M	L	-	-	-

The methodological assessment has considered the approximate biodiversity of each ecosystem, assuming that the greater the number of species, the higher the number of conserved habitats. Cultivated fields show high values where large natural grasslands are scarce and, especially when they are well managed, they constitute a remarkable habitat for a multitude of bird species, from birds of prey to partridges and even bustards. In addition, if properly managed, the boundaries between agricultural parcels can become real biodiversity corridors, as they were in the past. These parcels were home to a wide variety of plant species in their bordering vegetation, which provided shelter for rodents and birds. In this case, the territorial importance of certain ESs, such as the conservation of endemic species, soil fertilization or the buffering of high temperatures, can be assessed (Fig. 6).

The assessment applied to the Community of Madrid divides the regional territory in two major zones (Fig. 6). The first is made up of the sierras, the plateau, and the so-called "western tension zone", which includes numerous municipalities between the two sierras, such as Guadarrama, Galapagar, Santa María de la Alameda, and San Lorenzo de El Escorial. Despite the high altitude, this zone is provided with wooded ecosystems, scrub, and grassland ecosystems, being a typical example of the Mediterranean flora, among which holm oaks, junipers, and cork oaks stand out in the slopes of the Sierra de Hoyo de Manzanares. Here, extensive cattle population feeds on its fawn's pasture, producing meat of excellent quality, certified as *Ternera de Guadarrama* (Guadarrama Beef). The second major zone comprises the metropolitan concentric circles. On the one hand, the northern and western ones, which are also important for their regulatory contributions. These metropolitan concentric circles clearly divide this major zone into an area with very high contributions and an area with very low or no contributions. On the other hand, the eastern (made up of municipalities such as Alcalá de Henares, Coslada or Rivas-Vaciamadrid) and southern (made up of municipalities such as Getafe, Alcorcón, and Leganés) circles present little or no contributions in respectively 72% and 85% of their territory.

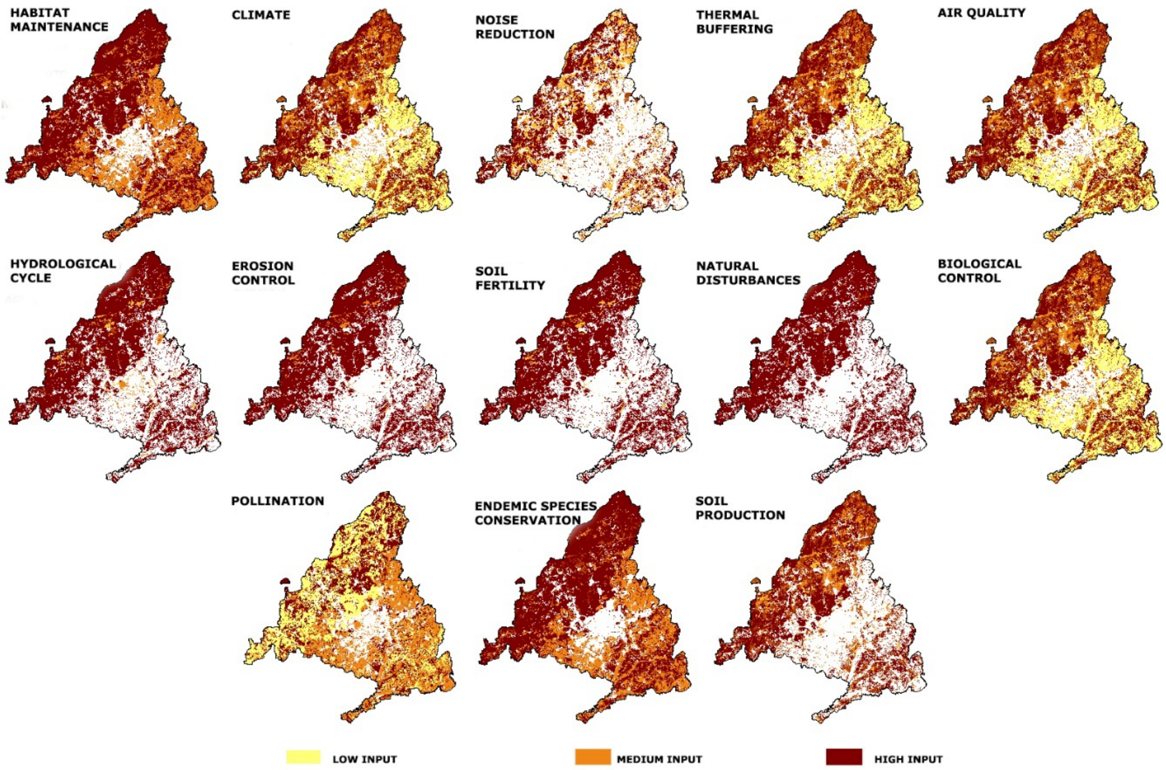

Figure 6. Territorialization of biophysical inputs of the regulating good service by ecosystem. Source: Authors' elaboration based on SIOSE14 data.

2.4. Step 4. Introduction of spatial planning as a factor in the ecosystem assessment

At the same time, it is necessary to analyze the spatial planning of the area where ecosystem vulnerability is to be assessed. Municipal spatial planning should be as up-to-date as possible with the physical reality: this is what can be called "effective planning". Effective planning aims to introduce the existing situation of the reality to analyze according to the current spatial planning and the names of classes and categories updated according to the regional land legislation.

Therefore, the territory to assess as vulnerable includes areas that are not affected by any sectoral legislation preventing urban development and areas comprising the ecosystems most vulnerable to impacts. These two types of areas should be assessed for future protection when it comes to modify the municipal spatial plan or to introduce a new one. Step 4 proposes two categories of protection in accordance with the criteria introduced by the fourth final provision of "Law 7/2021, of 20 May, on Climate Change and Energy Transition in the Royal Legislative Decree 7/2015, of 30 October, approving the revised text of the Law on Land and Urban Rehabilitation":

- Ecosystem vulnerability through spatial planning in relation to the ecosystem and biodiversity loss due to the direct drivers of change identified by the Millennium Ecosystem Assessment. This vulnerability regards areas with high or very high biodiversity transformation based on the combined effects of habitat transformation, climate change, introduction of invasive species, and pollution and nutrient enrichment identified in section 2.2.
- Ecosystem vulnerability to spatial planning in relation to the degradation or loss of essential ecosystem goods, functions, and services. This vulnerability concerns ecosystems with high or very high values in their contribution of goods-services. Their values make them worthy of special protection to prevent their disappearance or depletion.

The result of this step provides a new dimension of environmental problems affecting the Community of Madrid's territory, whose southern metropolitan concentric circle and the southern and eastern regional sectors have been identified as the most sensitive.

Bringing together the ecosystem vulnerability associated with the risks from ecosystem loss and the ecosystem vulnerability associated with the loss of services can help to change the perception of the real estate developments that the Community of Madrid should be promoting today. If none of the current development plans were implemented, the existing ES would not be reduced, nor would new sensitive areas be created by the drivers of change. On the contrary, the situation would be the opposite. The creation of a new classification of land – which could be called "resilient" – could introduce new reasons for protecting the Community of Madrid's territory. Table 3 shows the result of the new classification.

Table 3. Reclassification of Land for Development due to Ecosystem Vulnerability. associated with planning. NM: North Mountain; SM: South Mountain; ME: Meseta; WT: Western tension area; ST: South tension area; ET: East tension area; NT: North tension area; WC: Western Metropolitan Crown; SC: South Metropolitan Crown; EC: Eastern Metropolitan Crown; NC: Northern Metropolitan Crown; MD: Madrid municipality; CM: Madrid Community.

		SURB ecosystemically vulnerable		SURB with high risk of ecosystem loss		SURB for loss of ecosystem inputs	
Z	S (Ha)	S (Ha)	%	S (Ha)	%	S (Ha)	%
NM	17,083	11,910	69.7%	3,633	30.5%	8,277	69.5%
SM	4,572	4,128	90.3%	2,149	52.1%	1,979	47.9%
ME	43,147	41,939	97.2%	22,566	53.8%	19,373	46.2%
TW	6,909	4,825	69.8%	1,882	39.0%	2,943	61.0%
ST	14,853	13,607	91.6%	10,960	80.5%	2,647	19.5%
ET	16,956	16,036	94.6%	13,014	81.2%	3,022	18.8%
NT	8,216	7,036	85.6%	5,173	73.5%	1,863	26.5%
WC	7,044	6,356	90.2%	4,802	75.6%	1,554	24.4%
SC	7,690	7,370	95.8%	7,062	95.8%	308	4.2%
EC	5,020	4,416	88.0%	4,092	92.7%	324	7.3%
NC	8,143	4,313	53.0%	2,913	67.5%	1,400	32.5%
MD	6,196	5,847	94.4%	4,831	82.6%	1,016	17.4%
CM	145,828	127.783	87.7%	83.077	65.0%	44,706	35.0%

3. Results

3.1. Step 1. Homologation of the initial information with the necessary scale adaptation

The potentialities identified in the two international territorializations of ecosystems will be adapted to the specificities and scale of the national territory to provide a systematization adaptable to the different Member States. These cartographies are the European Nature Information System (EUNIS) project, which carries out an initial identification and grouping of ecosystems, and the Mapping and Assessment of Ecosystems and their Services (MAES) project, which regroups them according to the main impacts identified by the Millennium Ecosystem Assessment.

This identification is crucial as it may enable the European Commission to take joint decisions and policies in order to address biodiversity issues and ecosystem loss. However, the decisions are poorly effective at the national level due to their territorial scope and scale of work. For this reason, the first contribution of the research is to adapt the scale of the information provided by the national databases to facilitate the reinterpretation of the issues at scales closer to spatial planning. This achievement relied on the information provided by the Spanish Land Occupancy System (SIOSE), which has solved the various problems posed by the previous methodologies for their adaptation to spatial planning. These issues are the scale of the project, the minimum unit to map, the hierarchical simplification, the lack of integration of other types of natural information made available by the Autonomous Communities and the General State Administration, and the raster representation of freely accessible information.

This new identification of ecosystems is a much more useful tool as it begins to work at the scale used in spatial planning (1:20,000) and incorporates the environmental information necessary for the correct identification of natural values at the municipal level, as well as their main impacts.

The possibility of working with a vectorial tool, despite its territorial scale, allows including in the analysis the delimitations of the various territorial and sectoral planning, their zoning and, above all, the current spatial planning itself.

3.2. Step 2. Identification of the main impacts on ecosystems

A vantage point offered by this methodology is the mapping of ESs and their synergies, i.e., when the provisioning of two services increase or decrease simultaneously. CICES identifies different ecosystem inputs but does not territorialize them. In this second step, one of the issues to address is precisely territorialization. Based on the EUNIS ecosystems identification, the methodology assigned a specific value for each of the different contributions the ecosystems may provide. This step in turn provides the opportunity to incorporate this information into the early stages of the spatial planning process, thereby improving the quality of information and the outcome.

This new information on ecosystems can be compared with the spatial plan proposal at the various stages of its formulation. Highlighting the impact of new land for development on the natural environment and ecosystems can thus lead to elaborate alternatives that better fit with environmental goals. In this way, a national or regional database containing this information would enable better and systematized reasons for land protection, or even to redefine current regional and sectoral spatial planning tools according to the identified risks or the ecosystemic contributions bordering on the current perimeters.

3.3. Step 3. Identification, assessment, and relevance of ecosystem services

The introduction of spatial planning as a factor in the ecosystem assessment allows the incorporation of a new element of direct pressure on ecosystems. While this is a novelty, it would not be useful to incorporate it into the international methodologies identified in this paper due to the significant differences between planning systems at the European level.

Despite this controversy, it is worth recalling that among the direct drivers of change, habitat transformation is labelled as a pressure so it should undoubtedly be linked to spatial planning activities. The issue here is that at the European level only the direct degradation of habitat elements or functions, or the loss of a habitat and its replacement, are analyzed in terms of their impact on biodiversity. In other words, the analysis is on ex-post effects.

The consideration of spatial planning as a factor is essential because it identifies the pieces of land that are susceptible to transformation and incorporation into the urban project. The consequence of approaching spatial planning as a remarkable temporal element for ecosystem assessment led to two main results. The first is the identification of the future impact of spatial plans on ecosystems and, the second, is the modification of the existing spatial planning tools according to the impact and to the reduction in resilience that they cause.

3.4. Step 4. Introduction of spatial planning as a factor in the ecosystem assessment

Comparing current spatial planning protection with the assessments of both the main direct drivers of change and ecosystem inputs led to a remarkable result. This outcome is the identification of land whose capacity for positive adaptation to change would be most severely compromised by urbanization, being thus unable to reinforce endogenous weaknesses and to remove much of the response capacity. According to this identification, Table 4 spots ecosystems that, regardless of current spatial planning's contents, should be protected or preserved to maintain existing resilience, whether high or low.

Table 4. Assessment of ecosystems for their protection. Urban -URB; cropland -CR; grassland -GR; forest -FR; heathland and shrubland -H&S; sparsely vegetated land -S&V; wetlands -WET; freshwater (rivers and lakes - R&L) and marine -MAR

		MAES's conceptual framework for assessments								
		URB	CR	GR	FR	H&S	S&V	WET	R&L	MAR
Main direct drivers of change	Habitat transformation	VH	VH	M	H	M	H	VH	VH	VH
	Climate change	M	M	M	L	M	L	M	M	M
	Overexploitation of resources	L	H	L	M	L	M	H	H	H
	Introduction of invasive species	H	M	M	M	M	L	M	M	H
	Pollution and nutrient enrichment	VH	VH	L	M	L	L	VH	VH	H
Ecosyste m inputs	Supply	L	M	M	H	M	L	L	L	L
	Regulation	L	H	H	H	H	L	L	L	L
	Cultural	L	H	H	H	H	L	H	H	H

Table 4 shows that the drivers of change have the greatest impact on arable, wetland, coastal, river, and lake ecosystems, while forests, heathlands, and shrublands provide the greatest services to society. All of them should be protected for different reasons to maintain or increase the current resilience of a specific area.

The less-protected ecosystems would be those belonging to grasslands and sparsely vegetated areas, as they would have low values in either of the two approaches analyzed. However, the proposed methodology for determining these values does not exclude a certain degree of flexibility that could guarantee an increase in the level of protection for ecosystems with high or medium values whether considered necessary or unique in the area.

Prior to Law 7/2021 on Climate Change and Energy Transition, the definition of the basic criteria for land use did not specifically mention the assessment of risks related to the loss of ecosystems and biodiversity and the degradation or loss of essential ecosystem goods, functions, and services. It would be a mistake to ignore these risks and not protect land, as land is fundamental to building adequate resilience.

This research views lack of protection as a vulnerability for the future and therefore seeks its identification in order to address the problem before it arises. Once the vulnerability is identified, the lack of protection for either of the previous two considerations should be addressed through land protection and a clear statement of compatible uses and reasons for protection.

4. Discussion

4.1. Ecosystem protection as a reclassification argument

The Spanish Autonomous Communities hold exclusive competence in matters of "land-use planning, town planning, and housing" – "Ordenación del Territorio, Urbanismo y Vivienda" in Spanish. This fact means that the regulations in these matters may vary from Region to Region and follow general principles set by the State. The State, in turn, limits itself to regulating the basic conditions for exercising the right to property, the general guarantees of compulsory expropriation and the land assessment system, the patrimonial responsibilities of the administration, and various aspects related to the cadaster. Most municipalities rely on a model that divides land into three classes (urban, for development, and undevelopable). The main differences between the three classes depend on the definitions and reasons given by the Autonomous Communities, which may lead them to consider land in one way or another.

Several Regions made a clear effort to specify the criteria according to which certain areas must be excluded from development, by classifying them as "undevelopable land", while the General Municipal Master Plans (*Plan General de Ordenación Urbana*, PGOU, in Spanish) may establish different categories within the "undevelopable land". It is worth noting that the regional legislation specifies the reasons why certain areas must be protected from urbanization. Most of these reasons are based on natural, environmental, and landscape values, which may already be recognized in sectoral legislation or may be progressively granted by the municipal authority itself. The classification of certain land as "undevelopable" may also be based on other criteria related to the principles of sustainability, such as the rational and orderly growth of the city or the structural characteristics of the municipality. Nevertheless, sectoral legislation or spatial planning does not regulate these criteria, so it is up to the decision makers to recognize these values and determine the land-use.

An essential step for promoting territorial resilience and land protection and conservation is the correct identification of the most vulnerable areas to the loss of ecosystems and the services they provide. The identification of such land corresponds to the "land for development"' and can be carried out in two ways. On the one hand, the identification of "land to develop" that has not yet been transformed and, on the other hand, the verification of the existence of ES.

4.2. The challenges of spatial planning towards a real land protection

Article 128.1 of the Spanish Constitution lays down a compelling principle: "The entire wealth of the country in its different forms, irrespective of ownership, shall be subordinated to the general interest". Public administrations should therefore guarantee reliable land classification and take effective measures against speculation, but this seems a complex issue. By adopting this principle in whatever form or ownership, land classification should also be subordinated to the general interest. Doing so through spatial planning would result in the harmonization of two constitutional rights: spatial planning – aimed at economic and social development – and environmental protection. A general social consensus on the need to protect and preserve biodiversity due to its fragility seems to be quite clear in Spanish society (Brand, 2009; European Commission, 2020; Hurlimann and March, 2012). However, a large extent of the Community of Madrid would experience higher ecosystem values or significant risks of being affected by the pressures identified by the Millennium Ecosystem Assessment as this regional territory is expected to be heavily urbanized (Córdoba Hernández and Morcillo Álvarez, 2020; Valenzuela Rubio, 2010). The economic values and the relevant risks occur usually simultaneously as the most sensitive ecosystems tend to produce the largest inputs, but this methodology proposes to study them separately to enable elaborating adequate reasons for land protection.

Today, the design of spatial planning instruments must not only address the traditional problems of the rural-urban imbalance. Planning has to deal with less controllable vectors, such as the recent displacement of people due to environmental problems or risk situations caused by climate change

(Maes *et al*., 2013). These vectors increase the resilience factors in need of assessment, making land conservation more relevant. The design and implementation of strategies and action plans for ecosystem conservation and the use of evidence-based planning tools to design networks of protected areas and their connectivity are pillars for a better integrated management of the natural environment and increased resilience (European Commission, 2020; Pickett *et alet al*., 2004). A fundamental role pertain to national and regional land-use legislation as both of them should regulate spatial planning and uphold protected areas from urbanization process and incompatible activities according to spatial planning, sectoral legislation, and ecosystem values.

The resilience of an area strongly depends on the reduction of its vulnerability, or at least preventing it from increasing. As a consequence, vulnerability should be considered in the environmental assessment procedures required by the land-use legislation. Today, these procedures focus on fulfilling the required formalities but lack in-depth analyses. On the one hand, the environmental assessment focuses on the protection of certain nationally and internationally agreed elements such as the Natura 2000 Network or on compliance with sectoral legislation – e.g., cattle routes, water, and public utility forests. On the other hand, these tasks do not consider the qualities and services the ecosystems provide. Having complete and reliable information on the state of ecosystems – and the services they provide – and monitoring the changes that may occur would help to answer to the following question: Are urban development processes meeting the objectives of the Strategic Environmental Assessment and conserving the natural environment?

As argued by several authors (Adem Esmail and Geneletti, 2017; Longato *et al*., 2021; Spyra *et al*., 2019; Veidemane *et al*., 2017), the development of new information on ecosystems and their goods and services can help support the implementation of environmental legislation, the integration of environmental objectives into urban policies, and the changes needed to achieve these objectives.

5. Conclusion

Urban ecological restoration often focuses on everything but nature, intervening in elements such as public transportation, renewable energy production, and energy-efficient building systems. While these are major aspects of reinventing urban life, they are not enough. Any vision of a sustainable urban future must focus directly on nature and on the presence and preservation of existing green features and natural ways of living.

In this paper, we proposed a new methodology for the evaluation of ecosystems for protecting land at risk of degradation. The proposed methodology can become a useful tool for land use planning for three main reasons: it works at the same scale as regional planning (1:20,000), it incorporates the environmental information necessary for the correct identification of natural values and impacts at the municipal level, and it works with geographic information systems. These reasons are the right basis for a simpler and faster integration of ecosystems in the drafting and approval process of land use planning, while at the same time they led to an interpretation and comparison of different aspects of land protection, such as ecosystem loss and ES.

The methodology also introduces two innovations. The first is the possibility of working with a vector tool. Despite its territorial scale, the vector tool integrates three factors into the municipal plan – i.e., the delimitations of the different territorial and sectoral planning, their zoning, and the current municipal planning. The second is the possibility of mapping ESs that are not mapped in international cartography. By doing so, the methodology adds a new set of attributes to the existing ecosystems based on the interactions between ecosystems and their own services. The direct consequence of such novelties may be the incorporation of this information in the municipal plan from the early stages of its drafting, improving the quality of the information provided and the outcome.

Finally, the new information on ecosystems can be compared with land-use planning proposals to identify alternative ways of managing the natural environment and conserving terrestrial ecosystems. Firstly, by organizing the range of the reasons for land protection and, secondly, by redefining the zoning of the spatial plans according to the identified risks or ecosystem services. At the national level, the introduction of spatial planning in the ecosystem assessment led to the inclusion of a new element of direct pressure on ecosystems based on the Law 7/2021 on Climate Change and Energy Transition. At the international level, the incorporation of this methodology in the drafting of international planning is perfectly compatible due to the use of free information and the adequate scales it uses.

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