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# The application of ecosystem assessments in land use planning: A case study for supporting decisions toward ecosystem protection

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ABSTRACT

This paper proposes a flexible methodology for ecosystem assessment oriented to climate-change adaptation and mitigation policies focused on ecosystem protection. This analysis is based on a methodology developed at the European level which is adapted and applied in a specific Spanish context, providing a practical application that can be replicated in other European contexts after cartographic adaptation. The novelty of the proposed method is the inclusion of ecosystem assessment for land use planning as an element to consider when justifying the reasons for land protection. It involves three main steps. The first step introduces the spatial information of the different ecosystems of the study area, including the identification of ecosystem services (ES) and the capacity of the different ecosystems to provide them. The second step proposes the ecosystem assessment methodology at the regional and local planning scale based on the Mapping and Assessment of Ecosystems and their Services (MAES) project. The third step concerns the evaluation of the expected impacts on the ecosystems due to land-use-planning-related development trajectories to depict the possible negative consequences on ES. Such results show how the integration of ES assessments into land use planning tools could motivate land protection through providing evidence information on ecosystem risks, ES loss, or both.

## 1. Introduction

### 1.1. Resilience in ecological theory and its application to climate change issues

The concept of 'resilience' deserves special attention considering that this term in ecological theory refers to the system ability to absorb the changes or shocks of a perturbation while maintaining its internal relationships, although it lacks of an internationally agreed definition (Holling, 2013).

Current debates on environmental changes deal with resilience, with a growing use in academic, political, and popular media focusing on climate change issues (Brown, 2014; Tyler & Moench, 2012), so this concept is being gradually introduced into the everyday vocabulary and increasingly applied to the territorial sphere (Kumar, 2021). Part of its incorporation stems from our society's growing interest in understanding and addressing the significant threats that climate change will pose and how we will need to adapt to

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them and other hazards (IPCC, 2014a, 2014b). In this context, 'territorial resilience' is conceived as the capacity of a specific territory to positively adapt to crises caused by external factors due to an internal transformation that enhances its endogenous resources and promotes collaborative and sustainable planning of urban space (Córdoba Hernández, 2021). Land use planning processes should thus consider visions for the future such as 'anticipatory resilience', conceived as a "futures-oriented knowledge system that intentionally addresses uncertain climate conditions and explores alternative, desirable future states" (Muñoz-Erickson et al., 2021). In this context, territorial resilience becomes critical within the projected increase in urban population expected in the next decades (with nearly 7 of 10 people living in cities by 2050) (United Nations, 2019) to appropriately address challenges related to the management of resources and services, adequate urban infrastructure to meet increasing demands, quality of urban life, and climate change adaptation.

### *1.2. Climate change policy: balancing mitigation and adaptation strategies in urban contexts*

Until the late 20th century, the dominant neoliberal political and economic model was based on market-driven and constant economic growth relying on depleting sources of resources (Riedy, 2020). In the last decades it became clear that global challenges such as climate change and economic inequality were not being effectively addressed by our institutions, and global social and environmental conditions were deteriorating (Wakefield, 2022). The interaction between policies and territorial resilience has become a central issue in Europe, where important initiatives have tried to address these challenges. Climate change policies are developed in the context of national and urban policies (Castán Broto, 2017; Kim & Song, 2018) and the planning processes encompass two mutually reinforcing strategies. On the one hand, mitigation strategies propose long-term transformative actions to address the anthropogenic causes of the current situation (Sebestyén et al., 2023; Vanhuyse et al., 2023). On the other hand, adaptation strategies include short- to medium-term measures and initiatives to mitigate and prevent the effects of climate change, such as droughts, floods, heat waves, more severe storms, increased precipitation, and wildfires (Göpfert et al., 2019; Moriarty & Honnery, 2015).

The attempts to interrelate adaptation and mitigation is crucial One of the most prominent European policies in this field is the "EU Mission on Climate Neutral Cities" (European Commission, 2022), which focuses on transforming cities toward climate neutrality by measures aimed to reduce greenhouse gas emissions to net zero levels and adapting cities to face climate change effect. Additionally, the European Commission has implemented comprehensive policies and strategies aimed at tackling climate challenges in urban environments. These include promoting energy efficiency, transitioning towards renewable energy sources, fostering sustainable land use planning, and enhancing resilience to extreme weather events. Examples are the "European Green Deal" (European Commission, 2020), focused on a sustainable economy with specific measures to improve mobility and urban energy efficiency; the "Sustainable Mobility and Clean Energy Strategy" (European Commission, 2021b), which establishes goals to reduce emissions and promote more sustainable urban mobility; and the "Climate Change Adaptation Strategy" (European Commission, 2021a), with a focus on resilient infrastructure and risk management. Specific funds allocation depends on "Horizon Europe" to support research and innovation projects for urban climate solutions, whereas the "EU Recovery Fund" supports investments in more sustainable cities, facilitating the transition toward resilient and ecologically responsible urban models. All these initiatives demonstrate a thorough dedication to converting European cities into a more sustainable future, ready to confront climate challenges.

A relevant factor worth highlighting is the fact that there is no unified territorial planning at continental level in Europe due to places´ environmental, socio-economic, geographical, historical, cultural, and institutional characteristics. Each member country possesses its own regulatory framework and territorial planning capacity, resulting in a variety of territorial development approaches and strategies. Therefore, planning policies and practices differ markedly among nations, leading to a diverse urban, rural, and regional growth and development patterns.

Decentralization of decision-making in territorial planning presents both challenges and opportunities in a context in which the EU promotes cooperation and the exchange of best practices across Europe through regional programs and policies. While decentralization grants each state member the adaptability to tailor their strategies to their unique needs and priorities, it also poses difficulties in coordinating and implementing EU-fostered territorial policies. The absence of a shared territorial framework hinders the ability of state members to coordinate objectives and cooperation towards resolving cross-bordering issues, such as managing natural resources or reducing environmental impacts that surpass national boundaries. This research is inserted amid this situation, exploring how planning strategies at territorial level can complement and enrich urban initiatives to achieve a more complete and sustainable transition towards a climate-resilient European environment.

### *1.3. Toward integrated territorial and municipal planning: addressing environmental risks and sustainable development in Spain*

Although the Royal Legislative Decree no. 7/2015 provided the national regulatory framework in land use matters placing a significant emphasis on environmental and economic sustainability, particularly in urban settings (Jefatura del Estado, 2015), only the Law no. 7/2021 on climate change and energy transition (Jefatura del Estado, 2021) clearly identified five types of environmental risks now incorporated into Article 20 "Basic criteria for land use." These include risks from coastal flooding or sea level rise, risks from extreme weather events affecting critical infrastructure and utilities, fires, and risks associated with the loss or degradation of ecosystems. This paper focuses on the capacity of land use planning to address the latter, arguing that the risks associated with the loss of ecosystems and biodiversity, as well as the degradation or loss of essential ecosystem goods, functions, and services, need to be considered when planning future cities.

Based on this inventory, the competent land use planning authorities must analyze the potential risks in the drafting process of new land use planning instruments. However, the Autonomous Communities hold exclusive authority for Territorial Planning, Land Use Planning, and Housing. This fact results in differing regulations on these matters in each community, which only have enforceability within their respective territories. Currently, none of these regulations are considering Law 7/2021 as a basis for territory protection, despite the requirement to respond to and comply with state legislation. To address this issue, territorial and municipal planning should directly include this form of protection in their policies.

On the one hand, municipal land use planning in Spain involves implementing norms, guidelines, and strategies that rule urban development within the municipal administrative boundaries. This planning approach aims to efficiently manage and organize a city, ultimately improving the quality of life for residents, promoting economic and social development, and ensuring a sustainable and functional urban environment. To achieve so, land use planning addresses aspects such as land use, housing, infrastructure, transportation, public services, and zoning, among others. On the other hand, territorial planning deals with broader issues and encompasses larger areas, examining not only municipal boundaries but also the interconnections among different municipalities and regional territories. This comprehensive approach involves aspects such as natural areas conservation, resource management, infrastructure planning at regional scale, protection of cultural and environmental heritage, and promotion of balanced and sustainable development at a broader scope than the municipal level.

The two planning levels complement each other. The municipal level regulates and plans for development within local administrative boundaries. The regional level addresses issues that go beyond those boundaries and seeks coherence and coordination between different municipalities or regions. In many cases, their integration is necessary to ensure coherent and effective territorial management that considers both local and regional aspects. Effective coordination is crucial for efficient land use and sufficient preservation of cultural and natural resources in every level, ranging from local to regional. Therefore, the approach proposed by this methodology can be adopted in both territorial and municipal planning levels.

### *1.4. Research context, objectives, and hypothesis*

Ecosystems, understood as dynamic systems formed by the interaction between living organisms and their physical environment, provide a wide range of ecosystem services (ES), which are direct and indirect benefits that humans obtain from ecosystems. The ES supply refers to the capacity of ecosystems to provide benefits to people, and their demand is independent of the localization of ecosystems (Burkhard et al., 2012). Ecosystems can provide essential material things for people's daily lives (such as food, timber, wool, and medicines) and spiritual well-being through their cultural significance or the opportunities they provide for recreation and the enjoyment of nature (Balvanera et al., 2006). Additionally, other benefits derived from ecosystems are easily overlooked but play an important role in regulating the environment in terms of climate (Ghaley et al., 2014), clean water flows (Stürck et al., 2014), water cycle (McGrane, 2016), and preventing hazards such as flooding, soil erosion, landslides, and tsunamis (Gómez-Baggethun & Barton, 2013). However, ecosystems are experiencing decline or loss due to changes in biodiversity, and national environmental policies are claimed to inadequately prevent negative outcomes (IPCC, 2014a, 2014b).

Failure to adequately consider these services has significant impacts on the health of ecosystems and thus on society and the environment. For example, deforestation and loss of vegetation cover, which are direct consequences of this lack of consideration, lead to a series of problems, such as soil degradation and exposure to erosion. These adverse effects not only affect the capacity of ecosystems to provide essential natural resources, such as food and drinking water, but also increase the vulnerability of communities to extreme weather events associated with climate change (IPCC, 2022a, 2022b).

Analyzing the importance of ecosystems in land use planning requires an objective approach to understanding the wide range of ESs that urban areas provide for human well-being and city functioning (Lehmann, 2021; McPhearson et al., 2015). While these services are fundamental to maintaining the quality of life in urban environments and supporting local infrastructure and the economy (Grunewald et al., 2021), several authors argue that land use planning must consider the conservation and sustainable management of the environment of these spaces as well to ensure the development of healthy and sustainable cities (Fossey et al., 2020; Staiano et al., 2021; Teixeira da Silva et al., 2018). However, these territorial studies approach the problem just conceptually, without focusing on the tools necessary to incorporate them into planning.

Instead, an integrated approach can be especially relevant when considering territorial planning tools, such as the municipal and regional spatial plans. These tools play a crucial role in managing urban and rural development by establishing guidelines for land use and natural resource conservation. However, if planning tools do not consider ecosystem studies and solely focus on urban needs, they risk making fragmented decisions that fail to address long-term environmental challenges. Therefore, it is crucial for land use planning to integrate both urban and rural ecosystem information to ensure the sustainability of cities and their surrounding in the future.

In this context, this study seeks to develop a method that combines assessments of ecosystems and their services with their suitability to be degraded/urbanized according to current land use planning to support the introduction of protection schemes in valuable ecosystems and promote more resilient territories.

The *Mapping and Assessment of Ecosystems and their Services* or MAES project (Maes et al., 2013) provides information on the spatial extent and distribution of key ecosystems by considering the site-specific conditions caused by natural factors such as climate and geology, and the drivers and pressures to which the site is exposed. The proposed typological classification enables the comparison between different parts of the European territory, maintaining a pan-European scale, and regards regular cartographic aspects by applying CLC data for delineation.

The hypothesis of the research is that MAES, the methodology proposed at the EU level for mapping and assessing ecosystems and their services, provides important information for understanding the main stressors acting on ecosystems. However, by not taking into account land use plans that can lead to land use changes and land use that cause environmental degradation, MAES neglects one of the main causes of the problem (McGrane, 2016).

The methodology here proposed combines spatial information from the assessment of ecosystems and their services with current land management plans (zoning). The aim is to identify land sectors that, despite their capacity to provide ES, are considered suitable for future development and/or are not currently included in protection plans. The goal is thus to further inform future planning processes with more arguments to support appropriate decisions/regulations for their conservation.

## 2. Methods and materials

The methodology starts from the premise that the selection of broad habitat or ecosystem types to be assessed for their condition and their contribution to the provision of ESs should be carefully chosen to ensure a balanced representation of relevant European ecosystems. The result is a first level of classification identifying three major groupings of ecosystems (terrestrial, marine, and inland waters). This first level is, in turn, disaggregated into three sub-levels to compare these major groupings with SIOSE.

When identifying the main pressures or direct drivers of change detected by the *Millennium Ecosystem Assessment* (Millennium Ecosystem Assessment, 2005) on these ecosystems, land use planning is a supplementary tool to alleviate upcoming pressures on ecosystems and their services, despite acknowledging the potential benefits that it holds for environmental conservation. Integrating environmental assessment into land use planning requires a compatible scale and access to appropriate information for well-informed decision-making. The proposed methodology endeavors to equip with the essential justifications for land preservation, primarily suited for implementation at the municipal or regional level. The exemplification of such methodology takes place by considering the Spanish case through three steps (Fig. 1):

- Step 1. Introduction of the spatial information about ecosystems.
- Step 2. Assessment of pressures, trends, and impacts on ecosystems.
- Step 3. Ecosystem Protection Categories in accordance with Urban Planning and Climate change Legislation.

### 2.1. Step 1. Introduction of the spatial information about ecosystems

While this methodology proposes the use of the CLC for the European context, the SIOSE (Information System on Land Occupation in Spain, "*Sistema de Información sobre Ocupación del Suelo de España*" in Spanish) is more accurate for the specific Spanish case due to its reference scale (1:25,000 vs. 1:100,000). The scale of municipal land use planning can vary, but tends to be more detailed, usually 1:5000 or even 1:2000 for urban land. However, the scale used for territorial preservation and protection ranges from 1:25,000 to 1:50,000. Spanish land classification and categorization operates at the latter scale, so it is at this level that decisions are taken in the agricultural, livestock, forestry, urban, and environmental sectors.

SIOSE provides other advantages such as minimum mapping unit, hierarchical simplification, and certain types of natural information that are provided by the Spanish Autonomous Communities and the General State Administration, such as the forest map. 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.

This step aims also to establish a connection between the classifications and categorizations of ecosystems used in MAES, EUNIS

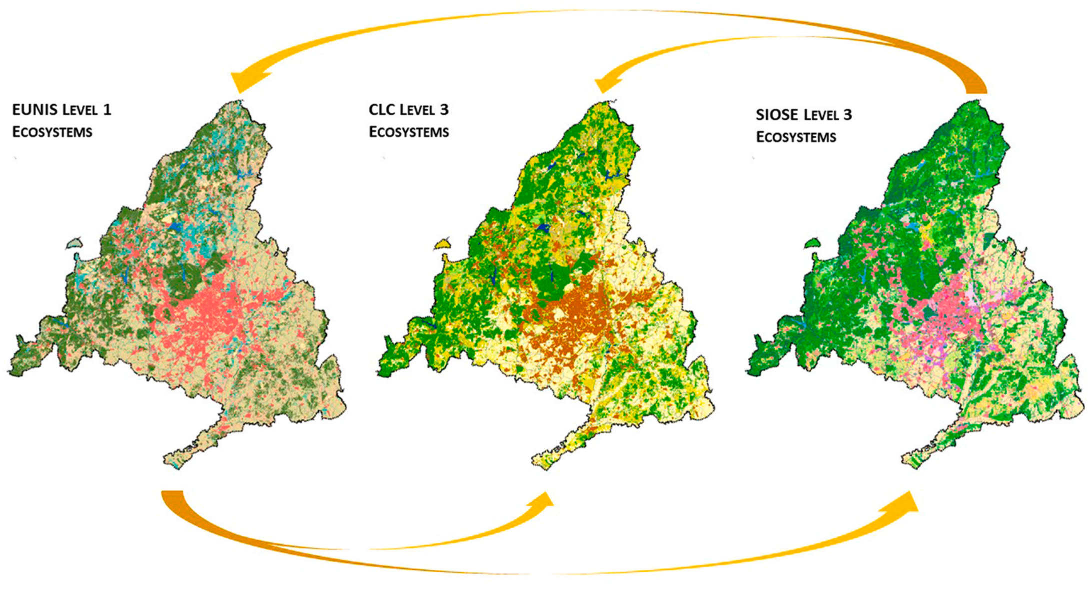



**Fig. 1. Crosswalk between the SIOSE, CLC, and EUNIS projects in the Community of Madrid.**
Source: Córdoba Hernández elaboration (2024).

and SIOSE projects, which is named 'crosswalk.' At the European level, there is an existing crosswalk that correlates and aligns the ecosystem classifications used in the context of the MAES project with the habitat and ecosystem classifications used in the EUNIS project. The added value of the proposed methodology is to add a new relationship element with the Spanish SIOSE, whose purpose is to trigger the interoperability and comparability of the data and results obtained from the three projects. This, in turn, enables better understanding and management of ecosystems (see Table 1).

Once the ecosystems have been grouped, the next step is assessing the human impacts on ecosystems and their effects on the capacity to provide services. This assessment considers 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 invasive species, and pollution and nutrient enrichment) 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.

The identification of ecosystems is performed through the territorially adapted grouping through SIOSE. This methodology groups habitats into 8 terrestrial ecosystem types: urban -URB; cropland -CR; grassland -GR; forest -FR; heathland and shrubland -H&S; sparsely vegetated land -S&V; wetlands -WET, and rivers and lakes -R&L. In this way, the ecosystems least affected by climate change are forests (FR) and sparsely vegetated land (S&V) (Fig. 1).

### *2.2. Step 2. Assessment of pressures, trends, and impacts on ecosystems*

Pressures, trends, and impacts on ecosystems are challenging to assess. 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 ESs 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). This form of classification was promoted by the European Environment Agency in its report "Mapping and assessing the condition of Europe's ecosystems: progress and challenges (2016) and was used as the basis for this research.

Based on the general classification of ES utilized by the Common International Classification of Ecosystem Services (CICES), this research phase establishes the ecosystem contribution to ES supply is identified on the basis of their biophysical dimension and are then evaluated according to the criteria of the "Diagnosis of the territory based on ecosystem services" (Fernández de Manuel et al., 2020) and the research by Jacobs et al., (2013, 2014, 2015). A total of 5 provisioning, 13 regulating and 7 cultural ESs are identified. In

**Table 1**
Crosswalk between the SIOSE, CLC, and EUNIS projects.

| SIOSE Level 3 | CLC Level 3 | EUNIS Level 1 |
|---|---|---|
| 111. Urban core; 112. Expansion area; 113. Discontinuous urban fabric; 114. Urban green area; 121. Agricultural and/or livestock installation; 122. Forestry installation; 123. Mining extraction; 130. Industrial; 140. Service facilities; 161. Road or railway network, 162. Port, 163. Airport; 171. Supply infrastructure; 172. Waste infrastructure | 1.1.1. Continuous urban fabric; 1.1.2. Discontinuous urban fabric; 1.2.1. Industrial or commercial units; 1.2.2. Road and rail networks and associated land; 1.2.3. Port areas; 1.2.4. Airports; 1.3.1. Mineral extraction sites; 1.3.2. Dump sites; 1.3.3. Construction sites; 1.4.1. Green urban areas; 1.4.2. Sport and leisure facilities | J. Constructed, industrial and other artificial habitats |
| 150. Agricultural settlement and orchard; 210. Herbaceous crops, 220. Greenhouse; 236. Combination of woody crops; 250. Mixed crops; 260. Mixed crops with natural vegetation | 2.1.1. Non-irrigated arable land; 2.1.2. Permanently irrigated land; 2.1.3. Rice fields; 2.2.1. Vineyards; 2.2.2. Fruit trees and berry plantations; 2.2.3. Olive groves; 2.4.1. Annual crops associated with permanent crops; 2.4.2. Complex cultivation patterns; 2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation; 2.4.4. Agro-forestry areas. | I. Regularly or recently cultivated agricultural, horticultural and domestic habitats |
| 351. Beach, dune or sandy area; 352. Rock outcrop; 353. Temporarily unwooded due to fires; 354. Bare soil; 516. Glacier and/or perennial snow | 3.3.1. Beaches, dunes, and sand plains; 3.3.2. Bare rock; 3.3.3. Sparsely vegetated areas; 3.3.4. Burnt areas; 3.3.5. Glaciers and perpetual snow. | H. Inland unvegetated or sparsely vegetated habitats |
| 231. Citrus orchard; 232. Non-citrus orchard; 234. Olive grove; 235. Other woody crops; 311. Broadleaved forest; 312. Coniferous forest; 313. Mixed forest | 3.1.1. Broad-leaved forest; 3.1.2. Coniferous forests; 3.1.3. Mixed forests; 3.2.4. Transitional woodland shrub | G. Woodland, forest and other wooded land |
| 233. Vineyard; 330. Scrubland; 340. Combination of vegetation | 3.2.2. Moors and heathland; 3.2.3. Sclerophyllous vegetation | F. Heathland, scrub and tundra |
| 240. Meadow; 320. Grassland | 2.3.1. Pastures; 3.2.1. Natural grasslands | E. Grasslands and lands dominated by forbs, mosses or lichens |
| 411. Wetland and marsh; 412. Peatbogs | 4.1.1. Inland marshes; 4.1.2. Peatbogs | D. Mires, bogs and fens |
| 511. Watercourse; 512. Lake or pond; 513. Reservoir; 514. Artificial waterbody | 5.1.1. Water courses; 5.1.2. Water bodies | C. Inland Surface waters |

Source: Córdoba Hernández elaboration (2024) this way, the ES can be mapped independently to obtain results at other levels such as the groupings of ESs by families of contribution (provision, regulation, and cultural; see Table 2) or by their overall territorial relevance.

The most sensitive ecosystems to deterioration or loss of ESs is here determined using the same proposed grouping as in the case of the direct drivers of change based on the MAES ecosystem grouping map. The objective of step 2 is to identify ecosystems that offer high or very high value in terms of ESs and are deserving of special protection to prevent depletion or disappearance. These ecosystems are evaluated based on their individual contributions as well as their interactions, resulting in a more comprehensive assessment of their relevance. The new scale ranges are established taking into account the assessments provided by different sources at international (Henderson, 2015; Longcore & 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 (Table 2).

High-value areas for a specific ES are identified through a detailed analysis that considers the capacity of an area to offer and sustain that specific ES in a significant and sustainable manner. These areas become benchmarks within a territory because of the intensity or exceptional quality with which they provide a vital service. For example, a wetland with outstanding water filtration and purification capacity, can reduce flooding and provide habitat for aquatic species, would have a high value for water regulation services. These areas not only fulfill their functions exceptionally but also offer additional benefits such as providing habitats for biodiversity, recreation, tourism, and cultural benefits for neighboring communities.

### *2.3. Step 3. Ecosystem protection categories in accordance with urban planning and climate change legislation*

Considering vulnerability as the propensity or predisposition to be negatively affected by a series of changes, two aspects that directly impact ecosystems and planning can be identified and encompassed by the broader concept of 'Ecosystemic Vulnerability due to Planning'. Step 3 suggests two subcategories of this vulnerability based on the criteria introduced by the fourth Final Provision of Law 7/2021, which is analyzed in Section 1.3.:

- Ecosystem vulnerability in relation to the ecosystem and biodiversity loss due to the five direct drivers of change identified by the Millennium Ecosystem Assessment (2003). This vulnerability regards the identification of 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 Table 1 (Section 2.2). Non-urban ecosystems that would suffer future anthropization would deteriorate their resilience due to a lower ESs they would receive. The deterioration of natural habitats into urban ecosystems by means of urban expansion, new roads, and soil sealing is expected to have the following repercussions: the reduction of the capacity to adapt to possible adversities; the risk of floods, fires, droughts, or heat waves would increase due to the depletion of ecosystems that are better adapted to these issues than urban ecosystems; the introduction and spread of invasive and exotic species would damage the preexisting species and biological communities; and, eventually, the increase in waste, sludge, water, or air pollution would reduce the capacity to adapt to changes compared to the previous situation.
- Ecosystem vulnerability to land use planning in relation to the degradation or loss of essential ecosystem goods, functions, and services concerns ecosystems with high or very high values in their contribution of goods-services and not protected by land use planning. Their values make them worthy of special protection to prevent their disappearance or depletion. The territorial implications of anthropization can be assessed in detail for each of the services and constitutes the reasons for protection of one, two or all three families of ecosystem contributions. However, due to the interdependence between the three inputs, it seems logical to

**Table 2**
Intensity of the impact of direct drivers of change on ecosystems at the territorial level.

| Main direct drivers of change | URB | CR | GR | FR | H&S | S&V | WET | R&L |
|---|---|---|---|---|---|---|---|---|
| Habitat transformation | VH | VH | M | H | M | H | VH | VH |
| Climate change | M | M | M | L | M | L | M | M |
| Overexploitation of resources | L | H | L | M | L | M | H | H |
| Introduction of invasive species | H | M | M | M | M | L | M | M |
| Pollution and nutrient enrichment | VH | VH | L | M | L | L | VH | VH |

URB: urban; CR: cropland; GR: grassland; FR: forest; H&S: heathland and shrubland; S&V: sparsely vegetated land; WET: wetlands; and R&L: rivers and lakes

| | Low | Medium | High | Very High |
|---|---|---|---|---|
| Legend | L | M | H | VH |

Source: Córdoba Hernández (2021)

simultaneously consider contributions and synergies between them to assess the losses caused by the anthropization. This consideration implies that the resilience capacity of an ecosystem is directly related to both the number of species and the transfer of its ecosystem functions. Therefore, both territorial and municipal planning should take these issues into account by favoring the protection and conservation of ecosystems with the greatest diversity and ecological functions.

By cross-referencing data on unbuilt land and land designated for development in accordance with the current land use plans and the ecosystem assessments mentioned in Step 2, it is possible to generate a map that identifies potential vulnerabilities within the territory. This map must consider all types of land classification, including planned but undeveloped urban areas, those already built, and the land protected by municipal regulations, territorial plans, and sectorial legislation (on matters of natural areas, forests, livestock trails, and water) that would be applicable in the event of a modification of the existing planning tool. Therefore, the vulnerable area identified by this methodology includes land not subjected to the restrictions that could otherwise limit their development, as well as ecosystems that are highly vulnerable to impacts. These ecosystems demand special attention from municipal and territorial planning to ensure their preservation in future modification of planning tools.

## 3. Results

### 3.1. Intensity of the impact of direct drivers of change on ecosystems at the territorial level

The application of the methodology enables to identify the most susceptible or fragile ecosystems as presented in Table 2. According to the ecosystem categories proposed in the MAES project, the most affected areas by habitat transformation are:

- Urban ecosystems. Due to cities expansion, urban ecosystems are among the most impacted by these transformations. This expansion involves the conversion of natural areas into urban infrastructure, resulting in the loss of green spaces, the fragmentation of natural habitats, and the interruption of ecological corridors. Urbanization also increases soil imperviousness, which affects the water cycle and leads to increased flood risks. Additionally, the concentration of human activities in urban areas generates pressure on resources, leads to greater levels of air and water pollution, and diminishes overall environmental quality.
- Croplands. They undergo significant transformations due to intensive agricultural practices. The extensive utilization of agrochemicals and monoculture have negative impacts on land conditions and reduce biodiversity. Consequently, this leads to adverse problems, including land erosion, loss of natural habitats, and reduced provision of essential ESs.
- Wetlands, rivers, and lakes. The conversion of wetlands and the alteration of rivers for agricultural or urban activities reduces aquatic biodiversity, disrupts natural hydrological cycles, and impairs water filtration. These activities have a significant impact on habitat quality and water resource availability.

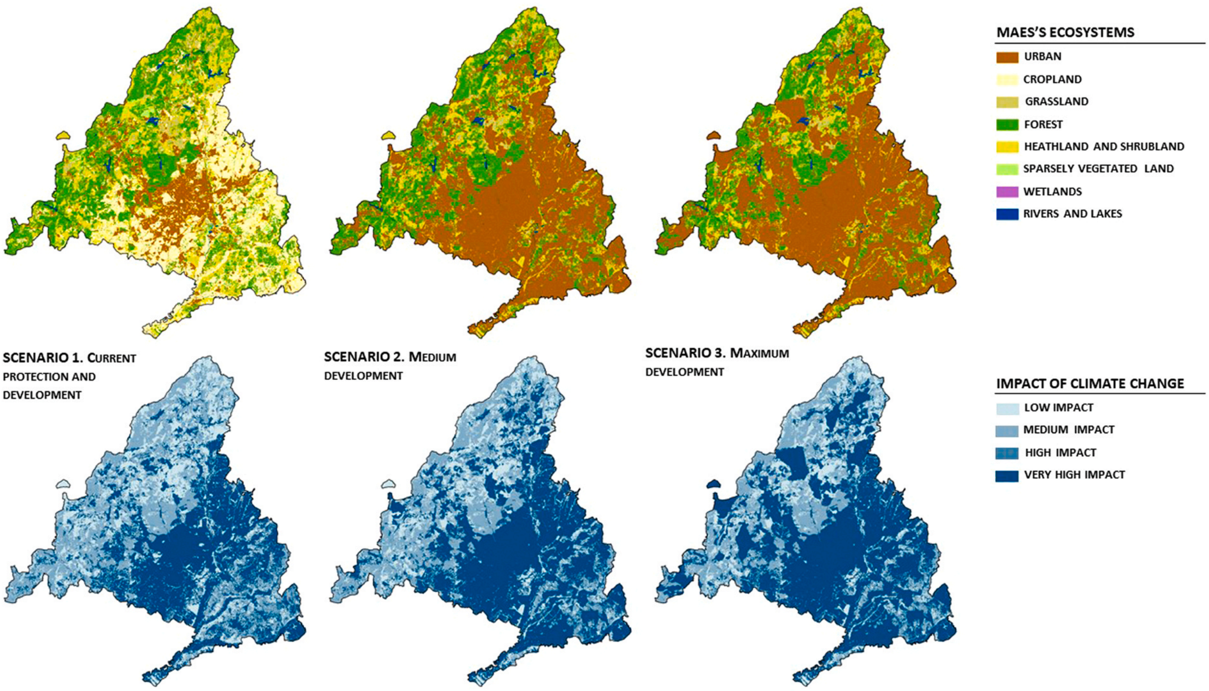



**Fig. 2.** Exemplification of the degree of impact of climate change in three different scenarios of urban development in the Community of Madrid. Source: Córdoba Hernández elaboration (2024).

All these areas present moderate or low impacts of climate change for various reasons. Urban areas generate and retain heat due to density, creating an "urban heat island" effect. While this can lead to higher temperatures locally, it typically does not result in significant large-scale climate change. In the case of croplands, the adoption of modern agricultural practices, such as efficient irrigation systems and more resistant crops, acts as an adaptation mechanism in the face of climate variations. These measures can mitigate the effects of climate change, reducing its impact in terms of extreme changes in temperature and precipitation. Wetlands and rivers are situated in less urbanized areas, so they are less susceptible to abrupt temperature alterations. Nevertheless, they remain susceptible to fluctuations in precipitation patterns and severe events, such as floods or droughts, which could exacerbate due to climate change. Despite their natural resilience, these ecosystems are sensitive to climatic changes and alterations in hydrological regimes. Therefore, it

**Table 3**
Biophysical assessment of the different contributions of each family of services.

| | | Main ecosystems according to MAES | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ecosystem services | GRE | CR | GR | FR | H&S | S&V | WET | R&L |
| PROVISIONING | Food | L | H | H | L | M | - | L | L |
| | Fresh water | - | - | H | H | M | L | H | H |
| | Raw materials | - | L | L | M | L | - | - | - |
| | Genetic diversity | M | H | H | H | H | M | H | H |
| | Natural active ingredients for medicinal use | M | M | L | L | H | L | - | - |
| REGULATION | Habitat maintenance | M | M | H | H | H | H | H | H |
| | Climate | M | L | M | H | M | L | M | M |
| | Noise reduction | H | - | - | H | L | - | - | - |
| | Thermal buffering | H | L | M | H | M | L | A | A |
| | Air quality | H | L | M | H | M | L | A | A |
| | Hydrological cycle | M | - | H | H | H | L | A | A |
| | Erosion control | - | - | H | H | H | M | - | - |
| | Soil fertility | - | - | H | H | H | L | - | - |
| | Natural disturbances | - | - | H | H | H | - | H | H |
| | Biological control | H | M | H | H | H | H | H | H |
| | Pollination | M | H | H | L | H | M | - | - |
| | Endemic species conservation | - | M | H | H | H | H | H | H |
| | Soil production | - | - | M | H | M | L | - | - |
| CULTURAL | Recreation | H | - | M | H | M | - | H | H |
| | Scientific knowledge | H | H | H | H | H | H | H | H |
| | Environmental education | H | M | H | H | H | H | H | H |
| | Traditional knowledge | - | H | L | H | M | - | L | M |
| | Landscape enjoyment | M | H | H | H | M | - | H | H |
| | Cultural identity | L | H | H | H | H | L | H | H |
| | Cultural inspiration | M | L | M | H | M | L | H | H |

GRE: green zones in urban areas; CR: cropland; GR: grassland; FR: forest; H&S: heathland and shrubland; S&V: sparsely vegetated land; WET: wetlands; and R&L: rivers and lakes

| | Low | Medium | High | Low | Medium | High | Low | Medium | High |
|---|---|---|---|---|---|---|---|---|---|
| Legend | L | M | H | L | M | H | L | M | H |

Source: Córdoba Hernández (2021)

is essential to protect and conserve them as they play a vital role in maintaining ecological balance.

Fig. 2 shows how certain ecosystems would suffer urbanization according to the different municipal degree of protection in the Autonomous Community of Madrid (Spain). Scenario 1 represents current protection and development, Scenario 2 medium development, and Scenario 3 maximum development. As a result, climate change and related effects such as temperature rise, and land use change will affect the regional territory depending on the scenario. This formulation comes from a larger research included in the UN-HABITAT's 3rd Compendium of Inspiring Practices of the Urban-Rural Linkages to Advance Integrated Territorial Development (Córdoba Hernández, 2023).

Croplands, wetlands, lakes, and rivers are the most prone to resource overexploitation, i.e., where agricultural intensification has evident impacts. The intensive farming practices involve extensive usage of agrochemicals, frequent application of pesticides and fertilizers, as well as monoculture. These practices rapidly deplete land nutrients and thus decrease quality. Overexploitation can cause land degradation, reducing its ability to produce and increasing susceptibility to extreme weather events like droughts or floods. Furthermore, the overexploitation of groundwater in these areas, particularly in croplands, wetlands, and surroundings of lakes and rivers has resulted in an alarming decline in water levels. This depletion can cause a reduction in the volume of water in rivers and lakes, thereby impacting aquatic ecosystems and the accessibility of water for human and agricultural purposes. The overexploitation has already led to reduced water flows, wetland decline, and loss of biodiversity among aquatic ecosystems, all underscoring the urgency of implementing sustainable resource management practices. Priority should go towards land fertility conservation and water source protection for the sake of their long-term viability.

The introduction of exotic plant and animal species poses potential risks, with the highest risk being in urban areas where invasive species are being introduced to gardens. Grassland ecosystems, in contrast, would have minimal impact.

Finally, the effects of pollution and nutrient enrichment would negatively impact urban ecosystems, crops, wetlands, lakes, and rivers. Land contamination from heavy metals due to industrial activities, air pollution, critical ozone levels, and water pollution resulting from inadequate management of sewage, sludge and waste are major concerns.

### *3.2. Biophysical assessment of the different contributions of each family of services*

This section shows the most sensitive ecosystems using the proposed MAES grouping. This determination is subsequently used to establish the Ecosystem Vulnerability related to the degradation or loss of necessary ecosystem goods, functions, and services. The purpose is to identify ecosystems that provide ESs of high or very high value to warrant special protection against their depletion or disappearance (Table 3).

#### *3.2.1. Identification and assessment of provisioning ESs*

Based on the data presented in Table 3 which outlines ESs categorized under CICES, a first ES regards "food provision", which is prominently located in the pastures, where livestock is provided with food, and in the croplands. In other ecosystems, such as heaths and heathlands, the extent of their honey production remains relatively unexplored. Nevertheless, it is the Castilian plateau that boasts the greatest output of honey. Parks are included as potential food producers due to their ability to function as such in urban areas with minimal variation in tree management policies. Additionally, wetlands, rivers, and lakes have the potential to produce amphibians and fish for consumption. However, legislative reasons prevent these ecosystems from being used for food production. A second ES is "fresh water". We have evaluated not only water sources that directly provide water supply but also those that can aid in filtering water into aquifers, such as grasslands, forests, and heathlands. It is worth mentioning that well-maintained urban parks may significantly contribute to water purification. A third ES is the utilization of "raw materials". Eventually, the natural active ingredients for medical use are assessed based on the presence of common shrubs and herbs in this traditional practice, which are more closely related to shrubs than to forests.

#### *3.2.2. Identification and assessment of regulating ESs*

ESs related to "habitat maintenance" and "endemic species conservation" have a crucial role in enhancing territorial resilience. Habitat maintenance ensures the stability and productivity of natural environments by providing shelter and sustenance for biodiversity. This function is critical for maintaining the ability of ecosystems to adapt and recover from pressures or changes, thus enhancing the regional resilience to environmental hazards, including climate change and biodiversity loss. Endemic species conservation, whether referring to animal or plant species, has a significant impact on specific geographic areas and this is why territorial planning plays an essential role. These unique species have adapted to their environment, making them a crucial component of the ecological balance and an indispensable part of territorial resilience. Protecting these species not only conserves biological diversity, but it also preserves traditional knowledge and unique species-environment interactions. This preservation enhances ecosystem resilience and adaptability to change, thus improving long-term regional stability and capacity to provide critical human services.

It is vital to safeguard ecosystems that contribute to "climate regulation". Natural ecosystems like forests offer ESs that include carbon sequestration, temperature regulation, air purification, and modulation of local and regional climate patterns. These ESs are essential for their capacity to sequester carbon, which helps to mitigate climate change by reducing greenhouse gas concentrations in the atmosphere. Additionally, ecosystems like forests, wetlands, and green areas assist in regulating temperatures and moderating local climatic conditions. This, in turn, mitigates the impact of extreme heat waves or abrupt climate variations.

Regulating ESs contribute to improving "air quality" by filtering pollutants and particulate matter, promoting healthier environments for human life and biodiversity. The preservation and restoration of these ESs are decisive for territorial resilience, as they not only help to cope with climate change, but also contribute to maintaining environmental stability, public health, and the capacity of territories to adapt to future climate challenges.

"Thermal buffering" is also crucial for strengthening territorial resilience. These ESs, provided by ecosystems such as forests, green areas, and water bodies, help moderate and reduce the impact of extreme temperatures. Their cooling function contributes significantly to a region's adaptation to climate change and extreme weather events. These ecosystems serve as effective natural thermal regulators by providing shade, facilitating evaporation, and promoting evaporative cooling of water. Reducing local temperatures helps to alleviate heat stress in urban and rural areas, thereby lessening its impact on human health and infrastructure. Conserving these ESs also helps to maintain natural water cycles, contributing to enhancing biodiversity. These factors strengthen territorial resilience of communities to extreme climate conditions and advance the creation of livable and sustainable environments in the long run.

"Soil fertility" plays a crucial role in sustaining the productivity and health of ecosystems, contributing to maintaining soil quality and fertility through natural processes like organic matter decomposition and soil biological activity. Natural soil fertilization is essential for agricultural production, native vegetation growth and biodiversity conservation, all of which will be affected by climate change in the future. Robust and fertile soils not only support food security and sustainable crop production, but also enhance ecosystems' ability to withstand and recover from disturbances like droughts or floods. In addition, by maintaining soil structure and fertility, regulating ESs help to "erosion control", improve water and nutrient retention, and reduce the effects of soil degradation, thereby strengthening the capacity of territorial areas to maintain sustainable ecological systems. The uncontrolled flooding of rivers, which deposits sediments in meadows and alters the course of rivers, is one of the most fascinating natural phenomena. The existence of rivers and wetlands, where such activity can occur freely, is of significant value.

ESs linked to "natural disturbances", like forest fires and floods, are crucial for territorial resilience by facilitating regeneration and balance in ecosystems. Although these events may seem destructive, they play essential roles in renewing and eliminating dead material, which promotes biodiversity. Protecting these habitats depends on their ability to regulate natural cycles, mitigate disasters, and act as buffers, such as absorbing excess water during floods, increasing environmental resilience, and enabling human communities to cope with extreme events.

Other ESs, such as "soil production", "hydrological cycle", "pollination", "biological control", and "noise reduction", have a direct correlation with resilience to the effects of climate change. Forests, wetlands, and natural areas support these ESs, which play a crucial role in mitigating and adapting to the impacts of climate change. For instance, soil production in forests and natural ecosystems helps to sequester carbon, thus mitigating the increase of greenhouse gases in the atmosphere. Additionally, these ecosystems are pivotal for regulating the hydrological cycle, which reduces the frequency and intensity of floods and droughts caused by climate change. Pollination, performed by the biodiversity present in these ecosystems, is decisive to guarantee crop production in an ever-changing climate. The biological control that these natural habitats provide helps to maintain the balance of agricultural ecosystems, lessening pressure on resources and boosting their resilience to pests and diseases, which can become more severe in altered climactic environments. Eventually, preserving green spaces and reducing environmental noise in urban ecosystems directly enhances the quality of life for communities, serving as a protective measure against the harmful effects of climate change on individuals' mental and physical health.

### *3.2.3. Identification and assessment of cultural ESs*

The loss of cultural ESs has significant implications concerning climate change and territorial resilience. The current climate crisis poses a direct threat to preserving cultural and ecosystem values, thereby reducing the adaptive capacity of communities in response to these changes.

The decrease in "scientific knowledge" and access to "environmental education", impacted by the degradation of natural environments, hampers our understanding and ability to respond to climate change effects. These factors are vital for implementing

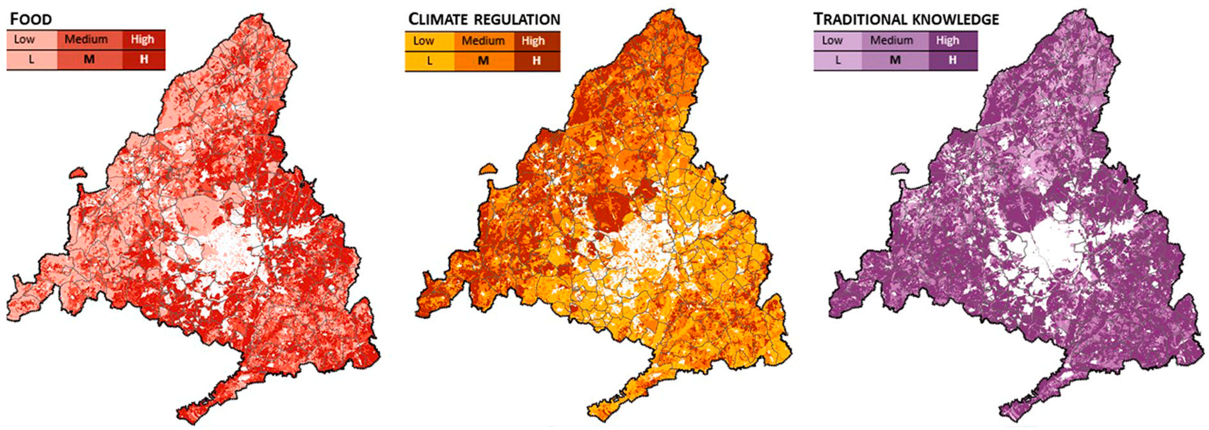
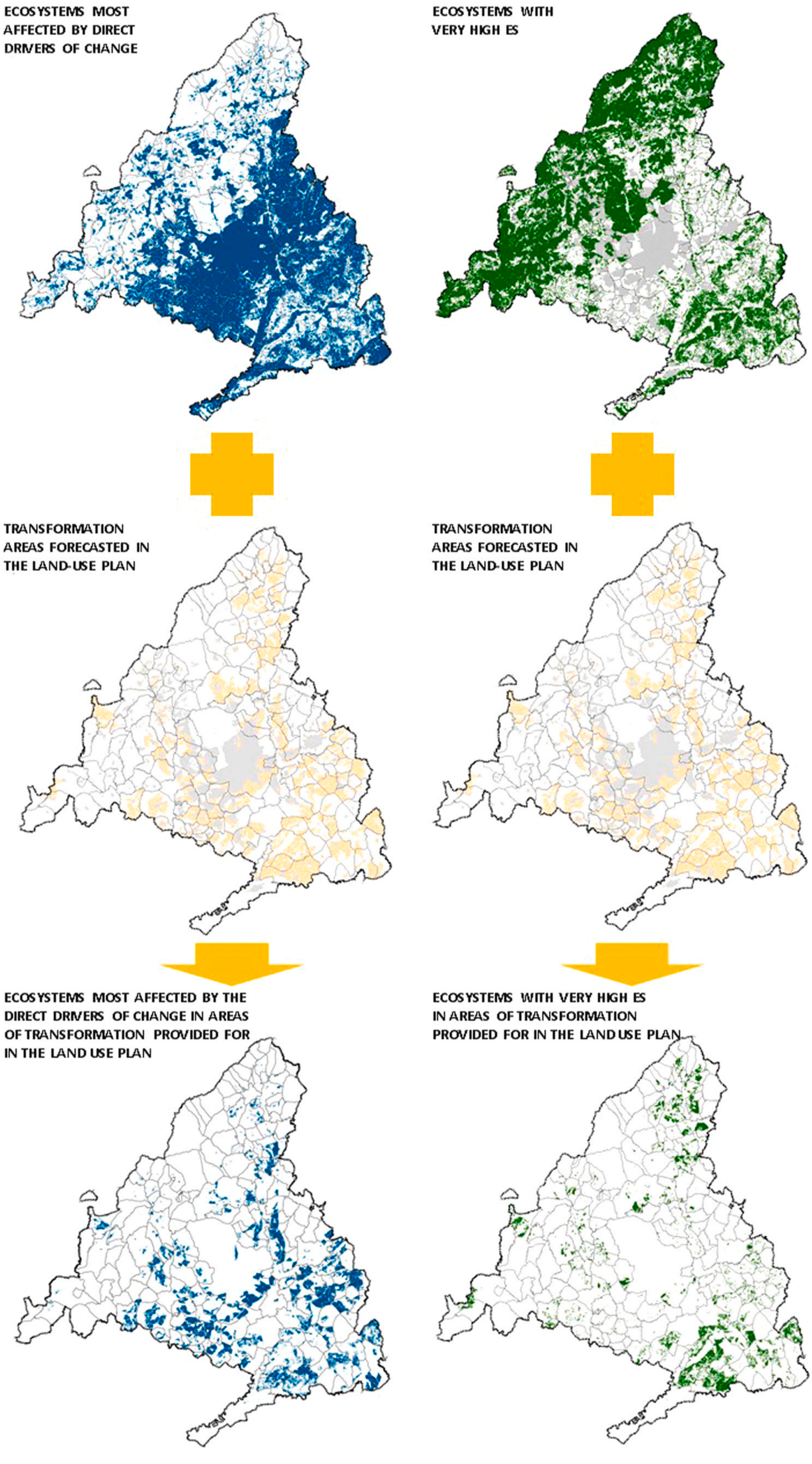



**Fig. 3.** Spatial distribution of food provision, climate regulation and traditional knowledge according to the ecosystem capacity to supply them. Source: Córdoba Hernández elaboration (2024).




(caption on next page)

**Fig. 4. Ecosystems most affected by the land use plan-fostered transformation depending on direct drivers of change (blue; on the left) and ESs (green, on the right).**
Source: Córdoba Hernández elaboration (2024).

adaptive measures and mitigation strategies capable of dealing with environmental impacts. The loss of "traditional knowledge" poses a significant threat, as it frequently includes resilient strategies that have been developed over generations to adapt to environmental changes. Diminished traditional knowledge curtails the adaptive capacity of local communities when confronted with extreme climatic events or ecological pattern shifts. Furthermore, the impacts on "recreation", "landscape enjoyment", and "cultural identity-inspiration" can hinder individuals' emotional and spiritual ties with nature. Consequently, this disconnection may result in reduced care and concern for environmental preservation, leading to weakened endeavors to enhance territorial resilience..

### *3.3. Identification of the vulnerability based on the proposed methodology*

The comparison of existing land use planning protection with ecosystem assessment raises a concern: certain land, which holds a remarkable capacity to adapt positively to environmental changes, could be adversely affected by the urbanization process. Urban expansion not only risks weakening the natural conditions of land but also threatens its ability to properly adapt to future stress. Therefore, it is crucial to avoid jeopardizing the intrinsic strengths of these spaces.

Identifying both *Ecosystem vulnerability in relation to the ecosystem and biodiversity loss due to the five direct drivers of change identified by the Millennium Ecosystem Assessment* and *Ecosystem vulnerability to land use planning in relation to the degradation or loss of essential ecosystem goods, functions, and services,* and solve them, is a key goal of this methodology. The absence of ecosystem protection may entail future risks for the sustainability and resilience of a specific territory. Thus, once vulnerable areas are identified, the necessary measures should be taken to protect land and establish a regime of compatible land use to prevent future threats.

The application of the methodology identifies ecosystems that, regardless of current planning contents, should be protected or preserved to maintain the existing resilience, whether it is high or low.

Drivers of change have the greatest impact on crop, wetland, coastal, river and lake ecosystems (Fig. 4, on the left), while forests, heathlands, and shrublands provide the greatest services to society (Fig. 4, on the right). All of them should be protected for any reason to maintain or increase the current territorial resilience.

The least protected ecosystems would be those belonging to pastures and lands with scarce vegetation since they would not have a very high value in either of direct drivers or ESs. The proposed methodology for determining these values does not, however, deprive of a certain degree of flexibility, for example, to extend the scope of protection to those ecosystems with high or medium values, if this is considered necessary or unique in the area.

Until Law 7/2021 on climate change and energy transition was approved, the basic criteria for land use planning did not mention the necessity of considering risks related to the loss of ecosystems and biodiversity, especially the decay or destruction of essential ecosystem goods, functions, and services. Being aware of these risks and not protecting land to avoid risks would be a mistake for our future as they are fundamental elements to establish adequate territorial resilience.

## 4. Discussion

Too often, many action that address climate change mitigation and adaptation focus on everything but nature, emphasizing elements such as public transportation, renewable energy production (Córdoba Hernández et al., 2023), or energy-efficient building systems (Cortinovis & Geneletti, 2018). While important, these aspects alone are insufficient for reinventing urban life. A vision for sustainable future territory must have as a priority the preservation and integration of natural green spaces and ways of life (Longato et al., 2023).

Land use planning has traditionally sought to organize land use and regulate the conditions for its transformation or protection, becoming an essential instrument for the making of cities and their surroundings and the implementation of public policies such as the environmental ones. Although land use planning has demonstrated sufficient capacity to adapt to changing times and ensure the proper implementation of public policies, this has not always been the case. Due to various factors, such as the development of real estate megaprojects or the degradation of protected areas, it is not always possible to prevent environmental damage.

Moreover, land use planning aims to identify existing (and future) risks and provide responses to societal challenges, such as climate change, to improve current and future human-nature relations. However, these tasks are often hindered by various factors, including economic and political interests, lack of stakeholder coordination, limited financial resources, socioeconomic inequalities, and institutional inertia. While national, autonomous, or sectoral legislation is often blamed for this, the problem is usually the interpretation of the instrument rather than the instrument itself.

These are the reasons why land use planning should directly incorporate the obligations arising from European policies on climate change by, for instance, adapting the land use plan to the adverse effects of hydrological changes or analyzing the ways urban development may affect greenhouse gas emissions. The proposed methodology is a feasible tool to deal with these challenges and to respond to the obligation and responsibility to articulate climate-resilient planning. The potentialities identified in different international ecosystem territorializations, such as the European Nature Information System (EUNIS) or the Mapping and Assessment of Ecosystems and their Services (MAES), need to be adapted to the specificities and the local scale to provide a systematization adaptable to different territories.

This paper proposes a novel way that tries to do so via integrating ES knowledge into land use planning. By doing so, it enables to develop future new capabilities such as a wider involvement of challenging issues to address during the management process of land use planning (Córdoba Hernández & Camerin, 2023; Longato et al., 2023); the incorporation of an ES-based perspective to decipher various data and information (Arkema et al., 2015; Verutes et al., 2017), and establishing a foundation for a fruitful stakeholder participation into the decision-making process (Adem Esmail & Geneletti, 2017; Spyra et al., 2019). Overall, these improvements can make a contribution to legitimate decisions on more sustainable spatial allocation of uses and management options (Longato et al., 2021). In particular, the sorts of futures literacies/capabilities that it can expect planners to develop through using the proposed methodology and the sorts of future cities that might emerge because of this research can be the following:

- The implementation of this research can lead to the projection and improved understanding of eventual urban development scenarios to assess how changes in ecosystems and land use could influence the configuration and functionality of future cities. This involves not only envisioning what cities might look like, but also understanding how they will function and adapt to emerging environmental and socio-economic challenges. The methodology provides an approach to make better informed and strategic decisions with a more holistic vision that consider the long-term impacts by integrating the MAES methodology into land use planning. This fact allows to develop more sustainable and resilient strategies that address increasingly complex issues such as environmental conservation and risk management, along with quality of life. By providing a deeper understanding of how ecosystem change and spatial planning influence urban development, this research paves the way for more sustainable, adaptive cities capable of dealing with future environmental challenges.
- The methodology can thus support a variety of planning decisions for a more sustainable spatial allocation of uses and management options based on the understanding that it provides on the role of biodiversity, its relationship with ESs, and the different conceptual frameworks established at the international level for their assessment. These novelties are fundamental for adapting land use plans toward better human-nature relationships (Baffo et al., 2023; Nti et al., 2022). The regional and local application of the methodology will promote the design of territorial and municipal land use plans that consider the main pressures on ecosystems and their services (Jia et al., 2023) and address them where land use planning prescriptions are lacking (Córdoba Hernández, 2021). Additionally, land use planning protection for a specific territory does not exempt it from a series of risks affecting its ecosystems. However, the protection derived from land use planning tools provides with arguments for preserving or protecting areas currently highly affected by risks or whose situation could worsen according to the planning-induced decisions for future developments and/or protection.
- The use of an ecosystem assessment to identify crucial ecosystem areas for maintaining territorial resilience and biodiversity will significantly impact land use planning and the promotion of legally binding protection schemes. The proposed methodology enables the identification of areas with significant ecological importance, highlighting the zones that require protection to maintain their functionality and contribution to territorial resilience. A careful integration of these findings into land use planning processes can result in the development of specific strategies for conserving and sustainably managing these spaces. This would require enacting regulations and policies that advance the preservation of these ecosystems by designating protected areas or imposing limitations on human activities that may adversely impact their integrity.
- The proposed methodology identifies the different ecosystem inputs and adds a new set of attributes to the previous ecosystems by considering the existing interactions between ecosystems and their own inputs. Therefore, this information can be incorporated from the early stage of the land use proposal for the future. This aspect meliorates not only the quality of the information provided, but also the outcome, as ESs are essential in planning cities based on the quality of life. The new information generated on ecosystems can be used in the different phases of the formulation of planning documents to identify alternatives and the impacts of urbanization on the natural environment and ecosystems. In this way, a regional or statewide database of this information can allow the systematization of the rationale for land protection or the redefinition of existing land use plans according to environmental risks or existing ecosystem contributions.
- The comparison of current planning protection with the proposed assessments allows to identify those transformation areas forecasted in the land use plan whose capacity to positively adapt to change would be most severely compromised by urbanization. Moreover, from the point of view of resilience, this approach from a more local scale would favor the establishment of uses that are more compatible with the ES to be protected, preserved, or implemented by municipal regulations. Consequently, the methodology can directly support innovative performance of land use planning for two main purposes. On the one hand, to direct influencing habitat transformation since land use planning identifies, in accordance with the typology of classes provided for by Regional Laws, land to develop and protect (Newbold et al., 2015). On the other hand, the methodology can provide valuable arguments and evidence during the planning process for a wider and substantial implementation of ecosystem protection schemes in land use planning that can limit the loss of territorial resilience in the light of, e.g., climate change impacts and overexploitation of resources.
- Habitat transformation was identified as a pressure among the direct drivers of change so it should be linked to land use planning activities. At the European level, only the direct degradation of habitat elements or functions, or the loss of a habitat and its replacement, is analyzed in terms of its impact on biodiversity. In other words, ex-post effects are analyzed. As land use planning identifies areas to develop it would become relevant for assessment. The use of planning as a factor can thus detect future effects of a land use plan on ecosystems so decision makers can be able to modify the planning tool according to planning-induced impacts and decrease in resilience. The comparison of the current land use planning guidelines with the proposed assessments allows the identification of areas subjected to forecasted urban transformation. The identification of such land corresponds to the "land for development"' and can be performed 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. The disappearance of this kind of land may result in the impossibility to reinforce endogenous weaknesses and to eliminate a large part of the response capacity.
- The identification of high-value areas is crucial for environmental management and land use planning as it allows targeting conservation, restoration, and even sustainable efforts to maximize ES efficiency. When multiple high-importance ESs overlap in an area, a zone of high multifunctional relevance emerges. This is essential for environmental balance and human well-being. The understanding and precise delimitation of these high-value areas for specific ESs provides a solid basis for the development of more effective and sustainable territorial management strategies, considering both nature conservation and human needs.

In contrast with other European countries, Spain's decentralized administrative structure due to its system based on 17 Autonomous Regions (*Comunidades Autónomas*) generates variations in the implementation of instruments, including land use plans called "General Urban Development Plans" (*Planes Generales de Ordenación Urbana*). This setting facilitates the implementation of the methodology by providing a decentralized framework that enables adjustment of planning tools to regional particularities, ultimately advancing the incorporation of specific factors in each locality. Furthermore, the variety of territorial approaches and priorities necessitates the examination of a broader range of factors during the planning process. This approach can enhance the evaluation of ecosystems and their services. At the regional level, territorial strategies can vary in their objectives and approaches according to regional priorities, but this variability should not affect the outcome of territorial protection. Generally, there is an increasing emphasis on sustainability, including the integration of environmental, social, and economic considerations into planning, reflecting varying regional contexts and priorities.

## 5. Conclusion

For the European Commission, one of the feasible solutions towards resilience can be the creation of a strategically planned network of high quality natural and semi-natural areas with other environmental elements. These elements should be designed and managed to provide a wide range of ESs and protect biodiversity in both rural and urban areas, including green and/or blue spaces and other physical elements in terrestrial and marine areas. The proposed methodology tries to systematize, based on the information provided by public and administrative data sources, the process for identifying areas at risk due to their ecosystem vulnerability and lack of planning protection. These areas, in turn, may be included in the same European-Commission-envisaged large green infrastructure.

This identification is of great importance in the European context as it can allow joint decisions and policies by the European Commission to address the problems of biodiversity and ecosystem loss. However, due to the territorial scope and scale of work, EU strategies and policies need to be downscaled and adapted at the national level to be effectively implemented. For this reason, the main contribution of the research is the introduction of land use planning as a factor in the ecosystem assessment results in the inclusion of a new element of direct pressure on ecosystems. This novelty would be useless to include in EUNIS and MAES due to the considerable differences between planning systems at the European level.

It is at the local scale, where this methodology is proposed, that land use planning is best managed and can make the greatest contributions to climate change adaptation and to the other four direct drivers of change: habitat change, resource overexploitation, introduction of invasive species, and pollution and nutrient enrichment. It is also at this scale that the provision of ESs can have the greatest impact on increasing the resilience of an area.

The results of its application can support the creation of legal instruments that establish concrete conservation measures, such as legislation for the protection of natural areas, the establishment of reserves or parks, and the implementation of restoration programs for degraded ecosystems. It can also influence the formulation of policies at the local, regional, or national level to ensure the effective and continuous application of conservation measures.

These aspects acquire even more relevance as resilience comprises multiple dimensions and does not only encompass issues arising from climate change. Ecosystem assessment may help not only to develop a new model for the city-making and to modify existing urban development patterns while drafting a new land use plan. The added value of this methodology regards its capacity to address the increasingly societal threats and ensuring the preservation of the most vulnerable spaces by avoiding new waves of urbanization.

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## CRediT authorship contribution statement

**Federico Camerin:** Writing – review & editing, Writing – original draft, Resources, Formal analysis, Conceptualization. **Rafael Córdoba Hernández:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Methodology, Investigation, Formal analysis, Conceptualization.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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