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ECOSYSTEM VULNERABILITY ACCORDING

TO THE LAND PROTECTION PLANNING OF THE COMMUNITY OF MADRID[1]

LA VULNERABILIDAD ECOSISTÉMICASEGÚN EL PLANEAMIENTO EN LA PROTECCIÓN DEL SUELO DE LA COMUNIDAD DE MADRID

RAFAEL CÓRDOBA HERNÁNDEZ 2

1 This article considers results of the doctoral thesis, “La estructura territorial resiliente: Análisis y formalización a través del Planeamiento Urbanístico” within the Doctorate on “Urban Regeneration and Sustainability, of the Universidad Politécnica de Madrid, Spain

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La *Vulnerabilidad Ecosistémica según el Planeamiento* (VEP) buscar valorar el papel de los servicios ecosistémicos para el mantenimiento y fortalecimiento de nuestras ciudades través de la identificación de los ecosistemas, su valoración y consideración desde la planificación. Esta investigación es una adaptación metodológica de un proyecto europeo que busca, a través de una propuesta de la Agencia Europea de Medioambiente, cartografiar sus ecosistemas y las presiones que reciben. Gracias a ello se deberían establecer políticas reductoras de estas presiones sobre el medio natural o evitar traspasar niveles críticos con el resultado de cambios en su nivel de resiliencia. La consideración del planeamiento como otro factor de presión supone la visibilización de un nuevo riesgo para estos ecosistemas que, si bien no había sido contemplada por el momento, tiene una gran relevancia en nuestro contexto. En ese sentido, es preciso aumentar la escala de trabajo y contar con las previsiones de crecimiento y protecciones de suelo existentes cuya información a nivel internacional sería muy difícil de homogenizar y obtener. Así, esta propuesta metodológica se centra concretamente en la Comunidad de Madrid (España) para identificar las presiones contempladas por la metodología europea y sumar una nueva variable que altera el riesgo de pérdida de estos sitios. El caso de estudio plantea desafíos importantes debido a la alta presión urbana presente, pero ejemplariza la problemática de los ecosistemas en el área analizada, identificando los espacios con menor resiliencia conjunta antes estos cambios, a razón de su predisposición a la urbanización.

Palabras clave: desarrollo sostenible, ecología, impacto ambiental, medio ambiente, planificación territorial

Ecosystem Vulnerability according to Planning (VEP, in Spanish) seeks to value the role of ecosystem services for the maintenance and strengthening of our cities through the identification of ecosystems, their valuation, and consideration from planning itself. This research is a methodological adaptation of a European project that seeks to map ecosystems and the pressures these receive, through a proposal from the European Environment Agency. Thanks to this, policies should be established to reduce these pressures on the natural environment or to avoid exceeding critical levels with resulting changes in its level of resilience. The consideration of planning as another pressure factor means seeing a new risk for these ecosystems that, although it had not been contemplated until now, is greatly relevant in our context. In this sense, it is necessary to increase the scale of work and to have the growth forecasts and existing land protections, whose information at an international level would be very difficult to homogenize and obtain. Thus, this methodological proposal focuses specifically on the Community of Madrid, Spain, to identify the pressures contemplated by the European methodology, and to add a new variable that alters the risk of losing these spaces. The case study poses important challenges due to the high urban pressure there is, but exemplifies the problems of ecosystems in the area analyzed, identifying the spaces with less joint resilience on facing these changes, due to their predisposition to urbanization.

Keywords: sustainable development, ecology, environmental impact, environment, regional planning

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I. INTRODUCTION

The multitude of pressures and impacts that cities generate as a center for economic, social, and cultural attraction, has a dimension that clearly transcends their boundaries. These dynamics have an influence on the change of land use and, therefore, present challenges for planners, especially for the integration of environmental aspects in their projects (Hurlimann & March, 2012). One of the main challenges that the profession has in the planning, is incorporating the valuation of the state of ecosystems and their contributions for citizens. The composition of biological communities is altered by urbanization, through multiple activities that change both the properties of ecosystems and the services and goods they provide us and, as a result, the quality of life of the inhabitants who were previously supplied by these services (Gardi, Panagos, Van Liedekerke, Bosco & De Brogniez, 2015; Huemann *et al*., 2011; Koukoui, Gersonius, Schot & Van Herk, 2015). The protections of ecosystems that provide these goods is completely necessary and must be worked on comprehensively, establishing ties between the continental and local analysis scales (European Environment Agency, 2017). Given issues, like planning, have a local or regional character, in the Spanish case, and could barely be included at a national or European scale. However, the adoption of new sources of information and the urban perspectives there are on environmental information, can help to improve the interpretation of these spaces and to consider them in local resilience calculations (Hernández Aja *et al*., 2020).

The research starts with the hypothesis that the European ecosystem assessment methodology provides important keys to know the main pressures that act on ecosystems but that, on not contemplating urban planning, one of the fundamental causes of environmental damage, is being overlooked. For the introduction of this factor, it is necessary to adapt the information and scales typology of the European methodology to the region under analysis, and to consider planning. With this, a comparison is established between the protection derived from planning and the risk levels that emerge from the rest of the components involved.

With this purpose, the European project is analyzed and adapted to a given region, the Community of Madrid (Spain), to later incorporate the planning factor as a new anthropic pressure exercised on ecosystems. Despite this being a case study, the methodology developed has enough flexibility to adapt to different regions which, depending on the level of detail in the information they have, could work similarly to that outlined.

II. THEORETICAL FRAMEWORK

Ecosystem services are understood as the benefits that human beings obtain from the environment (Millennium Ecosystem Assessment, 2014), and addressing them in cities requires a combination of socioeconomic and environmental monitoring tools where ecosystems can serve as a framework to achieve this combination (Maes *et al*., 2014). These ecosystems are formed by the interaction of communities of living organisms with abiotic surroundings, where biodiversity is the base behind them and allows them to be resilient in the face of global change ((Harrison *et al*., 2014; Linney, Henrys, Blackburn, Maskell & Harrison, 2020).

Despite the growing interest to use the concept of ecosystem services as a means to transfer knowledge of environmental science to decision makers and planners (Haase *et al*., 2014; Hassan, 2005; Kumar, 2012; United Nations, 2017), only initial steps have been taken in studies/plans to make integrated assessments about the ties between urban functionalities and environmental aspects (Guerry *et al*., 2015; Simón Rojo, Zazo Moratalla, Alonso & Jiménez, 2014), and the integration of this knowledge in the practice of planning continues to be a challenge, in particular in urban areas where sustainability related issues are not integrated into planning strategies (Artmann, 2014). In the meantime, the exhaustion of resources, both of energy and material nature, or the effects of extreme climate phenomena jeopardize our survival (Fernández Durán & González Reyes, 2014; Sala *et al*., 2000) and, although internationally there is a general acknowledgment about the importance of ecosystems and goods-services, outlining the problem of their management and degradation among the Sustainable Development Goals (Everard, Johnston, Santillo & Staddon, 2020; United Nations, 2018), great progress is not being made from the planning area.

Anthropic impact on ecosystems and its effects on the service provision capacity

It is difficult to evaluate the different pressures, trends, and impacts corresponding to each ecosystem due to the lack of specific data. Because of this, these are associated and valued considering the five large groups of actions -habitat transformation, climate change, overexploitation of resources, introduction of invasive exotic species, and contamination and enrichment of nutrients- identified by the Millennium Ecosystem Assessment (2004). However, this methodology does not talk about urban pressure or the role of conservation that planning has.

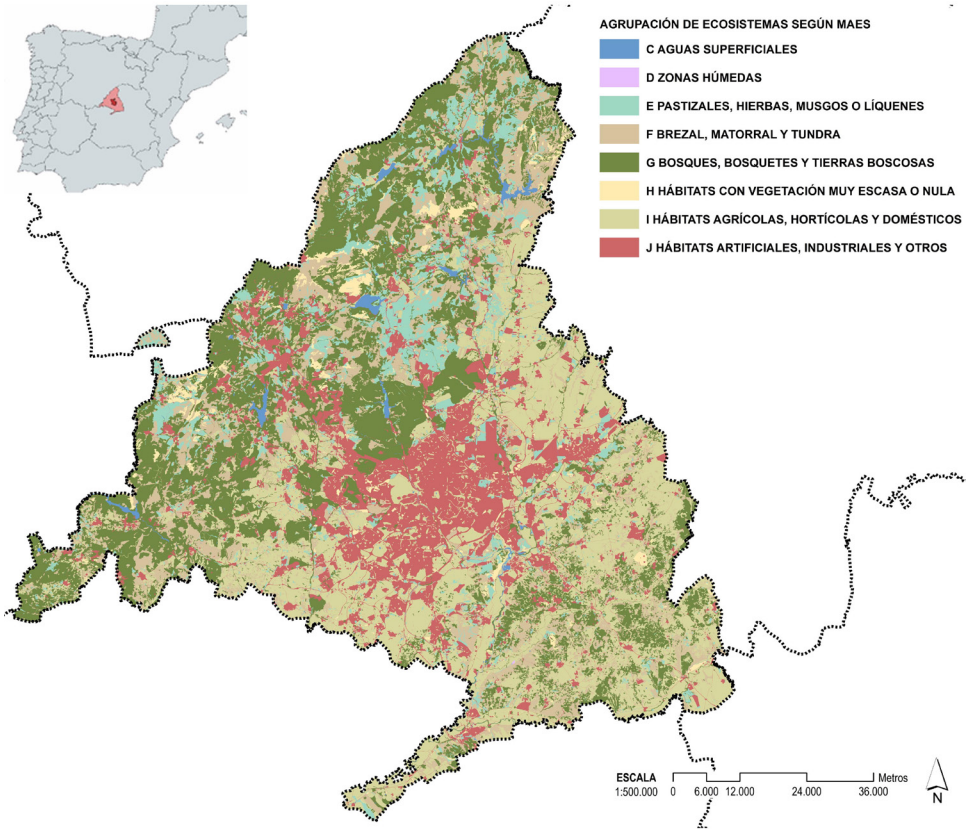

Figure 1. Identification of the Community of Madrid within Spain and its main ecosystems. Source: Preparation by the author based on data from the CORINE and EUNIS projects.

The pressures mentioned can help to assess the conditions of our ecosystems and the effects these have on their characteristics. It does not matter who we are or where we live, our wellbeing depends on the way in which the ecosystems work. The most obvious aspect is that ecosystems can provide us with material things that are essential for our lives, like food, water, or medicine. Although other benefits that we obtain from ecosystems are easily overlooked, they also play an important role in the regulation of where we live. These can help with climate regulation (Ghaley, Vesterdal & Porter, 2014), ensure the flow of clean water (Stürck Poortinga & Verburg, 2014), regulate the water cycle (McGrane, 2016), protect us from flooding (McGranahan, Balk & Anderson, 2007), and other hazards like soil erosion, landslides. and tsunamis (Gómez-Baggethun & Barton, 2013). In addition, they can contribute to our spiritual wellbeing, through their cultural importance or the opportunities they provide for leisure purposes or enjoying nature (Haines-Young & Potschin, 2012; Sandifer, Sutton-Grier & Ward, 2015). This information can be very useful to formulate specific urban policies, identifying for example, those areas that should be incorporated to the protection measures due to their ecosystem contributions or their greater vulnerability to change. Nevertheless, to suitably interpret the mapping of these issues, it is also necessary to incorporate possible future developments considered within the planning sphere.

III. CASE STUDY

The Community of Madrid, Spain is defined, in urban terms, by the non-existence of comprehensive regional planning, the inadaptability of municipal planning to current legislation, and an environmental sectorial legislation that could be used to achieve greater regional sustainability (Córdoba Hernández & Morcillo Álvarez, 2020; Valenzuela Rubio, 2010). Currently, the main environmental problems come from the conflict between the population, their different activities, the region where these take place, and existing property pressure, especially in the

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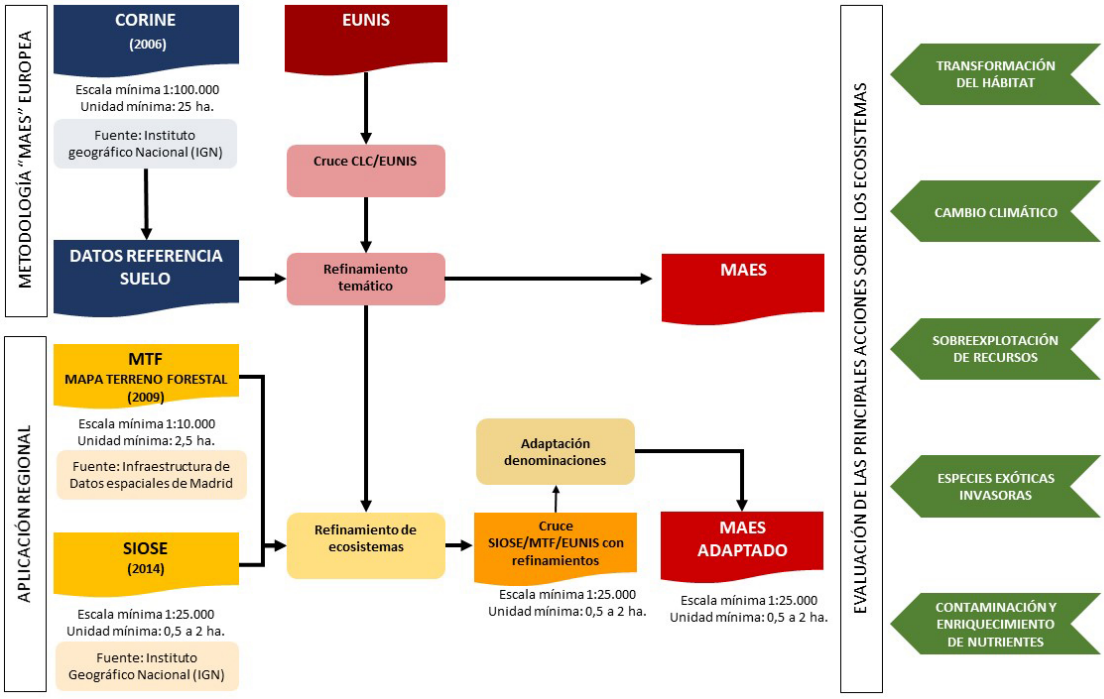

Figure 2. Comparison of the MAES methodological outline and its regionalized adaptation. Source: Preparation by the authors.

metropolitan area. The traditional way to try to alleviate this conflict, without leaving socioeconomic development or environmental protection aside, was through planning and environmental assessment. The main characteristics this case has and that favor its interpretation, are its provincial scale and suitable size (802,200 ha), the elevated population affected, 6.685 million to January 2020, the existence of 8 ecosystems according to the habitat groups of the European Nature Information System (EUNIS), and the absence of marine ecosystems, that are less developed by the European methodology, that is sought to be adapted (Figure 1).

IV. METHODOLOGY

Consideration of planning as a complementary pressure factor on ecosystems leads to seeing a new risk, neglected until now by the methodology of the European Environment Agency (EEA) vis-a-vis this issue. In order to carry out this study and include this factor in the assessment, it is necessary to work at a scale where planning is governed by the same rules, and where information is accessible, as is the case of the Community of Madrid.

The first step is standardizing and complementing the European methodology to the national case with the necessary adaptation of the scale. For this, the information available from the National Geographical Institute and the services of the Madrid Spatial Data Infrastructure is used. Both provide open information that can be managed using Geographic Information Systems (GIS).

This process begins through the Mapping and Assessment of Ecosystems and their Services (MAES), which identifies 12 ecosystem types (Maes *et al*., 2014), and evaluates each action described by the EEA, aiming at analyzing the environmental problems and identifying measures to resolve them. These types are formed by ecosystem groupings considered in the European Nature Information System (EUNIS), whose classification seeks to identify all habitats, starting from the land use information provided by Corine Land Cover (CLC), and the maps of different habitats. The application of this analysis at a greater scale presents five problems: reference scale; minimum mappable unit; hierarchical simplification; lack of natural information at a regional scale; and free access only possible in raster format, which does not adapt to the detailed vectorial local map due to the size of the resolution cell.

So that the data available about ecosystem contributions and their comparison with urban protections have a greater

			Reduction risk of ecosystem contributions due to the pressures detected by the Millennium Ecosystems Assessment				
MAES Ecosystem	**Surf. (Ha)**	**% Total**	**Habitat transformation**	**Climate change**	**Overexploitation of resources**	**Invasive exotic species**	**Contamination and enrichment of Nutrients**
Urban	120,885	15.07	Very high	Moderate	Low	High	Very high
Agricultural lands	222,907	27.79	Very high	Moderate	High	Moderate	Very high
Pastures	63,633	7.93	High	Low	Moderate	Low	Low
Forests and Woods	231,106	28.81	High	Low	Moderate	Moderate	Moderate
Moors, bushes and land with scarce vegetation	156,897	19.56	Moderate	Moderate	Low	Moderate	Low
Wetlands	62	0.01	Very high	Moderate	High	Moderate	Very high
Rivers and lakes	6,709	0.84	Very high	Moderate	High	Moderate	Very high
Total Community of Madrid	**802,200**	**100.00**					

Table 1. Reduction risk of ecosystem contributions due to the pressures detected by the Millennium Ecosystems Assessment, considering the MAES ecosystem classification Source: Preparation by the Authors.

reliability, it is suggested to adapt them to the information available in a specific region. In this way, the categories of the Spanish Land Occupation Information System (SIOSE, in Spanish) are reclassified, which helps to mark out the ecosystems and incorporates, with a better approximation, elements that divide habitats, such as communication or energy infrastructures, due to their scale.

In order to complete this map, the 46 land types identified by SIOSE are adapted to the 12 main ecosystems of the MAES project. The allocation is not direct, as CLC categories differ from those of SIOSE, and it is necessary to include information from the Community of Madrid Forestry Land Map (MFE, in Spanish) that details the ecosystems of agricultural lands, pastures, forests and woods, moors, and bushes (Figure 2). Once this process is done, a SIOSE map is obtained, where EUNIS ecosystem units can be assigned in greater detail than when they are crossed with the European CLC/EUNIS.

The following step is to measure the risk of reducing ecosystem contributions due to the pressure detected by the EEA (European Environment Agency, 2017) in the case under study. For this, the 44 covers identified by the SIOSE are grouped into 20 EUNIS ecosystems that are translated into 8 MAES ecosystem units. In this way, each ecosystem unit can be assessed considering the pressures exercised using the project's criteria and, given that the rest of the associated aspects are mapped, it is possible to regionalize the affectation (Table 1).

Alongside this, the autonomous planning is analyzed. This is characterized by three levels of formulation: regional planning; land conditioned by legislation; and municipal planning, where different councils have gone for a specific model of land protection and development in line with prevailing land legislation.

With this information, the fourth methodological step is made, which consists in comparing the risk levels of reducing ecosystem contributions with the urban planning of the Community of Madrid. From crossing the lands foreseen for the development not affected by any sectorial legislation that impedes their development, with the habitats most vulnerable to impacts, those lands that must be especially considered by municipal planning at the time of their revision emerge, given that maintaining their foreseen development would jeopardize the continuity of their ecosystem contributions.

The overlapping of these ecosystems with planning allows identifying Ecosystem Vulnerability according to Planning (VEP, in Spanish), which would be the last step of the methodology. These lands are defined as those which, on having a high or

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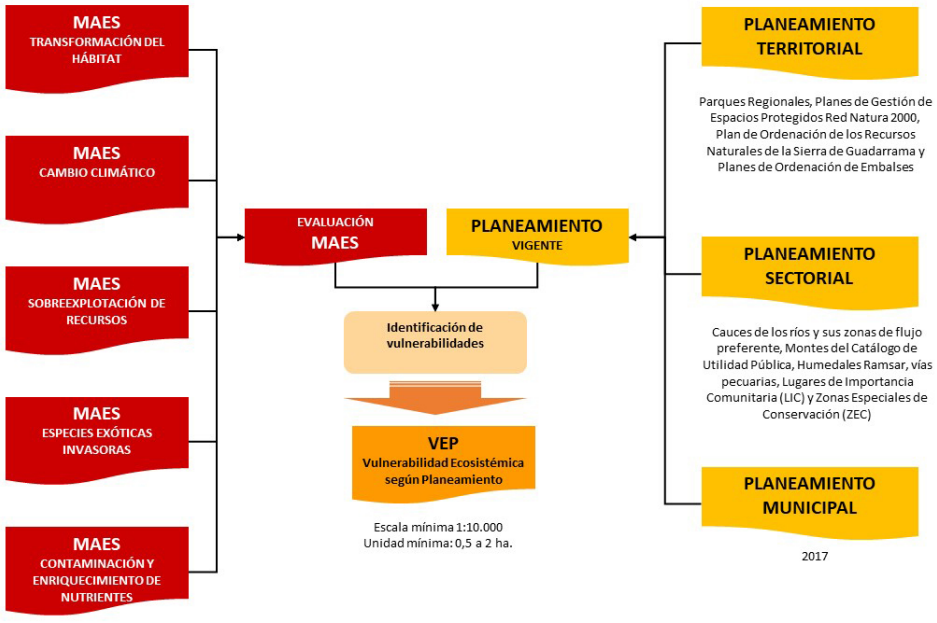
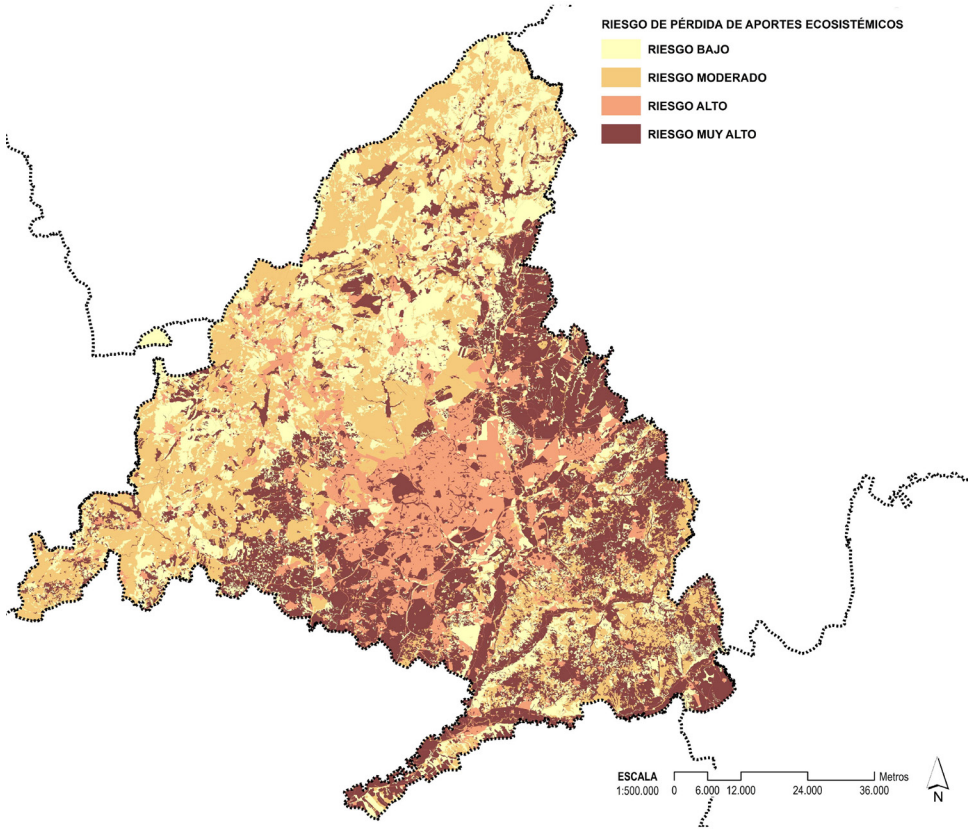


Figure 3. Integration of planning in the regionalized adaptation of the MAES methodology. Source: Preparation by the Authors.



Figur3 4. Regionalization of the impact of the actions detected by the Millennium Ecosystems through the adaptation of the MAES methodology. Source: Preparation by the Authors. Regionalization of the impact of the actions detected by the Millennium Ecosystems through the adaptation of

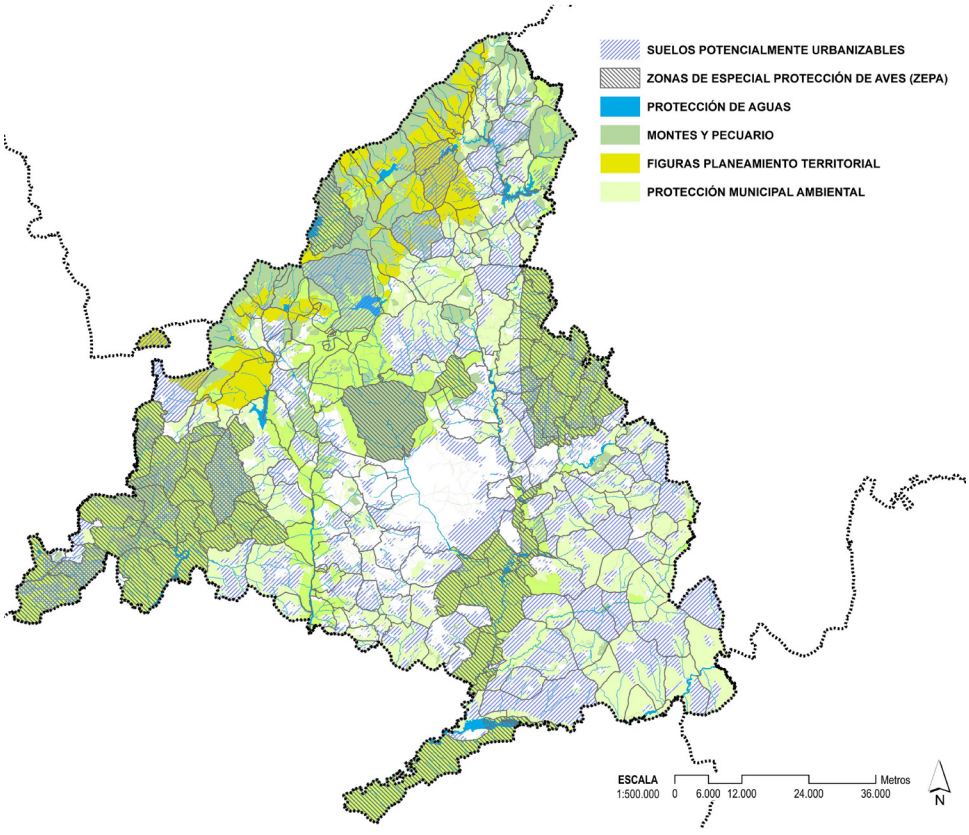


Figure 5. Regionalization of the sectorial protections and regional planning figures with environmental considerations.Source: Preparation by the Authors based on information from the Community of Madrid Regional Information System.

very high sensitivity to the effects of the actions suggested on biodiversity, also lack a suitable protection from urban regulation, permitting in these, uses that would harm this condition yet further (Figure 3).

V. RESULTS

Starting from the results obtained, it is possible to indicate that the region whose ecosystems endure greater pressure coincides with urban ecosystems, agricultural land, wetlands, and rivers. According to the projection, the effects will mainly be noticeable in the central and southern part of the Community. The effects of climate change will be moderate or low, and the urbanized land, agricultural areas, wetlands and rivers, will be those that would suffer more temperature and rainfall flow changes, and extreme events and fires in the rural environment. The areas where overexploitation of resources could be most seen are those of agricultural areas, wetlands, lakes and rivers. where agricultural intensification through intensive agriculture and the overexploitation of crops and groundwater are already starting to manifest their first effects. Considering the potential risks that the introduction of exotic species would imply, the greatest danger lies in urban areas, while the effects of contamination and enrichment of nutrients would especially disturb the urban, agricultural, wetlands, lakes and rivers ecosystems. The simultaneity of these five actions allows grading the degree of vulnerability of these ecosystems in Figure 4.

On the other hand, the regionalization resulting from the different protections of sectorial legislation, the regional planning or municipal planning figures, can be seen in Figure 5. The general consideration of these matters, without delving deeper into their actual use, nor into valuing how suitable these are, would imply a high protection of the region, with 66.43% of the land with some type of protection. The main problem of regional planning figures is that, despite their denomination, they consider some inherited growth as occurs in the case of the PORN of Sierra de Guadarrama.

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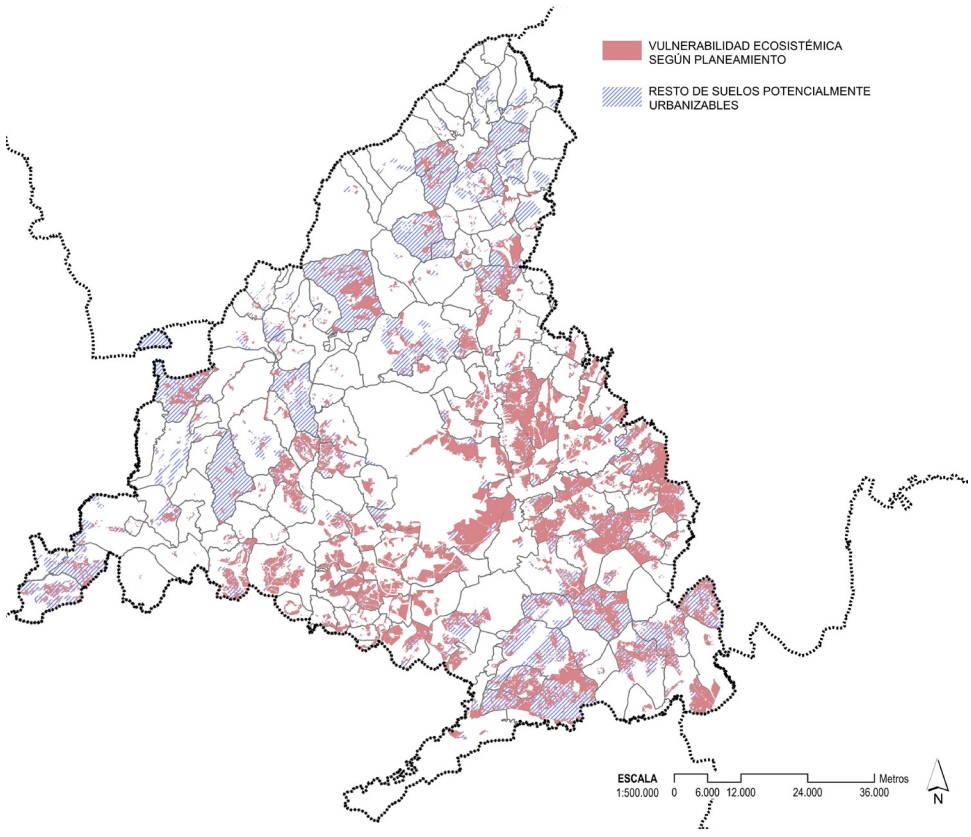

Figure 6. Ecosystem vulnerability according to planning. Source: Preparation by the Authors.

The consideration of the developments proposed to identify the VEP comes next. These have a size of 239,513 ha, equivalent to 29.86% of the region. From this surface, 62.61% would have a high or very high ecosystem vulnerability, according to the planning, and the contribution of their ecosystem resources would be jeopardized with its execution, harming the habitability not just of these future developments, but also of already urbanized land (Figure 6).

VI. DISCUSSIONS

The consideration of both the adaptability capacity on the reduction of consumption needed to carry out an urban development, and to determine the protection needs of a given region, requires identifying the components of the regional model that determine its resilience capacity. Not doing so may jeopardize human wellbeing and maintaining the economic and social development of the region. This resilience could be defined as the capacity of a system to maintain itself, or to return to the functions desirable before a disturbance, to adapt to the change, and to transform the systems that limit current or future adaptation capacity (Meerow, Newell & Stults, 2016), and should form part, both of the urban planning and of the regional, urban and living policies of the coming years. But, for this, it is necessary to know the main problems that each region faces considering their physical and natural reality.

The trend towards global urbanization has caused a clear imbalance between the rural and urban worlds, a trend that continues to be encouraged by a lack of work, a new economic crisis or a growing lack of coverage of basic needs in some regions (Córdoba Hernández & García-Burgos Pérez, 2020; HIC-AL/ PSH Work group, 2017).

If these aspects condition, clearly and by themselves, the practice of planning, other less controllable vectors like the recent displacements derived from environmental problems and situations of risk caused by climate change (Oyedeji, 2017), increase the resilient factors to be assessed. These are not trivial matters, if consideration is paid to the forecasts that estimate

that more than 143 million people could be forced to move within their own countries to escape these threats (Rigaud *et al*., 2018).

The design and implementation of strategies and action plans for the preservation of ecosystems, the use of evidence-based planning tools to design conservation areas and networks and their connectivity, are essential for integrated natural environment management, as well as to increase the resilience of these regions against the adverse effects that may continue to arrive. In this sense, current land legislation should be in charge of regulating planning in this region, safeguarding the activities typical of urban land; those lands subject to special protection regimes, that are incompatible with their transformation following the regional planning, sectorial legislation, or their values.

For this, aiming for the construction of a coherent multiscale ecological network through the improvement and strengthening of European green infrastructure, directly considering the mandate of Objective 2 of the EU Strategy on Biodiversity for 2020 (European Union, 2011), focused on the improvement and upkeep of ecosystems, creating a transborder green infrastructure, may be a solution to the problems analyzed here. This network would be linked, at the same time, with the need of establishing ties at different scales: continental, national, regional, and local.

By the end of 2020, the State strategy for green infrastructure and connectivity and national ecological restoration (Ministry for Ecological Transition and Demographic Challenges, 2020) has been added to the aforementioned strategy. Its purpose is protecting nature, strengthening ecological resilience, promoting low carbon growth that uses resources efficiently, reducing threats for human health and wellbeing associated to contamination, chemical substances, and the impact of climate change, adhering to the VII General Action Program of the Union on matters of Environment, living well, within the limits of our planet (European Commission, 2013), and in line with the Sustainable Development Goals (United Nations, 2018).

According to the European Commission, green infrastructure is a strategically planned network of natural and semi-natural spaces and other environmental elements designed and managed to offer a broad range of ecosystem services, which the most vulnerable ecosystems identified with this methodology could perfectly be part of.

To carry out this task, it is necessary to reduce or not increase the detected vulnerability. This vulnerability should be considered in the environmental assessment procedures demanded by the regulations for land legislation.

From this perspective, having complete and reliable information about the status of ecosystems and their services, and delving deeper into the follow-up and monitoring of the changes that can happen, it becomes essential to know whether the goals of the strategic environmental assessment have been met or not, and if we are fulfilling our international commitments, not just referring to the mitigation and adaptation to climate change, but also to the preservation of the valuable natural environment that surrounds us.

Development in these aspects can contribute to supporting the implementation of environmental legislation, the integration of environmental conservation goals in the policies and development sector, and enacting all the changes needed to comply with these statements. In this context, conservation more than preservation should be targeted, despite being concepts that often used indistinctly. However, the difference is noticeable if we want to consider our future needs. In this way, while the first of the terms assumes the present and future defense, preservation only supposes a protection against what may happen in the future, but does not necessarily imply that a given action is done when that future arrives.

Looking further into this type of studies, the identification and mapping of ecosystems could be used to spatially define interactions between different spaces, prioritizing conservation and protection actions of our heritage or minimizing the compensations among ecosystem services.

VII. CONCLUSIONS

This research shows the importance of mapping both the effects of given actions over ecosystems and of the planning itself and the different regional issues of sectorial legislation to diagnose the current situation, facing the challenges and uncertainty of their effects on urban planning in the current context. Although the European project handles the first of these matters to assess the ecosystem risk, it is also true that the urban pressure is difficult to integrate on this scale and it needs a national or autonomous context. The inclusion of planning in these valuations can be of great importance to suitably establish future uses of the region and their valuation, as well as the identification of the most vulnerable ecosystem lands, according to planning, to have a suitable conservation.

This mapping must identify and mark out the spatial extension of different ecosystems through the spatial integration of qualitative data on land cover and its environmental characteristics. In addition, in the search for a greater conservation of ecosystems, their state must be assessed, analyzing the main pressures, valuing the links between their conditions, quality and biodiversity, and establishing how this affects the capacity of the ecosystem to provide its services. Finally, it will be possible to rate the consequences for human beings and their wellbeing. The relevance of these questions is such, that planners cannot be left out and must take part,

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suitably regulating future uses of these lands, not just valuing them because of their natural or scenic values, but also considering the contribution of their goods-services.

Information on the pressure of given ecosystems can help to assess this service provision capacity. In this way, it is essential to inform about the policies to reduce these pressures, as well as to avoid exceeding critical pressure levels that are capable of causing a radical alteration in the ecosystem with the introduction and/or disappearance of species or a change in its resilience level. For this reason, before reaching this situation, work has to be done for the prevention and care of these areas using the suitable tools that each country or region provides. One of these tools is urban planning which, in the Spanish case, must seek efficiency of conservation and improvement measures for the natural environment, preserving land values whose transformation is unjustified to consider urban transformation needs or to minimize air, water or subsoil contamination, as its own legislation establishes. The inclusion of planning as such, must be a task performed by each one of the countries or regions, as the differentiations between these would complicate the task of homogenization at a European level greatly, running the risk of simplification. All in all, the methodology proposed opens new paths in this sense, being able to be adapted straightforwardly in other regional contexts, both autonomous and provincial in the Spanish case, as well as with other administrative figures at an international level.

Given the singularity of the planner's work, due to the implicit conditioning factors that the land classification itself implies, the greater definition of impacts the methodological change involves, should help Councils to suitably comply with these regulations. Ultimately, the analysis about the risk of reducing the contributions of ecosystems should be part of the Strategic Environmental Assessment of planning. With this, a strategic green network could be formed that would consider establishing points of control or follow-up indicators of their state and level of stress, all of which would allow having a more detailed analysis of the vulnerability situation of ecosystems.

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