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Review

Ecosystem Services Supply from Peri-Urban Landscapes and Their Contribution to the Sustainable Development Goals: A Global Perspective

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Abstract: Peri-urban landscapes (PULs) play an important role in the supply of ecosystem services (ES), which support development and well-being in urban and rural areas. Understanding the impacts of policy actions on the supply of ES and how they might contribute to the achievement of a range of sustainable development goals (SDG) is a key challenge, especially for spatial planning. The aim of this article is to explore the links between the ES supply from PULs and how they support different SDGs from a global perspective. For this, we implemented a review of the literature oriented to identify (1) the most relevant ES provided by PULs at a global level, (2) how they support the achievement of different SDG, and (3) the type of policy interventions and actors related to PULs. We identified the supply of 17 different ES by PULs and a relationship to 12 SDGs. In 58% of the cases, the SDGs were related to two ES sections, where regulation and maintenance was dominant. Pure research was the main type of intervention, mainly at the municipal scale. Increasing the cooperation between science and policy and expanding the scale of analysis beyond municipal boundaries are critical aspects.

Keywords: peri-urban landscape; ecosystem services; sustainable development goals; governance; spatial planning

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1. Introduction

Currently, more than half of the world's population resides in urban areas, and it is expected that this number will increase to almost 70% by 2050 [1]. As a result of this demographic dynamic, urban areas have expanded, increasing pressures, especially on ecosystems located close to the city boundaries [2], and creating transitioning peri-urban landscapes (PULs). According to [3], in simple terms, a landscape could be understood as multiple ecosystems over a watershed or any other type of boundary, such as geopolitical borders. PULs are a particular type of landscape that combine urban and rural features and include a mosaic of land uses/land covers (LULC), such as farmlands, woodlands, conservation areas, and different types of urban fabrics, which extend beyond the administrative boundaries of a municipality [4]. Therefore, PULs are the results of economic and political decision-making processes that take place at different scales, from global and national to regional and local, and involve a range of governance actors [5,6].

According to [6], PULs are susceptible to being transformed faster than other more stable landscapes, such as agriculture or forests. The main reason for this is the high availability of land for a variety of investments and the significant proximity to urban cores. For instance, in the case of Europe, the European Environmental Agency [7] identifies the following critical drivers of transformation, ranked by relevance: (1) the establishment of industrial and commercial facilities, (2) diffuse urban sprawl, (3) construction sites, (4) mine sites, (5) transport infrastructure, (6) sport and leisure sites, and (7) other drivers that cover less surface in comparison to the previous ones, such as dumpsites, airports, green urban areas, harbors, and dense urban sprawls. Thus, PULs play a relevant role in the interplay between local and regional economies but also in other aspects of development, such as quality of life and well-being [8]. All this encompasses a range of public and private actors and, at the same time, a combination of different policies, plans, programs, and projects, mainly oriented to support investment and, in fewer cases, to promote the protection of the ecosystems present in PULs. The latter aspect is critical because the ecosystems present in PULs are often endangered by fast transformations of such landscapes, where natural ecosystems are transformed into anthropogenic ones. On the other hand, ecosystem services (ES) provided by PULs are significant not only for their peri-urban inhabitants but also for people living distantly from PULs. Thus, peri-urban ES has a substantial potential to support multiple demands from our societies [9].

The Millennium Ecosystem Assessment report defines ES as "the benefits people obtain from ecosystems". This is a milestone report launched in 2005, but until the present, both definitions and classifications have been reviewed by several scholars with the aim of improving ES mapping and assessment [10,11]. According to [12], there are different classifications of ES. They reflect the need to address the concept from a scientific perspective but also from an economic and policymaking point of view. Today, one of the most widely used classification systems for ES mapping, natural capital accounting, and assessment is the common international classification of ecosystem services (CICES) [13]. Some advantages of CICES are related to its hierarchical structure of classification (from section, division, group, class, and class type), and also that is closely associated with the 18 ES categories defined by the intergovernmental science-policy platform on biodiversity and ecosystem services (IPBES) [14].

Under different geographic and cultural contexts, the ecosystems present in PULs have the potential to provide diverse ES, which contributes to sustainable development at different scales. For instance, in Germany, the work by [15] reported that peri-urban forests have a high intrinsic value for the urban population given the cultural ES they provide. Similarly, in Kenya, ref. [16] investigated the different regulating ES provided by PULs (air purification, drought regulation, storm protection, and flood regulation) were investigated alongside how LULC changes affected their potential to be supplied. In the case of provisioning ES in Poland, ref. [17] highlighted the important contribution of PULs to food and biomass production, but also how this generates complex trade-offs with regulating ES.

Thus, PULs have a substantial potential to enhance both peri-urban and urban sustainability at the global level [18], and they also support progress in implementing the UN sustainable development goals (SDGs).

An increasing amount of research argues that many SDGs are underpinned directly or indirectly by the supply of one or more ES [19,20]. Ref. [20] suggests that the provision, regulation, and cultural ES contribute to at least 12 SDGs and more than 40 targets, which are crucial for most of our primary needs, such as food, water, energy, and medicine consumption, among others. However, despite their relevance, PULs face increasing challenges mainly related to (1) their highly heterogeneous landscape mosaic, (2) fast changes in cultural and social structures that might transform these areas, and (3) different types of government schemes that include several institutions, scales, and public and private interventions [21].

According to [21,22], research focused on the transitional aspects of PULs still remains marginal, specifically when it comes to investigating the effects of peri-urbanization processes on the sustainability of landscapes and the ES they provide. Thus, it is essential to understand the dynamic and complexity of contemporary peri-urbanization processes to see how they influence the supply of ES, the sustainable development of PULs, and to what extent such processes influence the implementation of a range of SDGs. This will allow for improving the policies and planning approaches addressing such landscapes.

Until now, there has been no report on the information that connects the potential of PULs to provide ES and how this might contribute to achieving the SDGs. To close this knowledge gap, we aim to explore the links between the supply of ES from PULs and how they provide support to achieve different SDGs from a global perspective. In this research, we understand the "links" as relations that influence both the supply of ES from different LULCs, and the delivery of co-benefits provided by ES for SDG implementation [23]. These relations might be either positive or negative. However, we did not focus on a trade-off analysis.

To fulfill this aim, we performed a structured review of the literature in order to provide information and reflections based on all the available scientific research at a global level, considering the following research questions:

(1) Which LULC and ES are the most frequently identified in PULs from a global perspective?
(2) Which type of governance and planning interventions (policy, plans, programs, projects), scales, and governance actors are examined by research articles addressing PULs, ES, and sustainable development?
(3) Which SDGs are addressed or impacted by the governance and planning intervention explored by articles, and how are they related to one or more ES?

2. Materials and Methods

2.1. Data Collection and Selection of Papers

To explore the relations between PULs and ES and how these landscapes might support sustainable development through the achievement of different SDGs, we analyzed a set of scientific articles based on a systematic review of the literature. Thus, to produce transparent and reliable scientific evidence, we largely considered the guidelines proposed by the collaboration for environmental evidence [24], which suggested a set of steps to be considered in a review, such as (1) the identification of evidence needs, (2) the planning of the review, (3) conducting the review, and (4) reporting the review (see as an example [25]).

The set of articles was collected from the Scopus database, which, according to its website, was the most extensive database of the peer-reviewed literature (www.scopus.com (accessed on 4 July 2021)). In addition, a number of scientific papers in fields such as ecosystem services or sustainable development support the use of SCOPUS, given its vast, comprehensive, and multidisciplinary features of documents in the database (e.g., [26,27]).

The search was performed on 4 July 2021 based on the title, abstract, and keyword fields of the articles. After testing different combinations, we defined a search query that consisted of the following keywords: "periurban" OR "peripher" OR "fringe" OR "edge" OR "suburban" OR "exurban" AND "ecosystem services" OR "environmental services" AND "sustainable development". Like previous reviews of the literature, this study focused on urban peripheries (e.g., [21]), we also chose a broad set of keywords expressing synonyms for peri-urban landscapes in order to include all the possible articles suitable for analysis. To select the set of articles, we adopted six eligibility criteria: (1) access: all types of papers, (2) year of analysis: 2015–2021 (the starting date considers the launch of the SDGs), (3) document type: articles (to ensure quality after a peer-reviewed process), (4) publication stage: published and in press (to avoid work in progress, such as conference proceedings), (5) source type: journals (complete research and peer-reviewed are mainly published in journals), and (6) Language: English.

The initial number of papers was 72, which was reduced to 38 once the described above eligibility criteria were applied. Upon this set, we reviewed all the full articles and removed duplicated manuscripts and any other paper that was out of the scope of our

research. After this process, we obtained a final set of 21 documents for further analysis. Figure 1 illustrates the geographical and temporal distribution of the selected papers.

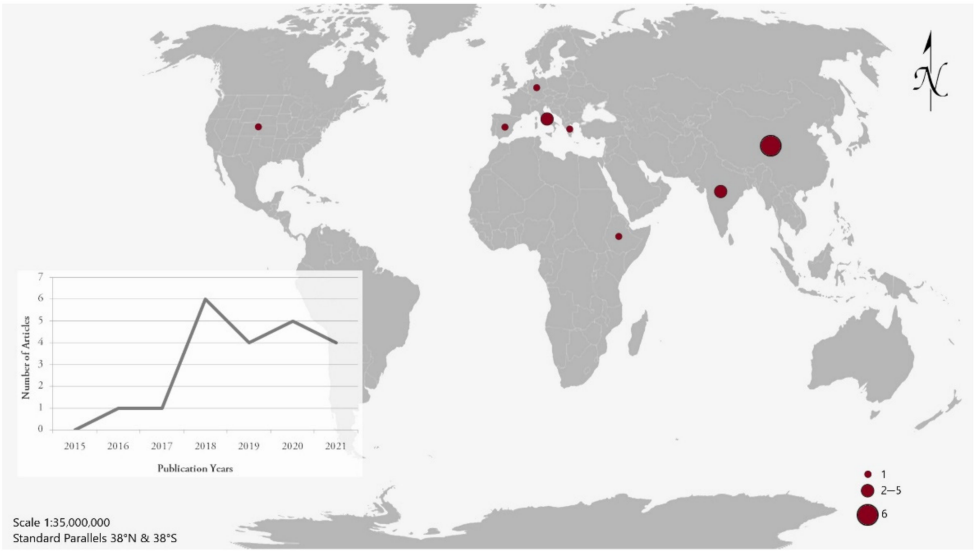

Figure 1. Selected articles for analysis grouped by country.

2.2. Analysis

The selected articles were examined by using a content analysis approach. The study of [28] defines content analysis as a research approach to perform replicable and valid inferences from qualitative information (e.g., textbooks and scientific articles) to answer specific research questions. To implement the analysis, we designed a review framework that structured the extraction of information and systematization in a database (database in Supplementary Materials). The framework included different key aspects to be identified through the articles (Table 1).

Table 1. Review framework and key aspects for analysis.

Key Aspect	Rationality	Section of the Article Used to Search
Authors	General information for the article	Cover page
Title	General information for the article	Cover page
Year	Articles identified since 2015, considering the launch of the SDGs	Cover page
Country	It aims to identify geographical hotspots of research related to peri-urban landscapes and ES/SDGs	methodology
Level of intervention	The spatial scale where the intervention examined by the article takes place. It could be global, national, regional, municipal, or local (e.g., a specific neighborhood). This information was extracted from the section "study area" of each article	Methodology
Type of intervention	It aims to identify the type of intervention/case study examined by the article. It could be a "policy", "plan", "program", or "project", information extracted directly from the article itself. For instance, an article might analyze the impacts of project implementation. Then, the type of intervention is "project". In case the article does not mention any specific intervention to be analyzed, we classified it as "research".	Introduction and/or Methodology

Table 1. *Cont.*

Key Aspect	Rationality	Section of the Article Used to Search
Land use/land cover involved (LULC)	The type of LULC addressed or impacted by the intervention or research. Given the variety of categories utilized to refer to the same LULC, we used the CORINE land cover (level 2) nomenclature to standardize the information (see: https://land.copernicus.eu/user-corner/technical-library/corine-land-cover-nomenclature-guidelines/html (accessed on 17 December 2021)	Methodology and/or Results
Ecosystem services involved	The type of ES addressed or impacted on by the intervention or research. When the ES was not explicitly referred to as such, we inferred it from the text. In both cases, we considered the three CICES sections: (1) provisioning, (2) regulation and maintenance, and (3) cultural. However, for representation, we used the "IPBES name" because it was broader and easier to communicate (https://cices.eu/ (accessed on 17 December 2021)).	Methodology and/or Results and/or Discussion
Actors involved	Type of governance actors involved in the intervention. In this research, we defined three general categories of actors based on the previous work by [29]: (1) experts/scientists, (2) stakeholders, (3) citizens	Introduction and/or Methodology and/or results
SDGs involved	The SDGs addressed or impacted on by the intervention. When the SDG was not explicitly referred to as such, we inferred it from the text. See the SDGs here: https://sdgs.un.org/goals (accessed on 17 December 2021)	Methodology and/or Results and/or Discussion

From this review framework, we performed a comparative analysis of the key aspects by using descriptive statistics. Additionally, we implemented a network analysis to investigate the interactions between the LULC identified in different PULs, their potential to supply ES, and how these ES were linked to one or more SDGs to support its performance (Figure 2). A network is a structure that represents a set of objects or people, formally known as "nodes (or vertices)", and the relationships between them, formally known as "edges (or links)". Then, network analysis facilitates the exploring of patterns from relationships and calculating a variety of metrics to reveal features of interest from the network [30].

The analyzed articles did not explore explicit links between LULC v/s ES or ES v/s SDGs, but they instead reported ES provided in general by PULs, and the dimensions of development to be benefited. Therefore, based on the existing literature, we created a cross matrix of relationships between each LULC/ES and ES/SDGs to perform the network analysis. To evaluate the potential of different LULCs to provide ES, we used relevant references by [31–33]. In the case of the relationship ES v/s SDGs, we used the research performed by [17,18,22], which provides valuable insights from a global perspective.

The open-source software Gephi V 0.9.2 was utilized to explore and visualize the networks (https://gephi.org/ (accessed on 11 April 2022)). The use of Gephi was considered suitable because it was free and easy to use, and it offered all the analyses requested in this research [34]. The metrics calculated were indegree, outdegree, weighted degree, and modularity. According to [35], indegree is the number of links received by a specific node e.g., if one specific ES receives links from five LULCs, then the in-degree of that ES node is five. The outdegree is the number of links sent by a node. In this case, one LULC may be linked to five different ESs, then the outdegree of that LULC node would be five. The weighted degree reflects the strengths of interactions between the nodes calculated as the sum of the weights of each link that directly connects a specific node [30]. In this research, the available literature allowed us to weigh the cross matrix of the relationships between LULC and ES on a scale from 0 = the null potential of a specific LULC to supply a specific

ES to 4 = very high potential (see Supplementary Materials). By contrast, the information available for ES and SDGs did not allow the use of weights. Therefore, a binary cross matrix was elaborated, where a value of 0 meant no relation, and 1 expressed a link from a particular ES to a particular SDG. Finally, we calculated modularity, a measure of the network structure in terms of the strength of the division of a network into modules called clusters or communities. The modularity metric implicated dense connections between the nodes within the clusters but weak connections between the nodes in different clusters [36]. Therefore, given its simplicity, it is frequently used for detecting community structure in networks.

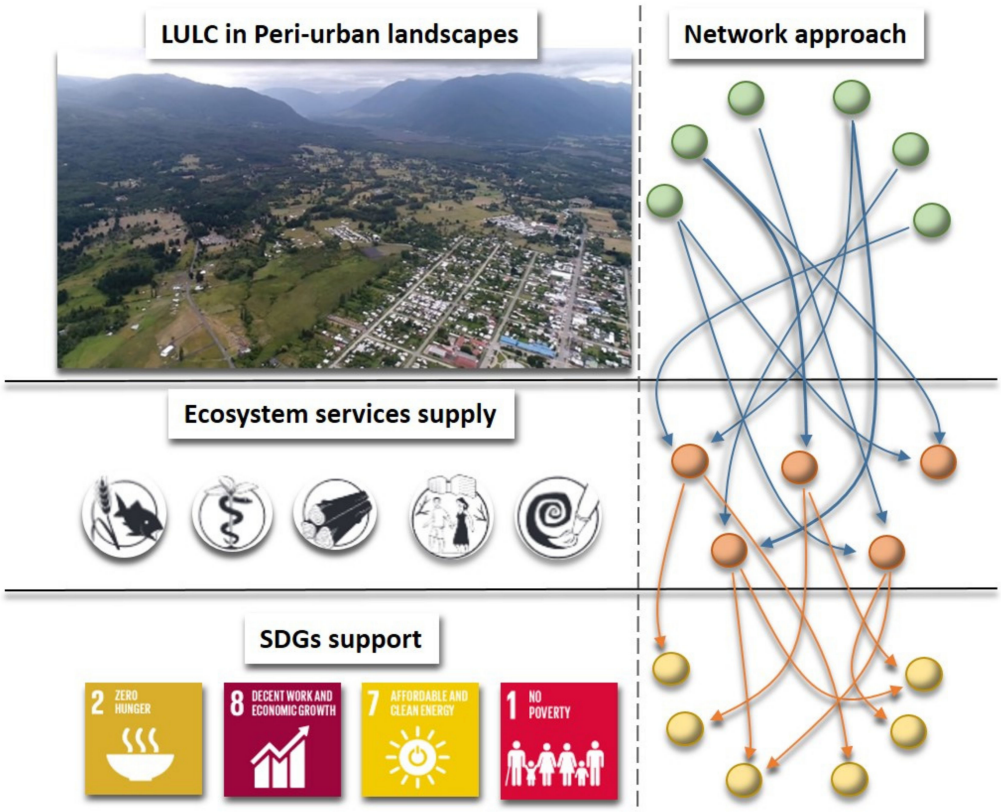

Figure 2. Schematic representation of the network interactions among LULC, ES, and SDGs. The illustrations for ES belong to the TEEB project (https://teebweb.org/ (accessed on 11 April 2022)).

3. Results

3.1. LULC and ES Identified in PULs

The results show 11 LULCs described in the 21 analyzed papers, defined according to the CORINE land cover classification, level 2. The most frequently identified correspond to urban fabrics, either continuous or discontinuous (81%), water bodies, mainly inland waters (76%), forests (76%), and arable lands (71%). However, under a more general picture (CORINE, level 1), "forest and seminatural areas" was the most dominant LULC (33%), followed by "agricultural areas" (26.2%), and, to a lesser degree, "artificial surfaces" (17.5%). On the contrary, water bodies and wetlands were the least frequently identified LULC (15.5% and 7.8%) (Figure 3).

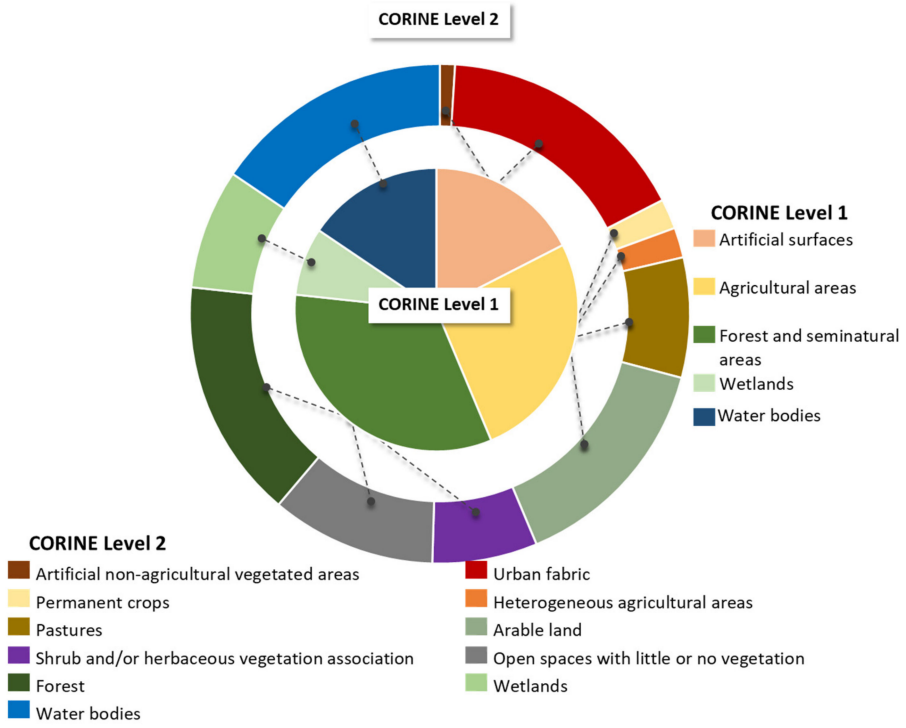

Figure 3. LULC identified in this research according to CORINE land cover classification Level 1 and Level 2.

Concerning the ES, 17 were identified considering their explicit and implicit mention in the articles (Figure 4).

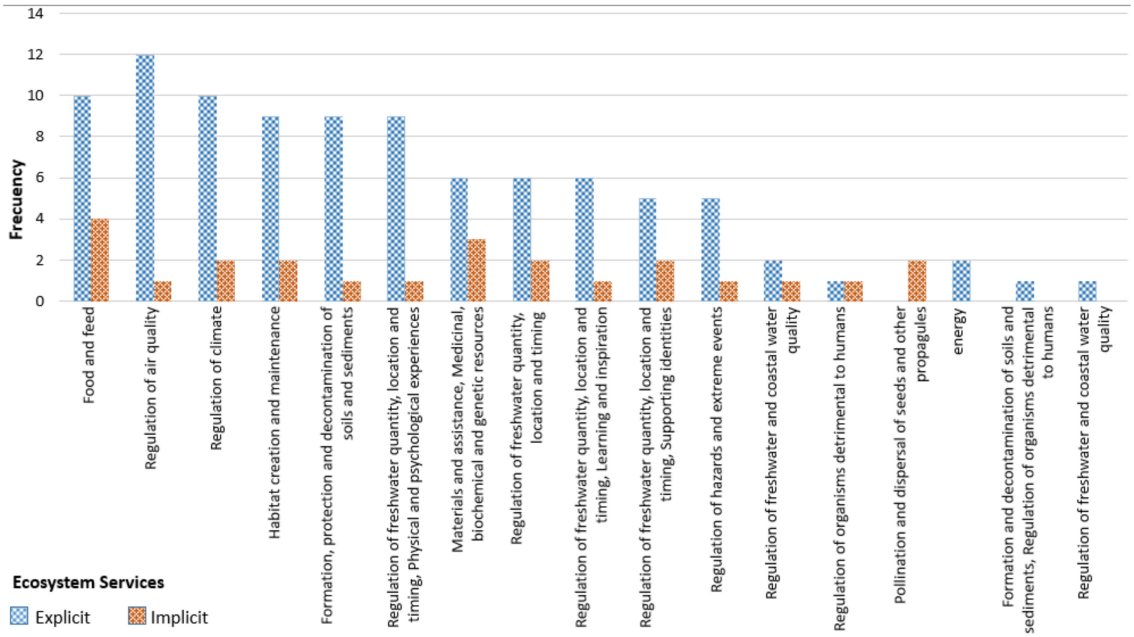

Figure 4. Explicit and implicit consideration of ecosystem services identified in the articles.

At the section level, "Regulation and Maintenance" was the most relevant in both the frequency and diversity of an individual ES (70.6%), followed by "Cultural" (17.6%) and "Provisioning" (11.8%). If we rank the 17 ESs at the class level, "food and feed" provisioning ES was the most frequently mentioned by the articles, followed by "regulation of air quality" in second place (regulating ES), and in third place "regulation of climate" (regulating ES).

Cultural ES appeared for the first time in position number six ("physical and psychological experiences"). In terms of explicit and implicit consideration, 80% of the mentions were explicit references to a specific ES (see Figure 4).

3.2. Type of Interventions, Scales, and Actors

From the analysis of the selected articles, three types of intervention were identified. The dominant was "research" (61.9%), followed by "projects" (28.5%) and "plans" (9.5%). "Policies" or "programs" were not identified as related to the research in PULs, ESs, or sustainable development. The type of intervention "research" was found to be the most frequently related to both ES and SDG, but ES predominated over SDGs.

In terms of the level of intervention, the municipal scale was by far the most frequently addressed (61.9%), followed by regional studies (19%), global (14.3%), and local (4.8%). The national scale was not present in any article. At the same time, ESs were considerably more prominent than SDGs at the municipal level. In contrast, at the "regional" and "local" levels, ES and SDGs presented the same frequency. Figure 5 shows the ES and SDGs found at different types and scales of intervention in PULs.

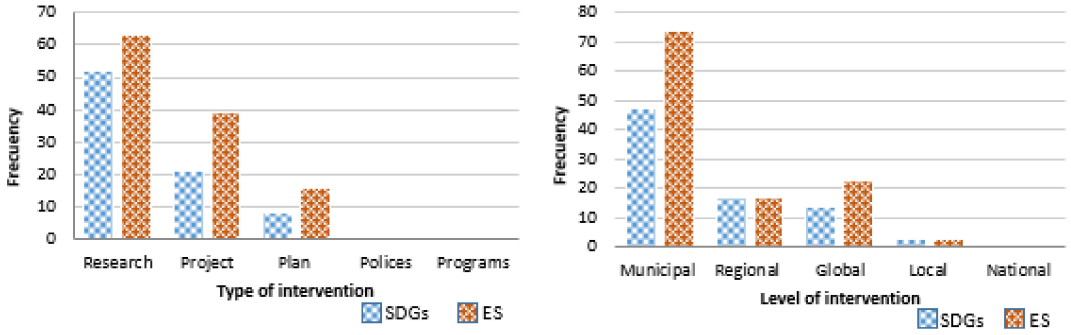

Figure 5. Frequency of ES and SDG and the different types and levels of intervention.

Regarding the actors, 18 different types were identified, including researchers, land planners, householders, senior citizens, farmers, and students. However, in many cases, the frequency associated with these categories was not significant (e.g., two planners and one student). Therefore, based on [29] only three general categories were considered for the analysis: (1) experts/scientists, (2) stakeholders, and (3) citizens (Figure 6). The category of experts represented 58% of the actors, who were prominent at all levels of intervention, from global to local, and especially at the municipal level. This category was also present in the three types of interventions examined, especially in "research". The category of citizens included 22% of the actors, and it was only present at the global, municipal, and local levels in the interventions mainly related to research and projects. Finally, the category of stakeholders included 20% of the actors, which were only present at the municipal and regional levels, related to research, plans, and projects.

3.3. ES Contribution to SDGs in PULs

From a total of 12 SDGs related to the analyzed papers, only four were mentioned explicitly (SDG 2, SDG 6, SDG 11, and SDG 13). The most frequently identified corresponded to SDG 11 (sustainable cities and communities), which was mentioned explicitly, followed by two others implicitly detected, SDG 15 (life on land) and SDG 3 (good health and well-being). In contrast, the less frequent SDGs corresponded to SDG 4 (quality education), SDG 7 (affordable and clean energy), SDG 9 (industry, innovation, and infrastructure), and SDG 14 (life below water). Figure 7 shows the identified SDGs, differentiating their explicit and implicit reference.

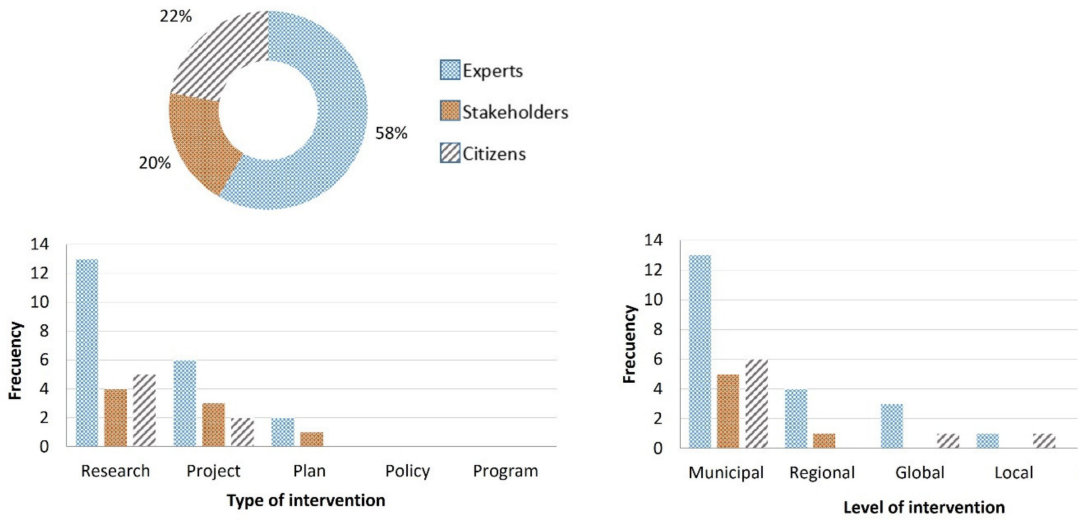

Figure 6. Actors related to the different types and levels of intervention.

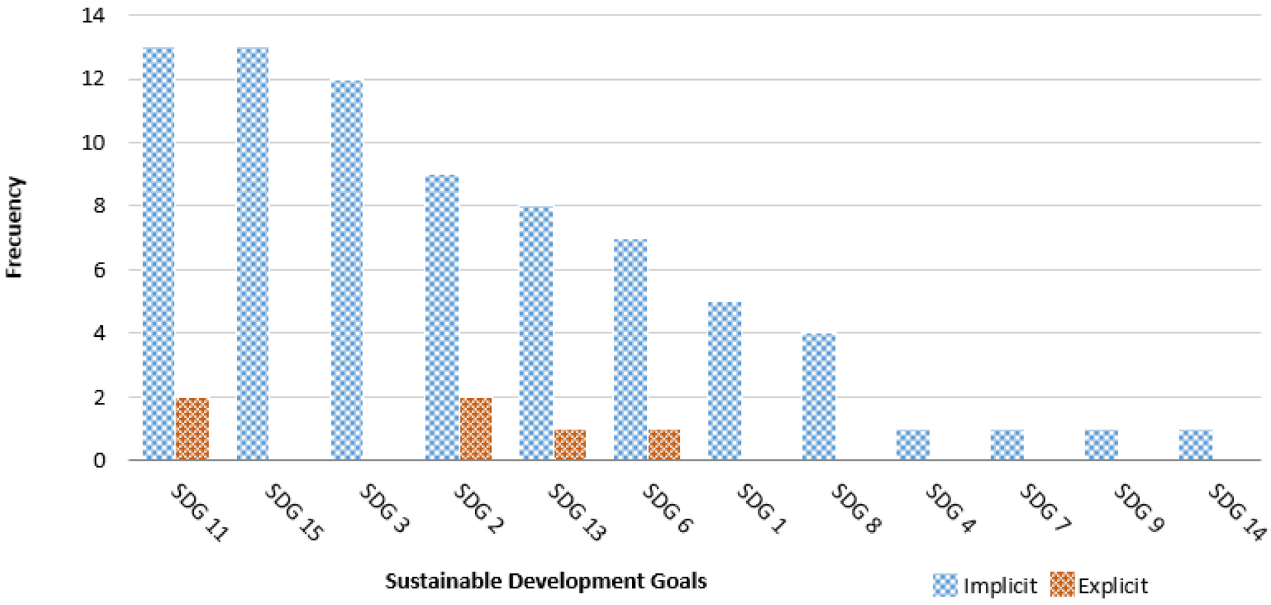

Figure 7. Explicit and implicit reference to the SDGs in the articles.

The Sankey diagram of Figure 8 represents flows from the different LULCs addressed by the articles to a specific ES, whose interactions have been described by previous research (see Section 2.2). Similarly, the diagram also shows the flows between ES and how they are linked to diverse SDGs. In order to facilitate visualization, Figure 8 illustrates the ES at the CICES section level; however, additional details at the class level are available in Supplementary Materials.

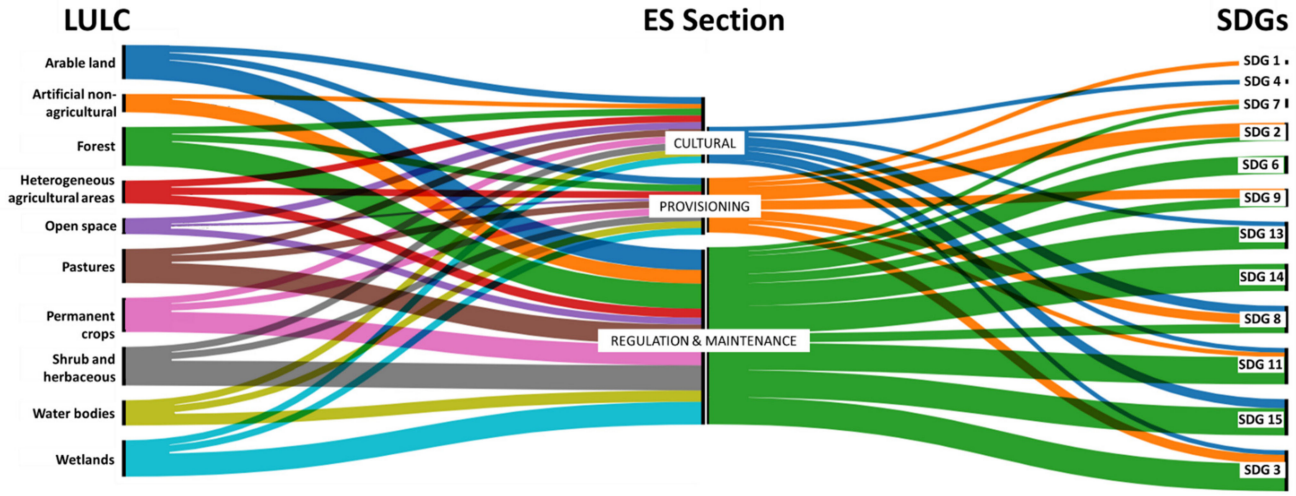

Figure 8. Sankey diagram representing the flow of relations among LULC, ES, and SDGs.

The results suggest that forests (13% of the total interactions), shrub and/or herbaceous vegetation (13%), and wetlands (12%) are the most connected LULCs to any ES. They are closely followed by arable lands, pastures, and permanent crops (11,4% each). The less connected LULCs are open spaces with little or no vegetation and urban fabric (5% and 0.75%). In 58% of the cases, LULC is linked to the ES section "Regulation and Maintenance", particularly to the regulation of fresh water and coastal water quality, and pollination as the more relevant ES. To a lesser degree, we found the section "Cultural" (22%), where three ES related to the regulation of freshwater quantity, location, and timing for: (1) learning and inspiration, (2) physical and psychological experiences, and (3) supporting identities, presented an almost equal relevance. Finally, the section "Provisioning" presented 20% of the links to any LULC, being materials, food and feed, and energy: the most relevant ES.

From a total of 12 identified SDGs, 16.6% were connected only to one ES section, 25% were connected to the three ES sections, and 58.3% were connected to two sections. "Regulation and Maintenance" presented the highest number of connections (66%), with the ES regulation of fresh water and coastal water quality as the most linked to an SDG. Unlike the relation between LULC and ES, in this case, the section "Provisioning" was more relevant than "Cultural", presenting 20% and 14% of the connections, respectively. The SDGs that were more related to any ES were SDG 3, SDG 11, and SDG 15 (15%, 14%, and 14%), where "Regulation and Maintenance" always presented the highest number of the ESs connected. SDG 13, SDG 14, and SDG 8 showed the same number of connections (10%), being "Regulation and Maintenance", once again, a key provider of ES. Only in three cases was "Regulation and Maintenance" not presented in the relation between SDGs and ES, where "Provisioning" instead appeared as the dominant section (SDG 9, SDG 7, and SDG 2).

In addition to only the individual connections from LULC to ES and ES to SDGs, we also evaluated the conformation of communities or clusters within the structure of interactions. The network analysis of Figure 9 shows three groups that reveal closer relations between a specific LULC and ES.

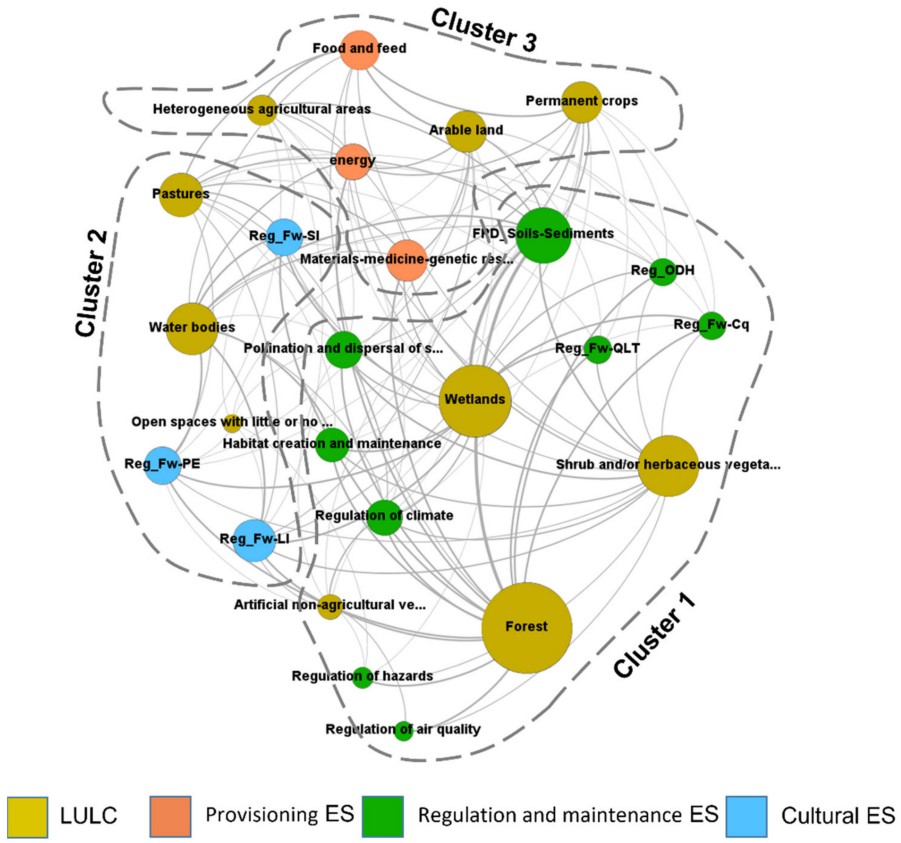

Figure 9. Conformation of clusters between LULC and ES.

Cluster 1 includes forests, shrubs and/or herbaceous vegetation, wetlands, and artificial vegetated areas. The first three correspond to the LULC with the highest number of connections to different ESs (with an outdegree of 15, 15, and 14, respectively). All the ESs present in this group are related to "Regulation and Maintenance", whether pollination, climate regulation, or the formation and protection of soils and sediments are the most relevant (with an in-degree of 10 and 9, respectively). Cluster 2 is formed by water bodies, pastures, and open spaces with little or no vegetation. This cluster is related to the section "Cultural", with three ESs associated with the regulation of freshwater quantity but in terms of learning and inspiration, physical and psychological experiences, and supporting identities. Cluster 3 comprises three LULCs. Arable lands and permanent crops showed the same number of links to ES (outdegree of 13), while heterogeneous agricultural areas had the lowest value in that cluster (outdegree of nine). All the LULCs were related to a different "Provisioning ES", where materials and assistance, food and feed, and energy presented a similar number of connections (with an in-degree of nine, eight, and eight, respectively).

In the case of ES and SDGs, closer relations among them are represented by four clusters (Figure 10). Cluster 1 is confirmed by five SGDs, where SDG 3 is the one with the highest number of connections (an in-degree of nine). All the ES sections are present in this cluster; however, "Provisioning" is the more predominant and is represented by ES, such as energy, food and feed, and materials, while "Cultural" is the less with only one ES (the regulation of freshwater for physical and psychological experiences). Cluster 2 includes three SDGs, including SDG 11, which is the one with the highest number of connections to a different ES (with an in-degree of eight). In this cluster, only "Regulation and Maintenance" ESs are present. Cluster 3 only has two SDGs, where SDG 6 shows the double number of connections to a different ES as SDG 7 (with an in-degree of four and two, respectively). This cluster is also related only to "Regulation and Maintenance" ESs, with a dominance in the regulation of freshwater quantity, location, and timing (with an

outdegree of eight). Cluster 4 also presents only two SDGs. SDG 15 is far more dominant than SDG 4 (with an in-degree of eight and one, respectively); however, unlike the above clusters, here, "Cultural ES" was the most important.

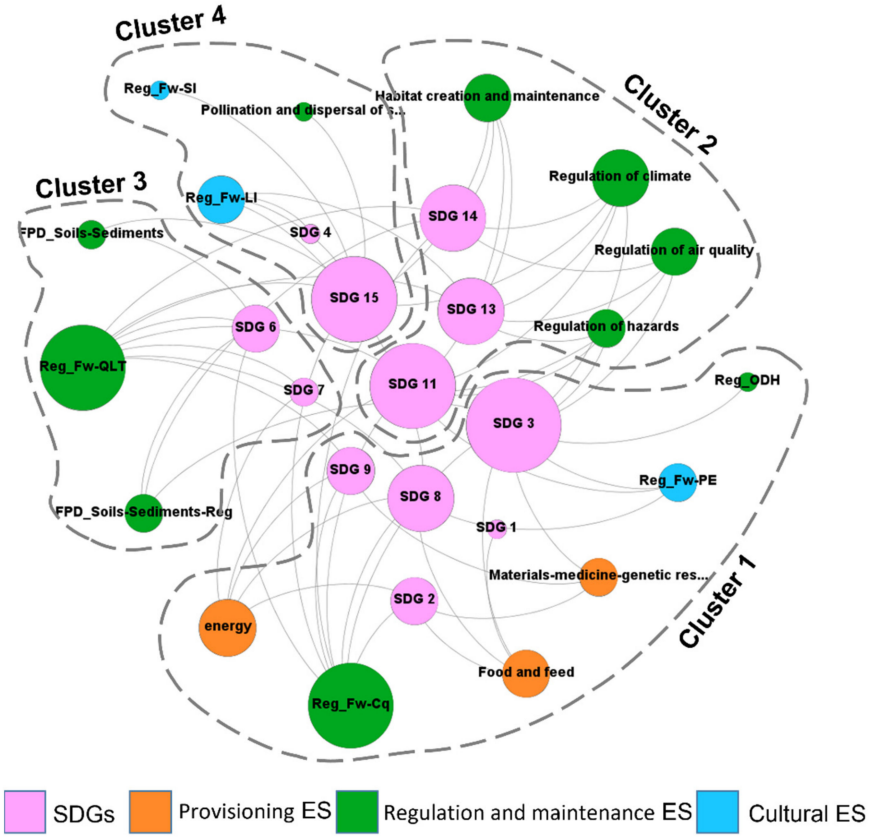

Figure 10. Conformation of clusters between ES and SDGs.

4. Discussion

4.1. Advantages and Limitations of the Research Approach

This study implemented a systematic review of the literature and a subsequent content analysis of each selected paper. In addition, a network analysis was performed to identify the patterns of relationships among our concepts of interest: LULC, ES, and SDGs. The main advantages of this combined approach are (1) flexibility because it allows qualitative and quantitative analysis of the information, (2) relatively easy implementation since a systematic review of the literature and content analysis are well-reported in the field with a number of examples (e.g., [9,21]), and (3) the ability to provide valuable information about general trends and patterns, in particular, together with the network analysis (e.g., [37]). In contrast, our approach also presents some limitations, mainly related to the reduced number of examined articles. This might affect obtaining a more detailed view of the current research in PULs and, therefore, limit our ability to draw more robust conclusions regarding the relationships among LULC, ES, and SDGs. Nevertheless, this low number of analyzed papers was based on a systematic search of the most extensive databases of the peer-reviewed literature available, which suggests that PULs represent an interdisciplinary research field that is still in an early stage of development. Thus, even though this study aimed to illustrate the global picture rather than a representative sample, further steps of research need to encompass other databases such as Google Academics, Web of Science, ScienceDirect, and others.

Another limitation is the lack of explicit references to specific links between LULC v/s ES or ES v/s SDGs. Then, we used a general approach based on the existing literature to perform the network analysis to explore those relationships. We considered this approach helpful in providing broad patterns that could be observed from a global perspective.

However, the interpretation of the results must be carefully evaluated and adjusted in different planning and territorial contexts to avoid confusion or generalizations.

4.2. LULC and ES Present in PULs under a Global Perspective

Based on the analyzed manuscripts, our study describes a variety of LULC and ESs present in different PULs. In this way, the results presented in this paper contribute to the ongoing scientific debate concerning the conceptualization and characterization of PULs. However, the focus on the contribution of PULs to sustainable development, particularly through the SDGs and the ES supply, is novel and, at the same time, relevant for governance and planning.

Existing conceptualizations of PULs are frequently based on peri-urban LULC aspects and underline that such landscapes are mainly composed of a mixture of urban, forest, and agricultural land [9,38]. Our results confirm that fact, showing that "forest and seminatural areas", "agricultural areas", and "artificial surfaces" are the most dominant LULC types mentioned in the analyzed manuscripts. Water bodies and wetlands are also present in PULs, but with a lower frequency, particularly in the case of wetlands. The reasons for this might be diverse, such as the geographical and climatic conditions, but in most cases, they are related to anthropogenic impacts associated with land use transformations [39]. This is a critical aspect since wetlands play a significant role in peri-urban sustainability and urban citizens' well-being. This transformation results in a substantial loss of the ES offered by PULs and the dissatisfaction of peri-urban inhabitants (see [40]). A similar situation was observed concerning peri-urban water bodies, where the diminishment of such LULC fostered a decrease in many ESs exemplified by, i.e., problems with water quality and supply in urban areas.

The mixture of LULCs present in PULs and the associated ecosystems has a significant potential to supply a diverse ES, which contributes to local or regional development goals and well-being [6]. This is confirmed by our research, where 17 ESs were identified as being related to the three CICES sections: provisioning, regulation and maintenance, and cultural. It should be noted that, in this work, the explicit consideration of ES alongside the documents was 80%, representing a great contrast with other research where ESs were mainly implicitly mentioned [41,42]. However, the difference might be explained because, in this study, the documents were scientific articles, while in the other cases, they were policy documents. Still, this discrepancy provides insights related to the gap between science and policy in terms of the implementation of the ES concept in actual decision-making, coinciding with previous ideas outlined by [43].

Among the different LULCs reported in the selected papers, all of them were linked to one or more ES, except urban fabrics. Remarkable contributions to the ES supply were observed from forests, shrubs, and wetlands, which is consistent with earlier results obtained by [44,45]. From all the relations between LULC and ES, 58% of the cases were connected to regulation and maintenance, which suggests a high relevance of PULs, for instance, in the regulation of climate, air quality, pollination, and habitat availability, among other benefits for well-being (details in Supplementary Materials). To a lesser degree, cultural ESs were also present in connection to aspects such as learning and inspiration, supporting identities, and physical and psychological experiences. Provisioning ES werethe less frequently identified, mainly associated with materials, food, and energy provision. In this regard, similar results were reported by [46], who emphasized the importance of regulating ES in a range of landscapes in Spain, and [37] in Chile, where regulating and cultural ESs were dominant at an inter-municipal level, which is the place where PULs are mainly present.

4.3. Governance and Planning Interventions in PULs

Most of the interventions identified in our study are theoretical or exploratory research initiatives, also known as pure research. Even though such results were the most likely to be obtained because the primary source of information was scientific papers, we also

expected more practical applications, including, for instance, the analysis of the impacts of a specific policy, spatial plan, or project on ES or SDGs. Numerous examples of these practical applications are available for rural and urban areas (e.g., [47]). However, our findings indicated that, besides pure research, only a few papers focused on neither projects nor planning interventions in PULs. Surprisingly, our results did not detect any paper where a policy or program was related to ES and SDGs in PULs, which might depict either a significant gap in the governance practices associated with PULs or a lack of collaboration between science and policy in these matters. Accordingly, the dominant type of governance actors were "experts", mainly from academia, followed though distantly by citizens and stakeholders. This might suggest, on the one hand, that science and decision-making are still in an early stage of cooperation in this theme. This condition is not new, and many scholars have reported similar challenges, particularly in the field of ES implementation in decision-making under multiple actor settings [37,48]. On the other hand, this might also represent a potential risk for ES management and the SDGs implementation in PULs, given that the effective governance of such landscapes needs to be implemented by involving multiple groups of actors that play a role in different scales of decision-making [49,50]. In this regard, the main scale of intervention addressed by the selected articles was the municipal level (62%). This could be explained based on the close relationship between the urban and peri-urban areas in terms of different economic, cultural, and environmental dynamics that occur within the boundaries of a municipality [6]. However, these findings could also reveal that PULs are currently addressed under a fragmented approach (e.g., independent municipal spatial plans) which do not consider the whole extent of such landscapes (e.g., regional level or inter-municipal), as they are, per definition, spread over several municipalities or communes [51]. This outlines a potential risk related to PULs governance, as such landscapes cannot be directly governed only by the municipal level [4].

4.4. SDGs and the Role of ES in PULs

The findings of this research suggest that PULs play an important role in supporting sustainable development, which aligns with the conclusions of [18]. Based on the 17 SDGs consigned in 2015 by the UN 2030 Agenda (https://sdgs.un.org/goals (accessed on 12 September 2022)), we identified 12 of them through the revised papers. The most relevant in terms of frequency are related to SDG 11 (sustainable cities and communities), SDG 15 (life on land), SDG 3 (good health and well-being), SDG 2 (zero hunger), SDG 13 (climate action), and SDG 6 (clean water and sanitation). The high frequency of these particular SDGs is consistent with previous research on the supply of ES in PULs, which are linked with benefits to sustainable development related to, for instance, flood regulation (e.g., SDG 11), psychological well-being (e.g., SDG 15), air purification (e.g., SDG 3), biomass production (e.g., SDG 2), and drought regulation (e.g., SDG 13, SDG 6) [13,15]. Among them, SDG 11 shows a particular relevance because it is the most frequently present but also the one with the highest number of explicit mentions in the documents. Therefore, this SDG seems critical in the context of PULs. A possible explanation is that our results show that the municipal scale is the most dominant, probably, given the close relationship between the urban population and the dynamics and/or benefits provided by the PULs to these areas [47]. Then, a sustainability approach for cities and communities might give valuable support to aspects related to PULs, such as upgrading slums and providing basic services (target 11.1), developing a safe and accessible transportation system, which is a critical need in peri-urban areas (target 11.2), promoting inclusive and sustainable urbanization (target 11.3), protecting the cultural and natural heritage (SDG 11.4), reducing the negative impacts of cities (SGD 11.5), among others (see details on the targets of SDG 11 at: https://sdgs.un.org/ (accessed on 12 September 2022)).

Conversely, underrepresented SDGs, such as SDG 4 (quality education), SDG 7 (affordable and clean energy), SDG 9 (industry, innovation, and infrastructure), and SDG 14 (life below water), might suggest sustainability topics that are not yet well addressed in research related to PULs. Nevertheless, our results contrast with the available evidence on

the role of PULs, for instance, in electricity generation (SDG 7) [52], industry, innovation and infrastructure (SDG 9) [52], and education (SDG 4), although this SDG seems to be addressed more from NGOs reports than research papers [52]. Regarding SDG 9, we expected a higher relevance along the revised papers since the aspects addressed by this SDG were reported as one of the main drivers of change in PULs (e.g., the location of different types of industries and infrastructure). Then, one possible explanation might be related to the search terms of our research, which included the concepts of "sustainable development" and different synonyms of "peri-urban" and "ecosystem services". Thus, we argue that the low frequency of the SDGs indicated above is more related to a mismatch with the search terms when used together. Still, this mismatch could be used to explore a potential gap in the scientific literature related to PULs and the relation between ES and specific SDGs.

In terms of the potential support provided by different ESs to the SDGs, our results indicate that the 12 identified SDGs are linked to at least one ES section, the majority being related to two ES sections (58%) and also a considerable number related to three ES sections (25%). This confirms the conclusions of the earlier research, which outlined the contribution of ES to the SDGs [23]. However, to our knowledge, there are no works available of this type in the specific case of PULs that would allow particular comparisons and provide more enhanced conclusions.

The most significant contribution to the SDGs is associated with the ES section "regulation and maintenance", which represents 66% of the links. This section, then, plays a vital role in the context of PULs, not only because it showed the highest frequency but also because it presented the largest diversity of an individual ES. These results are similar to previous ones, where regulation and maintenance presented the highest number of interactions with different SDGs, followed by provisioning and cultural sections [23]. Regarding the most connected SDGs to any ES, our results are also close to the cited work of [23], where SDG 15, SDG 13, and SDG 14 presented the largest number of links. One significant difference is related to SDG 11 and SDG 3, which are among the most connected to ES in our research, while they have minor importance in the cited work of Yang. The possible reason for this is that in the context of PULs, given the nexus with urban areas and citizens' well-being, these SDGs and the contribution of a bundle of ESs are more relevant than from a global perspective, as is the case of the cited research.

Finally, based on the cluster analysis, we detected clear associations between certain LULC and the potential supply of a specific ES. The same situation occurred regarding ES and specific SDGs. Certainly, these associations do not aim to propose exact interactions or fixed clusters; instead, they try to illustrate a general closeness concerning their components. In this manner, we argue that more in-depth research is needed to explore these interactions but with particular emphasis on synergies and trade-offs, which are a critical need to support planning and governance in PULs.

5. Conclusions

Our research provides a general overview of the scientific research in PULs and the supply of ES to support the SDGs from a global perspective. The presented findings suggest that this field is still in an early stage of development, dominated by "pure research", but almost nonexistent practical applications focus on supporting concrete governance and planning issues.

Based on our research questions, we can conclude firstly that PULs are generally shaped by a mosaic of forest and seminatural areas, agriculture, and urban-related land uses. Even though additional LULCs, such as water bodies and wetlands, were identified, their frequency was low among the reviewed papers. Such peri-urban LULC mixes have great potential to provide a broad spectrum of ES, where regulation and maintenance appear as the most relevant, associated mainly with the regulation of climate, air quality, pollination, and habitat availability, among others. However, the current dynamic of intensive and extended land use transformations in PULs decreases such potential.

Secondly, knowledge about governance and planning addressing peri-urban ES in connection to SGDs is still limited and remains mainly addressed from a theoretical perspective provided by experts from academia. The involvement of other actors, such as stakeholders or citizens, is a critical missing aspect strongly suggested by our findings. Another critical point is that the municipal level is the dominant scale of research, even though it is well-known that PULs extend beyond the boundaries of a specific municipality or even region. This research, then, points out a potential risk for the present and future governance and planning of PULs, given the lack of cooperation between science and the multiple actors that can play a role in different scales of decision-making. In our view, this might condition the capacity of PULs to provide a range of ESs that support the achievement of diverse SDGs and the consequent benefits for the population in urban and peri-urban contexts.

Thirdly, PULs provide an important contribution to sustainable development at different scales, from local and municipal to regional levels. As shown by our research, PULs contribute to 12 of the whole set of 17 SDGs. In this sense, the dominant SDGs were SDG 11, SDG 15, SDG 3, SDG 2, SDG 13, and SDG 6. At the same time, most SDGs are related to the supply of different types of ES. However, it is necessary to highlight that, more than an individual ES, the SDGs are related to bundles of them coming from two different ES sections in almost 60% of the cases. Further studies, then, should consider an assessment of trade-offs in specific peri-urban case studies.

Thus, we argue that governance and collaborative planning actions to protect key ecosystems present in PULs are critical to maintaining and increasing the supply of ES and enhancing their flows. However, among other aspects, this needs a structured and cross-sectored framework of collaboration focused on planning and sustainability in PULs. This framework should be promoted by the government and other relevant actors according to the specific context in each country (e.g., academia). This might contribute to the achievement of a range of SDGs and increase the opportunities for well-being, not only in PULs but also in both rural and urban areas.

Future research perspectives could consider exploring the potential to establish a PULs monitoring system based on spatially explicit indicators related, for instance, to planning and governance aspects of projects implementation and LULC transformations. Thus, ES supply, ES trade-offs, their contribution to SDGs, and other features could be measured to inform decision-making.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/xxx/s1.

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