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Review

A systematic review on the ecosystem services provided by green infrastructure

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ABSTRACT

Urbanization and climate change are endangering the sustainability of public spaces through increased land artificialization, ecological fragmentation, reduced resource availability, and limited accessibility to natural and seminatural areas. Properly managing Green Infrastructure (GI) can contribute to mitigating these challenges by delivering multiple provisioning, regulating, supporting and cultural Ecosystem Services (ES). This would facilitate the implementation of strategically planned GI networks in cities for urban regeneration purposes. In this context, this study developed a systematic review on the ES provided by GI using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The analysis of 199 eligible articles indicated that more efforts should be made to address more ES at once, which connects to the need for conceiving GI as a strategically planned network of areas aimed at delivering diverse benefits. Based on the methods used in the items reviewed, geoprocessing tools and multi-criteria decision analysis are proposed to develop systems of indicators capable of accounting for multiple ES. These systems should also rely on multidisciplinary and participative procedures to encompass various facets of GI and represent the priorities of all relevant stakeholders.

1. Introduction

Ecosystems underpin human quality of life through a variety of benefits that people obtain from them (Limburg et al., 2002). These are usually defined as Ecosystem Services (ES) and arranged into provisioning (food, water, timber or fiber), regulating (climate, floods, disease, waste or water quality), cultural (recreation, aesthetics or spiritual benefits) and supporting values (soil formation, photosynthesis or nutrient cycling) (Millennium Ecosystem Assessment Board, 2005).

Although there is a growing debate about ecosystems disservices that can be harmful to human wellbeing (pests, litter, biological hazards, etc.) (von Döhren and Haase, 2015), the maintenance of ecosystems has become a priority for years due to the increasing stress posed by land cover change, population density and urban sprawl (Long et al., 2014; Maes et al., 2015). The developments entailed by these phenomena often result in natural landscape alterations (Wang et al., 2020). In addition, some effects driven by climate change such as rising temperature or droughts are also affecting the status of ecosystems (Turner et al., 2020).

As noticed by Tan et al. (2020), there is a paradox in the consideration of natural capital as the basis for human development and the constant exploitation of such capital. However, there is a need for supporting natural processes to face the current degradation of ecosystems, especially in urban areas (Adla et al., 2022). Hence, natural capital should be exploited responsibly to ensure the delivery of ES (Buonocore et al., 2020).

The use of Green Infrastructure (GI) has also been suggested in the scientific literature over the past years to better manage different ES (Amorim et al., 2021; Yacamán Ochoa et al., 2020). From the analysis of several definitions of GI (Interreg Central Europe, 2021), the EU project MaGICLandscapes referred to GI as “a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned)

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and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings" (European Commission, 2013).

More in detail, GI should contribute to better manage floods, heat stress, water scarcity, carbon storage, energy use, groundwater recharge, erosion, wellbeing, ecological connectivity, environmental education, aesthetics/amenity, food production or green job opportunities, among others (Choi et al., 2021). Even though these benefits are very diverse, most of them can be organized and understood as ES.

Considering the importance that GI and ES have in the present and future of the planet, the number of studies focused on both topics have increased over the past years. The literature contains different reviews on these topics whose figures vary depending on the search framework. Following the results of Parker and Zingoni de Baro (2019), the number of publications focused GI and ES have gone from less than 10 in 2010 to more than 180 in 2018.

These authors considered publications up to 2018, whilst others covered until 2016 (Wang and Banzhaf, 2018), 2017 (Suppakittpaisarn et al., 2017) and 2019 (Ying et al., 2022). The latter was particularly extensive by collecting more than 2000 publications; however, if the same search conditions were used again, 1500 new results would be obtained between 2020 and 2021. Considering this situation, we identified a need for developing a study to complement and update the trends in this field of research.

Among others, previous reviews highlighted important facts such as the ability of GI to positively affect the physical and mental health of individuals as well as the socio-economic conditions of communities (Suppakittpaisarn et al., 2017; Tzoulas et al., 2007). This links to the lack of studies focused on developing regions in Africa, Asia and South America as identified by Ying et al. (2022). The need for analyzing GI and its ES at different scales has also been emphasized by several authors (Lee and Oh, 2019; Minixhofer and Stangl, 2021; Tiwari et al., 2019). These facts, coupled with the urban and rural scope of the definition of GI considered, suggested that assessing the studies on GI and ES in geographic terms should be necessary.

Other authors put emphasis on multifunctionality as one of the key factors to magnify the benefits offered by GI (Caparrós-Martínez et al., 2021; Monteiro et al., 2020; Wang and Banzhaf, 2018). For this reason, addressing a topic as the combination of GI and ES has been argued to require a multidisciplinary approach. However, several authors agree in pointing out that this still needs to be addressed (Angelstam et al., 2013; Caparrós-Martínez et al., 2021; Choi et al., 2021; Wang and Banzhaf, 2018). Hence, analyzing the profiles of the authors who have published on the topic became a central concern of this study, since their most common fields of research may give insight into the involvement of different areas in the assessment of GI and ES.

The scope of these reviews is also quite diverse. For example, Tzoulas et al. (2007) focused on specific journals, Chatzimentor et al. (2020) studied only European publications, and Van Oijstaeijen et al. (2020) searched for toolkits. Likewise, some of them pointed to specific topics such as principles and urban and local practices (Monteiro et al., 2020), cultural services (Cheng et al., 2021) or climate change action, adaptation and mitigation (Choi et al., 2021). Despite this variety, we could not find any review that analyzed the different categories of ES and their relationships, which is essential to maximize the benefits delivered by strategically designed networks of GI. Therefore, it seemed relevant to account for the frequency, variety and form in which ES were addressed in the publications found. Finally, although some studies dealt with the methodological variety with which the subject is faced, we were also unable to find information on the specific methods used for planning, developing, applying and/or evaluating GI.

In light of these considerations, this review aimed at updating the existing knowledge on GI from the perspective of their ES, with emphasis on the analytical techniques used and the profile of the people participating in their assessment. With this, we sought to find response about which GI-related ES are more recurrent in the literature, how they are addressed (methods applied) and who is conducting these studies (main disciplines involved).

The results to be achieved shall be of interest for policymakers because they can help identify priorities and strategies to preserve ecosystems due to their importance for human beings. Researchers can also benefit from the outputs of this review by finding knowledge gaps and ideas for collaboration opportunities, whereas practitioners and consultants might learn about methods to support the planning and implementation of GI for ES maximization.

The rest of the document is structured as follows: Section 2 describes the methodology used to conduct the review, which includes the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach as well as data mining and statistical tests. Next section presents and discusses the results collected, with emphasis on the ES addressed and the methods and research profiles involved in their analysis. The document ends by highlighting the main findings of the study, while suggesting some lines of research to develop in the future.

2. Methodology

The methodology used to conduct the systematic review was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach (Liberati et al., 2009), as shown in Fig. 1. The search strategy used before applying the PRISMA statement is described below. Furthermore, an overview of the process followed to examine the full texts is provided too. Finally, the text mining, frequency and statistical methods used to analyse the data extracted from these documents is outlined.

2.1. Search strategy

The motivation to develop this review follows a series of research questions (RQ) concerning the spatiotemporal trends of the publications in the field, as well as their scope in terms of ES, methods and profile of the researchers involved. These questions can be summarised as follows:

- RQ1: Is there any GI-related ES that is more frequently studied in the literature?
- RQ2: How many studies jointly address all the ES provided by GI?
- RQ3: What are the methods and models commonly used to assess GI benefits?
- RQ4: What are the profiles of the researchers involved in the study of GI and ES?
- RQ5: Are the existing scientific outputs evenly distributed in spatial terms (context, scale and country of origin)?
- RQ6: How is the evolution in the number of publications in this field of research since the last decade (2010–2021)?

To answer these questions, a search equation was built according to the following inclusion criteria (IC):

- IC1: The publications are original research articles involving novel contributions to the field of GI and ES AND
- IC2: The articles address GI from the perspective of their ES AND
- IC3: The articles are indexed in the Scopus database AND
- IC4: The articles are published in English, Spanish, Portuguese, Italian OR German

The first criterion (IC1) served to exclude publications derived from conferences, books, and book chapters. Furthermore, it also entailed the exclusion of papers lacking clear and original methodological contributions. This was important due to the scope of the review, which, among others, aimed at producing knowledge on the most suitable methods used to facilitate the strategic design of GI to maximize their ES. Therefore, publications exclusively focused on e.g., exploratory analyses or overviewing case studies were discarded if they were not founded on the proposal and application of methods or combination of methods.

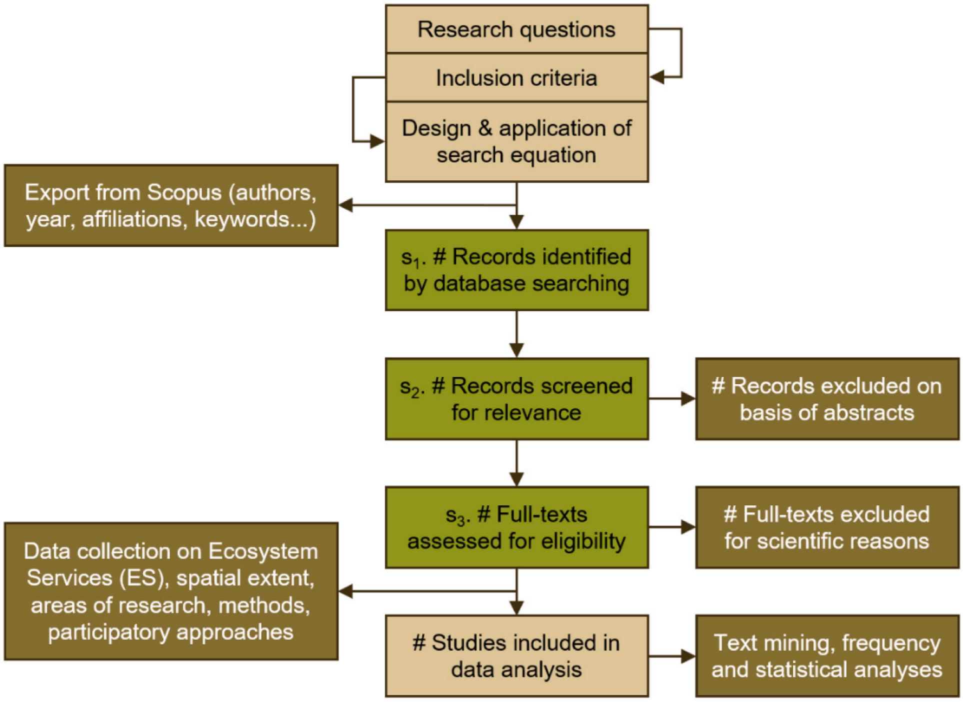

Fig. 1. Flowchart of the steps taken to conduct the systematic review.
Adapted from the PRISMA statement (Liberati et al., 2009).

IC2 was relevant from a conceptual point of view, since linking GI with ES was the premise of this study. As such, those contributions not acknowledging this relationship explicitly were discarded. Despite the emergence of new scientific databases, Web of Science (WoS) and Scopus remain as the most comprehensive bibliographic sources nowadays. In line with the findings of Pranckutė (2021), the latter was chosen for being more practical and providing wider and more inclusive contents (IC3). It also includes profiles for all authors and institutions, which is especially relevant to apply the multidisciplinary approach proposed. The review was conceived to be carried out in English; however, other languages spoken fluently by the authors were also considered in IC4 for the sake of opportunity.

The combination of all these criteria resulted in the search query formulated in Eq. (1). As highlighted throughout this section, it included only two technical terms: GI and ES. The former was required in the title for being the core term of the review, while the latter was also accepted in the abstract and/or keywords of the documents.

TITLE (“green infrastructure”) AND TITLE-ABS-KEY (“ecosystem* service*”) AND DOCTYPE (“ar”) AND (LIMIT-TO (LANGUAGE,”English”) OR LIMIT-TO (LANGUAGE,”Spanish”) OR LIMIT-TO (LANGUAGE,”Portuguese”) OR LIMIT-TO (LANGUAGE,”Italian”) OR LIMIT-TO (LANGUAGE,”German”)) (1)

The inclusion of ES in Eq. (1) instead of specific terms framed within these services aimed at encompassing studies showing a broad vision of the benefits of GI. This orientation is important to ensure a focus towards the very concept of GI, which must be understood as an interconnected network of spaces strategically planned to maximize its ES.

2.2. Data collection

The items returned by Eq. (1) were exported to comma-separated values (.csv) in Scopus, including the following fields: Author(s), Document title, Year (RQ6), Affiliations, Correspondence address, Abstract, Author keywords and Index keywords. Apart from these data, additional information was tabulated through the reading of the full-texts of the remaining articles after the second filtering (s_2) of the PRISMA approach (Fig. 1).

Eight fields were added to identify the most frequently ES addressed in the literature (RQ1 and RQ2). Four of them indicated the absence (0) or presence (1) of the ES categories in the articles, whilst four others were devoted to indicating which terms in Table 1 were used for each category. These were established based on those suggested by international organisations (Egoh et al., 2012; FAO, 2022; National Wildlife Federation, 2022). In case some articles included terms not assimilable to those in Table 1, they were added separately.

Another field was added to specify the reasons for dropping articles throughout the different steps ($s_1 - s_3$) of the workflow (Fig. 1). The next two fields added manually were devoted to enumerating the methods applied in the articles and the use of participatory approaches (RQ3). In

Table 1
List of terms proposed to account for the Ecosystem Services (ES) provided by Green Infrastructure (GI).

Ecosystem Service	Terms
Provisioning	‘food’ OR ‘crop’ OR ‘raw material’ OR ‘biomass’ OR ‘freshwater’ OR ‘fresh water’ OR ‘harvest’ OR ‘medic’ OR ‘natural resource’ OR ‘fuel’ OR ‘timber’ OR ‘wood’ OR ‘nutrient’ OR ‘gas’ OR ‘oxygen’ OR ‘forest’
Regulating	‘air quality’ OR ‘air pollut’ OR ‘heat island’ OR ‘therm’ OR ‘energ efficien’ OR ‘carbon’ OR ‘greenhouse’ OR ‘climate change’ OR ‘flood’ OR ‘stormwater’ OR ‘water quality’ OR ‘drought’ OR ‘landslide’ OR ‘wastewater’ OR ‘soil ero’ OR ‘soil fert’ OR ‘land degrad’ OR ‘desertif’ OR ‘pollinat’ OR ‘biolog control’ OR ‘govern’ OR ‘decompos’ OR ‘purificat’
Supporting	‘biodiversity’ OR ‘habitat’ OR ‘species’ OR ‘gene’ OR ‘ecolog’ OR ‘connect’ OR ‘fragment’ OR ‘corridor’ OR ‘landscape’ OR ‘network’ OR ‘regen’ OR ‘conservat’ OR ‘preservat’ OR ‘protect’ OR ‘plant’ OR ‘animal’ OR ‘wildlife’
Cultural	‘recreation’ OR ‘social’ OR ‘mental’ or ‘physical’ OR ‘walk’ OR ‘sport’ OR ‘touris’ OR ‘aesthetic’ OR ‘relie’ OR ‘inspir’ OR ‘sense’ OR ‘emotion’ OR ‘belonging’ OR ‘experience’ OR ‘creativ’ OR ‘educat’ OR ‘spiritu’ OR ‘enrich’ OR ‘heritag’ OR ‘artistic’ OR ‘dignif’ OR ‘enjoy’ OR ‘entertain’

the first instance, the methods were recorded as reported in the articles. Then, they were progressively grouped until reaching representative heterogeneous clusters. If participatory methods were adopted, the profiles of the participants were specified to differentiate among academics, authorities, citizens, practitioners, and volunteers. The resulting table, provided as supplementary material, can be consulted in Appendix A.

To complement the information provided by the affiliations of the authors, their predominant areas of research were also retrieved (up to a maximum of six) based on their most contributed SciVal's Topics between 2016 and 2020 according to Scopus (RQ4). The spatial extent of the studies (RQ5) was represented by two fields: context (urban, peri-urban and/or rural) and scale (micro, meso and/or macro). Microscale referred to site-specific locations such as buildings or neighbourhoods, whereas mesoscale accounted for broader areas like cities or municipalities. Macroscale was the term used when the extent of the study amounted to provinces, watersheds or even countries.

2.3. Data analysis

The analysis of eligible documents was conducted using R 4.1.0 (R Core Team, 2022). The approach taken for the revision led to the compilation of three kinds of data: text, binary and frequency. Text data was processed through mining techniques (Feinerer and Hornik, 2020), which enabled creating a corpus, eliminating undesired characters and words, reducing the terms to their roots (basic words to which affixes are added) and building document-term matrices. The correlation among the most frequent terms thus identified was also explored (Wijffels et al., 2021).

Binary data resulted from setting some of the characteristics considered in the review as dichotomous variables, such that the reading of the publications served to determine their presence (1) or absence (0). The numeric nature of these data enabled conducting correlation analyses to identify whether certain aspects were related to each other (Kirch, 2008). This was particularly applied to determine the intra- and extra- interconnections involving the four categories of ES.

Frequency data resulting from counting present and absent characteristics were used to identify differences in the proportions in which the different categories included in the fields appeared in the publications. This was checked using the two-proportions Z test (Agresti, 2019), which served to determine whether such differences were statistically significant or not and, if positive, in what sense. In addition, this test served to compute the probability that a certain characteristic is present in a study on GI and ES.

The results obtained for the correlation coefficients and the tests for comparing independent samples were referred to significance levels of 0.01, 0.05 and 0.10 (Labovitz, 1968). Hence, the correlation coefficients determined were considered significant when their associated p-values were below these thresholds. Similarly, p-values below the significance levels for the two-proportions test indicated that the categories under analysis were statistically different from each other.

3. Results and discussion

3.1. Search results

When entering the search equation (Eq. (1)), 273 publications were returned (s_1). Among these, five were discarded because of their restricted accessibility, which was limited to their abstract. In accordance with IC1, another 24 items were not considered further because they were review articles but not tagged as such.

As a result, the number of full texts to review amounted to 244 (s_2). After reading, additional 45 records were excluded because of their lack of specific methodologies to address any facet related to GI and ES. Instead, they were rather descriptive studies focused on aspects such as lessons learned, best practices or policies' comparison. In the end, the number of items remaining for data analysis was 199 (s_3). Only one of these articles was not written in English, so that this study can be concluded to be a review in the language of science (Elnathan, 2021).

Table 2 provides a summary of the number of publications per year referred to the categories in four fields: ES, Scale, Context and Participation. These variables were presented as an overview because they were arranged according to fixed categories, unlike other variables such as methods or research topics. All details for each item can be consulted in Appendix A.

3.2. General trends

The wordclouds in Fig. 2 pointed out to a bias in the publications towards urban areas, which are particularly prone to denaturalization processes and ES deficits (Elliot et al., 2022). This is especially remarkable in the abstracts (Fig. 2a), which also include the term 'citi' and other related words such as 'develop' and 'studi'. There are also other recurrent terms that concern the spatial dimension of GI, such as 'land', 'landscap', 'area', 'architecture' and 'environment'. The presence of these terms may point out to a focus on planning GI for its integration in the landscape rather than as a separate element.

Affiliations (Fig. 2b) corresponds to the only wordcloud in which 'urban' is not the most frequent term. This fact might be linked to the multidisciplinary nature of both the departments or research groups included in the review and the urban environment, a context where a variety of areas can converge (architecture, civil engineering, landscape planning, geography, etc.).

The wordcloud for author keywords (Fig. 2c) were aligned with the trends observed in the abstracts, revealing a great difference between its first two terms ('urban' and 'plan') and the others. Instead, the index keywords (Fig. 2d) contained other frequent terms such as 'area', 'environment', 'biodivers', 'manage', 'water', etc.

Although the trends are similar in the four wordclouds, the roots 'climat' and 'change' are more frequent in both types of keywords than in the abstracts and the affiliations. This may have to do with the breadth of the concept of climate change, which is an illustrative tag for many publications but is less representative than specific terms such as floods, warming, droughts, etc.

The most frequent terms included in these four fields were further explored using correlation plots. According to these plots, there were strong links between generic terms such as 'urban' and 'space' or 'develop', 'plan' and 'benefit' in the abstracts (Fig. 3a). Fig. 3b clarified the focus of some of the most recurrent affiliations, such as built environment, civil engineering, landscape architecture or natural resource management. The associations found for Fig. 3c and d were more specific by underlining adaptation to climate change as a recurrent concept in both types of keywords, as well as biodiversity conservation in the case of index keywords.

To explore general trends with respect to the fields in Table 2, the two-proportions Z test was run (Tables 3 and 4). The results revealed a significantly higher probability (p) for mesoscale ($p = 0.593$) than for the two other categories at a 0.01 level. Although the differences remained when comparing microscale ($p = 0.151$) and macroscale ($p = 0.231$), their significance was only at a 0.10 level. The situation was even clearer for the context, with urban areas being very recurrent ($p = 0.889$). Again, the less frequent categories showed differences at a 0.10 level in favour of peri-urban contexts ($p = 0.301$), which were slightly more frequent than rural studies ($p = 0.216$).

The share of proportions was much more balanced in the case of participation, with a slight preponderance of citizens ($p = 0.191$), whose presence was significantly higher (0.01 level) than that of academics ($p = 0.075$), practitioners ($p = 0.085$) and volunteers ($p = 0.055$). This means that authorities were the other main target of participatory studies ($p = 0.136$), whereas the three less frequent profiles were similar in terms of proportion.

The values obtained for the ES revealed that the presence of

Table 2
Number of publications per year identified for the categories in Ecosystem Services (ES), Scale, Context and Participation. More details be consulted in Appendix A.

Year	References	ES				Scale			Context			Participation				
		Prov	Reg	Supp	Cult	Mic	Mes	Mac	Urb	P-Urb	Rur	Aca	Aut	Cit	Pra	Vol
2021	(Bai, Guo (2021); Barrios-Crespo et al., (2021); Alizadehtazi et al., (2020); Anisimova, (2020); Badenhausser et al., (2020); Basnou et al., (2020); Blazy et al., (2021); Borysiak et al., (2017); Bush et al., (2021); Calderón-Contreras and Quiroz-Rosas, (2017); Campbell-Arvai and Lindquist, (2021); Caparrós Martínez et al., (2020); Castelli et al., (2017); Chen et al., (2020); Dai et al., (2021); de Manuel et al., (2021); Deeb et al., (2018); Delgado-Capel and Cariñanos, (2020); Derkzen et al., (2017); Dimitrov et al., (2018); Dipeolu and Ibem, (2020); Xia et al., (2021); Xu, Zhao (2021); Zulian et al., (2021))	13	24	20	19	3	22	7	28	9	4	3	3	6	2	2
2020	(Abramowicz, Stępniewska (2020); Andersson et al., (2020); Donaldson and João, (2020); Drius et al., (2020); Elbakidze et al., (2017); Elliott et al., (2020); Fňukalová et al., (2021); Furberg et al., (2020); Fusaro et al., (2015); Garau and Annunziata, (2019); García et al., (2020); Garcia-Cuerva et al., (2018); Ghofrani et al., (2020); Gill et al., (2020); Gómez-Villarino et al., (2021); Guo and Bai, (2019); Hamann et al., (2020); Hansen et al., (2019); Hermoso et al., (2020); Hernández-Moreno and Reyes-Paecke, (2018); Hoerbinger et al., (2018); Honeck et al., (2020); Wuyts et al., (2020); Zalejska-Jonsson et al., (2020))	14	39	28	23	9	27	12	44	10	7	4	5	7	2	1
2019	(Bartesaghi-Koc et al., (2019a); Bartesaghi-Koc et al., (2019b); Caplan et al., (2019); Capotorti et al., (2019a); Capotorti et al., (2019b); Hu et al., (2018); Huera-Lucero et al., (2020); Hysa, (2021); Jerome et al., (2019); Khoshnava et al., (2020); Kimic and Ostrysz, (2021); Klimanova et al., (2021); Klimanova and Illarionova, (2020); Kopp and Preis, (2019); Kowarik et al., (2019); La Rosa and Privitera, (2013); Lai et al., (2019); Lai et al., (2018); Landor-Yamagata et al., (2018); Langemeyer et al., (2020); Lanzas et al., (2019); Leonard et al., (2019); Li et al., (2020b); Liao et al., (2020); Lieberherr and Green, (2018); Zhang, Muñoz Ramírez (2019); Zhang et al., (2019); Zölch et al., (2019))	12	25	19	14	2	22	5	28	13	6	1	4	6	4	2
2018	(Cannas et al., (2018); Cortinovis et al., (2018); de la Fuente et al., (2018); Lin et al., (2016); Lin et al., (2019); Liquete et al., (2015); Liu and Russo, (2021); Liu et al., (2020); Lonsdorf et al., (2021); Lynch, (2016); Ma et al., (2021); Majekodunmi et al., (2020); Maragno et al., (2018); Marando et al., (2019); Marcucci and Jordan, (2013); McWilliam et al., (2017); Meerow, (2019); Meerow et al., (2021); Meerow and Newell, (2017); Mekala and Hatton MacDonald, (2018); Miller and Montalto, (2019); Moyzeová, (2018); Muvuna et al., (2020); Nguyen et al., (2021); Vasiljević et al., (2018); Wong et al., (2018); Wong, Jim (2018))	11	17	20	14	5	17	9	27	9	10	3	5	6	4	1
2017	(Albert, Von Haaren (2017); Angelstam et al., (2017a); Angelstam et al., (2017b); Artmann et al., (2017); Zardo et al., (2017); Zhang et al., (2017); Zidar et al., (2017))	7	13	15	13	4	12	8	21	7	11	1	4	6	3	1
2016	(Di Leo et al., (2016); Guerrero et al., (2016); Kati, Jari (2016); Niedźwiecka-Filipiak et al., (2019); Nielsen et al., (2017); Niţă et al., (2018); Norman et al., (2021); Orantes et al., (2017); Padró et al., (2020); Palliwoda et al., (2020); Palme et al., (2020); Pappalardo et al., (2017); Parker and de Baro, M.E., (2019); Paulin et al., (2020); Pavao-Zuckerman and Sookhdeo, (2017); Pelorosso et al., (2017); Piacentini and Rossetto, (2020); Piedelobo et al., (2019); Privitera and La Rosa, (2018); Rall et al., (2019); Ramyar et al.,	2	4	3	3	2	7	0	9	1	1	0	1	1	0	0

(continued on next page)

Table 2 (*continued*)

Year	References	ES				Scale			Context			Participation				
		Prov	Reg	Supp	Cult	Mic	Mes	Mac	Urb	P-Urb	Rur	Aca	Aut	Cit	Pra	Vol
	(2020); Ring et al., (2021); Montgomery et al., (2016); Pinho et al., (2016); Zölch et al., (2016))															
2015	(Barau (2015);Kim et al., (2016);Kim et al., (2015);Kim et al., (2021);Kim et al., (2020); Rodríguez-Espinosa et al., (2020); Rodríguez-Loinaz et al., (2018); Ronchi et al., (2020); Rubiano Calderón, (2019); Russo et al., (2021); Salomaa et al., (2017); Sanesi et al., (2017); Santiago Ramos and Hurtado Rodríguez, (2021); Schiavon et al., (2021); Schifman et al., (2018); Schmidt and Hauck, (2018); Sebastiani et al., (2021); Semeraro et al., (2020); Shackleton et al., (2018); Shi and Qin, (2018); Shi et al., (2021); Shifflett and Yess, (2019); Sikorska et al., (2017); Mathey et al., (2015);Mekala et al., (2015);Sussams et al., (2015))	2	6	6	4	1	4	2	7	4	2	1	1	2	1	1
2014	(Faehnle et al., (2014); Kopperoinen et al., (2014))	1	1	1	2	0	1	1	2	1	1	0	2	1	0	1
2013	(Andersson et al., (2013); Barbati et al., (2013); Farrugia et al., (2013); Simić et al., (2017); Sturiale, (2019); Sun et al., (2021); Svensson et al., (2019); Tran et al., (2020); Valente et al., (2020); Valeri et al., (2021); Vallecillo et al., (2018); van Vliet and Hammond, (2021); Venter et al., (2021); Venter et al., (2020b); Wang et al., (2019); Wang et al., (2021); Wijffels, (2021); Wong and Montalto, (2020); Young, (2011); Roe, Mell (2013); Schäffler, Swilling (2013); Young, McPherson (2013))	2	5	5	4	4	3	1	8	4	1	2	2	1	1	2
2012	(Barnhill, Smardon (2012))	0	1	1	1	0	1	0	1	0	0	0	0	1	0	0
2011	(La Greca et al., (2011))	0	2	1	1	0	2	0	1	2	0	0	0	1	0	0
2010	(Isely et al., (2010))	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0
Frequency per field (f)		65	138	120	99	30	118	46	177	60	43	15	27	38	17	11

ES = Ecosystem Services / Prov = Provisioning; Reg = Regulating; Supp = Supporting; Cult = Cultural / Mic = Microscale; Mes = Mesoscale; Mac = Macroscale / Urb = Urban; P-urb = Peri-urban; Rur = Rural / Aca = Academics; Aut = Authorities; Cit = Citizens; Pra = Practitioners; Vol = Volunteers. Dots (…) in the 'References' field stand for the remaining and nonexplicitly cited authors of the publications per year.

provisioning services ($p = 0.327$) was significantly lower than the others (0.01 level). Instead, regulating ($p = 0.693$) and supporting ($p = 0.603$) ES were the dominant categories, to the extent that their proportions only differed at a 0.10 level. Cultural ES ($p = 0.497$) were in an intermediate situation, showing a significantly lower frequency than supporting ES at a 0.05 level.

3.3. Ecosystem Services (RQ1 and RQ2)

Delving into the results of Table 3, Fig. 2 shows the terms with the highest frequency (f) for each ES according to the words proposed in Table 1. The most frequent term was 'biodiversity' (f = 74), followed by 'recreation' (f = 68), 'air quality' (f = 52), and 'stormwater' (f = 50). Apart from its own relevance as a global concern (Roe, 2019), the predominance of 'biodiversity' may relate to the role of supporting ES as basic ecological processes that sustain the remaining services, whereby they might be considered even if the articles primarily focus on another ES category. In the case of cultural services, Fig. 2c emphasized the recreational, social, and aesthetical values of GI. The contribution of GI to physical health was the main specific subject of research, with the combination of 'physical', 'walk', and 'sport' resulting in f = 52. Regarding regulating services, their relevant role might have to do with the increasing importance of climate change, as suggested by the most frequent words in Fig. 2b. Provisioning services were the least approached ES group in the records reviewed, proving that the use of GI as a source of natural resources still needs to be further investigated. Although the provision of water, raw materials, and energy was addressed in some publications, the feeding potential of GI was the most frequent topic of study in this group (f = 58 when combining 'food', 'crop', 'nutrient', and 'agricultur') Fig. 4.

Regarding the combined assessment of several ES, the two-proportions Z test indicated that the number of publications focused on only one group (f = 87) was significantly higher (0.01 level) than those addressing two (f = 34), three (f = 41) and four (f = 36) ES at once. The joint frequency of combined approaches proved that the records involving two or more ES (f = 111) were significantly higher (0.05 level) than those targeting a single ES group. Although all ES should be considered to achieve strategic networks of GI, these results suggest that most studies provided broad perspectives by accounting for diverse ES values.

The specific associations among the ES families were examined through a correlation analysis. Table 3 compiles the correlation coefficients obtained from the presence (1) or absence (0) of ES categories in the publications. The only ES groups lacking a statistically significant correlation were regulating and cultural, whereas the association between regulating and supporting services was negative. However, it corresponded to the weakest significant correlation coefficient, so that the relevance of this result was limited.

The strongest coefficients corresponded to the relationships of provisioning services with regulating and cultural services. The former may lay in the multiple implications of water management, since its catchment and retention (regulation) are a precursor to its potential reuse for potable and non-potable purposes (provisioning). The association between provisioning and cultural services might relate to the agricultural use of GI, which entails a recreational component because of the care of crops.

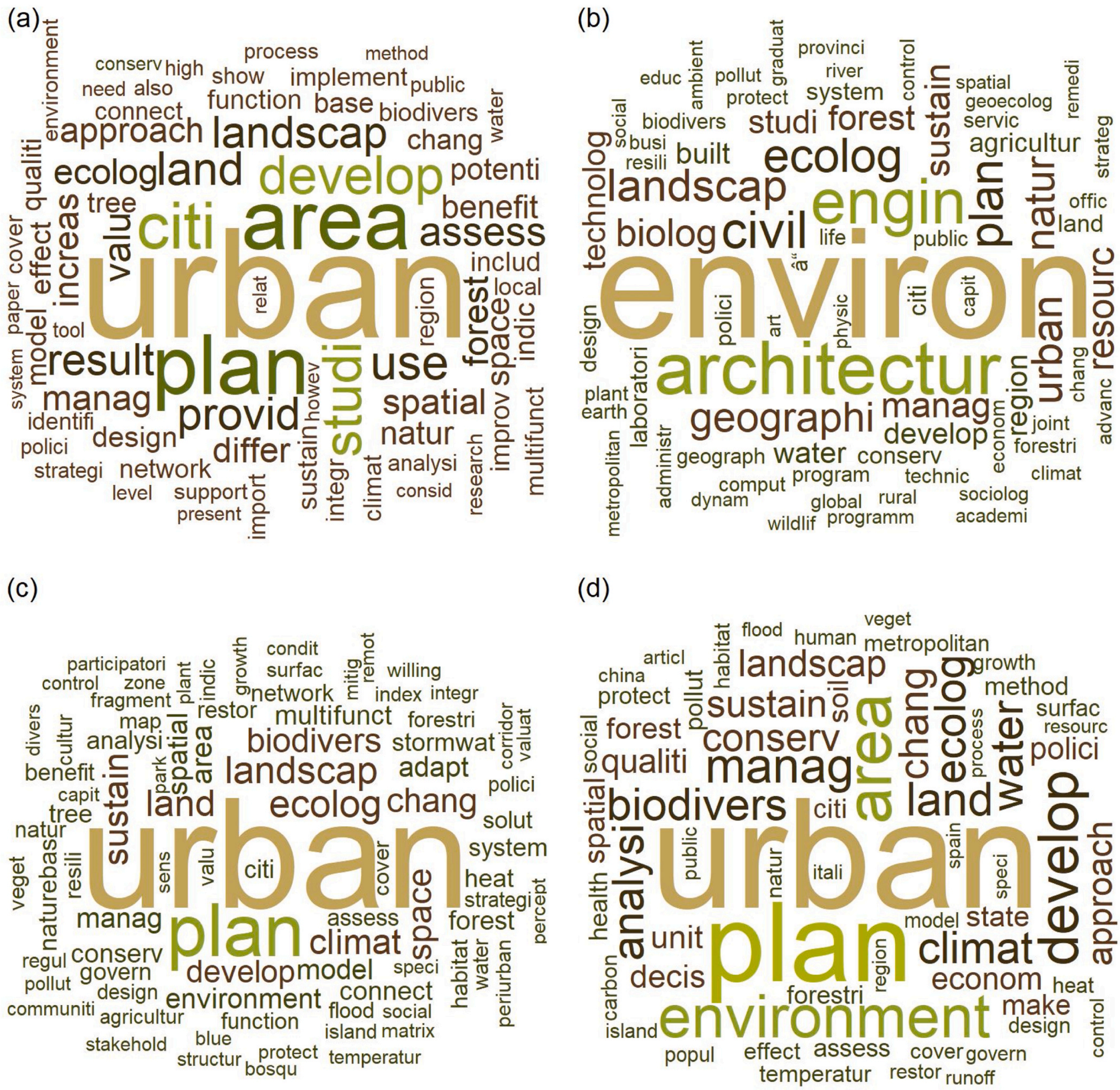

Fig. 2. Wordclouds of the most frequent terms found in the (a) Abstracts, (b) Affiliations, (c) Author keywords and (d) Index keywords.

3.4. Methods (RQ3) and topics (RQ4)

The values of frequency obtained for the methods used were rather homogeneous (Fig. 5). Still, certain trends were found when combining some methods according to their similarity. For instance, the use of indicators is included in indication theory, rating scale and connectivity index, whose combination amounts to f = 47. Several ES are difficult to characterize using direct metrics, which explains the recurrency of these approaches.

Another important group deals with the relationship and/or combination of variables, such as regression analysis, multi-criteria decision analysis (MCDA), Moran's I, supervised classification, or correlation analysis (f = 65). These tools emphasize the complexity inherent in the modelling of ES, which are often the result of the interactions among physical, social, climate or spatial considerations (Longato et al., 2021; Yamaguchi and Shah, 2020). This is especially remarkable in the case of regulating ES related to environmental hazards (floods, air quality, urban warming, etc.) (Li et al., 2020a; Zhang et al., 2022).

A completely different cluster can be found when grouping methods involving people, i.e., interviews, questionnaires, focus groups and workshops (f = 51). Stakeholder engagement is a key aspect to consider in GI management, because green spaces and their benefits have multiple implications at different levels, from political decision-making to the impacts of such decisions on the daily life of citizens (Spanò et al., 2017; Yiwo et al., 2022). As such, these methods are helpful to ensure that GI is planned according to the perceptions of all the parties involved.

Finally, the largest group contains methods related to the spatial component of GI, which includes spatial sampling, terrain analysis, spatial processing, imagery analysis, patch identification, distance analysis, MSPA, spatial algebra, least-cost path analysis, zonal statistics, buffer analysis and remote sensing (f = 97). This preponderance

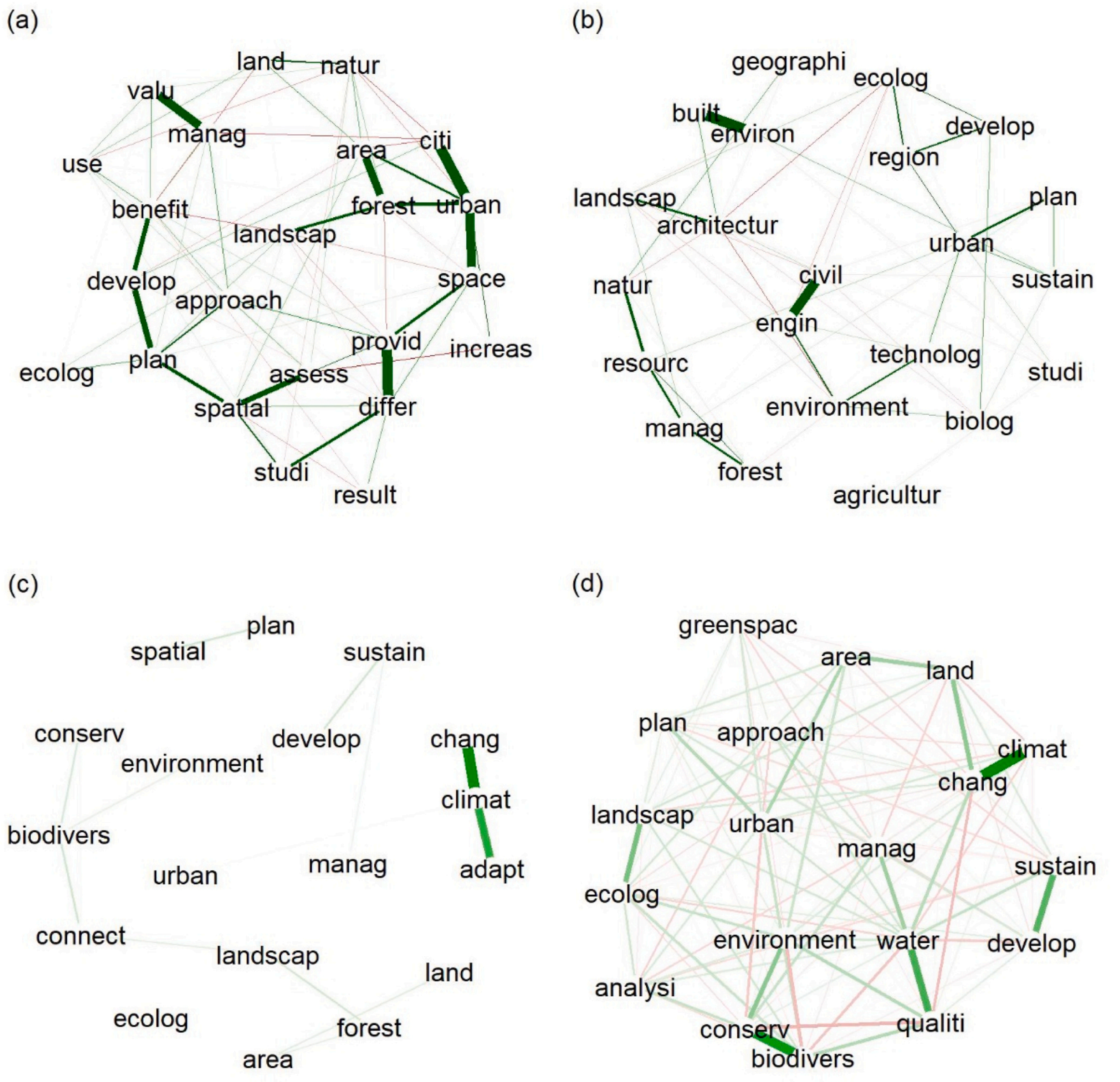

Fig. 3. Correlation plots of the most frequent terms found in the (a) Abstracts, (b) Affiliations, (c) Author keywords and (d) Index keywords. Thick vivid green links indicate strong positive correlations (the terms appear together in the corresponding fields), and vice versa for thin faint red links.

completely aligns with the definition of GI as a strategically interconnected network of green areas. The spatial tools included in this group are oriented to support the calculated location of GI for ES maximization purposes.

Table 5 compiles the most frequent SciVal's Topics associated with the publications reviewed. These topics represent the most common areas of research of the authors between 2016 and 2020. They can be referred to either the number of documents by the authors involved in the review for each topic or the number of times each topic appears in the review. Table 5 accounts for those topics whose frequency was equal to or greater than 10 in both cases.

The representation of the frequencies associated with the topics shown in Table 5 yielded Fig. 6, which reveals a great difference between T.2046 and the others. Unlike other topics in Table 5, this one accounts for a whole group of ES (cultural ecosystem services) and also refers to the term natural capital, which is a broad concept that encompasses both GI and all ES. Also, having the term natural capital at the top of these topics may be critical to understand the approach taken by some of these studies to address the discussion on GI and ES.

Leaving this aside, there is a cluster of frequent topics (T.4552, T.2433, T.7284, T.7304 and T.5774) related to the use of GI in urban areas for regulating purposes such as thermoregulation, stormwater management or air quality. Other recurrent topics (T.1410, T.1364 or T.48272) address wider concepts such as ecosystem stability, forest management or national parks, which can be related to ecological aspects framed within the supporting ES. The presence of provisioning ES was limited to T.3095, which deals with the agricultural use of GI for feeding purposes.

Table 3
P-values yielded by the two-proportions Z test when comparing the categories in different fields.

Field	Probability (p)	Comparison	p-value
Scale	Microscale (0.151)	Microscale vs Mesoscale	0.000
	Mesoscale (0.593)	Microscale vs Macroscale	0.056
	Macroscale (0.231)	Mesoscale vs Macroscale	0.000
Context	Urban (0.889)	Urban vs Peri-urban	0.000
	Peri-urban (0.301)	Urban vs Rural	0.000
	Rural (0.216)	Peri-urban vs Rural	0.067
Participation	Academics (0.075)	Academics vs Authorities	0.072
	Authorities (0.136)	Academics vs Citizens	0.001
	Citizens (0.191)	Academics vs Practitioners	0.854
	Practitioners (0.085)	Academics vs Volunteers	0.543
	Volunteers (0.055)	Authorities vs Citizens	0.175
		Authorities vs Practitioners	0.150
		Authorities vs Volunteers	0.010
		Citizens vs Practitioners	0.004
		Citizens vs Volunteers	0.000
		Practitioners vs Volunteers	0.327
Ecosystem Services	Provisioning (0.327)	Provisioning vs Regulating	0.000
	Regulating (0.693)	Provisioning vs Supporting	0.000
	Supporting (0.603)	Provisioning vs Cultural	0.001
	Cultural (0.497)	Regulating vs Supporting	0.074
		Regulating vs Cultural	0.000
		Supporting vs Cultural	0.044

3.5. *Interactions among fields (RQ1-RQ5)*

The analysis of interactions concerned the examination of the relationships between ES and the remaining fields considered. Their correlation coefficients with the other fields in Table 2 are provided in Table 6. Although the strength of these associations was reduced in most cases, they highlighted some interesting trends.

Provisioning and regulating ES were found to have opposite relationships to macroscales. This is consistent with some of the terms considered in regulating ES (Fig. 4), such as flooding, air quality or the Urban Heat Island effect, which are especially relevant at limited scales. Similarly, provisioning ES were positively correlated to rural contexts, due to the potential of these areas to support the use of GI for producing food and energy.

Regarding participation, the clearest association corresponded to citizens and cultural ES, probably because these are more tangible for people due to their daily life impact. Instead, provisioning ES had a high share of studies involving authorities, which is reasonable considering the role played by administrations in the supply of services such as water or energy. The highest and most significant correlation of supporting ES was with practitioners. This might lay in the professionalism of Geographic Information Systems (GIS) (Li et al., 2020) and the spatial importance of supporting services, which deal with broad aspects such as ecological connectivity and landscape design.

The interactions of ES with other fields were explored through a frequency analysis. The values obtained in Fig. 7a for the methods used highlighted the polyvalence of regulating ES for modelling a variety of aspects through either indicators, questionnaires, statistical tools, or spatial methods. Although this also applied to supporting ES, this group often resorted to map overlays through reclassification, indicators, spatial algebra, and MCDA, which links to the geographical component inherent in these services. The high frequency of correlation analysis for cultural ES may respond to the use of this test to support the identification of significant relationships between accessibility to GI and the social benefits of green areas. The distribution of ES across the most frequent countries (Fig. 7b) was similar to that observed for the whole list of publications in Table 2, with regulating and supporting services being the most widely addressed GI benefits.

Fig. 7c shows logical results regarding the main SciVal's Topics of the authors. For instance, regulating ES had strong associations with T.4552 and T.7284 (Table 5) due to the role of trees and urban forests for heat attenuation and water retention, respectively. As for supporting ES, their highest frequency corresponded to T.4585, T.1364 and T.2041, which deal with stable ecosystems and biological corridors to ensure biodiversity and habitat protection. Cultural ES had remarkable frequencies in topics such as T.1410 or T.1567, probably because of the use of parks for multiple purposes, including thermal comfort. Provisioning ES had the lowest frequency for all topics except T.7284. This may relate to the potential of GI for water harvesting and reuse.

Table 4
Correlation coefficients among the Ecosystem Services (ES).

	Provisioning	Regulating	Supporting	Cultural
Provisioning	1.000	0.324*	0.149*	0.400*
Regulating		1.000	-0.205*	0.095
Supporting			1.000	0.212*
Cultural				1.000

* Statistically significant at a 0.01 level

3.6. *Spatiotemporal trends (RQ5 and RQ6)*

In general, the number of publications released about GI and ES has grown during the last years, except for 2021 (Fig. 8). This anomaly might be due to the COVID-19 pandemic, which caused a general shift of scientific productions towards this topic (Aviv-Reuven and Rosenfeld, 2021). According to Fig. 8a, regulating services were the ES group that grew faster, followed by cultural ES. The increase in provisioning and supporting ES-related papers was less pronounced, despite the latter was the group with the second highest number of documents in the review.

In line with the increase in the number of publications over the years, participation experienced a substantial growth as of 2017 (Fig. 8b). With some nuances, this is common for all types of participants. The implication of citizens has remained almost constant, whereas academics and volunteers have increased their participation. Instead, authorities and especially practitioners are the two profiles whose engagement has decreased. Although this fact might be due to a variety of reasons, it is important to stress that the achievement of significant progress in the academia largely depends on its linkage with reality and practicality. In this sense, involving authorities and practitioners shall be a priority in future research to keep a broad perspective.

The trends with regards to the country revealed a constant predominance of European countries over time (Fig. 8c). The growth experienced by China and Spain is especially remarkable, with both countries increasing their release of publications on the topic in 2020

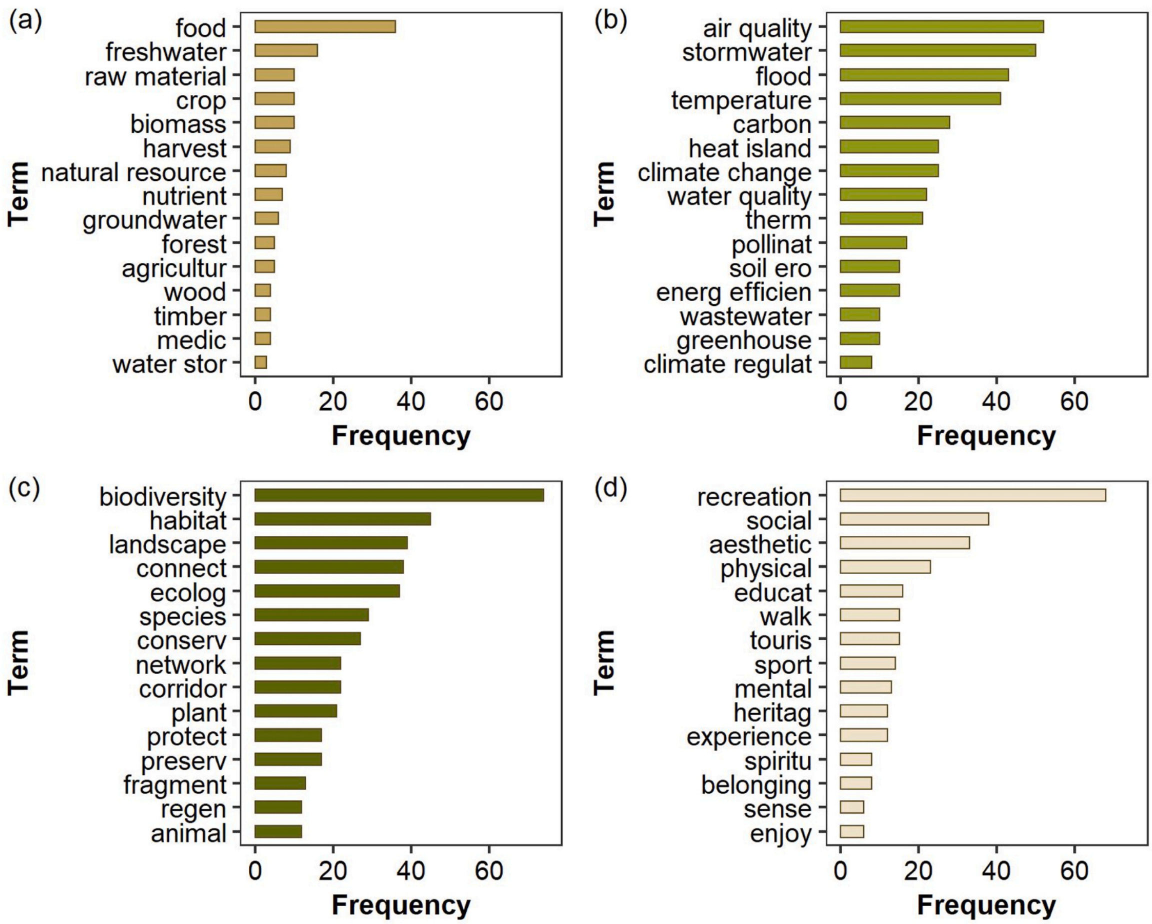

Fig. 4. Most frequent terms associated with the Ecosystem Services (ES): (a) Provisioning services, (b) Regulating services, (c) Supporting services and (d) Cultural services.

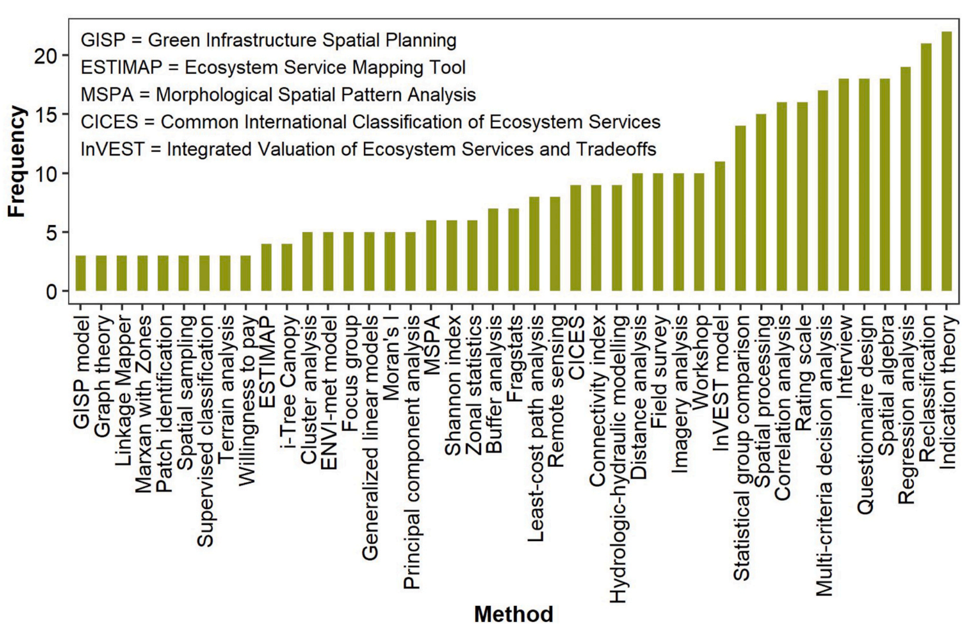

Fig. 5. Most frequent methods used to assess the Ecosystem Services (ES) of Green Infrastructure (GI).

Table 5
Code and full meaning of the most frequent SciVal's Topics.

Code	SciVal's Topic
T.2046	Cultural Ecosystem Services; China; Natural Capital
T.4552	Street Trees; Urban Forests; Green Infrastructure
T.1410	Greenspace; Green Infrastructure; National Parks
T.2433	Heat Islands; Land Surface Temperature; Land Cover
T.7284	Bioretention Areas; Stormwater Management; Green Infrastructure
T.1567	Climate Change Adaptation; Urban Climate; Resilience
T.1364	Ecosystem; Plant Communities; Ecosystem Stability
T.48272	Forest Policy; Landscape History; Forestry
T.7304	Thermal Comfort; Hot Temperature; Microclimate
T.5774	Street Canyon; Air Quality; Deposition Velocity
T.3781	Dead Wood; Saproxylic Organism; Beetles
T.2696	Conservation Planning; Reserve Design; Environmental Protection
T.2041	Bombus; Bees; Neonicotinoids
T.1857	Sleuths; Cellular Automaton Model; Urbanization
T.3646	Resilience; Ecological Resilience; Advocacy Coalition Framework
T.7718	Green Roofs; Hot Temperature; Sedum acre
T.8537	Urban Biodiversity; Urbanization; Birds
T.4585	Ecosystem; Landscape Genetics; Biological Corridors
T.3095	Community Supported Agriculture; Urban Agriculture; Local Food Systems
T.809	Maximum Entropy; Ecosystem; Environmental Space
T.3433	Brazilian Amazon; Tropical Deforestation; Land Cover
T.2347	Decision Making; Social Impact Assessment; Environmental Impact Statements

and 2021. Instead, Italy, which was one of the greatest contributors to the review between 2015 and 2019, has slightly reduced its production in the last years.

Regarding the topics (Fig. 8d), one of the clearest trends found corresponds to T.7718 (Table 5), which grew rapidly until the general decline observed in 2021. Another topic whose production increased steadily, even in 2021, is T.2433. Both cases are related to the thermoregulation potential of GI, which may reflect an increasing importance of climate change in daily life. The use of automaton models to deal with the other great challenge for sustainable development (urbanization) was the only topic (T.1857) experiencing a notable increase in 2021 with respect to previous years (more than twice the number of publications).

3.7. Discussion

The results of the data analysis pointed out to regulating services as the most frequently addressed ES. The coupling of this fact with the results obtained for the context of study (Table 3) aligns with the growing stress posed by urbanization and climate change, which increase the vulnerability of communities to multiple hazards (Williams et al., 2019). There are multiple reviews on the potential of GI to increase urban resilience, especially against floods (Li et al., 2019) and the Urban Heat Island effect (Balany et al., 2020).

Along with climate change, the loss of biodiversity entailed by urbanization is the other main environmental impact caused by humanity (Skogen et al., 2018). This coincides with the results of Fig. 4, whereby biodiversity was the most frequent term among all ES. The concerns raised by some publications years back (Garmendia et al., 2016; Salomaa et al., 2016) about the lack of specific strategies to enhance biodiversity through GI are reflected in our results, which indicate a substantial increase in the number of studies devoted to this matter from 2017 onwards (Fig. 8a). Although not all these works may result in specific strategies, the preponderance of biodiversity as a research topic in the review might indicate that at least the basis to developing such strategies are being addressed.

Despite the need for planning multifunctional GI to maximize its ES is being emphasized for years (Lovell and Taylor, 2013), only about a quarter of the publications reviewed accounted for the four ES groups at once. This connects with collaboration among different disciplines, which is another requirement for properly managing GI (Pauleit et al., 2019). Although the results in Figs. 2b and 6 suggested that the authors involved in the review belonged to divergent research areas and had different topics of publication, this variety was not aligned with the number of ES categories addressed in the articles, which was limited to one in almost half of the cases.

The engagement of academics was also addressed from the perspective of participatory approaches, whose proportion is provided in Table 2. Considering that not all studies may require stakeholder engagement, the share of articles involving at least one stakeholder profile (28.64%) was fair. However, this figure might still be far from the prominent role of participatory frameworks allocated to landscape and urban planning by Pamukcu-Albers et al. (2021). The rather stagnant

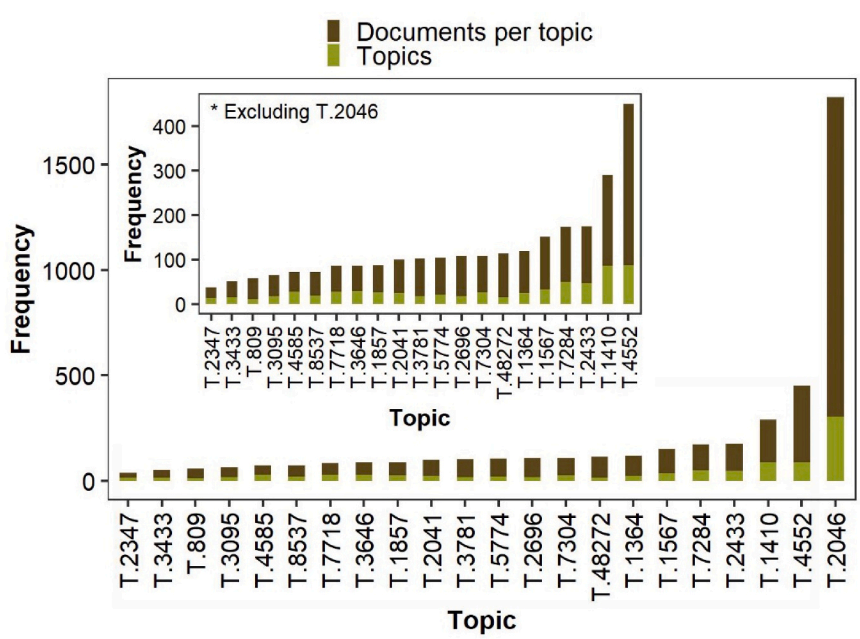

Fig. 6. Most frequent SciVal's Topics of the authors of the publications reviewed. The figures are referred to either the number of documents by the authors for each topic or the number of times each topic appears in the review. The full meaning of the topics can be consulted in Table 5.

Table 6
Correlation coefficients of the Ecosystem Services (ES) with other variables.

Ecosytem Services	Scale		Context		Participation		
	Meso	Macro	Urban	Rural	Authorities	Citizens	Practitioners
Provisioning	-0.201 * **	0.203 * **	-0.039	0.230 * **	0.131 *	0.043	0.132 *
Regulating	0.115	-0.127 *	0.125 *	-0.131 *	0.104	0.101	0.086
Supporting	-0.108	0.079	-0.113	0.081	0.111	0.081	0.138 * *
Cultural	-0.055	0.003	0.016	0.059	0.134 *	0.335 * **	0.091

Statistically significant at a * 0.10 / * * 0.05 / * ** 0.01 level.

trend in Fig. 8b between 2017 and 2021 with respect to that of Fig. 8a may also be insufficient compared with the importance of participation for assessing all the ES values of GI (Venter et al., 2020a), which is especially crucial to implement cross-scale planning strategies (Zulian et al., 2021).

Stakeholder engagement was also emphasized by Adegun et al. (2021) as a key aspect to sustain rapid urban development in Nigeria through GI planning. This same author also pointed out to GI for improving the lives of slum dwellers in African countries through improved food security, environmental quality, etc. (Adegun, 2021). As such, the spatial distribution of results depicted in Fig. 8c should ideally evolve towards a better representation of developing countries, given the potential of GI to balance societal progress with environmental protection and primary production (Haase, 2021).

The general rise in the production of articles observed in Fig. 8 from 2017 might respond to the permeation of the concept of GI in worldwide policies. For instance, the US Congress approved an act in 2019 to provide an integrated planning process for promoting GI (US EPA, 2015). In China, the Ministry of Housing and Urban–Rural Development declared the Greenway Planning and Design Guidelines in 2016, which provides evidence of the recognition of GI to achieve sustainable urbanization (Zhang et al., 2020,2020). Although the EU Strategy to promote investments in GI dates from 2013 (European Commission, 2016), the Council conclusions of 2015 called for putting forward a trans-EU network for GI by 2017. However, the cross-boundary cooperation required for this approach still needs more time to be successful, as demonstrated by e.g., the Spanish Strategy for Green Infrastructure and Ecological Connectivity and Restoration (MITECO, 2021), which took effect in late 2021.

Comparing the findings of this study with those of previous reviews is not easy, because the approach taken here was deliberately different from theirs to result in a new perspective. For instance, some previous reviews were limited to a single ES category (Cheng et al., 2021; Suppakittpaisarn et al., 2017), whilst others used narrower concepts of ES (Chatzimentor et al., 2020). Still, several studies coincided in pointing out to multifunctionality as a key issue to deliver multiple ES and develop potential avenues for future research (Choi et al., 2021; Wang and Banzhaf, 2018). Our outcomes also agreed with previous reviews in specific matters such as the clear focus on urban areas (Ying et al., 2022), bias in the number of publications according to the region of origin (Parker and Zingoni de Baro, 2019) or the involvement of different stakeholders, especially academics, practitioners and authorities (Monteiro and Ferreira, 2020; Ferreira et al., (2021); Van Oijstaeijen et al., 2020). Therefore, this review can be argued to update the conclusions drawn by other authors and provide new insights into the ES delivered by GI, as well as into the methods and research disciplines involved in their analysis.

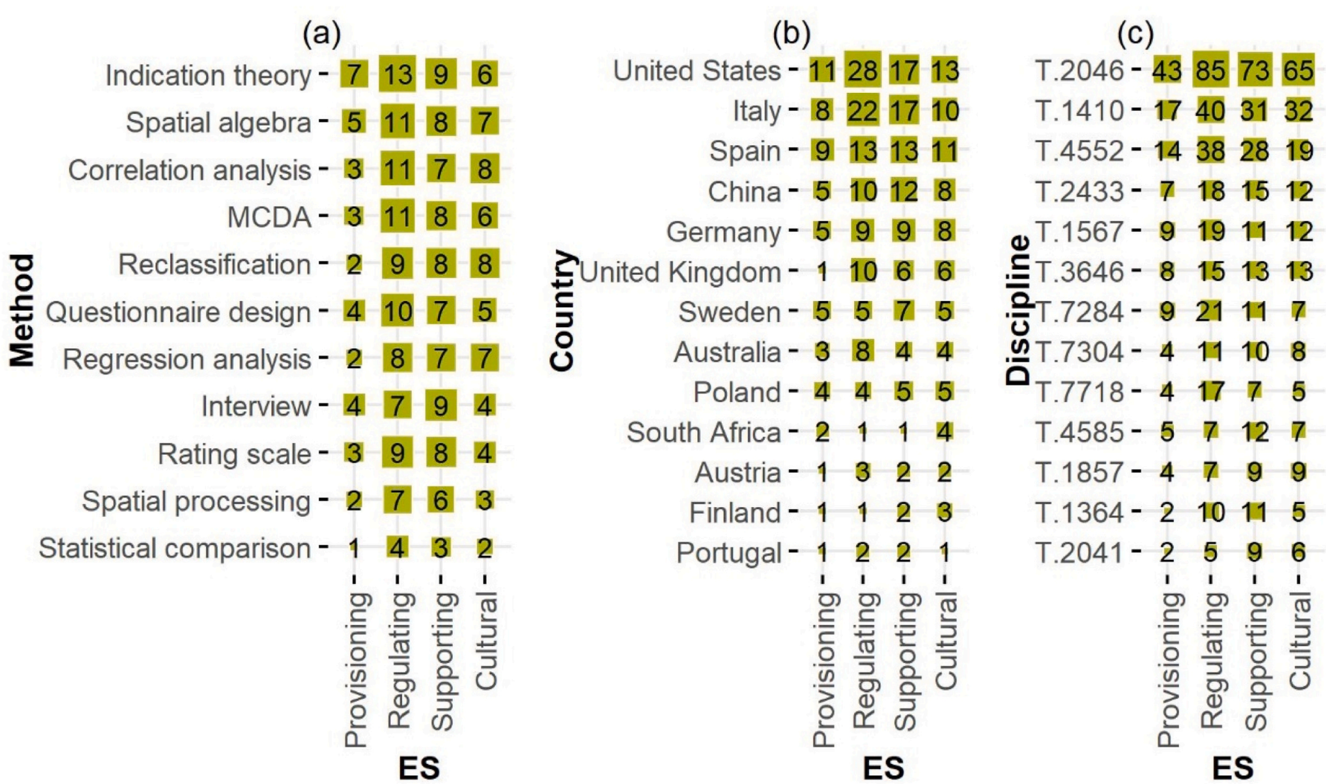

Fig. 7. Frequency values across the Ecosystem Services (ES): (a) Method, (b) Country and (c) Topic. The full meaning of the topics can be consulted in Table 5.

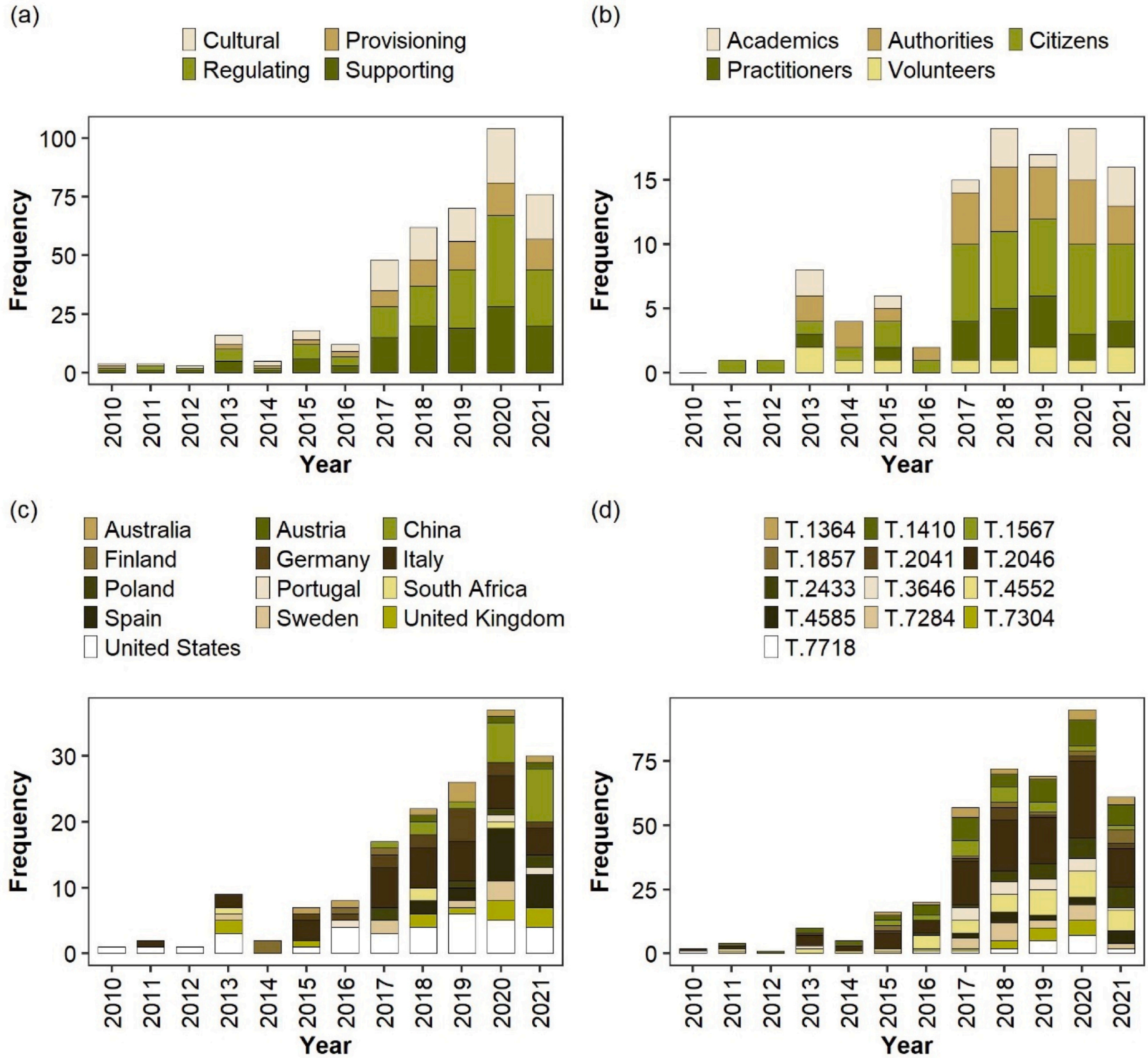

Fig. 8. Breakdown of the publications released over time with respect to (a) Ecosystem Services, (b) Participation, (c) Country and (d) SciVal's Topic. The full meaning of the topics can be consulted in Table 5.

4. Conclusions

The outcomes of this review provide insight into the patterns according to which the ES delivered by GI have been investigated for more than ten years. The 199 eligible research papers were examined according to multiple fields whose analysis gave response to the research questions set before conducting the review:

- There is a growing trend in the number of publications over the years, especially between 2017 and 2020. This has changed in 2021, probably due to the COVID-19 pandemic.
- The U.S. concentrated most of the publications reviewed, followed by European countries such as Italy or Spain. Except for China, the presence of Asian and African countries was marginal.
- The profiles of the authors highlighted by their variety, including affiliations such as architecture, civil engineering, geography, or ecology. The most frequent research topics were slightly biased towards climate change adaption; still, they covered the four ES.
- The proportion of studies addressing regulating services was significantly higher than any other group, although supporting ES were also very recurrent.
- There were not too many studies jointly addressing all the ES, although the number of investigations addressing two or more ES was significantly higher than that of the studies focused on a single ES.
- The largest cluster of frequent methods found concerned the use of spatial techniques, which were present in almost half of the publications reviewed.

Overall, the outputs of this review contribute to generating knowledge about the current state of research on GI and its ES. The breakdown of these results underlined an imbalance in the analysis of the ES, with provisioning and cultural services being less addressed than regulating and supporting services. This stresses the need for either delving into these two types of ES individually or carrying out multidisciplinary investigations where they are addressed along with other services framed within other categories.

In this sense, the diversity of affiliations and research topics associated with the authors of the documents suggests that the evaluation of GI and ES involves a wide range of disciplines. Hence, researchers in this broad field of study should seek for intradepartmental collaborations in which several of these perspectives are brought together to foster the effective deployment of ES at different scales. However, specific studies carried out by researchers specialized in individual disciplines are also important to properly understand the conditions required for the provision of different ES.

The same logic applies to stakeholder engagement, whereby involving other actors outside the academia should be prioritized in the future to facilitate the implementation of GI. Due to their flexibility, online questionnaires are suggested as a first step to get insight into the perceptions of citizens, administrations, professionals, and NGOs. For a more elaborated vision of their interests, workshops including representatives for all these profiles can be arranged to favour discussion and opinion sharing.

The body of scientific findings in the topic of GI and ES is increasing, so that the priorities and research needs might fluctuate in the future. However, based on the most frequent methods observed in the review, the design of systems of indicators to be processed using multi-criteria decision analysis and geoprocessing tools is proposed to account for the variety of ES that can be delivered by GI at once. If developed, these systems might guide the regeneration of urban areas by maximizing the benefits of GI.

This is of particular interest in a context where climate change and rapid urbanization are posing increasing stress to current cities. The ES-oriented strategic planning of GI provides an opportunity to mitigate climate impacts such as global warming, while contributing to the environmental sustainability of urban developments.

Still, the scope of this study is affected by certain limitations. The ES-targeted approach taken in the design of the search equation can have caused the exclusion of some scientific studies in which these services are not explicitly referred to. Also, some other GI-related experiences may also have been omitted because they were not presented as research articles. Finally, the focus of the review has left aside the ecosystem disservices caused by GI, as well as other potential obstacles associated with the development of these nature-based solutions.

Therefore, there are several lines of research to explore in the future. First is using other terms in the search equation and/or accounting for other sources beyond scientific databases. There is also an interest in focusing on the concept of natural capital to translate the ES of GI into economic benefits and social well-being that could build a bridge to governments and institutions. In this sense, this research might be used to support the development of educational resources to teach minors about the importance and possibilities of ES and GI.

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CRediT authorship contribution statement

Daniel Jato-Espino: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing, Visualization. **Fabio Capra-Ribeiro:** Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Vanessa Moscardó:** Investigation, Methodology, Writing – review & editing. **Leticia E. Bartolomé del Pino:** Investigation, Writing – review & editing. **Fernando Mayor-Vitoria:** Investigation, Writing – review & editing. **Laura O. Gallardo:** Investigation, Writing – review & editing. **Patricia Carracedo:** Investigation, Writing – review & editing. **Kristin Dietrich:** Investigation, Writing – review & editing.

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.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2023.127998.

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