

Ecosystems and People

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/tbsm22

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To cite this article: Michael Leone, Ieva Misiune, Luís Valença Pinto, Julia Palliwoda, Raïsa Carmen, Sander Jacobs & Jörg A. Priess (2023) Lost in implementation? A field study of the uptake of the 'green infrastructure' term and concept in urban policies, Ecosystems and People, 19:1, 2220831, DOI: 10.1080/26395916.2023.2220831

To link to this article: https://doi.org/10.1080/26395916.2023.2220831

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ECOSYSTEMS AND PEOPLE
2023, VOL. 19, NO. 1, 2220831
https://doi.org/10.1080/26395916.2023.2220831

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Lost in implementation? A field study of the uptake of the 'green infrastructure' term and concept in urban policies

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ABSTRACT

With growing urban populations and increasing demands for more liveable, healthy and resilient cities, green infrastructure (GI) emerged over the last decade as a strategy to improve the quality of life in urban areas, delivering ecological, socio-cultural and economic benefits. To reach the European Union's political ambitions, it is vital that the concept and its content are used consistently and coherently from national to local scale. Regarding the content, the ambiguity of the multifunctionality characteristic of GI presents an opportunity for adaptation to local values, while also risking to remain a vague and abstract promise. A policy analysis was conducted in four European cities to investigate the uptake of the GI concept in policies relevant for urban green spaces and if it is in line with EU's understanding. Additionally, we investigate through interviews how interactions between agencies contribute to the mainstreaming of the concept to the municipal level. We found variations in uptake level and interpretation, which can partly be explained by the competition of new and established concepts, and existing structures (legislation and routines of practice). Each case study made multifunctionality concrete by linking multiple values to it, although the amount of values and depth of consideration differs. We found interactions between policymakers themselves, as well with science and civil society, contributing to the mainstreaming of the concept.

ARTICLE HISTORY
Received 27 January 2022
Accepted 29 May 2023

EDITED BY
Davide Geneletti

KEYWORDS
Urban green infrastructure; multifunctionality; environmental justice; urban green space policies; policy analysis; biodiversity strategy

1. Introduction

Over half of the world's population lives in urban territories, causing an enormous pressure on, and decline of, natural environments, biodiversity and ecosystem service (ES) provisioning through urban sprawl, pollution and environmental degradation (Lyu et al. 2019; United Nations 2019). One of the key strategies to mitigate the negative impacts of urbanisation and to improve the quality of life in urban areas is to restore, improve and to create new urban green spaces (United Nations 2017). Those strategies come into policy arenas through various environmental concepts.

The application of environmental concepts in policy plays an important constitutive role as they help to create the environment they describe (Van Herzele et al. 2019). Environmental concepts guide (the processes of) spatial planning through imposing a particular logic for discussing, designing and implementing spatial plans (Van Herzele and van Woerkum 2011). (Urban) policy arenas are populated with multiple environmental concepts, such as ES, natural capital, socio-ecological system, nature-based solutions (NbS) and green infrastructure (GI). These concepts represent their own specialised way of looking at the environment and in an ideal world they can be aligned to each other in a conceptual framework (Galan 2020). However, spatial planning is portrayed as time and labour intensive, resource-limited and influenced by environmental, professional, cultural and political contexts (Di Marino et al. 2019) and not all potentially valuable concepts will – and can – be applied simultaneously.

(New) scientific environmental concepts do not naturally extend to policy, planning and practice. A window of opportunity (also known as policy window) needs to present itself for the uptake of new (scientific) ideas into policy (Kingdon 2003; Rose et al. 2020). To advance to widespread and consistent operationalization, it needs to further disseminate into new policy arenas and its content requires recognition at all levels of government (Daily and Matson

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/26395916.2023.2220831

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2008; Young 2013). Consistency and coherence of (conceptual use in) policies is important as intentions and content of policies at higher level can differ from the uptake and implementation at lower levels. This may cause (unforeseen) conflicts between policies at the implementation level (Radaelli 2003; Urwin and Jordan 2008) or can cause ineffective local implementation that does not contribute to the environment that is originally described. Prominent presence of a concept at multiple policy levels ensures consistency and coherence between levels and avoids hindrance of effectiveness of local implementation (Afionis et al. 2020).

Thus, a concept and its content need to be recirculated for it to be recognized and bring its ideas into existence in new policy arena's (Hook 2001; Van Herzele and Aarts 2013). Interactions between agencies are important for the dissemination to new policy arena's such as communication and direct links between science and policymakers (Hurley and Tittensor 2020) or between policymakers at different administrative levels. However, little is known about how these interactions contribute to the mainstreaming of a concept at the actionable municipal level (see, e.g., Wamsler and Pauleit 2016).

One of the environmental concepts that gained popularity over the last decade is 'Green Infrastructure' (GI) with the expectation that it can respond to urban environmental challenges, mitigate urban environmental issues, increase resilience and maintain or improve quality of life (Benedict and McMahon 2006; Hansen et al. 2016). The concept was originally introduced in the mid-1990s (Pauleit et al., 2011), and during the 2000s, it became part of the sustainability discourse used by a wide range of institutions (Wang and Banzhaf 2018). Its prominent emergence in EU policy through the Biodiversity Strategy 2020 (target 2 (European Commission 2011)) and in the GI strategy (European Commission 2013) can be seen as the policy window that brought the concept to a large policy arena and spread it to other EU policy domains (Chatzimentor et al. 2020).

There are multiple examples of implementation of GI (or at least some elements) in the EU and how local policies supported it (Hansen et al. 2016). This paper, however, aims to gain an understanding of the consistency and coherency of the presence of the concept and its content from EU-level to low-level administrations and what interactions between agencies contribute to the mainstreaming to the actionable municipal level. We translated this to the following research questions:

(1) What is the uptake of the GI concept as defined by the EU in relevant urban planning policies, and how has this uptake transformed since its emergence at EU level?
(2) Which content (expressed in characteristics and values) is understood to be part of GI in urban planning policies?
(3) Which interactions between agencies supported the spread of the concept and its content to the actionable municipal level?

For RQ1 and RQ2 we focus our investigation on the presence of the concept and its content in policy documents (national to local) in four cities across Europe. Section 2 presents the definition of GI as well as what is understood as its content. For RQ3, our investigation focuses on the experiences of the public servants on the presence of interactions that supported the spread of GI concept to the four cities.

2. Green infrastructure concept in the European Union

The EU defined 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*' (European Commission 2013, p. 3) and includes urban areas such as parks, forests, allotment gardens, vacant lots and water bodies. Two functional characteristics that lay at the core of this definition are connectivity and multifunctionality (Hansen and Pauleit 2014; Wang and Banzhaf 2018).

The connectivity characteristic represents the structural connectivity (or physical connectedness) of green spaces as well as functional connectivity that enables the movement and interaction for wildlife (Baudry and Merriam 1988; Hansen and Pauleit 2014).

Whereas connectivity is just one element, multifunctionality acts as an umbrella for an interchangeable set of functions. The idea of multifunctionality is that one single GI intervention can provide multiple cross-cutting ecological, social and economic benefits (Liquete et al. 2015; Hansen et al. 2016; Pakzad and Osmond 2016; Wang and Banzhaf 2018). GI can address multiple emerging urban issues simultaneously such as increasing heat stress, air filtration, water retention, water hazards, carbon storage and grey-water treatment (Jato-Espino et al. 2018; Calfapietra and Cherubini 2019; Kalantari et al. 2019; Martín et al. 2020). Hansen and Pauleit (2014) have shown that ES and multifunctional GI are closely related, strengthening each other's roles in the development of a common framework for implementation.

Which functions end up in GI's design depend on the values that are considered during its development. IPBES categorises values in three dimensions: intrinsic dimension (values related to *nature* itself), instrumental dimension (nature *contributions* people, including to ecosystem services) and relational dimension (values related to the well-being of *people* and a good quality of life) (Díaz et al. 2015).

Multifunctionality, and its prospect to create win-wins, is a key attraction of GI to policymakers. Moreover, multifunctionality covers a broad understanding of values (going beyond economic monetary values), which is not always specified (Wang and Banzhaf 2018), making the concept fluid and pluralistic (Mell et al. 2017) as well as abstract and complex (e.g. deciding upon multiple functions and how to combine them spatially, especially when dealing with potentially conflicting functions, such as high-intensity recreation and resting areas). Abstractness facilitates flexibility in application as policymakers can focus on different values and allow the GI concept to be adapted to local contexts and interests as it enables multiple interpretations to negotiate its content (Lowy 1992; Allen 2009). However, its complexity increases the risk that multifunctionality remains a vague and abstract promise. GI's operationalization and implementation could be hampered when core principles lose their meaning through reducing the complexity into a simpler and manageable understanding, leaving out characteristics or components that are part of the concept (Van Herzele and Aarts 2013).

3. Methodology

3.1. Case study descriptions

The research was conducted in four case study (CS) cities in Europe: Coimbra in Portugal, Genk in Belgium, Leipzig in Germany and Vilnius in Lithuania (Figure 1), which were all involved in a study to evaluate the (ecological, social and economic) performativity of urban GI (see Supplementary Material 1 for concise case study context descriptions). These European cities were chosen to include various contexts as they vary in size, environment, socio-political and cultural context.

3.2. Data collection and analysis

The first two research questions are addressed through the collection, review and analysis of relevant policy documents. A summative content analysis was used to explore the usage of the GI concept and its content for urban planning. Such an approach was used to find and analyse manifest content, such as the presence of terms, and latent content, such as the presence of characteristics and values (Hsieh and Shannon 2005). The latter is content that can be more inexplicitly presented in the documents and

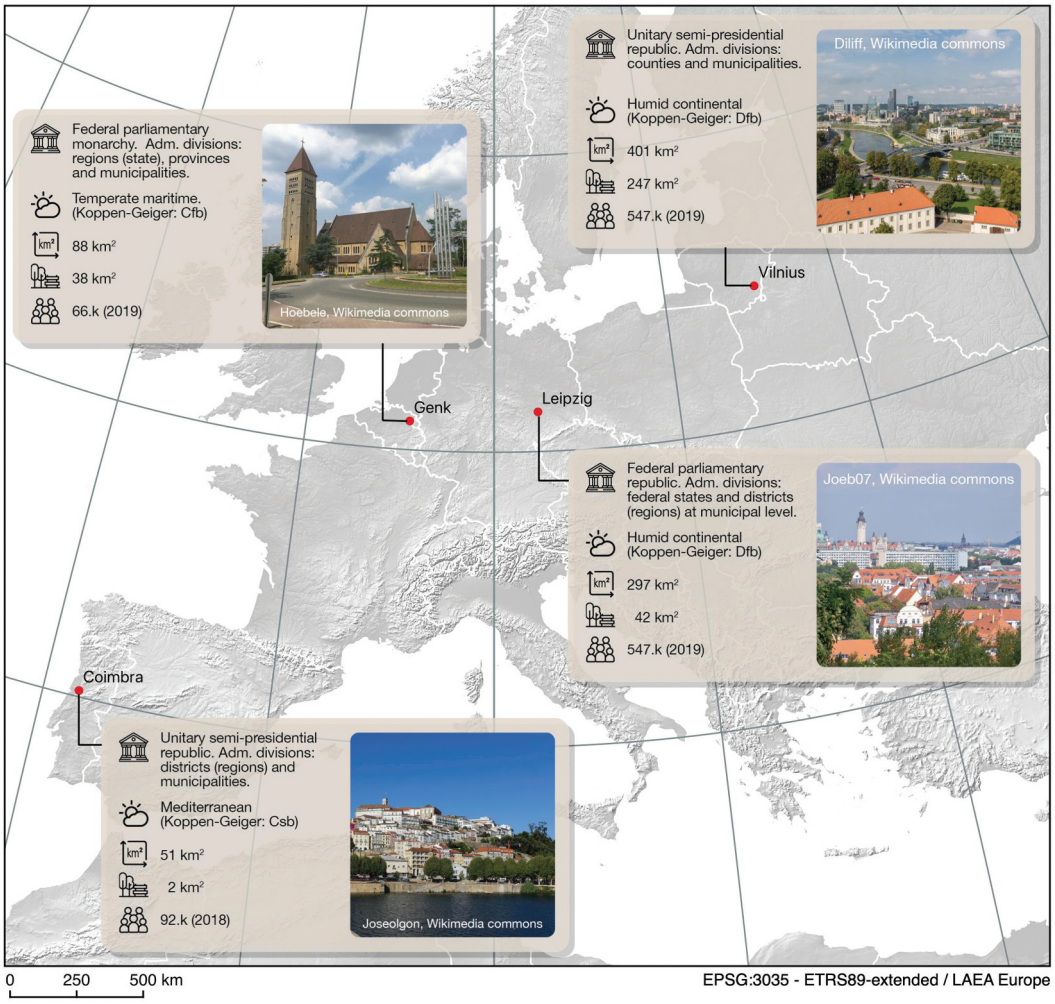


Figure 1. Map with the location and characteristics of the four case studies.

requires interpretation of the researchers, which is guided through a coding scheme (Potter and Levine-Donnerstein 1999).

We developed a data collection protocol to perform the content analysis of national, state, regional and local policy documents relevant for urban planning and implementation of GI in each CS. The data collection protocol consists of three sections: document collection, uptake analysis and value assessment (Supplementary Material 2; see Sections 2.2.1, 2.2.2 and 2.2.3, respectively). The documents were manually coded following the protocol (Braun and Clarke 2013). The quantitative data derived from the protocol was cleaned and visualised in RStudio using the *tidyverse, cowplot* and *ggplot2* packages.

Simultaneously, public servants responsible for green public spaces of these cities were interviewed to collect insights on the third research question (Section 2.2.4). The methodological approach is summarised in Figure 2.

3.2.1. Document collection

The first section of the protocol identified the relevant policy documents in relation to urban planning and implementation of GI in each CS (Supplementary Material 2, part 1). Based on stakeholder knowledge, online search and snowball sampling, relevant documents were retrieved from official governmental websites or received directly from public servants. The search was not restricted to certain policy fields. The search focused on laws/decrees, norms, strategic and planning documents from public agencies. Policy documents published until the end of 2019, relevant for the current and near future (<5 years from 2019) for urban planning and implementation of GI, were included in the search. For a document to be selected for further analysis, it needed to (1) contain the term GI, a different term but clearly contains the multifunctionality and/or connectivity characteristic, or no specific term but clearly mentions connected and multifunctional green spaces (namely, 'direct use', 'related concept used' and 'indirect use' in the analysis, respectively) and (2) be relevant for urban planning. Considering the diversity of terms used for connected and/or multifunctional green spaces and to ensure that the analysis captured the diversity of those terms, the documents were scoped using an initial keyword-search analysis. Data on implementation year, policy field, type of document, implementation level and responsible authority were recorded for each relevant document. A descriptive analysis was conducted on how the identified policy documents function in relation to each other in each CS.

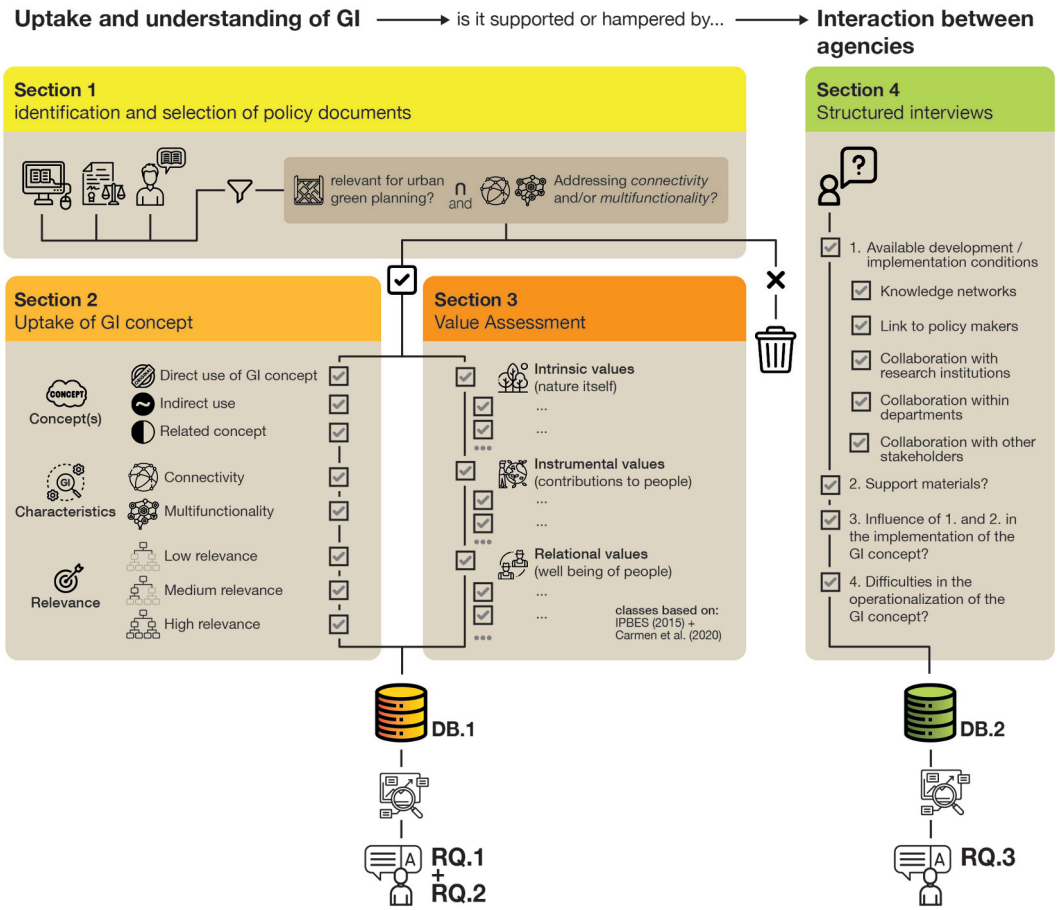


Figure 2. Methodological framework guiding the collection of data.

3.2.2. Document analysis for the uptake of green infrastructure

For each relevant document, we recorded if the GI concept was used directly, indirectly or a related concept was used (name of related concept was recorded as well). Furthermore, an assessment was made of the relevance of GI, or related concepts, in the policy document. This was done by investigating the extent to which the concept is applied in the policy document. For example, if a policy document proposes to investigate the use of GI or a related concept in future urban planning and does not elaborate more than a definition, the relevance scored low. On the other hand, if a policy document proposes to implement GI or related concepts in urban planning and elaborates the (multiple) benefits, costs, its governance, etc. applied to the local, regional or national context, a high score has been given (Supplementary Material 2, part 2). Additionally, we distinguished documents before the release of the EC GI strategy (<2013) and after (2013–2019) to investigate whether a shift in use of GI-related concepts can be observed.

3.2.3. Assessment of values present in policy documents

Using the same approach, we assessed which value types are considered in the relevant policy and planning documents and in relation to GI. We applied a tailored analytical values framework based on the plural valuation framework of nature-human relationships as applied in IPBES (Díaz et al. 2015), adapted to a European GI context (Table 1, see Carmen et al. 2020). The initial framework was adapted to cover blind spots in the cases by work sessions with representatives from each CS. The typology was amended and adopted in a plenary meeting in order to cover the local specificities within validated categories.

An ordinal scale (Supplementary Material 2, part 3) was applied to score the level of consideration of each value type. One score was given to each value for each governance level, and each score was accompanied by a description of why the score was given to the relevant document(s). For example, if one policy document at one governance level devotes a chapter or a goal to a certain value, this governance level scored 'very high consideration' as it is presented very prominently at that governance level and given high importance. In comparison, a value is scored 'low consideration' when it is only briefly mentioned in the policy documents at one governance level without linking any actions to it. Regular discussions among the researchers ensured consistent scoring across CS.

To compare the presence of values across CS we use the following terms: (1) consistently considered value: a value that has a mean score of 2 or higher, (2) width: amount of consistently considered values and (3) depth: level of consideration of values (= mean score of value). For comparison, the width and depth of the considered values are expressed from low to high in relation to each other.

Table 1. Analytical framework for document analysis (adapted from the IPBES framework).

Dimension	Value Target	Value	Explanation
Intrinsic values	Nature	Maintaining and strengthening nature and biodiversity	The maintenance or strengthening of nature or ecological quality. This can refer to maintaining or strengthening individual organisms, biophysical assemblages, biophysical processes or biodiversity.
Instrumental values		Quantity and quality of GI	The design of urban GI in terms of its quantity and quality and can be valued for intrinsic and instrumental aspects. Aspects related to the quantity of urban GI can be hectares of urban green space or amount of green space per capita. Quality can refer to ecological quality, in function of human utilisation and benefits, or the quality of the design of urban GI such as connectivity (e.g. walking/cycling paths), accessibility (e.g. opening hours, fences, gates), facilities (e.g. benches, picnic areas, sport areas) and location.
	Contributions	Regulation services	Beneficial nature contributions to people obtained from the regulation of ecosystem processes, such as regulation of air quality, climate, freshwater quantity, flow and timing, etc.
		Material contributions	Provision of materials from ecosystems such as food, water, timber, etc.
		Non-material contributions	The (non-material) physical and psychological experiences that nature provides, such as recreational experiences. This includes experiences that stimulate learning and inspiration. Furthermore, non-material contributions also include the supporting role of nature to identities of regions, cities, neighbourhoods or social groups.
Relational values	People	Cultural relations	Cultural relations include aspects such as heritage (historical elements), sense of place (meeting place for (sub)communities, organisation of events) and stewardship (nature management activities by citizens, adopted trees).
		Health & wellbeing aspects	Health & wellbeing includes aspects such as physical and mental health, wellbeing, safety, social relations and education and knowledge.
		Economic aspects	The effects of surrounding urban GI on the local economy such as attractiveness to new businesses, tourism, (new) inhabitants and new jobs created related to green.
		Governance aspects	This category focuses on decision-making and implementation processes of urban GI. Relevant aspects related to urban GI governance are the inclusion and participation of stakeholders, aiming at multifunctionality to achieve multiple objectives, etc.
		Justice aspects	This category focuses on two justice aspects namely procedural justice (e.g. inclusion of vulnerable groups in governance) and distributional justice (fair social and spatial division of urban GI).

3.2.4. Data collection and analysis for interactions influencing mainstreaming

The structured interviews were conducted with at least one local public servant responsible for public urban GI in each CS to provide on-the-ground-level insights into interactions influencing the mainstreaming of GI in policy making or planning. A total of six interviews were collected to investigate the presence of interactions between different agencies and whether these interactions influenced the uptake of the GI concept. All interviewees were identified to be highly knowledgeable about GI and recent processes of their municipal policy-making. A list of interviewees and the interview guidelines are presented in Supplementary Material 3. The interviews were carried out in October 2020 through a phone call or online meeting. Notes were taken and reviewed immediately after the interview. For each interview, an overview was made on which interactions supported the spreading of new ideas.

4. Results

4.1. Uptake of green infrastructure

GI or related concepts are found in multiple policy documents on most administrative levels of each CS (Figure 3). Differences in governing and administrative structures can be observed. For example, national and local decrees and norms play a larger role in governing GI or related concepts in Coimbra and Vilnius, while in Genk and Leipzig, strategic documents are the main type of documents to govern them. Planning documents were mostly found at the local and regional level, indicating that GI or related concepts trickle down from strategy, decree or norm to local planning and implementation. The list of identified documents is presented in Supplementary Material 4, and a description of the interplay of policies relevant for urban green infrastructure at each CS is found in Supplementary Material 5.

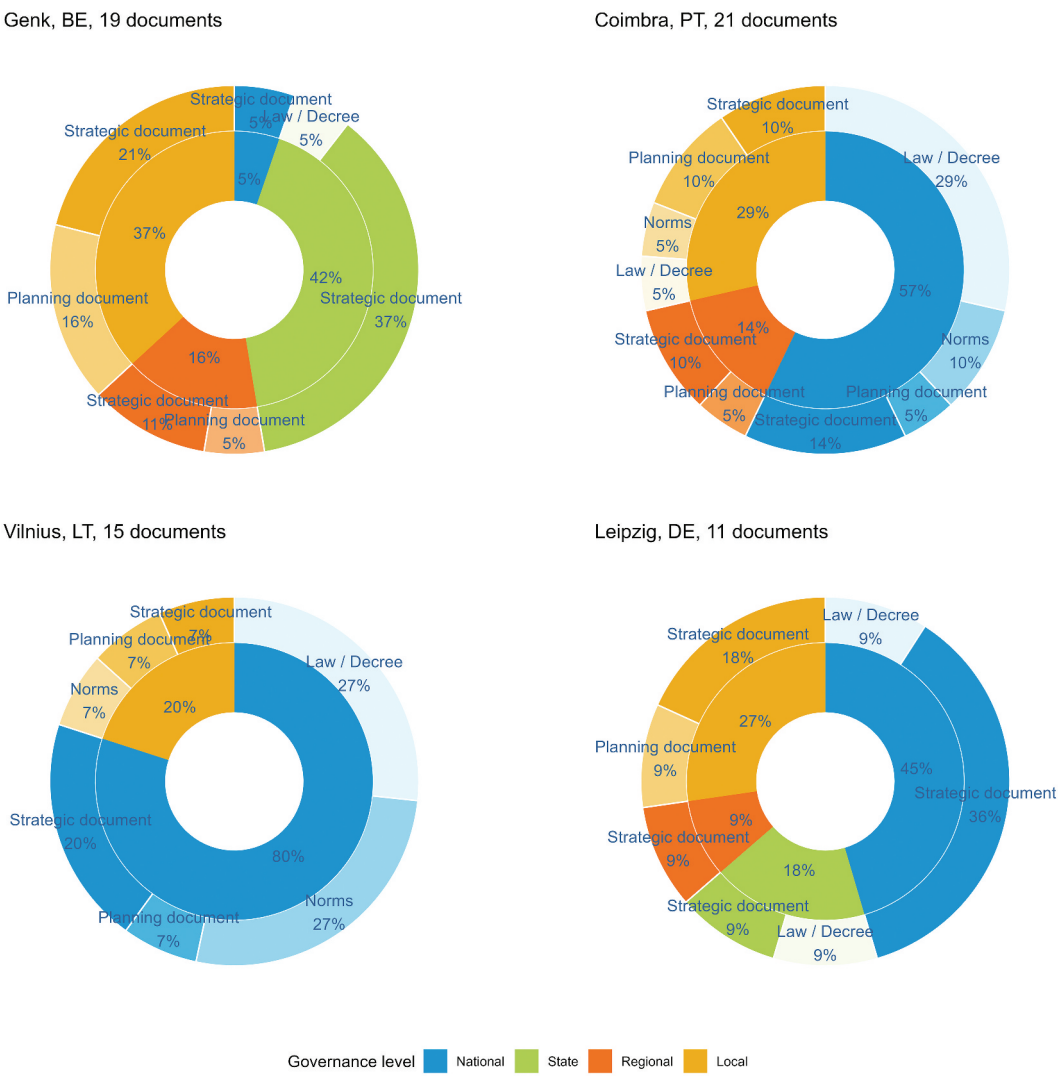


Figure 3. Types of document per governance level per case study. The inner donut presents the governance level and the outer donut shows the type of document at that governance level.

Various terms are used in the selected policy documents (Table 2). Before 2013, the term GI was not found, rather related concepts were used independently in each CS. In Coimbra and Genk varying terms were identified at different scales, including concepts focusing either on the connectivity or the multifunctionality aspect. In some of the Coimbra documents, concepts with one of the GI characteristics are combined, resulting in connected and multifunctional green spaces (combining 'green spaces for collective use' with 'municipal ecological structure' or 'green ring').

Figure 4 shows from 2013 onwards an increase in both direct and indirect use of the term GI and an increase in the relevance of the concept. The general trend visible in Figure 4 could be observed in each CS. In each CS, the direct use of GI was encountered, however, only used in strategic and planning documents, and never directly in any law or norm (Table 2). In laws and norms, only country-specific concepts established before 2013 were used. These concepts are often re-used in policy documents from 2013 onwards (see 'Ecological Structure' and 'Green Spaces for Collective Use' in Coimbra, 'Integrated Interrelation and Support Network' (IVON) in Genk, and 'Nature Frames' and 'Greenery System' in Vilnius). The IVON concept, which, prior to 2013, was only focused on the connectivity characteristic, was later redefined and made a synonym of GI (having both characteristics) in recent policy documents. Furthermore, the table shows that multiple related concepts appearing before 2013 disappeared in documents after 2013 (mainly in Genk and Leipzig), indicating that the GI concept replaced them.

Additionally, the data reveal the following inconsistencies in GI uptake in the CS. First, there are inconsistencies across CS' administrative levels. Different terms are used at different administrative levels, or GI is used directly at one level and used

Table 2. Concepts related to GI used in policy documents. A distinction is made between before the release of the EC GI strategy (<2013) and after (2013–2019) to show the evolution of concepts used.

Before 2013				Between 2013 and 2019			
Term	Case study	Level	Type of document	Term	Case study	Level	Type of document
Concepts with connectivity and multifunctionality characteristic				**Concepts with connectivity and multifunctionality characteristic**			
Ecological structure	Coimbra	National	Law, Planning	GI	Coimbra	National, Regional	Strategic
					Genk	National, State, Regional, Local	Strategic, Planning
					Leipzig	National, Local	Strategic
					Vilnius	National	Strategic
Regional Structure for Environmental Protection and Valuation	Coimbra	National	Planning	Ecological Structure	Coimbra	National	Law
Ring Radial System	Leipzig	Local	Planning	Integrated Interrelation and Support Network	Genk	State	Strategic
Nature Frames	Vilnius	National	Law, Planning	Green Ring	Leipzig	Regional	Strategic
				Nature Frames	Vilnius	National, Local	Law, Norm, Strategic
				Greenery System	Vilnius	National, Local	Law, Norm, Strategic
No concepts used but both characteristics present				**No concept used but both characteristics present**			
	Coimbra	Local	Planning		Coimbra	Local	Strategic
	Leipzig	National	Law		Genk	Local	Strategic
					Leipzig	National, State	Strategic
					Vilnius	National	Norm
Concepts with only connectivity characteristic				**Concepts with only connectivity characteristic**			
Municipal Ecological Structure	Coimbra	National	Norm	GI	Genk	State, Local	Strategic
National Ecological Reserve	Coimbra	National	Law,				
Green ring	Coimbra	Local	Strategic				
Integrated Interrelation and Support Network	Genk	State, Province, Local	Law, Strategic				
Ecological Infrastructure	Genk	State, Province	Strategic				
Green Structure/Ecological Network	Genk	Local	Strategic				
Green-Blue Network	Genk	Local	Planning				
Concepts with only multifunctionality characteristic				**Concepts with only multifunctionality characteristic**			
Green spaces for collective use	Coimbra	National, Local	Law, Norm, Strategic	Green spaces for collective use	Coimbra	National, Local	Law, Norm, Strategic
Urban Natural Elements	Genk	State	Strategic	Recreational and Leisure green areas	Coimbra	Local	Planning
Landscape Park	Genk	Local	Strategic	Green areas of Protection and Framing	Coimbra	Local	Planning
				GI used but characteristics not clearly expressed			
					Vilnius	National, Local	Strategic, Planning

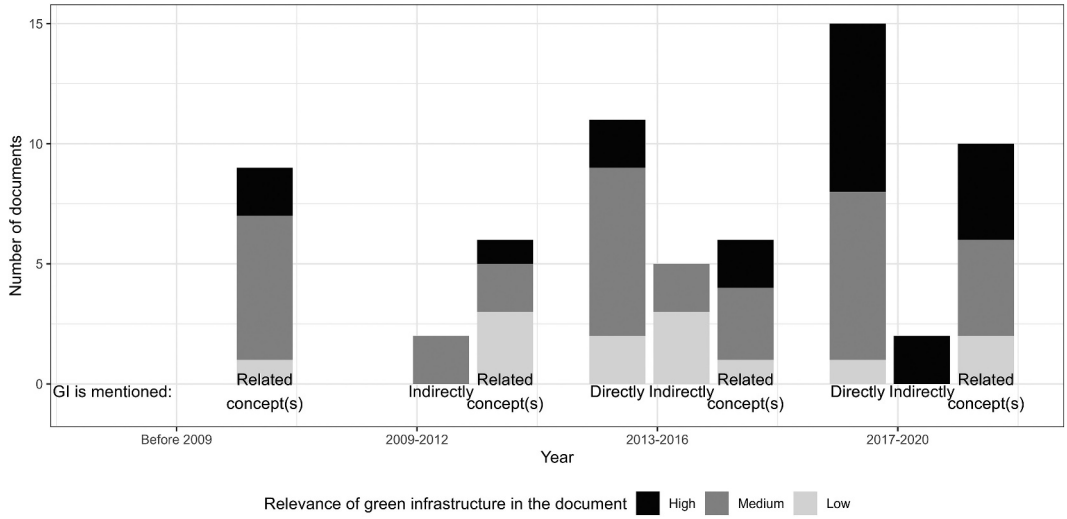


Figure 4. Number of policy documents over time (1995–2019) that mentioned GI directly, indirectly or if a related concept was used. The grey scale of the stacked bars reflects the relevance of GI (as defined in Supplementary Material 2).

indirectly at another level (Coimbra, Genk, Leipzig). Second, the GI concept is not used directly in any decrees or norms; only related concepts or indirect use was found (Coimbra, Leipzig, Vilnius). Third, the multifunctionality characteristic is not associated with GI in two policy documents (Genk). Last, the term GI is used but with a different understanding (not associated with the two characteristics); however, related concepts with both characteristics were used (Vilnius).

4.2. Values associated with green infrastructure

Each CS associates multiple values with GI and related concepts to a larger or smaller extent (Figure 5). Generally, the intrinsic dimension (*nature*) contains the most associated values, especially values related to '*maintaining and strengthening nature and biodiversity*'. Values related to *regulating functions*, *non-material contributions* and *governance aspects* are also commonly associated with

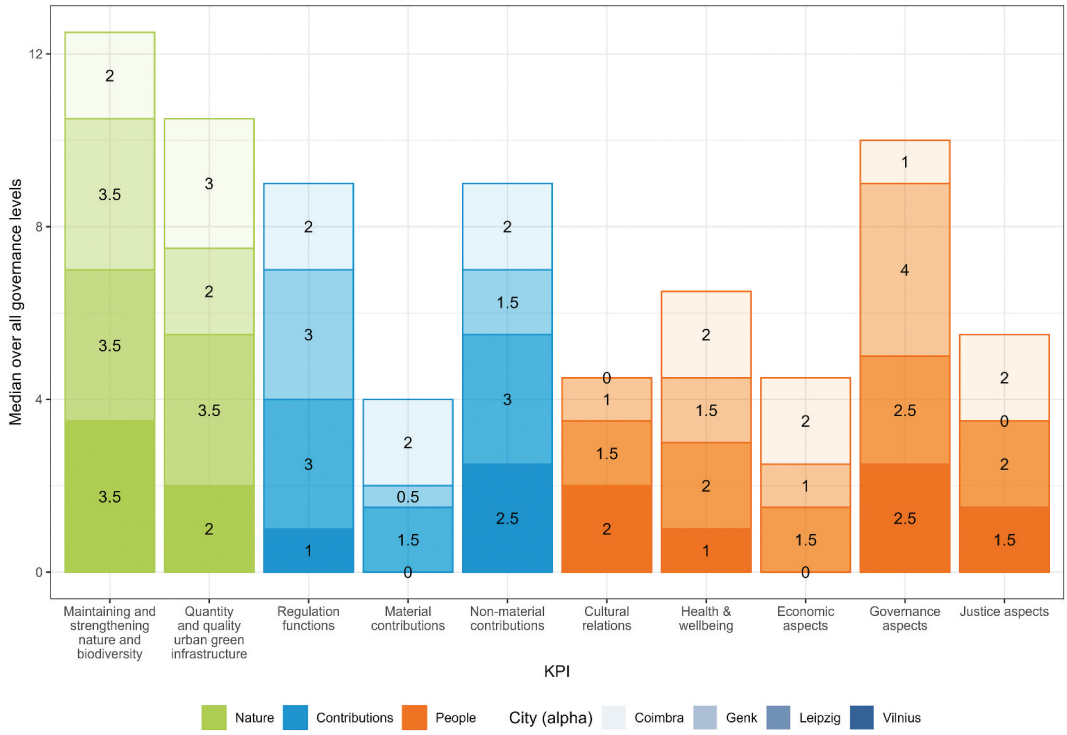


Figure 5. Median score of all governance levels per case study for each nature/contributions/people value associated to GI or related concepts in the respective policy documents.

GI or related concepts, while the other values are associated less or in some cases not at all. Most of the lower scoring values are in the relational (*people*) dimension. *Governance aspect* is the only value in the relational dimension to have relatively higher scores.

Coimbra consistently considers the most diverse set of values in relation to multifunctional GI (Figure 5). The intrinsic (*nature*) dimension is considered most important; the other consistently considered values score less high (high width, medium depth). In Vilnius, in comparison, less values are consistently considered in relation to multifunctional GI although those have slightly higher scores, pointing to a more explicit consideration (medium width, medium-high depth). In Genk, values related to *biodiversity*, *regulating functions* and *governance* are strongly considered in relation to GI, while only one other value is considered consistently as well (low width, high depth). Leipzig shows the highest consideration of *nature* and *contributions* combined (with exception of *material contributions*), while also consistently considering *people* (medium-high width, high depth).

4.3. Interactions influencing urban green space policy

The expert interviews highlight that the cities are involved in various interactions concerning urban GI knowledge exchange. However, form and extent of these interactions differ for each city (see Table 3 and Supplementary Material 6 for more details). For example, in Leipzig, we find that multiple interactions are formalised/institutionalised (interactions with higher-level policymakers, professional networks, use of national professional journals), while in Genk, the interactions are a result of a proactive stance of the staff to exchange and gain new knowledge. Additionally, the interviews revealed that a key element for bringing in new ideas and concepts is the personal interest of staff exploring (innovative) new approaches and a willingness to challenge established approaches or routines. For example, the Director of the Public Space Department in Coimbra is interested in GI-related themes and searches for synergies to implement them and, in Genk, the mayor strongly endorses and encourages innovative solutions in one particular GI project, and the green space department engages itself with new ideas and aims to implement them.

On the contrary, one of the challenges for operationalizing the GI concept in policy and planning was the encountered difficulties to replace established ways of working due to scepticism towards the new concepts within and between the departments. Other identified challenges are the limited staff within the municipality to work on the topic, the little available space for conceptual thinking as the focus is often on executing plans and the lack of finance for GI projects.

5. Concluding discussion

The GI concept is not lost in implementation as it sets foot in all the CSs. However, it is also not consistently and coherently implemented as the level of uptake varies within and between our CS. We discuss the following points to move the concept from a temporal buzzword to widespread and consistent operationalization: the need to challenge established concepts and structures, the strengths and pitfalls/dangers of the flexibility of the concept and the importance of different types of interactions to mainstream a concept to other policy arenas. We finish with a reflection on the limitations of this study and possibilities for future research.

5.1. Uptake in a reality filled with established concepts and structures

Our results show that many GI-related concepts existed before 2013 with no uniformity in terms

Table 3. Presence of interactions between agencies per CS bringing knowledge into local policy.

Interactions	Coimbra	Genk	Leipzig	Vilnius
Interactions with higher level policymakers for local alignment	Limited, only when part of a programme	Yes, but unstructured and city need to be proactive	Yes, structured in networks, conferences, etc.	Yes, through constant communication between agencies
Professional networks for knowledge exchange on urban green spaces	No, formal network doesn't exist	No, formal network doesn't exist	Yes, regular exchange between green space administrations	Yes, but only through an European network
Knowledge exchange within municipality departments.	Yes, but hard to overcome silos	Yes	Yes	Yes
Collaboration with research institutes	Yes, when the needs arise	Yes, proactively searches for opportunities	Yes	Yes, and allocates budget for research
Use of professional journals, leaflets, handbooks, guidelines or other printed or online material on green infrastructure	Little, limited accessibility	Yes, not offered but searching proactively	Yes, use of national professional journals	Yes, not offered but search for online material
Other interactions	Civil organisations proposing ideas	-	-	-

across the different CSs. As Van Herzele et al. (2019) noted, new environmental concepts do not enter a blank world, but rather a world of already established concepts and practices embedded in policies. Nevertheless, our exploration highlights the increase of the uptake of the GI concept from 2013 onwards for the four CS. Some of the older concepts disappeared from recent policy documents, while a direct or indirect use of the GI concept was introduced with increasing relevance over time. However, there are differences in the policy uptake of the concept between CSs and between CS's governance levels. Differences in uptake of the GI concept in policy documents were also found in other European studies (Mell et al. 2017; Di Marino et al. 2019).

One explaining factor for the inconsistent uptake is that newly introduced environmental concepts have to deal with existing structures (see, e.g., Van Herzele et al. 2019) in which established concepts are embedded. One rigid existing structure is legislation. Laws usually do not evolve fast enough to include new environmental concepts (Ruhl 2011). Also, in this study, GI was absent in all laws and norms and older concepts were used. Consequently, these concepts are re-used in more recent policy documents. This was most evident in Coimbra and Vilnius where laws and norms play a larger role in governing GI-related concepts, indicating that policy context plays an important role in the uptake of new environmental concepts.

We found different approaches to dealing with the rigidness of legislation and the concepts embedded in them. On the one hand, environmental concepts can be aligned to coexist with each other without increasing complexity or losing utility. In Genk CS, the understanding of the IVON concept (originally introduced by Flemish law) was adapted and extended in order to be the same as GI. Established structures did not need to be changed while introducing the multifunctionality characteristic and managing the complexity of applying multiple environmental concepts by aligning them. Also, Van Herzele et al. (2019) found evidence of concepts aiming at sustainable human-nature interactions to be moulded in order to coexist and support one another.

On the other hand, attempts to fit a new concept with well-established concepts and practices can result in a transformation in which the original understanding of the new concept is lost (Van Herzele et al. 2019). In Vilnius CS, two related concepts are embedded in laws and norms already. GI has now been used in local documents without clear agreement on the content of this term at the higher governance levels. Such sporadic use transformed the term by giving it a different understanding compared to the EU definition. This situation removed the connectivity and multifunctionality characteristics from the GI concept as it is used now and allowed us to avoid the need to adapt or change existing structures by finding ways to deal with three related concepts simultaneously. This example demonstrates that there is a limit of concepts that can be applied simultaneously within (local) policy-making without increasing complexity or losing utility.

Besides the rigidness of legislation, perceptions and positions of public servants are also an existing structure that hampers the uptake. Wamsler and Pauleit (2016) found that local staff showed no interest in a new environmental concept (ES) due to the existence of other well-established concepts. They perceived no added value of the new concept. Introducing a new concept may have multiple implications for formal procedures and professional practices (as observed for ES in Rinne and Primmer (2015)), which can create scepticism among professionals expected to work with it. The uptake of a new concept can be further hampered by strong or inflexible established planning traditions (Lafortezza et al. 2013; Lähde and Di Marino 2019). Indeed, the interviews revealed the scepticism towards the new concepts as a bottleneck, as well as a defensive position regarding established ways of working. On the contrary, the interviews also stressed, in line with Wamsler and Pauleit (2016), the importance of 'champions' (convinced/motivated staff) who take voluntary actions to take up, apply and spread new ways of working.

Thus, effort is needed to bring GI into these existing structures with a clear added value and good arguments as to why an established concept should be supplemented or replaced altogether. Other studies found as well that time and commitment are required for a new (environmental) concept to be taken up in policy and planning (Mell et al. 2017; Di Marino et al. 2019) through challenging, replacing or coexisting with established concepts and structures (Thomas and Littlewood 2010; Lähde and Di Marino 2019; Van Herzele et al. 2019). Besides competing with established structures and concepts, GI also competes with other new concepts. As the introduction portrayed, they are not all being used simultaneously and policymakers make a decision on which concept they apply. For instance, the municipal public servant of Genk noted that while connectivity and multifunctionality are indeed important elements for their planning of green areas, they were more familiar with concepts from ongoing research projects, such as ESs and NbS, even though the latter was not named directly in their policy documents.

Considering the difficulty to consistently and coherently take up new concepts across policy arenas, we argue that policymakers and scientists should be careful with introducing them in policy arenas – as

well as science-policy arenas – to avoid increasing competition and complexity and losing utility.

5.2. Fair multifunctionality or opportunistic cherry picking?

In our study, we found that each city CS has a different set of values that shape the application of multifunctionality, while *nature* was considered important in all of them. This is not surprising as natural elements are the concept's starting point and other values can be selected as is deemed important for the local or regional context. Similarly, *contributions* generally scored high. These values are linked to ES, and this reconfirms the strong linkages between GI and ES concepts (Hansen and Pauleit 2014). However, *people* is considered least, with exception of the governance value.

Each CS made multifunctionality concrete by considering multiple values. We found differences between the width and depth of the consistently considered values, which shows the concept's flexibility to give meaning to multifunctionality. However, our study does not identify if the values presented in the policy documents reflect the values present in society or if these are the values solely of policymakers. It is possible that GI is a 'corruptible concept' (Collinge 2010 in Wright 2011) and is misused to justify potential environmental or social damage by other environmental benefits through its ambiguity (Wright 2011). Furthermore, ignoring certain values overlooks the wellbeing of people who embrace these values (Jax et al. 2013). Whose values are reflected in policy documents requires further research, but it stands out that policymakers need to apply a holistic and inclusive approach, considering all values relevant to all stakeholders, especially the voiceless and marginalised (e.g. young, elderly, poor or other groups who experience boundaries to participate in decision-making), in the development and design of (urban) GI.

On a positive note, governance aspects are generally well considered in GI policy. Governance processes – depending on how they are organised - can further flesh out the multifunctionality aspect through negotiation among involved stakeholders. Although related to each other, environmental justice aspects are generally less explicitly expressed in our analysed policy documents. This finding is supported by Kronenberg et al. (2020) stating that justice aspects are not among the guiding principles of GI planning in cities in Central and Eastern Europe. This again risks that the values of local stakeholders, especially vulnerable communities, are not considered in the final design of a local GI. We argue that multifunctionality should always be considered in tandem with environmental justice aspects (e.g. justice in ES planning: Langemeyer and Connolly 2020) and could act as a bottom-up approach to defining local multifunctionality. This would ensure utilising GI's flexibility to adapt to local contexts. Consequently, justice aspects should be presented as an additional core characteristic of GI in (high level) policy documents in order to operationalize increasingly just and multifunctional GI.

5.3. Natural selection or careful nurturing: interactions supporting the uptake of a concept

The interviews show that each city has multiple types of interactions between agencies that enable the sharing of knowledge to local policy arenas that can support the mainstreaming of a concept. We can distinguish three categories of interactions.

The first are interactions between policymakers, such as (multi-level) networks exchanging policy developments from higher-level administrations as well as exchanging knowledge and experiences. Wamsler and Pauleit (2016) revealed that the ES concept was promoted at the national level and was rapidly adopted at the municipal level. In Leipzig and Vilnius, multiple platforms for interaction between higher- and lower-level administrations exist, which explains the relative uniform use of concepts between those levels (GI for Leipzig and nature frames and greeneries for Vilnius).

Second are interactions between science and policy, such as dissemination activities to spread new findings and ideas (Hurley and Tittensor 2020), collaboration through research and innovation projects to apply state-of-the-art concepts (Di Marino et al. 2019), development of tools or the collection of good practices. All CS indicated that they receive new ideas through such interactions, but especially Genk highlighted the added value of participating in EU-funded research projects and the impact it had on their policy (documents). The direct collaboration with research institutes and research projects played an important role in the use of underlying concepts. Similarly, Hansen et al. (2015) noticed an increase of interest to implement ES elements into policy after policymakers participated in the URBES project.

The last are interactions between civil society and policymakers, such as NGOs or environmental movements demanding change, or citizens involved in agenda setting (e.g. Van der Stoep et al. 2017). Only in Coimbra, we found this type of interaction in which civil organisations proposed ideas to the municipality. Thomas and Littlewood (2010) noted a rapid transmission of GI discourse in two regions in the UK with the help of experts of NGOs, consultants and nature protection agencies.

However, the knowledge shared through these different types of interaction is not uniform (e.g. sharing of other (established) concepts between agencies, as

seen in Vilnius) or the absence of certain types of interactions can hamper the circulation of a discourse and (re-)use of a concept (e.g. formalised platforms between higher- and lower-level administrations are missing, as seen in Genk, possibly causing the discrepancy in the use of the concepts between those levels). More research is needed on how the application of various interactions can be further stimulated or applied in order to successfully spread (new) environmental concepts to all relevant policy arenas.

There are additional strategies to mainstream a concept besides such interactions (see Wamsler and Pauleit 2016). Strategies that contribute to coherency among policies at different levels are modification of (in)formal planning procedures, regulations and instruments as well as clear policy documents at higher-level administrations with clear objectives and guidance that provide a clear mandate. This supports aligned local policy development and influences policy content (Hansen et al. 2016; Wamsler and Pauleit 2016; Afionis et al. 2020).

5.4. Limitations and future research

We acknowledge a few methodological limitations to better interpret the results and the meaning of this work. The limited sample size prevents making generalised conclusions on the uptake of GI across the whole EU. However, our cases do indicate that an uniform uptake of a concept across multiple administrative levels across the EU is a challenging procedure (which requires proper support for mainstreaming). Furthermore, conducting scientific research is a lengthy process; meanwhile, new policy documents could have appeared with new definitions or content in relation to GI. This does not diminish the value of our analysis, but rather reminds us that the situation might have evolved further. Future research can do a similar investigation on the concept of NBS (the latest environmental concept put high on the EU agenda) on a larger scale. Also, further studies on the (non)sense of introducing new environmental concepts with the ambition to spread coherently to multiple new policy arenas would be meaningful.

Additionally, conducting a content analysis with multiple researchers risks different interpretations of content. Our study design, with the application of the protocol to code the content and regular discussions between the researchers on their coded data, should have limited this risk. Another strategy could have been to create a more extensive coding scheme; however, this also increases the complexity of the schemes (Potter and Levine-Donnerstein 1999) which we wanted to avoid.

Acknowledgment

We thank the cities' local governments and their partners for their time and effort invested in the project.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was performed in the UrbanGaia project, funded through the ERA-net BiodivERsA 3 2015 call under grants BRAIN-be BR/175/A1/URBANGAIA-BE (Belgium), [01LC1616A] (Germany), S-BIODIVERSA-17-17-1 (Lithuania) and BIODIVERSA/0008/2015 (Portugal).

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