Développement durable et territoires
Économie, géographie, politique, droit, sociologie

Vol. 14, n°2 | Octobre 2023
Que font les solutions fondées sur la nature aux politiques de gestion des risques liés à l'eau ?

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Electronic version
URL: https://journals.openedition.org/developpementdurable/23038
ISSN: 1772-9971

Publisher
Association DD&T

Brought to you by Institut Français de Recherche pour l'Exploitation de la Mer (Ifremer)

Electronic reference
Klervi Fustec and Alix Levain, "From Green Infrastructure to Blue and Green Infrastructure Network: institutionalization of ecological connectivity at the science-policy interface. A literature review", *Développement durable et territoires* [Online], Vol. 14, n°2 | Octobre 2023, Online since 30 October 2023, connection on 09 February 2024. URL: http://journals.openedition.org/developpementdurable/23038

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The authors thank the Interreg Europe program for funding the project "Improving the management of Atlantic Landscapes: accounting for biodiversity and ecosystem services" (no. EAPA_261/2016) and are grateful to the ALICE team for the fruitfulness of their collaboration.

1 Nature-based solutions (NbS) is an umbrella concept that includes a variety of ecosystem-based approaches such as green infrastructure (GI), ecological restoration, ecosystem-based disaster risk reduction, and ecological engineering (Cohen-Shacham, 2016). GI can refer to elements such as nature reserves, green parks, restored rivers, green roofs and hedgerows. Decision makers rapidly adopted the GI concept after its conceptualization was refined at the beginning of the 21st century (Wright, 2011), while it was being used and circulating in and between scientific and policy-making communities. Investigating the political life of the GI concept is a way to understand the history and theoretical framings of the concept of NbS. Indeed, environmental concepts are neither fixed nor neutral: they evolve over time and space and are intertwined within power relations. Studying the context of production and circulation, the history and the geography of ecological concepts helps understand "*how ideas are put to work in the world*" (Greer and Cameron, 2015: 451). Scientific concepts serve diverse institutional and social roles, empower actors and organize both

nature and humans (Bocking, 2015). Socio-political construction of environmental concepts should be studied not only for itself but also to improve understanding of the concepts' socio-political effects. GI is one such concept used in both scientific and policy-making arenas. Because a concept's intrinsic qualities cannot explain its success, stakeholders' strategies and contingences should be studied (Forsyth, 2003). Following Latour (1987), Lennon uses the term "*blackbox*" that "*provides a critically informed lens on [GI] deployment*" (2015a: 34) to enhance the fact that the GI concept packs different meanings together, which obscures potential conflicts between them. Considering GI as a "*blackbox*" means that the variety of its definitions and associated stakeholders, history and theoretical origins is a relevant research topic from the perspective of social studies of science. Extending this approach, the present article contributes to the field of critical political ecology, by focusing on environmental knowledge production, circulation and applications (Goldman and Turner, 2011).

2 As noted by Lennon (2015a), few scholars have explicitly analyzed GI from a social science perspective, and even fewer have adopted a critical approach. The present article aims to capture the socio-political life of the concept at the interplay between science and policy, leading to conceptual definition, extension, stabilization and refinements of GI and its consequences on biodiversity conservation and relationships among stakeholders. It presents a genealogy of GI through the lens of scientific literature addressing GI with a conceptual and/or critical perspective and in depth social science analysis that explicitly address socio-political issues. We hypothesize that the high performativity of the concept explains its spread in scientific and policy-making arenas.

3 We first present the materials and methods used. The general approach draws on an in-depth social science literature review and a brief quantitative assessment. Second, we analyze framing activities, i.e. narratives of the concept, how specific definitions are constructed and promoted[1], and meaning of the aggregation from GI to current refinements, such as "*blue and green infrastructure networks*" (BGIN). Then, we explore its institutionalization and adaptation to local contexts. Finally, we study the encapsulation of ecological properties – ie, ontologies, functions, values and services - in spatial planning and management and its consequences. The conclusion presents and synthesizes all results of this study.

1. Materials and methods: an in-depth social science literature review and a brief quantitative assessment to explore socio-political dimensions of GI

1.1. Materials and methods

4 We draw on a scientific literature review to analyze the socio-political construction of the concept of green infrastructure, how its properties have stabilized – or not – and how it is used by stakeholders. We followed a 3-step method (Fig. 1):

1. We performed quantitative bibliometric assessment using Thompson Web of Science (WoS) Core Collection, with two objectives: (1) quantify the publications about GI over time to characterize dynamics of the concept in academic communities and (2) identify social science articles that critically analyze GI.

Two major scientific databases, Scopus and WoS, are increasingly cited in academic

articles and used for bibliometric-related studies (Zhu and Liu, 2020). Scopus "*could be used as an alternative to the Web of Science as a tool to evaluate the research impact in the social sciences*" (Norris and Oppenheim, 2007). Nevertheless, WoS has the best coverage and retrieves more unique items than Scopus or Google Scholar (Leslie *et al.*, 2013). We excluded Google Scholar because it "*doesn't have a strong quality control process and simply crawls any information that is available on academic related websites*" (Harzing and Alakangas, 2016). For these reasons, and also because WoS includes scientometric tools, we used the WoS database for this study.

We subsequently identified 5,970 articles that mentioned "green infrastructure" in the topic, which includes the title, abstract, author keywords and "Keywords Plus". We used this result to quantify the evolution of GI-related publications, the dominant journals, their geographic distribution and the ramification of the concept (from GI to Blue and Green Infrastructure Networks).

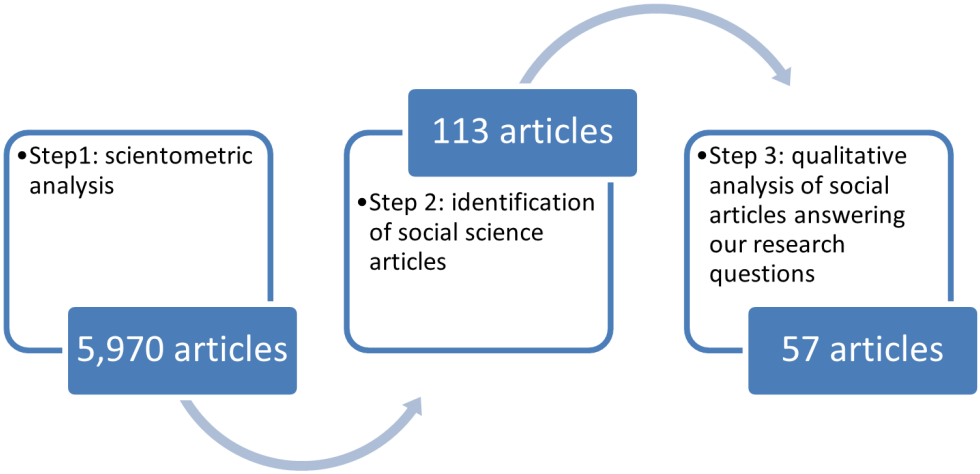
2. To perform a qualitative analysis, we selected social science articles from the 5,970 by looking at their journal of publication. We identified 113 articles that address GI using social sciences literature and/or methods. By closely analyzing these articles, we found that they were mainly applied-research articles published in multidisciplinary journals and articles that identify barriers and factors that influence implementation of GI.

We thus selected from the 113 previous articles only articles that adopted a critical view and/or partly addressed our research questions: What are the origins of the GI concept? How has it been adopted in both scientific and policy-making arenas? Who uses it, for what purposes and with what consequences?

5 We found additional articles for the qualitative assessment by 1) searching the WoS, Scopus and Google Scholar databases using other keywords related to our study, such as "green corridor" and "ecological infrastructure" and 2) using the snowball technique to identify relevant articles cited by previously selected articles. We also searched the French database Cairn, which indexes social sciences articles. Being involved in a European Union (EU) project[2], we realized that the translation of BGIN in French ("*Trames vertes et bleues*") was not literal; consequently, we used this translation as a search term.

6 Ultimately, we qualitatively analyzed 57 articles in English or French. The qualitative analysis was not based on an exhaustive review but on articles identified during our preliminary quantitative assessment and additional articles we found during step 3 that addressed our research questions. We qualitatively analyzed the selected articles using an analysis table divided into several questions about the genealogy (history and epistemological origins) of the concept, its institutionalization, the stakeholders who promote it, its uses and their consequences. When needed, we referred directly to gray literature such as EU reports.

Figure 1. The 3-step literature review method used



1.2. Overview of the selected social science literature

7 The selected corpus of 57 articles can be described and organized as follows:

1. literature reviews (e.g. Da Silva and Wheeler, 2017; Ghofrani *et al.*, 2017; Sahak *et al.*, 2018; Escobedo *et al.*, 2019; Deely *et al.*, in press) that describe the concept and are prescriptive (i.e., recommend paths for wider or specific use). This research helps promote and thus institutionalize GI and allowed us to follow its political genealogy.

2. articles that focus on relationships between policy and practice to advise policy makers about GI, promote the concept and analyze discourses, policies and local adaptations of GI (e.g. Benedict and McMahon, 2006; Cormier and Carcaud, 2009; Mell, 2010, 2017, 2018; Thomas and Littlewood, 2010; Benedict *et al.*, 2012 Mell and Clement, 2020)

3. articles that develop critical approaches (i.e., question established typologies and dominant framings). Lennon critically examines the interpretation and representation of GI in planning policy (Lennon, 2015a; Lennon *et al.*, 2017), and the emergence and institutionalization of GI (2015b) in Ireland. Salomaa *et al.* (2017) critically assess implications of GI for environmental policies in Finland. Finewood (2016) and Finewood *et al.* (2019) develop a political ecology approach to explore power relations intertwined within the concept of GI for stormwater management in Pittsburgh, United States (USA). Vimal *et al.* (2012) and Garmendia *et al.* (2016) question the policy-science interface and explore the role of expertise within the development of GI. Wright (2011), Lennon (2015a) and Thoresen (2018) critically address the meaning, nature and politics of GI.

4. articles that explore GI and similar concepts, study their scientific construction and use Science and Technology Studies (STS) theories either explicitly or implicitly (e.g. Windt and Swart, 2008; Wright, 2011; Cowell and Lennon, 2014; Garmendia *et al.*, 2016).

2. From the GI concept to its derivatives: a three-fold heritage

2.1. Tracing the genealogy of the GI concept and its derivatives

8 Social science literature identifies three main origins of the GI concept: hygienist philosophy, landscape ecology and sustainable development's conceptualization and operationalization literature (Fig. 2).

9 The first origin can be traced in the idea of providing recreational areas for urban populations in industrialized regions, for either public health or ecological purposes, or both (Lennon, 2015a; Garmendia *et al.*, 2016). It is related to the hygienist philosophy developed by landscape architects in the USA at the end of the 19th century. The idea was to consider urban development by connecting urban parks with greenways. After the Second World War, reconstruction became the priority in Europe, and the idea of greenways in cities moved to the background. Urban planning focused on organizing housing and transport infrastructure (Cormier and Carcaud, 2009). Nonetheless, with rampant suburbanization, the idea of greenbelts attracted new interest: agricultural, wooded and natural zones would surround the city and provide suburban citizens with leisure possibilities and fulfilment.

10 The second origin of GI conceptualization is linked to the development of landscape ecology from 1980-1995. It corresponded to an increase in ecological concerns about urban sprawl and played a key role in developing and disseminating three instrumental concepts in landscape ecology communities (Cormier and Carcaud, 2009): matrix, patch and ecological corridor (i.e., from a landscape ecology perspective, a functional zone of passage between habitats for species that depend on a specific environment). In the context of urban planning and regeneration projects, additional functions were progressively associated with this concept, often re-labelled as "green": green corridors would create and restore habitat, restore functioning of ecological systems, increase urban biodiversity and improve ecosystem services (Garmendia *et al.*, 2016). GI was thus considered a better way to plan and manage suburban areas (Thomas and Littlewood, 2010). In the field of water management, *"[i]n the US, a 1987 amendment to the Clean Water Act (CWA) of 1972, requires municipalities to obtain permits to discharge stormwater (US EPA, n.d.a), and green infrastructure is increasingly encouraged in this context*" (Serra-Llobet and Hermida, 2017).

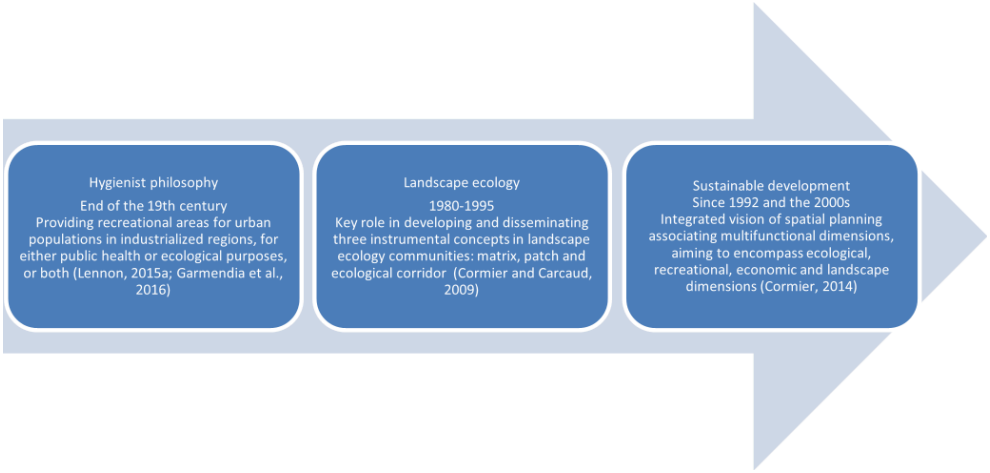
11 The third origin began with the 1992 United Nations Conference on Environment and Development and the rise of the concept of sustainable development. This origin favors a more integrated vision of spatial planning that associates multifunctional dimensions, aiming to encompass ecological, recreational, economic and landscape dimensions (Cormier, 2014). According to the literature review, since the 2000s, GI has been actively discussed in both academic and policy-making arenas (Mell, 2010, 2017).

12 Beyond this three origins of the GI concept, a dominantly urban framing of GI has been described for both academic research (Da Silva and Wheeler, 2017) and policy-making as a tool for green planning (Ghofrani *et al.,* 2017). Da Silva *et al.* (2017) describe restriction of the use of GI to urban issues by researchers such as Sinnett *et al.* (2015) and Matthews *et al.* (2015). They trace GI back to a Florida Greenways Commission (USA) report in 1994 and note that its seminal promoters are rooted in traditional criticism of

urban planning and renewal of conservation approaches (see Benedict and McMahon, 2002). This urban anchorage can still be detected in the definition of GI given by urban geographers such as Ahern (2007: 267): "*Green infrastructure plans apply key principles of landscape ecology to urban environments [...]*".

13 The rapid shift from ecological science concepts developed at the landscape scale towards land use management and urban planning, as observed through our review echoes enduring controversies and uncertainties in conservation science about connectivity-based management (e.g. Bennett *et al.*, 2006; Wyborn, 2015). Among salient issues appear the relevant spatial and temporal scale at which to assess landscape connectivity (Lindenmayer and Fischer, 2007; Wright, 2008), the risk of oversimplification and the focus on few species, with a limited impact on biodiversity conservation (Boitani *et al.*, 2007), and uneven effects of restoring connectivity on targeted and untargeted species in the context of climate change (Krosby *et al.*, 2010). Such views inform the publication of critical social science articles questioning the relevance of GI for biodiversity conservation (section 5.2).

Figure 2. The green infrastructure concept: a three-fold heritage



14 From the origin of the concept to its recent development, GI is ultimately strongly intertwined with the design of urban planning and the combination of positive social, economic and environmental outcomes. The wide use of the concept is related to its symmetrical institutionalization in both academic and policy-making areas and coincides with the emergence, in the 1990s, of a dominant policy framework of sustainable development and its operationalization in the field of spatial planning.

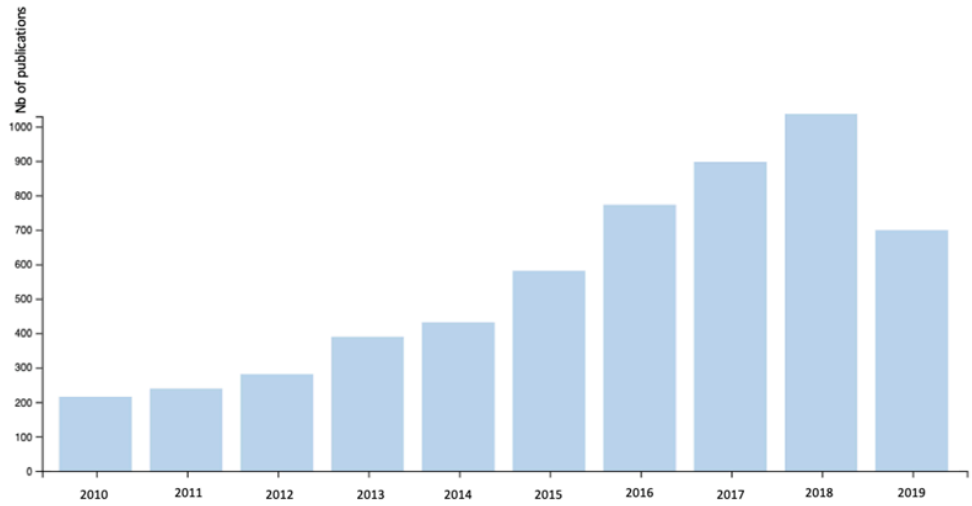
2.2. Dissemination of the GI concept

15 Since the 2000s, GI has been a robustly established concept in several scientific communities. As Da Silva *et al.* (2017) note in their scientometric study, GI now partly replaces the use of "ecological infrastructure" in the scientific literature. Developed in 1984 by researchers in the Man and Biosphere Programme (MAP) for urban planning, "ecological infrastructure" was before 2004[3]. Da Silva *et al.* (2017) show that, from then until the 1990s, "green infrastructure" coexisted with several similar concepts (e.g. greenways, ecological networks, corridors, conservation corridors) in the field of landscape-level conservation planning, with no clear differentiation between concepts,

but a common background in promoting what has later been called "nature-based solutions" in applied conservation research (Da Silva and Wheeler, 2017; Mell, 2017).

16 Mell (2017) identify Benedict and McMahon (2002)'s article as the first one to use contemporary terminology for GI. In it, the authors related its use to the smart conservation movement in North America, which ensured the expansion of the concept of GI (Mell, 2017). According to Benedict and McMahon (2002: 13) "*Green infrastructure offers a smart solution to our land conservation challenges because it seeks to plan land development and land conservation together in a way that is consistent with natural environmental patterns. In doing this, green infrastructure promotes both smart growth and smart conservation*." Escobedo *et al.* (2019) *"[...] found that ES appears in 2006, GI in 2007 and NBS in 2015*". Stabilization of GI was key to the institutionalization of landscape conservation and its integration in public-policy frameworks. Mell (2017: 137) identifies "*three periods of GI development: Exploration (1998-2008), Expansion (post-2008-2011) and Consolidation (2010-2012 onwards)*", and interprets this progression as framing activities that engaged both academics and practitioners. His article retraces, through academic discussion, similar pathways and framings in North America and northern Europe. GI research has now reached a consolidation point, characterized by an orientation towards a "*more detailed, grounded and robust evidence base to support*" use of the concept (Mell, 2017: 139). Our quantitative assessment provides evidence of this continuous expansion and consolidation, and of some of its key characteristics. Of the 5,970 articles identified that mention GI in the topic, the number of these articles published per year exceeded 50 in 2007, 100 in 2009 and 1000 in 2018 (Fig. 3)[4]. In the general context of exponential growth of the volume of scientific literature (Fortunato *et al.*, 2018), publications mentioning GI in topic surpassed 100 in 2009 and continue to rise.

Figure 3. Number of published articles that mention green infrastructure in the topic in the Web of Science database



17 The five research areas most represented are environmental sciences and ecology (49.5%), engineering (34.6%), business economics (23.0%), geography (17.7%) and computer science (17.4%), which confirms the dominance of applied research (Tab. 1).

Table 1. Number and percentage of published articles (out of 5,970 identified) that mention green infrastructure in the topic in the Web of Science database, by research area

RESEARCH AREA	NUMBER	PERCENTAGE
ENVIRONMENTAL SCIENCES, ECOLOGY	2956	49.5
ENGINEERING	2068	34.6
BUSINESS, ECONOMICS	1375	23.0
GEOGRAPHY	1060	17.8
COMPUTER SCIENCE	1043	17.5
SCIENCE TECHNOLOGY, OTHER TOPICS	996	16.7
BIODIVERSITY CONSERVATION	958	16.0
ENERGY, FUELS	815	13.7
WATER RESOURCES	801	13.4
PUBLIC ADMINISTRATION	796	13.3
AGRICULTURE	746	12.5
URBAN STUDIES	671	11.2
METEOROLOGY, ATMOSPHERIC SCIENCES	664	11.1

18 The scope of the journals publishing GI-related articles also demonstrates the entanglement between use of the concept and urban, applied and interdisciplinary research. The four main journals publishing articles referring to GI from 2003-2018 are *Urban Forestry & Urban Greening* (173), *Sustainability* (157), *Science of the Total Environment* (155) and *Landscape and Urban Planning* (126). GI indeed has its promoters, who come mainly from geography and planning departments in northern Europe and North America: 13 authors published more than 15 articles on the topic from 2003-2018, among which researchers in urban and landscape ecology dominated – a result that converges with those obtained from the Scopus database by Escobedo *et al.* (2019).

2.3. GI derivatives: adding a “blue” dimension to the GI concept

19 Does the consolidation period herald an increase in the precision of the definition, growing consensus or, instead, persistent contrasting approaches? According to Lennon (2015a), contrasting approaches (e.g. focusing on ecological networks grounded in theories of landscape ecology, on regional development grounded in theories of economic competition, on recreation facilitation grounded in perspectives of the supply of accessible green spaces) prevail, since GI is used more as a set of principles and common assumptions that connect major planning communities (e.g. ecologists, planners and heritage officers, in the Irish case) than as a substantive concept.

20 In contrast, according to our quantitative assessment, “blue and green infrastructure” (BGI) is a more recent and less established reconceptualization and refinement that emerged during GI’s consolidation period. The unstable blue-green tandem reveals alternative and situated approaches, frames and definitions, as does the emphasis placed (or not) on connectivity and networks. When applying the 1-step method and

replacing "green infrastructure" with "blue and green infrastructure", we identified only 26 occurrences in the title and 210 in the topic. Most of these articles were published recently (2017-2019), mostly by European researchers working in EU member states, revealing a close relationship between scientific publication and the EU funding of research projects, with specific frames and terms aligned with EU public policies. For instance, using the CORDIS database[5], we found that the EU project AQUACROSS recently published an article about green and blue infrastructure: Barbosa *et al.*, 2019.

21 In contrast, the "blue" dimension seems to remain implicit in GI itself in North America. Despite this conceptual invisibility, the "blue" dimension encounters the same trend of public agencies placing emphasis on water infrastructure and watersheds (Mell, 2017). The addition of the "blue" dimension to GI reveals a framing in terms of water security and urban planning, with many researchers focusing on urban stormwater (e.g. Fitzgerald and Laufer, 2017; McPhillips and Matsler, 2018; Finewood *et al.*, 2019; Cousins and Hill, 2021; Hoover *et al.*, 2021; Scarlett *et al.*, 2021). This contrast suggests that science-policy interactions and the institutionalization process should be considered carefully in their specific local contexts.

3. From policy institutionalization to framing activities: scale, technology and water

3.1. Institutionalizing and refining GI in the context of EU environmental policies

22 According to the literature review, GI has been rapidly adopted by decision makers while circulating across institutional scales (Wright, 2011; Lennon, 2015a). Its definition has changed through circulation and implementation (Alphandéry *et al.*, 2012; Vimal *et al.*, 2012; Lennon, 2019).

23 The USA and EU offer contrasting views of the operationalization of GI: the former incorporates it in a general philosophy of planning, while the latter favors the idea of ecosystem services (Lennon, 2015a; Garmendia *et al.*, 2016). In the EU, this has two major consequences: (1) refinement and operationalization of the GI concept and its derivatives become key issues in public policies of several sectors (e.g. water management, spatial planning[6]) and (2) the normative dimension of the concept becomes stronger, and spreads from the EU level to local ones.

24 The spreading of GI concept in the EU follows EU policies' conceptualization and implementation. In 1995, the Environmental Ministries of the EU member states developed a European strategy for biological and landscape diversity to restore an ecological network at the scale of the Eurasian continent. In 2013, the European Commission's definition of GI serves as a basis for subsequent EU reports: "*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) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings.*"

25 According to Lennon (2015a), the definition of GI varies among member states and rarely refers to academic literature on the topic. Member states' transposition of EU policies thus seems to imply significant local reformulations. At the European level, the

dominant frame is that of ecological conservation. Emphasis is placed on rare and remarkable ecological sites and on construction of a pan-European network. At national and regional levels, naturalistic considerations still predominate (Alphandéry *et al.*, 2012). At the local level, the example of France shows a switch towards sustainable-development frames, which stress the benefits that GI will bring to meeting sustainable-development requirements (Cormier and Carcaud, 2009). In Ireland, the term "infrastructure" was useful for asserting the need for public policy and for providing ecological conservation with the legitimacy of the "infrastructure" category (Cowell and Lennon, 2014).

3.2. What "infrastructure" does to "green": a technicist prism

26 There is no single clear and normalized definition of GI, and some authors even maintain that it has as many definitions as there are scholars who study it (Mell, 2010). Indeed, defining GI is a social process: its meaning depends on who is using it and in what context (Cowell and Lennon, 2014; Lennon, 2015a; Lennon *et al.*, 2017; Salomaa *et al.*, 2017; Sahak *et al.*, 2018). Despite this lack of consensus, there are basic shared ideas about GI. "Green" is described as a symbol of the ecological functions in a landscape and "infrastructure" as the physical elements that enable these functions (Benedict and McMahon, 2006; Wright, 2011; Thoresen, 2018). According to Wright (2011: 1003), the three main ideas in common are "*connectivity, multifunctionality, and 'green'*".

27 Despite this common ground, considering ecosystems as infrastructure dates back to the 1980s, in the context of conservation concerns and alerts (Yu, 2012), when there was no spontaneous movement towards acknowledging ecological systems as part of the key infrastructure supporting human well-being (Da Silva and Wheeler, 2017). Hence, from a discourse-analysis perspective, Lennon (2015a) analyzes GI as a "linguistic device". "*The strategic use of metaphor*" is considered to play a key role in the currency of a new policy (Lennon, 2015b: 1043). In other words, using the term "infrastructure" implies that GI must be planned and managed with the same level of engagement (and material resources) that applies to gray infrastructure (Benedict and McMahon, 2006). The term "infrastructure", also used in the planning-policy community because it was familiar (Lennon, 2015b), could associate GI with the technical vision of gray infrastructure.

28 However, this strategic assimilation process is, as Finewood (2016) points out, somehow double-edged: merging GI into "*grey epistemology*" is anything but neutral. First, it embeds the process in a specific epistemology and frame for public action. Instead of expanding practice and participation, it "*reproduces uneven urban landscapes under greener cover*" (Finewood, 2016: 1001). Then, it favours "*grey infrastructure (largely impervious surfaces made of asphalt and concrete, such as pipes and sewers) [...] standard practice for capturing urban stormwater and treating wastewater as quickly as possible*" whereas "*green infrastructure is designed to control water at the source [...] by utilizing scaled systems that mimic ecological processes of soils and plants*" (Finewood, 2016: 1001).

3.3. When hydrology and networks come into play

29 Regarding the scientific literature, Finewood's (2016) research also raises the "blue or water" question: isolating "blue" from "green" goes along with specific local framings and contexts that are characterized by the prevalence of water-flow-regulation issues, especially in highly anthropized environments, such as large cities or, in the EU, polders in the Netherlands or rural regions with severe flood-management issues. According to the quantitative assessment, articles promoting the BGI concept notably relate to such water-flow-regulation contexts. Significantly, Da Silva and Wheeler (2017: 33) find the first mention of BGI in 2006, in an article "*describing the efforts of the city of São Paulo, Brazil [...] to reduce risks in floodplains and other flood-prone areas (Frischenbruder and Pellegrino, 2006)*". The term "blue" is used mostly to refer to conservation and management of freshwater (including wetlands) and coastal-marine systems. Ghofrani *et al.* (2017) note, however, that while most studies are "urban-based", a wide range of water-management issues from rural areas is also addressed in articles on BGI. In the EU's gray literature, "blue" was first used in 2010 and 2011 as a translation of "*trame verte et bleue*". Then, in the European Commission's 2013 report, "blue" is implicitly included in the definition of GI (see part 4.1). In its 2019 report, "blue" is explicitly included in "Green and Blue Infrastructure".

30 Emphasis on the blue dimension has an indirect effect: it deprives the green dimension of its inclusive, general and symbolic meaning of "nature-based" or "ecological". The fact that "*natural infrastructure and blue infrastructure are the two most recently coined terms*" (Da Silva and Wheeler, 2017: 33) should be interpreted in this perspective. We hypothesize that some approaches consider GI's holistic character to be more performative and inclusive, while others add or use "blue" to stress the centrality of aquatic environments in thinking and managing connections for conserving biodiversity.

31 What about the recent tendency to emphasize the network dimension? The acronym BGIN appeared in an Interreg EU project "Improving the management of Atlantic landscapes: accounting for biodiversity and ecosystem services" (ALICE), in the early stages of the project[7], leading to scientific publications using the term BGIN (e.g. Terêncio *et al.*, 2021). The idea of a water network is central to hydrology and, more generally, to research on aquatic environments. It is also a key dimension of GI as a design device, as Ahern (2007: 267) points out: "*Green infrastructure is an emerging planning and design concept that is principally structured by a hybrid hydrological/drainage network, complementing and linking relict green areas with built infrastructure that provides ecological functions*." This emphasis recalls and reveals that, to urban-planning communities that promote GI, GI and gray infrastructure are interconnected more than they are opposed. GI thus entails a crucial tension and ambivalence between conceiving and building alternatives, and managing interfaces.

4. Encapsulating ecological properties in spatial planning and management

4.1. Theorizing ambiguity: GI as a "boundary object"

32 Because of its multifunctionality (e.g. protecting an ecosystem's state and biodiversity, protecting ecosystem functioning, promoting ecosystem services, promoting societal health and wellbeing, supporting development of a green economy and sustainable land and water management, European Commission, 2012), GI is sometimes described in the publications we analyzed as a "corruptible", "ambiguous" or "umbrella" concept (e.g. Wright, 2011; Abunnasr and Hamin, 2012; Sussams *et al.*, 2015). The main difficulty associated with this apparent conceptual weakness lies in its consequences in terms of implementation, regarding to which interpretations may vary. Wright (2011) describes the discomfort among the community of planners he interviewed in England, whose members believed that because of the ambiguity of the concept political agendas would overtake practical applications and raise suspicion among stakeholders. Sussams *et al.* (2015) obtain similar results in the context of assessing the value of the GI concept as a relevant policy response to challenges of adapting to climate change.

33 In contrast, according to many social sciences publications, this flexibility in the definition of GI could help a wider range of practitioners engage with it and increase its political popularity, which would help create a "*political momentum*" (Lennon, 2015a). Thus, instead of evaluating positive or negative results of this flexibility, the social uses and political stakes of the ambiguity should be studied. In this perspective, research should not seek "*to condemn or condone GI*" (Lennon, 2015a: 6). The lack of consensus about GI's definition is characteristic of an evolving, living concept. Setting a single definition in stone would be problematic "*because the concept is evolving, divided and gravitating toward socio-economic centres*" (Wright, 2011: 1004). GI's ambiguity should be understood in order to highlight power relations among the stakeholders involved (Wright, 2011) and the social life of the concept. To do so, authors have "*unpack[ed] the 'black box'... of the concept's meaning and provide[d] a critically informed lens on its deployment*" (Lennon, 2015a: 34).

34 Considering a concept as a boundary object allows its success to be explored by considering not only its scientific soundness but also its social robustness. "*[Boundary objects are] strong enough to bind and flexible enough to leave room for different operating forms and interpretations*" (Windt and Swart, 2008: 125). GI has been described as a "boundary object", "*plastic enough to be interpreted differently among communities or interest groups, yet [...] robust enough to enable cross-communication*" (Garmendia *et al.*, 2016: 315), as ecological corridors had been, since "*its vagueness, its flexibility and its metaphorical appeal*" were considered to be its strength, allowing its use "*by many people and groups for different landscapes, biotopes, species and populations*" (Windt and Swart, 2008: 130).

35 In this case, the GI concept can connect planners, conservationists, academic communities and other groups (Garmendia *et al.*, 2016). The fluidity of the GI concept has contributed to its development (Lennon, 2015b). In this case, the GI concept "*consequently promotes 'increased dialogue between planners, developers, and policy-makers'* (Mell, 2010: 241)." (Lennon *et al.*, 2017). Here, being a boundary object provides the opportunity to connect a variety of actors involved in various environmental issues

(e.g. water management, flood prevention and, more recently, climate policy). GI's circulation and success are combined with the involvement of stakeholders who coalesce around GI.

36 Social science literature shows that considering GI as a boundary object that enables cross-communication and stakeholders to develop and implement policies may conceal power relations involved in these processes. For the flood management in Pittsburgh analyzed by Finewood (2016), when the metropolitan region's sewage and water systems were to be updated to meet federal, state and local requirements, two epistemic communities - gray infrastructure and green infrastructure – met at one point. The latter had to reframe its message to conform to gray epistemology, while the former had to recognize the importance of GI. At first glance, GI seems to have enabled these two communities to converge, but in fact, green epistemology was reframed into the gray one, which remains the prevailing framework of the new water-management plan. For instance, GI advocates in Pittsburgh (e.g. low-income neighborhoods, labor unions, small environmental organizations, community development groups, universities, regional philanthropic foundations) conducted their own research on the location of GI, while the Allegheny County Sewer Authority "*used it to prioritize certain sites that were visible, rather than focusing on the potential value to communities*" (Finewood, 2016: 1015). Thus, *"[d]ominance and reproduction are achieved, not through force, but by controlling the narrative*" (Finewood, 2016: 1015).

4.2. GI policy and knowledge grounded in power relations: GI as a "conceptual ecological trap"[8]?

37 Authors generally argue that GI carries a specific representation of biodiversity, with "infrastructure" associated with gray infrastructure and grounded in a technical vision of the environment. Lennon (2015a) describes a depoliticization of ecology through the conceptualization of GI. GI forms part of the ecological modernization process that claims that economic growth and nature conservation are mutually beneficial (Wright, 2011; Lennon *et al.*, 2017). Concerning GI, Garmendia *et al.* (2016) consider that the idea of a green economy assumes "*trade-offs between environmental protection and economic growth*", while Sussams *et al.* (2015) consider that "*some see GI to be an extension of the [ecosystem services] concept*".

38 In Ireland, Lennon (2015a: 26) explains that human use of nature is a "*prerequisite for 'conservation'*" and that it is correlated with the increase in the amount of literature about ecosystem services and international endorsement of the rationale of the Millennium Ecosystem Assessment. Due to the economic justification for conservation actions included in the idea of ecosystem services, Salomaa *et al.* (2017: 37) argue that, "*Putting emphasis on the conservation of ecosystem services rather than protection of biodiversity carries the risk of undermining biodiversity conservation efforts*". Considering biodiversity conservation through the lens of ecosystem services may silence the intrinsic or substantial value of biodiversity. Hence, projects to enhance ecosystem services can fail to protect biodiversity, and conflict can arise between both issues.

39 Social science literature thus emphasizes that framing GI in terms of conserving ecosystem services may be a major obstacle to conserving biodiversity. Garmendia *et al.* (2016: 10) thus argue that, "*To draw an analogy from ecology, there is a risk GI could act as a conceptual 'ecological trap' (Battin, 2004; Robertson and Hutto, 2006) — an idea that attracts*

funding and effort from specific conservation measures that could deliver better biodiversity conservation outcomes." GI would act as a conceptual trap by becoming a dominant framework that excludes other ideas or solutions that could conserve biodiversity better.

40 Vimal *et al.* (2012) explain that the literature on conservation biology and ecology also questions the pertinence of the ecological network concept. Researchers in the broad field of natural sciences have shown how human measures such as habitat restoration (Severns, 2011) and green roofs (Williams *et al.*, 2014) can act as ecological traps. Garmendia *et al.* (2016: 9), even mention "*a risk that biodiversity loss will be legitimized under this banner [GI], and this loss hidden behind a generic rhetoric of 'green planning'*." Salomaa *et al.* (2017: 29) detail possible negative impacts of framing biodiversity into ecosystem conservation: first, "*biodiversity conservation will be undermined if a number of ecosystem services that have high synergies with biodiversity conservation (e.g. regulating services) are ignored*" and then, if ecosystem services are understood to use natural resources, policies will focus more on *"maintenance and utilisation of (some) ecosystem services that are valued more than conservation"*. Garmendia *et al.* (2016) question the solution promoted by GI: "connectivity" related to the extent or quality of habitats. The rapid institutionalization of GI in both academic and policy arenas seams not to be correlated to its ability to conserve biodiversity, but to its characteristics as a "boundary object".

Conclusion

41 This study analyzed how social science literature has critically studied the GI concept, by combining a quantitative assessment of publications on GI with an in-depth qualitative review of publications in social sciences. GI lies under the umbrella of NbS. NbS "*[...] could be construed as the most recently developed extension of the previous metaphors by moving decidedly into a more transdisciplinary knowledge-exchange domain while providing for more pragmatic solutions*" (Escobedo *et al.*, 2019: 10). Understanding the genealogy and socio-political life of GI helps to better understand the epistemology of NbS. The origins of the GI concept are found in urban planning, with the underlying idea of positive interactions between economic development and biodiversity conservation. Since the 2000s, institutionalization and refinement of the GI concept have been rapid, and related to the performativity of a concept that integrates ecological properties into planning activities. The articles studied show that some authors consider GI to be vague and flexible, to represent a technicist perception of nature and public action and raise concerns about its ability to conserve biodiversity. As ES, GI and NbS share a similar root (Escobedo *et al.*, 2019) and some criticism (e.g. Bridgewater (2018) highlights the "*lack of clarity regarding what Nature-based solutions offer*"), these concerns should be kept in mind when focusing on the current spread of NbS.

42 This comprehensive social science literature review lies within the scope of critical studies that question established concepts and study framings processes. Our study highlights the importance of analyzing power relations among stakeholders and politicization and depoliticization processes as part of the life of the GI concept at the interface between science and policy.

43 We suggest three paths to explore the social and political life of the GI concept further. Following Escobedo *et al.* (2009), who highlighted a North-South divide in GI research

productivity and networks, we suggest broadening the scope of the analysis beyond industrialized countries. Attention should be paid to interactions between biodiversity conservation and development policies that focus on circulating and adapting the GI concept and on the power relations inherent to these movements. The second path is to focus on defining GI territories and scales. Indeed, the method or specific tool chosen to identify and define GI is performative: some species or processes become highly visible, while others are excluded. Since scales are social products (Zimmerer and Basset, 2003; Sayre, 2005), defining scale includes certain people while excluding others (Lebel *et al.*, 2005). Thirdly, politicization and depoliticization of the GI concept and policies should be documented in more detail, by placing them into the multiscale power relations at stake and emphasizing: how stakeholders invoke nature to justify their choices.

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NOTES

1. Framing activities can de described, mobilizing a photographic metaphor, as deciding what will stay in the frame and what will remain outside (Neveu, 2017). This implies studying the processes of social problem definition with regards to confrontation and negotiation among stakeholders (Gilbert et Henry, 2012: 38).

2. Interreg EU project ALICE, *Improving the management of Atlantic landscapes: accounting for biodiversity and ecosystem services*.

3. MAP followed the International Biological Program, which successfully obtained funding due to a shared belief between American ecologists and the United States Congress about the need to control nature (Kwa, 1987).

4. The 2019 decrease is explained by the fact that the scientometric analysis was carried out in January 2020. Escobedo *et al.* (2019) found 389 relevant citations published since 2005 using the search term "green infrastructure" in Scopus.

5. CORDIS, the Community Research and Development Information Service, is the European Commission's primary source of results from the projects funded by the EU's framework programmes for research and innovation (FP1 to Horizon 2020).

6. For instance, the European Commission published a paper entitled "Green Infrastructure and the Water sector" stating that "*Green Infrastructure is an important instrument for achieving and maintaining healthy water ecosystems and offers multiple benefits to the water sector by: providing a regulation of water flows, water retention for further use later on, water purification and water provisioning, species protection, biodiversity enhancement, climate change mitigation and adaptation and disaster reduction by the prevention and mitigation of floods*" and presenting good practices such as: restoration zones for water purification ecosystem function of wetlands or flood protection regulations through wetland European Commission, consulted on 12/12/2022.

7. *"The main goal is to promote sustainable investments in Blue-Green Infrastructure Networks (BGINs) through identification of the benefits of Ecosystem Services delivered at the terrestrial-aquatic and land-sea interface in the Atlantic Region.*", ALICE Website, consulted on 13/12/2022.

8. Garmendia *et al.* (2016: 10) define such a "trap" as "[...] *an idea that attracts funding and effort from specific conservation measures that could deliver better biodiversity conservation outcomes*".

ABSTRACTS

Nature-based solutions (NbS) is an umbrella concept that includes a variety of ecosystem-based approaches such as Green Infrastructure (GI), ecological restoration, ecosystem-based disaster risk reduction, and ecological engineering (Cohen-Shacham, 2016). Decision makers rapidly adopted the GI concept after its conceptualization was refined at the beginning of the 21st century (Wright, 2011). Environmental concepts are neither fixed nor neutral: they evolve over time and space and are intertwined within power relations (Greer and Cameron, 2015). This

article draws on an in-depth social science literature review and a brief quantitative bibliometric assessment to analyze the socio-political construction of the concept, how its properties have stabilized – or not – and how it is used by stakeholders.

Les solutions basées sur la nature sont un concept englobant diverses approches basées sur les écosystèmes telles que les infrastructures vertes, la restauration écologique, la réduction des risques de catastrophes basée sur les écosystèmes, l'ingénierie écologique (Cohen-Shacham, 2016). Les décideurs ont rapidement adopté le concept d'infrastructure verte au début du 21e siècle (Wright, 2011). Les concepts environnementaux évoluent dans le temps et l'espace et sont imbriqués dans les relations de pouvoir (Greer and Cameron, 2015). Cet article s'appuie sur une revue de la littérature en sciences sociales et un état des lieux bibliométrique pour analyser la construction socio-politique du concept d'infrastructure verte, la stabilisation – ou non – de ses propriétés et son utilisation par les parties prenantes.

INDEX

Keywords: green infrastructure, ecological connectivity, science-policy interface, critical studies, European Union, power, institutionalization, science and technology studies
Mots-clés: infrastructure verte, connectivité écologique, interface science-politique, études critiques, Union Européenne, pouvoir, institutionnalisation, science and technology studies

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