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Nurturing nature: Exploring socio-spatial conditions for urban experimentation

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ABSTRACT

Cities are critical places for the emergence of sustainability transitions. The early phases of transition are often characterised by experimentation. Socio-spatial conditions, such as local policy, governance networks, localised learning and funding structures, are known to influence experimentation, yet there is little empirical knowledge on *how* these conditions contribute. We construct a framework to analyse how these conditions coincide with patterns in urban experimentation, distinguishing between incremental and radical experimentation and between social, technological, and systemic experiments. We introduce a method for large-N analysis and apply this to a database of 520 NBS in 100 European cities. This creates detailed insights into which socio-spatial conditions are associated with particular types of experimentation and how this relates to the urban innovative environment. Empirically, this paper focuses on 'Nature-Based Solutions' (NBS), which is an emerging concept for the innovative use of nature to address societal challenges.

1. Introduction

Cities, confronted with challenges such as climate change and urbanisation, are increasingly at the centre of the debate and action related to sustainable transitions (Hodson and Marvin, 2010; McCormick et al., 2013). In particular, there is ongoing debate about the enabling socio-spatial conditions of urban areas for urban sustainability experiments (Van den Heiligenberg et al., 2017; Torrens et al., 2019). Such an experiment can be conceptualised as an 'inclusive, practice-based and challenge-led initiative, which is designed to promote system innovation through social learning under conditions of uncertainty and ambiguity' (Sengers et al., 2019, p. 153)[2]. Urban experimentation can prompt wider institutional change (Evans et al., 2016), and thereby marks a first step towards a possible sustainability transition. The pathways along which experiments develop are shaped in part by their particular socio-spatial context. 'Socio-spatial conditions' signify that experimentation is anchored in particular social and spatial contexts and processes and is therefore likely to be a different phenomenon across different territories (Murphy, 2015). Hence, while transitions occur through interactions across various scales and networks, the experiments that form the seeds of change for these transitions are also embedded in specific localities, which are determined by historically developed and place-specific cultures and sub-cultures, localised institutions, political systems, social networks

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[2] In this interpretation of urban experimentation, derived from transition studies and sustainable innovation literatures, experimentation is seen as a way to achieve innovation and system change. Although we focus on experimentation, this literature often refers to innovation. Hence, in our conceptualization of socio-spatial conditions these terms are occasionally used interchangeably.

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and resources (e.g. Torrens et al., 2018). Socio-spatial conditions are therefore important in understanding and explaining differences between socio-technical transition pathways (Hodson and Marvin, 2010; Coenen and Truffer, 2012; Murphy, 2015; Håkansson, 2019).

Yet, pioneering work, such as that by Castán Broto and Bulkeley (2013) and Hansen and Coenen (2015), suggests that evidence of the influence of socio-spatial conditions on transition pathways is biased towards emphasising the particularities of certain places, often in single case studies. As such, Hansen and Coenen state that there is consensus '*that* place-specificity matters while there is little generalisable knowledge and insight about *how* place-specificity matters for transitions' (Ibid, p. 105; emphasis in original). Spatial differences between transition pathways and experimentation have been distinguished, but not explained, prompting a call for more systematic and comparative research that is designed to identify the influence of geographical conditions on transition processes and, in particular, the development of experimentation (Hansen and Coenen, 2015; Wolfram, 2016a; Hodson et al., 2017; Köhler et al., 2019; Sengers et al., 2019).

With this paper, we aim to contribute to this debate by asking how urban socio-spatial conditions shape patterns of urban experimentation, based on a quantitative analysis, comparing 520 experiments across 100 cities in Europe on 57 variables (Almassy et al., 2018). As a point of departure, we constructed a framework outlining which socio-spatial conditions are considered key to urban experimentation, drawing on insights from geography of transitions and urban experimentation literature, and particularly building on the work by Hansen and Coenen (2015). Noting the pioneering work by Håkansson (2019), we aim to add novelty to the existing body of literature by creating a nuanced overview of how specific place-based socio-spatial conditions correlate with different types of urban experimentation, based on a large-N study. Furthermore, we provide insights into how those correlations might differ between cities with a relatively large number of radical experiments and cities with a relatively small number of radical experiments. Using these insights, we assess the existence of innovative city environments and their specific socio-spatial conditions.

Empirically, this paper focusses on Nature-Based Solutions (NBS). NBS is an emerging concept that refers to the innovative use of nature for addressing societal challenges, such as climate change, biodiversity, health and inclusive societies. Examples of NBS are green roofs, bioswales and urban agriculture. We considered NBS to be a useful case for our purpose, as these solutions are inherently place-based and ecologically and institutionally interdependent, in a local, often urban, environment (Nesshöver et al., 2017; Raymond et al., 2017). Drawing on the definition of experiments provided by Sengers et al. (2019) as outlined above, we conceived of NBS as experiments that, through their multifunctional nature, would offer an innovative alternative to the provision of urban infrastructures and exhibit a sustainability challenge-oriented approach.

Section 2 presents our conceptual framework on socio-spatial conditions in relation to different forms of experimentation with NBS. Section 3 outlines the methodology for the quantitative analysis. Section 4 presents the significant findings per socio-spatial condition. Salient findings are discussed in Section 5, and Section 6 provides conclusions.

2. A framework for exploring patterns in urban experimentation

The literature on experimentation in sustainability transitions goes back to ideas on the role of niches in enabling wider regime shifts towards sustainability (Sengers et al., 2019). This literature argues that radical environmental innovations tend to develop in niches, because these offer protective spaces that allow for such innovations to gain momentum. Niche formation, or so the argument goes, could be supported through a process of designing and implementing socio-technical experiments, which, in turn, would benefit three complementary processes: learning, the articulation of expectations and social network building (Kemp et al., 1998). The geography of sustainability transitions literature voices constructive criticism on the limited conception of place-based factors in these earlier niche-based strategies to transitions, showing that experimentation and niche development are greatly influenced by their socio-spatial environment (Coenen et al., 2010, 2012). Moreover, the socio-spatial conditions that influence the development of experimentation are interdependent (Van den Heiligenberg et al., 2017). Together they constitute a supportive or restrictive environment for experimentation. In the literature on economic geography, the term cluster is used to denote place-based agglomerations that favour certain industries and, as such, are fruitful locations for innovation (Porter and Stern, 2001; Breschi and Malerba, 2005). Van den Heiligenberg et al. (2017) use the term 'habitat' to denote the configuration of contextual, mainly locally and regionally embedded factors for innovative experiments, and indicate that certain types of experiments may flourish in particular habitats. For instance, experiments in habitats and regions with a focus on high-tech innovations (such as Silicon Valley in the United States) have features and requirements for flourishing and diffusion that differ from those of experiments in regions and habitats characterised by regional community values and cooperative traditions. Similarly, Torrens et al. (2019) demonstrate ways in which urban environments could become conducive to experimentation, tracing the often long-term development of experimental innovation, and highlighting the various urban environments through which it might emerge.

While the literature on urban experimentation prominently argues that socio-spatial conditions are important for urban experimentation, so far less systematic attention has been devoted to unpacking how particular conditions shape different dimensions, processes or elements in experimentation. We drew on a longer tradition of research on experimenting in the context of urban sustainability transitions (Sengers et al., 2019), and the geography of transitions more generally (Hansen and Coenen, 2015), to construct a framework outlining the socio-spatial conditions that are particularly relevant for unpacking patterns in experimentation. These include policy visions and plans, governance and stakeholder networks, learning capacity, financial resources and funding structures, informal localised institutions, and place-specific natural endowments and resources. We note here that we conceptualised these conditions as place-specific, i.e. we understood them to be embedded in a particular locality (e.g. a city vision developed by a local council) or embedded across multiple scales (e.g. a city deal between national and local authorities providing investment support). Together, they shape a place-specific environment in which urban experimentation is embedded, giving rise to place-specific forms of experimentation (Raven et al., 2017). Below, we elaborate on each condition to tentatively explore how it affects urban experimentation towards sustainable innovation.

Policy visions and plans, such as comprehensive regional planning strategies, urban development plans or national environmental policies

(e.g. clean air or water acts), are used to articulate and align expectations, provide direction for localised learning processes and serve as a reference point for network building and stakeholder engagement, thereby providing several essential elements in the emergence and development of innovation (Hodson and Marvin, 2010; Dignum, 2013; Peng and Bai, 2018). Cities and regions can function as arenas for negotiating the visions that steer transition dynamics such as experimentation, not only because of the envisioning that takes place at the municipal and regional governance levels, but also because of their place-based capacity, actions to demonstrate feasibility, and the potential of visions to inspire visions elsewhere (Späth and Rohracher, 2012; McPhearson et al., 2016; Sengers et al., 2019; Torrens et al., 2019).

Heterogeneous *governance and stakeholder networks* drive knowledge generation and exchange and resource pooling (Schot and Geels, 2008). Three dynamics that are particularly relevant in the governance of urban experiments are 1) the heterogeneity of actors involved; 2) the presence of social networks, formal and informal, and 3) the multilevel character of governing urban sustainability (McCormick et al., 2013; Bulkeley et al., 2016; Evans et al., 2016; Voytenko et al., 2016; Hodson et al., 2017). Particularly cities arguably provide the diversity of perspectives and needs that tend to stimulate innovative solutions to address current unsustainable infrastructures (Wolfram and Frantzeskaki, 2016; Martiskainen, 2017). Yet, networks are not necessarily confined to the urban scale; the extent to which actors in urban experiments are embedded in multilevel networks shapes the opportunities for urban experimentation (North and Longhurst, 2013; Raven et al., 2017; Smeds and Acuto, 2018).

To overcome barriers related to the uncertainty and different perceptions of the introduction of innovations, *localised learning* about needs, problems, possibilities and the desirability of innovation is essential to its development (Kemp et al., 1998; Brown et al., 2003; Luederitz et al., 2017). This learning is localised, because it is territorially embedded within place-specific networks and institutions. Relative to more sparsely populated areas, cities are considered to provide a beneficial context for innovation due to the generally higher potential transfer of tacit knowledge through social interaction, which emphasises the relevance of localised learning (Campbell, 2009; Coenen et al., 2010). Experimenting and learning in 'real-life' laboratory settings is increasingly considered key to acquire knowledge and experience on environmental innovation (Nevens et al., 2013; Bulkeley et al., 2016; Evans et al., 2016; Voytenko et al., 2016; Von Wirth et al., 2018).

Sustainability innovation often exhibits high levels of uncertainty, regulatory dependence and capital-intensiveness, making it less attractive for investments by market parties (Polzin, 2017). Following earlier work in strategic niche management, protective spaces are perceived to shield these innovations from harsh market pressures. In addition to regulatory measures, financial buffers against market pressures enhance such protective spaces (Kemp et al., 1998). *Financial resources and funding structures* that are oriented to protect the niche from market pressures thus strengthen niche formation (Polzin, 2017). So far, there has been limited exploration in the context of urban experimentation of how such resources and structures are place-specific, but it is certain that they originate from specific spatial scales (e.g. local governments).

Informal localised institutions, defined here as 'territorially bound norms, values and practices' (Hansen and Coenen, 2015, p. 97), also give rise to territorial differentiation in urban experimentation (Raven et al., 2017). Informal, localised institutions, such as trust or enduring environmental preferences, drive collaborative cultures, political culture and consumer demands, among other things (Wirth et al., 2013; Longhurst, 2015), which in turn may create particular urban patterns in experimentation as well as patterns in wider institutional transformation (Wolfram and Frantzeskaki, 2016).

The importance of *natural endowments and resources* is highlighted in several studies, but not often explicitly theorised in relation to urban experimentation (Hansen and Coenen, 2015). Resource scarcity (e.g. fossil fuels) or natural disasters, sea level rise or decreasing air quality can factor in as enablers for investments in sustainable alternatives (Munoz-Erickson et al., 2016; Dignum, 2013). Local natural endowments are particularly relevant when urban experiments are part of and dependent on local climate and the natural environment, as is the case with NBS.

Lastly, the urban built environment, its physical infrastructures and their development form the *urban materiality* that affects transition pathways and urban experimentation (McFarlane and Rutherford, 2008; Rutherford, 2014; Rutherford and Coutard, 2014; Gailing and Moss, 2016). For instance, the 'tangible' city and its infrastructures mediates resources (Monstadt, 2009), or forms a source of inequality and fragmentation (Graham and Marvin, 2002) or obduracy that needs to be navigated to stimulate sustainable urban innovation (Hommels, 2005).

To unpack how these socio-spatial conditions relate to the emergence of heterogeneity in urban experimentation, we first differentiate between incremental and radical forms of experimentation. Acknowledging long-standing attempts to characterise innovations into different typologies and differentiating incremental and radical innovation (e.g. Garcia and Calantone, 2002; Elzen et al., 2004; Dahlin and Behrens, 2005), our analysis defines radical experiments as those completely new to their environment, where 'completely new' is operationalised as novel in their region or country. Incremental experiments build on previous experiments. Furthermore, the analysis includes insights to characterise experiments as predominantly technological, social or systemic in nature (Hoogma et al., 2002; Geels, 2005; Sengers et al., 2019). Technological experimentations encompass the introduction of new or significantly altered products, production processes, or technological infrastructures (in our case in the context of urban nature). Social experimentation encompasses transformations in social relationships through, for instance, innovative policies, governance structures or cultural framings (Moulaert, 2009). Systemic experiments explicitly incorporate both social and technical dimensions and the relationships between them. Examples from the database that our empirical analysis drew on (see Section 3 and https://naturvation.eu/atlas[3]) illustrate this categorisation. For instance, one of the first green roofs in Romania was marked as a technological experiment, while a green roof in Genoa (where green roofs are more common) that was used to collect data to inform policy-making in new ways was marked as a social experiment. An example of a systemic experiment is a green roof in Malaga that is used as a test-site for vegetation types, while offering educational and professional programmes for vulnerable social groups.

[3] Accessed on: 30 July 2019.

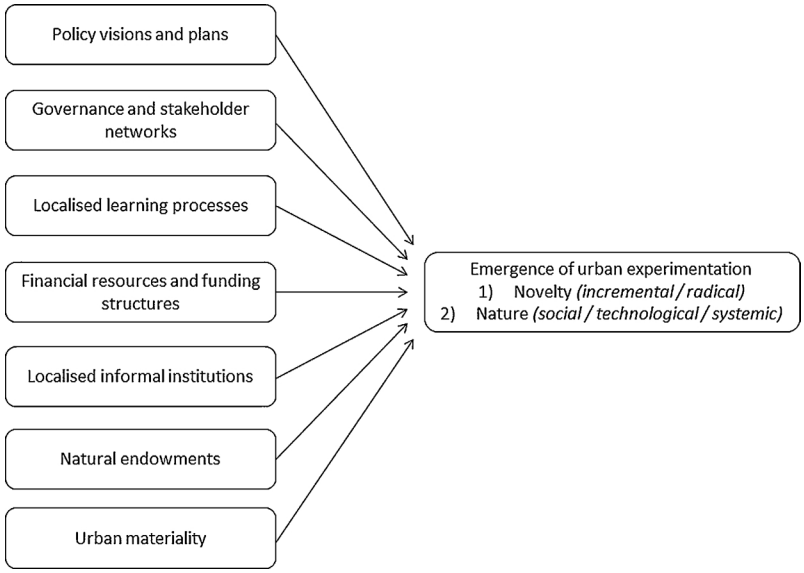

Fig. 1. Conceptual framework: place-based conditions for urban NBS experiments.

Fig. 1 visualises our conceptual framework for exploring how particular place-based conditions shape diversity in urban experimentation. We note here that this visualisation rests in an attempt to start unraveling how socio-spatial factors shape different patterns of experimentation. As such, it does not provide a dynamic representation of recursive relationships between urban environments and forms of experimentation.

3. Methods

For this paper an extensive database of European NBS in 100 European cities of which 520 experiments with NBS contained innovation characteristics was analysed. This database is referred to as the Urban Nature Atlas (http://www.naturvation.eu/atlas) and was constructed between June-August 2017 as part of the NATURVATION[4] research project. The cities were selected to represent a variety of urban and environmental conditions of cities with at least 250.000 inhabitants (Almassy et al., 2018). On average a city counted 703.000 inhabitants. To allow comparison between cities, a maximum of 10 NBS per city was collected based on diversity between the experiments. The NBS were identified to offer solutions to urban-challenges including urban economic performance, climate vulnerability, ecological domains, sustainability challenges and governance arrangements (Almassy et al., 2018).

Information on the NBS was collected through desk research using 57 questions, referred to as variables. In addition to general information, innovation type, and novelty of each experiment, the database included 34 variables that provided information on four socio-spatial conditions of our framework (see Section 2 and Appendix A). These conditions were 'policy visions and plans', 'governance and stakeholder networks', 'localised learning processes' and 'financial resources and funding structures'. The variables generally distinguished between the local level, national level and the European level. The database did not contain information related to 'localised informal institutions', 'natural endowments', and 'urban materiality' which were excluded from the analysis. These variables could be addressed in future data collection and analysis.

The information resulted in 400 columns of data for each initiative that were referred to as L-numbers (L-1, L-2, etc.). The tables in the results section present the Questions (Variables) and the responses to these questions. The database included binary 'yes' or 'no' responses, and fields with additional explanation. Each column was separately assessed (e.g. this means that a 'Yes' response to a question has a different L-no than a 'No' response to the same question). For example, L-268 outlines a Yes [response], indicating that a total of 58 % of the incremental and radical experiments are implemented in response to a local regulation, strategy, or plan [question] (see Table 4). A question was marked as 'unknown' when after intensive data collection no verifiable answer could be found. Almassy et al. (2018) provided an elaborated overview on the database construction and selection procedure of cities and NBS.

In the analyses we identified correlations between the occurrence of specific socio-spatial conditions between cities and novelty and innovation type (see Fig. 1). This resulted in insights such as a higher correlation between local visions and plans and incremental social experimentation compared to radical social experimentation.

To prepare the database for analysis, we excluded experiments for which no data on innovation was recorded. This reduced the number of experiments from 976 to a subset of 520 experiments. These experiments were categorised into 6 types based on incremental or radical novelty, and on innovation type, distinguishing between technological, social or systemic (see Table 2).

The analysis comprised three steps (Table 1). Each step provided additional information on socio-spatial conditions that do (or do

[4] https://naturvation.eu/

Table 1
Structure of the analysis.

Step	Action	Contents
0.	Preparation	*Aim: Prepare database for analysis.* Action: i Exclude experiments that omit a novelty status (remaining n = 520). ii Categorise experiments based on novelty status (incremental or radical) and type of innovation (social, technical, systemic).
1.	Quantity analysis	*Aim: Identify variables that are of key importance for both incremental and radical experiments.* Action: i Identify variables that occur in > 50 % of at least one category of experiments of both novelty types.
2.	Difference analysis	*Aim: Identify variables that are significantly different for radical and incremental experiments.* Action: i Identify variables that statistically significantly differ between radical and incremental experiments within each type of innovation (social, technical, systemic).
3.	Innovative environment analysis	*Aim: Identify the socio-spatial conditions of innovative city environments.* Action: i Identify innovative cities based on the clustering of radical and incremental experiments in cities (to make comparable groups a threshold of 3 radical experiments marked the 22 'most innovative' cities in the database). ii Categorise experiments based on novelty status and innovative city environment. iii Identify variables that statistically significantly differ between radical and incremental environments within novelty status groups (by subsequently comparing incremental and radical innovations between both groups of cities).

Table 2
Database contents for innovation type and novelty.

Type of innovation	Radical	Incremental	Total
Social	32 (6.2 %)	149 (28.7 %)	181 (34.8 %)
Technological	81 (15.6 %)	133 (25.6 %)	214 (41.2 %)
Systemic	44 (8.5 %)	81 (15.6 %)	125 (24 %)
Total	157 (30.2 %)	363 (69.8 %)	520

not) coincide with the specific elements of our typology. The most important information for all three analyses was the relative frequency of occurrence of specific socio-spatial conditions, such as 'participation in the experiment is voluntary'.

First, the quantity analysis identified variables occurring in a majority of cases (> 50 %) indiscriminate between incremental and radical NBS. This created insight into variables that are generally important for experiments.

Second, a 'difference analysis' identified variables that are different for different types of experimentation (e.g. whether citizens participated more often in a radical experiment compared to an incremental one). This analysis distinguished between radical or incremental as well as between social, technological and systemic experiments. To identify statistically significant differences, a (two-tailed) difference of proportion test[5] was used. It should be noted that the statistical test serves to filter out most irrelevant findings (certainty interval of 95 %). However, differences closer to the extremes (0 and 100 %) test significant at smaller differences. For example, incremental social experiments were 26 % more frequently co-governed (between government and non-government actors) than radical social experiments, with a z-score of 2.7. For systemic experiments this difference was only 2 % with a z-score of 0.2. The significant scores of the 95 % confidence interval were used in the analysis. For supporting insights, we also registered projects just outside the 95 % confidence interval, up to the 90 % confidence interval. The tables in the results section display all variables that include at least one significant score. The 95 % significant score was marked as a dark-grey field, and the 90 % was marked with light grey fields. In cases where the 90 % confidence interval was considered, this is explicitly mentioned.

Lastly, the 'innovative environment analysis' compared conditions of experiments in highly innovative environments with those in less, or incrementally, innovative environments. This was done by marking cities with three or more radical experiments as innovative cities (Radical Innovation Cities, 'RI-cities'). The threshold of three radical experiments was chosen to balance the number of radical experiments in the two groups. The analysis compared the differences in socio-spatial conditions between the 22 RI-cities to those in the 78 non-RI-cities. We compared radical experiments in RI-cities with those in non-RI-cities. Subsequently, we compared incremental experiments in both groups of cities. The analyses in this step served to assess whether there are indications for an 'innovative-city' environment, and to identify conditions that characterise such an environment. For instance, we show that RI-cities tend to have a higher involvement of public sector institutions (schools or hospitals) in radical experiments (compared to non-RI-cities).

4. Results

Table 2 presents the 520 analysed experiments divided along the novelty-innovation type typology. This selection contains 363 incremental experiments (149 social, 133 technological, and 81 systemic), and 157 radical experiments (32 social, 81 technological,

[5] Differences z-level smaller than [-]1.96 were considered insignificant.

and 44 systemic). Table 3 provides an example for each type of experiment, such as a community garden, orchards, green roofs, or an eco-friendly urban district.

Table 3
Example experiments from the NBS database.

Innovation	Radical	Incremental
Social	Food for Good, Utrecht: A community garden to promote social cohesion and equity in the neighbourhood.[a]	Las Moreras Orchard, Seville: Publicly accessible orchards for recreation and education. Children can learn and cultivate the land.[b]
Technological	Bosco Vertical, Milan: Two residential towers (heights 110 and 76 m) hosting 900 trees and over 20,000 plants distributed along the facade.[c]	Sheffield Bus Shelter, South Yorkshire: Development of green roofs of bus shelters, providing an attractive green space and shade in concrete-dominated urban streets. The roofs also filter particulates from transport, and hence protect the health of waiting passengers.[d]
Systemic	Green and blue culture Street, Aarhus: A climate-friendly makeover of a street in the city centre including water elements and greenery realised by collaboration between businesses, house owners, tenants, and municipal departments.[f]	Hammarby Sjöstad, Stockholm: The development of an eco-friendly city district, including walkways, green spaces, and several large parks including environmentally cyclic solutions regarding energy, waste, water, and sewage.[e]

[a]see https://naturvation.eu/nbs/utrecht/food-good; http://www.foodforgood.nl. Accessed on 30 July 2019.
[b]see https://naturvation.eu/nbs/sevilla/las-moreras-orchard; https://huertalasmoreras.wordpress.com/. Accessed on 30 July 2019.
[c]https://naturvation.eu/nbs/milano/vertical-forest. Accessed on 30 July 2019.
[d]see https://naturvation.eu/nbs/sheffield/sheffield-bus-shelter; http://www.greenroofs.com/projects/pview.php?id=760. Accessed on 30 July 2019.
[e] see https://naturvation.eu/nbs/arhus/green-and-blue-culture-street. Accessed on 30 July 2019.
[f]see https://naturvation.eu/nbs/stockholm/hammarby-sjostad; http://www.hammarbysjostad.se/. Accessed on 30 July 2019.

This section presents the results structured by the analysed socio-spatial conditions. Section 4.1 presents the quantity analysis, Section 4.2 the difference analysis, and Section 4.3 the innovative environment analysis.

4.1. *Quantity analysis: generic conditions for experimentation*

This section identifies correlations in the Urban Nature Atlas that are relevant for radical as well as for incremental experiments. Table 4 depicts the relevant variables for *policy visions and plans* present in the majority of cases. This shows that most NBS tend to

Table 4
Proxies for policy visions and plans present in over 50 % of cases of at least one category of experiments.

			Radical			Incremental			Total
L-nr	Question	Response	Social	Tech.	System	Social	Tech.	System	
264	NBS intervention implemented in response to an EU Directive/Strategy	Unknown	66%	67%	66%	63%	60%	65%	64%
267	NBS intervention implemented in response to a national regulations/strategy/plan	Unknown	59%	67%	68%	58%	69%	54%	63%
268	NBS intervention implemented in response to a local regulation/strategy/plan	Yes	41%	49%	61%	64%	58%	60%	58%
272	Voluntary intervention	Voluntary (spontaneous)	75%	53%	64%	63%	62%	51%	60%
287	Presence of specific city-level Green Infrastructure/NBS vision/strategy/plan mentioned in connection to the project	Unknown	66%	69%	59%	48%	71%	49%	60%
288	Presence of specific city-level Green Infrastructure/NBS section/part in a more general plan mentioned in connection to the project	Yes	44%	40%	64%	49%	40%	57%	47%
290	Presence of specific city-level Green Infrastructure/NBS section/part in a more general plan mentioned in connection to the project	Unknown	50%	56%	36%	46%	53%	37%	48%
296	Presence of Green Infrastructure/NBS research project mentioned in connection to the project	Unknown	63%	62%	50%	59%	61%	60%	60%

be implemented in response to local policy, although this is slightly less common for radical social and technological experiments (L268). Compared to social and technological experiments, systemic experiments more often occur when an explicit section on NBS, or on green infrastructure, is included in city-level plans (L288). Notably, most of the experiments are implemented voluntarily rather than through mandatory mechanisms (L272).

Table 5 on *Governance and stakeholder networks* shows that citizens or community groups form the primary beneficiaries for almost all NBS (91 % of all NBS) (L205). Citizens and community groups are also actively involved in most NBS (L247). The local government is involved in the majority of cases (L239), often as an initiating actor (for mostly incremental experimentation (L224)). Additionally, systemic experiments often correlate with a shared responsibility in the governance of an experiment (L210). These same experiments often occur in the presence of a city or regional network (L291).

Table 5
Proxies for governance and stakeholder networks present in over 50 % of cases of at least one category of experiments.

			Radical			Incremental			Total
L-nr	Question	Response	Social	Tech.	System	Social	Tech.	System	
197	Spatial scale	Micro-scale: District/neighbourhood level	47%	47%	45%	49%	32%	**57%**	45%
198	Spatial scale	Sub-microscale: Street scale (including buildings)	47%	41%	43%	38%	**53%**	36%	43%
200	Primary beneficiaries identified by the project	Local government/ Municipality	**56%**	**51%**	45%	42%	37%	**63%**	47%
205	Primary beneficiaries identified by the project	Citizens or community groups	**100%**	**88%**	**95%**	**96%**	**81%**	**96%**	**91%**
210	Power distribution within the initiative	Co-governance or hybrid governance mix of responsibilities between government and non-government actors	28%	48%	**55%**	**54%**	33%	**57%**	47%
224	Initiating organization of the NBS	Local government / municipality	38%	**52%**	48%	**55%**	**53%**	**62%**	**53%**
239	Type of stakeholders involved	Local government / municipality	**78%**	**75%**	**82%**	**79%**	**68%**	**84%**	**77%**
241	Type of stakeholders involved	Non-government organization / civil society	**53%**	21%	39%	46%	22%	**52%**	37%
243	Type of stakeholders involved	Private sector / Corporate / Company	38%	**53%**	**66%**	30%	**64%**	**57%**	50%
247	Type of stakeholders involved	Citizens or Community groups	**75%**	**53%**	**66%**	**77%**	45%	**81%**	**65%**
250	Participatory methods/forms of community involvement used	Co-planning	47%	23%	41%	**52%**	11%	42%	34%
253	Participatory methods/forms of community involvement used	Dissemination of information and education	**53%**	30%	50%	50%	25%	**51%**	41%
261	Participatory methods/forms of community involvement used	Unknown	16%	36%	18%	12%	**50%**	10%	26%
291	Presence of city network or regional partnerships focused on NBS mentioned in connection to the project	Yes	44%	33%	**59%**	**54%**	32%	**54%**	45%
293	Presence of city network or regional partnerships focused on NBS mentioned in connection to the project	Unknown	**53%**	**63%**	41%	45%	**66%**	46%	**53%**

Despite an intense data collection process, information on *localised learning processes* remains largely absent (Table 6- L373; L376; L379; L382; L385; L397; L400). The absence of knowledge on citizen involvement in the assessment or evaluation of the NBS (L397; L388; L400) is particularly striking as citizens or community groups are considered the main beneficiaries (see governance and networks).

Table 6
Proxies for learning processes present in over 50 % of cases of at least one category of experiments.

L-nr	Question	Response	Radical			Incremental			Total
			Social	Tech.	System	Social	Tech.	System	
373	Presence of formal monitoring system	Unknown	**69%**	**58%**	50%	**58%**	**62%**	**63%**	**60%**
376	Presence of indicators used in reporting	Unknown	**72%**	**63%**	**52%**	**63%**	**71%**	**67%**	**65%**
379	Presence of monitoring/evaluation reports	Unknown	**69%**	**69%**	48%	**60%**	**66%**	**60%**	**63%**
382	Availability of a web-based monitoring tool	Unknown	**72%**	**78%**	**68%**	**69%**	**75%**	**57%**	**70%**
385	Use of GIS in mapping impacts	Unknown	**81%**	**81%**	**80%**	**81%**	**80%**	**83%**	**81%**
397	Citizens involvement in the analysis of the assessment/evaluation	Unknown	**88%**	**88%**	**95%**	**79%**	**87%**	**74%**	**84%**
386	Citizens involvement in assessment/evaluation of the NBS intervention	Yes	50%	17%	45%	**52%**	29%	**56%**	41%
388	Citizens involvement in assessment/evaluation of the NBS intervention	Unknown	41%	**74%**	**55%**	46%	**65%**	43%	**55%**
400	Follow-up to the evaluation/assessment	Unknown	**88%**	**91%**	**89%**	**87%**	**86%**	**80%**	**87%**

Results on *financial resources and funding structures* (Table 7) show that more than half of all experiments (53 %) receive city-level funds, subsidies or investments earmarked for NBS – most commonly out of the local authority's budget (L297; L311), and through direct funding (L319). Compared to technological and systemic experiments, social experiments frequently receive non-financial contributions, such as services or labour (L329; L334).

Table 7
Proxies for financial resources and funding structures present in over 50 % of cases of at least one category of experiments.

L-nr	Question	Response	Radical			Incremental			Total
			Social	Tech.	System	Social	Tech.	System	
297	Subsidies/investment for Green Infrastructure/NBS in the city mentioned in connection to the project	Yes	41%	49%	**68%**	**56%**	47%	**60%**	**53%**
311	Source of funding	Public local authority's budget	**53%**	47%	**61%**	**56%**	45%	**62%**	**53%**
319	Type of financing instruments used for the NBS intervention	Direct funding or subsidies	**59%**	**65%**	**61%**	48%	**61%**	**52%**	**57%**
329	Non-financial contribution	Yes	**69%**	17%	45%	**58%**	19%	43%	39%
331	Non-financial contribution	Unknown	22%	**64%**	43%	36%	**52%**	42%	45%
334	Type of non-financial contribution	Provision of services and labour	**63%**	15%	34%	**50%**	15%	40%	33%

4.2. *Difference analysis – contrasting incremental and radical experiments*

This section identifies differences between radical and incremental experiments, further divided between social, technological, and systemic experiments.

For *policy visions and plans* (Table 8), there are only a few significant differences. Notably, the results show that radical social experiments are more frequently shaped by local and regional policy and plans compared to incremental social experiments (L268; L285). Interestingly, incremental systemic experiments often explicitly do not link up with local policy plans (L269).

Table 8
Significant proxies for differences between radical and incremental innovation on local and regional policy and plans.

L-nr	Question	Response	Social		Techn.		System	
			Rad.	Incr.	Rad.	Incr.	Rad.	Incr.
266	NBS intervention implemented in response to a national regulations/strategy/plan	No	19%	15%	7%	12%	*5%*	*15%*
268	NBS intervention implemented in response to a local regulation/strategy/plan	Yes	**41%**	**64%**	49%	58%	61%	60%
269	NBS intervention implemented in response to a local regulation/strategy/plan	No	25%	15%	9%	10%	**0%**	**9%**
270	NBS intervention implemented in response to a local regulation/strategy/plan	Unknown	*34%*	*21%*	42%	32%	39%	31%
274	Intervention is mandatory, as a result of…	Spatial planning guidance	16%	21%	*22%*	*14%*	*20%*	*35%*
280	Intervention is voluntary, as a result of…	Voluntary building certification scheme	**3%**	**0%**	7%	4%	2%	2%
285	Presence of specific city-level Green Infrastructure/NBS vision/strategy/plan mentioned in connection to the project	Yes	**25%**	**44%**	26%	23%	41%	44%
286	Presence of specific city-level Green Infrastructure/NBS vision/strategy/plan mentioned in connection to the project	No	9%	7%	5%	6%	*0%*	*6%*
287	Presence of specific city-level Green Infrastructure/NBS vision/strategy/plan mentioned in connection to the project	Unknown	*66%*	*48%*	69%	71%	59%	49%
289	Presence of specific city-level Green Infrastructure/NBS section/part in a more general plan mentioned in connection to the project	No	6%	5%	5%	7%	*0%*	*6%*

Results on *governance and stakeholder networks* (Table 9) indicate that radical social experiments are more often initiated by national governments (L222) or EU bodies (L221) than incremental social experiments. However, governance of these radical social experiments often occurs by non-government actors, or as a shared responsibility between government and non-government actors (L210; L211). Public organisations such as schools or hospitals are more frequently involved in incremental social experiments than in radical social experiments (L240).

When comparing radical and incremental technological experiments, radical ones are more frequently initiated by a private foundation than incremental technological experiments (L229). These radical technological experiments are often led/co-governed by the civil society (L216) or public sector institutions like schools or hospitals (L212) and include more participatory methods such as co-planning with the community, a task force, and joint management compared to incremental technological experiments (L250; L252; L256). Shared responsibility between government and non-government actors (L210; L212) is also more common for radical technological experiments compared to incremental ones.

Radical systemic experiments are more often co-governed by researchers or universities compared to incremental systemic experiments (L215). NGOs or the civil society are more frequently the primary beneficiaries of incremental systemic experiments than of radical ones (L202).

Table 9
Significant proxies for differences between radical and incremental innovation on governance and stakeholder networks.

			Social		Techn.		System	
L-nr	Question	Response	Rad.	Incr.	Rad.	Incr.	Rad.	Incr.
197	Spatial scale	Micro-scale: District/neighbourhood level	47%	49%	**47%**	**32%**	45%	57%
198	Spatial scale	Sub-microscale: Street scale (including buildings)	47%	38%	*41%*	*53%*	43%	36%
199	Primary beneficiaries identified by the project	National-level government	*13%*	*5%*	5%	5%	11%	7%
200	Primary beneficiaries identified by the project	Local government/Municipality	56%	42%	**51%**	**37%**	*45%*	*63%*
202	Primary beneficiaries identified by the project	Non-government organisation/Civil Society	22%	13%	**14%**	**5%**	**9%**	**23%**
203	Primary beneficiaries identified by the project	Private sector/Corporate/Company	9%	10%	*21%*	*32%*	25%	26%
204	Primary beneficiaries identified by the project	Researchers/University	13%	11%	*21%*	*11%*	25%	19%
210	Power distribution within the initiative	Co-governance or hybrid governance mix of responsibilities between government and non-government actors	**28%**	**54%**	**48%**	**33%**	55%	57%
211	Power distribution within the initiative	Led by non-government actors	**47%**	**28%**	28%	38%	32%	25%
212	Non-government actors involved if the initiative is led by co/hybrid governance or by non-government actors	Public sector institution eg school or hospital	9%	14%	**15%**	**6%**	*14%*	*5%*
214	Non-government actors involved if the initiative is led by co/hybrid governance or by non-government actors	Private sector/Corporate/Business	9%	22%	47%	47%	*45%*	*28%*
215	Non-government actors involved if the initiative is led by co/hybrid governance or by non-government actors	Researchers, university	*3%*	*15%*	19%	11%	**23%**	**9%**
216	Non-government actors involved if the initiative is led by co/hybrid governance or by non-government actors	Citizens or community groups	41%	40%	**19%**	**9%**	20%	28%
218	Non-government actors involved if the initiative is led by co/hybrid governance or by non-government actors	Other	*6%*	*1%*	2%	2%	0%	5%
219	Non-government actors involved if the initiative is led by co/hybrid governance or by non-government actors	Unknown	0%	1%	*2%*	*0%*	2%	0%
220	Initiating organization of the NBS	Multilateral organization	0%	1%	*2%*	*0%*	0%	0%
221	Initiating organization of the NBS	EU bodies	**3%**	**0%**	1%	1%	0%	0%
222	Initiating organization of the NBS	National government	**16%**	**3%**	*10%*	*4%*	14%	11%
224	Initiating organization of the NBS	Local government / municipality	*38%*	*55%*	52%	53%	48%	62%
227	Initiating organization of the NBS	Business association	0%	1%	4%	1%	*5%*	*0%*
229	Initiating organization of the NBS	Private Foundation	0%	5%	**7%**	**2%**	5%	4%
230	Initiating organization of the NBS	Transnational network	0%	1%	*2%*	*0%*	2%	1%
233	Initiating organization of the NBS	Other	3%	2%	1%	2%	**0%**	**10%**
240	Type of stakeholders involved	Public sector institution (eg school or hospital)	**16%**	**34%**	21%	13%	30%	30%
244	Type of stakeholders involved	Private Foundation	*0%*	*9%*	**9%**	**1%**	9%	9%
246	Type of stakeholders involved	Researchers / University	31%	21%	30%	21%	*41%*	*25%*
247	Type of stakeholders involved	Citizens or Community groups	75%	77%	53%	45%	*66%*	*81%*
250	Participatory methods/forms of community involvement used	Co-planning	47%	52%	**23%**	**11%**	41%	42%
252	Participatory methods/forms of community involvement used	Taskforce groups	13%	15%	**10%**	**3%**	16%	11%
256	Participatory methods/forms of community involvement used	Co-/Joint management	41%	34%	**10%**	**2%**	20%	20%
259	Participatory methods/forms of community involvement used	Citizen monitoring and review	3%	9%	*1%*	*7%*	14%	15%
261	Participatory methods/forms of community involvement used	Unknown	16%	12%	**36%**	**50%**	18%	10%

The results on *localised learning processes* (Table 10) outline that radical social experiments are less likely to be monitored (L371) and tend to omit indicators for their reporting (L374) compared to incremental social experiments. The involvement of citizens in the assessment or evaluation is largely unknown (L397), yet appears more common for incremental systemic experiments (L395; L391) and for incremental technological experiments (L386) compared to radical experimentation.

Table 10
Significant proxies for differences between radical and incremental innovation on learning processes.

			Social		Techn.		System	
L-nr	Question	Response	Rad.	Incr.	Rad.	Incr.	Rad.	Incr.
371	Presence of formal monitoring system	Yes	**16%**	**35%**	38%	37%	45%	32%
374	Presence of indicators used in reporting	Yes	**13%**	**31%**	35%	27%	41%	30%
375	Presence of indicators used in reporting	No	*16%*	*6%*	2%	2%	7%	4%
377	Presence of monitoring/evaluation reports	Yes	*16%*	*33%*	26%	31%	48%	36%
386	Citizens involvement in assessment/evaluation of the NBS intervention	Yes	50%	52%	**17%**	**29%**	45%	56%
387	Citizens involvement in assessment/evaluation of the NBS intervention	No	*9%*	*3%*	9%	6%	0%	1%
391	Mode(s) of citizen involvement in evaluation/assessment of the NBS intervention	Focus Group	9%	12%	7%	7%	**7%**	**23%**
393	Mode(s) of citizen involvement in evaluation/assessment of the NBS intervention	Submission of monitoring data (citizen observation)	16%	10%	7%	10%	*2%*	*11%*
395	Citizens involvement in the analysis of the assessment/evaluation	Yes	*3%*	*16%*	4%	7%	**5%**	**22%**
397	Citizens involvement in the analysis of the assessment/evaluation	Unknown	88%	79%	88%	87%	**95%**	**74%**
398	Follow-up to the evaluation/assessment	Yes	13%	9%	*4%*	*11%*	11%	19%

When focussing on differences in *financial resources and funding structures* of radical and incremental experimentation (Table 11), the differences in social experiments stand out. Radical social experiments more often receive city-level funding, subsidies, or investments (L298) and more often have a lower budget (L300; L302; L303).

Radical technological experiments are more often supported by equity funding (L321) and through the provision of goods (L333) compared to incremental technological experiments. Incremental systemic experiments appear more likely to be financed through crowd-sourcing compared to radical system experiments (L315).

Table 11
Significant proxies for differences between radical and incremental innovation on financial resources and funding structures.

L-nr	Question	Response	Social		Techn.		System	
			Rad.	Incr.	Rad.	Incr.	Rad.	Incr.
298	Subsidies/investment for Green Infrastructure/NBS in the city mentioned in connection to the project	No	**16%**	**3%**	4%	7%	2%	4%
300	Total Cost	Less than 50 000 EUR	**28%**	**13%**	5%	5%	5%	11%
302	Total Cost	100 000 - 500 000 EUR	*0%*	*11%*	6%	9%	9%	6%
303	Total Cost	500 000 - 2 000 000 EUR	*0%*	*8%*	6%	12%	7%	9%
305	Total Cost	Above 4 000 000 EUR	16%	10%	*36%*	*24%*	30%	28%
315	Source of funding	Crowd-sourcing	16%	9%	2%	5%	**0%**	**10%**
320	Type of financing instruments used for the NBS intervention	Loan	**3%**	**0%**	0%	2%	2%	2%
321	Type of financing instruments used for the NBS intervention	Equity funding (investment in shares)	0%	0%	**4%**	**0%**	0%	1%
325	Type of financing instruments used for the NBS intervention	Donations	13%	17%	*10%*	*4%*	9%	11%
327	Type of financing instruments used for the NBS intervention	Other	*13%*	*4%*	4%	4%	9%	14%
328	Type of financing instruments used for the NBS intervention	Unknown	13%	17%	**10%**	**23%**	18%	21%
330	Non-financial contribution	No	9%	6%	*19%*	*29%*	11%	15%
331	Non-financial contribution	Unknown	22%	36%	*64%*	*52%*	43%	42%
333	Type of non-financial contribution	Provision of goods	9%	19%	**9%**	**2%**	11%	10%

4.3. Innovative environment analysis

This section presents the specific socio-spatial conditions related to experiments in regions with more radical experimentation versus in regions with fewer radical experiments. For the analysis the 100 cities are divided in 22 cities[6] (RI-cities) with more radical experiments and 78 cities (non-RI-cities) with fewer radical experiments. The cities are depicted in Fig. 2. The analysis subsequently compares radical and incremental experimentation between the two groups of cities on the variables relevant to identify socio-spatial conditions (Table 12).

[6] These are: Amsterdam (NL), Antwerp (BE), Bari (IT), Bilbao (ES), Coventry (UK), Craiova (RO), Genoa (IT), Greater Manchester (UK), Greater Nottingham (UK), Hamburg (DE), Hannover (DE), Iaşi (RO), Cracow (PO), Liège (BE), Liverpool (UK), Malaga (ES), Porto (PT), The Hague (NL), Utrecht (NL), Wirral (UK), and Wuppertal (DE). The RI-cities and the non-RI-cities are comparable with regard to average share of urban green areas and forest of total land space (RI-cities is 19.3% versus 14.7% for non-RI-cities); population with green urban areas in their neighbourhood (7.3% versus 7.1%); as well as average unemployment over the period 2008–2015 (10.9% versus 11.3%).

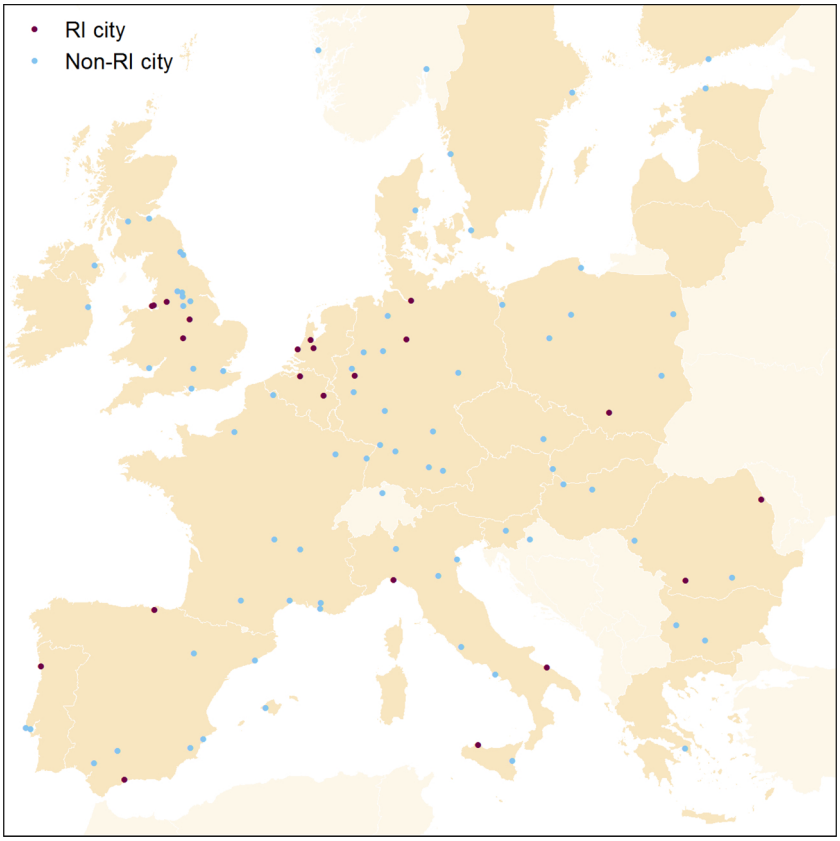

Fig. 2. Locations of RI-cities and non-RI-cities. Countries with a darker shade are EU-members.

Table 12
Comparative city analysis, with number of experiments per group.

	RI-cities (22 cities)	Non-RI-cities (78 cities)
Comparison 1: Radical experiments	87	70
Comparison 2: Incremental experiments	70	293

When comparing RI and non-RI-cities on *policy visions and plans*, only the comparison between radical experiments in these two groups of cities results in significant scores (Table 13). In non-RI-cities, radical experiments are more often based on mandatory policy (L271), for example, in spatial planning (L274) or building regulation (L278). They occur more frequently in direct connection to specific city-level NBS policies, strategies, or plans (L285) compared to radical experiments in RI-cities.

In contrast, radical experiments in RI-cities are more frequently voluntary (L272), based on voluntary environmental standards (L282), or voluntary planning guidance (L281). They also emerge more frequently in the absence of a direct connection with a city-level NBS policy, strategy, or plan (L286), or without a connection to an NBS section in a more general city planning document (L289).

For *governance and stakeholder networks* (Table 14), radical experiments in RI-cities, as opposed to those in non-RI-cities, more often include NGOs (L241) or public sector institutions such as a school or a hospital (L240). Also, schools and hospitals are more frequently the initiating actor (L225) and involved in the co-governance of such radical experiments (L212). Primary beneficiaries of radical experiments in RI-cities are more often NGOs (L202) or research institutes (L204) compared to radical experiments in non-RI-cities. Radical experiments in RI-cities appear to take place on a smaller scale than radical experiments in non-RI-cities (L196; L198).

When incremental experiments in RI and non-RI-cities are compared, the national government (L199) and disadvantaged groups (L206) are more often primary beneficiaries in RI-cities. In RI-cities, incremental experiments are more often governed, or co-governed, by NGOs (L213). Additionally, the national government (L237), the local municipality (L239), or a private foundation (L244; L229) are more often a key stakeholder in RI-cities compared to non-RI-cities.

Table 15 presents the differences between radical and incremental experiments regarding *localised learning processes*. The presence of a monitoring system is only registered as a 'no' when its absence could be confirmed. This means that radical experiments in non-RI-cities are more often not monitored than in RI-cities (L372; L375).

Table 13
Innovative environment analysis on policy visions and plans.

L-nr	Question	Response	Radical		Incremental	
			RI-city	Non-RI-city	RI-city	Non-RI-city
271	Mandatory intervention	Mandatory (based on policy)	**28%**	**44%**	43%	35%
272	Voluntary intervention	Voluntary (spontaneous)	**70%**	**49%**	56%	61%
274	Intervention is mandatory, as a result of…	Spatial planning guidance	**11%**	**31%**	14%	23%
278	Intervention is mandatory, as a result of…	Building regulation	**0%**	**7%**	4%	3%
281	Intervention is voluntary, as a result of…	Voluntary planning guidance	**24%**	**11%**	19%	19%
282	Intervention is voluntary, as a result of…	Voluntary environmental standards	**34%**	**17%**	20%	22%
285	Presence of specific city-level Green Infrastructure/NBS vision/strategy/plan mentioned in connection to the project	Yes	**22%**	**40%**	37%	36%
286	Presence of specific city-level Green Infrastructure/NBS vision/strategy/plan mentioned in connection to the project	No	**8%**	**0%**	7%	6%
289	Presence of specific city-level Green Infrastructure/NBS section/part in a more general plan mentioned in connection to the project	No	**7%**	**0%**	4%	6%

Table 14
Innovative environment analysis on governance and stakeholder networks.

L-nr	Question	Response	Radical		Incremental	
			RI-city	Non-RI-city	RI-city	Non-RI-city
196	Spatial scale	Meso-scale: Regional, metropolitan and urban level	**11%**	**27%**	20%	26%
198	Spatial scale	Sub-microscale: Street scale (including buildings)	*49%*	*34%*	47%	42%
199	Primary beneficiaries identified by the project	National-level government	7%	10%	**11%**	**4%**
202	Primary beneficiaries identified by the project	Non-government organisation/Civil Society	**21%**	**6%**	13%	13%
204	Primary beneficiaries identified by the project	Researchers/ University	**26%**	**13%**	16%	12%
206	Primary beneficiaries identified by the project	Disadvantaged groups	15%	9%	**24%**	**13%**
212	Non-government actors involved if the initiative is led by co/hybrid governance or by non-government actors	Public sector institution eg school or hospital	**18%**	**7%**	10%	9%
213	Non-government actors involved if the initiative is led by co/hybrid governance or by non-government actors	Non-government organisation/Civil society	29%	23%	**40%**	**26%**
214	Non-government actors involved if the initiative is led by co/hybrid governance or by non-government actors	Private sector/Corporate/ Business	*32%*	*47%*	29%	33%
221	Initiating organization of the NBS	EU bodies	0%	3%	**1%**	**0%**
225	Initiating organization of the NBS	Public sector institution (eg school or hospital)	**11%**	**3%**	3%	8%
229	Initiating organization of the NBS	Private Foundation	3%	7%	**13%**	**1%**
237	Type of stakeholders involved	National government	20%	21%	**27%**	**14%**
239	Type of stakeholders involved	Local government / municipality	77%	79%	**90%**	**73%**
240	Type of stakeholders involved	Public sector institution (eg school or hospital)	**31%**	**11%**	21%	26%
241	Type of stakeholders involved	Non-government organization / civil society	**39%**	**24%**	46%	37%
244	Type of stakeholders involved	Private Foundation	7%	7%	**13%**	**4%**
247	Type of stakeholders involved	Citizens or Community groups	*68%*	*53%*	70%	65%
256	Participatory methods/forms of community involvement used	Co-/Joint management	*24%*	*13%*	26%	18%
291	Presence of city network or regional partnerships focused on NBS mentioned in connection to the project	Yes	*37%*	*50%*	49%	45%

Table 15
Innovative environment analysis on localised learning.

L-nr	Question	Response	Radical		Incremental	
			RI-city	Non-RI-city	RI-city	Non-RI-city
372	Presence of formal monitoring system	No	**2%**	**11%**	4%	5%
375	Presence of indicators used in reporting	No	**2%**	**11%**	4%	4%
383	Use of GIS in mapping impacts	Yes	9%	13%	*3%*	*9%*
384	Use of GIS in mapping impacts	No	7%	10%	**4%**	**13%**
385	Use of GIS in mapping impacts	Unknown	84%	77%	**93%**	**78%**
393	Mode(s) of citizen involvement in evaluation/assessment of the NBS intervention	Submission of monitoring data (citizen observation)	8%	7%	*16%*	*9%*

The results on *financial resources and funding structures* (Table 16) show that radical experiments in RI-cities are more often funded by donations (L325), the provision of goods (L333), and the provision of services and labour (L334) compared to radical experiments in non-RI-cities. Taking a 0.9 confidence level of statistical significance, there also appears to be more earmarked public budget (L318) and crowd-sourcing (L315).

Incremental experiments in RI-cities receive direct funding or subsidies far more often than incremental experiments in non-RI-cities (L319). This includes city-level subsidies and investments (L297), EU funding (L308), funding from NGOs (L313), or private foundations (L314), and non-financial contributions through goods and services (L334). In RI-cities there appears to be a wider range of funding structures (L321; L323; L324) and funding also appears to be more transparent (L328; L331 – less unknowns).

The innovative environment analysis signals that conditions coinciding with radical and incremental experiments differ for innovative and non-innovative environments.

Table 16
Innovative environment analysis on financial resources and funding structures.

L-nr	Question	Response	Radical		Incremental	
			RI-city	Non-RI-city	RI-city	Non-RI-city
297	Subsidies/investment for Green Infrastructure/NBS in the city mentioned in connection to the project	Yes	55%	50%	**77%**	**48%**
299	Subsidies/investment for Green Infrastructure/NBS in the city mentioned in connection to the project	Unknown	39%	44%	**19%**	**47%**
308	Total Cost	EU funds	17%	17%	**24%**	**12%**
313	Source of funding	Funds provided by non-governmental organization	13%	11%	**26%**	**10%**
314	Source of funding	Private Foundation	8%	13%	**20%**	**8%**
315	Source of funding	Crowd-sourcing	*7%*	*1%*	9%	7%
318	Type of financing instruments used for the NBS intervention	Earmarked public budget	*51%*	*37%*	37%	44%
319	Type of financing instruments used for the NBS intervention	Direct funding or subsidies	63%	63%	**83%**	**47%**
321	Type of financing instruments used for the NBS intervention	Equity funding (investment in shares)	3%	0%	**1%**	**0%**
323	Type of financing instruments used for the NBS intervention	Asset-backed funding eg leasing	0%	0%	**3%**	**0%**
324	Type of financing instruments used for the NBS intervention	Tax exemption	0%	1%	**1%**	**0%**
325	Type of financing instruments used for the NBS intervention	Donations	**15%**	**4%**	11%	11%
328	Type of financing instruments used for the NBS intervention	Unknown	**8%**	**19%**	**11%**	**23%**
329	Non-financial contribution	Yes	*41%*	*29%*	*50%*	*38%*
331	Non-financial contribution	Unknown	**43%**	**59%**	**31%**	**46%**
333	Type of non-financial contribution	Provision of goods	**14%**	**4%**	10%	11%
334	Type of non-financial contribution	Provision of services and labour	**37%**	**21%**	**46%**	**32%**

5. Discussion

This research sought to identify how socio-spatial conditions influence the development of urban experiments with NBS, based on three quantitative analyses. Our study confirms that the four examined socio-spatial conditions – policy visions and plans, governance and stakeholder networks, localised learning, and funding structures – indeed all play a role in urban experimentation. Additionally, this study adds refinement to existing insights into the relevance of the social-spatial context for urban experimentation by assessing the impact of various variables per condition quantitatively, through an analysis of a large number of experiments (N = 520), and by distinguishing between different types of experiments (radical and incremental; social, technological, and systemic). This section discusses the nuances that our research adds to the existing literature as well as methodological reflections and limitations.

Policy visions and plans are considered an important driver for urban experimentation (Hansen and Coenen, 2015; Van den Heiligenberg et al., 2017). Our data confirm this: a majority of all NBS are implemented in response to local policy. However, the importance of local policy proves dependent on the type of environment. In innovative environments (RI-cities), radical experiments occur more often on a voluntary basis without a connection to existing policy than in less innovative environments (non-RI-cities). Potentially, the harbouring of innovative experiments in a city signals a culture of openness towards novelty and innovation, even without explicit policy. Future research could further explore this issue by taking a longitudinal historical perspective on the development of innovative urban environments. Innovative urban environments may experience different development phases with changing dominant conditions that drive innovation and experimentation over time (Torrens et al., 2019).

Additionally, findings show that radical experiments in less innovative environments tend to be implemented on a larger scale than radical experiments in innovative environments. As radical experiments in less innovative cities are also more strongly connected to policy, this could indicate that these experiments have been tested on a smaller scale elsewhere, which could foster insight and familiarity to adopt the innovation in policy and implement it on a larger scale. Less innovative environments may thus be an important breeding ground for the growth of successful experimentation that originated elsewhere.

Our findings on *governance and stakeholder networks* confirm the idea that stakeholder diversity characterises an innovative environment (Feldman and Audretsch, 1999; Wolfram, 2016b). Particularly public sector organisations (e.g. schools, hospitals) stand out as initiating or governing actors in radical experiments in RI-cities. In an innovative environment, these organisations are key actors in the initiation and governance of radical experimentation, while in general they tend to engage more in incremental innovation. A potential explanation for the salient presence of public sector institutions in cases of radical experimentation is that innovating with nature appeals to these actors. The NBS literature also suggests that nature-based innovation offer opportunities for social inclusivity (Kabisch et al., 2017; Frantzeskaki, 2019). The prominence of disadvantaged groups as beneficiaries for incremental innovation in innovative environments (compared to less innovative environments) supports the importance of social inclusivity with regard to innovation with NBS.

Furthermore, city networks and regional partnerships are increasingly engaging in urban sustainability and experimentation (Bulkeley and Castán Broto, 2013; Van den Heiligenberg et al., 2017; Smeds and Acuto, 2018). However, not all types of NBS seem to benefit equally from the involvement of city networks: particularly systemic experiments (both radical and incremental) and incremental social experimentation tend to be embedded in a regional or city network (for other innovation types such a relationship is not found). Potentially, due to their complexity and changes in social behaviour linked to such experimentation, systemic experimentation benefits from additional embedding in inter-local actor networks. Further research can add to this finding by creating more detailed insights regarding the types of experimentation for which more trans-urban or regional actor networks are favourable and why this relationship exists in these cases.

Lastly, the governance of urban sustainability transformations is inherently multilevel in nature (Bulkeley and Betsill, 2005). Our research confirms that, in addition to a strong connection to local policy and the local community, also national governments and the EU are often connected to the experiments. Our research also shows that these administrative levels tend to be associated with different experimentation types – incremental experiments with local governments, radical social experiments with national or EU-level authorities. More qualitative research could determine the nested governance mechanisms beyond the urban realm that affect the novelty of local experimentation.

Local learning is considered another critical factor in (urban) experimentation (Kemp et al., 1998; Brown et al., 2003). Despite an intensive data collection process, information on localised learning proxies was largely absent. In case such learning does take place, the absence of publicly accessible information prevents insights to be shared and inhibits learning by others (Antikainen et al., 2017). The research findings indicate that while citizens and community groups are the main beneficiary of the NBS, it is often unknown whether they are involved in monitoring and evaluation. This seems a missed opportunity. Participation and inclusion of the local community in the evaluation can enhance commitment and provide feedback on whether the problem and solution indeed match the local needs (Heiskanen et al., 2015). The overall lack of information supports existing claims that attention to localised learning processes is insufficient (Van Mierlo and Beers, 2018).

City-level *funding*, through subsidies or direct funding, is important for experiments with NBS. Findings indicate that all experiments in innovative environments (RI-cities) have more funding opportunities compared to less innovative environments. The difference is particularly large for incremental experiments. This strengthens the insight that the accumulation of radical innovations can reconfigure the socio-spatial conditions in such a way that a location becomes more favourable to experimentation in general (Torrens et al., 2019).

Lastly, we highlight a number of *methodological reflections* and suggestions for future research. First, this research considers all NBS to be experiments. While indeed many initiatives exhibit characteristics of experimentation such as a practice-based and sustainability challenge-led approach, with many NBS emphasising social inclusivity (Sengers et al., 2019), the database was constructed based on a broad interpretation of innovative NBS. Future work could focus on a stricter operationalisation of experimentation with NBS, and explore whether the correlations identified in this study still hold.

Second, the framework identifies seven socio-spatial characteristics that are important for experimentation in relation to transitions. This research generated empirical insights into four of these conditions. Future research could focus on gaining detailed insight into the remaining three socio-spatial conditions that were excluded due to data availability. Potentially, future research may also identify additional conditions

such as the role of particular demographics and welfare development, or could focus on identifying additional, meaningful variables. For example, there might be localised learning platforms (e.g. social media, participatory planning tools) that enhance social learning. Furthermore, future work could extend the findings from this study with data collected at the city-level, for instance from existing databases such as Eurostat or OECD Stats.

Lastly, there are also research possibilities to expand insights beyond NBS to other empirical domains. Overall, our insights could be complemented with in-depth qualitative research to provide additional context for the correlations. Such mixed-methods approaches can be particularly insightful to identify whether or not different social-spatial characteristics are co-dependent and dynamic. Future research could focus on identifying how variables affect one another in how they are conducive to different types of experimentation (cf. Van den Heiligenberg et al., 2017) and how they can reconfigure their environment in in multilateral ways (Hodson et al., 2017).

6. Conclusion

This paper set out to show how urban socio-spatial conditions shape particular patterns in urban experimentation. The inclusion of data of 520 interventions in 100 European cities provided the possibility to analyse localised conditions for urban experimentation and to substantiate and advance insights from transition studies that were mainly developed based on qualitative in-depth case studies. These qualitative studies, combined with theoretical insights, formed the input of our conceptual framework. The novelty and added value of this study lies in the quantitative approach that was subsequently taken to analyse localised conditions for urban experimentation with NBS.

The database analysis showed that: 1) Local policy is important to all urban experimentation; it tends to facilitate incremental innovations. Additionally, radical experimentation in less innovative environments is generally linked to policy, while radical experimentation in innovative environments has greater opportunity to emerge without links to existing policies. 2) Not all NBS experiment types depend to a similar degree on the involvement of certain stakeholders, city networks, or administrative government levels. A salient finding is the key role for non-traditional actors such as schools and hospitals in radical innovation when the environment is supportive to such a role. 3) Explicit mechanisms for localised learning from experiments, and the involvement of citizens therein, appear insufficiently developed. 4) Innovative city environments tend to offer a wider range of funding structures for urban experimentation and facilitate a different division of governance roles between the stakeholders compared to less innovative city environments.

Overall, the results indicate that radical and incremental urban environments differ significantly in how they affect the emergence of incremental or radical innovation, for instance in terms of funding structures, the importance of policy, and the role of public sector institutions. As such, our findings confirm that socio-spatial conditions are important for the development of experiments, and add a nuanced view to how socio-spatial conditions affect different patterns of urban experimentation.

Declaration of Competing Interest

The authors declare to have no conflict of interest.

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Appendix A

In this representation, the database variables are thematically grouped to make the table more manageable. Where possible, insight is provided regarding the multi-level nature embedded in questions and answers. Most generally, a distinction is made between EU, national, regional and local levels. Depending on the question, more nuance (e.g. building level) is provided in some occasions.

Conditions	Variables
Local and regional visions and plans	Is the intervention mandatory or voluntary? If the intervention is mandatory, what type of mandatory intervention? If the intervention is voluntary, what type of voluntary intervention? If the intervention is mandatory, as a result of what is it such? (e.g. based on policy or to deliver policy objectives and/or ensure regulatory compliance) If the intervention is voluntary, as a result of what is it such? (i.e. not based on policy or delivering policy objectives and/or ensure regulatory compliance) Is the NBS intervention implemented in response to a local regulation/strategy/plan? Is the NBS intervention implemented in response to a national regulations/strategy/plan? Is the NBS intervention implemented in response to an EU Directive/Strategy? Is there a Green Infrastructure/NBS research project mentioned in connection to the project? Is there a specific city-level Green Infrastructure/NBS section/part in a more general plan mentioned in connection to the project? Is there a specific city-level Green Infrastructure/NBS vision/strategy/plan mentioned in connection to the project?

Governance and stakeholder networks	Are citizens involved in the assessment/evaluation of the NBS intervention?
	Who is the initiating organization of the NBS?
	What mode(s) of citizen involvement is/are present in evaluation/assessment of the NBS intervention?
	If the initiative is led by co/hybrid governance or by non-government actors, which non-government actors are involved?
	What participatory methods/forms of community involvement are used?
	How is power distributed within the initiative? (government led, mix between non-government and government actors, non-government led)
	Is there a city network or regional partnerships focused on NBS mentioned in connection to the project?
	Who are the primary beneficiaries identified by the project?
	What is the spatial scale of the project? (national or larger [continental global]; regional, metropolitan and urban level; district/neighbourhood level; street or building level)
	Which type(s) of stakeholders is/are involved?
Localised learning processes	Is there a web-based monitoring tool available?
	Are citizens involved in the analysis of the assessment/evaluation?
	Is there a follow-up to the evaluation/assessment?
	Are there monitoring/evaluation reports?
	Is there a formal monitoring system?
	Are indicators used in reporting?
	Is GIS used to map impacts?
Financial resources and funding structures	Is there a/are there non-financial contribution(s)?
	What is the source/are the sources of funding? (EU, public national, public regional, public local authority, corporate, NGO, Crowd sourcing, other)
	Are subsidies/investment for Green Infrastructure/NBS in the city mentioned in connection to the project?
	What are the total costs?
	What type of financing instruments is/are used for the NBS intervention?
	What type of non-financial contribution(s) is/are used for the NBS intervention?

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