

# 1 **A relational turn in climate change adaptation: evidence from urban** 2 **nature-based solutions**

## 3 **Abstract**

4 The emergence of nature-based solutions (NbS) in science, policy, and practice signals a  
5 paradigmatic shift in urban climate change adaptation, yet empirical investigations into its  
6 impact on adaptation definitions and progress tracking remain scarce. Addressing this gap,  
7 we conducted thematic analysis on semi-structured interviews (n = 15) with practitioners  
8 responsible for implementing and evaluating urban NbS in different countries. We provide a  
9 nuanced understanding of urban adaptation goals within urban NbS according to the insights  
10 from these practitioners, extending beyond hazard mitigation and towards cultivating and  
11 strengthening relationships between humans and nature. Tracking adaptation progress  
12 towards such relational adaptation goals requires acknowledging knowledge pluralism and the  
13 diversity of human-nature relations. We propose an alternative definition of adaptation  
14 supported by our data that aims to foster a more holistic approach to urban climate adaptation  
15 that accounts for the potential benefits of urban NbS across interconnected climate,  
16 biodiversity, and social goals.

## 17 **Keywords**

18 Climate change adaptation, cities, urban nature-based solutions, adaptation success,  
19 imaginaries, relationality

20

## 21 **1. Introduction**

22 The emergence of nature-based solutions (NbS) has contributed to a shift in how climate  
23 change adaptation success in cities is understood and what information and tools are needed

24 to track its progress (Raymond et al., 2017). It is increasingly assumed that urban adaptation  
25 progress is linked to “greening” cities (Angelo, 2019; Depietri and McPhearson, 2017; Dorst  
26 et al., 2019). The rise of the NbS agenda is currently influencing narratives on what successful  
27 adaptation looks like in cities in this way (Melanidis and Hagerman, 2022; Neidig et al., 2022;  
28 Westman and Castán Broto, 2022). However, critics highlight how the narrative shift has not  
29 necessarily clarified how to recognise or evaluate successful adaptation in practice (Tozer et  
30 al., 2020; Westman and Castán Broto, 2022; Woroniecki et al., 2020). This is partly because  
31 adaptation projects often suffer from poorly articulated definitions and expectations about their  
32 success (Olazabal et al., 2019). In addition, they are rarely (if ever) followed up on (Eriksen et  
33 al., 2021; Mills-Novoa, 2023).

34  
35 Conceptually, adaptation is not safe from ambiguities or rigidities either. Critical scholars  
36 highlight the need to challenge received wisdom embodied within dominant framings of  
37 adaptation (Castán Broto et al., 2024; Olazabal et al., 2024). Those include definitions from  
38 the Intergovernmental Panel on Climate Change (IPCC), and are argued to limit the ontology  
39 and epistemology of adaptation to an overly technocratic and universalised process of  
40 “adjustment” to changing biophysical conditions (Dujardin, 2020; Goldman et al., 2018; Mabon  
41 et al., 2022). In its ontology, adaptation is argued to additionally be a function of social  
42 vulnerability and resilience that depends on the strength of human-nature relationships and  
43 (inter)subjective felt experiences of climate impacts (Goldman et al., 2018; Haverkamp, 2021;  
44 Nightingale et al., 2020; Olazabal et al., 2021; West et al., 2020). Taking into account these  
45 components of adaptation requires an epistemology within the adaptation process  
46 (encompassing the design, implementation and implementation of adaptation plans,  
47 strategies, and interventions) that includes pluralistic and transdisciplinary forms of (local)  
48 knowledge (Kythreotis et al., 2024; Rahman et al., 2023) that have been historically

49 marginalised in dominant adaptation discourses over scientific and technical forms of  
50 knowledge (Chmutina et al., 2023; Fischer et al., 2012; Wise et al., 2014).

51

52 Dominant framings of adaptation could be enriched by what are termed “urban climate  
53 imaginaries”, defined as “sets of ideas about what the world is and how it works” (Lawhon et  
54 al., 2023, p. 128) shaped by individual and collective visions of cities (Castán Broto et al.,  
55 2024; Westman and Castán Broto, 2022). When employed as a theoretical frame to interpret  
56 local understandings and evaluations of adaptation success, these imaginaries have the  
57 potential to enrich real-life adaptation processes by generating “common understandings of  
58 important issues, underlying causes, and pathways toward optimistic futures” (Cork et al.,  
59 2023). However, there has been little empirical use of the concept of climate imaginaries  
60 applied to urban NbS in attempting to challenge dominant framings of (urban) adaptation  
61 (Olazabal et al., 2024), with recent research suggesting instead that adaptation planning has  
62 become increasingly homogenised (and globalised) over time (Westman et al., 2023;  
63 Westman and Castán Broto, 2022). Analysing local urban climate imaginaries is therefore  
64 critical and timely (Castán Broto et al., 2024; Nalau and Cobb, 2022; Pelling et al., 2024).  
65 Urban NbS make a particularly interesting application of the concept of urban imaginaries  
66 because of the unique entry point of urban NbS to adaptation that centres the importance of  
67 highly context-dependent human-nature relationships that contradict technocratic narratives  
68 on adaptation (Dorst et al., 2019; Pörtner et al., 2023; Rochell et al., 2024).<sup>1</sup>

69

70 To fill this gap, and thus, understand how imaginaries, goals and their evaluation connect with  
71 framing urban NbS to climate adaptation, we ask two interconnected research questions: (1)

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<sup>1</sup> As we only discuss NbS in the context of urban adaptation benefits, the use of the term NbS throughout this paper should be read to refer only to that context.

72 What does adaptation success mean in the context of urban NbS according to local NbS  
73 practitioners, and (2) whose and what types of knowledge are important for developing their  
74 definitions and assessing progress towards adaptation goals?

75

76 We answer these two questions based on insights gained from practitioners responsible for  
77 adaptation processes for urban NbS on the ground. The urban climate imaginaries emerged  
78 from a thematic analysis of targeted interviews conducted with 14 concluded urban NbS  
79 projects around the world (n = 15 interviews) associated with a diversity of urban geographies,  
80 actors behind NbS processes, and adaptation goals. We performed a qualitative (thematic)  
81 analysis based on information from in-depth interviews since eliciting and analysing urban  
82 climate imaginaries requires deep insight into individual and collective worldviews (Iossifidis  
83 and Garforth, 2022; Verlie, 2019; Westman and Castán Broto, 2020). The goal of this thematic  
84 analysis is to explore a research area that has not been widely studied and does not have  
85 much existing data to rely on. We are not trying to make broad generalizations based on our  
86 interview results, but instead, we aim to help fill this gap by contributing to "a situated, reflexive  
87 and theoretically embedded practice of knowledge generation or construction, rather than  
88 discovery." (Braun and Clarke, 2021) (see Supplementary Information 1 for further  
89 discussion).

90

## 91 **2. Theoretical framework to understand urban climate imaginaries**

92 The concept of urban climate imaginaries provides a useful body of theory to make underlying  
93 ontological and epistemological assumptions explicit within local framings and evaluations of  
94 adaptation success through NbS (Cork et al., 2023; Westman and Castán Broto, 2020). Urban  
95 climate imaginaries come with their own vision of what successful adaptation means (or, "ways  
96 of being" adapted to climate change, i.e., ontology), and how to recognise adaptation success

97 in practice (or, “ways of knowing” adaptation is occurring, i.e., epistemology) (Lawhon et al.,  
98 2023). Imaginaries on ways of being and knowing adaptation converge to form the processes  
99 that operationalise desired states of being and the knowledge used to verify them, referred to  
100 as “ways of doing” (Goldman et al., 2018).

101

102 Imaginaries of ways of being adapted to climate change include any conceptualisation of what  
103 adaptation is, as well as what success in adaptation may look like. They can manifest explicitly,  
104 for example in institutional definitions of adaptation like those of the IPCC (Eriksen et al., 2015;  
105 IPCC, 2023a), or may implicitly underpin how adaptation success is defined and evaluated,  
106 for example through heuristics (Preston et al., 2015; Vogel and Henstra, 2015). Heuristics of  
107 adaptation include ontological assumptions of what adaptation is and what its practice requires  
108 by those designing, implementing, studying, or benefiting from it, for example that it “local”,  
109 “novel”, and “urgent” (Nalau et al., 2021). Other imaginaries are more normative in that they  
110 contain assumptions about what adaptation should be in order to succeed. These include, for  
111 example, that adaptation processes must account for affective, intersubjective felt experiences  
112 on the understanding that climate change impacts are affective in nature (Nightingale et al.,  
113 2022), or that they should be participatory and encourage learning processes (Nalau et al.,  
114 2021). Ontological assumptions about adaptation are also influenced by other concepts, for  
115 example what it means to be vulnerable or resilient to climate change (Folke et al., 2010;  
116 Holling, 1973; IPCC, 2023b).

117

118 Ways of knowing adaptation describe imaginaries of what and whose knowledge counts as  
119 valid, legitimate, and useful to define and evaluate adaptation success. These imaginaries  
120 have implications in how they define what kind of knowledge goes into defining and evaluating  
121 adaptation and whose voice counts within those discussions that perpetuate assumptions

122 about valid, legitimate, and useful knowledge (Chmutina et al., 2023; Eriksen et al., 2015).  
123 Ways of knowing adaptation operate in an individual and collective manner in climate change  
124 governance, and are also therefore a function of “discursive” power in terms of who gets to  
125 decide on definitions and which voices are included within decision-making processes (Arias-  
126 Arévalo et al., 2023; Westman and Castán Broto, 2022; Woroniecki et al., 2020). Discursive  
127 power dynamics do not only operate on the intergovernmental level, but filter down too into  
128 local practices of citizen participation in adaptation processes. Different city-level adaptation  
129 policies, plans, and interventions embody their own epistemology on whose voice will be heard  
130 and how that influences decision-making processes, and those left out (Olazabal et al., 2021).

131

132 Ways of being and knowing urban adaptation converge in the processes that bring them to life  
133 (ways of doing). Beyond taking an NbS approach, ways of doing urban adaptation extend to  
134 broader practices and procedures used within adaptation processes, for example through the  
135 use of different theories and approaches to monitoring, evaluation, and learning (MEL)  
136 (Eriksen et al., 2021). In particular, theory of change approaches are advocated for in  
137 adaptation projects within MERL processes, and in particular for NbS generally whether or not  
138 they aim to have adaptive benefits (IUCN, 2020). Using this approach often relies on back-  
139 casting or visioning processes. In addition, high-level goals of adaptation tend to be defined  
140 in generic terms (e.g., “increase climate resilience”) and traced back to the present moment,  
141 identifying the actions and resources required to bring them about and identifying what  
142 information is needed to assess progress towards meeting adaptation goals (Leiter, 2021;  
143 Ssekamatte, 2018).

144

145 Theorising the local practice of adaptation through the lens of imaginaries of ways of being  
146 and knowing that converge in ways of doing helps identify key weaknesses in current

147 adaptation practice as well as opportunities for disrupting hegemonic imaginaries (Castán  
148 Broto et al., 2024). For example, given that adaptation approaches like NbS are highly context-  
149 dependent to the local scale (Dorst et al., 2019; Pörtner et al., 2023), limited ways of being  
150 (e.g., unclear adaptation goals) and knowing (e.g., lack of inclusive processes for developing  
151 them) may result in similarly stunted or potentially harmful ways of doing adaptation (i.e.,  
152 unintended or maladaptive outcomes) which ultimately stifle adaptation progress (Goldman et  
153 al., 2018; Mabon et al., 2022; Nightingale et al., 2020).

154

### 155 **3. Methods**

#### 156 *3.1 Data collection through interviews*

157 Key Informants were identified from a global sample of urban NbS for adaptation (see  
158 Goodwin et al., (2023)). Purposive sampling of NbS was done in a two-step process. First, an  
159 initial sample of NbS was selected that first evidenced some form of MERL processes (n = 74)  
160 to ensure Informants were able to reflect on their experience with the NbS before, during, and  
161 after implementation. A sub-sample (n = 15) was then identified based on additional purposive  
162 and strategic criteria accounting for (1) the experience of the Informant with the development  
163 of the NbS they were engaged with (verified through asking whether they formed part of the  
164 core design/implementation team of the NbS), (2) diversity of NbS (in the initial sample, mostly  
165 categorised as wetlands, public parks/gardens, green roofs, urban forests, river re-  
166 naturalisation, and urban agriculture as per Goodwin et al. (2023)), and (3) geographical  
167 diversity (relating to the five primary world regions according to the United Nations  
168 categorisation – Africa, Americas, Asia, Europe, and Oceania) (United Nations, 1999). The  
169 availability and ability of potential Informants to take part in online interviews in English within  
170 the interview period (March to May 2023) further acted as a sample limitation criterion (see

171 Table S2 for the effect this had on the sample). Regarding (2) and (3), diversity relates to the  
172 diversity of NbS types and geographies present within the initial sample (n = 74).

173

174 Our aim within this study is to describe the themes we found in our data that we believe tell a  
175 “rich, complex, and multifaceted story about the patternings of [our] phenomena of interest”  
176 (*ways of being, knowing, and doing* urban adaptation through NbS) based on the situated  
177 knowledge(s) of Informants (Sim et al., 2018). There is some debate about what sample size  
178 is enough to achieve a detailed description, but as a general guideline, some authors suggest  
179 that a sample of six to sixteen participants may be enough. However, the size of the sample  
180 alone is not a reliable way to measure whether the themes in the data are fully explored.  
181 Instead, in addition to having a sample size in or above this range, answering several reflective  
182 questions from Braun and Clarke (2021) can give more credibility to thematic analyses. These  
183 questions include the type of thematic analysis being used, the underlying assumptions of the  
184 research (such as its paradigmatic, ontological, and epistemological foundations), how codes  
185 and themes are defined, and how any numeric criteria for evaluating samples are justified.

186

187 With this in mind, our sample of 15 fits within the suggested range of six to sixteen. However,  
188 we also understand that saturation is not about reaching a specific number of interviews but  
189 rather ensuring that the sample size is sufficient to answer the research questions. The  
190 interviews were conducted in a semi-structured and in-depth way, which allowed us to support  
191 the themes with quotes from the participants and thereby provide detailed answers to our  
192 questions. As mentioned in the introduction, our research takes a constructivist approach,  
193 where knowledge and meaning are not discovered but are interpreted. This interpretation  
194 relates to the situated knowledge of Informants and their worlds, rather than on a general level.

195 This interpretive process was made systematic through our coding system, as described



196 below (Section 3.2). While the approach was exploratory, it was not arbitrary, and we aimed  
197 to stay true to the words of our participants (see Supplementary Information 1 for further  
198 discussion).

199

200 Two questions directed the semi-structured interviews. First, Informants were asked about the  
201 process of selecting information to evaluate their urban NbS that they were closely involved  
202 with, which allowed us to undertake detailed discussion not only on MERL processes but also  
203 on the overall NbS aims and how the Informants understood adaptation on the ground.  
204 Second, Informants were then asked to reflect on the overall process of MERL they were  
205 involved in from their own perspective (see Supplementary Information for the list of  
206 Informants and interview guide).

207

### 208 3.2 *Thematic analysis of interview data*

209 Interviews were transcribed verbatim and analysed following the approach to thematic  
210 analysis suggested by Boyatzis (2010) using NVivo software (release 1.2.1). Following this  
211 approach, short individual summaries (3-4 sentences) were produced for each interview  
212 regarding both *ways of being* and *ways of knowing*. A meta-summary was then produced that  
213 drew together the most influential themes across the individual summaries. We deemed  
214 themes to be influential (Braun and Clarke, 2006) if they played an influential role in how the  
215 Informant defined adaptation and what information was needed to evaluate progress towards  
216 adaptation goals. These themes were then transformed into codes, which in turn were applied  
217 to all interviews (Figure 1. below). The answers given by Informants were broken down into  
218 coding units which were each coded to one or more theme. Each coding unit was a separated  
219 passage of text that contained a single topic of conversation. Each interview transcript then  
220 became the unit of analysis.

## Process

### Step 1.

Conducting interviews and producing verbatim interview transcripts.

### Step 2.

Creating individual summaries of interviews that reflect Informant imaginaries of what adaptation is in cities through NbS (*ways of being*) and how it can be known that it is occurring (*ways of knowing*)

### Step 3.

Re-reading all individual summaries and extracting influential themes on *ways of being* and *ways of knowing* across the entire dataset that amount to shared imaginaries of what adaptation is and how it can be recognised as occurring.

### Step 4.

Themes are transformed into codes by naming and describing each individual theme, as well as clarifying its distinguishing features compared to other themes with examples of coded text (inclusion and exclusion criteria).

### Step 5.

Applying the resulting coding scheme on a thematically diverse sample of interviews to ensure their applicability. After making any adjustments, which can include revising or abandoning irrelevant themes, the final coding scheme is applied to the entire set of transcripts.

### Step 6.

Analysis of the results of the coding process across all interviews through scoring and clustering. Clusters of different *ways of being* and *ways of knowing* adaptation are identified as different *ways of doing* adaptation through their co-occurrence across coding units (i.e., passages of text containing a single topic of conversation), revealed by the scoring process.

## Outputs



221

222 **Figure 1.** Summary of the thematic analysis process.

223 A hybrid approach was taken to the thematic analysis that was part inductive and deductive.

224 We deductively used the concept of urban climate imaginaries as a way to locate more

225 abstract theories of ways of being and knowing urban adaptation through NbS within the

226 experiences and perspectives of Informants throughout the thematic analysis process. The

227 individual summaries aimed to inductively encapsulate the perspectives and worldviews (or,

228 imaginaries) of each Informant in terms of how they understood what adaptation is (ways of  
229 being) and how it can be recognised (ways of knowing). Then, the meta-summary reflected  
230 the shared imaginaries on ways of being and ways of knowing that were later translated into  
231 individual codes that particularise the most important features of those imaginaries across the  
232 data. In this way, the concept of imaginaries was used to frame the individual interview  
233 responses to uncover ways of being and ways of doing in the data in the form of themes.

234

235 The first result of the thematic analysis involved the themes themselves which are summarised  
236 descriptively. The second result was then a detailed analysis of the themes through a process  
237 of theme scoring and clustering (Boyatzis, 2010). This involved running matrix queries in  
238 NVivo to determine the magnitude of the co-occurrence of themes (called “scoring”) across all  
239 coded passages of text (coding units). The resulting co-occurrence matrix was analysed to  
240 identify which themes co-occurred often, which was checked against a qualitative analysis of  
241 the coding units, which suggest they may be thematically grouped (called “clustering”). The  
242 different thematic clusters of ways of being and ways of knowing urban adaptation through  
243 NbS were then taken as ways of doing adaptation.

244

245 The differences between distinct ways of doing adaptation that resulted from the clustering  
246 were additionally explored through an ANOVA type nonparametric multivariate inference test  
247 using the nrmv package in R version 4.3.2 (Burchett et al., 2017). This test is a useful non-  
248 parametric statistical method to verify differences between two groups within the data where  
249 there are numerous binary response variables (i.e., co-occurrence of numerous themes within  
250 the same coding unit) with low sample sizes and high-dimensional data as is the case here  
251 (Fouani et al., 2024; Van Valkengoed et al., 2021).

252

253 **4. Results**

254 **4.1 Theme descriptions**

255 All Informants partly conceptualised adaptation as a process of protecting communities  
256 against climate hazards, with some additionally noting that it was also a process of building  
257 relationships among people and/or the natural world (Table 1). We called these themes  
258 “hazard-centric” and “relationship-centric”, respectively. Relatedly, Informants spoke of  
259 adaptation as either something interconnected or separate between human communities and  
260 ecosystems. Distinct from how Informants conceptualised adaptation, the theme on  
261 *adaptation success* then summarised what the personal (though shared across the sample)  
262 accounts of what Informants felt were key attributes of their NbS (i.e., of different processes  
263 of design and implementation) that made it successful in providing adaptive and associated  
264 co-benefits. Though it is not possible to exclude that these attributes could apply more broadly  
265 to the successful implementation of NbS, discussions focused on those factors noted to be  
266 particularly relevant to the intersection of NbS and adaptation.

267 **Table 1.** Definitions of *ways of being* adapted to climate change according to Informants (n = the number  
268 of interviews the theme appeared in). All theme and sub-theme names are later italicised in the main  
269 text to signal that the term used is reference to the coded themes, as these terms may be used  
270 differently in other contexts.

Guiding theory	Themes	Sub-themes	Description	Quote (examples)
<i>Ways of being</i>	Hazard-centric (n = 15)	Reducing climate impacts (n = 15)	Protecting against the impacts of climate hazards by reducing exposure or sensitivity to their effects.	“[Being adapted to climate change] means reduc[ing] the urban heat island effect we are suffering from” (Informant #3)
		Supporting adaptive capacity (n = 5)	Preparing populations to cope in the face of climate hazards.	“We also found that the level of awareness was quite low, so some people didn’t even know what climate change was or meant. So we then decided that in order to raise awareness, it’s not enough to

				just have awareness sessions to tell people what climate change is.” (Informant #4)
Relationship-centric (n = 10)	Among people (n = 7)	Adaptation is achieved by building relationships among people within society. Creating and strengthening relationships of care within communities create opportunities for mutual assistance and support to prepare for, and survive, climate hazards.	“[Adaptation is achieved by] doing the heart to heart, [developing] people connections, ... trust and human bonds” (Informant #2)	
	With nature (n = 6)	Adaptation is achieved by building relationships between people and nature. The lack of mutually beneficial and supportive relationships between humans and nature is highlighted as a key driver of both climate change and ecosystem decline. Creating and reinforcing these relationships is then crucial to addressing their underlying drivers.	“... there is this movement of people working towards bringing and raising consciousness about the importance of having access to the waters again. And getting the words of the rivers out. So, the idea is more like being the speaker for the rivers” (Informant #13)	
	Both humans and nature (n = 4)	Adaptation is achieved by both building relationships among people within society and between people and nature.	“... [people] feel that this is their belonging... this plant belongs to me and this plant needs to grow. And that’s why this land needs to be very secured and safe. And that way, partnership is built and ownership is also built because of that.” (Informant #11)	
Connectivity (n = 12)	Interconnected (n = 10)	Adaptation is something deeply interconnected between humans and the natural world.	“[Defining] nature-based solutions as something that used nature to simultaneously help nature and the social aspects.... splitting it down into sub-compartments helped people see how interconnected everything is” (Informant #7)	
	Separate (n = 2)	Adaptation in human and natural systems are separate.	“It’s a garden... [the NbS] will recover.... they could sort of handle those climate impacts. But then the other thing is what to do when there’s drought, and [the farmers] have to adapt their cultivation technique.” (Informant #12)	
Adaptation success ( <i>thriving</i> ) (n = 14)	Context sensitivity (n = 9)	For an NbS to thrive, it needs to respond to the social and ecological context it exists within.	“...the whole entire context was something that was very favourable to these other groups growing.” (Informant #14)	

		Flexibility (n = 4)	For an NbS to thrive, it must be implemented and evaluated in ways that enable reflection, learning, and path restructuring towards the intended goal.	"[We] need to be agile... and more flexible on the situation on the ground." (Informant #5)
		Sustainability (n = 10)	For an NbS to thrive, it must persist over time, to continue and increase the provision of benefits into the future following implementation, and be "self-renewing" because it is closely integrated into how the city system functions.	"[NbS] interventions aren't supposed to finish with the end of the project, that's when they start. And so in order to see if you were successful at all or not, you have to go there, not at the end of the project when everybody is still around and the beneficiaries still remember you." (Informant #10)
		Synergy (n = 9)	For an NbS to thrive, it must create and strengthen synergetic links between actors involved in implementing the project as well as beneficiaries. Synergy means that different actors are brought together to do something in a better way than if they had done so alone, as all involved bring to bear their unique skills, knowledge, experience, and other strengths to contribute to the project that fills in the gaps left by others.	"We actually worked in partnership with the airforce, the military police, Indigenous peoples, religious communities, African heritage religious communities, catholic communities, evangelical communities, you name it they were there, public agencies, federal police, the army... we had a lot of support. We got together whatever anyone could donate, bring it together. For example, the cavalry, they would bring the manure, so we composted it ...we had to rotate the place, but it worked perfectly, it was a really rewarding experience." (Informant #2)
		Growth (n = 7)	For an NbS to thrive, it must grow, meaning that the physical boundaries of the project expand either on the site or across the city, or that more people joined or benefited from the project over time.	"It's all to do with nature. How do you know that the species is successful? How is life successful? Ultimately when it breeds, when it spreads..." (Informant #2)

271

272 The main themes relating to *ways of knowing* urban adaptation through urban NbS centred

273 around identifying from and for whom knowledge needed to be gathered and whether or not

274 they expressed a belief in a hierarchy among these different forms of knowledge (Table 2).

275 **Table 2.** Types of knowledge used to identify when and how adaptation is taking place (n = the number  
 276 of interviews the theme appeared in). All theme and sub-theme names are later italicised in the main  
 277 text to signal that the term used is reference to the coded themes, as these terms may be used  
 278 differently in other contexts.

Guiding theory	Themes	Sub-themes	Description	Quote (examples)
Ways of knowing	Knowledge from (n = 14)	Local (n = 14)	Knowledge that is accumulated by people local to the project over time, which is sourced from their direct experiences, observations, interactions, and relationships with the site of the NbS.	"Feelings, [...] perspectives, [and] lived experience [...] of the people living there [close to the NbS]" (Informant #9)
		Scientific (n = 12)	Knowledge that is created following a scientific method that was "reproducible" and "unbiased". Key to producing scientific knowledge was following set methodologies and protocols, especially relating to the natural sciences.	"[the information we use is good] because it is performed with a methodology, they are always done [in the same way], we are doing a transect of, whatever, 15 minutes, taking notes of all the birds we have heard." (Informant #15)
		Technical (n = 13)	Knowledge that may have been produced using technology or technical expertise (for example, engineers, architects) in some way. For example, this includes using instruments or software to numerically evaluate the performance of an NbS in terms of its inputs, outputs, costs, or efficiency, which was not necessarily collected in a way that strictly follows a scientific methodology.	"The flooding officer, which is working downstream of [the NbS], says it's [the NbS] made a noticeable difference already to some of their projects." (Informant #7)
		Indigenous * (n = 2)	Knowledge was framed to encompass the knowledge held by Indigenous people based on their worldviews, cosmologies, experiences, and relationships that are intimately tied to the lands and waters of the territory where an NbS is implemented.	Informant #10 noted the specific work and philosophies of Indigenous people informed their belief that "progress is something that needs to be re-evaluated... the new progress needs to look back", in noting the importance of redefining people's relationship with nature in urban environments.
	Knowledge for (n = 15)	Human systems (n = 15)	Knowledge that is needed to understand adaptation dynamics within human systems.	Informant #5 specified that the goal of project evaluation was to know that "the capacity of participating local government authorities surrounding [the city]

				[had] improved their service delivery”.
		Natural systems (n = 11)	Knowledge that is needed to understand adaptation dynamics within natural systems.	Informants noted the importance of creating knowledge to understand ecological benefits within natural systems, such as “diversity of species, structural diversity, and with the idea of it [the NbS] becoming a functional ecosystem.” (Informant #6)
		Both (n = 12)	Knowledge that is needed to understand adaptation dynamics that connect both human and natural systems.	“... we're doing [the NbS] because we want to have access to the rivers. Not only for ourselves, but for everyone and for the river in itself...” (Informant #13)
	Knowledge hierarchy (n = 14)	Hierarchy (n = 8)	There is a hierarchy among the different kinds of knowledge that may be used to understand adaptation.	In noting the differing levels of credibility of different kinds of knowledge for assessing NbS, one Informant noted “...it's not science, it's more technical support... they publish things, but it isn't like in the university”. (Informant #15)
		Pluralism (n = 8)	There is no hierarchy among the different kinds of knowledge that may be used to understand adaptation, rather, all forms of knowledge are equally useful and valid.	“We have to put ourselves in a very humble position. It is not because we have the means or the knowledge that we can tell everyone how it's going to be. This is exactly the kind of thought that brought us to the crisis. This is a hierarchical, dialectic process. ... This is limited. ... This is not systemic, for me, we need a systemic solution.” (Informant #2)

279 \* Note that because of the inductive method used, this is a synthesis of how Indigenous knowledge was understood by  
 280 participants, who did not specifically identify as Indigenous themselves. This cannot and should not be used as a broader  
 281 definition of Indigenous knowledge(s). This applies more broadly to how other forms of knowledge were defined. These definitions  
 282 should be understood as how the different forms of knowledge mentioned by Informants were understood by them.

283

284 4.2 Scoring and clustering of themes



285 Scoring and clustering of themes on *ways of being* and *ways of knowing* are used here to  
286 distinguish *ways of doing* adaptation. These *ways of doing* are therefore the result of  
287 converging *ways of being* and *ways of knowing* urban NbS.

288

289 *Distinguishing between ways of doing urban adaptation through NbS*

290 Upon an initial analysis of the co-occurrence of themes across coding units (i.e., thematic  
291 passages of text), the *hazard-centric* way of understanding adaptation seldom co-occurred  
292 with the *relationship-centric* understanding in interviews, leading us to explore the possibility  
293 that they are thematically distinct (see co-occurrence matrix in Table S5 in Supplementary  
294 Information). The only way the two main ways of understanding adaptation cross over in the  
295 data was through the *supporting adaptive capacity* sub-theme, which provides some common  
296 ground among the two themes.

297

298 The ability for these two themes to distinguish two groups within the data was further supported  
299 by the nonparametric multivariate inference test as it indicated a highly significant difference  
300 between those coding units coded with either theme (ANOVA test statistic = 13, df = 8, df2 =  
301 927,  $p < 0.0001$ )

302

303 This test additionally provides insight into defining features of each approach as it further  
304 provides information about the probability of a coding unit being coded as either approach in  
305 addition to another one of the themes on ways of being and knowing adaptation (Table S7,  
306 summarised in Figure 2). The trends within these results match the absolute differences in co-  
307 occurrence of these two themes and all other themes (Table S6) and so they are discussed  
308 below together. As these are relative differences, it is difficult to identify a specific cut-off value  
309 that would identify which variables are the most statistically significant. However, presenting

310 the results in this way is more easily interpretable because they are on a common scale.

311 Taking a pragmatic approach, we discuss those sub-themes with the largest difference in  
312 probability per theme (Burchett et al., 2017).

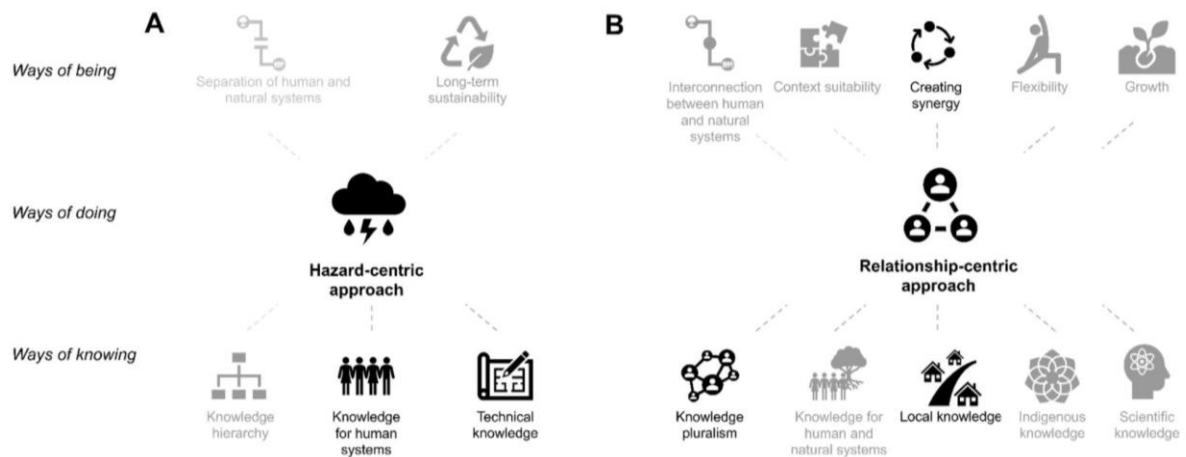
313

314 In terms of ways of being, neither approach could be said to strongly relate to a *separation of*  
315 *human and natural systems* in terms of how adaptation was defined, though only co-occurred  
316 with the *hazard-centric approach* (Table S7). Both approaches were associated with an  
317 *interconnected definition of adaptation between human and natural systems*, though this was  
318 slightly more so within the *relationship-centric approach*. The largest difference in co-  
319 occurrence between understandings of adaptation success related to *creating synergy*, which  
320 more strongly related to the relationship-centric approach, along with weaker connections to  
321 *context suitability, flexibility and growth*. Discussions of the importance of *sustainability* as a  
322 measure of success co-occurred more often with the hazard-centric approach.

323

324 Regarding ways of knowing, the largest differences in co-occurrence could be seen in stronger  
325 connections between the importance of *creating knowledge for human systems in isolation*  
326 with the *hazard-centric approach*, with more slight but notably higher association between the  
327 *relationship-centric approach* and *creating knowledge for human and natural systems in an*  
328 *interconnected way*. The *relationship-centric approach* was more strongly differentiated from  
329 the *hazard-centric approach* in its association with the importance of *local knowledge*, while  
330 the *hazard-centric approach* more often co-occurs with *technical knowledge*. The difference  
331 between associations between both approaches and the importance of *scientific and*  
332 *Indigenous knowledge* only showed slight differences. Neither approach co-occurred strongly  
333 with the belief in *knowledge hierarchy*, however the *relationship-centric approach* was more

334 explicitly related to the importance of *knowledge pluralism* compared with the *hazard-centric*  
335 *approach*.



336

337 **Figure 2.** Summary of the scoring and clustering of themes into two groups: (A) the *hazard-centric*  
338 *approach*, and (B) the *relationship-centric* approach. Themes were allocated to either group based on  
339 whether they more often co-occurred with one theme over another, where those with the higher  
340 statistically significant differences appear more prominently.

341 To contextualise these results further, the hazard-centric approach was more often seen in  
342 interviews about NbS located in Africa relating to urban forests and green roofs. By  
343 Comparison, the relationship-centric approach was much more present in interviews with NbS  
344 located in the Americas (in our case, mostly in Latin America and the Caribbean), also relating  
345 mostly to urban forests (see Tables S8 and S9 for full regional and type distributions).

346

347 Several interconnections between other themes also emerge from the co-occurrence matrix.  
348 On the general connection between *adaptation success* and *whose knowledge* was relevant  
349 to recognise it, *local* knowledge was the dominant form of knowledge that was deemed as  
350 being more useful to identify if the NbS was *thriving* overall. Recognising whether NbS were  
351 *thriving* by using local knowledge mostly related to recognising *synergy* among different  
352 collaborating actors in projects as well as *sensitivity to the local context*, compared to other

353 themes on *thriving*. The role of *technical* knowledge was then emphasised most often in terms  
354 of helping to understand the long-term *sustainability* of projects. *Scientific* knowledge was  
355 framed as playing only a modest role, mostly towards recognising *synergy* and *sustainability*.

356

357 The belief in a *hierarchy* of forms of knowledge co-occurred more often with some forms of  
358 knowledge than others. Those Informants that highlighted the importance of *scientific* forms  
359 of knowledge also expressed a belief in a *hierarchy* among forms of knowledge, where  
360 *scientific* knowledge was held to be superior to others. By contrast, those highlighting the role  
361 of *local* knowledge more often spoke of the *pluralistic* nature of knowledge for adaptation  
362 where such hierarchies did not exist. That being said, *local* knowledge also often co-occurred  
363 with a discussion of the importance of *scientific* knowledge, though in a way that framed the  
364 two forms of knowledge as complementary rather than in competition.

365

366 The framing of adaptation as being *interconnected* among human and natural systems  
367 connected with the need for information about both *human* and *natural* systems. *Local*  
368 knowledge was framed as being key in understanding both *human* benefits in isolation as well  
369 as the interconnection of *human* and *natural* systems, whereas *scientific* knowledge was more  
370 strongly associated with understanding either *human* or *natural* systems separately.

371

372 Summarising these results, several components of *ways of being* and *ways of knowing* urban  
373 adaptation through NbS were identified through thematic analysis. Themes on *ways of being*  
374 included different definitions on what adaptation is (*hazard-centric* or *relationship-centric*), how  
375 *successful adaptation* is defined, as well as how the *connectivity* between human and natural  
376 systems was framed in the context of adaptation goals. Themes on *ways of knowing* then  
377 differentiated between *for whom*, and *from whom*, knowledge was needed to define and

378 evaluate adaptation goals, as well as whether a *hierarchy* existed among these forms of  
379 knowledge. From the co-occurrence of these different themes on *ways of being* and *knowing*,  
380 two distinct *ways of doing* urban adaptation through urban NbS were identified that were also  
381 statistically significant, which were called the *hazard-centric* and *relationship-centric*  
382 approaches. Though some differences between these approaches were slight in terms of their  
383 relationship with other themes, the two groups differed mostly in terms of their understanding  
384 of adaptation success (*creating synergy*), from and for whom knowledge should be generated  
385 (*local vs technical* knowledge, and *human vs both human and natural* systems), and  
386 knowledge *pluralism*.

387

## 388 **5. Discussion**

389 Understanding what it means to be adapted to climate change (*ways of being*) and how we  
390 know adaptation is happening (*ways of knowing*) helps to distinguish two very different  
391 approaches to how adaptation is done (*ways of doing*). In the sections that follow, we chart  
392 how these different approaches to adaptation that clearly manifested in the interview data  
393 bring important insights to communities of research and practice on urban adaptation that call  
394 for a change in the way adaptation is understood and done. This change is located in the  
395 literature that calls for a “relational turn” in sustainability science that can be connected directly  
396 to urban adaptation through our results (West et al., 2020).

397

### 398 *5.1 A call for a relational turn in how adaptation is understood and done*

399 Our results suggest that urban adaptation to climate change is not only about protecting urban  
400 dwellers from the risks posed by a changing climate but further deepening relationships among  
401 one another and with nature. Defining adaptation in this way, as well as assessing progress  
402 towards adaptation goals, requires knowledge plurality that recognises that human and natural

403 systems are interconnected and inseparable. However, current high-level definitions of  
404 adaptation such as that of the IPCC do not refer to the role that these relationships and  
405 knowledge pluralism play in how adaptation is successfully done. Instead, these definitions  
406 explicitly separate adaptation in “human” and “natural” systems. Hence, here we attempt to  
407 re-imagine existing definitions of adaptation with a relational entry point that foregrounds  
408 interconnectivity as follows: *“Adaptation is the process of cultivating and strengthening*  
409 *relationships both among humans and between humans and nature in a way that respects*  
410 *their innate interconnectivity. These relationships help identify, motivate and guide necessary*  
411 *adjustments to actual or expected climate and its effects in order to moderate harm and*  
412 *maximise the potential for those relationships to thrive.”*

413

414 Rather than attempting to conclusively redefine core concepts of adaptation, we instead  
415 provide a re-imagination of the IPCC definition that maintains its core concepts and  
416 complements it with elements of relationality and interconnectivity that are supported by our  
417 data (Iossifidis and Garforth, 2022; Verlie, 2019). This re-imagined definition identifies the  
418 unique contributions of a relational entry point to adaptation compared to the *hazard-centric*  
419 approach. For example, our thematic analysis has generated several unique components of  
420 *thriving* that were more strongly associated with the *relationship-centric* approach that open  
421 new avenues of exploration to better identify how they can complement future research and  
422 practice. Complementing existing definitions of adaptation in this way could form part of a  
423 larger “relational turn” in adaptation research and practice that has already begun in other  
424 areas of sustainability science (West et al., 2020).

425

426 This relational turn draws attention to four key contributions of relationality to sustainability  
427 science: continuously unfolding processes, embodied experiences, reconstructing language

428 and concepts, and ethics and practices of care (West et al., 2020). Some of these points have  
429 already made their way into how adaptation is currently defined (Table 3). For example, West  
430 et al. (2020) discuss how relationality calls particular attention to the importance of  
431 understanding sustainability challenges and their solutions as processes that are continually  
432 unfolding, rather than being static (Hertz et al., 2020).

433 **Table 3.** Comparison of IPCC and relational approach to defining adaptation in terms of four key  
434 elements of the “relational turn” according to West et al. (2020).

	IPCC definition	Relational approach
<i>Continuously unfolding processes</i>	Adaptation is defined as a process.	Maintains process-oriented language.
<i>Embodied experiences</i>	Embodied experiences are not located in the context of adaptation.	Embodied experiences of thriving within relationships with others as well as nature are located in the context of adaptation.
<i>Reconstructing language and concepts</i>	The end goal of adaptation is limited to adjusting to harm and exploiting opportunities.	The language is expanded beyond adjustment and situates humanity as interconnected to the world around it. The language of adjustment is maintained but re-contextualised in terms of how relationality may help “identify, motivate, and guide” action taken to adjust to a changing climate.
<i>Ethics and practices of care</i>	Not mentioned.	Relational framing invokes ethics and practices of care as adaptation is something that is done in the context of cultivating and strengthening relationships for shared thriving.

435  
436 Adopting a relational approach to adaptation clarifies the manner in which language and  
437 concepts actively shape reality, rather than merely reflecting it (Cook and Wagenaar, 2012).  
438 Viewed through this lens, it is possible to better identify how definitions of adaptation serve to  
439 limit its scope to “*adjusting... to moderate* harm or *exploit* beneficial opportunities”, where  
440 dimensions of this process among human and natural systems are isolated by providing  
441 separate definitions of adaptation in human and natural systems. A re-imagined perspective  
442 would expand adaptation to include notions of thriving under different climatic conditions in a

443 way that respects the interconnection both among humans as well as the world around them,  
444 beyond simply adjusting to change (Abson et al., 2017; Artmann, 2023).

445

446 Re-framing adaptation with the language of relationality and interconnectivity centres  
447 adaptation within ethics and practices of care, capturing the embodied experiences of thriving  
448 within those relationships. It does so by calling attention to what is argued to be the root cause  
449 of, and solution, to issues posed by climate change, including adaptation: mutually destructive  
450 relationships among humans and between humans and the “more than human” world  
451 (Haverkamp, 2021). Others have highlighted how defining adaptation relationally has the  
452 potential to embed ethics and practices of care into a definition of adaptation as it makes  
453 explicit the role and power of emotion, empathy and connectedness as levers for positive  
454 change already highlighted across numerous sustainability fields (Jax et al., 2018; Nightingale,  
455 2016), including in the realm of adaptation (Nightingale et al., 2022; Riechers et al., 2022;  
456 Riechers, 2021). Relational approaches can also provide an opportunity to address other  
457 challenges at the core of defining and practising adaptation, for example, unequal distribution  
458 of power and agency among actors (Garcia and Tschakert, 2022), as well as the need for  
459 intersectionality in understanding climate vulnerability (i.e., overlapping layers of disadvantage  
460 or privilege along lines of racial identity, social or economic class, gender identity, ability,  
461 sexual orientation, among others) (Amorim-Maia et al., 2022).

462

463 Our re-imagination of adaptation pushes beyond existing literature focusing on the heuristics  
464 of adaptation discussed in earlier sections by providing alternative starting points to  
465 understanding the concept (Nalau et al., 2021; Preston et al., 2015; Vogel and Henstra, 2015).

466 Our approach builds on an emerging body of literature that incorporates these concepts into  
467 transformative governance and learning for urban climate change adaptation through NbS



468 (Wickenberg et al., 2022) as well as adaptation governance (Burger et al., 2023; Marion  
469 Suiseeya et al., 2021; Sebastian and Jacobs, 2021) and planning (Dujardin, 2020). Integrating  
470 relationality into adaptation is rooted in Indigenous and feminist fields of research (Haverkamp,  
471 2021; Johnson et al., 2022), as well as empirical work conducted across numerous regions in  
472 the Global South (Alare et al., 2022; Chakraborty et al., 2023; Kuruppu, 2009; Mubai et al.,  
473 2023).

474

## 475 5.2 *Implications of the relational turn in adaptation*

476 Currently hazard-centric MERL practices prioritise evaluation of results of implementation  
477 (outputs) rather than longer-term outcomes and impacts (Chmutina et al., 2023; Goonesekera  
478 and Olazabal, 2022; Oakes et al., 2022). Our findings echo previous calls to re-focus MERL  
479 processes instead on evaluating whether or not local needs are being met rather than just  
480 outputs alone (Caillon et al., 2017; Dilling et al., 2019). Further study is then needed on how  
481 the kind of synergetic relationships highlighted by our Informants as critical to adaptation  
482 success can emerge and how they influence processes and outcomes within adaptation  
483 interventions. On a practical level, awareness of the influence of relationships and networks  
484 needs closer attention, particularly for local practitioners responsible for adaptation processes  
485 to understand their role in creating networks and communities of trust through their adaptation  
486 projects. Similar calls have been made in recent literature, focusing for example on identifying  
487 and supporting individuals within projects that operate as bridges between different actors and  
488 forms of knowledge within adaptation projects through connective leadership (Oakes et al.,  
489 2022; Peterson St-Laurent et al., 2022). Further study and practice is needed to uncover what  
490 kind of relationships we need to make adaptation work and how they can be identified and  
491 fostered, rather than identifying specific indicators and metrics alone.

492

493 Our results also imply that knowledge plurality under a relational approach to adaptation  
494 requires that scientific knowledge takes its place among other forms of knowledge that are  
495 equally valid, legitimate, and useful. Scientists need to be humble in recognising that their way  
496 of knowing is one of many (West et al., 2020; West, 2021). This change in positioning will  
497 require some scientists to challenge their belief in a hierarchy of knowledge (Bamzai-Dodson  
498 et al., 2023; Eriksen et al., 2015). Doing relational adaptation requires relational science, which  
499 must acknowledge that science too “results from relationships among human societies,  
500 scientists and the subject under study” (Eyster, 2023).

501

502 Addressing the challenges of a relational turn in adaptation requires overcoming paradoxes  
503 that future research and practice must tackle. Discussing relationality within political  
504 processes, such as by eliciting urban climate imaginaries for adaptation planning, demands  
505 high engagement from diverse actors to ensure credibility and equity. However, this  
506 engagement also complicates the creation of shared visions as they become more diffuse and  
507 may also reveal disagreements about desirable futures (West et al., 2020). A key challenge is  
508 to provide practical guidance on how these imaginaries can be incorporated into adaptation  
509 planning across governance levels in ways that are inclusive yet decisive. Progress is already  
510 being made, such as using normative future visioning tools to enhance local monitoring,  
511 evaluation, and learning processes (Pelling et al., 2024).

512

### 513 5.3 *Limitations of our findings*

514 Our results should be interpreted in light of several methodological limitations, specifically the  
515 sample of interviews. Although sufficient to form the basis of a thematic analysis, the sample  
516 of 15 interviews may limit the generalisability of our results. However, we have noted how our

517 aim is not to generalise, but to particularise the diversity of adaptation imaginaries within a  
518 heterogeneous sample of NbS practitioners.

519

520 Several other aspects of the data may inform how they should be interpreted, for example,  
521 that they come from different types of NbS, respond to different hazards, and come from  
522 different organisational types. For example, a majority of the sample related to urban greening  
523 in some way (relevant to terrestrial ecosystems, for example urban forests, green roofs, or  
524 urban agriculture) which may mean that our results relate more heavily to adaptation projects  
525 relating to these ecosystems or that require different kinds of technical expertise. Further, a  
526 majority of Informants were from non-governmental actors implementing NbS (i.e., either  
527 international organisations or grassroots movements) which may further influence the kinds of  
528 themes that emerged based on their specific organisational goals or priorities.

529

530 The relatively small sample size may also mean that the thematic analysis was sensitive to  
531 different heterogenous attributes of projects, for example that projects were developed on the  
532 basis of different criteria for project funding, national regulations and priorities,  
533 available/relevant knowledge and solutions, as well as local culture (including both the general  
534 culture of different societies, as well as planning and governance cultures). Addressing this  
535 sensitivity through the mixed method approach taken was therefore crucial to be able to  
536 quantify and identify which sub-themes were more influential in differentiating the two identified  
537 approaches to adaptation, given that the numerical difference between the distribution of some  
538 sub-themes between the approaches was slight.

539

540 **6. Conclusions**

541 We have approached the question of whether and how real-world experiences with applying  
542 NbS to urban adaptation challenges could enrich how adaptation goals are formulated, and  
543 what information is required to assess progress towards these goals. Our answers to these  
544 questions were drawn from the on-the-ground perspectives of those involved in implementing  
545 urban NbS. The themes emerging from the analysis of these perspectives suggest that in  
546 addition to the current hazard-centric framing of adaptation and evaluation metrics,  
547 relationality and interconnectivity were also important concepts. Drawing on literature that has  
548 tracked a relational turn in sustainability sciences more generally helped us to analyse how  
549 we could re-imagine a definition of adaptation that accounted for relationality and  
550 interconnectivity. We have argued that this definition, while not replacing existing ones, can  
551 help access deeper leverage points for urban transformation through adaptation strategies  
552 that address not only climatic hazards, but also the unbalanced relations of power, agency,  
553 and intersectional vulnerability that create and reinforce them.

554

555 Moving forward, our main recommendation is to clarify and expand currently limited definitions  
556 of adaptation at the institutional level. This change in entry point to adaptation may help  
557 expose possible root causes of adaptation challenges, and illuminate ways of addressing them  
558 that align with local needs and priorities as well as interconnected biodiversity conservation  
559 and social justice challenges. While we have forwarded a single definition of adaptation here,  
560 decision-makers on NbS to adaptation ought to invest more time, energy, and resources into  
561 similarly defining what adaptation means to those they intend to support in a non-hierarchical  
562 and pluralistic manner. In our case, we have highlighted the role of relationships and  
563 interconnectivity in this discussion, however, we acknowledge that additional or alternative  
564 imaginings of adaptation are equally possible and indeed required to reflect local contexts.

565

566 Our findings open several avenues for further research in the field of urban adaptation more  
567 broadly. For example, critics of the “relational turn” in sustainability science question the  
568 applicability of the concept to real-world adaptation practices (Raymond, 2021). While we have  
569 highlighted the specific ways in which doing so could contribute to adaptation in the practical  
570 sense, future research is nonetheless required to understand how relational understandings  
571 of adaptation contribute to real-life MERL practices for urban NbS. Applied to adaptation more  
572 broadly, this line of research would also help clarify whether relationality and interconnectivity  
573 is a unique feature of adaptation through NbS, or if it applies to adaptation more broadly.  
574 Clarifying the significance of the relational turn in this way may enable future research to  
575 explore in what other ways local imaginaries can enrich definitions of adaptation and  
576 information used to assess progress towards adaptation goals. Our results make a first step  
577 in this direction by identifying the potential for local knowledge to challenge and reshape  
578 accepted wisdom on what adaptation is and how we can know it is happening.

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