




Integrative literature review on co-concepts in connection with nature-based solutions

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ARTICLE INFO

Keywords:

Collaboration
Process, Nature-based solutions, Integrative literature review
Qualitative analysis

ABSTRACT

Collaborative approaches are increasingly analyzed in literature on environmental planning, governance, and management. However, three recent systematic literature reviews found that several co-concepts such as co-creation, co-design and co-production are often used interchangeably. We aim to add conceptual clarity on the co-concepts by using Nature-based solutions (NBS) as a case study. We conduct an integrative qualitative literature review on the concepts of co-creation, co-design, co-production and co-governance as used in connection to NBS. We screened 93 papers to identify key principles associated with the co-concepts linking especially to who are included in collaboration (stakeholders from policy, business, society and science), and why these collaborative approaches are needed (e.g. to develop contextual NBS approaches). We identified also key differences relating especially on the targeted output of the collaboration, and on how the collaboration is envisaged to happen across the co-concepts. Based on the results, we propose definitions for these concepts where co-creation refers to overall NBS “cycle”, co-design links to tools, co-production targets knowledge, and co-governance wider socio-environmental system. Furthermore, we also discuss emerging theme to consider multispecies actors as active collaborators in shaping NBS grounded in coevolutionary view. Our review helps to bring conceptual clarity on the use of co-concepts in NBS literature, and also to enhance their collaborative development, implementation, evaluation and finally impact. This is especially important in the era when co-concepts are widely used, but without clear definitions on their meaning.

1. Introduction

Current sustainability challenges – climate change, biodiversity loss, and inequal development – require urgent solutions. One promising approach to combat sustainability challenges (e.g. linked to

environmental change and wellbeing of all humans) are nature-based solutions (NBS) (Raymond et al., 2017; Seddon et al., 2020). NBS is an umbrella concept covering ecological restoration, ecosystem-related approaches, green infrastructure approaches, ecosystem-based management, and nature conservation (Cohen-Shacham et al., 2016).

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According to the European Commission nature-based solutions are “Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience” (European Commission. Directorate General for Research and Innovation, 2021). NBS are commonly understood as solutions to protect, sustainably manage, and restore natural or modified ecosystems (IUCN, 2020), or to create new ecosystems to enhance delivery of ecosystem services that benefit people (Almenar et al., 2021; Pereira et al., 2023). Furthermore, NBS may adopt solutions from nature to maximize benefits provided by nature (European Commission, 2015; Sowińska-Świerkosz and García, 2022).

NBS can be implemented as expert-based solutions without stakeholder engagement, but often they include collaboration with local actors to develop site specific solutions and are based on broad and deep stakeholder participation (Cohen-Shacham et al., 2016; Cooper et al., 2023; Wickenberg, 2023), which become pivotal for implementing contextual, just, and practical solutions for sustainability challenges (Puskás et al., 2021). In the present paper, we focus only on NBS, which are based on collaborative approaches to NBS planning and implementation (e.g. Lupp et al., 2021b; European Commission, 2023).

NBS seek to offer co-benefits for diverse human and natural non-human actors, but still they are not silver bullets for solutions to sustainability challenges. Hence, it has been recognized, that while co-benefits often occur, there are simultaneously costs and trade-offs associated to NBS (e.g. Raymond et al., 2017; Giordano et al., 2020; Ommer et al., 2022; Pereira et al., 2023). To understand problematic socio-environmental situations, design NBS appropriate to the local context and beneficiaries, manage trade-offs, understand the meaning and the significance of costs and negative impacts, and to foster ownership and trust, it is widely recognized that collaborative approaches to NBS are needed (e.g. Naumann et al., 2023; Wickenberg, 2023). This requires transdisciplinary approach that honors the nuances within diverse local communities and also in science and policy (Nesshöver et al., 2017). Collaborative approaches can increase diversity of available knowledge including local contextual knowledge, and increase legitimacy and wider acceptance of the NBS (e.g. Soini et al., 2023). Benefits of collaborative approaches for NBS can be considered as similar than those related to stakeholder participation in environmental management. Reed’s (2008) comprehensive review identifies set of normative (e.g. democracy, empowerment, trust building, social learning, better decisions), and pragmatic reasons (quality and durability of decisions, adapting interventions to local context, meeting local needs, more complete information for decisions, helping to find new ways to work together, enhancing ownership over decisions, and reducing implementation costs) for enhanced stakeholder participation in environmental management. In short, collaborative approaches imply planning and implementing NBS with (local) stakeholders.

Given the promises of collaborative approaches, it is not a surprise that many ‘co-concepts’ addressing collaborative processes of NBS development are used frequently. Among the concepts used in connection to NBS are co-creation (e.g. Soini et al., 2023), co-design (e.g. Slinger et al., 2023), co-production (Hölscher et al., 2024), collaborative or co-governance (Battisti et al., 2024), and coevolution of NBS with the human and non-human spheres (Herrmann-Pillath et al., 2022). Co-creation, co-design and co-production have been addressed also by recent previous reviews on co-concepts (Hakkarainen et al., 2022; Nguyen et al., 2024; Lee et al., 2024) finding that co-creation refers to planning / implementation cycle including co-design and co-production as part of the cycle. Importance of co-governance links especially to implementation and maintenance of NBS (e.g. Naumann et al., 2023). Coevolution can place the NBS to wider context of change intermingling NBS, multispecies behavior, socio-environmental systems, and governance. Given the plethora of co-concepts used in general and also in connection with NBS, it is of crucial importance to make sense of these concepts and distinguish them from each other (Hakkarainen et al.,

2022). This can help to avoid implementation failures of collaborative approaches, facilitate their applications in connection to NBS, and guide NBS implementation in practice. Furthermore, use of consistent operational definitions for co-concepts would support more meaningful stakeholder engagement (Nguyen et al., 2024).

Our paper adds novelty to the previous reviews (Hakkarainen et al., 2022; Nguyen et al., 2024; Lee et al., 2024) by following ways. 1) none of the previous reviews focus on NBS literature; 2) none of the previous reviews analyze the definitions of co-concepts found from the literature, 3) none of the reviews employ qualitative integrative review method, and 4) none of the reviews address co-governance or coevolution (see Section 3.1 for detailed positioning of our paper vis a vis these three prior reviews close to our topic). Rather than duplicating or critiquing the previous reviews, we consider that our paper complements the existing works, which alone or together provide insightful reading for those interested about co-concepts in socio-environmental field, and beyond (see reviews on co-concepts in health studies: Grindell et al., 2022; Messiha et al., 2023).

Our objective is to understand how different forms of collaboration are linked to the ultimate aim of the NBS, to produce benefits for both human and non-humans. This is explored through analyzing usage of various co-concepts (co-creation; co-design; co-production; co-governance) in NBS literature by qualitative integrative review. Our research questions are: 1) What are the differences and similarities between the co-concepts used in NBS literature; and 2) what kind of definitions and interlinkages can be proposed for co-concepts in relation to NBS? Our specific analytical strategy is to use six detailed questions guiding the reading of the reviewed papers: 1) how the concepts have been defined in NBS literature, 2) whether these concepts are used simultaneously, 3) who are taking part in collaboration; 4) why the collaboration is needed, 5) what is the targeted output of collaboration, and 6) how the collaboration takes place. We use qualitative analysis to propose definitions for each co-concept in connection to NBS, and outline the relationships of the concepts.

Based on the findings, we propose and discuss an emerging theme of coevolution and multispecies collaboration (Section 5.3). Multispecies actors have been seen to play crucial roles in NBS planning and functioning (Maller, 2021; Pineda-Pinto et al., 2022) and a coevolutionary view has been used to explain how NBS can actually lead to change in environment and institutions (see Herrmann-Pillath et al., 2022). Yet our analysis revealed that papers using co-concepts only human stakeholders were considered as collaborators, and that coevolution concept was not used in NBS literature beyond minor exceptions. Hence we had to exclude coevolution from our analysis of NBS literature.

2. Background for Co-fixation in nature-based solutions

2.1. Roots of co-concepts

The so called “participatory turn” grounding the co-fixation can be traced back the 1960’s where it emerged as a radical political project to transform unequal relationships between state and the society in ways that could boost emancipation and empowerment of citizens (Bherer et al., 2016) (Fig. 1). The participatory turn has been also institutionalized in policy making, for example in European Union in the 1990’s (Saurugger, 2010). The participatory turn landed in research for example by Participatory Action Research emerging in the 1980’s (Whyte, 1991), and in design literature in the 1970’s. Co-prefix denotes to collaborative approaches, where diverse actors come together to deliberate and solve problems. Collaborative approaches help to build trust between diverse groups of actors, for example from society, business, policy and science (Cvitanovic et al., 2021). Collaborative approaches are considered to be able to enhance justice and democracy of the processes with a view to complexity, which cannot be addressed best by decision makers, planners or scientists alone (De Marchi and Ravetz, 2001).

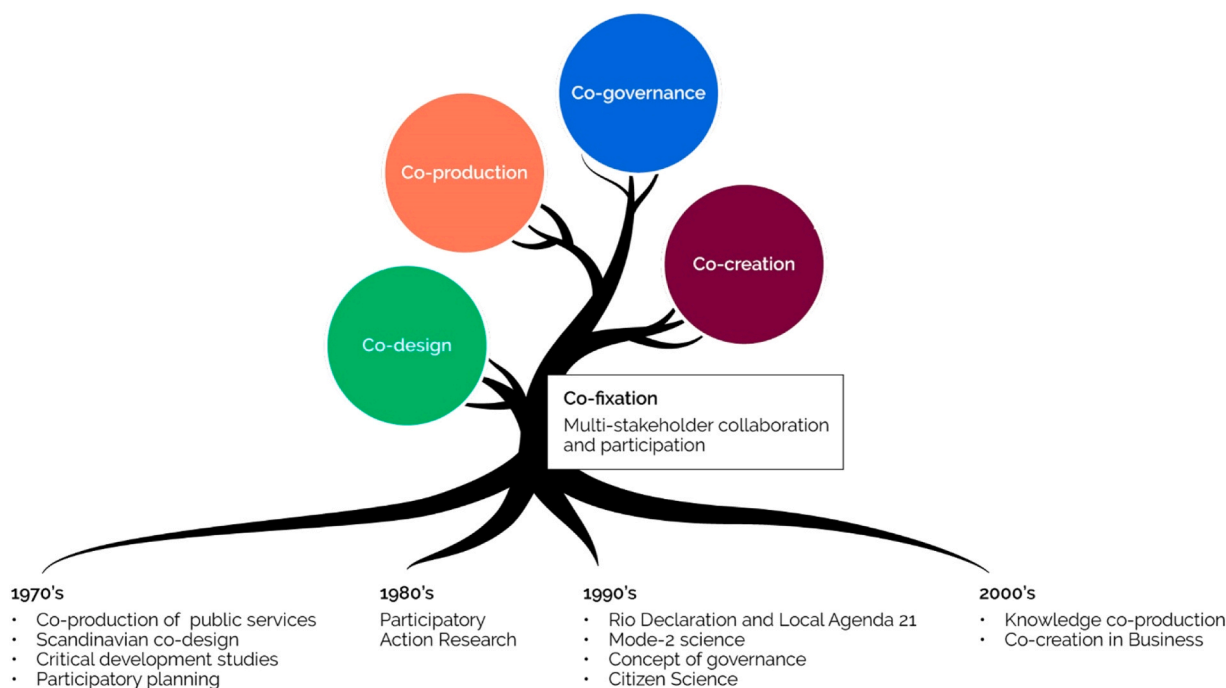


Fig. 1. Non-exhaustive origins of “Co-fixation” by the turn of the millennia. In the 1970’s, public planning studies (Arnstein, 1969); critical development studies (Huesca, 2008), Co-design in Scandinavian work places (Gregory, 2003), and co-production of public services (Sorrentino et al., 2018), in the 1980’s Participatory Action Research (Whyte, 1991), in the 1990’s Rio Declaration and Local Agenda 21 (De Marchi and Ravetz, 2001), and Mode-2 science (Gibbons et al., 1994), Citizen Science (Bonney, 1996), and conceptual move from government to governance (Fukuyama, 2016), and in the 2000’s co-creation in business and marketing studies (Prahalad and Ramaswamy, 2000), and knowledge co-production in sustainability science (Wyborn et al., 2019) form origins for the Co-prefix.

2.2. Co-fixation and nature-based solutions

The Co-fixation has also strongly entered to the literature on NBS. Wamsler et al. (2020) find a widespread consensus on that NBS planning supports and requires transdisciplinary and collaborative approaches engaging citizens to find innovative solutions. Collaborative approaches can help in tailoring and need to be tailored to place-specific contexts to be relevant, effective and successful (van der Jagt et al., 2023). Such tailoring can be considered to take place through cyclical processes of NBS development. NBS is often viewed as being developed through different stages including: 1) identify problem or opportunity; 2) select NBS and related actions; 3) design NBS implementation processes; 4) implement NBS; 5) engage stakeholders and communicate co-benefits; 6) transfer and upscale NBS; and 7) monitor and evaluate co-benefits across all stages (Raymond et al., 2017). Such a cycle can include stakeholder collaboration at each stage. Planners, therefore, need to consider just transitions through NBS as an iterative process of relationship building (Raymond et al., 2023). Collaborative approaches have been viewed also as crucial for successful NBS implementation, enhancing acceptance and ownership (e.g. Soini et al., 2023), and to deal with conflicts and issues raising during NBS planning and implementation (Lupp et al., 2021a). Furthermore, collaborative approaches can help in realization of the social and economic benefits that are not typically obtained by NBS based on a non-participatory process (Jakstis et al., 2023).

This implies a hype around Co-prefix, which can perhaps be explained by scientists using those concepts to impress policy makers, other scientists, and, of course, research funders. The wide use of Co-prefix in connection to NBS highlights that, despite the anticipated ambiguity of the definitions of the co-concepts, collaboration is key feature for NBS development. However, collaboration does not always go without challenges. In general, challenges associated with stakeholder participation in environmental planning management include inability to cope with existing power relations, that participation may

reinforce existing privileges, participation fatigue, poorly ran participatory processes, participatory workshops may turn to “talkshops” with no observable impact, and insufficient expertise of participants for meaningful contribution (Reed, 2008). Furthermore, the depth of participation has been addressed by referring to Arnstein (1969) ladder of citizen participation, distinguishing three general forms of participation: nonparticipation, tokenistic participation, and citizen control. A review by Puskás et al. (2021) finds that ‘consultation’ and ‘partnership’ in Arnstein ladder are the dominant levels of participation in NBS, while adoption of deeper levels of participation, such as delegated power and citizen control, would be needed. Another review by Kiss et al. (2022) finds also that tokenistic forms dominate citizen participation across a variety of NBS contexts, and deeper forms of engagement could strengthen and diversify both expected and unexpected social outcomes, including social learning, enhanced sense of belonging, environmental stewardship, and inclusiveness and equity. To move forward from tokenistic participation, it has been proposed that NBS need to be revised to support social change by moving away from hegemonic framings that dichotomize nature towards more inclusive, collaborative, and interconnected framework (Cooper et al., 2023). In fact, set of best practices with examples, and guidelines on co-creating and collaboration for NBS have been published recently targeting Europe (EC 2023; Naumann et al., 2023; Dushkova and Kuhlicke, 2024), and with global scope (Nature-based solutions initiative, 2025).

3. Material and methods

In our review, we focus on four co-concepts: co-creation, co-design, co-production, and co-governance. Coevolution was included in the preliminary literature screening, but not in the full review due to only 5 SCOPUS hits. There are also various other co-concepts that address collaborative processes in and around NBS development. However, concepts such as co-monitoring, co-learning, co-evaluation, co-development, and co-planning did not yield sufficient number of hits ($N < 10$)

to be included in our review (Table 1). We considered minimum 10 papers as a threshold for including a co-concept for our review. Furthermore, co-benefits is widely used concept in NBS literature, but we consider that it targets ideal outcomes, instead of collaborative process to achieve the outcomes.

3.1. Positioning vis-a-vis previous reviews close to our topic

Co-concepts have been reviewed in the socio-environmental field previously by e.g., Hakkarainen et al. (2022); Lee et al. (2024); Nguyen et al. (2024). Table 2 outlines key focuses on these reviews and outlines also our focus illuminating key differences across these reviews (Table 2).

3.2. Analytical strategy

We applied qualitative integrative literature review approach to synthesize NBS literature on the co-concepts and to elaborate their definitions further. Unlike systematic review approach, which aims to systematically and quantitatively synthesize and compare evidence of effect, integrative review focuses on qualitative analysis of empirical and theoretical literature to understand the research topic and to contribute to conceptual development (Snyder, 2019; Hopia et al., 2016; Torraco, 2005; Whittemore and Knafl, 2005). While there are no strict rules and protocols for conducting an integrative review, Snyder (2019) and Whittemore and Knafl (2005) propose following steps to enhance the rigor of the integrative review method: 1) designing the review, which includes defining the aim of the review, the research questions, and the search string; 2) conducting the review, which encompasses literature search and selection of included articles; 3) analyzing the selected papers (i.e. abstracting/extracting information from the papers and their potential further analysis); 4) writing and presenting the review. We employed five step approach in our integrative literature review on co-concepts in NBS context (Fig. 2).

We used SCOPUS as a search engine to find scientific peer-reviewed literature on the co-concepts published in English (Baas et al., 2020). While acknowledging the limitations of using a single search engine, we considered it appropriate for our literature searches because of the aim of the paper and the applied review method. Integrative reviews often focus on emerging topics, like the co-concept definitions, with the objective to create preliminary conceptualizations instead of reviewing old models, and therefore, they do not aspire to cover all the papers published on the topic (Snyder, 2019). Furthermore, theoretically oriented integrative reviews analyze available theories addressing a phenomenon, critically appraise those theories, and propose an advancement in the development of those theories. They do not seek to offer a complete evidence-based synthesis for focused questions, nor do they offer definitive guideline statements (Sukhera 2022).

We used five specific search term combinations at the end of November 2023. The searches led to 114 papers. We then removed six duplicates. Next we screened these 108 papers and excluded 15 papers based on abstract screening either because they did not address the NBS and the co-concepts (irrelevance to the research question) or because the full paper was unavailable (practical criteria). Inclusion criteria was

Table 1

Co-concepts excluded from our review due to small number of hits, or due to not referring to the collaborative process.

Search: "Nature-based solutions" AND	Number of hits in SCOPUS, 23 March 2025
"co-evolution"	5
"co-development"	9
"co-monitoring"	2
"co-learning"	2
"collaborative planning"	9
"co-evaluation"	1
"co-benefits"	284

based on clear connection to both NBS and a co-concept (relevance criteria). This led to 93 papers for review.

The included papers were analyzed by abstracting information on the six questions: 1) definitions of co-concepts found from the literature, 2) overlapping use of any co-concepts, 3) who are the actors included into collaboration, 4) why collaboration is needed 5) what is the target of collaboration, and 6) how collaboration is done. Rather similar approaches have been taken by Malekpour et al. (2021), who addressed co-governance from the point of view of why to collaborate, in what context the collaboration happens, who should participate, and how the collaboration takes place. Table 3 provides details on the six questions and establishes links between the questions to the three prior reviews close to our topic.

While the six key questions were predefined, and form deductive basis of our analytical strategy, we conducted qualitative inductive content analysis within the six deductive categories. This was done by identifying and copying excerpts from the screened papers to large excel files for each co-concept. The excerpts were then clustered thematically within the six questions for each co-concept, allowing to analyze commonalities and divergences of the co-concepts regarding the analytical questions. Such analysis strategy has been proposed for example by Elo and Kyngäs (2008) where content analysis starts by deductive development of analytical questions and gathering data under the questions, continuing with inductive approach by categorization, abstraction and building novel concepts. The identification and analysis of the excerpts was done manually by one person. In quantitative studies this can be considered a weakness. In qualitative view, it is difficult to harmonize the coding and categorization of the data, which requires level of creativity. To avoid different rationales in identifying the excerpt from the papers, only one person performed the coding.

When analyzing the results to move towards proposing definitions for the co-concepts and their relationships, we lean on the model for three phase transdisciplinary concept development processes proposed by Star (2010) and further elaborated by Steger et al. (2018) (Table 4). We elaborate these phases and consider that together these phases make co-concepts in NBS literature less fuzzy and easier to operationalize also in NBS practice.

4. Results

4.1. Loose use of the co-concepts

Our results indicated loose use for all the four concepts. Table 5 shows numerical overview of the definitions found from the screened literature and frequency of simultaneous use of several co-concepts in the same paper. The relatively low number of clear definitions for the co-concepts together with their simultaneous use highlights that it is often unclear to what these concepts are used for and why. The results imply that co-concepts are frequently used in combination with each other. Additional confusion is created by use of several other co-concepts to those reviewed here. For example, co-benefits, co-development, co-implementation, co-evaluation, and co-monitoring were also mentioned in our sample. This analysis verifies previous findings that the co-concepts are used in loose way, and hence there is need for additional conceptual clarity (Hakkarainen et al., 2022; Nguyen et al., 2024; Lee et al., 2024).

4.2. Overview of the co-concept definitions

Our review of the 26 co-concept definitions found from the literature (Annex 2) shows that not only the co-concepts are rarely defined, there seems to be no clear consensus on the content of the definitions, and that the definitions were often formulated in fuzzy way. However, some common threads appeared from the analysis of the definitions.

Co-creation was defined in 10 papers (Annex 2a). We find that 8 out of 10 found definitions consider co-creation was frequently used as an

Table 2
Basic information about the three prior reviews, and the present paper.

Authors	Hakkarainen et al. 2022	Lee et al. (2024)	Nguyen et al. (2024)	The present paper
Journal Field and scope	Sustainable Development Transdisciplinarity and natural resource management	Cities Multi-stakeholder collaboration in managing public space	Environmental Science & Policy Community needs, and public engagement regarding green spaces.	Environmental Science & Policy Collaborative approaches in Nature-based solutions
Co-concepts analyzed	Co-creation, Co-design, Co-production, Co-learning, and (adaptive) Co-management.	Co-creation, Co-design, and Co-production,	Co-creation, Co-design, and Co-production	Co-creation, Co-design, Co-production, and Co-governance
Method and approach	Scoping review	Systematic literature review, and bibliometric analysis	Systematic literature review	Integrative qualitative literature review
Data bases screened	Web of Science	Web of Science (WoS) and SCOPUS	SCOPUS, Web of Science, EBSCOhost, and Proquest.	SCOPUS
Dimensions to analyze co-concepts	i) relationships between concepts and collaborative knowledge processes, ii) transformative aims they were deemed to have, and iii) relationships with different interfaces (science-society, science-policy, and policy-society)	Actor (who is involved? who takes the lead?); Reason (motivation to become engaged in co-production); Input (resources used); Output (results of co-production); Phase (time and periodization); Means (such as contracting or partnership); Context (i.e., wider social and/or geographical environment).	Core principles; Purpose; Stakeholders; Stage in a process; Relationships with other co-concepts; Specific role of participants; Communication; Potential outcomes;	1) How the concepts have been defined in NBS literature, 2) whether these concepts are used simultaneously, 3) who are taking part in collaboration; 4) why the collaboration is needed, 5) what is the targeted output of collaboration, and 6) how the collaboration takes place.
Identified remaining gaps	..a gap between the demand for TD [transdisciplinary] outcomes and the mechanisms in society to participate in, and applying and utilizing collaborative knowledge production” approaches.	For future research, it would be relevant to delineate co-production, co-creation and/or co-design more clearly from other related concepts such as participation.	How the co-concepts are more effective than conventional participatory approaches in which participants play a passive role. Need for principles for best tailoring the approaches to different target populations and contexts.	1) considerations of multispecies actors as collaborators in NBS planning and implementation, and 2) how wider and long-term change could be addressed by the concept of coevolution.
Key findings	Practice reflexivity at individual and group levels; Consider the power and politics of co-concepts; Value process-orientation	The paper concludes by suggesting in which case it would be more appropriate to use which concept. Some clarity on the co-concepts can be provided by differentiating actor, phase, and topic/field.	Co-production/ Co-creation/ Co-design approaches have the potential to improve and develop green spaces that can meet the needs of the local community.	Proposing definitions for and relationships of the addressed co-concepts.

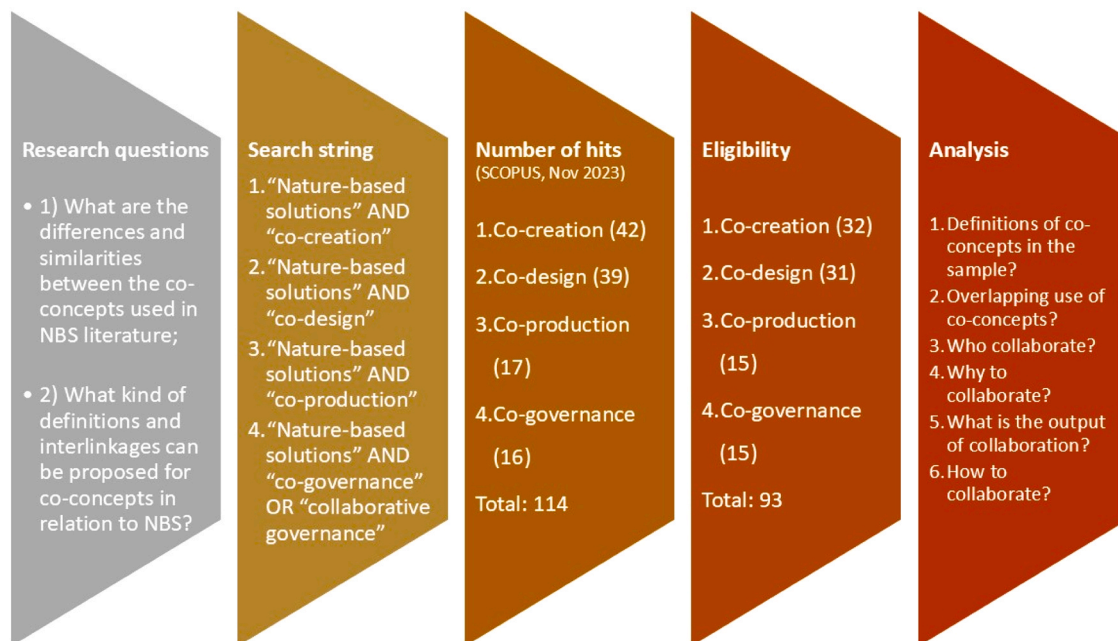


Fig. 2. Five steps in the integrative review on co-concepts in NBS context. We used four different SCOPUS searches combining “Nature-based solutions” AND each co-concept. For co-governance we used “co-governance” OR “Collaborative governance”.

umbrella term to refer to various phases or stages in an NBS development process including co-diagnostics, co-selection, co-design, co-implementation and co-monitoring (e.g. [Moniz et al., 2022](#); [Rödl and](#)

[Arlati, 2022](#)). Some papers considered the development through the subsequent stages as co-creation pathways, which may lead to innovation in current local governance structures and achieve transformational

Table 3

Our six analytical questions, rationale and link to prior reviews close to our topic.

Question	Rationale	Link to prior reviews
1. What kind of definitions for co-concepts have been proposed in NBS literature?	To collect, compare and synthesize existing definitions of co-concepts available in the literature.	The three prior reviews did not review the co-concept definitions in their literature samples.
2. To what extent the co-concepts are used in overlapping way?	To screen to what extent the co-concepts are used together with each other and considering their overlapping use.	The overlapping and interchangeable use of the co-concepts was the primary motivation for the three prior reviews (Hakkarainen et al. 2022; Lee et al. 2024; Nguyen et al. 2024).
3. Who are considered as part of the collaboration?	Co-prefix denotes to collaboration between multiple actors, hence it is essential to understand who are supposed to be collaborating under the co-concepts.	Lee et al. (2024) address “actors”, and Nguyen et al. (2024) address “stakeholders”, and also quantify their relative weights across the co-concepts.
4. Why the collaboration is needed?	Underpinning rationale for collaboration may or may not differ across co-concepts. We consider that usual rationales for collaborative approaches include enhanced knowledge on real-world contexts; normative reasons for enhancing participation; trust building; benefits for NBS design; enhanced legitimacy, etc.	Nguyen et al. (2024) address “purpose” of collaboration; Lee et al. (2024) address “reason” for collaboration. Hakkarainen et al. (2022) address “promises” linked to co-concepts.
5. What are the targeted outputs of collaboration?	Outputs are important to understand since they are tangible products of collaboration. Divergence across co-concepts on their targeted outputs can reveal differences and similarities.	Lee et al. (2024) address “outputs”; Nguyen et al. (2024) address “potential outcomes”.
6. How the collaboration is done?	Ways and methods to enhance collaboration are various (e.g. deliberative processes; negotiations; collaborative platforms; etc). Understanding the means of collaboration can reveal differences and similarities across co-concepts.	Nguyen et al. (2024) address “communication” and “specific role of participants”; Lee et al. (2024) address “means” of collaboration.

change (e.g. Arlati et al., 2021; Mitić-Radulović and Lalović, 2021; Bradley et al., 2022). The definitions included aspects of collaboration under different concepts, like citizen participation (Mitić-Radulović and Lalović, 2021), stakeholder engagement (DeLosRíos-White et al., 2020; Kumar et al., 2020; Soini et al., 2023), cross-sectoral collaboration (Van Rooij et al., 2020), social innovation and participation (Zingraff-Hamed et al., 2020).

Co-design was defined in 5 papers (Annex 2b). Co-design was hence the least frequently defined co-concept in our sample. Four definitions mentioned that co-design brings together practical experiences or engages with practitioners in a process of problem solving (Rubi and Hack, 2021; Neumann and Hack, 2022; Basnou et al., 2020; Schröter et al., 2022). Co-design was considered both as a collaborative process (Rubi and Hack, 2021; Neumann and Hack, 2022; Baró et al., 2022), and as a “creative approach” (Basnou et al., 2020; Schröter et al., 2022),

Table 4

Six phases in concept development. Note: Phases 2–4 derive from Star (2010) and Steger et al. (2018), while the phase 0, 1, and 5 are based on authors own elaboration.

Phases	Our analysis	Section
Phase 0: Establishing common background for the concepts under development.	We provide brief rationale for the Co-prefix concepts in general and in the context of NBS in Section 2.	2
Phase 1: Verifying the extent of pre-existing (un)clarity regarding concepts that are being developed.	We screened number of definitions for the co-concepts in the sample, and the extent of the use of many co-concepts in each paper (Question 1).	4.1
Phase 2: Concept framing providing overview of the concepts under development.	We provide overview on the contents of the concepts based on definitions found in the screened literature (Question 2).	4.2
Phase 3: Standardization where agreement about concepts components is reached and exclusion of terms and ideas, which may lead to new concepts, or are in contradiction with the core idea of the concept in question	We compare the insights on the co-concepts regarding the Questions 3–6, and seek to identify overlaps, similarities and unique characteristics of the concepts as used in the literature. This leads to standardization of the concepts. We recognize that the key distinguishing features between the co-concepts do not always have quantitative justification, but they are necessary to identify key differences between the co-concepts to avoid their use as undefined synonyms. Yet, we also identify common areas for the co-concepts, where clear divergence is not found.	4.3
Phase 4: Operationalization that formalizes the concept and leads to operational output	Proposing operational definitions for the four co-concepts, and a outline on their relations. This allows iterative feedback on conceptual development starting a new cycle to elaborate the concepts further in future studies.	5.2
Phase 5: Identification of emerging themes	We compared the derived definitions to the starting points we had in the phase 0, which led to identification of some emerging themes in the screened literature.	5.3

regarding NBS development.

Co-production was defined by seven papers (Annex 2c). These definitions were quite diverse. Some of them took the NBS implementation process cycle (Raymond et al., 2017) in their key foci (McEvoy et al., 2024; Diep et al., 2022), and some considered the public administration definition (see Wyborn et al., 2019) of co-production (Hoyle and Cottrill, 2023). Knowledge was mentioned as the key target of co-production frequently (Cousins, 2021; Wickenberg, 2023; Schuerch et al., 2022). Key uniting factor for the definitions was that they bring diverse perspectives together in a process seeking to integrate diverse knowledges and perspectives.

Co-governance was defined in four papers (Annex 2d). These vary in terms of highlighting collaborative governance as a general mode of decision-making (Malekpour et al., 2021; Bradley et al., 2022), or as concrete structures and processes where decisions are made (Waylen et al., 2023; Meng et al., 2023). Table 6 provides excerpts from the definitions found from the literature and synthesizes key insights from the definitions.

4.3. Detailed analysis on the who, what, how and why

The above section illustrated the existing definitions of the co-

Table 5
Numerical overview of the definitions of co-concepts in the screened literature.

	% and number of papers defining the co-concepts	% and number of papers using more than 1 co-concept
Co-creation	31 % (10 / 32)	72 % (23 / 32)
Co-design	17 % (5 / 31)	61 % (19 / 31)
Co-production	47 % (7 / 15)	60 % (9 / 15)
Co-governance	27 % (4 / 15)	53 % (8 / 15)
All papers	28 % (26 / 93)	63 % (59 / 93)

concepts found from the literature. While keeping these definitions in mind, in this section we assess the questions who, why, what and how regarding the four co-concepts with an aim to enrich the definitions found from the literature. The two first questions: who are the taking part in the collaborative processes, and why the collaboration should matter, did not create divergences between the co-concepts as the answers to these questions were similar for co-creation, co-design, co-production and co-governance. The two latter questions led to identifications of some key differences between the co-concepts.

4.3.1. Who are collaborating

The literature on each co-concept referred explicitly and frequently to the concept of stakeholders coming from diverse societal domains, such as policy, civil society, science, and business (e.g. Mitić-Radulović and Lalović, 2021; Bradley et al., 2022; Lupp et al., 2021a; van der Jagt et al., 2023; Meng et al., 2023). Clear distinguishing features regarding involved actors across the co-concepts proved to be hard to identify. Key findings imply firstly, that the NBS co-concept literature did not consider extensively private sector. Also, non-human actors were not considered as collaborators, even if they are increasingly recognized in NBS literature (e.g. Welden et al., 2023). Secondly, co-production papers focused mainly on civil society – expert linkages. Thirdly, beyond the usual suspects, some less usual groups of people were also identified as part of collaboration for NBS, such as children (Ward et al., 2023; Plassnig et al., 2022; Basnou et al., 2020; Baró et al., 2022; Hoyle and Cottrill, 2023). However, children were not addressed in co-governance literature. Also intermediary organizations and networks that could bridge administrative and other boundaries, were considered as key actors in collaborations (e.g. Wijsman et al., 2021; Kavouras et al., 2023; Diep et al., 2022; Waylen et al., 2023; Midgley et al., 2021). Furthermore, communities at risk and actors facing marginalization challenges were mentioned as particular and important kind of collaborators in NBS development (Bwambale and Kervyn, 2021; Cousins, 2021; van der Jagt et al., 2023). We observe that none of the papers screened mentioned multispecies collaborators beyond humans. This was a surprise given the crucial roles that multispecies actors play in making NBS function and operational. NBS are by definition “supported by nature”, and hence it could be expected that the co-concepts would address also multispecies actors beyond humans as collaborators. Table 7 provides an overview of actors targeted by the co-concepts.

4.3.2. Why collaboration is important

The reasons why collaboration is needed were quite diverse under all four concepts, and clear divergences across the four literatures were not found. Rather, the reasons linked to inclusion, openness, boosting innovation, ability to develop context specific knowledge and solutions, and to address pressing sustainability challenges.

Co-creation was in general considered as a way to include citizen voices and perspectives into NBS planning and implementation (Larrinaga et al., 2021; Mahmoud and Morello, 2021; Moniz et al., 2022; Mitić-Radulović et al., 2021), to enhance democracy (Ascione et al., 2021), in a way that leads to deeply place-based socio-cultural view on real life contexts (Gulstrud et al., 2018; Soini et al., 2023). Ultimate outcomes of co-creation of NBS were connected to healthy, livable and biodiversity friendly cities (Mohr-Stockinger et al., 2023), to addressing inequality, socioeconomic disparities, and fractures in society (Nunes

et al., 2021), to green transition (Matos et al., 2022), to innovations and transformative change (Bradley et al., 2022), to social cohesion, citizen security, environmental justice, and human health (Ariati et al., 2021), to changing behavior (Ward et al., 2023). Finally, co-creation can also make trade-offs between stakeholders visible (Wijsman et al., 2021).

Co-design was considered to contribute to solving defined shared and complex problems (Granai et al., 2022; Lupp et al., 2021a), and urban green and blue spaces (Jakstis et al., 2023) in open, inclusive and transparent way (Baró et al., 2022). Co-design helps to gain context specific information (Neumann and Hack, 2022), and to harness ‘place-based’ interests and knowledge, which ensures that NBS are tailored to socio-ecological context, enhancing their likely success (Collins et al., 2022). Co-design takes into account lived experience of targeted stakeholders (Slinger et al., 2023), can identify co-benefits and trade-offs (Coletta et al., 2021), helps to understand stakeholder perceptions (Lecina-Diaz et al., 2023), and helps to incorporate NBS user demands and needs into NBS design (Basnou et al., 2020). Co-design environments also provide a mutual learning space to develop and test and learn from NBS (Kempa et al., 2023; Slinger et al., 2023). Finally, co-design can also help to overcome the considerable and multi-faceted institutional barriers for NBS implementation (Hutchins et al., 2021), enable community ownership of projects, and hence plays a crucial role in NBS effectiveness over time (Diep et al., 2022).

Co-production helps to address real world problems or societal challenges and even catalyze transformative change (Cousins, 2021; Wickenberg, 2023). Also measures that are co-produced with local communities tend to gain more traction during implementation and are often sustainable (Mugari and Nethengwe, 2022). Knowledge co-production may also create capacities to mainstream NBS by connecting and building skills and evidence base among key players, including practitioners, academics, and consultants (Adams et al., 2023). Furthermore, co-produced solutions can respond to the challenges prioritized by citizens (van der Jagt et al., 2023).

Collaborative governance is needed to make decisions addressing complex socio-environmental challenges (Waylen et al., 2023; Meng et al., 2023; Bradley et al., 2022; Brink and Wamsler, 2018) to mainstream NBS (Malekpour et al., 2021; van der Jagt et al., 2023; Voskamp et al., 2021; Midgley et al., 2021), to successful, place-based implementation and uptake of NBSs (Voskamp et al., 2021), to foster innovation (Ferreira et al., 2020), and can have place-based impacts, program level impacts and sectorial or system level impacts (Malekpour et al., 2021). Collaborative governance is important since it can catalyze local and tacit knowledge in the planning of nature-based solutions (Frantzeskaki, 2019).

4.3.3. What is the envisaged output of collaboration

While the who and why seemed more or less similar across all the four co-concepts, the targeted output of collaboration differed more clearly. However, also overlapping focuses were identified. Fig. 3 outlines our key results on the four co-concepts and their core distinguishing features regarding the key target of collaboration, and deviances from the core distinguishing features.

4.3.4. How the collaboration happens?

Co-creation has two commonly used and agreed characteristics in the screened literature: the concept of co-creation refers to sequence of

Table 6
Excerpts on definitions of co-concepts found from the screened literature.

Co-concept	Excerpts from the screened literature	Key components of the definitions
Co-creation	<p>"... implying citizen participation in all NBS development stages: in their planning, design, implementation, and monitoring and evaluation" (Mitić-Radulović and Lalović, 2021).</p> <p>"... collaboration with the stakeholders (users of the knowledge or solutions) to identify problems, design the solution options, and deploy them" (Soini et al., 2023).</p> <p>"... co-creation pathway that encompasses other phases of co-implementation, co-monitoring and co-development of NBS" (Mahmoud and Morello, 2021)</p>	<p>Inclusive participation (also Kumar et al., 2020). (Zingraff-Hamed et al., 2021).</p> <p>Collaboration across the co-creation cycle (also Van Rooij et al. 2020)</p>
Co-design	<p>"Experts and end-users are encouraged to participate in the process in order to combine professional expertise and lived-experience in problem solving" (Rubi and Hack, 2021).</p> <p>"Co-design is a creative approach that enables bringing together real-life experiences, views and skills of many different perspectives to address a specific problem" (Basnou et al. 2020).</p> <p>"...solution-oriented, transdisciplinary research with mutual learning, that incorporates values, norms and context into knowledge production" (Lavorel et al., 2019)</p>	<p>The co-creation cycle includes other co-concepts within (Also Moniz et al. 2022)</p> <p>Combining expertise and experience-based knowledge (Also Schröter et al., 2022)</p> <p>Creative approach to problem solving (also Schröter et al., 2022)</p>
Co-production	<p>"An inclusive co-production approach, with the project team engaging closely with community members and local stakeholders" (McEvoy et al., 2024)</p> <p>"... consistent and deep forms of engagement at every step of project development" (Diep et al. 2022)</p> <p>"Co-production is 'a reciprocal process of exchange between diverse stakeholders, to generate outcomes that are only possible because of this deliberate intersection of difference', (Durose et al., 2022)" (Hoyle and Cottrill, 2023)</p>	<p>Knowledge co-production (also Schuerch et al., 2022).</p> <p>Inclusivity and deep forms of engagement</p>
Co-governance	<p>"... involvement of governmental and non-governmental actors in the processes and structures of decision-making and management" (Waylen et al., 2023).</p> <p>"...the totality of actions and interactions in which governments, public, private, and civil society actors participate," (Malekpour et al., 2021).</p> <p>"Organizational structures, institutional rules, and funds' allocation are fundamental characteristics of a governance setting" (Meng et al. 2023)</p>	<p>Reciprocal process of exchange between diverse stakeholders (also Wickenberg, 2023; Cousins, 2021)</p> <p>Decision-making structures and processes (also Bradley et al. 2022)</p> <p>Governmental, public, private and civil society actors (also Bradley et al., 2022; Waylen et al. 2023)</p> <p>Institutions</p>

phases from problem definition via planning and design to implementation (Ward et al., 2023; Rödl and Arlati 2023; Larrinaga et al., 2021; Mohr-Stockinger et al., 2023; Mitić-Radulović and Lalović 2021). The phases in co-creation process are called differently across literature and there was no standard way to refer to the different phases. Bradley et al. (2022) considered initiation, mobilization, and consolidation phases. Larrinaga et al. (2021) considered stages of conceptualization, design, development, deployment. DesLosRios-White et al. (2020) considered CoExplore, CoDesign, CoExperiment, CoImplement and CoManagement, phases in NBS co-creation process. In order to use phases in co-creation cycle for the identifying divergence between co-design, co-production and co-governance we rely on view according to which co-creation pathway can inform "decision-makers to embed citizen engagement methodologies as an approach to co-design and co-implement NBS in shared-governance processes" (Mahmoud and Morello, 2021 [emphasis ours]). Also Lupp et al. (2021b) make the distinction between co-design and co-implementation. We connect co-governance to generic co-implementation phase including for example implementation, maintaining, transferring, and upscaling NBS. We connect co-design and co-production into the co-design phase, which we however call "co-planning" to distinguish it from more specific meaning of co-design elaborated in the present paper. Co-planning includes phases of problem identification, agenda setting, NBS development, and also monitoring and evaluation (see Raymond et al., 2017 for NBS cycle).

Co-creation happens often in Living Lab contexts (Dogan et al., 2023; Sarabi et al., 2020; Ascione et al., 2021; Soini et al., 2023; Arlati et al., 2021; Kumar et al., 2020). Living Labs are recognized as a progressive form to foster innovation and to strengthen collaboration, and they are used to co-create innovative NBS with stakeholders in a certain societal and environmental, real-life context (Soini et al., 2023). Living Labs approaches can contribute to collaborative planning and implementation of NBS through fostering in-depth stakeholder engagement (Lupp et al., 2021b). Living Labs were considered as enabling environment for NBS co-creation (Mahmoud and Morello, 2021) and as innovation network of companies, public agencies, universities, users, and other stakeholders in the pursuit of collaborating for the creation, prototyping, validating, and testing of new technologies, services, products, and systems in real-life contexts (Zingraff-Hamed et al., 2020). Living labs and step-wise co-creation process were also considered simultaneously in several papers (Zingraff-Hamed et al., 2020; Mahmoud and Morello, 2021; Moniz et al., 2022; DesLosRios-White et al., 2020). Living Labs are important sites for collaboration also regarding the other addressed co-concepts.

Co-design literature covered participatory processes in workshop or Living Lab setting as learning environments for engagement of diverse actors (Slinger et al., 2023; Granai et al., 2022; Bogatinoska et al., 2022; Collins et al., 2022; Diep et al., 2022; Herranz-Pascual et al., 2023; Basnou et al., 2020; Baró et al., 2022; Kempa et al., 2023; Neumann and Hack, 2022; Lupp et al., 2021a). Specific tools to be used within these processes included Geodesign (Gottwald et al., 2021), map-based planning tools (Schröter et al., 2022), immersive digital participatory tools (Mahmoud and Morello, 2021), and causal loop diagrams and performance matrix (Coletta et al., 2021). Co-design in real world laboratories were mentioned as sites to reveal and solve conflicting interests and build trust, and to jointly evaluate and test solutions (Kempa et al., 2023; Neumann and Hack, 2022). Co-design taking place in Living Labs should be based on openness, knowledge development, learning processes for all participants, and meeting on equal ground (Lupp et al., 2021a). Co-design was also considered possible through questionnaires (Lecina-Diaz et al., 2023; Jakstis et al., 2023). Justice was also a key consideration when doing the codesign (Raymond et al., 2023).

Co-production linked to efforts to integrate several knowledge systems including traditional, local and scientific knowledge (Cousins, 2021; Lavorel et al., 2019; Schuesser et al., 2022), collaboration across disciplinary and sectoral boundaries, and across different types of

Table 7
Overview of actors engaged in NBS planning and implementation across the co-concepts.

	Governmental actors	Scientists and experts	Civil society	Private sector
Co-creation	Governmental decision makers (Bradley et al. 2022; Ferranti, et al. 2023) Municipal or city officials (Nunes et al. 2021; Mohr-Stockinger et al. 2023; Moniz et al. 2022; Mitić-Radulović and Lalović 2021)	Research-practitioner networks (Wijsman et al. 2021); Experts (Kavouras et al. 2023)	Local residents (Mohr-Stockinger et al. 2023) Citizens (Nunes et al. 2021; Sarabi et al. 2020; Moniz et al. 2022) Children and teachers (Plassnig et al. 2022; Ward et al. 2023); Social networks (Van Rooij et al. 2020).	Private sector actors (Bradley et al. 2022; Mitić-Radulović and Lalović 2021)
Co-design	Policy and management authorities (Kempa et al. 2023; Neumann and Hack, 2022; Lecina-Diaz et al. 2023; Bwambale and Kervyn, 2021; Gottwald et al. 2021; Lilli et al. 2020; Schröter, et al. 2022). Policy champions (Dick et al. 2019)	Intermediary organizations (Diep et al. 2022) Scientists and experts (Bwambale and Kervyn, 2021; Herranz-Pascual et al. 2023)	(E)NGOs (Diep et al. 2022; Kempa et al. 2023; Neumann and Hack, 2022; Lupp et al. 2021a). Communities at risk (Bwambale and Kervyn, 2021) Children (Baró et al. 2022; Basnou et al. 2022).	Tourism actors (Kempa et al. 2023); Landowners and farmers (Lilli et al. 2020)
Co-production	City planners (Cousins, 2021) Governmental actors (van der Jagt et al., 2023)	Scientists (Lavorel et al. 2019); Schuerch, et al. 2022; Castro and Rifai, (2021); McEvoy et a. 2024 Wickenberg, (2023); (Hoyle and Cottrill, 2023; Schuerch, et al. 2022) Citizen scientists (Wild et al. 2019) Experts (van der Jagt et al. 2023); Consultants (Adams et al. 2023)	Local communities (Cousins, 2021; McEvoy et al. 2024; Mugari and Nethengwe, 2022; Schuerch, et al. 2022; Lavorel et al. 2019). Actors facing social justice challenges (Cousins, 2021; van der Jagt et al., 2023). Children (Hoyle and Cottrill, 2023) Citizens (Wamsler et al. 2020; van der Jagt et al., 2023; Pauleit et al. 2021; Diep et al. 2022). Practitioners (Castro and Rifai, 2021; Wickenberg, 2023; Adams et al. 2023)	
Co-governance	Municipal officers (Voskamp et al. 2021) Governmental organizations and actors (Meng et al. 2023; Bradley et al. 2022) State agencies (Waylen et al. 2023) Municipal staff and urban planners (Frantzeskaki, 2019; Malekpour et al. 2021; Voskamp et al. 2021)	Stakeholders operating across different organizational and jurisdictional boundaries (Dorst et al. 2022) Knowledge brokers (Frantzeskaki, 2019)	Social innovators (Frantzeskaki, 2019) Civil society and associations (Midgley et al. 2021) Citizens and municipalities (Brink and Wamsler, 2018) NGOs, and civil society (Malekpour et al. 2021; Frantzeskaki, 2019); Community , (Bradley et al. 2022) Local support networks (Midgley et al. 2021)	Private sector actors (Bradley et al. 2022; Waylen et al. 2023)

knowledge (cognitive, normative and practical) (Wickenberg, 2023). Embedding co-production with transformative agendas to overcome environmental inequities and bringing together different forms of knowledge and expertise were considered as important (Cousins, 2021; Wickenberg, 2023; Mugari and Nethengwe, 2022; Adams et al., 2023; Schuerch et al., 2022; Diep et al., 2022; Hoyle and Cottrill, 2023; van der Jagt et al., 2023). Several key issues for ensuring good quality co-production were identified: sensitivity to political and sociocultural contexts in efforts to empower stakeholders (van der Jagt et al., 2023), use of inclusive and participatory approaches (McEvoy et al., 2024), creating safe spaces for bringing diverse actors together (Wickenberg, 2023), bridging science and policy (Adams et al., 2023), engaging stakeholders early in a process, and ensuring quality of participation higher at the Arnstein (1969) ladder by iterative processes (Schuerch et al., 2022), and being sensitive with existing power relations (Diep et al., 2022). Practical approaches to be used in co-production processes included internet-based tools (Wild et al., 2019), collaborative workshops (McEvoy et al., 2024), participatory monitoring and assessment (van der Jagt et al., 2023), and good facilitation of the co-production process (Wickenberg, 2023).

Co-governance relied on participatory decision-making for breaking sectoral siloes by sharing information, capacities, resources and decision making (Malekpour et al., 2021; Voskamp et al., 2021; Ferreira et al., 2020; Midgley et al., 2021; Waylen et al., 2023; Dorst et al., 2022). Successful collaborative NBS governance was considered to require a process of maturation that is typically needed in order to build up the capacities in a network, including key roles and responsibilities for diverse stakeholders (Bradley et al., 2022). Collaborative governance

can take forms of 1) innovative cross-sectoral and public-private partnerships, and new business models (Ferreira et al., 2020; Midgley et al., 2021; Voskamp et al., 2021), 2) coordination across and between levels (e.g. from national, to regional or landscape, to local or individual land-manager). (Waylen et al., 2023), 3) crossing organizational and jurisdictional boundaries (Dorst et al., 2022), 4) balancing interests of citizens and market actors (Meng et al., 2023), and 5) governing citizen–municipality interactions (Brink and Wamsler, 2018). Experimentation was considered as important way to advance collaborative governance (Frantzeskaki, 2019) conducting local experiments as an arena for reflexive, adaptive, and multi-actor learning environments was considered important (Bradley et al., 2022). Openness and transparency to establish trust and commitment were highlighted (Frantzeskaki, 2019; Waylen et al., 2023).

Fig. 4 summarizes the common element across the concepts being collaborative processes within inclusive space, and identifies also key distinguishing features for each of the four concepts.

4.4. Challenges for collaboration

While in general our literature sample highlighted positive aspects and promises of the collaborative approaches, also challenges were highlighted (Table 8). Our analysis questions did not include challenges topic, but these were coded as additional notes.

The concept	Core distinguishing features	Deviences
Co-creation	NBS as the target of co-creation (Rödl and Arlati 2022; Zingraff-Hamed et al., 2020; Nunes et al., 2021; Mahmoud et al., 2021; Ascione et al., 2021; Matos et al., 2022; Anderson et al., 2022; Soini et al., 2023; Frantzeskaki 2019; Arlati et al., 2021; Kumar et al., 2020)	Co-creation of decision-support tools to enable NBS (Sarabi et al., 2020; Mitić-Radulović and Lalović 2021; Plassnig et al., 2022; Larraniga et al., 2021). Co-creation of concepts (Hansen et al., 2021), and normative visions (Van Rooij et al., 2022) linked to NBS.
Co-design	Decision support tools for NBS (Bogatinoska et al., 2022; Hutschins et al., 2021; Herranz-Pascual et al., 2023; Schröter et al., 2022; Gottwald et al., 2021) Co-benefits of NBS (Coletta et al., 2021; Jaktsis et al., 2023)	Co-design of NBS (e.g. Diep et al., 2022; Rubi et al., 2021; Kempa et al., 2023; Granai et al., 2022; Lecina-Diaz et al., 2023; Slinger et al., 2023) Co-design of transformations linked to NBS (Hack 2022; Piga et al., 2021; Baró et al., 2022)
Co-production	Co-production of knowledge to support NBS (Wild et al., 2019; Wickneberg 2023; Mugari and Nethengwe 2022; Adams et al., 2023; Schuerch et al., 2022).	NBS as the output of co-production (McEvoy et al., 2024; Hoyle and Cottrill, 2023; Lavorel et al., 2019; Cousins, 2021; Pauleit et al., 2021). Decision support tools to enable NBS (Castro and Rifai 2021; van der Jagt et al., 2023; Diep et al., 2022)
Co-governance	Governing socio-environmental systems where NBS projects are embedded (Waylen et al., 2023; Franzeskaki 2019; Dorst et al., 2022; Bradley et al., 2022) Governance of risks by developing NBS (Brink and Wamsler, 2018; Meng et al., 2023)	Governance of NBS uptake (Voskamp et al., 2021).

Fig. 3. The four co-concepts and their core distinguishing features regarding the key target of collaboration, and deviances from the core distinguishing features. The color code in the two left columns links the color to each co-concept, and the right column identifies overlaps between the definitions by using the color code to imply linkage to the other co-concepts. White color code illustrates clusters that are general for all co-concept definitions.

5. Discussion

5.1. Commonalities and differences in co-concepts

Our results showed that in many aspects, the co-concepts were used in quite similar manner, but with some divergence. To bring light in the conceptual mess with the four co-concepts used frequently in NBS literature, we identified key distinguishing features for each concept. The questions on who are included and why were pretty much similar regarding all the four concepts. Divergences emerged regarding questions of how the collaboration happens, and what are the envisaged outputs of the collaboration. How question was clear for the co-creation literature considering the cyclical process often in Living Lab context to co-create NBS. Co-design was less consensual, but here we lift the focus on developing and using tools (e.g. scenarios, maps, digital tools), and focus on intermediary tangible outputs that could be considered as boundary objects relevant for different actors. This distinguishes co-design from co-production, which focuses on co-producing knowledge

by integrating diverse perspectives. A distinguishing feature for co-governance was its focus on governance of NBS as part of wider socio-environmental system by cross-sectoral partnerships and coordination. Co-governance literature also highlighted openness, transparency and experimenting to support NBS and collaboration (Table 9).

5.2. Proposing definitions for the co-concepts

Our integrative review was motivated by recent findings of systematic reviews that the co-concepts are used frequently but in elusive way (Hakkarainen et al., 2022; Nguyen et al., 2024; Lee et al., 2024). Therefore, we consider it important to seek to offer definitions for these concepts in the NBS context. Our results show that the question of who are taking part in collaboration across co-concepts encompassed actors from general domains of policy, society, science and also business in literature on all co-concepts. While our qualitative analysis did not reveal relative weights of different types of actors not major differences in overall reasons for collaborative approaches, other recent reviews close to the topic provide quantitative analysis on this aspect as well as on reason for collaboration (Nguyen et al., 2024; Lee et al., 2024). All addressed co-concepts require inclusive opportunities for participating actors to engage in the collaboration beyond non-participation or tokenistic participation.

Our major finding is that the envisaged output, and the question of how the collaboration is done across the co-concepts offer a promising way to distinguish between the co-concepts. We find that co-creation targets NBS in general, co-design is about tools and their use to support NBS, co-production targets knowledge, and co-governance targets the socio-environmental system in which the NBS are embedded. Also Hakkarainen et al. (2022) and Nguyen et al. (2024) consider co-design and co-production as part of co-creation cycle. Our conceptualization regarding co-production focusing on knowledge diverges from Lee et al. (2024) due to that they focus mainly on public administration definition of co-production of goods and services, instead of knowledge co-production.

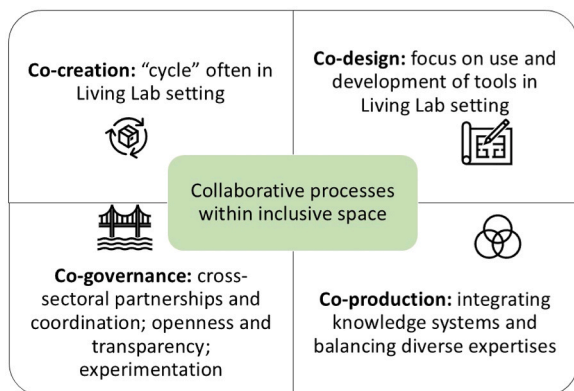


Fig. 4. Common aspects of how to do collaboration under the four co-concepts, and key distinguishing features in each concept.

Table 8
Challenges identified across the co-concepts.

Co-concepts	Identified challenges for collaboration
Co-creation	<ul style="list-style-type: none"> Living Lab based co-creation model may be reproducing traditional power relations, for example by re-proposing already established governance patterns that are not inclusive (Dogan et al. 2023). Use of participatory co-creation methods may be exploitative (i.e. enabling only one-way knowledge flows from participants to researchers), and can be used to legitimize solutions that provide little contribution to the actual needs and priorities of the included communities (Nunes et al. 2021). Challenges inherent to co-creation processes (i.e. related to balanced and fair deliberation), and to how actual contents of key concepts, like resilience, are assumed rather than negotiated in such processes (Wijsman et al. 2021).
Co-design	<ul style="list-style-type: none"> Lack of sensitivity towards cultural characteristics of the participating actors and issues related to justice, diversity, and gender (Basnou et al. 2020). Generic applicability of co-design methods in diverse contexts are limited by the need to properly understand and accommodate local circumstances and participants' insights within collaborative workshop setting (Slinger et al. 2023). Co-design processes can also raise legislative, socio-economic, technical and personal conflicts, especially if these processes are not opening proposed nature-based solutions to be negotiated among the participants (Lilli et al. 2020).
Co-production	<ul style="list-style-type: none"> Plausible biases reflecting unbalanced power relations, and hence attention is needed to avoid tokenistic and non-participatory forms of engagement by considering carefully how to enable empowering forms of co-production (van der Jagt et al. 2023). Different types of participation need to be timed carefully across the phases in the NBS co-creation cycle, (Schuerch et al. 2022).
Co-governance	<ul style="list-style-type: none"> Challenges related to a complex stakeholder landscape, silos in project management, and from the divided responsibilities and budgets over various government agencies and departments (Dorst et al. 2022). Power and resource allocation, existing institutional arrangements, and lack of incentives for stakeholder participation can hinder the collaboration in NBS governance process (Meng et al. 2023). Resources availability, level of expertise, lack of know-how or competence; and the rigid institutional settings can hinder capacity of decision makers (e.g. municipal officers) to do collaborative governance in practice (Voskamp et al. 2021). The collaborations should be designed up-front and proactively to avoid mismatches between intended impacts and actual outcomes resulting from the collaborative governance processes (Malekpour et al. 2021).

Table 9
Comparing the different co-concepts with focus on distinguishing features.

	Co-creation	Co-design	Co-production	Co-governance
By whom	Stakeholders from policy, business, society and science			
Why	To address sustainability challenges, to learn, to build trust, to enhance equality and inclusivity, to gain diverse perspectives			
How	By cyclical participatory processes in living lab context	By using and developing tools	By integrating different knowledge and perspectives	By cross-sectoral partnerships and coordination, openness and transparency, experimenting
Of what	Nature-based solutions	Decision support tools; tangible outputs (i.e. co-benefits)	Knowledge	Socio-environmental systems
Link to NBS cycle	Refers to all the phases in the cycle	Within the cycle (planning phases)	Within the cycle (Planning phases)	Partly inside (implementation phases) and partly outside the cycle

When thinking the overall NBS cycle, co-creation refers to whole cycle, co-design and co-production are part of the planning phases (e.g. phases of problem identification, agenda setting, NBS planning, and

evaluation and monitoring), and co-governance is part of the implementation phases (e.g. phases of implementing, maintaining, transferring, and upscaling the NBS). Table 10 outlines proposed definitions

Table 10
Proposed definitions for the four co-concepts (Source: authors).

Co-concept	Proposed definition in connection to NBS	Links to previous definitions and results.
Co-creation	Co-creation of NBS takes place through the overall stepwise process cycle of planning and implementing NBS, often embedded in Living Lab context, engaging diverse stakeholders, and aiming to address sustainability challenges.	Co-creation referring to all steps in NBS implementation cycle (Zingraff-Hamed et al., 2021); Soini et al. (2023); Moniz et al. (2022); Mahmoud and Morello, (2021); Kumar et al. (2020); DesLosRios-White et al. 2020; (Mitić-Radulović and Lalović, 2021). Co-creation in Living Labs (Dogan et al., 2023; Sarabi et al., 2020; Ascione et al., 2021; Soini et al., 2023; Arlati et al., 2021; Kumar et al., 2020).
Co-design	Co-design and use of tools to support NBS planning is a creative process, which brings together diverse real-life experiences, views, practices, and skills, and aims to create tangible outputs that help to address a problem and enhance co-benefits of NBS.	Use and development of tools (Gottwald et al., 2021; Schröter et al., 2022; Mahmoud and Morello, 2021; Coletta et al., 2021). Real-life experiences for problem solving (Rubi and Hack, 2021; Basnou et al. 2020; Schröter et al., 2022) Creative process (Basnou et al. 2020; Schröter et al., 2022)
Co-production	Co-production of knowledge supporting NBS planning refers to multidirectional deliberative process of knowledge exchange between actors with diverse situated practices, worldviews, and aims to solve existing societal challenges.	Focus on knowledge (Lavorel et al., 2019) (Wild et al., 2019; Wickenberg, 2023; Mugari and Nethengwe, 2022; Adams et al., 2023; Schuerch et al., 2022). Multidirectional interactions Cousins, 2021; Hoyle and Cottrill, 2023) Diverse perspectives (Cousins, 2021) (Lavorel et al., 2019) (Wickenberg, 2023) Deliberation (Wickenberg, 2023);(Hoyle and Cottrill, 2023)
Co-governance	Collaborative governance of socio-environmental systems in which the NBS are embedded takes place through inclusive decision-making structures and processes, and cross-sectoral partnerships across public, private and civic spheres, and it seeks to address problems or create opportunities by supporting NBS.	Socio-environmental systems (Waylen et al., 2023; Frantzeskaki, 2019; Dorst et al., 2022; Bradley et al., 2022) Participatory processes, (Bradley et al., 2022) (Waylen et al., 2023). Partnerships across public, private and civic spheres (Bradley et al., 2022) (Malekpour et al., 2021).

for the co-concepts and links them to literature supporting each key feature of the definitions.

However, some of the definitions found from the literature are in slight contradiction with our proposals. [Wijsman et al. \(2021\)](#) defined co-creation as knowledge production exceeding the boundaries between diverse actors, a definition that we propose for co-production. [Bogatynoska et al. \(2022\)](#) defined co-creation with the focus on tools, which in the present paper we propose to be distinguishing feature in co-design concept. In co-design definitions overlap was found between co-creation cycle and co-design process ([Rubi and Hack, 2021](#); [Baró et al., 2022](#)). While the co-design process can definitely include also stepwise path, in the present paper we propose to retain the step-wise NBS development process for the concept of co-creation. In co-production definitions, [Diep et al. \(2022\)](#) relied on public administration definition of co-production of services. [McEvoy et al. \(2024\)](#) considered the stepwise NBS project development as integral to the definition of co-production, which we consider to be in heart of the co-creation concept. Furthermore, [Cousins \(2021\)](#) considered co-production as shaping environmental governance. While this complies also with our definition, we stress the difference between knowledge co-production, which may or may not shape decision-making, and collaborative governance targeting directly decision-making.

5.3. Emergent themes: multispecies approach and coevolution

The multispecies actors are increasingly recognized in NBS literature (e.g. [Maller, 2021](#); [Pineda-Pinto et al., 2022](#); [Welden, 2023](#)), but our sample did not identify them as collaborators through the co-concepts. Rapid recent increase in NBS literature on multispecies aspect is shown by a SCOPUS search with a search string: "Nature-based solution" AND "multispecies" OR "more-than-human" OR "non-human" OR "interspecies" yielding 36 hits emerging especially during past 4 years. The coevolution concept was part of our initial research design, but search string connecting NBS and coevolution yielded only five SCOPUS hits.

Agency of multispecies actors is clear when considering NBS. This is because even though NBS are put in place by people, NBS are by default changing also bio-physical environments. Hence, it is somewhat surprising that the literature on co-concepts and NBS does not cover multispecies agency, and non-human actors as part of collaborations, which make NBS what they are today and in the future. NBS imply changes supported by nature in physical reality, and hence material agency of non-human actors is clear ([Latour, 2005](#)). One example of such multispecies agency is to consider beavers as coworkers implying that humans 'work with nature' to co-create NBS ([Welden, 2023](#)). Second example links to multispecies placemaking as an active process of empowerment taking place through arts and community-based approaches ([Sachs Olsen, 2022](#)). Multispecies co-design has been addressed for example in futures approaches. Firstly, future multispecies world have been imagined in multispecies symposium 2100, which functioned as collaborative tool to reflect on co-design with other living entities ([Romani, 2022](#)). Another example is "biofuturing," a creative research approach concerned with the co-design of multispecies speculations of worlds to come ([Jacobs et al., 2024](#)). Regarding co-production of knowledge, for example citizen science methods engaging with multispecies realities could be regarded as co-production approaches, which not only contribute to scientific knowledge but also enhance nature connectedness of participants ([Pocock et al., 2023](#)). However, as co-production of knowledge relies heavily on human language, alternative ways to collaborate are needed that could untap knowledge of multispecies actors without relying on human language. Regarding co-governance, [Meijer \(2019\)](#) has suggested that actions of multispecies actors can be considered as political voice to be considered in decision-making. [Herrmann-Pillath \(2024\)](#) suggests that 'nature-based governance' that enacts deep and comprehensive reciprocity between people and nature, and grounds governance mechanisms in embodied

more-than-human practices with normative force. Nature-based governance concerns decision arena where multispecies' actions are systematically recognised addressing vulnerability among and between the human and other species ([Kluvankova et al., 2025](#)). Hence, in multispecies co-governance, key issue is the embodied politics and communication through action allowing participation of multispecies actors in decision making.

One conceptual means to consider multispecies aspects in collaboration for NBS is the concept of coevolution. Coevolution is a concept that can explain how change happens. Coevolution has been considered by [Norgaard \(1984\)](#) not just interdependent change, but includes variation, selection of variants due to differential fitness, and trial and error adaptation. Here we consider that co-evolution linked to NBS takes place between biophysical processes, ecosystem characteristics, multispecies (including humans) actors and their behavior, and governance of socio-environmental systems. Coevolution could also target coevolution of various policy sectors to build bridges across siloes by collaboration that brings actors together for example in living lab settings from the domains of policy, business, society and science ([Huntjens and Kemp 2022](#)). The role of NBS developers in such processes is then to tweak complex coevolutionary processes to desirable direction. This can be done for example by experimenting with diverse governance approaches (i.e. co-governance), and also by innovative design of physical environments and green infrastructures (i.e. co-creation of NBS as material practice). While the emergent coevolutionary processes cannot be fully anticipated, NBS offer a way to initiate sustainability transformations by upscaling and mainstreaming (see [van der Jagt et al., 2023](#)). Therefore, we consider that the target of sustainability offers a desirable direction for the coevolution. Coevolutionary view can enable also to reframe co-dependence of people and environment in a way that considers regenerative relationships between people and environments and acts as leverage for transformative change ([Welden et al., 2021](#)). We propose that coevolutionary processes are key to understand how the socio-environmental change happens around and by NBS.

Leading from above, we propose, firstly, to consider also multispecies actors as key collaborators in NBS co-creation cycle, and stress the importance in finding ways to understand multispecies perspectives when collaborating to develop NBS. This can be done through coevolutionary view, which can offer a point of departure to understand the complex socio-environmental relations and processes now and in the future (see graphical abstract).

5.4. Limitations

While we gained interesting results based on our integrative literature review on the four co-concepts used in connection to NBS, our approach has also limitations. Firstly, we used only one search engine to identify the set of papers to be addressed. Yet, when doing the initial searches, we found relatively manageable, but still extensive amount of papers using the four co-concepts and NBS in title and / or abstract. As we did not aim for systematic and quantitative review, we considered that for integrative qualitative and exploratory review, the number of screened papers was appropriate.

We did not do quantitative analysis on the results, which can be considered also as a limitation. For example, relative weights of diverse stakeholders addressed in the papers on different co-concepts could have been interesting. Such information is already provided in previous reviews close to our topic ([Lee et al., 2024](#); [Nguyen et al., 2024](#)). Furthermore, our qualitative approach and use of inductive content analysis was able to identify similarities, differences between the four concepts, and also allowed us to propose new sharp definitions for those concepts to make sense of the mess of the co-concepts used widely in NBS literature. However, we did not review all the co-concepts used in the NBS literature (e.g. co-development, co-planning, co-monitoring, co-evaluation, co-benefits).

6. Conclusion

This integrative exploratory and qualitative literature screened 93 papers on co-creation, co-design, co-production and co-governance concepts used in connection to NBS. Our analysis found that key differences between the co-concepts relate especially to the targeted output of the collaboration, and on how the collaboration is envisaged to happen across the four co-concepts. Furthermore, based on the results, we also propose definitions for these co-concepts (Table 10), and illustrate their linkages in graphical way (Graphical abstract). This can help to bring conceptual clarity on the use of co-concepts in NBS literature, and also beyond. Sharper definitions can also lead to better quality of design, implementation of NBS, and finally the impact of NBS. This is especially important in the era when co-concepts are increasingly used without clear definitions on their meaning. While collaboration related to co-concepts is certainly promising and under hype in science and also policy, the co-concepts do not offer easy way out nor magic bullet for the pressing sustainability challenges of our times. Yet, detailed understanding of the co-concepts, and careful planning on how to operationalize them in NBS planning and implementation offers a viable alternative for technocratic or top-down approaches to NBS. Co-concepts emphasize need to plan and implement NBS together in a way that recognizes particularities of the peoples, multispecies actors, places and problems to which NBS are supposed to deliver solutions.

CRedit authorship contribution statement

Klůvankova Tatiana: Writing – review & editing, Funding acquisition, Conceptualization. **Ojala Ann:** Writing – review & editing. **Mishra Himansu:** Writing – review & editing. **Spacek Martin:** Writing – review & editing. **Sarkki Simo:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Soini Katriina:** Writing – review & editing, Project administration, Funding acquisition. **Pihlajamäki Mia:** Writing – review & editing, Project administration, Methodology. **Hiedanpää Juha:** Writing – review & editing, Validation, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Juha Hiedanpää reports financial support was provided by Horizon Europe. Tatiana Klůvankova reports financial support was provided by Slovak National Research Agency. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The work for this paper was done within Coevolvers (Coevolutionary approach to unlock the transformative potential of nature-based solutions for more inclusive and resilient communities) Horizon Europe project, Grant agreement ID: 101084220. We also acknowledge project VEGA, Slovak National Research Agency NO 2/001825. For graphic design, we acknowledge creative contributions by Daniel Fonagy.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.envsci.2025.104073](https://doi.org/10.1016/j.envsci.2025.104073).

Data availability

Data will be made available on request.

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