

Constructing a conceptual understanding of transformative change in the biodiversity nexus

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1. Introduction

BIONEXT is an innovative research project that produces action-oriented knowledge to halt biodiversity loss. The project demonstrates how biodiversity underpins every aspect of life through the nexus elements of water, food, climate, health, energy, and transport. BIONEXT's goal is to mainstream biodiversity into policymaking and provide concrete options on how to initiate, accelerate, and upscale biodiversity-relevant transformative change in society. Transformative changes are fundamental shifts in the way we think, act, and organise our society. A change is only transformative if it shakes up ecological, technological, and socio-economic systems. BIONEXT work package 2 'Triggering Transformative Change' aims to find what that change is and how we can set it in motion. And, how we can monitor and evaluate transformative change.

The aim of Work Package 2 is to create a conceptual understanding as a basis for the project. In this conceptualisation we build on literature on transformative change, spanning all nexus elements. Building on this literature review, we create an understanding of transformative change in the biodiversity nexus. In addition, this task will work towards defining "signposts for change" – which can be understood as seeds of the future in the present – that can be used to identify practices that have transformative potential.

This has been explored through an extensive literature review of transformative change in research describing the nexus elements; to map an understanding of transformative change across these nexus elements and identify how they relate to biodiversity; and illustrate necessary changes for and obstructions to transformative change in the nexus.

2. State of the art on transformative change

2.1. The need for transformative change in the biodiversity nexus

The world is confronted with pressing global crises such as climate change, biodiversity loss, and growing inequality (Vogel and O'Brien 2022). Scholars are increasingly united in the belief that the enormity, urgency, complexity, and interconnectedness of these crises make it impossible to continue a 'business-as-usual' trajectory if we are to ensure both biophysical and social well-being (Shove et al. 2012; Feola 2015). In response, the scientific and policy communities have become more attentive to the need for transformative changes in socio-ecological systems and deliberate steps towards sustainability over the last few decades (Bennett et al. 2019).

When highlighting the urgency of the biodiversity crisis, scholars build upon scientific evidence that demonstrates the worldwide deterioration of biodiversity and ecosystems, while underscoring the dependency of human existence on the functioning of natural systems (IPBES 2019; Díaz et al. 2019). Central to research that aims to understand these relations is the 'nexus' approach, which entails “A perspective which emphasizes the inter-relatedness and interdependencies of ecosystem components and human uses, and their dynamics and fluxes across spatial scales and between compartments. [...] In such complex systems there are trade-offs as well as facilitation and amplification between the different components” (IPBES 2019). To comprehend the loss of biodiversity, researchers generally distinguish between direct and indirect anthropogenic drivers. Among the most influential direct drivers are climate change, natural resource extraction, land-use change, invasive alien species, and pollution (Elbakidze et al. 2018; IPBES 2019), while indirect drivers encompass demographic, sociocultural, economic, technological, and institutional factors (Visseren-Hamakers et al. 2021).

Advocates of transformative change argue that previous conservation efforts have proven insufficient in reversing biodiversity loss due to their inadequate response to many of the underlying drivers (IPBES 2019). As a result, the primary goal of transformative change for biodiversity is to tackle these drivers, with a specific focus on the indirect ones, often termed as the root causes, which are deeply influenced by societal values and behaviours (Díaz et al. 2019).

2.2. Conceptualizations of transformative change

Due to the increasing recognition of the necessity for transformative change, the terms 'sustainability transformations' and 'transformative change' have become firmly established concepts among both scientists and policymakers (Scoones et al. 2020). However, the interpretations and applications of these terms differ significantly across various disciplines (Feola 2015). In the following sections we will first give a brief overview of the main conceptualizations of transformative change and the main applications of the concept in the academic community. Last, we will give a brief overview of the use of transformative change in the context of biodiversity.

2.2.1. Dominant perspectives to transformative change

The concept transformative change is generally understood as a “*fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values*” (IPBES 2019). Understandings of transformative change stem roughly from three prominent perspectives: social-ecological systems, sustainability transitions and political ecology.

Notable is that the terms transition and transformation are often used interchangeably. Some authors stress the differences between the two: Eckersley (2022) and Hordijk et al. (2014) for example, argue that transitions, due to its sectoral focus, imply incremental changes and are less radical and systemic than transformations. A review by Hölscher et al. (2018) shows that the differences in concepts do not necessarily lie in a difference in radicality, but mostly stem from different framings used by different research communities. The elasticity of the use of concepts like transitions and transformations makes it hard to make a clear distinction between them (Feola 2015).

Sustainability transitions

Sustainability transitions is an interdisciplinary approach to societal changes that occur over multiple decades (Loorbach et al. 2017). Transition scholars generally analyse social, technological, and institutional changes within a societal subsystem or sector such as the energy sector. Change is understood as a phased and multi-level process where different levels (niche, regime, landscape) influence changes toward the reconfiguration of a new regime. A large focus within this field is on initiating processes of change through transition management, which entails experimentation and the development and scaling of (social) innovations at a niche level. More recently attention has broadened to breakdown of unsustainable regimes and the role of power in transitions (Markard 2018; Davidson 2019; Hebinck et al. 2022).

Social-ecological systems

The social-ecological systems perspective is largely centred on the analysis of system properties such as resilience and adaptation against perturbations or crises, whether naturally occurring or human-induced (Patterson et al. 2017). Transformations were initially perceived as outcomes of disturbances that exceeded a system's adaptive capacity, whether ecological, economic, or social in nature (Fougères et al. 2022). Over time and through contributions from various disciplines, this perspective has broadened its scope, leading to improved understandings of the social component of social-ecological systems. While transformations were initially seen as emergent processes, it is now acknowledged that desired transformations contribute to increased resilience of systems (Folke et al. 2010; Patterson et al. 2017). In this, there is an increasing focus on 'transformative capacities' in social-ecological systems literature, responding to the idea that transformation cannot be steered but rather be 'navigated' (Moore et al. 2018). Additionally, the processes of transformations can be guided by deliberate and socially complex approaches to learning and decision-making (Fougères et al. 2022).

Political ecology

Perspectives within the political ecology cluster do not constitute a separate and distinctly defined field like sustainability transitions and social-ecological systems. Instead, they form a cluster of critical social science perspectives on transformative change. Scholars within this field emphasize the potential risks associated with promoting changes that still operate within existing hierarchies of knowledge and power (Massarella et al. 2021). Instead, they advocate for 'axial change', which involves breaking free from the status quo by questioning the entire system to uncover innovative and radical approaches to transformation (Massarella et al. 2021). From the perspective of political ecology, the most significant contributions lie in providing valuable insights on themes such as politicizing change, challenging hegemonic power structures, and addressing issues of (in)justice (Patterson et al. 2017; Temper et al. 2018; Massarella et al. 2021).

2.2.2. Compatibility of the three disciplinary understandings of transformative change

The three main perspectives are not inherently exclusive of each other. They primarily emphasize different aspects of transformation. Transitions literature typically begins with sectors as a basis, while social-ecological systems usually adopt a place-based approach. Perspectives within the political ecology cluster do not necessarily oppose other fields; instead, they draw attention to the deficiencies or risks linked to the existing body of knowledge and prevailing dominant approaches. This does not mean that the concept transformative change is uncontested. Within and across all perspectives debate remains on the desirability and effectiveness of certain deliberate processes of change and the directionality and radicality of the transformative changes being advocated (Feola 2015). In the following sections we outline some of these different approaches in literature.

2.3. Use of and critiques to transformative change in literature

The contested nature of the concept transformative change has also resulted in diverse approaches to researching transformative change in the literature. For example, while some focus on the cause or need for change, others explore the mechanisms that allow transformative change to take place. Often more than one approach to exploring transformative change is applied at the same time.

The most prevalent approach in the literature to exploring transformative change category is one that sheds light on the issues and crises prevailing in societies and advocate the need for change. This category displays contributions from diverse disciplines and is often driven by a “sense of urgency” (Bentz et al. 2022). However, scholars warn for the conflation of the ‘what’ and the ‘how’ of transformative change and to assume that “*once we know what needs to be done, then mobilization, organisation, decisions, and action will follow*” (Bentz et al. 2022, p. 498). In other words, the knowledge of *what* needs to change by itself – e.g., a need to reduce emissions 40-50% by 2030 (Rockström et al. 2017) – does not automatically result in action.

Only recently, more literature focuses on *what* needs to change and *how* such change might unfold and can be fostered. Depending on the school of thought, these are embedded in different ways of understanding the system. For example, the work that understands change processes as unfolding in a ‘non-linear’ way and thus being complex and uncertain, such as the sustainability transitions literature and the social-ecological systems literature, often explore patterns of change through a focus on properties such as complexity, path-dependency, emergence, and contestation (e.g. Hölscher et al. 2018). Literature oriented at the analysis of complex systems, similarly, see change as non-linear, complex, and uncertain, but tend to focus on what aspects influence systems: such as drivers and barriers. These factors encompass both practical aspects, like the availability of resources (Dawson et al. 2017), and systemic characteristics such as the ‘vested interest’ of institutions (Termeer et al. 2015).

Literatures combining both the ‘what’ and ‘how’ of transformative change investigate types of changes and actions that have the potential to result in transformative change. This requires both an idea of the required (or desired) change and an understanding of how change unfolds. Literature that both acknowledges the emergent nature of transformations and the agency to drive transformative change, explore the potential for deliberate interventions and actions (Olsson et al. 2014; Massarella et al. 2021). However, significant variations can be observed in the interventions proposed, spanning from technological innovations to policy measures and social innovations (Dias and Partidário 2019;

Dorninger et al. 2020). Literature outlining the interventions often makes the connection to the types of changes that the interventions should initiate, such as such as changing norms and values, shifting power dynamics, modifying behaviours, and bringing about institutional and political transformations. These proposals span a spectrum of radicality: from gradual incremental adjustments and reformation of existing structures to more revolutionary and transformative shifts (e.g. as discussed in Burch et al. 2014; Geels et al. 2015).

Lastly, a growing group of scholars focusses on the direction of change – or directionality, which revolves around envisioning desired futures or the critical interrogation of where the current course of change is leading towards (Muiderman et al. 2022). Especially in the literature exploring desired futures, the primary emphasis is on striving for sustainable societies and, in numerous instances, societies that prioritize justice and equity (Bennett et al. 2016). Whereas critical interrogation of futures, departs from the understanding that all claims on the future (and thus transformation) are political interventions that hold performative power (Jasanoff and Kim 2015) and aims to uncover how they might exclude certain choices, trajectories, or futures (Muiderman et al. 2022).

2.3.1. Main critiques voiced about transformations literature

As transformations and transformative change have become increasingly popular themes in research, they are also subject to critique. Feola (2015) argues that while criticism can signal a vibrant field within the social sciences, it also poses a particular risk when it comes to transformative change.

“[T]he high conceptual elasticity and lack of empirical grounding of the concept of transformation generate the risk of voiding the term of meaning, and consequently easily co-opted by actors who aim to defend the status quo rather than promoting radical societal change” (Feola 2015, p. 377).

Similar dynamics were noted around the use of ‘sustainability’, when use of the term has mainstreamed in diverse scientific communities and societal groups, although with diverse meanings and through diverse approaches (Scoones 2007). Much like the use of sustainability, both transformation and transformative change are susceptible to legitimizing existing or new structures of power that uphold ‘business as usual’ in disguise (Blythe et al. 2018). For example, it may be used by authorities to promote change that serves their own interests or gain public acceptance without questioning distributional consequences. Fougères et al. (2022) demonstrate how the ‘UN 2030 Agenda for Sustainable Development’, the ‘Post-2020 Global Biodiversity Framework’, and ‘Nature 2030’ use the term transformative change in a way to maintain or expand their power over biodiversity, territory, and people. The understanding of transformative change is often modified when translated into policies and practices, risking loss of its transformative potential and raising questions about how these may shape social, political, and environmental change in reality (Blythe et al. 2018; Fiasco and Massarella 2022).

Some scholars assign the lack of empirical grounding of the concept to an insufficient understanding of the processes of transformative change. They argue for the need for effective strategies and interventions to facilitate and put such changes in motion (Feola 2015; Bentz et al. 2022). Bentz and colleagues (2022) criticize the disproportionate attention given to the ‘why’ aspect of transformation, neglecting the crucial ‘what’ and ‘how’ aspects. Consequently, ‘what’ the problem exactly is and ‘how’ it can be resolved remain obscure, as well as the plurality of perspectives to the ‘what’ and ‘how’ that may exist (Blythe et al. 2018). This can explain why policies and interventions aimed at transformative

change tend to get stuck between the ambitions of change on the one hand, and the 'real-life' perceptions, experiences, norms, choices, and practices of society on the other (Gollata and Newig 2017). In addition, Tschakert et al. (2013) argue that processes of transformative change are hampered by insufficient knowledge on vulnerability dynamics, which are required to address fundamental and relational drivers of injustices. In a similar vein, scholars critique the use of transformative change that implicitly assumes that its outcomes are of universal benefit, overlooking losers of change (Blythe et al. 2018; Forsyth et al. 2022). In such cases, the positive effects of change tend to be uncritically embraced rather than subjected to critical analysis.

Other scholars warn that the limited awareness of the consequences of transformative change has resulted in insufficient attention to complex legal and institutional circumstances that shape governance of transformative change (Heffron 2021). Transformative change implicitly or explicitly relies on cognitive and normative framings of problems, which in turn guide normative and instrumental biases in governance approaches to transformative change. Such biases may be reproduced in the introduction of new norms, values, technologies, knowledge, expertise, principles, rules, and laws to regulate the direction of change. It is essential to consider how relationships between power and resources can influence changing forms of access and control, identifying who benefits and who loses in transformative change (Burch et al. 2014; Blythe et al. 2018; Fougères et al. 2022). Such considerations encompass for example factors like efficiency, productivity, trade-offs, equity, social and legal security, and recognition. Moreover, society must understand and accept possible consequences to ensure the public supports and acts towards a transition (Heffron and McCauley 2018). Especially with transformative change being co-opted by 'business as usual perspectives', there is the risk that the necessary radical change is not achieved.

Science is expected to play a significant role in reshaping the dominant social paradigm on change and intervening within the sustainability transformations it seeks to understand (Fazey et al. 2018). For example, by addressing underlying drivers of unsustainability (Blythe et al. 2018), and introducing new options and incentives to catalyse transformative change (Ehrlich et al. 2012). The conceptualization of transformative change ideally maintains the flexibility to accommodate diverse perspectives, while retaining its robustness to uphold its radical essence (Scoones et al. 2020). Science being both part of and intervening in processes of transformation, places an enormous responsibility on researchers to be critical and reflexive (Popa et al. 2015; Fazey et al. 2018). Building on these critical perspectives, researchers who advocate for transformative change within the biodiversity nexus must critically engage with the following 'red flags':

1. The concept "transformative change" is vulnerable to being co-opted by existing or new structures of power, possibly reinforcing the status quo. Uncertainties persist regarding the true meaning and potential impact of transformative change, especially when it interacts with different actors;
2. The concept of transformative change faces challenges stemming from a lack of empirical grounding and insufficient understanding of the underlying processes of change;
3. Inadequate knowledge on vulnerability dynamics hampers transformative change efforts, while an implicit assumption of universal benefit neglects critical analysis of potential outcomes;
4. The existing academic literature on transformative change often lacks awareness of its broader consequences, particularly within complex legal and institutional contexts;

5. The urgency of climate change and biodiversity loss necessitate an understanding of transformative change as being both rapid and fundamental. Science has a pivotal role in demonstrating the ‘what’ and ‘how’ of such fundamental changes.

2.4. Analytical approaches to transformative change

As the review on transformative change highlights, transformative change is a contested concept. The proliferation of the concept of ‘transformative change’ leads to approaches placing diverse emphases within the process of change: ranging from actor-configurations, the role of institutions, or to system dimensions. To come to a conceptual understanding of transformative change in the biodiversity nexus, we need to explore what the concept means and how it is used across diverse research communities.

In order to map these diverse understandings, we build on several academic works that attempt to analyse these different perspectives. We identified three papers which particularly underscore the need for transformative change to address global sustainability challenges and unite in the critique that existing paradigms and approaches to sustainability transformations do not provide sufficient insight into effective ways to achieve transformations.

Table 1. Analytical approach to transformative change of the three papers used as conceptual input for the analysis

Source	Analytical focus to transformative change	Conceptual input for the analysis
Feola (2015)	Differences and similarities among concepts of transformation based on their ‘anatomy’. Outlining how they approach the ‘system model’, the ‘form and temporal range’, the ‘seat of causality and social consciousness’, and the ‘outcome’.	<ul style="list-style-type: none"> • Exploring the ‘moving force behind the change process’ by focussing on the enablers and disablers to change • Focus on outcome of transformative change by focussing on the envisioned transformation • Reflect on the extent to which the understanding includes issues of social justice
Dorninger et al. (2020)	Analysis of types of interventions through a ‘Leverage points’ analysis resulting in four clustered scientific approaches to transformative change and interventions. Outlining how they consider fundamental aspects of the system (rules, values, paradigms).	<ul style="list-style-type: none"> • Exploring the values and paradigms embedded in the understanding of transformative change by focussing on the ‘problem framing’ • Structuring the analysis along the lines of clusters of scientific approaches that consider similar fundamental aspects
West et al. (2020)	Comparison of transformative change through a relational perspective, a complex coupled systems perspective, and a modernist perspective. Outlining the understanding of dynamics of change, human-nature connectedness, and proposals for transformative change.	<ul style="list-style-type: none"> • Exploring the relation to nature (and biodiversity) by attributing agency or not • Focus on proposals for transformative change by exploring solution spaces

The first is the article by *Feola (2015)*, who argues that the diverse understandings of ‘transformative change’ influence how one conceptualizes the system, the role and space for agency within that system, and what outcomes should be pursued through transformative change. These understandings, in turn, will define what the ‘end state’ of transformation might look like and through what means it might be achieved.

Dorninger et al. (2020) similarly argue that it often remains unclear what concrete interventions for transformative change exist, hindering the replication or scaling of promising interventions. Based on a systematic literature review, they uncover several clusters of scientific approaches and their ‘bias’ towards a particular solution space: an ‘engineering’ cluster characterized by technological solutions, a ‘technocratic’ cluster with an emphasis on policy solutions, a ‘sociopolitical’ cluster that focuses on solutions that address social problems, and a ‘social-ecological’ cluster that looks at solutions that have an ecological problem framing. They argue these clusters differently consider fundamental aspects of the system, such as its rules, values, and paradigms.

Lastly, we turn to *West et al. (2020)* who argue that the ‘conventional’ systems perspective to transformative change risks reproducing the separation between the ‘social’ and the ‘ecological’ as embedded in currently dominant system structures, and risks overlooking the continuously changing relations and processes between (non-)human entities. This in turn, limits the transformative potential of insights drawn from such research. They propose that a more relational approach to transformative change, might enable a more dynamic and place-based understanding of processes of change.

These three papers each provide ways to approach the fragmentation of the literature and the ability to derive useable knowledge from transformations literature. Following their insights (see **table 1**), we see a need to review the literature for the following elements:

- the framing of the system that is to be transformed and the mechanisms of change within that system
- the ‘problem’ that that transformative change is expected to address, and which shapes the envisioned outcome of transformation
- the solution spaces that these understandings of transformative change propose, including their enabling and disabling factors
- the extent to which transformative change link to biodiversity and justice

Based on these elements we answer the following research question: How can transformative change be fostered according to the research communities working on one or more of the seven nexus elements (water, food, energy, transport, biodiversity, climate, health)?

3. Methodology Setting up the literature review

The overall goal for this literature review was to provide an extensive review of literature spanning the nexus elements of water, food, energy, transport, climate, and health and to map these fragmented understanding of transformative change to understand how they considered change to unfold. We formulated the research questions as listed in **table 2** for this literature review.

Table 2. Research questions for the literature review

Main research question	How can transformative change be fostered according to the research communities working on one or more of the seven nexus elements (water, food, energy, transport, biodiversity, climate, health)?
Sub questions	<ul style="list-style-type: none"> • How do they conceptualize transformative change? • What do they describe as enablers of and disablers for transformative change? • How do these conceptualizations of transformative change link to the biodiversity nexus? • How do these conceptualizations of transformative change link to justice?

A search string to collect literature was developed based on this question (for details on the search string and flow diagram of the selection process, see **Annex I.i**), which yielded 849 articles. In the initial round of analysis (referred to as 'Phase A' in the literature review flow chart, see **Annex I.i**), all articles were reviewed for eligibility, meaning their title and abstract were screened for: 1) including focus on one or more of the nexus elements through a systems perspective; 2) describing transformative change in an operational sense, which includes information on end-states, visions, crucial mechanisms of change, and or actors. This resulted in 142 papers (see **Annex I.iv**) that were selected for a full-text review (referred to as 'Phase B' in the literature review flow chart, see **Annex I.i**).

3.2. Conducting the review

In this review, we set out to analyse how transformative change is understood in diverse research communities that do research on the seven nexus elements and what change they argue is required. Based on a review of seminal works on transformative change (**Table 1**), we conclude that the following aspects are of interest:

- the framing of the system that is to be transformed and the mechanisms of change within that system
- the 'problem' that results in the need for transformation and the envisioned outcome of transformation
- the solution spaces that these understandings of transformative change propose, including their enabling and disabling factors
- the extent to which transformative change link to biodiversity and justice

To enable review of the selected papers, we developed a set of questions to probe for these points of interests (see **table 3**). These questions were entered into a *Google Form* to streamline the review process and included both multiple-choice and open questions (see **Annex I.ii** and **I.iii**). The form included instructions to – where possible – capture quotes or sections of texts from the paper. The results from the review were then captured in an excel-based database. Subsequently, 118 papers were included for in-depth analysis and transferred to *Atlas.ti* to enable coding by the author team. The reviewed papers were coded within context, meaning that the review was uploaded per article-ID, rather

than in bulk form per sub-question. To supplement the review, 45 additional articles were added based on the reviewer's expertise of the field (see **Annex I.i** and **I.v** for a full list of the additional papers). These articles were not included with the search string but were deemed of high relevance to the review.

Justice was included as the points of interest in the question with respect to nexus elements, even though it is not considered a nexus element as such. Rather, justice is generally perceived as a cross-cutting dynamic (Whitfield et al. 2021). Given one of the key critiques to the literature on transformative change is the overlooking of issues of justice, we have included it as one of the multiple-choice options for the review to scope to what extent the reviewed articles pay attention to matters of justice.

Table 3. Questions used to assess transformative change in the full-text review, using a mixture of open-ended and multiple choice questions

Inquiry	Sub questions/categories
What nexus element(s) are captured in the paper? Which one does it prioritize?	Water, food, climate, energy, transport, biodiversity, health, justice, no priority
Does the paper describe nexus interlinkages and/or transformative change(s) in relation to biodiversity?	
How does the paper conceptualize transformative change?	if possible, a quote
Does the paper describe the transformed state or a desired future vision?	if possible, a quote
Does this transformation include change of incumbent structures?	
What type of changes does this transformation require?	Environmental, political and/or institutional, policies and policy instruments, economic and/or private sector, infrastructure, technological, cultural, behavioural, scientific, justice, health
What enablers of transformation are described?	What: opportunities, levers for change, triggers, disruption. How: processes, conditions, options for change, actions, strategies, solutions, alternatives. Who: actors, sectors, regions, states, institutions.
What obstacles to or disablers of transformative change are described in the paper?	What: opportunities, levers for change, triggers, disruption. How: processes, conditions, options for change, actions, strategies, solutions, alternatives. Who: actors, sectors, regions, states, institutions.
Does the paper describe elements of justice? What type?	Foreseen consequences, unforeseen and/or unintended consequences, key role for certain (non-human) actors

3.3. Coding and analysing the review

The coding of the review was conducted in *Atlas.ti* by the entire author team, utilizing the coding tree presented in **table 4**. A first draft coding tree was developed based on an additional literature review on the analytical approaches to transformative change, along with the overarching emphasis of the first IPBES Global Assessment on Biodiversity and Ecosystem Services (2019). These aim to capture the diverse approaches to transformative change as summarized in chapter 2.2 and 2.4 of this deliverable: the *why* of transformative change, the *what* of transformative change, and the *how* of transformative change. These included drivers for change, possible futures and, opportunities and challenges for

Table 4. Preliminary coding scheme

Codes	Corresponding Subcodes	
Context of the paper	Infrastructures Governance Social practices Societal functions	Commodification Scientific community Human-Nature Relations Commodification
Problem to be addressed	Norms and values, including dominance of anthropocentric values Power imbalances and social inequalities Specific unsustainability (i.e., GHG, energy use) Dominance of the economic growth paradigm	Governance problem Persistent, unsustainable regimes Market failure Colonial and post-colonial systems Dominance of companies
Solution space	Policy solutions Governance Behaviour change (of individual/consumer) Social innovations / alternative practices Changes in values / non-anthropocentric world views / nature positive solutions	Contestation / politicisation / activism (contesting the current way of doing) Regime shift (ecological or socio-economic) Research agenda / approach Technical solutions Social justice and equality/equity
Critiques	Social justice as a blind spot Concept used / co-opted for technological change	Universalism of the concept (i.e., unanimous with sustainability) Concept used in a narrow sense
Enablers of change	(Positive) narratives and visions Alternative modes of governance (i.e., collaborative, adaptive, deliberative) Information sharing Behavioural change (among citizens/consumers) Crises and shocks Capacity building Cross-sectoral collaboration Knowledge co-production Engage with politics and power New business models/innovations	Experimentation and scaling of good experiments Research approaches (how we do research) Scientific knowledge Market interventions such as economic/financial/policy instruments Regulatory and legal policy instruments Social innovation Technological innovation Spatial planning and resource management Strengthening social resilience or empowering people
Enabling actors	Actors in the knowledge sector Citizens Local/indigenous communities, minorities Multilateral arenas (e.g., United Nations)	Civil Society Organisations, Non-Governmental Organisations, and social movements Private sector Public sector
Disablers of change	Anthropocentric values and worldviews Broader societal processes (e.g., digitisation, population growth) In-effective policy and governance structures Lack of behaviour change and uptake Lack of knowledge (i.e., science or multi-stakeholder) Lack of (uptake of) technological innovation	Lack of transparency and/or accountability Lack of inclusion and/or participation Lack of capital and resources (i.e., labour, finance) Lock-in of physical infrastructures Lock-in of socio-economic pathways Unaddressed root causes Vested interests and/or power dynamics
Disabling actors	Actors in the knowledge sector Citizens Local/indigenous communities, minorities Multilateral arenas (e.g., United Nations)	Civil Society Organisations, Non-Governmental Organisations, and social movements Private sector Public sector

change. Based on this initial coding tree, all authors coded a portion of the articles that were assigned to them.

After having partially coded the data, the author team convened to discuss and revise the coding tree in detail (**table 4**). As a result, the coding tree included the 'Problem to be addressed' code to capture the 'why' of transformative change; it included codes on the 'Solution space' and 'Critiques' to capture the 'what' of transformative change; and the codes 'Enablers of change' and 'Disablers of change' were used to capture the described 'how' of transformative change. For the latter two groups, a separate category with actors was included, arguing that all actor categories can be perceived as enabling and/or disabling change. For each of the code groups, a set of subcodes was drawn up that was informed by our reading of the full-text literature.

During this meeting it was also concluded that several reviewed questions did not yield sufficient or relevant information and should thus be excluded. This included the question and code for visions for change, which included sub-codes such as green economy, good governance, eco-modernism, post-growth, etc. This question was omitted from the analysis, since the review data (and the original papers) often did not specify explicit enough what visions for change their proposed understanding of transformative change included. To structure the review, it was decided to add a code to capture the ways the papers anchored their analysis to specific socio-material features. These were defined as 'context of the paper' and included governance, human-nature relations, scientific community, infrastructure, social practices, societal functions, commodification. See **table 4** for the final coding tree used to on the 118 reviewed papers.

Clusters based on analytical anchoring

The reading and coding of the papers made evident that in the dataset 'transformation' and 'transformative change' was often used loosely to refer to profound, more-than-incremental change. The papers lacked a common theoretical and methodological footing. The screening had brought together a large diversity of analyses focusing on different countries, settings, and societal spheres. It was evident that this diversity had to be somehow sorted out to allow meaningful analysis of the papers. Fortunately, it was possible to identify some recurring commonalities between the papers based on the ways the analyses were anchored to specific socio-material features. This thematic focussing signalled where the papers located the variables and interactions critical for the unfolding of transformative change. Often the subject matter dictated how the anchoring was done. For example, scholars of urban water systems tended to analyse transformative change in relation to (water) infrastructures while policy researchers anchored their analysis to the operations of the public government. Nonetheless, the link between academic disciplines, nexus dimensions and analytical anchoring was not straightforward. Therefore, the data-driven typology of the modes of analytical anchoring was used to cluster the papers for further analysis, see **table 5**. The six anchoring-type clusters look at transformative change in the same context; their grouping is mostly based on a thematic pattern and emphasising parts of transformative change within the wider system, but each group contains a wide disciplinary diversity. We did not distinguish distinct fields of research (e.g., political economy or anthropology) which could overlap with each of these clusters.

Interpreting the results

To interpret the results, the coded papers were clustered by an anchoring-code, leading to 6 clusters of reviewed papers and associated codes. The clusters were divided among the authors, where large clusters were assigned to 2 or 3 authors. Based on the coded reviews, the authors formulated a 'narrative of change' for each of the clusters. These clusters were then reviewed by other members of the team, to ensure validation of the results. While justice is not included as a nexus element, this review and analysis does. This to emphasize and explore the extent to which clusters of papers pay attention to justice in transformative change.

Based on the narratives, a cross-cluster analysis was conducted to explore the commonalities and differences between the clusters. Based on these cross-cluster insights, the team developed recommendations and insights for transformative change research and the project.

Table 5. Overview of anchoring types used to cluster the reviewed papers

Anchoring types	Descriptions used to assign the anchoring types
Governance	Describing the processes, structures, and instruments through which policies and regulations are enacted, authority exercised, and governance networks coordinated. Papers within this cluster focus on achieving transformative change through governance.
Human-nature relations	Describing the interactions, connections, and interdependencies between human beings and the natural environment. This includes paper that focus on the way humans perceive, interact with and impact on the natural world, but also the vice versa: how nature might influence society.
Scientific community	Describing the agenda, approaches, and general conduct of the scientific community in a broad sense: any actor who conducts research and generates scientific knowledge. Papers included in this cluster describe how the scientific community influences transformative change, how the scientific community should perceive or reflect on transformative change, but also how research can play an active role in fostering transformative change.
Infrastructures	Describing the physical and organisational systems and facilities that enable systems to provide functions, services, or outputs. E.g., the infrastructure needed for fresh water supply. Papers included in this cluster describe how infrastructures relate to transformative change or how they should be adapted to enable transformative change.
Social practices	Describing the everyday actions, behaviours, and activities of individuals and communities to meet needs, interact with others, or shape norms and routines. Papers included in this cluster describe how social practices relate to transformative change and how transformative change can be achieved through everyday actions, behaviours, and activities.
Societal functions	Describing the essential roles, tasks, and activities that contribute to the functioning and stability of a system and that ensure the wellbeing of society. E.g., food security, health care or water management. Papers in this cluster focus on how transformative change is needed to ensure societal functions and what actions might enable such transformation.

3.4. Limitations to the review

The search performed to conduct the review was systematically structured, although limited by time constraints. The search strings used were designed to capture documents dealing with both transformative change and at least one of the nexus items. However, search strings were limited in that they did not include synonyms for both transformative change and for the nexus elements. For example, this meant that literature covering adjacent fields that are influential to transformative change were not included, such as sustainability transitions literature. Moreover, given the high number of documents retrieved, a selection was operated to focus on the most recent and most cited publications (further information in **Annex I.iv**). Overall, the results from this deliverable are based on a review of key scientific articles dealing with transformative change in relation to nexus dimensions, although by no means it is meant to be an exhaustive analysis of all the relevant material on the topic.

The focus on nexus elements that have a predominant natural science focus (e.g., food, water, health, energy, transport, biodiversity, climate) in combination with transformative change also meant the exclusion of articles that explore transformative change in topics more common to social sciences. For example, the papers that focus more exclusively on the role of social movements and contestation in transformative change or a focus on processes of decline and break-down as a crucial component of transformation processes. The red flags that were identified in section 2.3 are aimed at addressing some of these overlooked themes by way of critical reflection.

In the process of coding the reviewed articles, the author team decided to assign papers to only one anchoring code for analytical and timekeeping purposes. However, in some cases multiple anchoring codes may be relevant to an article. For example, when an article is about modes of governance, but also includes strong reference to scientific implications. For these papers, an additional review of the anchoring clusters was included in the process, to ensure the most relevant label was assigned.

4. Results of the review in clusters

The six anchoring-type clusters capture different nexus elements within parts of the transformative change process occurring across various levels (ranging from global to individual) and addressing various aspects of a system (such as energy production, food provisioning, etc.).

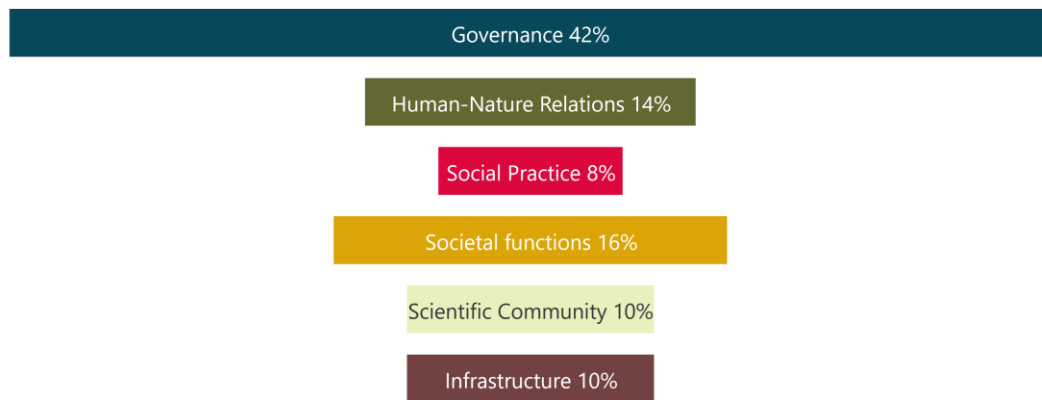


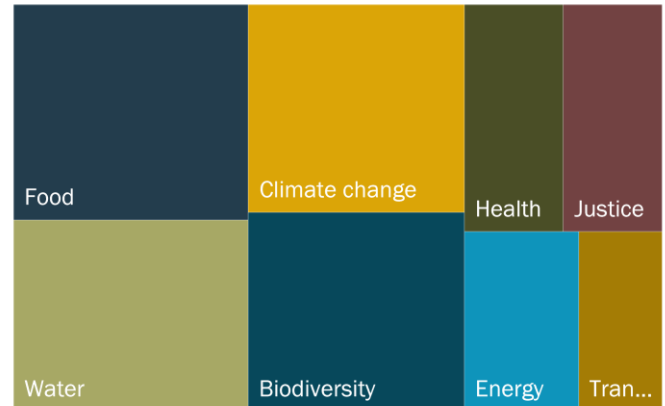
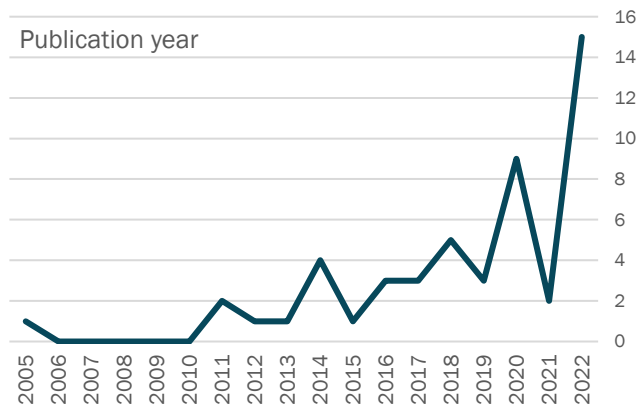
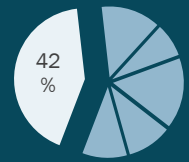
Figure 1. Overview of the spread of literature across the [clusters of scientific approaches] to transformative change

The 118 papers that were used for the full-text review had a rather unequal spread across the anchoring types. Most papers (42%) were labelled with ‘Governance’, meaning they described governance processes, structures or instruments, and networks key to achieving transformative change. Encompassing almost half of the reviewed papers, we can conclude that governance is a dominant theme within the field of transformative change. The other anchoring clusters ranged somewhere between 8-16% of the publication set, meaning they were far less influential to the results than the Governance cluster (see **Figure 1**).

In the next section we present each of the anchoring clusters in a structured manner. These results demonstrate the range of publication dates of the included full-text papers, the spread in nexus elements that have been mentioned across the entire cluster, and a summary of the coded review. This summary includes a rough description of the scope of the papers, or what the general line of inquiry was of these papers. Furthermore, the essence of the conceptualisations of transformative change, the perceived root causes of unsustainability and disablers of change, and the proposed solution spaces and enablers of change are presented. The most mentioned codes have been used to create a narrative: aiming to capture how it is understood in a more general sense across the cluster. However, none of the paper clusters show a unanimous understanding of change, meaning that these narratives to some level generalize the results. Even though these more general understandings of transformative change are useful to understanding the diversity of approaches to transformative change, the category ‘notable’ is used to capture any noteworthy outliers or differences of opinion within the cluster.

Transformative change in literature on

Governance



Selected articles illustrative of the cluster

- Visseren-Hamakers et al. (2021) *Transformative governance of biodiversity: insights for sustainable development*. *Current Opinion in Environmental Sustainability*. 53, 20-28.
- Pascual et al. (2022) *Governing for Transformative Change across the Biodiversity-Climate-Society Nexus*. *BioScience*. 72:7, 684-704.
- Pahl-Wostl (2019) *Governance of the water-energy-food security nexus: A multi-level coordination challenge*. *Environmental Science & Policy*. 92, 356-367.

Scope of the paper cluster

Papers included in this cluster focussed on transformative change in governance systems. Here, governance was interpreted in a broad sense, meaning it covered diverse societal decision-making processes by a range of societal actors. All nexus elements were covered in this cluster of papers, but with an emphasis on biodiversity, water, climate change, and food.

Conceptualisation of transformative change

The understanding of transformative change in the governance-focused literature is rooted in a system-change perspective. It emphasises the need to re-configure or re-organize the entire system and its interdependent components (i.e., economic, political, cultural, technological, power relations, consumption and production), rather than focussing on a single sub-domain or a sector.

Transformative change is regarded as a non-linear, complex, and emergent process that is hard to predict and manage. As such, action for transformative change is considered more as an ‘evolutionary search process’, rather than purposeful design. This cluster often outlines what aspects of society need to change and how changes come about.

Root causes of unsustainability and disablers of change

The current dominant mode of governance is seen as problematic in this cluster. This includes characteristics such as a lack of a system perspective and lack of ability to connect to diverse values or give space to societal dialogue. While papers covered a range of different countries, governance regimes, and scales, papers within this cluster see the (for their context) dominant governance regime as leading to solutions that are ineffective in the long run, only leading to incremental change and strengthening the status quo.

In some documents, rigidly top-down governance was considered conducive to detrimental path dependency and leading to issues such as: lack of inclusiveness and participation (e.g. democratically developed coherent visions and strategies for development); policy incoherence, ineffectiveness and lack of normativity (e.g. perverse incentives or too short-term investments into sustainable alternatives); deregulation trends and failure of markets and financial systems; disconnect between production and consumption, and between local practices and global commitments; need for knowledge (e.g. evidence on transformative change and investments effectiveness, traditional local knowledge).

The values embedded in dominant policy processes were seen as problematic, such as the focus on a growth-paradigm and inability to challenge vested interests and injustices. Transformative change is disabled by the co-option (i.e., appropriation or 'hijacking') of processes of change towards business as usual, as well as vested interests that are served by keeping the system in its current state. Here, ineffective policy integration and a focus on tech-fixes are mentioned as perpetuating unsustainability. Notable is that the assessment of these persistent and engrained issues is often not unpacked or further problematized – apart from stating they're disabling. Another mentioned disabler in governance was the limited suitability of monitoring frameworks.

Solution space and enablers of change

The required transformative change is described to emerge out of alternative governance paradigms, which especially emphasize the characteristics these new modes of governances should build on. These included an integrated systems-approach (i.e., taking the interconnections between diverse ongoing transition processes into account, for example in food and energy); adaptivity and reflexivity rather than reactivity; accountability and transparency; and inclusiveness and participation (decentralization, stewardship, pluralism). Nature-positive goals and values were also mentioned as a feature of new governance modes, in opposition to mere technological change. In this context, change is enabled for example by changes in the way knowledge and evidence is generated and made available to societal actors (interdisciplinary, transdisciplinary, co-creative), as well as more cross-sectoral collaboration, new business models and social/technical innovations (e.g., agroecology, biomass recycling), policy reforms and integration, changes in values and behaviours (e.g., food consumption).

This cluster sees governance as a key problem, but it also sees solutions in directing it to different modes and strengthening somewhat existing factors – rather than overhauling the foundations that it builds on. For example, by having private sector and wealthy nations take more responsibility for change or by making governance more science-based and inclusive through more knowledge co-production in governance. Enablers of transformative change included for instance the knowledge sector (scientists, educators, skilled workforce), the public sector (policy makers, public procurement),

private entities (farmers, landowners, suppliers, CSOs and NGOs, citizens, local and indigenous communities) and multilateral arenas.

Notable

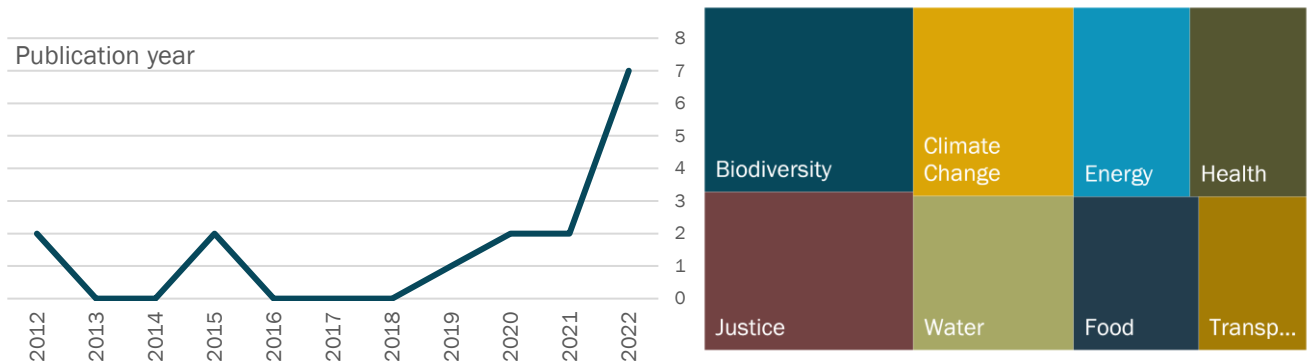
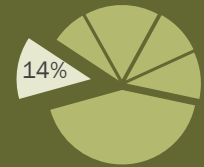
Throughout this cluster, the differences of opinion when it comes to the role of incremental change is notable: Some see incremental change as obstructive to transformative change and possibly even reinforcing existing power relations, while others see incremental change in an adaptive context – allowing to make small adjustments based on real-time information. Here, transformative change is regarded as a learning process where reflexivity is vital.

In addition, what is notable is the signalling of governance as both the problem and the solution. While the cluster still tends to take a complex, adaptive system approach, it rarely ventures into solution spaces that go *beyond* the realm of governance. The extent to which this can result in fundamental change, can thus be questioned.

In that same vein, justice and biodiversity are topics frequently mentioned, but only through the scope of 'governance'. For example, justice is mostly captured by referring to inclusive and participatory modes of governance, while biodiversity is often spoken about as something needing to be 'conserved', managed, and stewarded through governance. These fail to capture the multi-dimensionality of justice and biodiversity, again, questioning the extent to which it can bring about fundamental change.

Transformative change in literature on

Human-nature relations



Selected articles illustrative of the cluster

- Fiasco et al. (2022) *Human-Wildlife Coexistence: Business as Usual Conservation or an Opportunity for Transformative Change?* *Conservation & Society*. 20:2, 167-178.
- Turner et al. (2022) *Well grounded: Indigenous Peoples' knowledge, ethnobiology and sustainability.* *People and Nature*. 4:3, 627-651.
- Lam et al. (2020) *Indigenous and local knowledge in sustainability transformations research: A literature review.* *Ecology & Society*. 25:3.

Scope of the paper cluster

Papers in this cluster focused on the relations between humans and nature either from a conservation perspective or from the perspective of co-evolutionary changes in market logics, institutional frameworks, research approaches, social norms, and behaviour. Most of these papers argued for a shift towards a new value system and criticized the dominant perspective to nature conservation for its exclusion of indigenous and local knowledges and rights, and its anthropocentrism, leading to valuing nature based on the benefits to humans.

Conceptualisation of transformative change

Transformative change in this cluster is often conceptualized according to the definition by IPBES: Transformative change has been defined as “*fundamental, system-wide reorganization across technological, economic, and social factors, making sustainability the norm rather than the altruistic exception*” (Díaz et al. 2019, p. 7). Terms that are used intertwined with transformative change in this set of papers, are social-ecological transformations, systemic transformations, and sustainability transitions.

Processes of change are emphasized to be complex (incremental, abrupt, and interconnected), nonlinear and co-evolutionary, that may develop via contestation, politicization, and polarization. Some of the papers note the desired directionality of transformative changes toward societal wellbeing and strengthening the Earth’s life support systems.

Root causes of unsustainability and disablers of change

This cluster of papers strongly focus on the human pressures on the environment. Driven by population growth and consumption rates, locked into persistent, unsustainable regimes of market logics and industrial developments that are motivated by short-term profits. Yet, changes are equally recognized to be needed in the dominant social norms, behaviours, and practices, as in the political and organizational cultures of governance institutions.

A subset of papers centres on the materialistic values that underpin the capitalist drive for continuous economic growth and the powerful interests of rich actors and countries upholding these as root cause to unsustainability.

Solution space and enablers of change

Papers in the human-nature relations cluster engage with worldviews, values, and priorities in society, science, and governance. They argue for a drastic shift in our mindset towards intrinsic values for nature. Such as embracing relational conceptions of a good life, replacing the unsustainable desire for materialistic consumption. While some papers have a strong focus on values, others outline a broader paradigm shift where social norms, governance and economic models undergo transformative changes.

Governance is perceived to be pivotal for transformative change. Provided that the basis for decision making improves through knowledge co-production by different research disciplines and with local and indigenous actors that aids a plurality in understandings. Furthermore, change is assumed to unfold through governance systems that facilitate capacity building, stewardship, recognize the value of natural capital in developments and regulatory frameworks, and account for social justice and equity. The latter assumes attention to social differentiation, issues of power and participation.

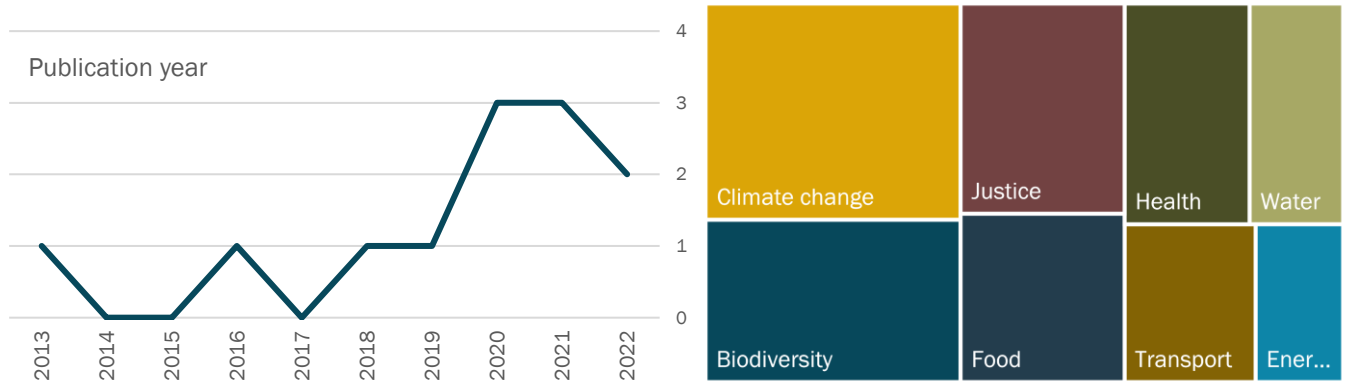
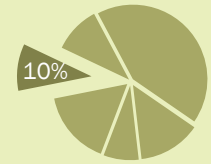
Notable

The Human-Nature Relations cluster of papers see social equity and inclusion are a prerequisite to transformative change and the only way for biodiversity governance to respect the rights of indigenous and local communities and valuing nature's intrinsic worth. As such, much of the literature argue for plurality in knowledge systems, including plurality in understanding transformative change.

Although not always mentioned explicitly, 'struggle' plays a central role in this cluster of papers: emphasising the power imbalances that exist between those that define biodiversity governance and conversation versus those most affected by their impacts. Throughout these papers, various dimensions of social, cultural, political, and environmental justice struggles are described, as well as prescribed.

Transformative change in literature on the

Scientific community



Selected articles illustrative of the cluster

- Massarella et al. (2021) *Transformation beyond conservation: how critical social science can contribute to a radical new agenda in biodiversity conservation*. *Current Opinion in Environmental Sustainability*. 49, 79-87.
- Fazey et al. (2018) *Ten essentials for action-oriented and second order energy transitions, transformations and climate change research*. *Energy Research & Social Science*. 40, 54-70.
- Ghosh et al. (2021) *Transformative outcomes: Assessing and reorienting experimentation with transformative innovation policy*. *Science and Public Policy*. 48:5, 739-756.

Scope of the paper cluster

Papers in this cluster describe varying ways in which researchers should carry out research on transformations, biodiversity, and sustainability and how researchers can and should take a more active role in fostering transformative change. They do so by discussing observations on the paradox between transformation and conservation, which alludes to the importance of being specific about interpretation of key concepts and choice of words. Papers focused on the transformative nature of farmers' mental models, the agency of countries in the Global South, the role of attitudes, imagination, and arts-based approaches, and the challenges of biodiversity conservation and knowledge about consequences concerning justice.

Conceptualisation of transformative change

Papers in the scientific community cluster understand transformative change as a shift in how the world is conceptualized, emphasizing inter-relationship and interdependencies between people, places, and the environment. It recognizes mutual vulnerabilities as a motivation for broad structural and societal change, with a focus on resilience. There is no single unified definition, but rather different wordings are used to describe the process. These wordings include radical multiscale changes, fundamental social change, largescale restructuring of social fields, and the rethinking of actions, systems, and structures. Transformative change is also framed as a phased approach, involving a preparation phase, transition phase, and consolidation phase.

The challenges addressed by transformative change revolve around issues related to biodiversity, sustainability, and climate change. Although there is some commonality in the terminology used to describe transformative change, it is essential to interpret these terms precisely, as they may be understood or elaborated differently in various contexts. To advance the understanding of transformative change, knowledge production should move beyond traditional positivistic and rational actor approaches. Instead, it should embrace diverse perspectives and information sources.

Root causes of unsustainability and disablers of change

This cluster places great emphasis on the need for different approaches to science. It highlights two main points: first, the necessity to change the way knowledge about transformative change is produced, moving away from dominant positivist and Western approaches to knowledge and conservation, and towards adopting more inclusive and imagination-focused methods. The critique is that countries in the Global South are currently often envisaged as passive recipients of regime-defining processes with little to no agency to act in the face of broader power structures. Second, it stresses the importance of the impact-driven 'how-to' question that addresses practical solutions and their implementation.

Solution space and enablers of change

Papers in this cluster advocate for a more integrated and transdisciplinary approach to science, incorporating societal aspects, social science, and participatory approaches. Emphasizing the need for action-oriented and impact-driven knowledge, which can benefit from imagination and arts-based approaches for stakeholders' inquiry. Moreover, there is a plea to move away from positivistic, reductionist, and Western-dominated science, considered irrelevant for addressing complex system challenges. Instead, greater attention is urged for emotional, intuitive, and multiple ways of knowing. Rethinking current economic models and focusing on One Health approaches are also suggested.

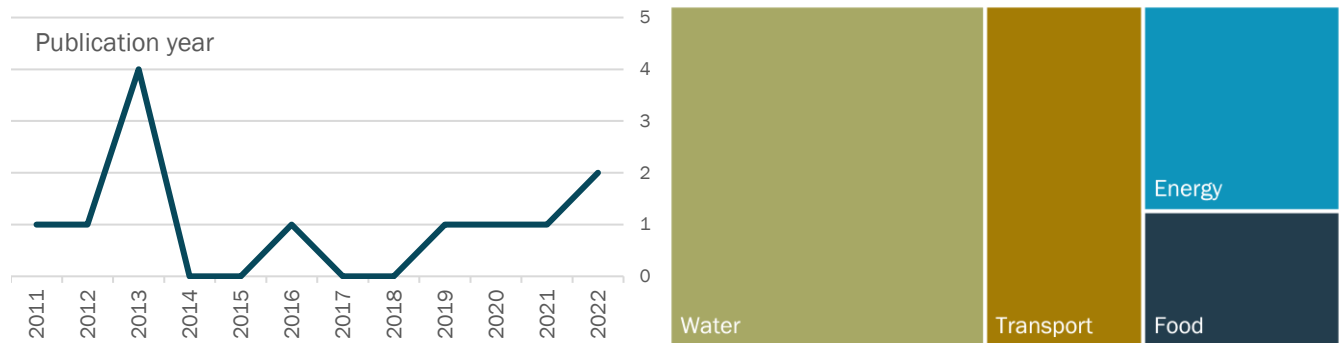
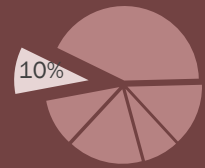
Transformative change thus requires new knowledge collaborations that can go beyond economically driven 'rational-actor' approaches and instead can include interdisciplinary and indigenous knowledge, as well as more practice-oriented science targeted at end-users. The latter is important as different end-users may need distinct knowledge, and outreach must be carefully tailored to meet their specific needs and interests. Actors influencing science, such as research councils, science and technology ministries, and innovation agencies are recognized as playing an important role for promoting such an integrated and transdisciplinary approach to science. To enable fundamental changes, it is vital for these new knowledge collaboration processes to align with both education and policy.

Notable

Biodiversity is discussed in the context of drivers for biodiversity loss, such as agricultural land conversion, developmental activities, ecosystem degradation, wildlife trade, intensive farming, changes in climate patterns, international travel, trade, and commerce. Justice issues are also pointed out in terms of the importance of empowering vulnerable communities with 'political capabilities' to influence policies related to adaptation, climate change, global food security, environmental sustainability, social and economic justice, soil health, and the recognition of the significance of values, solidarity, diversity, and climate change in addressing these challenges.

Transformative change in literature on

Infrastructures



Selected articles illustrative of the cluster

- Bugge et al. (2022) *The role of regional innovation systems in mission-oriented innovation policy: exploring the problem-solution space in electrification of maritime transport*. *European Planning Studies*. 30:11, 2312-2333
- O'Donnell et al. (2019) *The blue-green path to urban flood resilience*. *Blue Green Systems*. 2:1, 28-45

Scope of the paper cluster

This cluster includes documents advocating for change in the context of infrastructure planning, development, and management, ranging from specific technologies and policy instruments to more systemic approaches towards extensive and large-scale transformative change. The documents reviewed in this cluster largely dealt with urban environments, focusing on water, food, and transport.

Conceptualisation of transformative change

Transformative change was described largely in reference to the re-design of urban systems and infrastructures. This included alternative management approaches to guarantee most appropriate use of resource (e.g., based on user needs), context specific solutions, integrated multipurpose/multimodal infrastructures or systems (as opposed to large scale single purpose ones), compact land use patterns, as well as technological innovation (e.g., to reduce CO2 emissions and create blue-green infrastructure).

Root causes of unsustainability and disablers of change

While in some documents problem framing was rather narrow (e.g., CO2 emissions caused by transport), other documents pointed to ineffective policy and governance, as well as to infrastructural and institutional/cognitive lock-ins (e.g., centralised large-scale infrastructure instead of integrated multipurpose ones, separation of service provision in water sanitation and water supply, conservative and risk-adverse decision makers, and technocrats).

Solution space and enablers of change

A diverse array of solutions and factors enabling change was recorded in this clusters, including for example changes in governance and in policies, spatial planning and resource management technical solutions (e.g., blue-green networks, green roofs, bioswales, etc), knowledge co-production and more science-based knowledge (e.g., successful examples of alternative technologies or practices), technological and social innovation (e.g., large-scale electrification efforts and the abandonment of fossil fuels), and behavioural changes.

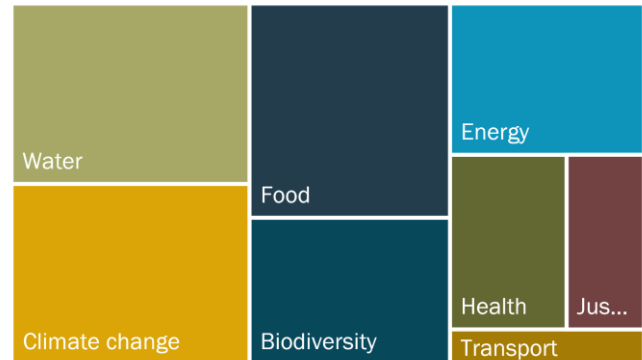
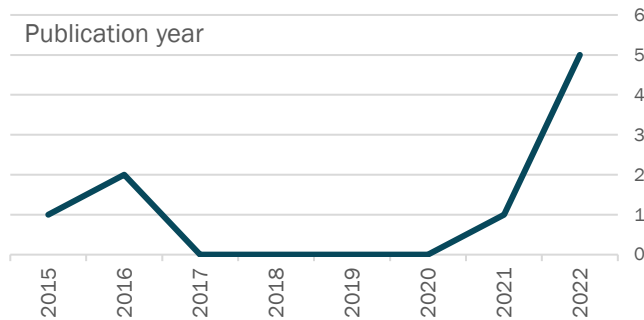
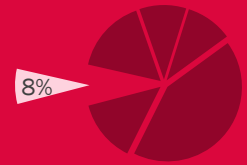
Actors enabling change included the public sector (e.g., in relation to infrastructure planning and to leaders promoting collaboration and learning), knowledge sector (e.g., longer research projects, inter/trans approaches, action research, different ways of conceptualizing and monitoring progress), citizens, collaborative intermediary organizations, partnerships, transition labs and grassroot initiatives. Moreover, reference was made to socio-technical systems, and key enabling factors like regional innovation systems, technologies, and multi-actor and multi-scalar agency are emphasized.

Notable

Biodiversity was not a central element in this cluster, and justice was only sometimes touched upon in reference to citizens engagement, demand-centred infrastructures, human well-being, and liveability of cities.

Transformative change in literature on

Social practices



Selected articles illustrative of the cluster

- Klitkou et al. (2022) *The interconnected dynamics of social practices and their implications for transformative change: A review*. *Sustainable Production and Consumption*. 31, 603-614
- Suitner et al. (2023) *Social innovation for regional energy transition? An agency perspective on transformative change in non-core regions*. *Regional Studies*. 57, 1498-1510.
- Sahakian et al. (2021) *Challenging social norms to recraft practices: A Living Lab approach to reducing household energy use in eight European countries*. *Energy Research & Social Science*. 72, 101881.

Scope of the paper cluster

Literatures on social practices focus on the ways in which institutions, infrastructures, and daily life interact. Household or consumer decisions are not viewed solely in terms of preferences or underlying values; instead, demand for provisions like water, food, or energy are very much structured by existing infrastructures and institutions and they are ingrained in routines and daily practices. Furthermore, as one of the papers show, everyday life practices like dwelling, mobility and eating are closely intertwined and not changing independently of each other. However, most papers focused only on one sector, primarily on alternative farming or energy use practices. Some had a relatively narrow focus on consumer behaviour (despite the stated focus on social practices) while others went beyond household level and focused on regional level social innovations in renewable energy production, showing how resources, relations, and reflexivity enabled agency to promote and sustain energy transition.

Conceptualisation of transformative change

Transformative change is conceptualised in terms of altering everyday practices and adopting sustainable methods for providing food and energy. Transformative potential is thus recognized within everyday customs and habits as well as cultural systems, which reproduce and sustain consumption of energy and materials. According to social practice literatures, social practices are recurrently and consistently reproduced but at the same time, they contain the seeds of constant change as they are re-crafted and substituted with new ones. A subset of papers focusing on social innovations define

transformative change as “*socio-technical system change that requires the purposeful adaptation of embedded directions and solution-oriented interactions*” (Suitner et al. 2023, p. 1499).

Root causes of unsustainability and disablers of change

Problems of unsustainability identified in this cluster are rooted in the existing status quo. These include disablers for change within globally connected agri-food markets, lack of transparency about the environmental friendliness of products, the limited availability of sustainable produce options, and barriers posed by state-controlled energy markets that impede citizen-led energy initiatives.

Solution space and enablers of change

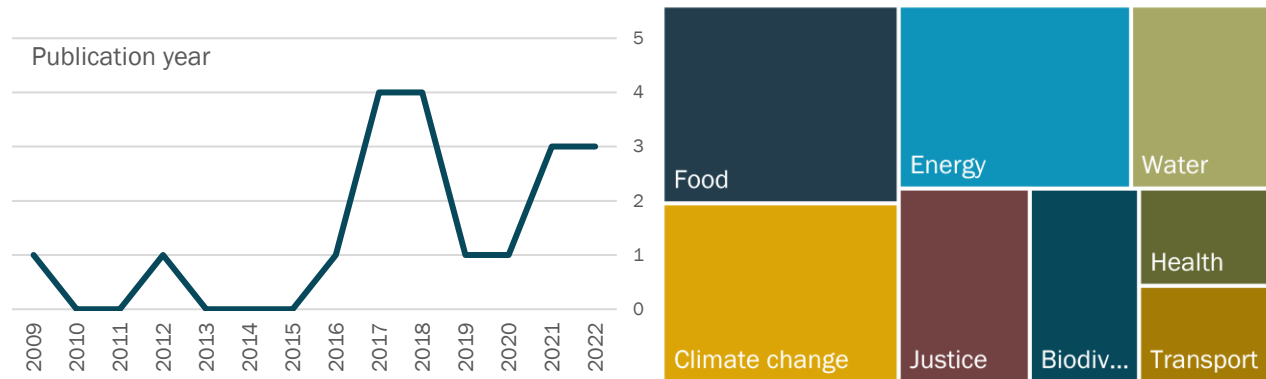
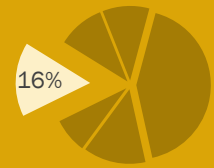
Literatures on social practices maintain that transformative change cannot be achieved by technological fixes or changes in individual behaviour alone, but requires comprehensive interventions that address interactions between materials, competencies (including technical competencies), and meanings. For example, energy transitions such as citizen energy initiatives are not purely technology driven but depend to a great degree on social relations, interactions, and collective action. A subset of papers focusing narrowly on consumer behaviour maintain that transformative change can be achieved through information-based policy instruments aimed at empowering people to make sustainable choices. For consumers, these instruments offer information to make informed, environmentally friendly consumption choices, or to reduce the overall amount of consumption. For households, they promote adopting sustainable water and energy consumption patterns. Similarly, farmers are encouraged to embrace sustainable farming practices. Some studies address the role of household experiments and ‘living labs’ in instigating novel, more sustainable practices and giving up old, less sustainable ones. Other papers emphasize the role of discursive processes such as communication, visioning, and policy development in enhancing citizens’ agency in transformative change.

Notable

Some papers emphasised environmental justice: The heaviest burden of emission reduction falls on those with the lightest carbon footprints but suffer the direct impacts of climate change.

Transformative change in literature on

Societal functions



Selected articles illustrative of the cluster

- Jenkins et al. (2018) *Humanizing sociotechnical transitions through energy justice: An ethical framework for global transformative change*. *Energy Policy*. 117, 66-74.
- Mosnier et al. (2023) *How can diverse national food and land-use priorities be reconciled with global sustainability targets? Lessons from the FABLE initiative*. *Sustainability Science*. 18, 335-345.
- Wezel et al. (2020) *Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review*. *Agronomy*. 40:40.

Scope of the paper cluster

The papers in this category analyse the provision of societal functions such as energy or food. They focus either on the changes within these systems to address issues of (predominantly) climate change, while upholding the provision of those functions or services. The papers are therefore often a combination of a one function (food, energy, water, health, or transport) and an issue such as climate change, justice, or biodiversity.

Conceptualisation of transformative change

In the sustainability transitions literature, shifts in the provision of social functions are analysed with the means of the multi-level perspective that focuses on the interplay between niche innovations, policy regimes and the exogenous socio-technical landscape. In one part of the reviewed papers, this kind of a heuristic seems to inform the analysis although the link is not always made implicit. However, many of the papers within this cluster lack a coherent theory or theorisation of change. When this is the case, the papers tend to provide lists of actions that need to be taken in different fronts and by different institutions or actor groups. Little is said about the ways the mentioned actions link to each other and trigger processes of change. Many of these actions depend on the deformability of markets or focus on policy changes.

Root causes of unsustainability and disablers of change

The very varied set of papers take, in one way or another, general unsustainability of established production modes and systems as their starting point. Some take a focus on the lack of resiliency of systems around societal functions. A couple of papers address the problems in historical and societal dynamics. Most notable obstructions to change are the co-dependencies between businesses and states and the regulations and favour industries.

Solution space and enablers of change

In a significant number of papers, the solution space is being carved out by the co-evolution of innovations and pilots on the one hand, and innovation policies and other incentives and regulations, on the other hand. These papers seem to implicitly adopt a multilevel perspective that focuses on the interplay between niche innovations, policy regimes and the exogenous socio-technical landscape.

In one segment of the papers, transformation is analysed as a change evolving through empowerment of local and regional communities and thereby emerging forms of stewardship – for example active energy citizenship. Likewise, some papers treat shifts in consumption patterns and behaviour as key enablers of change. Finally, a fraction of the papers examines the role of new modes of measurement and accounting as drivers of transformative change.

Notable

Throughout this cluster, biodiversity is addressed in an indirect and/or passive manner through system re-configurations aimed at ensuring societal functions. Although some papers see nature and biodiversity as 'valuable', they are not considered as an active agent in change. Justice is more prominent in the focus on societal functions, emphasizing the fairness of access and so on, but operationalised mostly through a participatory lens.

5. Cross-cluster analysis and discussion on transformative change

The literature collected with the search string proved disparate in terms of their scientific grounding, analytical approaches to transformative change, and focal topics. Within them, transformative change as a broad concept was widely acknowledged and appeared to be used in a rather generic fashion. In fact, the notion of transformative change seemed to be applied in a rather fluid sense: travelling effectively across the diverse groups of papers, differently applied each time, making visible different modes of analytical anchoring. While a structure based on the ‘nexus elements’ did not provide a feasible approach to making sense of the literature, an approach using ‘anchoring-types’ in diverse socio-material contexts did allow us to reflect on the research questions. This section looks across the different clusters and aims to glean insights from their conceptualisation of the concept, their perspective to enablers and disablers of change, their connection to the biodiversity nexus and justice. Here, we highlight elements that the clusters have in common, but also underscore how these clusters differ from one another. **Table 6** shows a summary of the analysis results of all clusters.

In addition, this section will reflect on several salient critiques to the transformative change literature, as highlighted in section 2.3. This section raises five ‘red flags’ for the transformations field, such as 1) the risk of co-optation of the concept by business as usual; 2) the lack of empirical grounding resulting in an insufficient understanding of underlying processes; 3) inadequate comprehension of the dynamics that shape vulnerabilities and assumption that transformative change is always ‘good’; 4) lack of awareness of the broader consequences of transformative change; and 5) a lack of emphasis on both the *what* and the *how* of fundamental change in order to deal with the urgency of climate change and biodiversity loss. While these points are not analytical findings of the review, they pose general concerns to the use of and conceptualisation of transformative change. They allow us to critically assess the extent to which the reviewed literature can overcome these concerns.

5.1. Clusters of thematic focal points to transformative change

As emphasized by Feola (2015) and Dorninger et al. (2020), the field of transformations research includes a range of different disciplines, scientific approaches, and thematic foci. The latter becomes clearly visible in the cross-cluster analysis, showing that each cluster focusses on a particular aspect of the system. The notion of ‘transformative change’ has become increasingly relevant considering the urgent sustainability challenges, resulting in the use of the notion as a lens to reflect on existing work in diverse fields of research. This enables a focus on diverse, thematically organized solution spaces that aim to draw out actionable insights to enable more sustainable systems. For example, the governance and human-nature clusters emphasize the importance of meaningful stakeholder participation in knowledge production and governance. These clusters advocate for inter- and transdisciplinary approaches that incorporate local and indigenous knowledge. The social practices cluster concentrates on everyday practices conditioned by existing technologies, institutions, and infrastructures, while scientific community cluster outlines agendas for research on transformative change.

Across all clusters, transformative change is described as fundamental change, which aligns with the definition used in the first IPBES assessment (2019). However, where IPBES talks about “*fundamental, system-wide reorganization across technological, economic, and social factors, including paradigms, goals and values*” (IPBES 2019), there is a spread in the extent to which the reviewed papers focus on system-wide fundamental change. A portion of the literature specifically emphasizes the reconfiguration of certain components within the system. For example, the attention is centred on the role of science

Table 6. Overview of the clusters and the analysis results

	Governance	Human-nature relations	Scientific community	Infrastructures	Social practices	Societal functions
Scope and core focus	Modes of governance and policy processes and their influence on processes of change	Connectedness between humans and nature and the role of values and worldviews in processes of change	Role of research, its practices and research agendas on processes of change	Physical structures that enable the functioning and change of societal systems	The role of daily practices in the functioning of societal systems and processes of change	Ability of systems to fulfil their societal roles, such as food security or energy provision
Conceptualisation of transformative change	Fundamental system change including institutions and paradigms, described as difficult to predict and manage	Non-linear, co-evolutionary process of system change. Place-based, open ended and moving at diverse speeds	Fundamental change in complex systems	Re-design of systems and infrastructure through adaptive actions	Changes in everyday practices (and cultures) towards alternative ways of doing	Often implicit – instead, papers outline lists of actions that are needed
Problems in current system	Lack of integrated/ system perspective and space for diverse (nature-centred) values; power asymmetries	Human pressures on Earth system driving by anthropocentric values ; Centrality of economic growth	Modes of knowledge production that are too positivist and lack plural values ; lack of action-oriented research	Carbon-centred infrastructures ; lack of system perspective in design of infrastructures	Lack of feasible alternatives ; normalization of unsustainable everyday practices	The inherent unsustainability of production systems
Solution space and enablers	New governance paradigms that build on new/plural values and move beyond a growth paradigm; incentivizing innovation, and experimentation,	Change in mindsets and dominant social norms (intrinsic values for nature); relational understanding of wellbeing, governance that facilitates stewardship and values natural capital	Co-production of knowledge , inclusion of indigenous/marginalised voices; integration of education, research, and policy; imagination and creativity	Participatory planning and strengthening citizenship; incentivizing change through (financial) policy reform	Incentivizing alternative practices , reflecting on entrenched routines and practices; social innovations and more sustainable ways of organising everyday life	Incentivizing innovation and experimentation and local empowerment
Barriers for change and disablers	Co-option of transformation processes by business as usual; solely technology-focused innovation ; lack of integration of sectors	Short-term interests of politics and industry aimed at economic growth	Positivist and Western dominated science ; lack of plurality/voices outside of academia	Incumbent or vested interests in maintaining current infrastructures; lack of participatory design	Policies and infrastructures which condition the options available for individuals; path dependency; lack of reflectivity	The current configuration of systems that fail to deliver on the societal functions that are desired from it
Approach to assess the system	Societal complex system perspective , at least acknowledging interconnections between system elements	Relational understanding of complex systems	Societal complex system perspective and sometimes a relational perspective	System perspective	Strong focus on the interlinkages between everyday human entity within the system and the broader system	Multi-level system perspective often used to the functioning of a particular system
Role of biodiversity	Changes in action and governance structures to indirectly support nature conservation and biodiversity restoration	Focus on understanding relations between humans and nature or assigning agency to the natural world for both direct and indirect regeneration	Creating different / more appropriate knowledge about nature , as well as societal systems to indirectly support nature and biodiversity	Changes in production systems to (indirectly) support nature conservation	Organising everyday life in a way that consumes less energy and resources and hence reduces negative direct and indirect impacts on biodiversity	Changes in system configuration to fulfil societal functions (i.e., not directly addressing/ emphasising nature)

and governance in incentivizing recycling, minimizing trade-offs, achieving decarbonization, and mitigating risk for investors in pathways for sustainable development. In these papers, the requirement for fundamental change is embedded ‘in between the lines’ and included rather implicitly. Building on Feola (2015), we see this as a slippery slope towards the term being used as a “metaphor”, where it is assumed to mean a fixed process or is even interpreted as an acknowledged societal goal. Ultimately, this risks the co-option of the term transformative change for processes that are not transformative.

Furthermore, all clusters underscore the need for change that goes beyond superficial change and addresses the root causes of the sustainability issues. The assessment of the root causes differs per cluster. The governance cluster criticizes the political, legal, and policy structures within dominant governance systems. For example, Dawson et al. (2017) highlight two primary shortcomings. First, they note the absence of established benchmarks for ecological restoration. Second, they point to the lack of effective planning and management methods, particularly related to multi-level collaborations among different sectors and parties. Other research papers critique the way dominant governance systems contribute to the establishment of "*market-based societies characterized by individualism and self-interest, materialism, privatization, short-termism, and a dogmatic focus on profit and economic growth*" (Huntjens 2021). This undermines social and environmental values, leading to the prioritization of excessive consumption, production, and the depletion of natural resources. The other clusters, in short, highlight several overarching concerns to be addressed: top-down approaches to planning (infrastructure), anthropocentric values (human-nature relations cluster), normalization of unsustainable production and consumption patterns (social practices), unsustainable energy and food production systems (social functions), and the limitations of dominant research approaches (scientific community). A common feature in these frameworks and research strategies was a call for more inclusive knowledge practices, which make use of both scientific and non-scientific knowledge, including place- and practice-based knowledge (see also **Table 6**).

The diversity of foci means that to create an understanding of ‘fundamental, system-wide’ change, we must look across the clusters, which in each hold ‘a piece to the puzzle’. Understanding transformative change as a *process* that involves a series of interconnected and dynamic actions, decisions, or adaptation, each cluster can be seen as representing different aspects of the *process* of transformative change. Described across the clusters are processes of change that unfold at various levels (ranging from global to the level of the individual) and that address various important aspects of the system (energy production, food provisioning, etc.). The “bundling” of all clusters may help in assessing interactions that lead to trade-offs or synergies. However, this approach could introduce additional analytical challenges (as it requires making, such as necessitating assumptions and amplifying uncertainty).

5.2. Lack of concreteness as to what fundamental change results in

Fundamental change is often emphasised as key within the clusters. However, many clusters are unable (or perhaps unwilling) to explicitly describe what fundamental change entails (i.e., concrete ideas of what fundamental change might look like). This lack of concreteness, which is also rooted in

a poor agreement over what are the fundamental causes of unsustainability, brings about two challenges.

One, it obscures the interpretation of ‘fundamental’ change and the extent to which it reorganizes the system. In some cases, the need to overhaul the foundation of our society is explicitly mentioned, such as the need to enable structural changes in governance or economic systems. In this regard, the social practices cluster mentions degrowth, while the human-nature relations cluster advocates for enhancing human-nature connectedness. The governance cluster envisions opportunities in establishing coalitions among diverse stakeholders to foster a new shared ideology in governance approaches to enable future possibilities. Whereas in other cases, the extent of change is much narrower. For example, within the social functions cluster, a suggestion was made to explore alternative sources of protein, such as pulse ingredients, that provide nutrition and are sustainable to produce and process. Especially a ‘narrower’ interpretation is prone to under-theorisation of transformative change and thus unable to provide a coherent analytical insight into phenomena they might label as potentially transformative.

Second, as already mentioned above, omitting a concrete vision or description of what transformation entails, enables a greenwashing and co-option of transformative change (i.e., the process by which powerful actors incorporate elements of ‘transformative change’ to serve their interests and/or maintain the status quo). Solely describing the change we envision as ‘sustainable’ and ‘just’, does not describe what pathways of solutions are part of that form of sustainability and justice – meaning it is unclear for *whom* that might be sustainable (Leach et al. 2010). To address this ambiguity, directionality (i.e., deliberate and purposeful orientation of change processes) is key. Enabling directionality requires setting clear goals that provide a sense of clarity and thus cannot be co-opted. In addition, directionality can enable a deeper understanding of the dynamic, intersectional, and contextual challenges faced by individuals within processes of change (Forsyth et al. 2022). This can help overcome uncritical assumptions about the outcomes of transformative change being ‘good’ for all.

In the Human-nature relations cluster, some papers criticize the focus on socio-economic structures or technological advancement and maintain that changes need to occur in the inner dimensions of the human, including “*the worldviews, social values, attitudes, and beliefs that shape what we believe is right*” (Daigle and Vasseur 2019). Somewhat paradoxically, these normative pleas for a wholesale change in our mindsets remain quite inconsequential as the proposed solutions—environmental education and information via news and social media—are very conventional and not likely to respond to the urgent need for reorganizing socio-technical systems in a more sustainable way. As social practice scholars have pointed out, the focus on individual’s values and deflects attention from the extent to which state and other actors structure possible courses of action (Shove 2010). In a similar way, the papers that emphasize degrowth provide relatively few concrete suggestions on how to achieve transformative change, limiting themselves to suggestions like eco-communalism and time-banking. As Geels et al. (2015) note, critiques that focus on emerging small-scale alternatives fail to account for how they can remedy environmental problems at the scale required. Furthermore, the calls for resistance and active citizenship, also common in other approaches to transformative change, seem to implicitly assume that ‘ordinary’ citizens are more

likely to advocate transformative change than policymakers and established interest-groups. However, also civil society consists of plurality of values and perspectives, epitomized by the Extinction Rebellion as well as the Yellow Vests Protests (i.e. 'Gilets Jaunes') movement, the first one campaigning for biodiversity protection, the latter one protesting gasoline taxes. Overall, very few papers address the political processes of transformative change, focusing only on the desired end-states or normative principles, like public participation of knowledge co-production. A notable exception is Kreienkamp's et al. (2022) analysis of the policy transformation of the European Green Deal and its implementation challenges in multi-level governance settings defined by institutional ambiguity and multiple venues.

More explicit descriptions of what fundamental change looks like, enable the purposeful design of pathways of change and the assessment of a wide range of actors whether this is 'their' just sustainability or not. For example, Loorbach (2022) explicitly describes what transformations should look like by highlighting the already visible and existing (social) innovations in mobility, food, and urban areas and describing how these might evolve further. Moreover, he describes transformation processes as challenging, altering, and ultimately replacing unsustainable regimes. This involves experimental exploration of potential and desirable future transitions. Simultaneously, a long period of agenda setting, selective participation, and learning along the way occurs, accompanied by reflexivity. These interacting dynamics encompass collapse and chaos, coinciding with emergence and institutionalization. Processes that together, underlie the *"the shift of a societal regime from one dynamic equilibrium to another"* (p. 3). Concrete descriptions of what fundamental change results in, allows for the scrutinizing and critical reflection of proposed visions for change and for *whom* they might be sustainable. In addition, this allows for more constructive design of pathways of change that go beyond superficial ideas of sustainability and justice.

5.3. The role of justice in transformative change

When looking across the literature, justice was cited as a crucial component of the desired or envisioned transformation. These ideas often align with how Heffron and McCauley's (2018) understand 'just transition', emphasizing that any shift toward sustainable development should not burden those already experiencing disproportionate impacts. It is noteworthy that justice emerges as a central concern across all clusters. However, similar to transformative change, a concrete and unanimous understanding of justice in transformative change is lacking and remains implicit across the majority of the literature. This raises the question as to what extent the reviewed literature considers justice as inherently intertwined with transformative change. Assessing the use of the notion justice across the reviewed articles reveals that most understandings align with various justice dimensions - distributive, recognition, and procedural - which are commonly used by justice scholars (see **Box 1**).

Biodiversity governance literature emphasize how decision-making processes often exclude diverse or marginalised stakeholders who capture distinct values, knowledge, beliefs, and power (Visseren-Hamakers et al. 2021). Such limited options for meaningful participation in biodiversity governance processes, results in constrained capacity of these excluded groups to address injustices, such as the unfair distribution of environmental burdens and benefits in decisions that bring about

environmental transformations (See e.g. case study by Malins 2023). In addition, Perreault and colleagues (2012) emphasize the significance of not only considering the distribution of environmental injustices but also understanding how these injustices are (re)produced through institutional frameworks and historically established social relations. They highlight a study conducted by Cole and Foster (2001), who demonstrate that environmental injustice can originate from seemingly neutral 'race-blind' policies, just as much as from clearly discriminatory decisions made by governmental bodies.

Box 1. *An overview of the conceptualisation of 'justice' in just transition and social justice literature*

Processes of change (be it 'sustainable development' or 'transformation') involve both winners and losers. Acknowledgement of this has resulted in popularisation of research on social justice and more recently just transitions (Leach et al. 2010) and even the use of the concept in policy contexts and societal discussions (Heffron and McCauley 2018). Literature on justice emphasizes the multi-dimensional nature of justice, crossing and influenced by multiple dynamics – such as economic, political, cultural, etc.

Scholars have developed a multi-dimensional framework to make sense of this multi-dimensional concept. Although the focus or choice of dimensions differs across the literature, commonly mentioned dimensions are *distributive justice*, *recognition justice*, *restorative justice*, *procedural justice*, *environmental justice*, and *cosmopolitan justice* (Kaljonen et al. 2023). Most commonly used across justice-related literature are the dimensions of distributive, recognition, and procedural justice. Here, *distributive justice* is conceptualised as the fair distribution of burdens and benefits, as well as the allocation of opportunities and material goods, such as natural resources, income, and wealth (Menton et al. 2020). *Recognition justice* refers to the recognition of and respect for different individuals and collective identities, including their specific values, knowledge, practices, needs and livelihoods (Fraser 2008). *Procedural justice* describes participatory fairness within political and societal decision-making processes, with specific focus on the fairness and transparency of procedures (Schlosberg 2007).

Although scholars often argue justice to be part and parcel of sustainability, included in the 'social' dimension, it is often overlooked or omitted from analyses (Hebinck et al. 2021). As such, explicit attention to and reflection on dimensions of justice within processes of change, is crucial for the enabling of just transformative change.

The governance and human-nature relations clusters similarly highlight injustices embedded in dominant governance and economic models. When it comes to fostering transformative change, most cited challenges are issues of procedural and recognition justice, which interconnect within the realm of epistemology. Epistemologies refer to what or whose knowledge(s) are valued and who is afforded the opportunity to engage in knowledge co-creation throughout the stages of problem definition, decision-making, and transitional governance processes (Fricker 2017). At present, governance and economic systems are predominantly influenced by values, preferences, and imperatives oriented towards growth, thereby upholding the status quo. This barrier to transformative change is acknowledged by the societal functions, social practice, and to some extent the infrastructure clusters as well. However, these clusters do not explicitly indicate the repercussions of this dominance. Instead, the governance cluster draws particular attention to how this dominance, in consequence, impedes opportunities for stakeholders to effectively confront

vested interests and systemic injustices. Furthermore, the governance cluster argues that the prevailing socio-economic models often neglect the integration of diverse values. Recognizing multiple values and ways of knowing will be essential in providing the necessary support for transformative change (Buxton et al. 2021). Von Wehrden et al. (2017) explain that values determine what constitutes a desirable situation, thus guiding a specific orientation and goals in decision-making. Decision-making that encompasses diverse values fosters a more robust societal dialogue and is, therefore, capable of generating transformative knowledge and actions.

In line with that, the clusters human-nature relations and scientific community point to processes of knowledge co-creation as the foundation of decision making for governance that facilitates transformative change. Co-production of knowledge, including diverse research disciplines and local and indigenous stakeholders, can aid a plural understanding of biodiversity and transformative change. To enable the connection of diverse knowledges, alternative modes of governance are needed that support both recognition and procedural dimensions of justice.

The human-nature relations cluster brings these dimensions of justice to the fore in the context of conservation governance, with particular focus on values for and of nature. So does a subset of these papers advocate for the recognition of the value(s) of nature within development and regulatory frameworks. Although the concept of 'ecological justice', which concerns justice for non-human entities, is not explicitly addressed, its essence is implicitly embedded in here. This is visible in the push to acknowledge and include stakeholders who see the human and natural world as intertwined and as one entity in processes of co-creating knowledge. Furthermore, the human-nature relations cluster expands on just governance for transformative change by touching upon temporal and spatial dimensions of justice. They do so by demonstrating how relations of power, social exclusion, environmental transformation, and environmental injustice are connected historically and geographically, and through preserving environmental quality for the wellbeing of future generations (Chapin et al. 2015; Fiasco and Massarella 2022).

One of the perspectives that was underrepresented in this review is the role of contestation, including social resistance, in transformations. This might be due to the difference in terms used for changes in fields that focus on contestation and to the lack of focus on this topic among transformative change scholars. Nonetheless, authors argue that historically contestation has played a major role in societal changes and that currently movements offer a productive approach to address hegemonic power relations in sustainability transformations (Temper et al. 2018; Pichler et al. 2021).

In summary, the analysis of biodiversity nexus literature on transformative change reveals a recognition of multiple dimensions of justice across the identified clusters. Concerns about justice predominantly centre on equity within governance processes, particularly in decision-making associated with distribution issues. Many of the papers advocate for the inclusion of a diverse spectrum of voices and values in decision-making processes, thus empowering their capacity to influence regime actors who uphold the prevailing status quo (e.g. Jenkins et al. 2018). The findings presented above, closely align with ongoing discussions about just sustainability transitions among justice scholars: they emphasize the need to establish whose voices are included or excluded, which

forms of knowledge are considered, who the winners and losers are of a certain transition, and how costs and benefits of transitions are distributed (e.g. Chan and Satterfield 2013; van Steenbergen and Schipper 2020; Zurek et al. 2021). Supporting justice in biodiversity-relevant transformative change thus requires a multidimensional approach to challenging the complex interplay of prevailing environmental, social, and political processes. However, the challenge remains to strengthen ecological forms of justice in these approaches. This aspect is overall missing in this review, as well as in the global debates around just transitions, but is argued to be imperative for addressing the biodiversity crisis (Kopnina and Washington 2020).

5.4. Overcoming human-centred perspectives to change

Understandings of change generally build on a human-centred (or anthropocentric) perspective, in the sense that places human agency, interests, or needs at the centre of transformative change. This has a strong influence of the direction and scope of efforts of transformative change, especially when it comes to the interconnectedness between humans and nature. While nature and biodiversity are often regarded as an important element of the system, they are rarely seen as an active agent. As such, transformative change often is of influence on nature and biodiversity, impacting the status of or the way processes unfold. For example, market-based conservation approaches that centre around tourism (Fiasco and Massarella 2022). Although all clusters, except for the infrastructure cluster, cited a shift in values towards non-anthropocentric values as a solution or vision for transformative change, the consideration of nature and biodiversity as equally crucial components of transformative change, enabling change through them, is less prevalent. The article by Daigle and Vasseur (2019) distinguishes itself by asserting that environmental challenges can only be effectively addressed by broadening the scope of ethical consideration to encompass all living beings, placing them on equal or even greater importance than humans. Chan et al. (2020) argue that the challenge of feeding humanity should be met without degrading land and nature, and climate goals should be achieved while safeguarding the vital contributions of ecosystem services to human well-being. While a human-centred approach does not necessarily exclude transformative changes in the biodiversity nexus, acknowledging the needs and rights of non-human entities, along with the advancement of non-dualistic accounts of human-nature connectedness in science (West et al. 2020), can accelerate more sustainable and inclusive transformation.

6. Concluding insights on transformative change in the biodiversity nexus

The biodiversity nexus is at the heart of the unprecedented challenges and pressures that society and the planet face today. Transformative change is essential to ensure and safeguard that people and nature will thrive and continue to do so in the future (IPBES 2019). However, the time to avoid the ‘point of no return’ is running out (IPCC 2023) and the continued and alarming rate of species extinction (Díaz et al. 2019) in combination with the lack of climate action (Stoddard et al. 2021), show little progress has been made thus far. This culmination of escalating crises and a shrinking timeframe to address them, have resulted in the rapid proliferation of research on transformative change in the last decade (Feola 2015; Dorninger et al. 2020). More and more researchers are exploring questions around the why, what, and/or how of transformative change (Bentz et al. 2022) to address issues such as biodiversity loss, climate change, food insecurity, and social injustices.

To support transformative change in the biodiversity nexus, this deliverable presented a review of literature on transformative change. Spanning research on change within the scope of the biodiversity nexus elements, it aimed to uncovering a conceptual understanding of transformative change that is conducive to transformative action. Here, a first step was to work towards consolidated insights on the meaning and mechanisms of change from the transformations literature that is fragmented across diverse fields of research. Second, aiming to move beyond a conceptual understanding alone, the research sought to review these conceptualisations of transformation through a critical lens to explore the main barriers to implementation and action.

Overall, this review indicates that it is widely acknowledged in research that transformative change refers to *fundamental* processes of change. Unsustainabilities run deep in our societal systems and only through change that is able to ‘rewire’ these systems, can we overcome them (Gordon et al. 2017; Oliver et al. 2018). How transformative change is applied in research that spans the biodiversity nexus elements, differs strongly between fields of research and topics. For analytical purposes the literature was clustered into different anchoring types, based on their commonalities in approaching specific socio-material features. This resulted in clusters on Governance, Human-Nature Relations, Scientific Community, Infrastructures, Social Practices, and Societal Functions. Dividing the literature across these clusters allowed to see patterns in approaching transformative change, demonstrating how none can create a ‘full picture’ of transformative change, but that each holds a different piece of this complex puzzle.

Despite its popularity, the concept transformative change has also become somewhat of a buzzword: Now commonly used beyond academia – in policy, business, society, and even marketing – the notion of transformative change runs the risk of being used without substance or without reference to fundamental change (Bentz et al. 2022). This review reflected on how the reviewed literature can deal with a few ‘red flags’ as synthesized from a diverse range of critical viewpoints to transformative change. Reflecting on issues such as the risk of co-option, lack of empirical grounding, inadequate comprehension of dynamics shaping vulnerabilities, lack of awareness on the broader consequences of change, and insufficient emphasis on *how* change should and can unfold. While none of the clusters can fully overcome these issues that hamper the capacity for transformative action, they do provide valuable insights on what is needed to enable transformative action.

6.1. Key insights for transformative action

The literature certainly shows a proliferation of the use of ‘transformative change’ and to make sense of this diversity the analysis was anchored in diverse socio-material features. Nevertheless, a few take-home-messages for transformative change in the biodiversity nexus can be identified from this diverse array of articles. These insights are drawn from the comparison of the different clusters of literature and the reflection on the ‘red flags’ that signal barriers for transformative action.

Key insight #1: Engage in a ‘multi-system’ perspective to approach the biodiversity nexus

The reviewed transformations literature generally acknowledges the complex and dynamic nature of societal systems and the processes of change towards sustainability. Most emphasize the need for a system perspective to understanding the deep-rooted causes of unsustainability and tackling these challenges that emerge within coupled, complex systems. Regardless, the review shows that very few articles approach change through a nexus perspective: instead, the literatures show an anchoring in a diverse socio-material features, such as governance or infrastructures.

Since the study of transformative change focusses on a *process* of change (Folke et al. 2010) it requires embedding in ‘something’, either in the form of a case (e.g., energy systems) or in a particular paradigm (e.g., practice theory or multi-level perspective). Studies of transformative change then explore change as highly dynamic and multi-dimensional processes within the scope of a particular case or paradigm, aiming to explore relations and patterns of change (Loorbach 2022). While a nexus perspective is rather similar in its aim to understand complexity, it often focuses on specific interconnections or dependencies between elements within a system (Liu et al. 2018).

For transformations literature to support nexus assessments with actionable insights, we argue more attention should be paid to ‘multi-system’ dynamics (Rosenbloom 2020). In this, focus should go to how ‘diverse’ systems interact with one another, how they are ‘layered’ across geographic scales, and how their boundaries evolve and change due to shifting dynamics (ibid.). By looking across different transformation processes that are embedded in diverse socio-material features and across multiple systems, a “*broader and more differentiated understanding*” of transformation processes can be cultivated. This would allow to uncover potential synergies and trade-offs, but also explore the ‘cascading consequences’ of interactions between complex dynamics systems (Rosenbloom 2020, p. 339).

Key insight #2: Provide concrete description of what transformative change entails

The need for research on transformative change only increases as sustainability challenges become more persistent and urgent. Although that call is answered by both a popularization and proliferation of the field, there is a lack of concrete description of what transformative or radical change entails (Feola 2015; Blythe et al. 2018). Simply stating “*presumed normativities*” for transformation (Stirling 2011) fails to acknowledge futures or anticipation processes as “*sites of political negotiation*” that shape prioritization and inclusion of

processes of change (Vervoort and Gupta 2018). Vague definitions of transformative change then become open to co-option by business as usual (See e.g. Halttunen et al. 2022) or the inadequate comprehension of the dynamics that shape our social world (See e.g. Whitfield et al. 2021)– both risking to further exacerbate existing injustices and unsustainabilities.

To overcome these risks, use of the concept transformative change must include concrete descriptions of the why, what, and especially the how of transformative change (Bentz et al. 2022). For example, by identifying and highlighting emerging processes of transformation that build on the values and goals that align with the envisioned radical change (Loorbach, 2022). Not only does this enable a more critical and rigorous assessment of the socio-political dimensions of the transformation that is presented, but it also enables more comparison between diverse ideas on transformation – both in the same socio-material field as across diverse processes of change. Concrete and deliberate descriptions of future imaginations in turn allow diverse actors to analyse, understand, and consequently influence ideas of the future, which nurtures what is also termed “*futures literacy*”, the capacity “*to act upon the future*” (Mangnus et al. 2021).

Key insight #3: Empowering and amplifying plurality of voices and perspectives

Transformative change requires a shift away from the current ways of doing, thinking, and organizing. At the same time, much needs to remain intact to support maintenance of societal functions and orders (Lazarevic and Valve 2020). This dilemma guides attention to the conditions and terms of transformative change. The review demonstrates that the persistence or resilience of current systems and powerful actors to maintain business as usual, is considered one of the biggest obstacles to enabling transformative change. The review also shows that most of the reviewed research also underscores the need for diverse values, perspectives, and voices as a solution to these persistent unsustainabilities. However, the dominance of vested interests and the imbalance of power between diverse societal actors is sometimes even described as a “wicked problem” (DeFries and Nagendra 2017): Not just when vested actors use their power to obstruct transformation, but especially the more elusive wielding of power to co-opt or hijack transformation processes.

The underlying, linear understanding of power as “*something one has or not*” impairs the agency of those who are perceived to have no power to enable and shape transformations (Avelino 2017). To address this persistence and resilience of powerful actors, we build on the work of Avelino (2017) who considers power in a more plural sense. Besides the ‘reinforce power’ that these vested actors show in maintaining and reproducing the status quo, the argues “*the capacity to invent or create new resources*” (innovative power) and the “*capacity to invent and develop new institutions and structures*” (transformative power) are similarly required in processes of transformation. Not only does this open to a perspective on change that is able to look beyond ‘the dominant forces’, it also is a plea for research to amplify and therewith empower the plural perspectives and voices to innovate and transform and help overcome vested interests.

Plurality is key to envisioning diverse solutions and pathways of change that can divert from business as usual and possibly even consider the needs and rights of those not heard or marginalized (Stirling 2011; Delina and Sovacool 2018). Transformations research should actively seek to amplify this plurality and explore mechanisms of change rooted in diverse place-based contexts (West et al. 2020). For example, through methods such as the 'Nature Futures Framework', which is used as a boundary object to capture diverse future perspectives (Pereira et al. 2020).

Key insight #4: Acknowledge of the needs and rights of non-human natures

The pivotal role and impact of human activities on the state of biodiversity and the broader natural world can no longer be denied (IPBES 2019). The persistent sustainability challenges we face today are a consequence of a history of human-centered interactions with the environment, focused on increasing human well-being through economic growth and development (Leach et al. 2010). Much of the reviewed literature acknowledges this anthropogenic influence as problematic, and a large portion of the reviewed articles see some shift towards non-anthropocentric values as a solution to this problem.

Although the proposed changes range from acknowledging the value of nature towards the recognizing of non-human entities as equal agents to humans, they have in common a move away from a view in which humans dominate, rule, or control the environment (Folke et al. 2021). Instead, the responsibility to care for, respect and safeguard the well-being of non-human entities is emphasized (West et al. 2020). Pathways to achieving this include recognizing the rights of the natural world and ensuring legal protection (Visseren-Hamakers et al. 2021); shifting to practices that are regenerative and restorative rather than exploitative (Thiessen Martens 2022); reevaluating our perspective to 'growth' as the only route to wellbeing and prosperity (Paulson 2017); and securing the rights of and enabling the stewardship by indigenous and local peoples that have long traditions of coexistence with the non-human world (Reyes-García et al. 2022).

To enable pathways of change that acknowledge the rights of non-humans, transformations literature should look to and learn from relational perspectives to understanding change and system dynamics based on the "non-essentialist" understanding that "humans are nature and vice versa" (West et al. 2020). For example, Blanco-Wells (2021) advocates for "*ecologies of repair*", a perspective in which crises present an opportunity for transformations: rather than reducing "*other-than-human-natures*" to "*things*" – *passive materials that decorate the material background of social life*" – he argues they may play a central role in processes of repair (Blanco-Wells 2021, p. 5). Echoing Anna Tsing's call for "*the art of noticing*" (Tsing 2015), he argues for an increased "*capacity to notice [...] the more-than-human-world*" and "*understand the possibilities and limits of our own humanity*". Here, we turn to the conclusions by West et al. (2020), who highlight relational approaches to transformation include themes such as 'continually unfolding processes', 'embodied experiences', 'reconstructing language and concepts', and 'practices of care'.

6.2. Insights for future research on transformative change

6.2.1. Avenues for future research

Although the term ‘transformation’ dates to Polanyi’s work “The Great Transformation” (1944), this deliverable also shows that it is only since more recently – during the last 15 years – that the concept of transformative change has been picked up by a broad group of sciences and societal actors. However, this brings about an acute need to strengthen the conceptual foundations of the term, also by bridging and harmonising disciplinary divides.

Complementary to expanding the conceptual understanding of transformative change, future research should invest in developing operational analytical frameworks that are needed to explore the ‘how’ or transformative change, as well as the monitoring of processes of change. Here, work such that of Kanger et al. (2020) who outline six policy intervention points to promote transformative change (e.g., stimulating and accelerating different niches, destabilizing existing regimes and tilting the landscape) can serve as a useful entry point to alter the broader framework conditions enabling change.

Progress is also needed regarding concrete empirical analyses of transformative change, currently largely missing, including for example the understanding of enabling and disabling factors, the identification of archetypes of solutions and patterns of change, as well as their context-specific or place-based elements, along with any potential for replicability and/or scalability. Finally, an important research avenue would be to explicitly address how research on transformative change and research on the biodiversity nexus might feed into each other, which is now missing from both a conceptual and empirical viewpoint.

6.2.2. The potential of the One Health perspective: connect the dots

Relatively new in the sustainability debate is the role of health and the health sector. Since COVID the awareness of the importance of this perspective has grown, interlinked with other societal domains. Health is a promising valuation perspective that goes beyond an only monetary approach and is closer to and more all-embracing in terms of quality of life.

The health sector plays a double role. On the one hand it contributes to environmental pressure, from for example high energy use, waste in general, medicinal waste. On the other it can play an advocacy and more preventative role towards a healthier living environment, in which the public health challenges bring important arguments: for example (re)naturing urban areas and climate change measures. Ultimately, this also leads to less curative medical treatments and related environmental pressures. The health sector also increasingly recognizes the importance of a One Health approach: an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems. The main challenge is how to incorporate these One Health challenges in practice. Science has an important role to play here, not only with specialist expert knowledge about slices of complexity, but mainly about an integrated practice relevant decision support systems that will support transformative changes.

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I. Annexes

i. Search string

The first step was to develop a search strategy that would result in a feasible and suitable list of articles. To aid this process, a literature review protocol was developed. This protocol consisted of the iterative development of search string through a process of trial and error and the development of critical appraisal techniques. This process was led by DRIFT, but each step of the review process was discussed and then revised in collaboration with the broader work package 2 team.

The first component of the literature review protocol was the development of the search string. After a few iterations (to illustrate: a first broad search, using synonyms for transformative change, like "transformation" or "systemic-change", yielded over 1 million articles, which we did not deem feasible), the final search string was selected and used to identify publications for the initial database. The Scopus database was searched to identify publications for the period 2002-current. Using the following search term: TITLE-ABS-KEY ("transformative change") AND TITLE-ABS-KEY ("[nexus element]") AND (EXCLUDE (DOCTYPE , "bk")) (see **table 2**).

Table 2. Search strings to identify literature on transformative change in the biodiversity nexus

Nexus element	Search string
Biodiversity	TITLE-ABS-KEY ("transformative change") AND TITLE-ABS-KEY ("biodivers*")
Climate	TITLE-ABS-KEY ("transformative change") AND TITLE-ABS-KEY ("climate")
Energy	TITLE-ABS-KEY ("transformative change") AND TITLE-ABS-KEY ("energy")
Food	TITLE-ABS-KEY ("transformative change") AND TITLE-ABS-KEY ("agricultur*")
Health	TITLE-ABS-KEY ("transformative change") AND TITLE-ABS-KEY ("health") OR TITLE-ABS-KEY ("wellbeing")
Transport	TITLE-ABS-KEY ("transformative change") AND TITLE-ABS-KEY ("transport")
Water	TITLE-ABS-KEY ("transformative change") AND TITLE-ABS-KEY ("water")

A Scopus search with the seven search strings conducted in October 2022 yielded a total of 849 potentially relevant articles, spread over seven separate Scopus lists – one per nexus element. Two publication sets were extracted from each of these seven lists: 1) the 40 most cited articles, to give an impression of the most authoritative studies in conceptualising transformative change; and 2) the 20 most recent studies, to include the latest publications and correct for the disproportionate weight of highly cited publications as newer articles have not yet been cited much. By selecting the 40 most recent and the 20 most cited publications per nexus element search, a total of 410 document results were exported from Scopus to Excel. Subsequently, the two publication sets per nexus element were merged and in total 117 duplicates were removed. All publications sets were categorized according to each nexus element and stored in the work package 2 SharePoint.

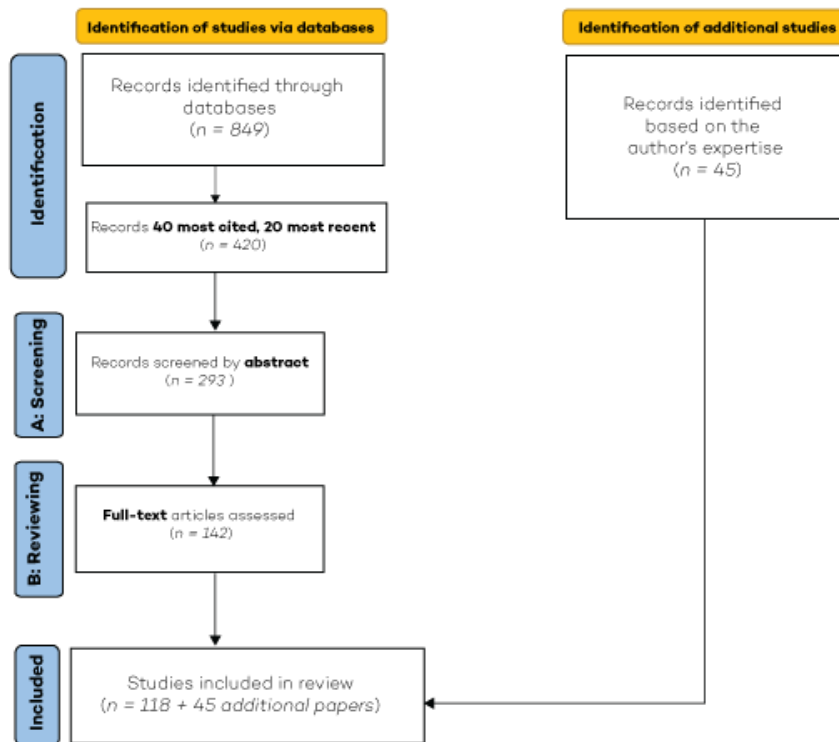


Figure I.12. Flow diagram of the literature review process and the number of identified papers for each of the steps

ii. Survey questions Phase A: abstract screening

BIONEXT Literature Review: Phase A - abstracts

Use this survey to screen abstracts for inclusion or exclusion in the study.

The paper is **INCLUDED** if the answer to both questions is **YES**. The paper is **EXCLUDED** if the answer to both questions is **NO**. The paper is a **MAYBE** one of the answers to the questions is **YES**.

Please also add the 'verdict' for the paper to the overview, so we can easily track our progress.

* Required

1. Reviewer (your name): *

2. Paper ID: *

3. The paper is about [1 or more of the 7 nexus elements]. **It takes a systems perspective to the domain**, by at least describing its relation to landscape dynamics.

The scale is not an excluding factor. *

Mark only one oval.

- Yes
 No: it describes (a) domain(s), but not in a system perspective

4. The paper is about transformative change. **It describes what transformative change should entail** (i.e. the end-state/vision; crucial mechanisms of change; actors). *

Mark only one oval.

- Yes
 No: it does not describe transformative change; or it only concludes with the need for transformative change.

5. Is the paper included or excluded for review?

Mark only one oval.

- Included
- Excluded
- Maybe?

6. The paper links to justice in the context of biodiversity. It is useful for T2.4. *
Mark only one oval.

- Yes
- No

iii. Survey questions Phase B: full-text review

BIONEXT Literature Review: Phase B - full-text

Use this survey to review the full-text papers on their understanding of transformative change.

* Required

Reviewer (Your name) *

Paper ID: *

BIONEXT Domains and Nexus Interlinkages

1. What BIONEXT biodiversity element(s) are captured in this paper? *

What systems does the paper link together? You can tick multiple boxes.

- Water;
- Food;
- Climate;
- Energy;
- Transport;
- Biodiversity;

- Health;
- Justice

1.a Does the paper **prioritize a particular nexus element**? *

*I.e. it touches upon multiple elements, but it is most detailed about this particular element.
Mark only one oval.*

- No it does not have a priority domain.
- Water
- Transport
- Energy
- Climate
- Health
- Biodiversity
- Food
- Justice

1.b. If there is a priority domain, is a **specific framing used to describe or analyse the domain**?

e.g. for health a focus might be on medication use vs water quality, but it could also be on fertility rates and ecological footprint. For Water this could be a focus on marine waters or on terrestrial waters.

2. Does the paper describe **nexus interlinkages**?

Mark only one oval.

- Yes
- No

3. Does the paper describe elements of **biodiversity** in relation to transformative change?

- No, it does not describe any biodiversity element;
- Yes, it describes a concrete role for biodiversity;
- Biodiversity is mentioned, but its role is not made explicit.

Conceptualizations of transformative change

4. How does the paper conceptualize **transformative change**? *

If possible, paste a direct quote from the paper and *put it between " "*.

4.a **Does the paper describe the transformed state / end state of the system after the transformation / the desired vision?**

If possible, paste a direct quote from the paper and put it between " " .

4.b **Does this transformation include change of incumbent structures?** (e.g. the current market system, governance approaches?)

4.c **Does the paper specifically argue against** particular conceptualisations of transformative change? If so.. briefly summarize their argument here.

Impact of transformation on subsystems

5. What **type of changes does this transformation require?** *

What changes are described as crucial for a transformation? You can tick multiple boxes.

- Environmental: changes in the natural environment, such as land-use, water quality;
- Political and/or institutional: changes in how we govern, governance approaches;
- Policies and policy instruments: policy interventions, strategies, directives, laws, subsidy or taxes;
- Economic and/or private sector: changes in how the market operates that originate from the market/private sector, business models;
- Infrastructure: changes in the physical structures, such as the design of our cities or rural areas, or the physical supply chain infrastructures;
- Technological: changes through technological innovations, such as processes of technological substitution (e.g. from fossil fuel driven mobility to electric mobility);
- Cultural: changes in how we value and understand [the biodiversity nexus], such as status/
- Behavioural: changes in human behaviour, such decreasing environmental footprint,

dietary change;

- Scientific: changes in how we measure, monitor, approach, and conceptualize the [biodiversity nexus], such as more inter/transdisciplinary approaches, longer-term projects, action-research;
- Health: changes in our public wellbeing, access to health services;
- Justice: changes in how impacts are distributed across human-natural systems, such as equitable distribution of system externalities and benefits, common approaches to resources, rule of law, accountability;

4.a If the paper describes some of **these changes in more detail**, can you note what these entail?
e.g. if the paper sees a particular policy change as important, or a specific change in supply chains as vital.

Leave this question blank if the paper does not describe it in more detail

Mechanisms of change

6. What **enablers of transformation** are described?

It does not describe any? Rethink whether the paper is eligible for review.

Check all that apply.

- WHAT: opportunities, levers for change, triggers, disruption;
- HOW: processes, conditions, options for change, actions, strategies, interventions, alternatives;
- WHO: actors, sectors, regions, states, institutions;
- None.

6.a If the paper describes **[WHAT] enables transformation**, can you provide some more detail?

WHAT: opportunities, levers for change, triggers, disruption.

6.b If the paper describes **[HOW] transformation is enabled**, can you provide some more detail?

HOW: processes, conditions, options for change, actions, strategies, solutions, alternatives.

6.c. If the paper describes **[WHO] enables transformation**, can you provide some more detail?
WHO: actors, sectors, regions, states, institutions.

Obstacles to transformative change

7. What **obstacles to or disablers of transformative change** are described in the paper?*

Check all that apply.

- WHAT: innovations, strategies, interventions, triggers, events;
- HOW: processes, actions, ...;
- WHO: actors, sectors, regions, states, institutions;
- None.

7.a If the paper describes **[WHAT] disables transformation**, can you provide some more detail?

What: Innovations, strategies, interventions, triggers, events

7.b If the paper describes **[HOW] transformation is disabled**, can you provide some more detail?

HOW: processes, actions,

7.c If the paper describes **[WHO] disables transformation**, can you provide some more detail?

WHO: actors, sectors, regions, states, institutions.

8. Does the paper describe **ways to overcome these obstacles** to transformative change?
Think of breakdown or phase-out of practices and policies, or exnovation.

Justice in the biodiversity nexus

9. Does the paper describe **elements of justice**? *

You can tick multiple boxes.

- No, It does not describe any justice element;
- Foreseen consequences for particular groups of people, regions, sectors, or non-human actors;
- Unforeseen and or unintended consequences for particular groups of people, regions, sectors, or non-human actors;
- It sees a key role for particular groups of people, regions, sectors, or non-human actors;

9.a Can you **expand on these elements of justice** that are described in the paper?

If possible, paste a direct quote from the paper and *put it between " "*.

All done!

Was the paper enjoyable to read? :-)

- Yes, it was great!
 - No!!! It sucked!
 - Meh... i have no strong feelings about this paper.
-

iv. List of reviewed full-text papers

ID	Anchoring type	Author(s)	Year	Title	Cited
73	Societal Functions	Åhman M., Nilsson L.J., Johansson B.	2017	Global climate policy and deep decarbonization of energy-intensive industries	91
157	Governance	Amann M., Kiesewetter G., Schöpp W.	2020	Reducing global air pollution: The scope for further policy interventions: Achieving clean air worldwide	42
234	Governance	Amundsen H., Hovelsrud G.K., Aall C.	2018	Local governments as drivers for societal transformation: towards the 1.5 °C ambition	34
162	Governance	Angeler D.G., Eyre H.A., Berk M.	2022	Adaptation, Transformation and Resilience in Healthcare Comment on “Government Actions and Their Relation to Resilience in Healthcare During the COVID-19 Pandemic in New South Wales, Australia and Ontario, Canada”	
166	Societal Functions	Augustin M.A., Cole M.B.	2022	Towards a sustainable food system by design using faba bean protein as an example	
35	Governance	Barrios E., Gemmill-Herren B., Bicksler A.	2020	The 10 Elements of Agroecology: enabling transitions towards sustainable agriculture and food systems through visual narratives	29
268	Governance	Bos J.J., Brown R.R., Farrelly M.A.	2015	Building networks and coalitions to promote transformational change: Insights from an Australian urban water planning case study	23
275	Governance	Brodnik C., Brown R.	2018	Strategies for developing transformative capacity in urban water management sectors: The case of Melbourne, Australia	13
74	Infrastructure	Brown R., Ashley R., Farrelly M.	2011	Political and Professional Agency Entrapment: An Agenda for Urban Water Research	90
127	Infrastructure	Bugge M.M., Andersen A.D., Steen M.	2022	The role of regional innovation systems in mission-oriented innovation policy: exploring the problem-solution space in electrification of maritime transport	5
66	Governance	Burch S., Shaw A., Dale A.	2014	Triggering transformative change: A development path approach to climate change response in communities	116
41	Scientific Community	Buxton R.T., Bennett J.R., Reid A.J.	2021	Key information needs to move from knowledge to action for biodiversity conservation in Canada	18
136	Scientific Community	Carlisle L.	2016	Factors influencing farmer adoption of soil health practices in the United States: a narrative review	95
227	Societal Functions	Castán Broto V., Baptista I., Kirshner J.	2018	Energy justice and sustainability transitions in Mozambique	85
29	Human-Nature Relations	Chan K.M.A., Boyd D.R., Gould R.K.	2020	Levers and leverage points for pathways to sustainability	57
31	Human-Nature Relations	Chapin F.S., III, Sommerkorn M.	2015	Ecosystem stewardship: A resilience framework for arctic conservation	46

ID	Anchoring type	Author(s)	Year	Title	Cited
105	Social Practice	Clissold R., McNamara K.E., Westoby R.	2022	Emotions of the Anthropocene across Oceania	1
51	Human-Nature Relations	Daigle C., Vasseur L.	2019	Is it time to shift our environmental thinking? A perspective on barriers and opportunities to change	10
32	Governance	Dawson L., Elbakidze M., Angelstam P.	2017	Governance and management dynamics of landscape restoration at multiple scales: Learning from successful environmental managers in Sweden	41
39	Governance	Delabre I., Boyd E., Brockhaus M.	2020	Unearthing the myths of global sustainable forest governance	23
46	Societal Functions	Delabre I., Rodriguez L.O., Smallwood J.M.	2021	Actions on sustainable food production and consumption for the post-2020 global biodiversity framework	14
57	Scientific Community	Destoumieux-Garzón D., Matthies-Wiesler F., Bierne N.	2022	Getting out of crises: Environmental, social-ecological and evolutionary research is needed to avoid future risks of pandemics	5
47	Scientific Community	Dhyani S., Bartlett D., Kadaverugu R.	2020	Integrated climate sensitive restoration framework for transformative changes to sustainable land restoration	13
76	Governance	Diercks G., Larsen H., Steward F.	2019	Transformative innovation policy: Addressing variety in an emerging policy paradigm	89
172	Human-Nature Relations	Downing A.S., Kumar M., Andersson A.	2022	Unlocking the unsustainable rice-wheat system of Indian Punjab: Assessing alternatives to crop-residue burning from a systems perspective	2
117	Infrastructure	Dyrhaug H.	2021	Discourses about EU Transport Decarbonisation: Towards a Paradigm Shift?	1
24	Human-Nature Relations	Ehrlich P.R., Kareiva P.M., Daily G.C.	2012	Securing natural capital and expanding equity to rescale civilization	156
63	Scientific Community	Fazey I., Schöpke N., Caniglia G.	2018	Ten essentials for action-oriented and second order energy transitions, transformations and climate change research	168
271	Governance	Fedele G., Donatti C.I., Harvey C.A.	2020	Limited use of transformative adaptation in response to social-ecological shifts driven by climate change	17
270	Infrastructure	Ferguson B.C., Brown R.R., Deletic A.	2013	A diagnostic procedure for transformative change based on transitions, resilience, and institutional thinking	19
81	Infrastructure	Ferguson B.C., Brown R.R., Deletic A.	2013	Diagnosing transformative change in urban water systems: Theories and frameworks	71
68	Infrastructure	Ferguson B.C., Frantzeskaki N., Brown R.R.	2013	A strategic program for transitioning to a Water Sensitive City	107
17	Human-Nature Relations	Fiasco V., Massarella K.	2022	Human-Wildlife Coexistence: Business as Usual Conservation or an Opportunity for Transformative Change?	
27	Societal functions	Folke C., Polasky S., Rockström J.	2021	Our future in the Anthropocene biosphere	74
92	Scientific Community	Forsyth T., McDermott C.L., Dhakal R.	2022	What is equitable about equitable resilience? Dynamic risks and subjectivities in Nepal	

ID	Anchoring type	Author(s)	Year	Title	Cited
18	Governance	Fougères D., Jones M., McElwee P.D.	2022	Transformative conservation of ecosystems	1
194	Governance	Freibauer A., Mathijs E., Brunori G.	2011	Sustainable Food Consumption and Production in a Resource-constrained World	24
123	Scientific Community	Ghosh B., Kivimaa P., Ramirez M., Schot J., Torrens J.	2021	Transformative outcomes: Assessing and reorienting experimentation with transformative innovation policy	8
202	Societal Functions	Gordon A., Becerra L.D., Fressoli M.	2017	Potentialities and constraints in the relation between social innovation and public policies: Some lessons from South America	13
287	Governance	Grumbine R.E., Xu J.	2021	Mountain futures: pursuing innovative adaptations in coupled social-ecological systems	3
55	Human-Nature Relations	Grumbine R.E., Xu J.	2021	Five Steps to Inject Transformative Change into the Post-2020 Global Biodiversity Framework	6
6	Human-Nature Relations	Hagen E.J., Gould R.K.	2022	Relational values and empathy are closely connected: A study of residents of Vermont's Winooski River watershed	
7	Social Practice	Haider V., Essl F., Zulka K.P.	2022	Achieving Transformative Change in Food Consumption in Austria: A Survey on Opportunities and Obstacles	
82	Governance	Hall S., Foxon T.J., Bolton R.	2017	Investing in low-carbon transitions: energy finance as an adaptive market	63
21	Governance	Harvey C.A., Chacón M., Donatti C.I.	2014	Climate-Smart Landscapes: Opportunities and Challenges for Integrating Adaptation and Mitigation in Tropical Agriculture	182
26	Governance	Head L., Adams M., Mcgregor H.V.	2014	Climate change and Australia	86
264	Governance	Hordijk M., Sara L.M., Sutherland C.	2014	Resilience, transition or transformation? A comparative analysis of changing water governance systems in four southern cities	35
215	Societal Functions	Howard J.A.	2022	Facing up to our converging climate and food system catastrophes	
20	Governance	Huntjens P., Kemp R.	2022	The Importance of a Natural Social Contract and Co-Evolutionary Governance for Sustainability Transitions	2
214	Social Practice	Ibro G., Abdoulaye I.M., Synnevåg G.	2022	Food security and child malnutrition in the regions of Maradi, Tahoua and Tillabéri in Niger: The status, the causes, and transformative change	
187	Societal Functions	Jacobs B., Cordell D., Chin J.	2017	Towards phosphorus sustainability in North America: A model for transformational change	35
118	Infrastructure	Jaynes C., Lethco T., Khuong Y., Riscica V.	2012	Looking back and moving forward	1
65	Societal Functions	Jenkins K., Sovacool B.K., McCauley D.	2018	Humanizing sociotechnical transitions through energy justice: An ethical framework for global transformative change	138
203	Governance	Jones N., Holmes R., Presler-Marshall E.	2017	Transforming gender constraints in the agricultural sector: The potential of social protection programmes	13

ID	Anchoring type	Author(s)	Year	Title	Cited
266	Governance	Koff H., Maganda C.	2016	The EU and the Human Right to Water and Sanitation: Normative Coherence as the Key to Transformative Development	31
179	Societal Functions	Lade S.J., Haider L.J., Engström G.	2017	Resilience offers escape from trapped thinking on poverty alleviation	79
90	Human-Nature Relations	Lam D.P.M., Hinz E., Lang D.J.	2020	Indigenous and local knowledge in sustainability transformations research: A literature review	48
209	Social Practice	Leitschuh B., Stewart W.P., van Riper C.J.	2022	Place-making in the Corn Belt: The productivist landscapes of the “good farmer”	1
216	Governance	Lemieux C.J., Beazley K.F., MacKinnon D.	2022	Transformational changes for achieving the Post-2020 Global Biodiversity Framework ecological connectivity goals	
94	Governance	Lidskog R., Sundqvist G.	2022	Lost in transformation: The Paris Agreement, the IPCC and the quest for national transformative change	
217	Governance	Lipper L., Puri J., Cavatassi R.	2022	How does climate change affect the evidence we need for agricultural development?	1
3	Governance	Loomis J.J., Bond A., Dziedzic M.	2022	Transformative effectiveness: How EIA can transform stakeholders’ frames of reference	
1	Governance	Loorbach D.	2022	Designing radical transitions: a plea for a new governance culture to empower deep transformative change	
30	Governance	Mabhaudhi T., Chibarabada T.P., Chimonyo V.G.P.	2019	Mainstreaming underutilized indigenous and traditional crops into food systems: A South African perspective	47
169	Governance	Malin S.A., Mayer A., Roeser K.	2022	Collective Neoliberalism and Market Fundamentalism: Why Concerned People Acquiesce to the Oil and Gas Industry ¹	
232	Social Practice	Marteau T.M.	2017	Towards environmentally sustainable human behaviour: Targeting non-conscious and conscious processes for effective and acceptable policies	41
43	Scientific Community	Massarella K., Nygren A., Fletcher R.	2021	Transformation beyond conservation: how critical social science can contribute to a radical new agenda in biodiversity conservation	16
62	Infrastructure	McCormick K., Anderberg S., Coenen L.	2013	Advancing sustainable urban transformation	266
33	Governance	McElwee P., Turnout E., Chiroleu-Assouline M.	2020	Ensuring a Post-COVID Economic Agenda Tackles Global Biodiversity Loss	36
78	Scientific Community	Menton M., Larrea C., Latorre S.	2020	Environmental justice and the SDGs: from synergies to gaps and contradictions	79
175	Governance	Milsom P., Smith R., Walls H.	2022	Expanding Public Health Policy Analysis for Transformative Change: The Importance of Power and Ideas	2
64	Human-Nature Relations	Moser S.C., Jeffress Williams S., Boesch D.F.	2012	Wicked challenges at land's end: Managing coastal vulnerability under climate change	141
213	Societal Functions	Mosnier A., Schmidt-Traub G., Obersteiner M.	2022	How can diverse national food and land-use priorities be reconciled with global sustainability targets? Lessons from the FABLE initiative	

ID	Anchoring type	Author(s)	Year	Title	Cited
201	Infrastructure	Nguyen M.T., Renaud F.G., Sebesvari Z.	2019	Drivers of change and adaptation pathways of agricultural systems facing increased salinity intrusion in coastal areas of the Mekong and Red River deltas in Vietnam	17
263	Infrastructure	O'Donnell E., Thorne C., Ahilan S.	2020	The blue-green path to urban flood resilience	37
229	Governance	Olazabal M., Pascual U.	2016	Use of fuzzy cognitive maps to study urban resilience and transformation	72
222	Governance	Pahl-Wostl C.	2019	Governance of the water-energy-food security nexus: A multi-level coordination challenge	166
274	Governance	Pahl-Wostl C.	2020	Adaptive and sustainable water management: from improved conceptual foundations to transformative change	13
260	Governance	Pahl-Wostl C., Becker G., Knieper C.	2013	How multilevel societal learning processes facilitate transformative change: A comparative case study analysis on flood management	104
236	Societal Functions	Pahl-Wostl C., Bhaduri A., Bruns A.	2018	Editorial special issue: The Nexus of water, energy and food – An environmental governance perspective	21
279	Infrastructure	Pakizer K., Fischer M., Lieberherr E.	2022	Entrepreneurial strategies for transformative change: An application to grassroots movements for sustainable urban water systems	
61	Governance	Park S.E., Marshall N.A., Jakku E.	2012	Informing adaptation responses to climate change through theories of transformation	350
9	Governance	Pascual U., McElwee P.D., Diamond S.E.	2022	Governing for Transformative Change across the Biodiversity-Climate-Society Nexus	4
83	Social Practice	Paulson S.	2017	Degrowth: Culture, power and change	63
235	Societal Functions	Pellicer-Sifres V., Belda-Miquel S., Cuesta-Fernandez I.	2018	Learning, transformative action, and grassroots innovation: Insights from the Spanish energy cooperative Som Energia	32
28	Human-Nature Relations	Pereira L., Karpouzoglou T., Doshi S.	2015	Organising a safe space for navigating social-ecological transformations to sustainability	63
34	Scientific Community	Pereira L., Sitas N., Ravera F.	2019	Building capacities for transformative change towards sustainability: Imagination in Intergovernmental Science-Policy Scenario Processes	35
196	Scientific Community	Pereira L.M., Drimie S., Maciejewski K.	2020	Food system transformation: Integrating a political-economy and social-ecological approach to regime shifts	20
124	Societal Functions	Pichler M., Krenmayr N., Maneka D., Brand U., Högelsberger H., Wissen M.	2021	Beyond the jobs-versus-environment dilemma? Contested social-ecological transformations in the automotive industry	5
97	Human-Nature Relations	Priebe J., Reimerson E., Hallberg-Sramek I.	2022	Transformative change in context—stakeholders' understandings of leverage at the forest-climate nexus	3
69	Governance	Reganold J.P., Jackson-Smith D., Batie S.S.	2011	Transforming U.S. agriculture	107
37	Human-Nature Relations	Reyes-García V., Fernández-Llamazares Á., Aumeeruddy-Thomas Y.	2022	Recognizing Indigenous peoples' and local communities' rights and agency in the post-2020 Biodiversity Agenda	25

ID	Anchoring type	Author(s)	Year	Title	Cited
249	Governance	Ripple W.J., Moomaw W.R., Wolf C.	2022	Six steps to integrate climate mitigation with adaptation for social justice	1
239	Governance	Romero-Lankao P., Norton R.	2018	Interdependencies and Risk to People and Critical Food, Energy, and Water Systems: 2013 Flood, Boulder, Colorado, USA	14
86	Societal Functions	Rosenbloom D., Meadowcroft J., Cashore B.	2019	Stability and climate policy? Harnessing insights on path dependence, policy feedback, and transition pathways	54
147	Governance	Rudolph T.B., Ruckelshaus M., Swilling M.	2020	A transition to sustainable ocean governance	57
15	Governance	Rusch G.M., Bartlett J., Kyrkjeeide M.O.	2022	A joint climate and nature cure: A transformative change perspective	1
19	Human-Nature Relations	Sandbrook C., Gómez-Baggethun E., Adams W.M.	2022	Biodiversity conservation in a post-COVID-19 economy	11
88	Societal Functions	Schmidt T.S., Born R., Schneider M.	2012	Assessing the costs of photovoltaic and wind power in six developing countries	52
242	Social Practice	Sharp L., Macrorie R., Turner A.	2015	Resource efficiency and the imagined public: Insights from cultural theory	14
72	Governance	Sharpe B., Hodgson A., Leicester G.	2016	Three horizons: A pathways practice for transformation	92
178	Governance	Shreck A.	2005	Resistance, redistribution, and power in the Fair Trade banana initiative	95
198	Governance	Skrimizea E., Lecuyer L., Bunnefeld N.	2020	Sustainable agriculture: Recognizing the potential of conflict as a positive driver for transformative change	19
185	Governance	Stein C., Pahl-Wostl C., Barron J.	2018	Towards a relational understanding of the water-energy-food nexus: an analysis of embeddedness and governance in the Upper Blue Nile region of Ethiopia	37
251	Social Practice	Suitner J., Haider W., Philipp S.	2022	Social innovation for regional energy transition? An agency perspective on transformative change in non-core regions	1
49	Governance	Tessnow-von Wysocki I., Vadrot A.B.M.	2020	The Voice of Science on Marine Biodiversity Negotiations: A Systematic Literature Review	11
211	Governance	Thiessen Martens J.	2022	Restoring social and ecological relationships in the agroecosystems of Canada's prairie region	
71	Scientific Community	Tschakert P., van Oort B., St. Clair A.L.	2013	Inequality and transformation analyses: a complementary lens for addressing vulnerability to climate change	94
13	Human-Nature Relations	Turner N.J., Cuerrier A., Joseph L.	2022	Well grounded: Indigenous Peoples' knowledge, ethnobiology and sustainability	2
200	Governance	van Zwanenberg P., Cremaschi A., Obaya M.	2018	Seeking unconventional alliances and bridging innovations in spaces for transformative change: The seed sector and agricultural sustainability in Argentina	18
45	Governance	Visseren-Hamakers I.J., Razzaque J., McElwee P.	2021	Transformative governance of biodiversity: insights for sustainable development	14

ID	Anchoring type	Author(s)	Year	Title	Cited
98	Governance	Wamsler C., Mundaca L., Osberg G.	2022	Rethinking political agency: The role of individuals' engagement, perceptions and trust in transitioning to a low-carbon transport system	
243	Human-Nature Relations	Weiland S., Hickmann T., Lederer M.	2021	The 2030 agenda for sustainable development: Transformative change through the sustainable development goals?	13
25	Societal functions	Wezel A., Herren B.G., Kerr R.B.	2020	Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review	104
190	Societal Functions	Winkel T., Bommel P., Chevarría-Lazo M.	2016	Panarchy of an indigenous agroecosystem in the globalized market: The quinoa production in the Bolivian Altiplano	26
80	Societal Functions	Winkler H., Marquand A.	2009	Changing development paths: From an energy-intensive to low-carbon economy in South Africa	73
240	Infrastructure	Yeh S., Yang C., Gibbs M.	2016	A modeling comparison of deep greenhouse gas emissions reduction scenarios by 2030 in California	14
289	Social Practice	Zagaria C., Schulp C.J.E., Zavalloni M.	2021	Modelling transformational adaptation to climate change among crop farming systems in Romagna, Italy	10

v. List of additional papers added to the review

#	Author(s)	YEAR	TITLE
1	Bennett (N.J.) et al.	2019	<i>Just Transformations to Sustainability</i>
2	Bennett (E.M.) et al.	2016	<i>Bright spots: seeds of a good Anthropocene</i>
3	Bentz et al.	2022	<i>Beyond “blah blah blah”: exploring the “how” of transformation</i>
4	Blythe et al.	2018	<i>The Dark Side of Transformation: Latent Risks in Contemporary Sustainability Discourse</i>
5	Chan and Satterfield	2013	<i>Justice, equity, and biodiversity (book)</i>
6	Chapin et al.	2015	<i>Ecosystem stewardship: A resilience framework for arctic conservation</i>
7	Davidson	2019	<i>Exnovating for a renewable energy transition</i>
8	Dias & Partidario	2019	<i>Mind the Gap: The Potential Transformative Capacity of Social Innovation</i>
9	Díaz et al.	2019	<i>Pervasive human-driven decline of life on Earth points to the need for transformative change</i>
10	Dorninger et al.	2020	<i>Leverage points for sustainability transformation: a review on interventions in food and energy systems</i>
11	Eckersley	2022	<i>Greening states and societies: from transitions to great transformations (book chapter)</i>
12	Elbakidze et al.	2018	<i>Direct and indirect drivers of change in biodiversity and nature's contributions to people (book chapter)</i>
13	Feola	2015	<i>Societal transformation in response to global environmental change: a review of emerging concepts</i>
14	Folke et al.	2010	<i>Resilience Thinking: Integrating Resilience, Adaptability and Transformability</i>
15	Fraser	2008	<i>From Redistribution to Recognition?: Dilemmas of justice in a 'postsocialist' age</i> <i>A critical appraisal of Sustainable Consumption and Production research: The reformist, revolutionary and reconfiguration positions</i>
16	Geels et al.	2015	<i>Policy implementation through multi-level governance: analysing practical implementation of EU air quality directives in Germany</i>
17	Gollata and Newig	2017	<i>An actionable understanding of societal transitions: the X-curve framework</i>
18	Hebinck et al.	2022	<i>What is the ‘Just Transition’?</i>
19	Heffron and McCauley	2018	<i>Transition versus transformation: What’s the difference?</i>
20	Hölscher et al.	2018	<i>Dreamscapes of Modernity (book)</i>
21	Jasanoff and Kim	2015	<i>Introduction to the special issue on just food system transition: Tackling inequalities for sustainability</i>
22	Kaljonen et al.	2023	<i>The interconnected dynamics of social practices and their implications for transformative change: A review.</i>
23	Klitkou et al.	2022	<i>Conservation and Justice the Anthropocene: Definitions and Debates (book chapter)</i>
24	Kopnina and Washington	2020	<i>Dynamic sustainabilities – technology, environment, social justice (book)</i>
25	Leach et al.	2010	<i>The next phase of the energy transition and its implications for research and policy</i>
26	Markard	2018	

27	Menton	2020	<i>Environmental justice and the SDGs: from synergies to gaps and contradictions</i>
28	Muiderman et al.	2022	<i>The anticipatory governance of sustainability transformations: Hybrid approaches and dominant perspectives</i>
29	Olsson et al.	2014	<i>Sustainability transformations: a resilience perspective</i>
30	Patterson et al.,	2017	<i>Exploring the governance and politics of transformations towards sustainability</i>
31	Perreault et al.	2012	<i>Environmental Injustice in the Onondaga Lake Waterscape, New York State, USA</i>
32	Rockström et al.	2017	<i>A roadmap for rapid decarbonization</i>
33	Sahakian et al.	2021	<i>Challenging social norms to recraft practices: A Living Lab approach to reducing household energy use in eight European countries</i>
34	Scoones	2007	<i>Sustainability</i>
35	Scoones et al.	2020	<i>Transformations to sustainability: combining structural, systemic and enabling approaches</i>
36	Shove et al.	2012	<i>The Dynamics of Social Practice: Everyday Life and How it Changes</i>
37	Steenbergen and Schipper	2017	<i>Struggling with justice in transitions. Essay. Drift for transition</i>
38	Temper et al.	2018	<i>A perspective on radical transformations to sustainability: resistances, movements and alternatives</i>
39	Termeer et al.	2015	<i>Governance Capabilities for Dealing Wisely With Wicked Problems</i>
40	Tschakert et al.	2013	<i>Inequality and transformation analyses: a complementary lens for addressing vulnerability to climate change</i>
41	Vogel & O'Brien	2021	<i>Getting to the heart of transformation</i>
42	Von Wehrden et al.	2017	<i>Methodological Challenges in Sustainability Science: A Call for Method Plurality, Procedural Rigor and Longitudinal Research</i>
43	West et al.	2020	<i>A relational turn for sustainability science? Relational thinking, leverage points and transformations</i>
44	Whitfield et al. 2021	2021	<i>A framework for examining justice in food system transformations research</i>
45	Zurek et al.	2021	<i>Looking across diverse food system futures: Implications for climate change and the environment</i>

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