REPORT ON THE SOCIETAL AND BEHAVIOURAL DIMENSIONS OF INNOVATIONS

Deliverable number: D1.3

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DAISY

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DAISY
LET'S TURN ON TRANSFORMATION

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List of abbreviations and acronyms used in this document

Acronym	Definition
AI	Artificial Intelligence
CBD	Convention on Biological Diversity
CU	Coventry University
DoA	Description of Action
GF	GreenFormation
GHG	Greenhouse Gas
GIS	Geographic Information System
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPLCs	Indigenous Peoples and Local Communities
KTU	Kaunas University of Technology
LLM	Large Language Model
MLU	Martin Luther University Halle-Wittenberg
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
REDD+	Reducing Emissions for deforestation and forest degradation in developing countries
TIMs	Transformative intervention mixes
TIESS	Transdisciplinary Institute for Environmental and Social Studies
TRD2	Transformative Diagnostic Tool
VCM	Voluntary Carbon Market
WOS	Web of Science
WP	Work Package

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Background: About DAISY

DAISY - DigitAl, technologIcal and Social innovation mixes enabling transformation for biodiversity and equitY - will advance understanding of how specific mixes of interventions including social-technological innovations can be used to induce transformation for biodiversity and equity.

DAISY's main objectives

- To understand which socio-economic, political and behavioural processes, and their interrelationships shape and enable our personal, political and practical ability to respond to the biodiversity crisis and how they impact on transformative change.
- To collect existing tools, processes, interventions and innovations that are conducive to triggering transformative change with the understanding of what enables them to address biodiversity loss and social inequity.
- To create intervention mixes based on existing tools and innovations and apply them in practice to induce transformation in all three spheres (personal, political, practical) to support biodiversity and equity prioritisation in decision- and policymaking.

Our case studies to test innovations

Innovation mixes will be tested and assessed for effectiveness in five seed innovation intensive case studies, within the domains of agri-food, education, energy and urban and regional development.

Turning on transformation

DAISY will have a special emphasis on amplifying innovation through bridging activities, networking events, wide stakeholder engagement and collection, connection and distribution of innovation seeds to switch on transformation.

Executive summary

This report explores how social-technological innovations – particularly those with digital and technological components – intersect with societal values, behaviours, and worldviews, as well as with broader institutional and structural dynamics, in the context of biodiversity and equity. The report draws on a comprehensive review of academic literature, combining a structured scoping review with an AI-assisted expert interpretative analysis. This dual analytical approach has enabled the research team to map and critically assess how innovations mediate what the DAISY project terms "response-able" relationships with biodiversity. These are relationships characterised by attentiveness, care, and ethical responsibility across personal, practical, and political spheres.

The findings reveal that while social-technological innovations can foster greater awareness, participation, and ethical engagement with biodiversity, their impacts are far from uniformly positive. Social-technological innovations can support inclusive and context-sensitive conservation efforts. However, they can also reinforce exclusion, surveillance, and technocratic control, especially when implemented without attention to justice, power dynamics, situated contexts or local knowledge systems. The report highlights that justice is not merely a desirable outcome but a foundational condition for transformative innovation.

The review also underscores the importance of addressing structural inequalities, such as those related to gender, class, ethnicity, and digital access, which shape who benefits from innovation and who is left behind. It cautions against over-reliance on 'tech-fix' solutions that depoliticise biodiversity governance and obscure the root causes of ecological degradation. Moreover, the report identifies a significant gap in the literature regarding the discontinuation of harmful or obsolete technologies, pointing to an "innovation bias" that favours emergence over decline.

In sum, the report affirms that digital and technological innovations can play a transformative role in fostering more ethical, inclusive, and response-able relationships with biodiversity. However, their success depends on how they are designed, governed, and embedded within broader systems of care, justice, and ecological integrity. These findings will inform the next phases of the DAISY project, including especially the development of transformative intervention mixes and

participatory processes that centre equity and pluralism, and the amplification of seed social-technological innovations.

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1. Introduction

1.1 Purpose of the Deliverable

This deliverable has been developed as part of the DAISY project's Task 1.3: *Understanding the societal and behavioural dimensions of social-technological innovations for biodiversity*. The primary purpose of Task 1.3 is to synthesise and critically analyse academic literature that explores how social-technological innovations intersect with societal values, behaviours, and worldviews, as well as broader structural and institutional dynamics, in the context of biodiversity and equity, with a particular focus on digital and technological innovations.

Within the DAISY project, the findings are being used to inform the development of DAISY's Transformative Diagnostic Tool (TRD2), guide the critical assessment of innovations in Work Package (WP) 2. They will also be used to support the design of transformative intervention mixes (TIMs) in WP3.

1.2 Context and Relevance

Task 1.3 is situated within WP1 of the DAISY project, which focuses on analysing the economic, political, and social processes that variously enable or constrain transformative change for biodiversity and equity.

This deliverable contributes to DAISY's overarching conceptual framework, which emphasises transformation across three interconnected spheres: practical, political, and personal (O'Brien, 2018). It also directly engages with the care ethics concept of "response-ability" (Despret, 2004; Haraway, 2016; Puig de la Bellacasa, 2017; Tronto, 2013), which highlights the ethical and relational dimensions of societal capacity to respond to biodiversity challenges.

By focusing specifically on digital and technological innovations — while recognising their embeddedness in broader social-technological systems — this report especially addresses indirect drivers of biodiversity loss such as values, social norms, and belief systems. It contributes to advancing understanding of how to design interventions that are socially inclusive, contextually grounded, and capable of supporting just and equitable transformation.

1.3 Scope and Objectives

This deliverable presents an in-depth review of interdisciplinary academic literature that explores the relationship between society, biodiversity, and social-technological innovations, with a primary emphasis on digital and technological forms. It draws on scholarship from such as science and technology studies (STS), political ecology, environmental sociology, environmental governance, environmental justice, cultural geography, and ethics of care.

The specific objectives (in accordance with DAISY's Task 1.3) are to:

- Distil key conceptualisations of how society engages with digital and technological innovations in biodiversity contexts.
- Examine how intersecting social characteristics (e.g. gender, class, ethnicity) influence attitudes and behaviours toward biodiversity and innovation.
- Identify enabling and constraining factors that affect societal uptake and impact of innovations.
- Explore the implications of science denialism and trust in technology for biodiversity-related interventions.

The review does not aim to be exhaustive in cataloguing all existing innovations or empirical case studies; however, it does undertake both a mapping of relevant innovations and case-based literature, and an interpretive analysis of their societal and behavioural dimensions. This is achieved through a combined methodological approach: a structured scoping review that codes literature against a set of categories derived from the two primary research questions, and an AI-assisted expert interpretive narrative that further explores how these categories manifest across different contexts (see below, Methodology, for further detail). Both components are guided by the overarching aim of understanding how social-technological innovations mediate response-able relationships with biodiversity and are shaped by enabling or constraining conditions across the personal, practical, and political spheres.

1.4 Structure of the Document

The remainder of this report is structured as follows: the next section details the methodology, outlining the mixed-method research design, which combines a structured scoping review with an AI-assisted expert interpretive narrative analysis. The methodology section explains how literature was selected, coded, and analysed, and includes reflections on researcher positionality, ethical considerations, and methodological limitations. Following this, the results and discussion section presents the key findings of the review.

In accordance with the mixed-method analytical approach, following a short introduction, the first part provides an overview of the findings as coded directly from the literature reviewed. This is organised to first show descriptives of the breadth and type of literature included in coding and then responses to coding split into the following sections: human-biodiversity relationship, special qualities of the innovation, special qualities of the context, impact on biodiversity, impact on equity/ fairness/ inclusiveness/ equality/ justice. Key take-aways identified during the structured coding are also shared.

In the remainder of the results and discussion section, the findings from the AI-assisted expert interpretative analysis are provided. These are organised thematically in relation to the two guiding research questions and also subsequently, to a set of thematically focused additional findings — on justice as a condition for transformative innovation; the tech fix debate, and on; innovation trajectories. This second part of the findings section not only summarises the evidence but also interprets its significance in accordance with DAISY's conceptual framework. It also draws connections to broader debates in the literature and highlighting implications for policy, practice, and future research.

The document concludes with a synthesis of the main insights from the literature review. It emphasises that social-technological innovations can foster ethical, inclusive, and response-able relationships with biodiversity, but also warns that their impacts are ambivalent and context-dependent. The conclusion reflects on the implications for theory, policy, and practice, and clarifies how the findings contribute to the aims of WP1 while informing future work in WP2 and WP3. It identifies gaps in the literature, particularly around the discontinuation of harmful technologies, and distils seven key takeaways to guide future research, policy development, and stakeholder engagement within and beyond the DAISY project.

1.5 Target Audience

This report is intended for a relatively diverse audience. Within the DAISY consortium it is particularly relevant to partners involved in WPs 2, 3, and 4 who will draw on its findings to inform the assessment of innovations, the development of transformative intervention mixes (TIMs), and support the equitable amplification of innovative initiatives within the five seed innovation case studies.

Beyond the project team, the report is aimed at research scientists, but also policymakers and innovators seeking to design inclusive, socially attuned interventions that support biodiversity goals. Researchers and practitioners working in areas such as social, digital and technological innovation, nature-society relations, human behaviour, behavioural change, environmental justice and environmental governance may find the insights and analytical approach valuable for advancing their own work.

The report is relevant also to civil society actors involved in biodiversity-related initiatives and interventions, who are interested in understanding how digital and technological innovations shape and mediate human–nature relationships, and how these dynamics are influenced by the social and institutional conditions that support or constrain transformative change for biodiversity and equity.

2. Methodology

2.1 Approach and Research Design

2.1.1 Overview

This study employed a mixed-methods analytical approach to explore how social-technological innovations mediate response-able relationships with biodiversity, and the conditions that enable or hinder such innovations. The design encompassed a scoping review, structured coding and an AI-assisted expert interpretative analysis. This was grouped into three main stages, with all stages guided by two primary research questions (RQs):

1. How do social-technological innovations mediate response-able relationships with biodiversity?
2. What are the underlying personal, practical, and political conditions that enable or hinder social-technological innovations for response-able relationships with biodiversity?

The first stage comprised a literature search, the results of which were then screened for suitability using abstracts, titles and key words. During the second stage, full texts, of the relevant titles were reviewed and information on the technological and digital innovations and interventions found were coded into a structured excel sheet which was designed to collect information in the following categories:

- Bibliographic/general information on the publication
- Theory/concept/framework used in the publication
- Innovation description
- Human-biodiversity relationships
- Special qualities of the innovation
- Special qualities of the context of the innovation in use
- Impact of the use of the innovation on biodiversity
- Impact of the use of the innovation on equity/ fairness/ inclusiveness/ equality/ justice
- Coder notes and articles summary

Running in parallel to the structured excel coding part of the analysis, the third stage of the analysis involved a second round of manual reading of all the full-texts that were originally screened as suitable, followed by AI-assisted expert interpretative analysis and synthesis. During this stage of the analysis consideration was also to a limited number of additional publications (where they formed key points of reference) cited within the reviewed source texts.

This multi-method approach was selected to manage a relatively large and diverse volume of literature, while ensuring conceptual depth and alignment with the DAISY project's theoretical framework. Conceptually the analysis was guided by feminist care ethics (especially, Tronto's (2013) five elements of care), the related concept of response-ability (Haraway (2016); see also Puig de la Bellacasa (2017), Despret (2018)), and by O'Brien's (2018) Three Spheres of Transformation (personal, practical, political).

2.1.2 Defining social-technological innovation

Within the DAISY project's Description of Action (DoA), the term 'social-technological innovation' is employed in reference to the project's aim of identifying and exploring purposive interventions that integrate digital, technological and social innovations within broader social-technical and social-institutional systems in order to address the interlinked challenges of biodiversity loss and social inequity. Such innovations are not seen as isolated technical fixes, but as embedded within complex systems of values, governance, and power. Their transformative potential is framed within the DoA as lying in their ability to catalyse systemic change across the practical sphere of tools and actions, the political sphere of institutions and governance, and the personal sphere of values and worldviews (O'Brien, 2018).

Serving as a starting point for Task 1.3, this inclusive and systemic framing of social-technological innovation was used — in accompaniment with the wider DAISY conceptual frame and guiding research questions — to inform the development of the keyword strings for the literature review (see below). This helped to ensure a sufficiently broad and conceptually grounded search strategy. Given, however, the relatively vast and diverse landscape of social innovations relevant to biodiversity, following the initial sifting of papers via the abstracts, the subsequent full paper analysis was restricted for Task 1.3 to publications explicitly addressing digital and technological innovations (see Table 1, below). This was a strategic decision to ensure analytical manageability while allowing for sufficient depth of review within the timeframe of the task. It also reflects the unique role of Task 1.3 within DAISY: it is the only task explicitly directed towards a *critical analysis* of scientific literature on digital and technological innovation. In contrast, the make-up and potential contribution of social innovations are explored across a number of DAISY Tasks, including via external literature review (e.g. within the thematic literature reviews of Tasks 1.1 (governance) and 1.2 (economy), and the intervention-focused Tasks of WP3 (especially Task 3.1)). By concentrating on digital and technological innovations, Task 1.3 thus occupies a distinct analytical niche within the overall research framework, complementing other strands of work that focus more directly on social innovation and practical interventions.

While it can be hard to distinguish between technological and digital innovations, as there is much overlap between categories and all digital innovations will include some technological elements, for the purposes of this deliverable we use the following definitions: technological innovations are those that encompass a broad range of tools, systems, and processes developed through scientific knowledge to solve problems or enhance human capabilities; digital innovations refer specifically to technologies that rely on digital data, computing, and connectivity — such as software, algorithms, sensors, and digital platforms.

2.2 Data Collection Methods

The selected keywords (see 2.1, above) were developed into a search string to be inputted into a search in both the Scopus and Web of Science (WOS) databases. Following an initial screening of titles and abstracts from the first search string, a second search string was developed in order to widen the breadth of the search as abstracts appeared skewed in favour of social innovations or interventions and were lacking in the areas of digital and technological innovations.

Final searches using the two search strings to search for key words in publication title, abstract and key words were run from a UK-based account on the 20/03/2025 (Table 1). All results from both searches were used to ensure as comprehensive a search as possible.

Table 1: Details of the search terms, databases and search date with number of articles found during the literature search

Search round	Search site	Search string used	Number of articles	Search date
1	**Scopus**	**Topic:** (digital OR techn* OR soci**)** **AND (**innovat* OR novel* OR disrupt* OR breakthrough**)**	**218**	20/03/2025

		And Topic: relat***** **And Topic:** biodiversity **And Topic:** equit* OR justice OR fair* OR inclus* OR equal* And Topic: view* OR attitud* OR perception OR perceiv* OR aware* OR understand* OR decision* OR care OR valu* OR belief* OR emotion* OR act* OR behavio* OR practi* OR norm* OR politic* OR policy* OR structur* OR institution* OR regulat* OR govern*		
1	**WOS**	**Topic:** (digital OR techn* OR soci***)** **AND (**innovat* OR novel* OR disrupt* OR breakthrough**)** **And Topic:** relat***** **And Topic:** biodiversity **And Topic:** equit* OR justice OR fair* OR inclus* OR equal* And Topic: view* OR attitud* OR perception OR perceiv* OR aware* OR understand* OR decision* OR care OR valu* OR belief* OR emotion* OR act* OR behavio* OR practi* OR norm* OR politic* OR policy* OR structur* OR institution* OR regulat* OR govern*	**186**	20/03/2025

2	**Scopus**	**Topic:** (digital OR techn* OR soci**)** **And Topic: (**innovat* OR novel* OR disrupt* OR breakthrough OR invent***)** **And Topic: (**human OR societ* OR citizen OR community) **And Topic:** biodiversity **And Topic:** equit* OR justice OR fair* OR inclus* OR equal* OR empath* OR trust **And Topic**: view* OR attitud* OR perception OR perceiv* OR aware* OR understand* OR decision* OR care OR valu* OR belief* OR emotion* OR act* OR behavio* OR practi* OR norm* OR politic* OR policy* OR structur* OR institution* OR regulat* OR govern*	**497**	20/03/2025
2	**WOS**	**Topic:** (digital OR techn* OR soci**)** **AND (**innovat* OR novel* OR disrupt* OR breakthrough OR invent***)** **And Topic: (**human OR societ* OR citizen OR community) **And Topic:** biodiversity	**416**	20/03/2025

		And Topic: equit* OR justice OR fair* OR inclus* OR equal* OR empath* OR trust **And Topic**: view* OR attitud* OR perception OR perceiv* OR aware* OR understand* OR decision* OR care OR valu* OR belief* OR emotion* OR act* OR behavio* OR practi* OR norm* OR politic* OR policy* OR structur* OR institution* OR regulat* OR govern*		

2.3 Data Sources and Selection Criteria

The study selection process for the structured Excel coding part of the analysis followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency and reproducibility (see Figure 1, below). The process involved four key stages: identification, screening, eligibility, and inclusion. A comprehensive search strategy was employed across multiple databases using a combination of keywords and Boolean operators tailored to the research questions (Table 1). This yielded a total of 1317 records.

De-duplication of titles was carried out to remove articles that occurred multiple times due to appearing in multiple searches, resulting in a list of 728 unique records. All titles and abstracts were then screened for inclusion by two researchers (Franklin and Green). Based on likely relevance to the research question, each researcher independently coded each record as ‘yes’, ‘no’ or ‘maybe’ as a response for whether the title should be included in further stages of review. Where divergences occurred, the following process was used to determine inclusion for the next stage:

- Yes + maybe = Include
- Maybe + maybe = Re-review
- Yes + no = Re-review
- No + maybe = Re-review

Records for re-review were then assessed again before a final decision on further inclusion was made. This resulted in a list of 286 titles. Due to the relatively high volume of articles still included at this stage, articles seeming likely to contain information on digital or technological innovations were prioritised for data extraction coding. This was done by filtering records to include only those that included one of the following words in the title or abstract: 'technology', 'technological', 'technical', 'digital', 'citizen science', 'machine', 'smart', 'internet', 'robot', 'precision' or 'AI' and resulted in exclusion of a further 154 records, leaving 132 to be put forward for full-text screening. This filter was to make sure the knowledge gap described in Task 1.3 was adequately addressed, and due to the ambiguity and challenge of defining a 'social innovation'. However, given the potential wider relevance of the excluded 154 records, they will be retained for review during DAISY Task 3.1.

Where possible, full-text articles of each title were retrieved and distributed amongst six researchers (SGr, KD, VK, PB, ET, HB) for initial reading and data extraction during the first part of the analysis. There were 19 records which could not be retrieved resulting in a total of 113 records undergoing full-text screening. Each article was read, and relevant information was coded into an excel spreadsheet. The spreadsheet consists of nine sections, each containing multiple questions to be answered (if possible) for each article.

Within this structured excel coding stage of the analysis articles were excluded if they did not contain specific information on digital or technological innovations relevant to the coding framework. Further details on inclusion and exclusion criteria for the purpose of structured excel coding are as follows:

Inclusion Criteria

Articles were included if they:

- Described, evaluated or assessed a digital or technological innovation or intervention either through a case study, review of literature existing on that innovation or intervention or through an empirical study.
- Were relevant to the research question and provided information that could help inform about the potential of an innovation to mediate response-able relationships with biodiversity

- Contained sufficient detail on at least one innovation or intervention for data extraction so that information could be added to at least 5 of the 9 coding question categories

Exclusion Criteria

Articles were excluded if they:

- Were duplicates, either from the same article being discovered in multiple searches or the same study published as a conference paper and then later as a journal article (if so, only keeping the journal article)
- Did not focus on digital or technological innovations
- Did not provide enough detail on any innovation or intervention to complete any questions in at least 5 of the 9 coding categories
- Were of poor quality with unclear methods,

In total, 44 records were included for coding. Books that were included were scanned for relevant chapters with one book (Digital technologies to Implement the UN Sustainable Development Goals (Leal Filho et al., 2024)) containing information used in coding in six of its chapters. If these chapters were considered as independent records, it would result in a total of 49 records. A complete list of the 114 records screened with the 49 records used in coding can be found in Annex 2.

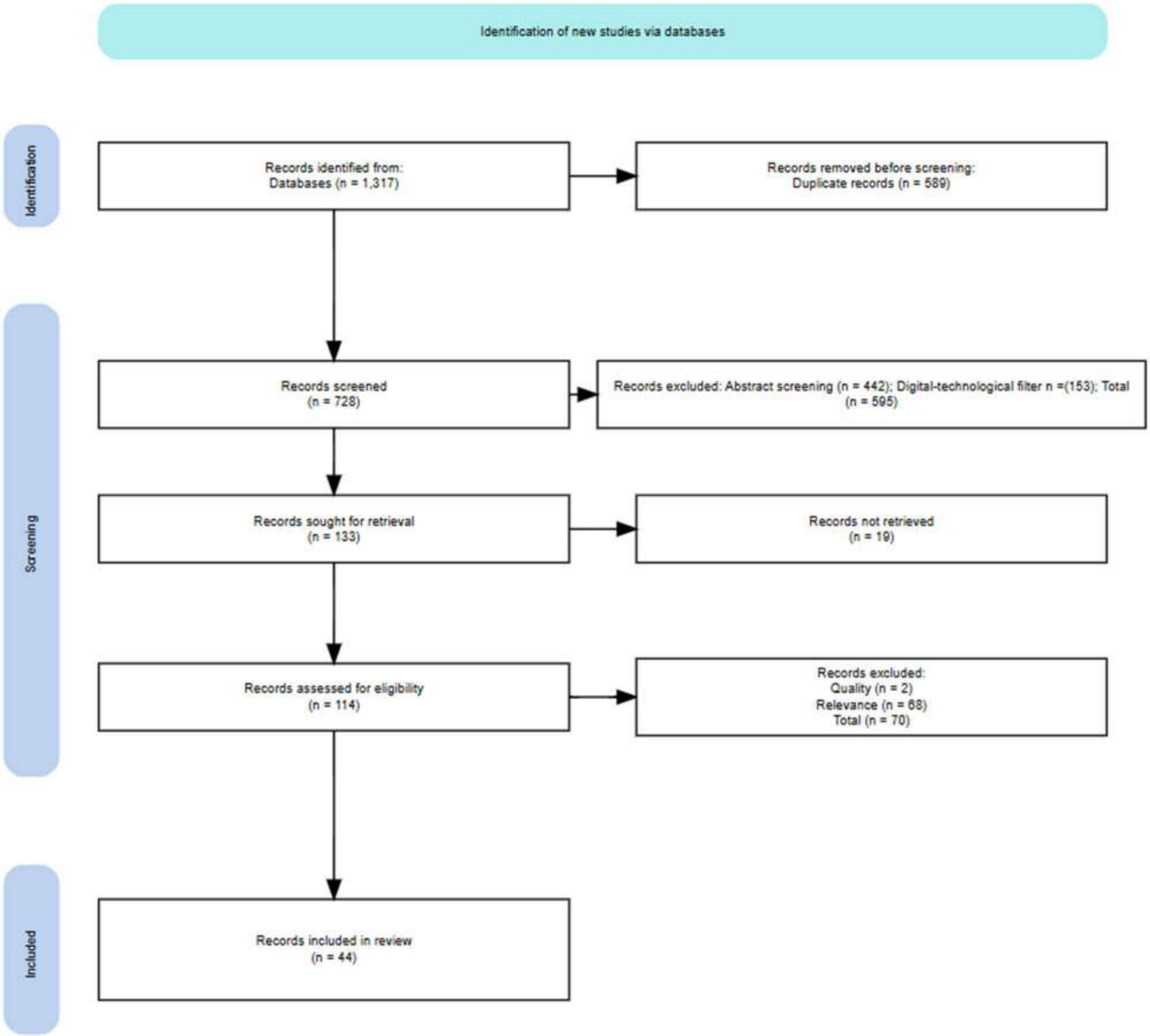

Figure 1. PRISMA diagram showing number of titles carried forward at each stage of the literature review process

In the case of the AI-assisted expert interpretative analysis of full texts, this was undertaken in parallel to the structured excel coding stage. A full-text review was undertaken (by the lead author, Franklin) for all 114 articles identified as eligible during the screening stage of the PRISMA process (see Figure one, above), as well as limited number of additional articles (where they formed key points of reference) cited within the source texts.

2.4 Analytical Methods

Coding in the excel sheet of the 44 included records from the literature review process consisted of both questions with set pre-defined responses and those with free-text options (all of which were developed in accordance with the two overarching primary research questions). Coded responses for the questions with pre-defined response options were aggregated to determine where the literature was stronger and where topics were commonly under-represented.

Meanwhile, coding for the AI-assisted expert interpretative analysis, although guided by the core research questions and Task 1.3 description, was intentionally kept far more open. All relevant passages within each publication were manually identified, extracted and collated into a single source file (retaining the association between extracts and individual publication sources). This file was then uploaded to the LLM - OpenAI's GPT-4-based Large Language Model (LLM) assistant: Microsoft Copilot (the AI LLM authorised for staff use by CU). The LLM was then instructed to run a series of interpretative analytical and synthesis tasks on the material within the source file, in accordance the two core research questions and also the broader description of Task 1.3.

On all occasions during this stage of the analysis, the LLM was instructed to work only with the material within the source file, to cite all sources, and retain direct quotes where appropriate. All results generated by the LLM were then independently (manually) reviewed by the lead author (Franklin), regularly resulting in multiple further edits and iterative refinements in accordance with her own knowledge of the source file (from her manual reading of all full texts from which the extracts were derived), and also her wider expert knowledge of the subject matter addressed by Task 1.3. The results were also further validated via presentation of, firstly, the entire methodology (during a WP6, Task 6.3 workshop), and secondly, the key findings (during a dedicated WP1 meeting), which were attended by multiple members of the wider DAISY project consortium.

2.5 Reflexivity and Research Ethics

The research team acknowledges its dual role as both users and interpreters of AI-generated content. While Copilot supported the synthesis process, all interpretive decisions were made by the human researchers, drawing on expert knowledge of the subject matter.

Ethical standards were upheld throughout. The desk-based review of secondary literature meant that no volunteer research participants were involved in this aspect of the DAISY project. Also, no personal or sensitive data were used, and expert review and validation of the emerging findings was undertaken entirely by members of the research consortium. In writing up the results and findings, all sources have been cited. The combined AI-assisted and expert-validated components of the process respected the intellectual sovereignty of the original authors. It ensured that AI outputs were critically reviewed and revised to maintain fidelity to the source material.

2.6 Limitations

Across the Task 1.3 research team there is a diverse range of disciplinary backgrounds, spanning human and cultural geography, ecological economics, political science, justice studies, zoology, and biological sciences. This diversity enriched the interpretive process and informed the overall analytical design, enabling a more nuanced engagement with the literature. However, the interdisciplinary nature of the work also introduced certain complexities, particularly in the development and application of the structured coding framework. Given the social science orientation of the research questions, some team members with natural science backgrounds approached the coding process from different epistemological standpoints. While this diversity of perspective was valuable, it carried a potential risk of variation in coding depth or emphasis. These differences were addressed through collaborative dialogue and the integrative nature of the broader analytical process. In accordance with the conceptual orientation of the task, where divergences occurred during the screening stage regarding article inclusion, final decisions were made by the lead author (Franklin), whose disciplinary expertise lies in the social sciences.

The interdisciplinary composition of the team also shaped the design and execution of the literature search. Selecting appropriate keywords for the structured review was particularly challenging, as terminology often carries different meanings across disciplines. This may have introduced some bias in the literature identified, and it is possible that a broader or differently constructed search strategy could have yielded additional relevant sources. Nonetheless, the review encompassed a wide range of innovations and drew from literature across multiple disciplines and global contexts, supporting the representativeness of the findings.

While the AI-assisted expert interpretative stage of analysis was based on text extracts coded and compiled by the lead author (Franklin), its outputs were guided by prompts aligned with the project's research questions. This focus may have led to the underrepresentation of broader contextual insights. The LLM's outputs required careful oversight to ensure alignment with the research team's interpretive frameworks. Although the use of an LLM enabled timely processing of a large volume of material, it may have introduced subtle biases or inconsistencies in tone or emphasis. These were mitigated through expert review and collaborative validation. Given the rapid pace of AI development, it is also important to note that the same analytical exercise, even if undertaken in the near future using updated models or tools, may yield different results, both in terms of synthesis quality and interpretive nuance. Despite these limitations, the approach enabled a transparent, rigorous, and conceptually grounded synthesis of a diverse body of literature, supporting the DAISY project's aim to explore the ethical, social, and political dimensions of biodiversity-related innovation.

3. Results and discussion

3.1 Introduction

By way of introduction to the analysis that follows, it is useful to briefly revisit the conceptual foundation guiding Task 1.3. As outlined in the Methodology section, the DAISY project defines social-technological innovation as purposive, system-embedded interventions that integrate digital, technological, and social dimensions to address biodiversity loss and social inequity. Task 1.3 focused especially on the digital and technological aspects of this framing, providing a distinct analytical contribution within the broader DAISY project.

In analysing the results of the literature review, attention was paid to how definitions and conceptualisations of social-technological innovation within the literature align with, or diverge from, the original framing articulated in the DAISY project. Based on the AI-assisted interpretative review, the term 'social-technological innovation', particularly in the context of digital and technological innovations, can be further understood as the co-evolving interplay between social and technical processes that shape the development, adoption, transformation, or decline of technologies within broader systems. This understanding is rooted in a social-technical perspective, which recognises that "the social and the technical are deeply interwoven. They do not exist in separate domains, but are mutually embedded in tight relationships" (Koretsky et al., 2023:6). From this viewpoint, social-technological innovation is inseparable from political, cultural, and psychological dynamics. Such a perspective is reinforced by feminist care ethics, and science and technology studies (STS) literature, with the latter emphasising that technologies are "stabilized by users, often in ordinary and even intimate social relations" (Bell et al., 2020:8) and that they "emerge alongside and in conversation with the ideologies and concerns of their human communities" (p8) (Bell et al., 2020:8). Digital and technological innovations are, thus, not simply tools or instruments, but elements of broader social-technical systems that reflect and reproduce particular values, power relations, (in)equities and worldviews.

This literature-derived definition of social-technological innovation is broadly consistent with DAISY's own original conceptual framing. Both emphasise the embeddedness of innovation within wider systems and the co-constitutive role of values, governance, and power. While DAISY's framing of social-technological innovation (within the DoA) is more explicitly normative, focusing on exploring the potential of innovation to address biodiversity loss and social inequity via the various tasks and actions of the DAISY project, the above cited literature provides theoretical depth and empirical nuance that reinforce this orientation.

The analysis that follows can be grouped into two main sets of findings, reflecting the dual-method approach of Task 1.3. The first set presents the findings of the structured coding of literature (sub-sections 3.2-3.8), offering a descriptive overview of the types, domains, and characteristics of innovations identified, as well as their reported impacts on biodiversity, equity, and human–nature relationships.

This is followed by a second set comprising the findings from the AI-assisted expert interpretative analysis (sub-sections 3.9-3.11). Together, these two sets of findings provide both breadth and depth in understanding how social-technological innovations mediate response-able relationships with biodiversity and the conditions that shape their transformative potential.

3.2 Breadth of coded literature

In total, 51 innovations were coded during the structured excel coding stage, from 44 unique sources (journal articles = 33, conference papers = 6, books = 5). This discrepancy in numbers is from a small number of articles and books that contained information on more than one innovation.

The number of works providing a critical description, discussion or evaluation of a digital or technological innovation has seen an increase since 2021, particularly for journal articles (Figure 2). While 2025 results are currently lower, searches were carried out in March of 2025. Based on this, it is likely the trend for increased attention in the area of technological and digital innovations for biodiversity conservation would have continued into 2025 if searches had been conducted at a later date. This indicates a growing interest in the area of digital and technological innovation and its potential role in providing solutions to the biodiversity crisis.

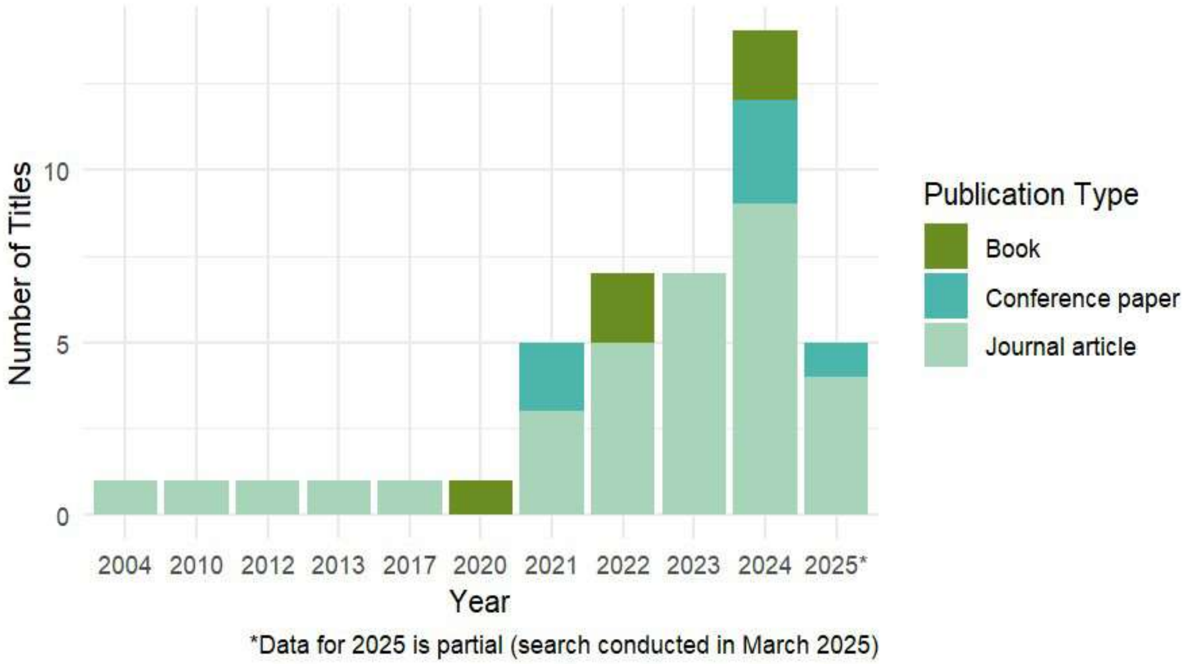

Figure 2. Number of books, conference papers and journal articles published over time that were included in coding of digital and technological innovations

Literature included in our analysis were distributed across continents (other than Antarctica), although there were fewer studies located in Oceania, Latin America and the Caribbean and Africa, particularly compared to Europe and Asia where the greatest number of studies were based. Many articles did not discuss an innovation in the context of any particular geographic location and were counted as 'non-specific' (Figure 3). This could be because the innovation is designed for global use, e.g. mobile applications or online platforms or its potential to be used across global locations e.g. precision agricultural machinery. Some entries described the use of an innovation in multiple locations, so the total number of entries on the map may be greater than the total number of titles coded. The large number of entries with no specific location can be attributed to many papers being primarily theoretical in basis and the potential, especially for digital innovations, to have a global application.

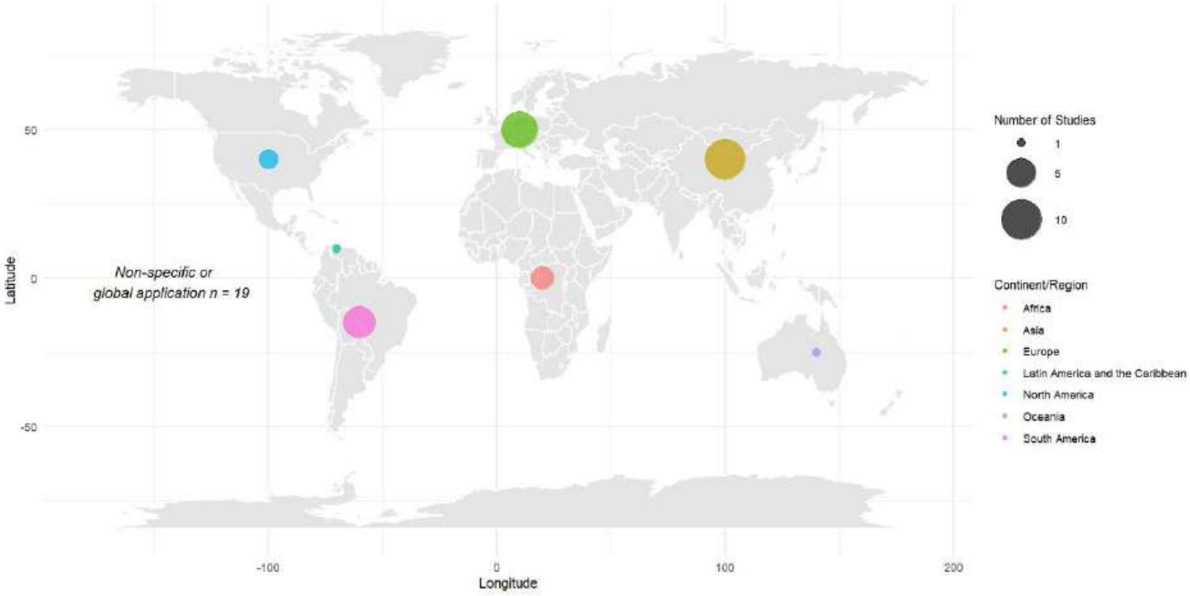

Figure 3. Map indicating the number of studies that had examples of innovation in use in different regions of the globe

The agri-food domain was the most well-represented of the DAISY domains in the coded literature, with relatively few digital or technological innovations coded for the other three domains (education, energy, urban and regional development). However, each innovation was only coded for its primary domain, and many within agri-food would have had secondary relevance to the other domains. Examples of fields present in 'Other' include pure research, or biodiversity monitoring innovations. Mixed innovation types include digital and technological elements, and most innovations contained at least some digital components (Figure 4).

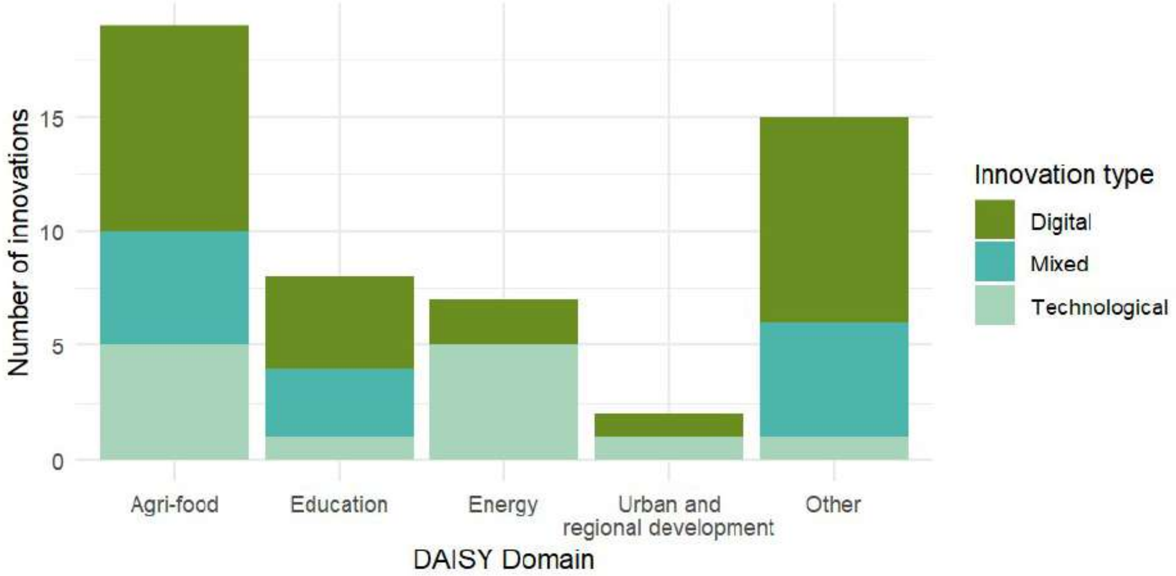

Figure 4. Number of innovations coded for in each of the DAISY domains broken down by innovation type

Literature was identified as belonging in different academic disciplines according to the book, journal or conference in which it was published (Figure 5). Each journal or publisher website, along with the main aims and scope of the journal publisher was viewed for each of the records included in the literature review coding and assigned to one of four broad scientific discipline categories according to its primary theme. Categories were 'Computing, Engineering and Technology', 'Natural Sciences', 'Social Sciences' and 'Multidisciplinary. The first three categories were chosen as these are the main areas of interest in this deliverable. Journals that contained a mix of articles from across disciplines, such as from the 'mega-journal' PLOS One were counted as 'Multidisciplinary. Within our review, the area of Natural sciences was most well-represented in the literature (29 records) and far fewer records came from the area of Social science (4 records). This could indicate a knowledge gap and need for greater research to understand the social implications of use of digital and technological innovations. It should be noted however, that while papers may be published in journals which fall predominantly within other disciplines some may still contain interdisciplinary elements including from the social sciences.

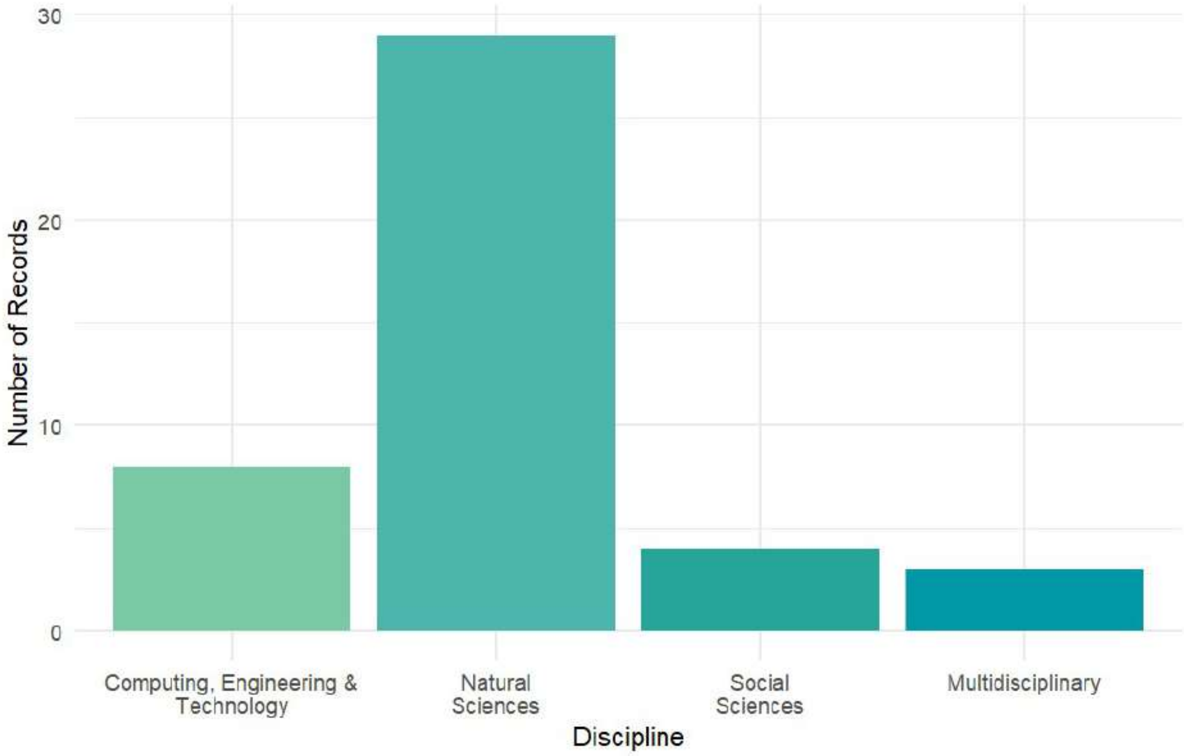

Figure 5. Number of records that were published in sources primarily associated with different academic disciplines.

Each title was coded as belonging to one of five types of paper (Figure 6). The review category contained all papers that were primarily based on existing literature and included policy pieces as well as traditional literature reviews. The review category contained the largest number of titles indicating that original research articles are under-represented in the reviewed literature.

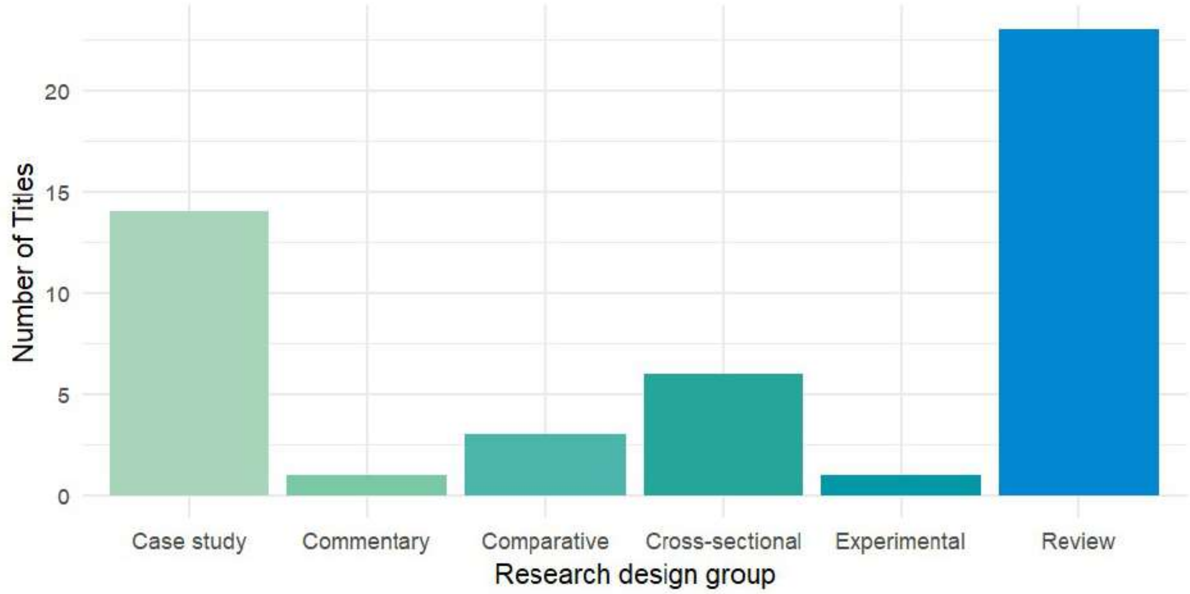

Figure 6. Number of coded titles that fit into each type of research group design

3.3 Human-biodiversity relationship

29 out of 51 innovations were coded as having an impact on the human-biodiversity relationship with 12 of these coded as improving 'Care' and 15 as improving action towards biodiversity (Table 2). This indicates there is more evidence for innovations impacting action, rather than care, with a high number of innovations also having an 'ambiguous' impact on action indicating potential for more to influence action but also a need for cleared discussion of these impacts in the literature

Table 2. Number of innovations for each response for coded questions from the literature examining human-biodiversity relationship

	Yes	No	Ambiguous	No data	Examples to illustrate impacts
Does it change the human-biodiversity relationship?	29	8	9	5	Reduced human-wildlife conflict (Bijoor et al. 2021)
Does the innovation	12	16	6	17	Increase connection to nature and willingness to

improve 'Care' specifically?					act to protect biodiversity (Rodríguez-Loinaz et al. 2024)
Does the innovation improve 'action' specifically?	15	5	15	16	Reduced use of fertilisers and pesticides (Kawtrakul et al. 2021)

Of the innovations that did have an impact the human-biodiversity relationship, more had an impact in the personal and practical spheres of life, with few have an influence on the political (Table 3). Despite having fewer innovations coded as within the Education domain, these innovations had more impact in the Personal and Practical Spheres, with several innovations impacting both spheres.

Table 3. Number of innovations within each of the DAISY domains that influence the human-biodiversity relationships via each of the personal, political or practical spheres

	Personal	Political	Practical	Ambiguous
All	15	6	14	10
Agri-food	3	1	4	3
Education	7	0	5	0
Energy	0	2	2	1
Urban and regional development	1	1	0	1
Other	4	2	3	5

3.4 Special qualities of the innovation (Biodiversity exploitation and innovation access)

Few innovations were coded as inherently making exploitation of biodiversity easier (Table 4). This is likely due to the key word searches used and the terms biodiversity, which is likely to bring up articles with innovations aiming to have benefits to biodiversity. While few innovations had inherent access limitations, a greater number were thought to still have equity issues with access, with many also coded as ambiguous or lacking an answer. This lack of clear data on access issues indicates that this is an area that merits further investigation to establish what is the cause of inequitable access and how such issues can be resolved.

Table 4. Number of innovations with each type of response for coded questions examining whether the innovation discussed can result in exploitation of natural resources or whether there are access issues based on information from the literature

	Yes	No	Ambiguous/ Maybe	No data
Exploitation -does the innovation inherently make it easier to use more natural resources and faster?	4	35	9	3
Access (equity) - does the innovation limit access inherently?	8	24	5	14
Access (equity) - does the innovation limit access to certain groups in some way?	19	3	15	14

3.5 Special qualities of the context of innovation use

A range of personal, practical and political conditions were found to be influential in the uptake of various innovations, with a slightly greater focus on practical and political conditions across the literature compared to personal conditions (Table 5). A greater number of innovations had information on risks or potential risks than for safeguards or potential safeguards. This indicates that more work needs to be done on the provision of safeguards to mitigate risks associated with the use of digital or technological innovations for mediating a more response-able relationship with biodiversity.

Table 5. Number of innovations with each type of response for coded questions examining the conditions and context for adoption and application of each innovation based on information from the literature

	Yes	No	Ambiguous	No data
Were personal conditions (who you are, abilities, preferences) influential in adoption of the innovation?	22	3	2	24

Were practical conditions in the context influential in adoption of the innovation?	29	1	4	17
Were political conditions in the context influential in adoption of the innovation?	28	0	2	21
Were any risks or potential risks identified?	33	5	3	10
Were any safeguards implemented, or potential safeguards suggested?	26	11	0	14

3.6 Potential impact on biodiversity

Many innovations (27) were coded as having a general/unspecified impact on biodiversity while 16 had an impact of species biodiversity and 14 had an impact on Ecosystem level biodiversity (Table 6). Few innovations addressed biodiversity at the landscape scale, and only one was coded as having an impact on genetic diversity. Of the innovations that were coded as having an impact on biodiversity most were from literature that was either purely or predominantly theory based (Table 7). Evidence for biodiversity impact in these cases would be predominantly based on referencing of pre-existing literature and not from the authors own empirical measure of biodiversity impact. Here we consider empirical elements of studies to include:

- **Use of real-world data** (e.g., case studies, survey results, observational data) to illustrate or support theoretical arguments.
- **Empirical inputs for models**, such as climate data, economic indicators, or biodiversity metrics, even if the analysis itself is primarily theoretical or model-based.
- **Reference to specific places or contexts** (e.g., a region, country, or ecosystem) where the theoretical framework is applied or discussed, especially when supported by data or examples from that context.

Table 6: Number of innovations that are coded as having an impact on each level of biodiversity measure overall and for each of the DAISY domains

	Genetic	Species	Landscape	Ecosystem	General/ unspecified	Ambiguous	No data
All	1	16	6	14	27	4	3
Agri-food	1	5	1	5	10	2	2
Education	0	3	0	2	5	0	0
Energy	0	1	0	2	4	1	0
Urban and regional development	0	2	0	0	1	0	0
Other	0	5	5	5	7	1	1

Table 7. Number of innovations that are coded as having an impact on each level of biodiversity measure and whether the evidence in the literature it was coded from had a primarily theoretical, empirical or mixed focus

	Purely theoretical	Largely theoretical, some empirical	Equal theoretical and empirical	Largely empirical, some theoretical
Genetic	0	1	0	0
Species	4	7	1	4
Landscape	1	3	2	0
Ecosystem	3	6	1	4
General/ unspecified	11	6	2	8

3.7 Impact on equity/ fairness/ inclusiveness/ equality/ justice

Only around half of innovations were coded as having evidence for the potential to impact equity, fairness, inclusiveness, equality or justice (Table 8). Innovations that did have an impact were evaluated and the type or types of equity and justice impacted were coded (Table 9). 22 innovations had a distributive impact with this being the most common level at which impact on equity was coded. This was followed by procedural (18 innovations), restorative (6 innovations), and retributive

(3 innovations). Again, as most literature was mostly theoretical this shows a lack of empirical evidence for impact on equity issues (for further discussion of impact on types of equity and justice see 3.11.1).

Table 8. Number of innovations that were coded as being able to change equity/ fairness/ inclusiveness/ equality/ justice through its use overall and for each DAISY domain

	Yes	No	Ambiguous	No data
All	25	5	9	12
Agri-food	8	2	3	6
Education	3	0	2	3
Energy	4	0	2	1
Urban and regional development	1	0	0	1
Other	9	3	2	1

Table 9. Number of innovations that are coded as having an impact at each type of equity measure and whether the literature it was coded from had a theoretical, empirical or mixed basis

	Purely theoretical	Largely theoretical, some empirical	Equal theoretical and empirical	Largely empirical, some theoretical
Distributive	8	8	1	5
Procedural	3	9	2	4
Restorative	1	3	0	2
Retributive	1	2	0	0
Other	0	1	0	0

3.8 Reflections on the structured coding: potentials and gaps

The structured coding component of the review highlights several important insights regarding the potential of digital and technological innovations to mediate more response-able relationships with biodiversity:

- **Potential for positive impact is contingent**: While many innovations show promise, their ability to foster ethical and inclusive relationships with biodiversity depends heavily on how they are designed, implemented, and governed. Without careful attention to context and justice, they may have limited or even harmful effects.
- **Equity risks remain significant**: The digital divide — in terms of access, literacy, and confidence — poses a major barrier to inclusive innovation. Without proactive measures to address these disparities, innovations risk reinforcing existing inequalities.
- **A notable evidence gap persists**: Across the reviewed literature, few studies provide empirical measures of impact on biodiversity or equity. Most claims are theoretical or based on secondary sources. This highlights a critical need for future research to incorporate robust, context-sensitive indicators and methodologies for assessing real-world outcomes.

These reflections provide a foundation for the interpretative analysis that follows, which builds on the coded data to explore deeper conceptual and strategic themes. In doing so, it addresses not only what innovations are being proposed or implemented, but how they are situated within broader societal, political, and ethical contexts.

3.9 How do social-technological innovations mediate response-able relationships with biodiversity (Research Question 1)?

Social-technological innovations are increasingly shaping the ways in which humans relate to biodiversity, not only by influencing our capacity to observe and manage ecological systems, but also by impacting upon the ethical, political, and epistemic dimensions of care for more-than-human life. These innovations — digital and technological components of which range from AI-powered monitoring systems and blockchain traceability tools to participatory digital platforms and citizen science apps (see Annex 1) — mediate our societal "response-ability" (Haraway 2016). That is, they shape how we, as a society, are able to respond with attentiveness, accountability, and competence — personally, practically, and politically — in ways that are situated and timely (O'Brien 2018). Yet, as the reviewed literature reveals, their effects are far from uniform. While some social-technological innovations foster reciprocity, inclusion, and relational ethics, for example, others risk reinforcing technocratic control, surveillance, and exclusion. In this section we examine each of these aspects in turn, tracing how the reviewed literature engages with the first core research question of how social-technological innovations mediate response-able relationships with biodiversity across ethical, political, epistemic, and practical dimensions. In doing so, we are guided also by Tronto's (2013) five integrated components and accompanying principles of care practice (caring about (attentiveness); caring for (responsibility); care practice (competence); receiving care (responsiveness); caring with (solidarity) (see also Tronto and Fischer 1998)).

The AI-assisted expert interpretative analysis of the reviewed literature indicates that a prominent way in which digital and technological innovations mediate response-ability is by cultivating attentiveness to biodiversity. Digital tools, such as eButterfly, Plantix, and other citizen science platforms, for example, allow users to identify species, track ecological changes, and build personal or collective records of biodiversity encounters (Heaton 2024; Simelton et al 2021). As Heaton (2024) explains, these platforms "teach users how to pay better attention to their natural environment" (p304), supporting the development of ecological literacy and emotional connection. Similarly, in the case of species literacy chatbots (for instance), Manik et al. (2024) evidence how, when trust in the technology is high and the interface aligns with users' learning needs, they can enhance attentiveness among students. Such tools thus do not merely deliver information; they shape how people notice, interpret, and value biodiversity in their everyday lives. However, as indicated in Manik et al.'s (2024) qualification with regards to trust, attentiveness is not guaranteed by technological mediation alone.

Sheard et al.'s (2023) survey of 66 citizen science projects, for example, found that fewer than half of respondents believed that digital tools increased engagement with nature. This suggests that while technologies can support attentiveness, they cannot replace the embodied, affective, and relational dimensions of care. Rather, technologies must be designed not only for efficiency, but also to foster curiosity, invite sensory engagement, and reflect local relevance — while embodying thoughtful intentions and supporting meaningful, respectful interactions (Manik et al. 2024). As Heaton (2024) further explains, digital biodiversity platforms are most impactful when they help users cultivate a deeper, place-base, and sensory connection with the natural world, rather than focusing solely on data delivery.

This requires designing tools that invite exploration, foster emotional connection, and reflect the ecological and cultural specificities of place and of user communities. An aligned example, from the reviewed literature, is the 'Rosted cow grazing association' in Denmark (see Laage-Thomsen & Blok, 2020), which combines voluntary conservation grazing with citizen science-style observation of rare plant species. In this case, participants engage in recurring, place-based monitoring activities — often in collaboration with local biologists — and share close-up photos and reflections online, reportedly cultivating a deep sense of care and attachment to their local ecology (Laage-Thomsen & Blok, 2020). According to the detailed account provided by Laage-Thomsen & Blok (2020), such innovations exemplify how technologies and practices can be structured to support sensory immersion, local stewardship, and shared learning.

Beyond individual attentiveness, social-technological innovations also enable new forms of collective responsibility and inclusive governance. To draw here on another example, Manga (2023) describes how the e-GIS Smart Indigenous Peoples Landscape Clearing-House Mechanism has the potential to empower Indigenous communities to manage their territories and biodiversity through digital mapping, mobile apps, and clearing-house platforms. According to Manga (2023) these tools can support inclusive decision-making, knowledge sharing, and rights assertion, reinforcing relational ethics and Indigenous stewardship. Notably, however, as is the case also with the majority of the innovations featured within the reviewed literature (and beyond), their effectiveness depends not only on the innovations themselves, but on how they are implemented and governed, thereby highlighting the importance of context-sensitive use and meaningful community participation. This crucial dimension is returned to later in this report, in response to the second core guiding research question.

Moving from Indigenous-led innovations to environmental governance more broadly, similar dynamics emerge in the application of blockchain technologies.

Blockchain technologies feature within the reviewed literature in the context enhancing transparency and accountability with respect to sustainable supply chains, carbon credits, and wildlife trade (Christiansen 2024; Shukla et al., 2024). Yet, as Christiansen (2024) warns, these same systems can also serve to legitimise off-setting practices that perpetuate extractive economies under the guise of environmental responsibility. This warning is evidenced through her analysis of digital Monitoring, Reporting, and Verification (MRV) technologies in the voluntary carbon market (VCM), which reveals that while these tools promise transparency, they often function as a 'technical fix' that addresses reputational risks and supply constraints without challenging the underlying logics of commodification. Instead, they enable nature to be made "legible to market logics" while leaving the structural causes of biodiversity loss and climate change intact (Christiansen 2024:1; see also the later section in this report on *The Tech Fix Debate* for broader critical perspectives on technological solutions).

In agricultural contexts meanwhile, innovations such as the Farmland Biodiversity Observatory (a nation-wide citizen science scheme in France (Billaud et al., 2025)), and BIO-AGRI-WATCH (a Thai government-led digital platform designed to integrate biodiversity and agricultural data to support sustainable and precision farming through cross-sectoral collaboration (Kawtrakul et al., 2021)), illustrate how farmers can use digital tools to monitor biodiversity, adapt practices, and co-produce knowledge. By shifting the locus of expertise from centralised institutions to local actors, these types of platforms have the potential to enable more situated and experiential forms of care.

The literature further demonstrates that social-technological innovations in agriculture are frequently embedded within systems of competing priorities, where trade-offs are not only common but often central to their function and impact. Approaches such as conservation agriculture, agroforestry, and cover cropping, for example, are promoted for their potential to reduce emissions and enhance sustainability in ways that align with biodiversity goals. However, as Kamyab et al., (2024) assert, these approaches often involve "intricate synergies and trade-offs between emission reduction strategies and carbon removal mechanisms" (p268). Similarly, sustainable intensification and agroecology are presented as dual pathways to navigate the tension between food security and environmental sustainability — each carrying distinct implications for biodiversity and equity (Chowdhuri & Pa, 2025).

When examined more closely, both these broader agricultural strategies and the specific digital platforms mentioned above, reveal tensions between prescriptive, data-driven models and the need for flexible, context-sensitive learning. From Billaud et al.'s (2025) study of the Farmland Biodiversity Observatory, the most meaningful forms of response-ability seemingly emerge not from standardised metrics but from "clinical" knowledge (p268) — built through trial, error, and trust in the agency of biodiversity itself. This is exemplified by the authors, through their empirically rich discussion of how farmers, faced with the limitations of standardised ecological models, began to rely on their own observations and experiences; as they engaged with biodiversity directly—through monitoring, experimentation, and dialogue— Billaud et al. (2025) document how the farmers cultivated a form of situated expertise grounded in trust, not certainty.

Technologies also play a role in (re)connecting people with nature in urban and educational settings. From a combined care ethics and transformation spheres perspective, the work of Kowarik & Busmann (2025), for example, illustrates how digital and physical tools can be mobilised in complementary ways to foster mindfulness, curiosity, and emotional engagement with biodiversity. While programmes such as the Nature Experience Areas and Nature Companions focus on direct, embodied experiences in urban green spaces — particularly for marginalised groups — they are embedded within a wider ecosystem of initiatives that includes significant digital engagement. This includes tools like the *Wild Berlin* video series and the *Environmental Calendar*, which extend the foundation's reach and accessibility far beyond physical participation. These initiatives operate within what can be described as the "personal sphere" of care, supporting individuals in developing the ethical and emotional capacities needed for response-ability. For instance, the Nature Experience Areas reportedly provides children in disadvantaged neighbourhoods with largely self-directed access to natural spaces, encouraging unstructured play and exploration (Kowarik & Busmann, 2025). Meanwhile, the Nature Companions programme is said to support individuals facing challenging life circumstances — such as refugees, caregivers, or those with disabilities — by facilitating inclusive, supported experiences in urban nature through partnerships with over 60 social institutions (Kowarik & Busmann, 2025).

These efforts to cultivate care and connection through urban nature experiences resonate with broader movements that embed relational values into everyday infrastructures. Within the domain of energy, an example from the reviewed literature is the combining of feminist energy systems and co-housing communities. Such social-technological innovations are depicted by Bell et al., (2020) as emphasising relationality, shared resources, and low-energy living to reconnect people with nature through everyday practices. These authors explore how this dual model acts to challenge dominant energy paradigms, not only through social organisation, but also through the technological orientation. Feminist energy systems, according to Bell et al (2020), advocate for the design of technologies that are responsive to human variation and ecological rhythms, shifting the focus from reactive remediation to proactive, inclusive planning. As they denote, such systems aim to “help to align energy and human variation” (Bell et al., 2020:10), embedding care and adaptability into the infrastructure itself. Co-housing communities, meanwhile, offer an intermediary that enables the uptake of sustainable technologies — such as shared energy systems or communal appliances — by expanding the palette of what is technically and socially feasible. In this innovation example, drawing from the rich analysis provided by Bell et al. (2020), it is the integration of social values with technological design that enables more response-able, relational modes of living with biodiversity and energy systems.

Yet, as was noted at the outset of this discussion, the same social-technological innovations that enable care can also compromise it. While often celebrated in the reviewed literature for their potential to democratise data and enhance ecological stewardship, they innovations can also reinforce existing power asymmetries — particularly when implemented without sufficient attention to context, consent, or justice. Accordingly, numerous studies caution against the uncritical embrace of digital and technological solutions. In conservation contexts, for instance, scholars highlight how such tools may perpetuate colonial governance models (see e.g.: Chaudhury & Colla, 2020; Trisos et al., 2021; Kashwan et al., 2021; Van Sant et al., 2021; Bersaglio et al., 2023), marginalise local knowledge systems (see e.g.: Scheba & Mustalahti, 2015; Woroniecki et al., 2020; Hampl, 2022; Simelton et al., 2021), or facilitate surveillance under the guise of environmental protection (see e.g.: York et al., 2023., Parris-Piper et al., 2023; Newton, 2018; Büscher, 2016; Lunstrum & Ybarra, 2018; Davis et al., 2021; McCarthy & Thatcher, 2019). York et al. (2023), for example, critique the use of drone technologies coupled with facial recognition AI in anti-poaching operations (see also Parris-Piper et al., 2023). Though framed as tools for biodiversity protection, such systems, they argue, risk legitimising militarised conservation and criminalising Indigenous Peoples and Local Communities (IPLCs), thereby reinforcing exclusionary practices rather than fostering relational care. Drawing on the work of Sandbrook et al. (2018), Sandbrook et al. (2021), and others, York et al. (2023) also raise concerns about how remote sensing tools — whether satellite-based or drone-mounted — can collect data on people both deliberately and inadvertently, leading to ethical dilemmas around privacy, consent, and the potential for “human bycatch” (Sandbrook et al., 2018:493, cited in York et al., 2023:3) in conservation surveillance.

A related concern lies in the growing reliance on targets-based governance and financialised conservation models, which often prioritise digital metrics and standardised indicators over situated knowledge (Corson & Campbell, 2023). As critiques of the Convention on Biological Diversity’s (CBD) Global Biodiversity Framework suggest, these approaches may sideline Indigenous and local epistemologies, reinforcing hierarchical decision-making and directing funding toward externally defined priorities (see e.g. Agrawal et al., 2021; Büscher & Fletcher, 2020; Survival International, 2021, as cited in Corson & Campbell, 2023). These concerns are, in turn, echoed more broadly in critiques of conservation innovations that document how digital tools have been used not only for ecological monitoring, but also to justify violent enforcement, displace communities, and entrench top-down governance structures (see e.g. Adams, 2019; McCarthy & Thatcher, 2019). Scholars emphasise how technologies such as remote sensing, drones, and AI-based surveillance can reinforce racialised assumptions about who poses a threat to biodiversity — particularly in regions where conservation is historically entangled with settler-colonial or militarised regimes (see Kashwan et al., 2021, Van Sant et al., 2021; Bersaglio et al., 2023, as cited in York et al., 2023). Though often presented as neutral or progressive, these tools can be mobilised to serve the interests of distant actors — states, corporations, or NGOs — who collect and control environmental data without being accountable to the communities or ecosystems most directly affected (Kashwan et al., 2021).

Even citizen science, often celebrated for its democratising potential, is not immune to these power dynamics. As noted, for example, in a review of emerging technologies in insect monitoring, the inclusion of novel tools must be context-appropriate and participatory; otherwise, they risk exacerbating disparities in access, technological literacy, and scientific recognition (Sheard et al., 2024). Furthermore, the growing role of the private sector in the collection and delivery of satellite remote sensing data raises related concerns about data commodification and unequal access to high-resolution monitoring capabilities (see Gabrys, 2016, Goldstein & Nost, 2022, as cited in York et al., 2023). Those who can afford to purchase such data may gain privileged influence over conservation decision-making, while those most affected by ecological degradation remain excluded from the process.

In the Global South, such dynamics are particularly acute. Simelton et al., (2021), for instance, warn that digital climate services, if not co-designed with farmers, risk reproducing digital colonialism by imposing external models of innovation that fail to reflect local realities or priorities. Hampl (2022) similarly documents how digital and technological innovation initiatives in Latin America and the Caribbean have, under certain conditions, contributed to exclusion, cultural erasure, and ecological degradation — particularly when driven by Western epistemologies and market logics. These critiques are also echoed in other studies that examine the use of remote sensing in conservation across the Global South, where surveillance is sometimes framed positively (e.g. for its deterrent or monitoring potential), but also frequently problematised for reflecting deeper asymmetries in power and access (see e.g. Acevedo et al., 2010, Shaffer & Bishop, 2016, Kiruba-Sankar et al., 2019, as cited in York et al., 2023). Such critiques underscore the importance of ethical design, transparency, and attention to power dynamics. In order to aid societal response-ability to the biodiversity crisis in a just and equitable way, technologies must be accountable to the communities and ecosystems they affect.

As Garrett et al. (2024) assert, transformative change thus requires not only new tools but new narratives, institutions, and infrastructures that prioritise justice, inclusion, and ecological integrity. This view aligns well with a number of other reviewed papers, including for instance, Hampl (2022), who calls for the integration of Indigenous ontologies and local knowledge systems into innovation frameworks, and by Bijoor et al., (2021), who emphasise the need for context-based conservation approaches that are co-developed with local communities (see also, Sarkki et al., 2023 (cited in Bell et al., 2022); Whyte, 2017 (cited in Urzedo et al 2022)). Together, such studies point to the necessity of embedding technologies within participatory, pluralistic, and justice-oriented frameworks—ensuring they support, rather than supplant, the relational and situated forms of care that underpin response-able conservation.

3.10 What are the underlying personal, practical, political conditions that enable or hinder social-technological innovations for response-able relationships with biodiversity (Research Question 2)?

Building on the insights explored in response to the first research question, this section further examines the enabling and constraining conditions that shape how innovations unfold in practice. Accordingly, our analytical focus here centres on the personal, practical, and political transformation spheres (O'Brien 2018) that shape the effectiveness, inclusivity, and equity of these innovations. Once again, the discussion is guided by Tronto's (2013) integrated care practice (see also Tronto and Fischer 1998).

At the personal level — intertwined with practical and political conditions — the capacity to 'care about' biodiversity often initially emerges through direct, embodied, and affective encounters with nature. Moreover, such encounters can be crucial when it comes to progressing beyond this dimension of care. Several of the reviewed studies, for instance, underscore the importance of purposively using digital and technological innovations to stimulate experiential learning and emotional connection in fostering attentiveness (see for example, the above earlier discussion of the Farmland Biodiversity Observatory (FBO) (Billaud et al., 2025)). Yet, personal engagement with social-technological innovations is also at the same time acknowledged to be profoundly shaped by broader social characteristics, including gender, class, ethnicity, and digital literacy. These factors influence who is able to access, use, and benefit from innovations, and who remains excluded or marginalised (Simelton and McCampbell 2021; Heaton 2023). Across the reviewed literature, the significance of this intersectional dimension is acknowledged in a number of studies, though often unevenly.

This variation reflects a wider trend across the cohort of reviewed literature whereby while some papers explicitly address structural inequalities and their implications for innovation, others focus more narrowly on technical or ecological outcomes, leaving social differentiation underexplored. For example:

- Victor et al., (2024) emphasise the technical performance of AI systems for forest health monitoring, with minimal consideration of how such technologies might be differentially accessible or impactful across social groups, or how they intersect with issues of equity, governance, or local knowledge;
- Pearson et al., (2023), in their study of blockchain and data-sharing infrastructures in food systems, give brief mention to the need for securing consumer engagement and trust, but otherwise centre their analysis largely upon the aspects of technological infrastructure and business-level innovation, with social inequalities — such as who has access to these technologies or how smallholders might be affected — not substantively addressed;
- Brister et al., (2024), in highlighting the transformative potential of cryopreservation technologies, note that such technologies could exacerbate inequalities, but with the primary emphasis on their technical capabilities and transformative potential, the discussion of social justice implications is relatively brief and not deeply integrated into the analysis of implementation or governance dimensions;

Overall, as the above examples serve to illustrate, while many of the reviewed papers acknowledge the potential of technological innovations to support biodiversity, only a subset engage substantively with the social conditions that shape access, use, and benefit. This gap underscores the importance of integrating intersectional and justice-oriented perspectives into the design, implementation, and evaluation of biodiversity-related innovations (for further discussion of this point, see Sandbrook et al. 2021; see also below section on *The Tech Fix Debate* for broader critical perspectives on technological solutions).

In parallel, the literature also highlights how trade-offs are inherent in many conservation practices. For example, Amit & Jacobson (2018) discuss how, in efforts to promote coexistence with large carnivores, stakeholders have debated whether financial compensation for livestock losses might inadvertently reward poor management practices. Some reportedly favour direct payments, others prefer insurance schemes or payment for ecosystem services (PES), each with different implications for biodiversity conservation and equity outcomes (Amit & Jacobson, 2018). Similarly, in marine and forest governance, competing economic interests — such as agriculture, logging, and bioprospecting — can undermine biodiversity goals unless pricing mechanisms and regulatory frameworks are in place (Koh et al., 2021; UNCLOS, 2023). Meanwhile, in the context of cryopreservation, trade-offs emerge between the benefits of long-term storage and the risks of shifting conservation priorities or exacerbating inequalities in access to technology and energy (Brister et al., 2024).

Of those that do provide an intersectional perspective, or critically engage with broader societal issues, several studies offer compelling insights into how structural inequalities — particularly around gender, class, and digital access — shape the lived realities of innovation. Gendered barriers are found to be particularly evident in agricultural contexts. Daum (2023), for instance, explores how women farmers are often excluded from mechanisation and digital innovation due to land tenure insecurity, limited access to credit, and entrenched social norms. Daum (2023) explains how these constraints not only limit women's ability to adopt new technologies, but also reinforce existing inequalities in agricultural productivity and decision-making. Similarly, in the case of the Sanjiangyuan National Park in China, Ma et al. (2023) describe how whilst the 'one household, one post' co-management scheme improved livelihoods and ecological outcomes, women were frequently overlooked for warden roles. This exclusion, they find, is not necessarily a result of formal policy, but rather reflects deeper gendered hierarchies within households and communities. Such examples further underscore the importance of designing innovations that are not only technically effective, but also attentive to the multi-scalar dynamics of power, justice, inclusion and exclusion.

Digital literacy and access to infrastructure also play a critical role in shaping who can participate in, and benefit from, technological innovations. Simelton and McCampbell (2021), for example, within the context of the agricultural domain (specifically, in the case of their study, in Southeast Asia), discuss how digital innovations often fail to reach smallholder farmers, particularly women and those in remote areas, due to limited internet access, low levels of education, and lack of involvement in the design process. They caution that without careful attention to local trust networks and peer-based learning, agricultural apps may unintentionally reinforce digital inequalities and information asymmetries, particularly among marginalised farming communities (Simelton and McCampbell 2021 see also Brown et al. 2018). These authors emphasise that without inclusive design and meaningful participation, digital tools risk reinforcing the very inequalities they aim to address. This concern is echoed within citizen science literature (which has relevance for multiple DAISY domains). Sheard et al., (2024), for example, in the context of comparing analogue and digital mosquito-monitoring projects, finds that digital platforms attracted a more diverse participant base — including more women, younger people, and non-academics — suggesting that well-designed digital tools can lower barriers to entry. At the same time, though, Sheard et al. (2024) also emphasise that digital platforms must be context-appropriate and accessible. For instance, the success of globally used apps like iNaturalist and Pl@ntNet is found to be partly attributed to their flexibility and localisation features, which allow users to tailor participation to their own environments and interests (Sheard et al., 2024).

While a sub-set of studies caution that social-technological innovation must not come at the cost of excluding those who rely on analogue methods or who lack access to digital infrastructure, a smaller but notable strand also highlights the importance of low-tech or affordable alternatives as a means of promoting inclusion and accessibility (Simelton & McCampbell, 2021; Manik et al., 2024; see also below section on *Justice as a Condition for Transformative Innovation* for further discussion). As Simelton and McCampbell (2021) observe, “typically, the least educated, poorest, most remote smallholders will be the last ones to benefit from the services they need the most” (p3; see also Trendov et al., 2019 (cited in Simelton & Campbell, 2021)), highlighting the need for more inclusive and context-sensitive approaches to digital innovation. Simelton and McCampbell’s (2021) observation draws attention also to the broader issue of class and economic inequality— another area that, although present in the literature, is similarly otherwise rarely foregrounded. In the context of digital climate services, for instance, Simelton and McCampbell (2021) further note that wealthier farmers and agri-businesses are better positioned to benefit from data-driven tools, while poorer farmers may lack the resources to act on the information provided. This creates a risk of "self-serving decisions" (p17) by those with more capital, potentially widening existing gaps in agricultural outcomes and resilience.

A related example is found in the implementation of payment for ecosystem services (PES) in smallholder agroforestry systems. Ibrahim et al. (2024) report that such innovations are often hindered by "complexities, trade-offs, risks, and barriers" (p1412), including limited institutional capacity, unclear property rights, and insufficient financial incentives. Their analysis, situated in the Global South, highlights how sociocultural dynamics, limited capital, and long production cycles further complicate adoption. In a similar vein, in the context of blockchain and AI-based conservation technologies, Christiansen (2024) and also Sandbrook et al. (2021) raise concerns that these tools often serve the interests of powerful actors — governments, corporations, NGOs — while marginalising local communities and reinforcing top-down governance structures. As, for example, Christiansen (2024) asserts in the case of digital MRV (Monitoring, Reporting, Verification): it "provides non-disruptive disruption to the market" (p6) and "serves to legitimise continued emissions predominantly from the global North and from large multinational companies, who can now more confidently promote an image of themselves as 'green'" (p12).

Within the subset of reviewed papers that engage with the intersection of social characteristics and innovation, gender is addressed more frequently than class or ethnicity, and digital literacy, where considered, tends to be mentioned in passing, rather than explored in depth. There is a relative paucity of studies that examine how intersecting forms of marginalisation — such as being a woman, a smallholder, and digitally excluded — compound barriers to participation (for exceptions, see e.g. Bell et al. 2020; Daum 2023; Bhawra et al., 2021; Ma et al. (2023); Simelton and McCampbell 2021). Moreover, few papers substantively engage with the ethical and political implications of these exclusions, or with the transformative potential of innovations that are co-designed with marginalised groups (for exceptions, see e.g. Bijoor et al. 2021; Corson & Campbell 2023; Cuéllar-Gálvez et al., 2018; Bhawra et al., 2021; Heaton 2024; Sheard et al., 2024; Simelton and McCampbell 2021). These interconnections across the personal, practical, and political transformation spheres underscore that response-able innovation is not simply a matter of individual engagement or technical design, but of systemic alignment. To deepen this understanding, the remainder of this sub-section explores how institutional competence, governance structures, and infrastructural conditions shape the capacity of innovations to support ethical, inclusive, and situated relationships with biodiversity.

In the practical sphere, the combined competence and design of technologies, institutions, and infrastructures are central to enabling ethically-grounded relationships with biodiversity. Projects such as the e-GIS Smart Indigenous Clearing-House Mechanism (Manga, 2023) and the FEEDS (Food, Equity and Data Sovereignty) platform (Bhawra et al., 2021), for instance, illustrate how digital tools have the potential to support Indigenous and community-led participation in biodiversity governance. However, their success hinges on equitable access to infrastructure, capacity-building, and data sovereignty. Without these, technologies risk becoming extractive rather than empowering.

The literature also reveals tensions between techno-optimism and techno-solutionism. For example, as discussed above, while remote sensing, AI, and blockchain technologies are often celebrated for their potential to enhance conservation monitoring and supply chain transparency, several studies caution that these tools can entrench surveillance, marginalise Indigenous knowledge systems, and reinforce centralised control over environmental governance (Corson & Campbell, 2023; York et al., 2023; Parris-Piper et al., 2023; Shukla et al., 2024). Similar concerns are raised about remote sensing and AI in conservation, which have been critiqued for enabling surveillance and militarised enforcement, raising ethical questions about privacy, consent, and the criminalisation of Indigenous communities (York et al., 2023; Parris-Piper et al., 2023; Sandbrook et al., 2021). These critiques echo the fact that technologies governed in ways that reflect the needs and rights of communities and ecosystems they affect, not just to abstract metrics or market logics.

In the political sphere, governance, policy, and structural change are decisive in shaping the conditions for innovation. The Amazonian socio-bioeconomy model, for example, as reported upon by Garrett et al. (2004) offers a potentially compelling vision rooted in distributive, procedural, and recognitional justice. It calls for dismantling harmful subsidies, supporting community enterprises, and aligning international goals with local visions — an approach that embodies Tronto's (2013) care ethics principle of 'caring with' at scale. Yet political resistance, regulatory inertia, and entrenched power dynamics often hinder such transformations. To take another example from South America: in Chile, stakeholders reportedly expressed willingness to use phytoremediation for mine tailings, but cited lack of funding, scientific support, and regulatory clarity as major barriers (Milla-Moreno & Guy, 2024).

Relatedly, the literature identifies a range of structural and institutional factors that shape how trade-offs are managed. One recurring theme is the challenge of policy coherence. Chan et al., (2019), for instance, notes that interventions aimed at achieving a few goals often "risk having negative effects on others and missing opportunities to realize synergies and manage trade-offs" (p694, see also: Singh et al., 2018; Tallis et al., 2018), particularly in biodiversity governance. This issue is also relevant in the pursuit of multiple sustainability goals, where siloed governance structures can impede integrated approaches (Chan et al., 2019).

Complementing these institutional dynamics, public perceptions also shape how innovations are received and implemented. For example, a study of public perception in the United States and Canada by Nawaz and Satterfield (2022) linked scepticism toward gene editing to broader systemic critiques of industrial agriculture and corporate control. Their findings also highlight how public attitudes toward biotechnology are shaped by perceived trade-offs between technological benefits and potential harms. For instance, they found that "a sense of ambivalence about climate change predicted preferences for both increased pesticide use and greater biodiversity loss, as opposed to greater use of gene editing" (Nawaz & Satterfield, 2022:10), while optimism about industrial agriculture predicted greater comfort with gene editing in trade-off scenarios. Such insights illustrate how innovations mediate biodiversity relationships not only through their technical design but also through the social values and political narratives that shape public perceptions of ecological risk and benefit.

Taken together, the above examples, ranging from socio-bioeconomic models and phytoremediation to public perceptions of gene editing, demonstrate that political transformation requires not only new policies, but also shifts in institutional values, narratives, and power relations (Garrett et al., 2024).

3.11 Additional Thematic Insights

3.11.1 Justice as a Condition for Transformative Innovation

The exploration, within the preceding sections, of how social-technological innovations mediate response-able relationships with biodiversity and the conditions that enable or constrain their uptake, is complemented here with a targeted summative engagement, explicitly focused on the issue of justice. This is deemed helpful both because of the ways in which matters of justice are addressed within the reviewed literature, and also because it is central to the aims of the DAISY project. Justice, in the context of the DAISY project, is not only a normative aspiration but a practical condition for transformation. It provides a lens through which to examine how innovations are experienced differently across diverse social-cultural and sectoral settings, and how they might either amplify or constrain society's capacity to respond to the biodiversity crisis in ways that are inclusive, equitable, and transformative.

This section is guided in its analysis by drawing on five widely recognised dimensions of justice: procedural, distributive, recognitional, restorative, and epistemic (Boogaard, 2021; Garrett et al., 2024); these dimensions are also used to structure the section. This summative discussion therefore serves to consolidate and clarify the role of justice within DAISY's broader analytical scope. It also reinforces the importance of intersectionality to the DAISY project, recognising that justice cannot be meaningfully addressed without attending to how gender, class, ethnicity, and other social characteristics shape access, participation, and benefit. This section also further sets the stage for the critical assessments of listings of social-technological innovations in WP2 and the development of intervention mixes in WP3.

Overall, while many studies reference the importance of justice, they tend to do so in ways that are either rhetorical or narrowly procedural, without fully unpacking the deeper structural and epistemic dimensions at play. There are, however, a few notable exceptions to this, the contributions of which inform this section (see especially Garrett et al., 2024; Christiansen, 2024; Billaud et al., 2025; Chan et al., 2019; Bijoor et al., 2021; Bell et al., 2020; Corson & Campbell, 2023).

In the case of *procedural* justice, within the reviewed literature this dimension is often associated with participatory governance and stakeholder engagement, yet the quality of participation is rarely interrogated. Exceptions, however, include Ma et al. (2023), who present the "one household, one post" model in Sanjiangyuan National Park as a mechanism for enhancing local livelihoods and ecological stewardship, but also critically reflect on how gendered hierarchies persist in job allocation, with men more likely to take up ecological guard roles. Similarly, REDD+ (a voluntary climate mitigation framework developed by the UN's Framework Convention on Climate Change) initiatives are critiqued for failing to ensure meaningful participation of Indigenous Peoples and local communities, often relying on passive consultations and limited representation — a critique made explicit in the analysis by Maraseni et al. (2020) (for further exceptions with regards to procedural justice see e.g. Bijoor et al., 2021; McDermott et al., 2013 (cited in Wynberg 2023)).

The dimension of *distributive* justice is raised within the reviewed literature through discussion of inequalities in access to resources and benefits associated with (or arising from) social-technological innovation. However, such discussion seldom engages deeply with the political economy of these disparities or proposes concrete redistributive mechanisms (though see e.g. Garrett et al., 2024; Bell et al., 2020). Smallholder farmers, for instance, are frequently identified as facing barriers to adopting social-technological innovation due to limited access to finance, land, and infrastructure (Kamyab et al., 2024; Simelton & McCampbell, 2021). In digital agriculture, disparities in connectivity and digital literacy risk reinforcing existing inequalities, with some scholars warning of "digital colonialism" (Hampl, 2022). *Recognitional* justice is addressed within the reviewed literature through calls for the respect and integration of diverse identities and knowledge systems, especially those of Indigenous and marginalised communities (see e.g. Chan et al., 2019; Bijoor et al., 2021; Corson & Campbell, 2023). A study of the Amazon socio-bioeconomy model, for example, centres on the recognition of Indigenous and traditional communities and their ethical frameworks, such as 'buen vivir'—a concept that emphasises harmonious relationships between people and nature and is embedded in several Latin American constitutions (Garrett et al., 2024). Feminist energy systems are similarly framed as intersectional and inclusive, attuned to the many hierarchies through which power and energy operate (Bell et al., 2020). Yet operationalising recognition remains uneven across the literature, with many studies affirming the value of local knowledge without detailing how it is validated, integrated, or contested within broader systems of governance and innovation.

Restorative justice appears more sporadically than the other dimensions, typically in relation to historical harms or ecological degradation. The phytoremediation of mine tailings in Chile, for instance, is framed as a way to repair environmental damage while also creating local employment opportunities (Milla-Moreno & Guy, 2024). While several studies explore the potential of digital and technological innovation to support inclusion or recognition — such as through participatory GIS, blockchain, or digital climate services — none explicitly frame these interventions in terms of restorative justice, such as addressing historical harms, redistributing power, or enabling reparations. As such, across the reviewed literature, few studies engage deeply with questions of accountability, reparations, or power redistribution.

Finally, *epistemic* justice is a relatively strong and cross-cutting theme across the review literature, with many texts critiquing the dominance of Western scientific paradigms and calling for the inclusion of local, Indigenous, and experiential knowledge (see e.g. Boogaard, 2021; Hampl, 2022; Billaud et al., 2025). The Farmland Biodiversity Observatory, for example, is presented by Billaud et al. (2025) as a boundary object that enables farmers to engage with biodiversity through experiential and contextual knowledge, rather than relying solely on prescriptive scientific models. The reviewed literature also highlights the role of power and knowledge in shaping trade-offs in global biodiversity governance. Targets that are supported by robust data and indicators — typically grounded in natural science — are more likely to be prioritised, reinforcing the dominance of Western scientific paradigms and sidelining other knowledge systems (Campbell et al., 2014b; Hagerman et al., 2021). This dynamic can create tensions between scientific and Indigenous or local perspectives, particularly when benefit-sharing mechanisms are weak or absent (Corson & Campbell, 2023; Garrett et al., 2024). These examples underscore how institutionalising epistemic pluralism presents ongoing challenges, particularly when conflicting knowledge claims arise (see also Corson & Campbell, 2023; Chan et al., 2019; Hampl, 2022).

Overall, from the literature which critically engages with the subject of justice, what becomes clear is that justice is not merely a background concern but a structuring condition for whether innovations succeed or fail in fostering inclusive and sustainable change (Turnhout et al., 2020; Van Kerkhoff & Lebel, 2015). Social-technological innovations that are co-designed with marginalised groups, embedded in local contexts, and aligned with relational values tend to produce more durable and equitable outcomes (Bijoor et al., 2021; Manga, 2023; Hajjar et al., 2020). Conversely, those that prioritise efficiency, scalability, or technical performance without regard for social differentiation, risk reinforcing exclusion and technocratic control (Christiansen, 2024; Sandbrook et al., 2021; Turnhout et al., 2020). In the case of scholarship that fails to engage critically or substantively with the subject, a common limitation is an assumption that inclusive language or participatory methods at the point of introduction are sufficient (Van Kerkhoff & Lebel, 2015; Díaz et al., 2015). This assumption obscures the deeper power dynamics that shape who participate, whose knowledge counts, who benefits, and also the longer-term sustainability of any initial commitment towards inclusive design (Turnhout et al., 2020; Miller & Wyborn, 2020).

3.11.2 The 'Tech Fix' Debate: Promise, Pitfalls, and Politics

As is evident from the above discussion of findings, the reviewed literature contains a diverse and often contrasting set of perspectives on the role of digital and technological innovations in mediating societal relations with biodiversity. Rather than a simple binary between pro-technology and anti-tech-fix positions, the texts reveal a spectrum of framings, shaped by disciplinary orientation, political commitments, and empirical context. Some contributions are strongly optimistic about the potential of technological innovation, while others are deeply critical, and many occupy a more ambivalent or conditional middle ground.

A significant portion of the literature adopts a broadly pro-technology stance, particularly in fields such as agricultural science, environmental engineering, computer science, and biotechnology (see e.g. Kamyab et al., 2024; Xu et al., 2022; Simelton & McCampbell, 2021; Huddart et al., 2021). These texts emphasise the potential of digital and technological innovations to enhance monitoring, efficiency, and decision-making in biodiversity conservation and sustainable agriculture. For example, precision agriculture is described by Kamyab et al. (2024) as “an advanced technology domain that aims to mitigate GHG emissions… and concurrently improve the efficiency of resource utilisation and crop productivity” (p276). Similarly, AI is framed by DeSantis et al., (2025) as a tool to bridge the gap between scientific data and policymaking. They note that it “offers a novel approach to assess the alignment between national and global biodiversity policies” (DeSantis et al., 2025:1). Blockchain is also presented as a transformative tool, capable of enhancing transparency and traceability in environmental governance, with its “decentralized and transparent nature” seen as promising for “enhancing trust” (Shukla et al., 2024: 323). Other examples include the use of genomics in biodiversity monitoring (Huddart et al., 2021), advanced cryopreservation for species conservation and aquaculture (Brister et al., 2024), and digital climate services for farmers (Simelton & McCampbell, 2021). These contributions often highlight the scalability, precision, and data-driven nature of technological solutions, and tend to assume that innovation is inherently beneficial if properly implemented.

In contrast, a substantial body of the reviewed literature adopts a more critical or sceptical stance, particularly from disciplines such as feminist theory, political ecology, environmental sociology, and participatory research. For example (as discussed in further detail in response to the first research question, above), these texts question the sufficiency, equity, and unintended consequences of technological fixes. Bell et al. (2020), for instance, argue that “renewable energy systems do not guarantee democracy and equality” (p4) and may “increase the precariousness of vulnerable communities” (p4). They instead advocate for a feminist energy system that centres “distributed and decentralized fuel power and people power” (p2), emphasising relationality, care, and intersectionality. Corson and Campbell (2023), meanwhile, critique the consolidation of elite power through conservation technologies, warning that “the combined impact of targets, finance, and technology abstracts conservation from localized contexts” (p2) and fails to challenge the root causes of biodiversity loss. Christiansen (2024) similarly argues that digital monitoring technologies in carbon markets serve as a “non-disruptive disruption” (p1), providing a technical fix that “relegitimises ongoing carbon offsetting practices” (p1) without addressing the structural drivers of ecological degradation. Billaud et al. (2025), meanwhile, highlight the limitations of large-scale statistical models in agricultural biodiversity monitoring, noting that farmers often shift from seeking prescriptive solutions to using biodiversity observation as a learning tool, accepting uncertainty and valuing experiential knowledge. As discussed earlier, further critiques are found in the reviewed literature on remote sensing and AI, where authors warn that technologies such as drones and satellite imagery can enable "socially harmful forms of surveillance" (York et al., 2023:1) and "militarised and violent interventions" (York et al., 2023:2, see also Büscher, 2016; Lunstrum and Ybarra, 2018), and that the "panoptic gaze" (Davis et al., 2021, cited in York et al. 2023:2) of satellite monitoring risks reinforcing structural violence and top-down decision-making (McCarthy & Thatcher, 2019).

Between these poles, many texts adopt a more ambivalent or conditional framing. These contributions often acknowledge the potential of technology but emphasise the importance of inclusive governance, ethical safeguards, and contextual adaptation (see, for example, Manga 2023, Simelton and McCampbell 2021, Milla-Moreno and Guy 2024). These texts often emerge from interdisciplinary or applied fields such as sustainability science, agroecology, and development studies, where the emphasis is on responsible innovation, participatory design, and context-sensitive implementation.

Overall, there is also evidence that disciplinary orientation influences the framing of technology. STEM (science, technology, engineering and mathematics) disciplines, including agronomy, AI, genomics, and engineering, tend to emphasise innovation, scalability, and efficiency, often assuming that technological advancement is inherently progressive. In contrast, social sciences and humanities scholars are more likely to interrogate the assumptions behind tech-fix solutions, focusing on power dynamics, historical injustices, and the need for participatory governance. Interdisciplinary and applied fields often blend these perspectives, advocating for inclusive, ethical, and adaptive approaches to innovation.

3.11.3 Science Denialism and Public Trust in Innovation

The reviewed literature does not explicitly or extensively address science denialism in the conventional sense — such as the outright rejection of scientific consensus on climate change, biodiversity loss, or vaccination (Diethelm and McKee, 2009). However, it does engage with adjacent and relevant themes that help illuminate the social dynamics surrounding public trust in science, the politicisation of scientific knowledge, and the contested legitimacy of certain scientific applications. These discussions suggest that while science denialism as a term is largely absent, the reviewed literature nevertheless still contains valuable insights into the broader terrain of public attitudes toward science and technology.

One of the clearest points of contact with the issue of science denialism appears in the study by Nawaz and Satterfield (2022), which investigates public perceptions of agricultural gene editing. The authors find that opposition to gene editing is not necessarily rooted in ignorance or rejection of science, but rather in broader societal critiques—particularly of industrialised food systems. Participants who were more certain about the urgency of climate change were, reportedly, more likely to support gene editing for climate-relevant applications, such as drought-tolerant wheat. In contrast, those who were critical of corporate agriculture and the legacy of the Green Revolution were, reportedly, more likely to reject gene editing altogether. This leads the authors to conclude that “attention to broader societal priorities in surveys of perceptions may help address calls for responsible research and innovation” (Nawaz and Satterfield 2022:1) and that opposition to gene editing may reflect concerns about ownership, equity, and the socio-economic context of technological deployment. This framing complicates the notion of science denialism by showing that resistance to certain technologies may stem from ethical and political concerns rather than a rejection of scientific evidence.

Another relevant strand of the reviewed literature reflects on the historical evolution of public attitudes toward science and technology. For example, one contribution, cited by Koretsky et al., (2023) traces the shift from post-war techno-optimism to the emergence of critical discourses in the 1970s, particularly following the publication of the Club of Rome’s Limits to Growth report (Feenberg, 2017). In so doing, Feenberg explains how the Limits to Growth report challenged the assumption that economic growth and technological development would inevitably lead to societal benefit, highlighting instead the risks of resource depletion and ecological collapse. They draw on critical theory of technology to argue that science and technology are not value-neutral or universally beneficial, and that democratic control and reflexivity are essential to avoid unintended harms (Feenberg, 2017, cited in Koretsky et al., 2023).

Also included within the reviewed literature are reflections on how scientific authority is negotiated in global governance contexts. For example, in the context of the Convention on Biological Diversity (CBD) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), there is concern that targets with strong data and indicators are more likely to be pursued, reinforcing the dominance of natural science in defining conservation priorities (Corson and Campbell 2023; see also Hagerman et al., 2021, Jacob, 2017). This dynamic can marginalise other knowledge systems, particularly those rooted in Indigenous and local traditions. The literature notes that "competing knowledge claims between Western and other knowledge systems and between natural sciences and social sciences" (Corson and Campbell, 2023:5) are often unequally weighted, which may lead to resistance or scepticism from communities whose perspectives are excluded from formal decision-making processes (see also Masood, 2018).

In addition, the reviewed literature touches on the role of powerful incumbents in resisting scientific evidence that threatens their interests. One article, for example, discusses how efforts to phase out harmful technologies — such as leaded petrol — are often met with "campaigns of obfuscation and ignorance construction" by actors with vested interests (Koretskey et al., 2023: 264, see also Newman 2023). These actors may seek to delay or derail policy interventions by questioning the validity of scientific findings or by promoting alternative narratives. While this is not framed explicitly as science denialism, it clearly aligns with the tactics used in denialist campaigns across various domains.

Despite these valuable insights, the reviewed literature does not directly confront the dynamics of denialism itself. There is little engagement, for instance, with the mechanisms of misinformation, the role of media and social networks, or the influence of populist politics in undermining scientific authority. Nor is there exploration of how denialism manifests in specific policy arenas, such as climate change or biodiversity conservation. A more focused analysis on the social, political, and communicative dimensions of science denialism remains an important area for further research.

3.11.4 Innovation Trajectories: Emergence, Decline, and Discontinuation

Whilst multiple examples of emerging technologies are explored within the reviewed literature, only a relatively limited set of contributions explicitly address the dynamics of declining innovations. Nevertheless, the few the articles that do, provide valuable insights into both the emergence of new technologies and the persistence or decline of older ones (see especially Koretsky et al., 2023; see also e.g. Elliott, 2018; Stegmaier, 2023; Callorda Fossati et al., 2023; Turnheim, 2023). A key observation is that innovation studies have historically focused on the emergence and diffusion of novelty, often neglecting the processes through which technologies become obsolete, contested, or deliberately phased out (Koretsky et al., 2023). Koretsky et al. (2023) frame this as an "innovation bias", noting that "processes of emergence and stabilisation are better documented and more widely discussed than those of disappearance, partial continuity and resurrection" (p4). This critique is particularly relevant in the context of DAISY's Task 1.3 interest in understanding not just the technical features of innovations, but their social meanings, institutional contexts, and political consequences. It also underscores the importance of context, power, and values in shaping innovation trajectories across the full life cycle of an innovation. The relative scarcity of direct engagement with such themes across the reviewed literature suggests a gap that the DAISY project is well-positioned to address.

The reviewed literature points to several examples of technologies that were once seen as symbols of progress but are now viewed as problematic. These include coal-fired power plants, pesticides, and internal combustion vehicles. The persistence of such technologies, despite their known harms, is attributed to a combination of infrastructural lock-in, cultural attachments, and resistance from vested interests (see e.g. Stegmaier, 2023, citing Callon, 1987; MacKenzie & Spinardi, 1995; Russell & Vinsel, 2018; see also, Elliott 2018). The reopening of coal mines or the continued expansion of SUVs, for instance, illustrates how "existing technologies and underlying systems remain relatively stable" (Koretsky et al., 2023:4, see also Markard et al., 2021) even in the face of ecological crisis. This inertia poses a challenge for transitions to more sustainable systems and raises questions about how to "reduce our dependence on harmful technologies and socio-technical systems" and how to discontinue "investment patterns related to harmful and polluting production" (Koretsky et al, 2023:4).

The reviewed literature also critiques the framing of certain innovations as inherently progressive or universally applicable. Garrett et al. (2024:1822), for example, in their discussion of socio-bioeconomies (SBEs) in the Amazon, warn against "promissory" framings that position advanced technologies from the Global North as the key to sustainability, while overlooking the biodiversity-conserving value of existing, locally rooted practices. They argue for a more inclusive approach that recognises both new and traditional technologies and that aligns international goals with local visions. This critique resonates with DAISY's emphasis on values, equity, and the situated nature of innovation.

4. Conclusion

Informed by the conceptual frame of the DAISY project — including especially feminist care theory (Tronto, 2013), O'Brien's (2018) transformation spheres, and Haraway's (2016) concept of response-ability — this report has explored how digital and technological innovations enable or inhibit ethical and situated relationships with biodiversity. In doing so it has been guided by two main research questions: how do social-technological innovations mediate response-able relationships with biodiversity, and; what are the underlying personal, practical, political conditions that enable or hinder social-technological innovations for response-able relationships with biodiversity?

The findings confirm that digital and technological innovations can foster attentiveness, participation, and ethical engagement with biodiversity. However, their effects are not uniformly positive. They can also reinforce exclusion, surveillance, and technocratic control — particularly when implemented without attention to justice, context, or power dynamics (Christiansen, 2024; Corson & Campbell, 2023; York et al., 2023).

Justice emerges as a structuring condition for transformation, not merely a normative aspiration. While engagement with justice dimensions varied across the reviewed literature, several studies foreground the importance of procedural justice (e.g. Ma et al., 2023), distributive justice (e.g. Simelton & McCampbell, 2021; Kamyab et al., 2024), recognitional justice (e.g. Garrett et al., 2024; Chan et al., 2019), restorative justice (e.g. Milla-Moreno & Guy, 2024), and epistemic justice (e.g. Billaud et al., 2025; Hampl, 2022). These dimensions are essential for ensuring that innovations are inclusive, accountable, and responsive to diverse knowledge systems and lived experiences — particularly in contexts where historical marginalisation and structural inequalities shape access to innovation.

The review also reveals a spectrum of perspectives on the role of digital and technological innovation in the context of biodiversity and equity. While some contributions celebrate digital tools for their efficiency and scalability (Kamyab et al., 2024; DeSantis et al., 2025), others caution against "tech-fix" solutions that depoliticise biodiversity governance and obscure structural drivers of degradation (Bell et al., 2020; Christiansen, 2024). This ambivalence underscores the need for critical reflection on the purposes, politics, and unintended consequences of innovation.

In addition, the literature draws attention to the politics of knowledge and the risks of science denialism. Public scepticism toward technologies such as gene editing is often rooted not in ignorance, but in broader critiques of industrial agriculture and corporate control (Nawaz & Satterfield, 2022). Similarly, the dominance of Western scientific paradigms in global biodiversity governance can marginalise Indigenous and local epistemologies (Corson & Campbell, 2023; Hagerman et al., 2021).

Finally, the review identifies a gap in attention to declining or obsolete technologies, particularly in relation to biodiversity and equity outcomes. While much of the literature focuses on emerging innovations, few studies examine how harmful or exclusionary systems persist, or how their discontinuation might be governed in ways that support ecological integrity and social justice (Koretsky et al., 2023; Stegmaier, 2023). This "innovation bias" limits our understanding of transformation as a full-cycle process — one that must include not only the emergence of new tools, but also the phasing out of technologies and infrastructures that undermine inclusive and sustainable futures.

Taken together, these insights reinforce the DAISY project's emphasis on relational, justice-oriented, and context-sensitive approaches to innovation. They also inform the design of future work in WP2 and WP3, including the development of diagnostic tools, transformative intervention mixes, and participatory processes that centre equity, care, and epistemic pluralism.

To conclude, the interpretative review conducted for DAISY Task 1.3 reveals that social-technological innovations can play a transformative role in fostering more ethical, inclusive, and response-able relationships with biodiversity; however, their potential is shaped by a complex interplay of enabling and constraining conditions. The following take-aways distil key insights from across the review, ending with the identification of key areas for future research:

(1) Innovation is not neutral — and its impacts are ambivalent

Technological innovations are embedded in social, political, and epistemic systems. They shape what is visible, valued, and acted upon in biodiversity governance, and reflect particular worldviews and power structures (Christiansen, 2024; Corson & Campbell, 2023). While they can foster attentiveness, participation, and relational ethics, they can also entrench surveillance, exclusion, and technocratic control. Their impacts are contingent on design, governance, and context and must be critically assessed to avoid reinforcing extractive or inequitable systems (York et al., 2023; Parris-Piper et al., 2023; Simelton & McCampbell, 2021).

(2) Justice is a structuring condition, not an add-on

Transformative innovation requires attention to procedural, distributive, recognitional, restorative, and epistemic justice (Boogaard, 2021; Garrett et al., 2024). Innovations that are co-designed with marginalised groups and embedded in local contexts have greater potential to produce equitable and durable outcomes — particularly when they are responsive to the situated realities of those communities. Conversely, innovations that prioritise efficiency or scalability without regard for social differentiation or context, risk reinforcing exclusion and technocratic control (Sandbrook et al., 2021; Turnhout et al., 2020).

(3) Structural inequalities shape who benefits and who is left out

Access to innovation is shaped by intersecting inequalities of gender, class, ethnicity, and geography. These dynamics operate not only between countries — such as those often grouped under the Global North and Global South — but also within them, where disparities persist across regions, communities, and social groups. Without inclusive design and governance, innovations risk reinforcing existing inequities and marginalising those most affected by biodiversity loss (Daum, 2023; Hampl, 2022; Ma et al., 2023).

(4) Innovation must be part of broader systemic change

Technological tools alone cannot address the root causes of biodiversity loss. They must be embedded in wider shifts in narratives, institutions, and infrastructures that prioritise care, justice, and ecological integrity (Garrett et al., 2024; Bell et al., 2020). This includes challenging dominant economic paradigms, dismantling harmful subsidies, and supporting community-led governance and alternative value systems.

(5) Participatory and pluralistic approaches are essential for transformation

Across the reviewed literature, participatory design and co-production of knowledge emerge as key enablers of ethical and effective innovation. Innovations that are co-developed with communities — especially those historically marginalised — are more likely to support biodiversity, equity, and resilience. This requires moving beyond tokenistic inclusion to genuine collaboration, shared authority, and long-term investment in trust and capacity (see e.g. Bell et al., 2020; Bijoor et al., 2021; Billaud et al., 2025; Trivellas et al., 2023).

(6) Transformation requires historical and systemic awareness of innovation trajectories

Innovation is not only about emergence — it is also about persistence and decline. The literature reveals a lack of attention to the discontinuation of harmful technologies and the structural inertia that sustains them. Addressing this requires governance approaches that consider the full life cycle of innovation, including resistance to change, lock-in effects, and the politics of obsolescence (see e.g. Koretsky et al., 2023; Stegmaier, 2023; Turnheim, 2023).

(7) Addressing persistent evidence gaps and underexplored dimensions

While the literature reveals growing interest in digital and technological innovations for biodiversity, it also highlights several areas where further research is urgently needed. Empirical evidence on the actual impacts of innovations — particularly on biodiversity outcomes and equity — remains limited, with many studies relying on theoretical or speculative claims. Similarly, the dynamics of innovation decline and discontinuation are rarely examined, despite their relevance for understanding how harmful or exclusionary systems persist. Intersectional analyses that go beyond gender to include class, ethnicity, and digital literacy are also underrepresented, as are studies exploring the role of science denialism and public trust in shaping innovation uptake. Finally, the influence of narratives and promissory framings on innovation trajectories warrants deeper investigation. Addressing these gaps will be essential for developing more robust, inclusive, and context-sensitive approaches to innovation assessment and design — both within DAISY and in the broader field of biodiversity governance.

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Annex 1

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
AI and robotics for creating autonomous systems for sustainable farming	Reduced chemical use. Reduced harm to non-target species. Reduced resource consumption.	Empowers farmers as biodiversity stewards through informed, sustainable practices.	Integration and standardisation of technology. Societal acceptance. Farmer training and support. Economic viability of technology.	High costs reducing equitable access. Gaps in digital and literacy and comfort level. Social resistance. Data privacy concerns. Over-reliance on automation and loss of local knowledge and connection to land. Environmental harm if technology is mismanaged	Can improve equity through democratizing precision farming, but risks job displacement and access inequality.	The technology could help to mediate a more response-able relationship with nature by supporting sustainable and environmentally friendly farming through increasing efficiency and reducing use of pesticides and fertilisers. This technology will be hindered by high cost and the knowledge needed to implement it and enabled by farmer training and support and creation of interoperable systems.	(Camaréna, 2021; Balaska *et al.*, 2023; Gackstetter *et al.*, 2023)
AI for digital monitoring, reporting and verification of carbon credit markets	Increases transparency and traceability of carbon credits. Reduced deforestation by giving biodiversity	Commodifies nature. Can empower smallholders and promote eco-conscious behaviour.	Accurate data, with ground-truthing. Clear regulations and governance. Digital infrastructure and literacy.	Greenwashing by larger companies who continue environmentally harmful practices. Reduced access to market benefits for small-scale businesses and landowners.	Enhances inclusion and trust but risks digital divides and exclusion which could deepen inequality; needs ethical governance and consumer protection.	AI can help mediate a more response-able relationship with nature by making carbon markets more transparent. This gives them legitimacy and gives biodiversity market value, thus providing protection. However, there is the risk that it legitimises damaging activities. Conditions that hinder the use of the voluntary carbon market are unequal access to the market for small landowners and developers and	(David, Yoshino and Varun, 2022; Christiansen, 2024)

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
	monetary value.		Cross-sector collaboration			irresponsible use of the market as a form of greenwashing by large companies	
AI/ machine learning with remote sensing for image classification	Increases scope to process data and provide information for biodiversity monitoring	Increased understanding and awareness of conservation issues. Access to information can increase stewardship. Remote technology and AI can increase distance between humans and nature	Accurate and ground-truthed data. Expertise for machine learning model development and interpretation. Integration of local knowledge	Inaccurate or biased data. Misinterpretation of data. Over-reliance on technology and reduced connection to nature and knowledge. Privacy concerns data collection and handling	If access and transparency are ensured, increased knowledge can empower local communities	Using machine learning for image recognition can mediate a more response-able relationship with biodiversity by increasing capacity for large-scale monitoring and providing data to base conservation decisions on. It is hindered by cost, inequitable access and lack of training data and enabled by engaging those with expert knowledge and access to computing power and infrastructure	(Victor, Mykhailo and Samuli, 2024)
AI for species identification for education and engagement	Improved accuracy of data from citizen science/ public	Increased knowledge and awareness can strengthen	Appropriate user-friendly technology (task-technology fit)	Inaccurate AI generated information. Lack of trust from users. Exclusion of those with lower digital literacy.	Access to tools can promote inclusivity in biodiversity education and empower communities.	Educational tools that use AI to aid in species identification can help mediate a more response-able relationship with biodiversity by increasing access to information and empowering more people to monitor wildlife. It	(Parningotan Manik *et al.*, 2024; Sheard *et al.*, 2024)

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
	participation groups. Increased awareness of biodiversity	connection to nature and motivation to take biodiversity positive actions	Open-source tools. Inclusive and engaging platform design. Training	Loss of traditional natural history skills	If poorly implemented access inequalities can be increased	is enabled by training for users and good technology design and application but hindered by lack of access to digital technology and issues with poor quality data and trust from the public	
Bioenergy	Can reduce fossil fuel consumption and promote, agroecological zoning, and multifunctional landscapes;	Promotes coexistence in integrated landscapes, supports rural livelihoods, and fosters ecosystem awareness.	Supportive policies, integrated resource management, innovation, stable pricing, certification, public engagement, and collaboration.	Land-use change, intensification, market volatility, social inequities, and slow deployment; mitigated by best practices and governance.	Emphasises just transitions, equitable energy access, stakeholder engagement, and fair distribution of benefits and rights.	Bioenergy can mediate a response-able relationship with biodiversity as it provides an alternative fuel source to fossil fuels and can assist in meeting emissions and climate change goals, which will benefit biodiversity globally, while also providing a reliable energy supply. A response-able relationship in this case could be hindered or enabled depending on agricultural approaches. Biofuel can be integrated into biodiversity friendly agriculture, but if large areas of land are converted for monoculture of biofuel crops, this could be damaging to biodiversity. To enable sustainable and equitable access to biofuel, appropriate policy and finance for infrastructure and education are needed.	(Souza *et al.*, 2017)
Blockchain	Increases transparency of trading, markets and supply chains.	Fosters accountability and responsible behaviour	Integrated and scalable technology. Appropriate regulation.	Crypto regulation gaps. Digital exclusion. Over-reliance on technology.	Transparency can improve equity and trust if access and compliance issues are addressed	Blockchain has the potential to mediate response-able relationships with biodiversity as the transparent nature of it highlights where problems are occurring and also prevents people tampering with the data. This increases	(Villares, 2021; Parameswaran *et al.*, 2024; Shukla *et al.*, 2024)

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
	Encourages sustainable business practices. Reduces illegal trade in wildlife	through transparency Builds stewardship by empowering communities through direct, traceable conservation funding.	Digital access training. Collaboration between parties.	Access inequality from lack of infrastructure. Data privacy concerns		awareness and accountability for unsustainable practices. Conditions that may hinder this technology are mainly associated with the financial cost of the tech and the knowledge and skills needed to manage it efficiently. It will be further enabled by ensuring equitable access for all.	
Corrals for predator proofing in livestock husbandry	Reduces retaliatory killings of carnivores.	Fosters coexistence and trust between communities and wildlife.	Community engagement for co-development of suitable corral. Cultural relevance of technology. Support, and transparency in development process.	High costs, logistical issues, and potential resistance.	Improves equity and trust through inclusive decision-making.	The livestock corrals mediate a more response-able relationship with biodiversity by offering livestock herders an alternate management option to help reduce conflict with predators. The conditions that enabled this innovation to be successfully developed is use of the PARTNERS framework to involve the local herders in the development and implementation	(Bijoor *et al.*, 2021)
Gene-editing technologies in agriculture	Reduced chemical inputs such as pesticides however	Can facilitate more sustainable agricultural practices but	Education to increase public acceptance. Further research into	Corporate monopoly, of technology and reduced access for some communities	Can support food security particularly for climate change impacted communities.	Gene-editing technologies could help societies develop a more response-able relationship with biodiversity, eg by developing climate resistant crops and reducing the need for use of fertilisers and pesticides which are damaging to	(Speiser *et al.*, 2013; Michalczuk, 2022; Nawaz

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
	use of some modified crops can reduce biodiversity	also may reduce agricultural diversity.	gene editing practices. Regulatory reform. Open access and sharing of data	Public scepticism and mistrust Promotion of monocultures and loss of traditional crops thereby reducing biodiversity	Potential for equity and sustainability, but risks undermining trust due to corporate dominance. Financial repercussions from consumer distrust of product	biodiversity, however there are also risks with this technology if it is not used carefully and responsibly. The technology is hindered by inconsistencies in policy regulations over different gene-editing techniques and lack of societal acceptance and trust of the gene-edited crops and livestock	and Satterfield, 2022)
GIS and mapping tools with local community collaboration	Can help incorporate remote sensing data with local and traditional knowledge leading to improved data and land management for biodiversity conservation	Fosters stewardship and democratises participation in environmental decisions.	State support, inclusive, participatory governance, tech integration, and community/ stakeholder engagement.	Issues with financial burden and data sovereignty. Data gaps, power imbalances, and technology access barriers. Lack of consensus among stakeholders.	Can improves equity and trust by empowering Indigenous or local community participation. Can be damaging to trust relationships if power imbalances lead to disregard of local knowledge in planning and land management	Use of GIS and mapping systems can help mediate a response-able relationship with biodiversity when local and indigenous community knowledge is integrated as it can empower communities to make to decisions for the sustainable management of land and prioritise areas for biodiversity conservation. It can be hindered by top-down forces and power imbalances over-riding local knowledge and opinions and enabled through good community engagement	(Balram, Dragićević and Meredith, 2004; Manga, 2023; Castrejón, Moity and Charles, 2024)
Green roofs in urban habitats.	Provides food, shelter, and nesting for wildlife.	Improves awareness, and opportunities for nature interactions in	Good design and suitable plant choice, regular maintenance, water	Crop or building damage from increased wildlife presence, spread of zoonosis or invasive species.	Promotes urban equity through accessible green spaces.	Green roofs can help mediate a response-able relationship with biodiversity as they can provide additional habitat for birds, including rare species, in urban environments. They can also increase contact with nature, which can improve care. conditions hindering this	(Fernandez-Canero and Gonzalez-Redondo, 2010)

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
		an urban environment.	management, habitat features for wildlife	Airport hazards from birds		innovation are the expense and effort of creating and maintaining green roofs and potential concerns around increasing pest species in urban areas	
Hydropower systems	Can repurpose previous mining land and provide clean energy to reduce pollution but can also damage habitats and have negative environmental impacts e.g. reduced water quality	Can disconnect people from land through altered land use and displacement of communities	Risk management, impact assessments, stakeholder engagement.	Technical, environmental, social, financial, regulatory risks including lack of public acceptance, risk of damage to environment and economic disruption	Requires equitable policies to mitigate displacement and inequality but if done well can support the just energy transition	Hydropower has an interesting nuance with regards to a response-able relationship with biodiversity, as while it can provide a source of clean energy, its development can cause direct harm to biodiversity and the environment. Creation of hydropower is strongly influenced by political position and financial issues as well as suitable geological and environmental conditions and can have negative impacts on local communities	(Garg *et al.*, 2025; Kruczek *et al.*, 2025)
Digital genetic sequence information	Supports conservation via traceable, responsible use of genetic resources and	Empowers Indigenous communities, fostering stewardship and inclusive	Community training, robust tech, legal frameworks, federated governance,	Data misuse, false entries, regulatory gaps, limited enforcement, digital exclusion or exclusion via restrictive regulations	Can enhance fairness, transparency, and benefit-sharing for biodiversity-rich nations	Shareable digital genetic sequence information can mediate a more response-able relationship with biodiversity by ensuring transparent, auditable, and benefit-sharing among all contributors of genomic data, including local populations. By implementing smart contracts and an internal monetary system, it can	(Rohden and Scholz, 2022; Kimura *et al.*, 2023)

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
	reduced biopiracy.	genomic research.	and system interoperability.			incentivise collaboration in data collection, processing, and storage, addressing the challenge of compensating non-academic actors in biodiversity genomics.	
AI for climate forecasting, environmental monitoring, disaster response, and smart city planning.	Monitoring, conservation planning, and tracking illegal activities.	Enhances sustainable planning, disaster preparedness, and efficient resource use.	Quality data, transparent AI, ethical frameworks, interdisciplinary collaboration, and infrastructure investment.	Data bias, lack of transparency, ethical concerns, and infrastructure gaps in low-income regions.	Promotes fairness and trust through inclusive, participatory AI development and bias mitigation.	AI based innovations can mediate a more response-able relationship with biodiversity by assisting with monitoring, data collection and data analysis, which can inform responsible decision making. This can be hindered by poor data quality, challenges in understanding complex models, and ethical issues regarding data privacy and transparency. AI can be enabled by promoting collaboration and partnerships to facilitate more equitable application of AI, particularly in developing countries.	(Al-Raeei, 2024)
Digital participatory platforms for biodiversity data collection and validation.	Helps biodiversity by supporting large-scale data for conservation.	Engages the public in science, fostering stewardship and awareness.	Needs tech integration, standardisation, engagement, and infrastructure.	Data quality, tech barriers, and sustainability issues.	Improves equity via democratised science, but access and bias must be addressed.	Digital platforms and databases can help mediate a response-able relationship with biodiversity as they allow more data to be collected at a greater rate via crowdsourcing which in turn provides knowledge to base conservation actions on. It can also engage more people in biodiversity monitoring and increase knowledge, awareness and connection to nature in people participating. Conditions that may hinder this innovation are lack of engagement and awareness among members of the public, alongside lack of access to technology needed	(Heaton, 2024)

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
						to participate and lack of ability e.g. not having the time or the skills (or confidence in their skills). Enabling factors are good and user-friendly design of the platforms and flexibility in participation allowing people to participate at whatever level they feel able	
Digital weather and climate services for agricultural decision-making.	Mixed; reduces inputs but lacks support for integrated systems.	Enhances resilience but limited integration with diverse systems.	Inclusive development, partnerships, transparency, and supportive policies.	Digital exclusion, data privacy, economic vulnerability.	Potential for equity but requires addressing access and literacy gaps.	Climate service apps for farmers have the potential to have both positive and negative impacts on response-able relationships with nature. A well-designed app could help inform farmers, allowing them to make more efficient choices in terms of crop selection, need for inputs etc. as well as provide information on environmentally friendly practices. However, if apps aren't providing high quality or up to date information then they could promote less nature friendly farming e.g. use of monoculture etc. This technology is hindered by lack of involvement of farmers in the development and design of apps, lack of trust and transparency in the apps and data sharing processes and also the level of digital literacy in some farming communities.	(Simelton and McCampbell, 2021)
Mobile game for environmental education, promoting sustainable	Helps biodiversity by encouraging proper waste disposal and	Fosters environmental responsibility and care for marine	Localised content, mobile access, curriculum integration, and	Access limitations, sustaining behaviour change, and need for content updates.	Promotes inclusiveness and environmental justice through accessible education.	The digital game could help to facilitate a more response-able relationship with biodiversity by enhancing awareness in a specific demographic: Portuguese-speaking high-school students, gamers. This innovation is enabled by	(Pereira, Gouveia and Dinis, 2022)

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
tourism and SDG-aligned behaviour.	reducing marine pollution.	ecosystems through gamification.	remote learning tools.			participants owning a phone, and potentially already having a degree of environmental consciousness in order to choose to play the game.	
Use of ICT and technological tools (e.g. AI, eDNA, lidar, radar, and mobile apps) in citizen science	Positive; improves monitoring and data quality, but may reduce direct engagement.	Mixed; fosters learning but risks commodifying nature.	Open-source tools, inclusive design, training, integration with existing frameworks.	Digital exclusion, data bias, surveillance, loss of traditional skills.	Can democratise science but may exacerbate inequalities if poorly implemented.	Integration of technologies into citizen science programmes can help mediate more responsible relationships with biodiversity by enabling more people to participate in biodiversity data collection which increases knowledge and encourages people to engage with nature. This can be hindered by inequitable access to technology and lack of comfort or confidence using technology so can be enabled by provision of training, including funding for equipment in project budgets and integrating citizen science programmes into schools	(Rodríguez-Loinaz, Ametzaga-Arregi and Palacios-Agundez, 2024; Sheard *et al.*, 2024)
Digital tools for monitoring wildlife conflict and compensation in tiger reserves.	Positive; supports conservation through community engagement.	Strengthens cooperation and empowerment in conservation.	Access, literacy, cultural inclusion, privacy, engagement.	Access barriers, literacy gaps, privacy concerns, cultural misalignment.	Improves fairness and inclusiveness if barriers are addressed.	Digital platforms for reporting wildlife conflicts can facilitate a response-able relationship with biodiversity as they can create a fair and transparent compensation process which can help people living alongside wildlife and help reduce negative impacts of this, and thus negative attitudes towards conservation, however there are conditions that can hinder the effectiveness of the innovation - socio-economic issues and lack of access to the technology by the communities that need it most. Also gender inequality with women not being involved and	(Tripathi and Singh, 2024)

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
						issues around trusts and differences in culture and language meaning appropriate app design is essential for it to be effective	
Farmland Biodiversity Observatory (FBO) for farmer-led biodiversity monitoring.	Positive; promotes awareness and conservation practices.	Builds trust and stewardship among farmers.	Trust, experiential knowledge, networks, continuous learning.	Data quality, uncertainty, operational limitations.	Enhances inclusiveness and cooperation in biodiversity efforts.	The app helps mediate a response-able relationship between farmers and biodiversity as it supports them with knowledge and tools to have confidence in and trust in biodiversity and how it can help in agricultural practices and can help them make informed decisions based on their own observations over farming practices. This could be hindered by by unsuitable apps, or poor usability as well as lack of awareness of such apps or tools and/or a lack of awareness as to how they might benefit from biodiversity	(Billaud, Porcher and Maclouf, 2025)
XR (AR/VR/MR) for immersive education, global collaboration, and sustainability awareness.	Indirectly supports biodiversity via education, reduced travel, and climate-conscious behaviour.	Fosters empathy, understanding, and engagement with environmental issues.	Affordable XR tech, skilled creators, inclusive platforms, and SDG-aligned frameworks.	Digital divide, privacy, user safety, high costs, and content development challenges.	Promotes inclusion and equity in education; requires access and safety safeguards.	Extended reality technologies can help to mediate a more response-able relationship with nature by increasing awareness and care for biodiversity by providing immersive and engaging learning experiences, particularly for individuals not able to physically access such spaces. Increased care and awareness can help promote biodiversity friendly behaviours, however increased care does not always lead to action. Access to XR technologies is hindered by their high cost, and effectiveness of them can be hindered by poor quality of experience.	(Bekaroo, 2024)

DAISY
LET'S TURN ON TRANSFORMATION

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
Plant-based and cell-based seafood alternatives.	Mixed; reduces pressure on ecosystems but depends on adoption and production methods.	Improves sustainability but depends on integration into food systems.	Tech development, market access, regulation, governance.	Economic inequality, social exclusion, nutritional concerns.	Potential for equity but requires inclusive policies and governance.	As an innovation, as long as the production of alternative seafood is done responsibly and ethically, it gives consumers the option to choose a more sustainable form of 'seafood' while gaining similar nutrition and eating experience. Underlying conditions hindering this innovation are consumer preferences and cultures, people might not like the taste or the idea of alternative seafood as it may not seem 'natural'. There may also be concerns around its healthiness and nutritional value. The price point may also be a limiting factor for some people. There is, however, increasing demand for such products with more people following vegan and vegetarian diets.	(Marwaha, Beveridge and Phillips, 2022)
Vertical farming (hydroponics, aeroponics, aquaponics)	Reduces land use, runoff, and emissions; supports local, sustainable food systems particularly in urban areas	Reconnects urban consumers with food production and promotes sustainable practices.	Consumer appeal, infrastructure, financial and technical support, and strategic alignment.	High energy use, consumer scepticism, technical complexity, and financial uncertainty.	Can improve food access and transparency, particularly in urban areas but needs support for small retailers to avoid inequality.	The use of vertical farming systems such as hydroponics, aeroponics and aquaponics can help mediate a more response-able relationship with biodiversity by providing sustainable food production options and reducing emissions from food transport, however these technologies require knowledge, infrastructure and finance in order to be set-up and enabled.	(Orsini *et al.*, 2013; Ben-Othmen, Julienne and Shaikh, 2024)
Use of remote sensing (satellites, drones) for conservation	Supports biodiversity via ecosystem monitoring and	Shapes conservation control and narratives; can empower or	Ethical guidelines, transparent governance, inclusive	Surveillance, privacy violations, algorithmic bias, exclusion, and structural injustice.	Can empower or marginalise; calls for data justice, Indigenous	The use of remote technology, in particular drones, can help to create a more response-able relationship with biodiversity by facilitating rapid and wide-spread collection of environmental data, however it can both	(York *et al.*, 2023)

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
monitoring, enforcement, and planning.	enforcement; risks if social justice is overlooked.	disempower communities.	participation, and interdisciplinary support.		sovereignty, and co-designed systems.	empower local communities or increase inequalities, depending on its application. Concerns around remote-sensing data increasing top-down governance, militarisation of data and invasion of privacy hinder it's ability to mediate a response-able relationship with biodiversity for all.	
Use of a large language model (GPT-3.5) to align national biodiversity targets with global goals.	Positive; improves policy alignment and conservation outcomes.	Supports coherent biodiversity strategies and stewardship.	High-quality data, transparency, expert engagement.	Bias, oversight needs, ethical concerns.	Promotes fairness and trust through collaborative AI use.	Use of large language models such as GPT 3.5 for comparing national and global biodiversity policy can help to create a more response-able relationship with biodiversity by informing policy development and identifying areas were national targets and policies are not in alignment with the global biodiversity framework. This innovation could be hindered by lack of trust in AI generated data and and inaccuracies from poor training data, but enabled by responsible, ethical and transparent use of AI processes.	(DeSantis *et al.*, 2025)
Phytoremediation using native plants for mine tailing restoration.	Positive; restores ecosystems and supports native species.	Enhances community involvement and landscape attachment.	Funding, plant access, community participation, regulation.	Funding gaps, plant suitability, water scarcity, logistics.	Improves trust and inclusiveness through community engagement.	The innovation of phytoremediation has the potential to mediate a more response-able relationship with biodiversity by offering a management solution to clearing up the environment post-mining operations in a biodiversity friendly way. This would be enabled by communication of scientific support for this as a solution, and enforcement of regulations so that mining companies take responsibility and	(Milla-Moreno and Guy, 2024)

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
						pay costs of environmental damage done by their companies	
Agricultural machinery	Mixed; increases productivity but may cause deforestation and landscape simplification.	Improves food security but may reduce agro-biodiversity.	Tech innovation, enabling environment, training, sustainable practices.	Environmental degradation, inequality, exclusion, fossil fuel dependence.	Can improve equity but risks exclusion of smallholders and women.	Mechanisation of agriculture has great potential to impact biodiversity by allowing agricultural expansion, leading to habitat loss and biodiversity loss, it also has impacts on soil and natural resource extraction e.g. of water for irrigation which can all negatively affect the environment, however there are social benefits such as increased food production and food security and reduced labour demands. Many factors such as gender, financial inequalities and government policies influence the uptake of agricultural mechanisation in different ways in different parts of the world.	(Daum, 2023)
Digital tools (AI, IoT, big data) for ESG goals—monitoring, education, governance, and sustainability.	Supports biodiversity via monitoring, digitisation, and conservation research.	Enables awareness, participation, and sustainable practices through digital engagement.	Digital infrastructure, inclusive access, policy integration, and cross-sector collaboration.	E-waste, digital inequality, privacy concerns, and overreliance on tech.	Improves inclusion and transparency; risks widening disparities without equitable access.	Digital technologies can play a part in mediating a more response-able relationship with biodiversity as they assist in collecting and storing large data sets with information on biodiversity and the environment, as well as making them more accessible and shareable. Digital versions can also help reduce consumption of physical goods, such as paper for printing. Digitalisation can be hindered by lack of access to digital technology in some communities and lack of digital literacy.	(Xu, She and Liu, 2022)
Youth-led tools and	Supports biodiversity via	Reconnects youth with	Equitable tech access, anti-	Tech co-option, biopiracy, inequality,	Promotes inclusion and fairness; needs	Food related apps can help to facilitate a more response-able relationship with biodiversity by	(Gee and Lee, 2020)

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Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
movements—apps, blockchain, urban farming, education, and entrepreneurship for food biodiversity.	traditional species use, agroecology, and awareness; risks from data privatisation.	ecosystems, revives traditional practices, and fosters stewardship.	monopoly safeguards, cultural relevance, and policy integration.	oversimplification, and unsustainable dependencies.	safeguards to ensure equitable benefit-sharing.	informing people and promoting sustainable practices, however they need to be accessible, particularly small holders who may not yet be confident with digital technology and need to recognise the different priorities of different communities and engage and appeal to them in different ways	
Smart environments and green tech (IoT, AI, renewables) integrated with evolving environmental law.	Supports biodiversity via sustainable land use, pollution reduction, and legal protections.	Encourages stewardship, public participation, and systems thinking.	Adaptive legal frameworks, enforcement, investment, collaboration, and tech standards.	Legal gaps, high costs, tech complexity, social exclusion, and resistance to change.	Enhances justice and inclusiveness; promotes fairness and trust through participatory governance.	Green technologies and particularly their integration into smart environments can mediate a more response-able relationship with data by providing data for monitoring and assessing environmental impact of technologies and improving efficiency to reduce environmentally damaging processes. These innovations can be hindered by technological or financial constraints. They can be further enabled by environmental law that supports sustainable development practices and punishes environmentally harmful practices	(Valiyev and Najafov, 2024)
Digital community for educator development in sustainability using peer learning and digital tools.	Indirectly supports biodiversity through improved sustainability education and environmental literacy.	Fosters understanding and action toward sustainability through empowered educators.	Sustained educator engagement, institutional support, digital access, and collaborative culture.	Digital access gaps, engagement fatigue, and difficulty measuring long-term impact.	Promotes equity by bridging divides and encouraging diverse voices in sustainability education.	Digital communities and online learning platforms for teachers to support professional development in sustainability education can help to mediate a more response-able relationship with nature as it supports information and knowledge sharing among environmental educators which can help improve the quality of sustainability education provided for students and thus help spread	(Miller Foster and Foster, 2024)

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
						more sustainable practices. This innovation can be inhibited by access issues for those living without resources and internet connection needed to access the platforms, as well as lack of awareness of their existence	
Global metaherbarium: a digitally interlinked, open-access network of herbarium specimens	Improved species identification, conservation planning, and data synthesis; supports IUCN assessments and biodiversity monitoring.	Improves access to biodiversity data, supports Indigenous knowledge, and fosters appreciation of plant diversity and its role in human well-being.	Digitisation with standardised metadata, open-access platforms, inclusive collaboration, addressing colonial legacies, and investment in infrastructure and governance.	Colonial legacies, collection biases, underrepresentation, specimen degradation, funding gaps, and potential data misuse or misinterpretation.	Can improve equity and inclusiveness through democratised data access and inclusive governance, but risks reinforcing inequalities if not ethically managed.	A global, digitalised metaherbarium could help facilitate a more response-able relationship with biodiversity by improving the amount of data on plant biodiversity, and access to said data, which can improve research to inform biodiversity conservation as well as being used in outreach and engagement. Conditions that may hinder this are colonial legacies causing bias in the data itself and reduced accessibility of the data to some communities. The innovation will be enabled through collaboration and involvement of stakeholders	(Davis, 2023)
BIO-AGRI-WATCH platform for precision agriculture, biodiversity conservation, and cross-agency	Promotes biodiversity through data-informed management, resilient crop planning, and sustainable	Empowers farmers, encourages ecological awareness, and fosters collaboration between	Cross-sector collaboration, data governance, digital literacy, standardised models, and	Data quality issues, digital divide, integration complexity, and technical limitations in drone-based monitoring.	Supports smallholders, inclusive governance, transparent data sharing, and equitable innovation access.	The digital information sharing platform has the potential to mediate a more response-able relationship between farmers/small-holders and biodiversity as it empowers them with information in order to be able to make environmentally friendly choices in their farming practices and work in a more biodiversity friendly way. Factors that could hinder this	(Kawtrakul *et al.*, 2021)

Innovation/ Intervention	Impact on Biodiversity	Influence on Human–Nature Relationships	Conditions for Effectiveness	Risks	Equity / Justice Impacts	Response-able relationships	Reference
data sharing in Thailand.	genetic resource use.	agriculture and conservation.	regulatory frameworks.			innovation are lack of digital literacy and trust in data governance, and data itself. Factors that enable the innovation are interoperability of the data, communication and collaboration between associated organisations and a good open data policy	
Seven Berlin-based programmes promoting urban nature engagement: guided events, rangers, wild play areas, mobile education, videos, and digital calendars.	Supports biodiversity indirectly by raising awareness, encouraging conservation behaviour, and promoting biodiversity-friendly green space management.	Strengthens human–nature relationships through direct experiences, inclusivity, and emotional engagement with urban ecosystems.	Cross-sector collaboration, legal and financial support, on-site personnel, accessible green spaces, and integration with schools and social services.	Access inequality, safety concerns, parental hesitation, staffing/funding constraints, and limited biodiversity in some parks.	Improves environmental and recognition justice, inclusiveness, procedural fairness, and trust through participatory governance and targeted outreach.	The Wild Berlin videos can help to mediate a more response-able relationship with nature by helping to educate people about their local urban wildlife and connect with nature, especially for people unable to physically spend time in urban nature. This innovation is enabled by collaborations, particularly with media organisations which increase the number of viewers of the videos and by being part of a wider suite of programmes from the Berlin Nature Conservation Foundation. While the programmes raise awareness and can improve connection to nature, the impact on biodiversity will only be seen if people are made aware of and motivated to participate in biodiversity friendly behaviours	(Kowarik, Busmann and Stopka, 2025)

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Annex 2

List of 113 records that were included in full-text screening for coding for the literature review

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***Included in coding for the literature review**

** Chapters included in coding from this book:
Bekaroo, G. (2024) 'Extended Reality and the Implementation of the UN Sustainable Development Goals: Opportunities, Challenges and Future Directions', in *Digital Technologies to Implement the UN Sustainable Development Goals*. Cham: Springer Nature Switzerland (World Sustainability Series). Available at: https://doi.org/10.1007/978-3-031-68427-2.

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