INNOVATION CASES PROFILES

Deliverable number: D2.3

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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
AF4EU	Agroforestry for Europe project
AI	Artificial Intelligence
AKIS	Agricultural Knowledge and Innovation Systems
AR	Augmented Reality
BERT	Bidirectional Encoder Representations from Transformers
CAP	Common Agricultural Policy
C40	C40 Cities Climate Leadership Group
CBD	Convention on Biological Diversity
CIFOR	Center for International Forestry Research
COP	Conference of the Parties
CU	Coventry University
DG	Directorate-General
DOI	Digital Object Identifier
EBSI	European Blockchain Services Infrastructure
EDIC	European Digital Infrastructure Consortium
EIP-AGRI	European Innovation Partnership 'Agricultural Productivity and Sustainability'
EP&L	Environmental Profit and Loss
EU	European Union
FAIR	Findable, Accessible, Interoperable, Reusable
FAO	Food and Agriculture Organization of the United Nations
FS	Forest School

GBF	Kunming–Montreal Global Biodiversity Framework
GBIF	Global Biodiversity Information Facility
GDPR	General Data Protection Regulation
GF	GreenFormation
GIAHS	Globally Important Agricultural Heritage Systems
GMO	Genetically Modified Organism
GPT	Generative Pre-trained Transformer
ICCA	Indigenous and Community Conserved Area
ICLEI	Local Governments for Sustainability
ICRAF	World Agroforestry
INSPIRE	Infrastructure for Spatial Information in Europe
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
KTU	Kaunas University of Technology
LLM	Large Language Model
ML	Machine Learning
MLU	Martin Luther University Halle-Wittenberg
MRV	Monitoring, Reporting and Verification
NbS	Nature-based Solutions
NFT	Non-Fungible Token
NGO	Non-Governmental Organisation
NHS	National Health Service (UK)
NLP	Natural Language Processing
NBSAP	National Biodiversity Strategy and Action Plan
OECD	Organisation for Economic Co-operation and Development
OFP	Open Forest Protocol

PDO	Protected Designation of Origin
PES	Payments for Ecosystem Services
R&D	Research and Development
RoN	Rights of Nature
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SDGs	Sustainable Development Goals
SEEA	System of Environmental-Economic Accounting
SEMH	Social, Emotional, and Mental Health
SEND	Special Educational Needs and Disabilities
SFSC	Short Food Supply Chains
SSE	Social and Solidarity Economy
SUCCESS	Support to the Development of Agroforestry Concessions in Peru
T2.2	Task 2.2
TCA	True Cost Accounting
TFFF	Tropical Forest Forever Facility
TIESS	Transdisciplinary Institute for Environmental and Social Studies
UK	United Kingdom
UN	United Nations
UNCRC	United Nations Convention on the Rights of the Child
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
UNEA	United Nations Environment Assembly
UNEP-WCMC	United Nations Environment Programme World Conservation Monitoring Centre
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America

USD	United States Dollar
VR	Virtual Reality
WP	Work Package
WWLF	Wales Wild Land Foundation

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 deliverable presents the outcomes of DAISY's Task 2.3. It assesses the validated list of innovations with transformative potential emerging from Task 2.2, and explores pathways and barriers to their deployment at scale – particularly within socio-political settings and existing policy frameworks.

This report provides and discusses 29 short profiles of priority innovations with an EU scope. Its purpose is to support the contextualisation of digital, social and technological innovations across DAISY's domains – agri-food, energy, education, and urban and regional development – and beyond. The profiles examine innovations with the potential to trigger transformative change at various levels across the personal, political and practical spheres, and across a broad range of sectors. The list includes both well-known innovations that are not yet mainstreamed or fully recognised in policy and practice, as well as innovations at early stages of development. Each profile includes an introduction to the innovation in question, followed by an illustrative case study, a discussion of deployment pathways with reference to applicable policy frameworks, a discussion of social, economic and regulatory barriers, a list of key references, and an overview of the main relevant policy instruments.

The profiles cover a wide range of innovations, from digital and technological tools for individual use – such as mobile apps and games, that could be used for awareness raising and education purposes – to developments promising large-scale changes in the information infrastructure of biodiversity governance and in biodiversity monitoring, including large language models, blockchain and macroscopes; and from citizen science and commons-based innovations to normative concepts such as the rights of nature. Overall, the analysis largely confirmed one of the main conclusions of Deliverable 2.2: innovation alone cannot drive transformative change but needs to be supported by enabling conditions that address structural, behavioural and cultural barriers, with attention to governance, vested interests and power structures, as well as policy and funding frameworks, with equity at the centre.

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Table of contents

1. Introduction

1.1 Purpose of the Deliverable

This deliverable presents the outcomes of DAISY's Task 2.3, the aim of which was to assess the validated list of innovations with transformative potential identified in Task 2.2 (Deliverable 2.2), and to explore pathways and barriers to their deployment at scale, particularly in socio-political settings, and with regard to presently applicable policy frameworks. This report provides and discusses 29 short profiles of priority innovations with an EU scope. Its purpose is to support a better contextualisation of a range of digital, social and technological innovations across DAISY's domains (agri-food, energy, education, and urban and regional development) and beyond.

1.2. Context and Relevance

This deliverable concludes Work Package (WP) 2, which focuses on identifying and assessing innovations with the potential to drive transformative change for biodiversity and equity. The analysis of innovations included in the report aims to support synthesising, developing and testing transformative interventions and policy mixes in WP3. The report also contributes to DAISY's broader goal of identifying and amplifying innovation mixes that can trigger systemic change across personal, political and practical spheres.

1.3. Scope and Objectives

Building on the outcomes of Task 2.2, which identified and assessed 49 innovations with transformative potential for biodiversity and equity, this report focuses on a subset of 29 innovation profiles with the strongest alignment to DAISY's transformative aims. The list includes a wide range of digital, social and technological innovations with the potential to trigger transformative change at various levels across the personal, political and practical spheres, and in sectors including, but not limited to, DAISY's domains. It includes both well-known innovations that are not yet mainstreamed or fully recognised in policy and practice, as well as innovations at early stages of development.

Each profile includes an introduction to the innovation in question, followed by an illustrative case study, a discussion of deployment pathways with reference to applicable policy frameworks, a discussion of social, economic and regulatory barriers, a list of key references, and an overview of the main relevant policy instruments.

While the focus is on the EU, references to global policy instruments, in line with the EU's international commitments, are included where relevant. In addition, while most case studies reflect European examples and realities, a limited number of case studies from other contexts are included when deemed necessary, and as explained under Section 2 below.

1.4. Structure of the Document

This report is structured to guide the reader through the rationale, process, and outcomes of the assessment of innovations in terms of pathways, barriers, and applicable policy frameworks. Section 2 outlines the methodology used, and Section 3 presents and discusses the results, including implications for policy, practice, and academic work, including for the DAISY project.

The Annex includes 29 brief profiles of cases across a wide range of social, digital and technological innovations. While the intention was to conclude 30 profiles, including artificial intelligence applications other than large language models (LLMs), no profile was completed due to a lack of data on other applications with the potential to enable transformation for biodiversity and equity.

The profiles address:

1. Agroforestry
2. Biodiversity data storage, e-infrastructure and sharing platforms
3. Blockchain technology
4. Camera traps/trail cameras
5. Citizen science (collaborative or co-created)
6. Citizen science (online or contributary)
7. Commons: Cecosesola: exploring commoning alternatives in food production and provisioning
8. Commons: L'Atelier Paysan

9. Community seed banks
10. Digital communities and platforms for biodiversity education and knowledge sharing
11. Forest schools
12. Globally Important Agricultural Heritage Systems
13. Indigenous and community conserved areas
14. Large language models (LLMs): Alignment of national biodiversity targets
15. LLMs: Conservation CoPilot
16. Macroscopes / global biodiversity monitoring tools
17. Mobile apps and games for biodiversity
18. Nature-based solutions: a global perspective
19. Nature-based solutions in Europe
20. Nudges and choice architecture
21. Organic farming
22. Payments for ecosystem services: True Cost Accounting
23. Payments for ecosystem services: Grain for Green in China
24. Rewilding
25. Rights of Nature
26. Smart agriculture
27. Urban design / infrastructure
28. Virtual reality
29. Wildlife vaccinations

1.5. Target Audience

This deliverable is intended for multiple audiences within and beyond the DAISY consortium. Internally, this deliverable concludes the analysis conducted as part of WP2 and supports project partners working on the development of transformative intervention mixes in WP3, as well as contributors to cross-cutting analyses in Work Packages 4 and 5. Externally, the report is relevant to policymakers, civil society organisations, innovation practitioners, and researchers working at the intersection of biodiversity, equity and systemic transformation. By providing a contextual and policy-relevant analysis of a wide range of innovations with transformative potential, the deliverable offers a valuable resource for those seeking to design, support or evaluate interventions that aim to address complex socio-ecological challenges.

2. Methodology

2.1. Approach, Research Design and Data Collection Methods

The research design was based on the analytical work conducted under Task 2.2, including expert validation and use of DAISY's Transformative Diagnostic Tool, to agree on a list of 49 innovations with sufficient transformative potential for biodiversity and equity. The research team (CU, KTU, MLU and TIESS) held two online meetings to review the outcomes of Task 2.2 and agreed by consensus on a list of the 24 most promising innovations. The team paid attention to balancing between digital, social and technological innovations, as well as ensuring relevance of the selected innovations for DAISY's domains (agri-food, energy, education, and urban and regional development). Due to the multifaceted nature of some of the innovations identified, the research team further agreed to draft two profiles for each of the following: commons and commoning; citizen science; LLMs; payments for ecosystem services; and nature-based solutions. The research team then discussed the outline and agreed to include an illustrative case study in each profile, to allow for better contextualisation of each innovation, in view of the work to be conducted under WP3. Each participating institution was then tasked with the drafting of seven-eight profiles, depending on preferences and available expertise.

The profiles were drafted based on online searches, literature reviews and previous assessments of: plausible deployment pathways; social, economic and regulatory barriers; and the relevant policy landscape at the global, EU, and Member State level, where applicable, to identify both barriers and support measures. The DAISY report on transformative policy dynamics in the EU (Deliverable 1.2) provided valuable context and information on the relevant policy landscape in the EU. During the drafting period, the leading institution (TIESS) reviewed early drafts and responded to questions.

2.2. Data Sources and Selection Criteria

This deliverable builds on the outcomes of expert validation and use of DAISY's Transformative Diagnostic Tool under Task 2.2, going into further detail and undertaking policy-relevant analysis for the selected innovations through online searches and literature reviews. Selection of the most promising innovation cases for biodiversity and equity was conducted via collective discussion, in view of DAISY's broader goal of identifying and amplifying innovation mixes that can trigger systemic change across personal, political and practical spheres.

The criteria for case study selection under each profile were also discussed during an online meeting of the research team. As a result, the majority of case studies selected come from a European context, primarily the EU but also the UK, in order to stay true to the focus of the deliverable on the EU. In some profiles, however, the research team chose to explore different geographic and socio-economic contexts. This was the case where the selected case study's effectiveness and sustainability were based on governance models and organisational principles that could be transferred to the European context. Two such cases are Cecosesola (Central Cooperativa de Servicios Sociales de Lara), a network of grassroots organisations and cooperatives organising food provisioning through collective governance, operating since 1967 in Venezuela; and Peru's agroforestry concessions scheme, the success of which is based on a combination of an innovative legislative measure with incentive mechanisms, awareness-building, and institutional learning for sustainability.

Other criteria used for case study selection included: relevance for the respective innovation; effectiveness and sustainability as reflected in outcomes, size or duration; potential for scalability; and use of multiple enabling conditions for transformation as discussed in Deliverable 2.2, including supporting laws and policies, equitable governance frameworks, funding support, and knowledge sharing.

2.4. Analytical Methods

The brief profiles were drafted based on an interpretative analysis of the reviewed literature in the context of the relevant policy frameworks, guided by Deliverable 2.2 and Deliverable 1.2.

2.5. Reflexivity and Research Ethics

We, the research team, approached the task with a reflexive awareness of the positionality of participating researchers. Given the qualitative nature of the work, we recognised assessments of transformative potential are shaped by disciplinary backgrounds, institutional affiliations and lived experiences. Acknowledging that we are all white European researchers, associated with institutions of the Global North, we did our best to ensure diversity of perspectives and keep the interests of the Global South and marginalised groups in consideration, particularly given DAISY's focus on equity and extensive research indicating that 'each wave of technological change brings inequality in new shapes' (UNCTAD, 2021, p. xvii).

2.6. Limitations

It should first be acknowledged that the analysis included in each profile is far from comprehensive. This was inevitable, as Task 2.3 calls for the development of *short* profiles for priority innovations. Each profile is thus an introduction to the respective innovation and a schematic analysis of deployment pathways and barriers, in the context of relevant policies. A list of key references and relevant policy instruments is included, however, to support the interested reader to acquire additional information. That said, the literature used is mainly in English, and we may have missed crucial publications written in other languages or produced by grassroots groups but not circulated widely.

In addition, both the selection of the list of innovations and the analysis of the transformative potential under each profile remain subjective. Despite rigorous academic work, some bias remains.

Finally, as highlighted in the Deliverable 2.2, the transformative potential of any innovation is inherently dependent on its application context – who uses it, for what purpose, under what conditions, and with what degree of inclusivity. Including an illustrative case study helped situate each innovation; however, its application in different contexts may produce different results, depending on enabling conditions related to law and governance, socio-economic considerations, education and cultural settings.

3. Results and discussion

The 29 profiles in the Annex address cases of digital, social or technological innovation with transformative potential for biodiversity and equity, of relevance to DAISY's domains. They cover a wide range of innovations from the individual to the global level, addressing behavioural, normative, economic, cultural and technical aspects of biodiversity governance, and situating them in the EU policy context. The examined innovations include:

- digital and technological tools for individual use, such as mobile apps and games, that could be used for awareness raising and educational purposes;
- innovations that can promote behavioural change, such as nudges and virtual reality;
- educational innovations, such as forest schools and digital communities for knowledge sharing;
- innovations based on citizen science, which aim to build awareness while contributing to biodiversity monitoring;
- developments promising large-scale changes in the information infrastructure of biodiversity governance and biodiversity monitoring, including LLMs, blockchain and macroscopes;
- a series of approaches to food and agriculture that, while not new, are still relatively marginal and aim to shift the focus from high-yield productivity and move towards agro-biodiversity-based and sustainable practices, such as agroforestry and organic farming;
- commons-based innovations aiming to propose organisational alternatives to the market, based on relationship-based governance and decentralised coordination, such as community seed banks, Atelier Paysan and the food provisioning network Cecosesola;
- normative concepts and incentive measures, such as payments for ecosystem services, nature-based solutions, and rights of nature; and landscape-level innovations, such as Indigenous and community conserved areas, globally important agricultural heritage systems, and rewilding.

While several profiles highlight the need for novel tools to increase awareness and incentivise public engagement in biodiversity governance, some **mobile apps and**

games combine public engagement with AI-supported recognition and gamified engagement pathways to translate local nature encounters into usable signals for global biodiversity monitoring. **iNaturalist,** for instance, an online network for sharing biodiversity information and learning about biodiversity, gathers observations and species identifications from members via a mobile app. The site currently holds over 287 million observations of more than 544 000 species from nearly 4 million observers. The data provided by the **eBird** platform, to give another example, has become a crucial instrument for biodiversity policy and scientific research on avian biodiversity. With over 500 million records shared globally through the Global Biodiversity Information Facility, the eBird database is one of the largest biodiversity databases worldwide, and holds records from almost all countries and from 97% of all known bird species, due to the citizen science-based mode of data collection.

There has been a vast increase in the number of online citizen science projects, such as iNaturalist, in recent years, taking advantage of the increased accessibility of the internet and smartphones. **Collaborative and co-created citizen science** projects, on the other hand, are not widely deployed, despite their transformative potential for biodiversity and equity. This is mainly because a cultural shift within academia is needed first, as traditional research norms often prioritise researcher-led agendas, disciplinary expertise, and conventional outputs, whereas co-created approaches emphasise shared decision-making, process-based outcomes, and the value of lived and local knowledge.

Cultural shifts require a combination of interventions, starting with behavioural change. A series of profiles focus on behavioural change: it is shown, for instance, that **virtual reality** can leverage storytelling to generate emotions that have the potential to influence both problem perception and behaviour, while information **nudges**, enabled through labelling regulations, can influence everyday routines involving food and transport without resorting to prohibitions or financial incentives.

Still, the work conducted indicates that financial incentives, such as **payments for ecosystem services** (PES) schemes, can be useful, context-sensitive governance tools. While their greatest potential lies not only in altering individual incentives but in fostering broader societal recognition of humanity's embeddedness within ecological systems, PES can eventually challenge conventional growth models by making ecological dependencies visible. A number of important design features are, however, identified for PES schemes to work well: the precise definition of the ecosystem service in question; strict monitoring; payments covering at least the opportunity costs of alternative use; and the need to gain social acceptance by addressing social inequalities, land rights and local power relations (Ezzine-de-Blas et al., 2016; Yan et al., 2022).

Adequate payment schemes, along with coherent regulatory frameworks, are also put forward as necessary factors to enable farmers' transition towards more sustainable models of agricultural production, such as **agroforestry** and **organic farming**. Although recognised in policy and practice, both models are treated as innovations, because they are still marginal and represent a paradigm shift: moving away from chemical-dependent intensive agricultural production methods towards knowledge- and often labour-intensive nature-based practices based on ecological processes. Italy's approach to organic farming is particularly noteworthy for supporting, through law, a new form of territorial organisation: the 'organic districts' (*distretti biologici or biodistretti*). These areas represent integrated territorial systems where organic farming is linked to rural revitalisation and the survival of small farms. The model thus goes beyond individual farm conversion to encompass entire territories, fostering collaboration among farmers, processors, local authorities, and civil society organisations. It aims to create economies of scale and strengthen local supply chains, as well as facilitate knowledge sharing and community building. The approach has attracted a new generation of farmers, who view it as economically viable and aligned with their values. It is also linked to an expansion of food networks in the country, including farmers' markets, community-supported agriculture, and direct sales to consumers, improving farmers' access to markets.

Commons-based systems are increasingly recognised as socio-technical innovations promoting transformation for biodiversity and equity. By decoupling essential goods from the sole pursuit of profit maximisation, commoning functions as a resilience mechanism that stabilises local food systems against macroeconomic volatility. Within the DAISY context, this is an innovation in social infrastructure: it provides the participatory management structures necessary to maintain the diversified, small-scale farming practices that EU biodiversity policies (such as the

Nature Restoration Regulation) ultimately require for success. As noted above, an example of the effectiveness and long-term sustainability of commoning is **Cecosesola** (Central Cooperativa de Servicios Sociales de Lara), a network of grassroots organisations and cooperatives based primarily in Barquisimeto, Venezuela. Founded in 1967, it has developed into a large-scale system for organising food provisioning and related services through collective governance. Its relevance for European contexts lies in the potential transfer of organisational principles – such as collective coordination, shared responsibility and reinvestment of surplus – rather than in direct replication of institutional forms. By linking small-scale producers directly with urban consumers, reducing the number of intermediaries, stabilising prices, and enabling continuous supply relationships, Cecosesola provides valuable lessons for the sustainability of non-mainstream and commons-based agricultural initiatives in Europe. These include **organic farming**, **agroforestry**, and **community seed banks**, which, despite their potential, struggle amidst a hostile policy landscape. They also include the few recognised **Global International Agricultural Heritage Systems** in Europe, a programme of the Food and Agriculture Organization of the UN (FAO), which shows the relevance of cultural agro-ecological systems for biodiversity, agricultural production and livelihoods, while advocating the importance of social organisation and community innovation work for the development of sustainable human activities that have survived and co-adapted with the environment through time.

Commons-based peer production is also put forward as a pathway for equitable technological innovation amidst wider economic centralisation tendencies in global agriculture, with relevant technologies being owned and controlled by only a handful of (mostly USA-based) companies. Thus, while **smart agriculture** is widely hailed as a vital tool for climate adaptation and food security, it still aligns with an industrial agricultural model that causes considerable negative sustainability spillover effects. It is particularly noteworthy, however, that the '**Hands Free Hectare**' project at Harper Adams University in the UK, which was a pilot project for demonstrating the utility of digital technologies, in conjunction with robotics, in the farming sector (Spencer, 2018), was effectively an open-source project. Going further, **l'Atelier Paysan**, a French cooperative of farmers, technicians, and educators, is developing farmer-driven open tools and construction plans that enable smallholders to build equipment themselves rather than rely solely on industrial suppliers (Atelier Paysan, 2018).

Community-based natural resource management practices have been historically used by biodiversity stewards to conserve and sustainably use biodiversity. They are increasingly recognised under international agreements, including notably the Convention on Biological Diversity (CBD), but remain poorly acknowledged in EU policy. At the landscape level, **Indigenous and community conserved areas** (ICCAs) can serve towards the achievement of international goals and commitments in the context of environmental protection, human rights and culture. A major obstacle facing ICCAs is that these areas do not look much like traditional conservation projects to agencies, officials and policymakers, whose explicit focus remains the protection of threatened and endangered species and their habitats. Despite this international recognition, few countries include them in their national protected area systems while respecting their governance mechanisms.

As most profiles indicate, policy mixes combining regulatory, financial and soft policy instruments are crucial for supporting the uptake and mainstreaming of innovations with transformative potential. The case of **nature-based solutions** (NbS) provides a good illustration of these enabling conditions. For instance, the Biodiver_City project in Costa Rica put forward an innovative approach to integrating biodiversity conservation with urban climate adaptation through the establishment of inter-urban biological corridors. The project employed a multi-faceted implementation strategy, combining scientific assessment, community engagement and policy integration. It created eco-corridors that link protected areas and enable species movement across urban landscapes; reduced urban heat island effects by increasing vegetation cover; and engaged citizens in biodiversity monitoring using the iNaturalist mobile app; all by integrating NbS into urban planning.

4. Conclusion

4.1. Key Insights

Overall, the analysis presented in the profiles confirmed one of the main conclusions of Deliverable 2.2. Innovation alone is rarely sufficient to drive transformative change; it needs to be supported by enabling conditions that address structural, behavioural and cultural barriers, with attention to governance, vested interests and power structures, and to policy and funding frameworks, with equity at the centre. Innovations that are technically sound or ecologically promising are not necessarily considered transformative unless they also demonstrate relevance to systemic change and inclusivity.

In this context, a series of commons-based socio-technical innovations and community-based natural resource management systems, operating from the seed innovation to the landscape level, demonstrate transformative potential, along with tangible results for biodiversity and equity. However, their uptake in the EU is limited, due to complex and incoherent governance structures, a policy framework that predominantly ranges from indifferent to hostile, lack of advisory services and targeted knowledge sharing, and a persistent tendency to neglect grassroots innovations in favour of highly technological and centralised ones. This often comes at odds with the EU's own goals under strategic documents, such as the EU Biodiversity Strategy 2030 and the Farm to Fork Strategy, as well as international commitments under the Convention on Biological Diversity and its Kunming-Montreal Global Biodiversity Framework.

In addition, this report showcases the importance of a coherent policy framework combining regulatory, financial and soft-policy instruments, while enabling behavioural change, community engagement and knowledge transfer. This reinforces the view, put forward in Deliverable 2.2, that transformation cannot emerge from one-size-fits-all innovations, but from context-specific interventions involving a set of innovations, enabling conditions, governance structures and societal values.

4.2. Wider Implications and Contribution to DAISY

The findings from Task 2.3 reaffirm and extend several core insights arising from Work Packages 1 and 2. The diversity of innovation types assessed reflects the complexity of transformation for biodiversity and equity, highlighting the importance of context-specific analysis and thus the work conducted under DAISY's WP4. The findings confirm that transformation requires a shift away from dominant economic paradigms (Deliverable 1.1) and highlight the centrality of inclusivity, equity and justice (Deliverables 1.3, 2.2).

Situating these innovations in the EU policy context further confirms that narrow consideration of biodiversity aspects in sectoral policies reduces policy integration to questions of formal alignment and procedural coordination (Deliverable 1.2). Achieving ambitious biodiversity goals requires approaches that address the underlying causes of biodiversity loss by breaking path dependencies defined by short-term economic interests and private profit over public good, which are often translated into policies favouring cutting-edge digital and technological solutions as a panacea. In contrast, several profiles indicate that misaligned policy regimes reinforce structural inequalities and entrenched economic priorities, operating as a barrier to the transformative potential of socio-technical innovations for biodiversity and equity.

These findings reinforce the conceptual foundations of the DAISY project and highlight the importance of maintaining a pluralistic and justice-oriented lens and context-specific approach in the design and evaluation of intervention mixes under Work Package 3. Digital, technological and social innovations show transformative potential as part of broader systems of governance, care and community relationships. This suggests that intervention mixes that are ecologically meaningful, socially just and capable of delivering transformation across personal, practical and political spheres, need to be tailored not only to thematic domains, but also to the specific socio-ecological contexts in which they are applied.

5. References

Atelier Paysan. (2018). Atelier Paysan – English overview document.

Ezzine-de-Blas, D., Wunder, S., Ruiz-Pérez, M., & Moreno-Sanchez, R. D. P. (2016). Global patterns in the implementation of payments for environmental services. *PloS one*, *11*(3), e0149847.

Spencer, J. (2018). Harvesting the 'Hands-free Hectare'. *Farmer's Weekly*, *2018*(18004), 52-53.

United Nations Conference on Trade and Development (2021). *Catching technological waves: Innovation with equity*. United Nations.

Yan, H., Yang, H., Guo, X., Zhao, S., & Jiang, Q. O. (2022). Payments for ecosystem services as an essential approach to improving ecosystem services: A review. *Ecological Economics*, *201*, 107591.

Statement on data availability

There is no additional raw data to be reported.

Statement on ethics

This study is based exclusively on publicly available online sources. No personal data were collected, and no ethical concerns arise from the research. The authors declare no conflicts of interest.

Annex

The Annex includes 29 brief profiles of innovation cases across a wide range of social, digital and technological innovations. While the intention was to conclude 30 profiles, including artificial intelligence applications other than Large Language Models, no profile was concluded due to lack of data on other applications with a potential to enable transformation for biodiversity and equity.

Each profile includes an introduction to the innovation in question, followed by an illustrative case study, a discussion of deployment pathways with reference to applicable policy frameworks, a discussion of social, economic and regulatory barriers, a list of key references, and a list of the main relevant policy instruments.

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7. Commons: Cecosesola: exploring commoning alternatives in food production and provisioning
8. Commons: L'Atelier Paysan
9. Community seed banks
10. Digital communities and platforms for biodiversity education and knowledge sharing
11. Forest schools
12. Globally Important Agricultural Heritage Systems
13. Indigenous and community conserved areas
14. Large language models (LLMs): Alignment of national biodiversity targets
15. LLMs: Conservation CoPilot
16. Macroscopes / global biodiversity monitoring tools
17. Mobile apps and games for biodiversity
18. Nature-based solutions: a global perspective

19. Nature-based solutions in Europe
20. Nudges and choice architecture
21. Organic farming
22. Payments for ecosystem services: True Cost Accounting
23. Payments for ecosystem services: Grain for Green in China
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27. Urban design / infrastructure
28. Virtual reality
29. Wildlife vaccinations

Agroforestry

1. Introduction

Agroforestry refers to practices of integrated land management that combine trees, crops, and often livestock. Founded on long-standing practices, it encompasses a diversity of land management systems practiced globally.

Agroforestry systems can provide important ecosystem services, such as improved soil health and water management, conserve biodiversity, contribute to climate change mitigation and adaptation, and improve food security, resilience, and farmers' livelihoods through income diversification (Satish et al., 2024).

Despite its demonstrated benefits, adoption and promotion of agroforestry remains limited in many regions, due to various social, economic and regulatory barriers, and limited policy support. Currently, agroforestry is gaining renewed attention as a form of climate-smart agriculture, for its potential to transform agrifood systems to become more adaptive and resilient. It is considered a crucial tool to address interconnected challenges by offering integrated solutions to climate change, soil degradation, biodiversity loss, and rural poverty and food insecurity. In this context, the Food and Agriculture Organization of the UN (FAO) has proposed a new and innovative direction for agroforestry, strengthening its technical support to ensure sustainable adoption and scaling-up. The new direction aims to optimise the potential of agroforestry by placing emphasis on topics, products and activities that can be mainstreamed through replication and adaptation in three priority areas: promoting agroforestry as a variety of sustainable production systems; improving agroforestry monitoring methodologies and tools; and supporting national agroforestry policy and strategy development.

2. Case Study: Agroforestry Concessions in the Peruvian Amazon

Peru's agroforestry concessions scheme illustrates how innovative policy instruments can formalise and incentivise agroforestry adoption among smallholder farmers.

In 2011, the Government of Peru established the agroforestry concessions scheme as part of the new Forest and Wildlife Law. It was an innovative legal and policy measure aimed at formalising the access and use of land and trees resources by smallholder farmers settled on state forest land to make them shift to more sustainable land management practices. The scheme provided smallholder farmers with 40-year renewable leases on degraded forest lands in exchange for implementing agroforestry systems that restore ecosystem functions. This approach aimed to formalise previously informal agricultural activities, creating legal pathways for smallholders to access land and thus improve their livelihoods, while simultaneously advancing forest restoration and climate mitigation objectives.

A series of projects built on this scheme, including the World Agroforestry (ICRAF)'s project entitled 'Support to the Development of Agroforestry Concessions in Peru' (SUCCESS) and Peru's AgroFor project. Collectively, the projects created a platform uniting a variety of stakeholders, including smallholder farmers, regional and national government institutions, the private sector, international organisations and non-governmental organisations providing technical assistance. Employing a series of activities including workshops and capacity building for agroforestry at the technical and practical level, they aimed to develop both smallholders' knowledge of agroforestry practices and the capacity of government institutions to administer the concession system.

On top of direct outcomes, including the agroforestry concession contracts granted, the scheme generated crucial institutional learning on the design and implementation of agroforestry concessions. This included identification of eligible areas, administrative procedures and incentive mechanisms. While demonstrating that innovative tenure mechanisms can create the necessary enabling conditions for agroforestry adoption, the case further underscored the need for awareness building, both among smallholders and among policymakers, and for a clear and consistent regulatory and institutional setting to facilitate such practices (Claus et al, 2021).

3. Deployment, diffusion, amplification

Scaling agroforestry practices requires specific mechanisms that enable knowledge transfer, reduce adoption risks, and create supportive institutional environments. These would require a combination of diffusion and amplification mechanisms through: institutional learning and governance approaches; knowledge transfer and capacity building; and economic incentives or support mechanisms (Plieninger et al, 2020).

Legal and political recognition and effective governance structures provide the basis for agroforestry diffusion. In addition, cross-sectoral policy coherence is necessary for creating an enabling environment. In the EU, this would require aligning the Common Agricultural Policy with sustainability goals while simplifying regulations and moving away from the mainstream view that treats agroforestry as peripheral to mainstream agriculture (Pabst et al, 2025). Importantly, agroforestry systems can be employed to implement the obligations to restore degraded agricultural landscapes under the EU Restoration Regulation.

Agroforestry projects around the world have indicated that multistakeholder platforms and participatory governance structures facilitate collective action and shared learning. At the same time, experience shows that knowledge gaps represent a primary obstacle to agroforestry adoption by farmers as well as agricultural advisors and policymakers. Training programmes would thus need to address both technical agricultural aspects, as well as policy and business skills. A series of Horizon projects, including AF4EU and AFINET, have produced technical and policy-relevant knowledge tools aiming to promote agroforestry in Europe.

Market development and value chain integration are considered critical for ensuring the economic viability of agroforestry systems. Depending on national and local circumstances, a variety of strategies has been adopted either directly by farmers or by policymakers, including cooperative models and associations, direct sales to consumers, certification schemes, including geographic indications, and financial incentives, including subsidies.

Investing in market development and value chain integration has the potential to improve economic viability, while participatory governance structures in agroforestry projects can promote shared learning. In addition, policy-relevant research prioritises the mainstreaming of agroforestry into national agricultural policies and climate action plans as a necessary step to ensure institutional and funding support.

In the EU, the Common Agriculture Policy (CAP) would be the most relevant vehicle for promotion of agroforestry, but it continues to suffer from a lack of targeted measures, historical focus on monocultures, and a misaligned definition of agricultural land, as noted below.

4. Barriers

Despite agroforestry's demonstrated potential to address various challenges, adoption rates remain low due to persistent social, economic and regulatory barriers, including:

- Limited awareness, knowledge gaps and resistance, particularly if smallholders are required to bear the cost and risk of transition;
- Negative or indifferent attitudes of agricultural advisors;
- Financial constraints and high upfront costs, combined with gaps in value chain development; and
- Lack of market access and of access to credit and financial services.

On the institutional and regulatory level, insecure land tenure, complex and incoherent governance structures which fail to mainstream agroforestry into agricultural policies, and regulatory ambiguities, create barriers that weaken the adoption of agroforestry practices. In the EU, agroforestry is included in the 2023-2027 CAP but uptake remains low, as it is not sufficiently addressed in many national Strategic Plans, and dedicated agroforestry measures are limited. In addition, a traditional focus on high-yield monocultures and the legacy of past rules that penalised high tree density in agricultural land persist. Specialised advisory services and knowledge-sharing are required to increase adoption, particularly since the complexity of rules and the long-term nature of agroforestry, combined with low payments that often do not meet the conversion costs, discourage farmers.

5. References

Claus, R., Davel, R. & Belcher, B. (2021). Support to the Development of Agroforestry Concessions in Peru (SUCCESS) Project. CIFOR. https://doi.org/10.17528/CIFOR/007935

Hillbrand, A., Borelli, S., Conigliaro, M. & Olivier, A. (2017), *Agroforestry for landscape restoration – Exploring the potential of agroforestry to enhance the sustainability and resilience of degraded landscapes*. FAO.

https://www.fao.org/sustainable-forest-management/toolbox/tools/tool-detail/en/c/1103703/

Pabst, H., Lang, J. & Sterly, S. (2025). Navigating Europe's agricultural transition: Systemic policy approaches to mixed farming and agroforestry. *Open Research Europe*, 5. https://doi.org/10.12688/openreseurope.20398.1

Plieninger, T., Muñoz-Rojas, J., Buck, L.E. et al. (2020). Agroforestry for sustainable landscape management. *Sustainability Science*, 15(5). https://doi.org/10.1007/S11625-020-00836-4

Satish, K. V., Akshay F Madiwalar, Michelle C. Lallawmkimi, K. Jaisimha Reddy, Shayma Parveen, Ashoka, P, Thejavath Laxman, M. Kiruba, and G. Anand (2024). Agroforestry: Multifunctional Benefits and Implementation Strategies. *Journal of Geography, Environment and Earth Science International*, 28(10). https://doi.org/10.9734/jgeesi/2024/v28i10821

6. List of policy instruments

Regulation (EU) 2024/1991 of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 [2024] OJ L178/1

Regulation (EU) 2021/2116 of the European Parliament and of the Council of 2 December 2021 on the financing, management and monitoring of the common agricultural policy and repealing Regulation (EU) No 1306/2013 [2021] OJ L 435/187

Regulation (EU) 2021/2115 of the European Parliament and of the Council of 2 December 2021 establishing rules on support for strategic plans to be drawn up by Member States under the common agricultural policy (CAP Strategic Plans) and financed by the European Agricultural Guarantee Fund (EAGF) and by the European Agricultural Fund for Rural Development (EAFRD) and repealing Regulations (EU) No 1305/2013 and (EU) No 1307/2013 [2021] OJ L 435/1

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Biodiversity data storage, e-infrastructure and sharing platforms

1. Introduction

The rise in advanced computing capabilities and data storage, along with the development of standards for good practice biodiversity data recording, have opened doors to more effective and equitable digital biodiversity data storage, access and interpretation. Like traditional recording schemes, these platforms link species occurrences with spatial and temporal data, as well as the provenance of the record. Biodiversity data platforms frequently represent both the e-infrastructure to host the records, as well as a network of actors working towards the shared goal of making the data available.

Biodiversity data platforms collate, verify and aggregate species records from a wide range of sources, including historic museum specimens, DNA barcoding, traditional recording schemes and citizen science and crowd-sourcing apps. There are now many platforms operated by a range of organisations, regionally, nationally, or internationally, some focusing on specific taxa (e.g. birds, amphibians) or habitats (e.g. the Ocean Biodiversity Information System for marine species) and others collating records more broadly. These different platforms may feed into one another, with data from specific schemes feeding into national recording platforms.

Use of standardised fields and Findable, Accessible, Interoperable, and Reusable (FAIR) reporting using discipline-specific metadata standards help to ensure the interoperability of any data submitted and facilitate reuse. This also allows appropriate attribution of datasets and records to those who collected them. Many biodiversity data platforms also offer an end-user interface to explore, analyse and export data for further reuse.

A single record may progress through a range of different biodiversity data platforms, for example a taxon-specific recording scheme that feeds into a national recording scheme such as the UK's National Biodiversity Network (NBN), before reaching an international platform such as the Global Biodiversity Information Facility. This offers multiple opportunities to check the accuracy and completeness of the record, as well as to identify potential duplication.

Biodiversity data platforms offer a scalable solution to biodiversity data collation and retrieval, allowing analysis of data on a near-global scale, yet also allowing interested individuals, organisations and even countries, the ability to explore data relevant to their context. Data producers such as citizen scientists may not interact directly with biodiversity data platforms, as they may use an intermediary app such as iNaturalist to upload their observations, from which verified records are exported to national data platforms or directly to the Global Biodiversity Information Facility (GBIF).

Biodiversity data platforms are considered an innovation as they are only possible due to recent technological advances and collaboration between groups gathering and recording data. They represent a step-change from traditional manual systems for recording species occurrences due to the potential for free and open access to standardised records, allowing wider reuse and appropriate attribution.

2. Case study: The Global Biodiversity Information Facility (GBIF)

The Global Biodiversity Information Facility (GBIF) is an international network and data infrastructure funded by governments and aimed at providing anyone, anywhere, open access to data about all types of life on Earth (GBIF 2025a). GBIF was established in 2001 through a Memorandum of Understanding between participating governments and is coordinated through a Secretariat based in Copenhagen. As of December 2025, the GBIF network comprises 111 participants, representing a range of countries and relevant organisations (GBIF, 2025b), and the data infrastructure contains 3,571,732,431 occurrence records from almost 120,000 datasets provided by more than two and a half thousand publishing institutions. GBIF data is estimated to contribute to approximately five scientific articles per day (GBIF, 2025a).

As well as providing the infrastructure for data collation and storage, the GBIF network is constantly working to develop and drive improvements in biodiversity data quality and availability. For example, GBIF is a champion of FAIR data (optimising the potential for reuse of data) and of Digital Object Identifier (DOI)-based data citation to persistently and uniquely identify the original data set or source.

A study by Deloitte Access Economics (2023) attempted to quantify the economic valuation and assess the impact of the GBIF network. The study estimated that every €1 invested in GBIF provides €3 in direct benefits to users and up to €12 in societal benefits. Further, almost half of all data users reported their research would have been impossible to achieve without GBIF, and use of GBIF saves an estimated 64 hours per user versus finding data through alternative sources. Nearly all users surveyed (92 per cent) linked their use of GBIF-mediated data to advancing contributions to the UN Sustainable Development Goals.

A 2025 policy brief describes how Belgium's national use of GBIF has been transformative (Groom et al., 2025). Belgium has contributed over 55 million species observation records to GBIF to date. GBIF data is used to underpin the Belgian National Biodiversity Strategy and how it aligns with international targets, report progress towards Sustainable Development Goals (SDGs) and inform a range of land use planning and designation, early warning and invasive species management activities. The availability of quality data means that policy decisions are evidence-based, cost-effective, transparent and accountable. The authors estimate that the Belgian use of GBIF-mediated data reduces effort and speeds up data flows, and saves the scientific community a minimum of €2 million a year (Groom et al., 2025).

However, there are wider social and environmental benefits identified from Belgium's GBIF participation. The use of GBIF data to inform land management, agriculture and forestry contribute to environmental sustainability and socio-economic resilience, and participation in GBIF has contributed to capacity building through the development of expertise, supporting training and mentoring networks, fostering a culture of open science, empowering citizen scientists and creating collaborations with neighbouring countries (Groom et al., 2025).

3. Deployment, diffusion, amplification

The deployment of biodiversity data storage, e-infrastructure, and sharing platforms has expanded significantly over the past two decades, driven both by technological advances and by the collaborative nature of biodiversity science. Much of the development of large-scale platforms – most notably GBIF – takes place within the networks themselves. Because these infrastructures are built through open, community-led processes, the tools, standards, and software components they produce are freely available for reuse and adaptation. This openness is especially important for less well-resourced national or thematic platforms, which can adopt and build upon existing modules rather than developing systems independently. As a result, deployment tends to be incremental yet robust, with the core infrastructure continuously strengthened by distributed contributions from participating institutions, data publishers, and technical communities.

Uptake of such platforms is high. Many countries are formal GBIF participants, and multiple additional biodiversity data platforms exist at national and regional scales – often tailored to specific taxa, habitats, or thematic research domains. Individual countries commonly use several systems simultaneously; for example, the UK uses both the National Biodiversity Network (NBN) and GBIF, each serving complementary functions. This multi-platform ecosystem reflects the diversity of biodiversity data needs, while still allowing integration through shared standards. A major factor enabling diffusion across systems is the widespread adoption of Darwin Core, which provides a standardised terminology for biodiversity records. Darwin Core ensures that data originating from different projects, monitoring schemes, or recording communities can be seamlessly aggregated, interpreted, and exchanged (Wieczorek et al., 2012). Its role in establishing a common linguistic and structural foundation has been central to the rapid diffusion of interoperable biodiversity data infrastructures.

Amplification of impact is further supported by the sector's increasing adherence to the FAIR principles, which guide platform design, data formatting, and long-term storage practices. FAIR-aligned infrastructures encourage high-quality metadata, transparent workflows, and stable, well-documented data products, enhancing trust and usability among researchers, policymakers and citizen science communities. Complementing these principles is the adoption of controlled vocabularies across recording platforms, for example, the consistent use of 'juvenile' rather than abbreviated or localised alternatives such as 'juv'. Such standardisation improves data comparability, reduces ambiguity, and enhances the ability of automated systems to integrate data at scale.

In recent years, amplification has also been driven by the development of technical tools that support high-quality, standardised data publication. Tools such as

BiSciCol Triplifier convert heterogeneous biodiversity datasets into standardised, linked-data compatible formats, enabling them to be shared more widely and queried more efficiently across platforms (Stucky et al., 2014). Similarly, the implementation of accredited pathways for data submission has helped reduce duplicate records from multiple sources and increased confidence in data provenance. These structured submission workflows are particularly important in systems that ingest large volumes of citizen science data, where duplication and variable data quality are common challenges.

Underlying all successful deployment, diffusion, and amplification efforts is the need for strong communication, collaboration, and trust between recording groups, data publishers and database management organisations. Recording communities – ranging from professional surveyors to volunteers – play a crucial role in generating biodiversity data, yet their motivations, capacities and practices vary widely. Building trust requires transparent data policies, recognition of contributors, clear communication about data use, and consistent feedback loops that show how uploaded data support conservation decisions. Strong relationships between communities and infrastructure providers ensure that the systems evolve in ways that meet user needs, maintain data integrity, and encourage continued participation.

Biodiversity data infrastructures and sharing platforms are closely shaped by EU legislation that requires robust, standardised, and interoperable biodiversity information. The EU Biodiversity Strategy for 2030, the EU Nature Directives (Birds and Habitats), and the recently adopted Nature Restoration Regulation collectively generate strong obligations for Member States to monitor species, habitats, conservation status, and ecosystem condition. These policies depend on consistent, high-quality biodiversity datasets to track progress toward EU-wide targets, restoration commitments, and Natura 2000 reporting requirements. As a result, they directly drive the adoption and expansion of shared data infrastructures such as GBIF, Ocean Biodiversity Information System, and national biodiversity portals, ensuring that biodiversity information can be accessed and used for EU environmental assessment and policy implementation.

EU research and data policy reinforce this foundation. Horizon Europe funds biodiversity data mobilisation, digitisation, harmonisation, and e-infrastructure development, supporting the tools, pipelines, and technical standards needed for cross-border integration. Its strong emphasis on open science aligns with the sector's widespread adoption of the FAIR data principles, which guide how biodiversity data should be structured, documented, and stored for long-term, interoperable reuse

4. Barriers

Biodiversity data platforms such as GBIF attempt to make accessibility and reuse of biodiversity data as open and equitable as possible. However, they are reliant on species records being submitted in the first place, and factors including computer literacy, access to technology and lack of translated interfaces may be prohibitive, particularly in countries with the greatest biodiversity.

The time required to submit data to data platforms is often not factored or costed into projects, meaning that records from consultancy, conservation practice and even research may not be uploaded, or may rely on volunteers to complete. Submitted records often need verification from species experts (who frequently verify records in a voluntary capacity), and this can impact on the timely availability of crucial data.

Other challenges include a lack of consistency in data collection and recording, differing terminology and changing species names and definitions, and data ownership and usage concerns. Privacy concerns and the responsible management of sensitive data (for example data revealing the specific locations of species of conservation concern) can prove a challenge in both securing and providing records. Duplicate entries of the same record through different pathways or from multiple recorders also pose a challenge for data platform hygiene.

Perhaps the biggest barrier to wider uptake at a national level would be a lack of awareness of process or potential benefits, however membership offers a range of opportunities for countries seeking to modernise their data infrastructure, and new countries continue to join the international GBIF network (Groom et al., 2025). As the Belgian example demonstrates, joining the networks behind biodiversity data platforms can be economically beneficial by reducing operational and strategic costs through shared infrastructure and standards, allowing work to take place that might not be viable otherwise (Groom et al., 2025).

5. References

Deloitte Access Economics (2023). Economic valuation and assessment of the impact of the GBIF network. Online: https://www.deloitte.com/content/dam/assets-zone1/au/en/docs/services/economics/deloitte-economics-global-biodiversity-information-facility-260623.pdf Date accessed: 07/01/26.

GBIF (2025a) GBIF: Global Biodiversity Information Facility. https://www.gbif.org/ Date accessed: 04/12/2025

GBIF (2025b) The GBIF Network. Online. https://www.gbif.org/the-gbif-network Date accessed: 04/12/2025

Groom, Q., Adriaens, T., Desmet, P., Vanderhoeven, S., & Yovcheva, N. (2025). *Why countries need the Global Biodiversity Information Facility: Lessons from Belgium*. https://doi.org/10.35035/doc-0kkq-0t82

Stucky, B. J., Deck, J., Conlin, T., Ziemba, L., Cellinese, N., & Guralnick, R. (2014). The BiSciCol Triplifier: Bringing biodiversity data to the Semantic Web. *BMC Bioinformatics*, *15*(1). https://doi.org/10.1186/1471-2105-15-257

Wieczorek, J., Bloom, D., Guralnick, R., Blum, S., Döring, M., Giovanni, R., Robertson, T., & Vieglais, D. (2012). Darwin core: An evolving community-developed biodiversity data standard. *PLoS ONE*, *7*(1). https://doi.org/10.1371/journal.pone.0029715

6. List of policy measures

Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora [1992] OJ L206/7, as amended by Council Directive 2013/17/EU of 13 May 2013 [2013] OJ L158/193

Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds [2010] OJ L20/7.

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Biodiversity Strategy for 2030 Bringing nature back into our lives, COM/2020/380 final

DAISY

LET'S TURN ON TRANSFORMATION

Regulation (EU) 2024/1991 of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 [2024] OJ L178/1

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Blockchain technology

1. Introduction

Blockchain technology could amount to a paradigm shift in environmental data governance, moving from centralised verification to decentralised record-keeping. In the context of biodiversity, it is defined as a system that 'facilitates the establishment of immutable records that assure the integrity and traceability of environmental data' (Shukla et al., 2024). By establishing a ledger that cannot be retrospectively altered, blockchain addresses issues of legitimacy and trust. These elements are typically pivotal for the success of conservation initiatives (Carlson et al., 2018).

The application of blockchain extends beyond data storage as it can also be used to create a secure digital infrastructure to combat illegal wildlife trade: by creating digital identities for animal products and recording transactions on a secure ledger, blockchain creates a traceable history that makes the laundering of illegal goods significantly more difficult.

Blockchain technologies are increasingly used within the biodiversity domain, though many potential applications remain speculative. One notable current application relates to Monitoring, Reporting and Verification (MRV), for instance with the Open Forest Protocol (see below). Speculative applications include tokenised nature assets, Non-Fungible Tokens (NFTs) for species protection, or genetic data tracking.

The technology is highly scalable and granular. It can be tuned to specific use cases, ranging from tracking global supply chains to storing micro-scale animal movement data. It is a potentially transformative innovation because it automates trust, thus reducing the need for centralised intermediaries.

2. Case study: Open Forest Protocol

A major example of blockchain application in biodiversity is the Open Forest Protocol (OFP). Developed by a Swiss company founded in 2021, OFP is an MRV tool for forestry projects. OFP provides a blockchain-based digital infrastructure specifically designed for carbon financing. It addresses the lack of transparency often found in carbon markets by ensuring data and financing transactions are publicly available and trustworthy. It employs a network of multiple organisations as validation/ verification bodies rather than a single central authority, using various data inputs, including pictures collected by users of a dedicated app. The purpose of this initiative is to ensure that transfers of carbon credits correspond to forest carbon offsets on the ground. By using blockchain, OFP positions itself as an economic challenger to Verra, the world's leading carbon certification company.

3. Deployment, diffusion, amplification

Beyond the OFP, the diffusion of blockchain in biodiversity is evident in the emergence of similar platforms. Regen Registry, a similar carbon verification project, focuses on ecological projects and data registries, while numerous projects in Latin America are leveraging the technology to protect local biodiversity.

Currently, policy pathways are predominantly broad rather than biodiversity-specific. The European Commission, for instance, has established a Blockchain and Web3 strategy which supports infrastructure development through the European Blockchain Services Infrastructure (EBSI). EBSI facilitates cooperation between Member States, though these initiatives are currently designed for general public services rather than specifically for environmental governance.

For the moment, most development of blockchain technology in the biodiversity domain appears to occur with regard to forest carbon, and thus at the biodiversity-climate change interface.

The EU has introduced several measures that, while not exclusive to biodiversity, establish broader regulatory frameworks for blockchain. In 2024, the EU established a new legal entity, EUROPEUM-EDIC, to oversee the expansion of European blockchain infrastructure. The EU is piloting the Markets in Crypto-Assets regulation, providing a legal framework for distributed ledger technology and crypto-assets. Support for research and development (R&D) is provided by the EU's Horizon Europe funding programme. The European Commission also promotes standards for blockchain technology to ensure interoperability and security across Member States.

4. Barriers

Despite its potential, the deployment of blockchain in biodiversity faces hurdles. The digital divide, notably between Global North and South, means that countries and regions differ in their ability to acquire and use the necessary hardware, software and technical knowledge. Public ledgers also pose risks of harmful disclosure. For instance, location data of endangered species could be breached by poachers. On the regulatory side, legal frameworks for tokenised ecological assets remain underdeveloped, creating uncertainty for investors and project developers.

5. References

Villares, L. (2021) ‘Blockchain and Conservation: Why Does It Matter: Applications in Payments for Ecosystem Services and Bolsa Floresta Program’, in Proceedings of IDEAS 2019: The Interdisciplinary Conference on Innovation, Design, Entrepreneurship, And Sustainable Systems. Cham: Springer International Publishing (Smart Innovation, Systems and Technologies). https://doi.org/10.1007/978-3-030-55374-6.

Shukla, S. et al. (2024) ‘Blockchain Technology for Environmental Conservation’, in Microbial Biocontrol Techniques: Importance in Ensuring Food Security. Singapore: Springer Nature Singapore (Microorganisms for Sustainability). https://doi.org/10.1007/978-981-97-8739-5.

Parameswaran, S. et al. (2024) ‘Optimizing Food Production with a Sustainable Lens: Exploring Blockchain Technology in Raw Plant Materials and Organic Techniques in Achieving Sustainable Development Goals’, in 2024 International Conference on Trends in Quantum Computing and Emerging Business Technologies. 2024 International Conference on Trends in Quantum Computing and Emerging Business Technologies (TQCEBT), Pune, India: IEEE, pp. 1–9. Available at: https://doi.org/10.1109/tqcebt59414.2024.10545026

6. List of policy instruments

Directive 2014/65/EU of the European Parliament and of the Council of 15 May 2014 on markets in financial instruments and amending Directive 2002/92/EC and Directive 2011/61/EU [2014] OJ L 173/349

Proposal for a regulation of the European Parliament and of the Council on Markets in Crypto-assets, and amending Directive (EU) 2019/1937, COM/2020/593 final

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Camera traps / trail cameras

1. Introduction

Camera traps, or trail cameras, are remotely triggered cameras used for capturing images of wildlife. When an animal is detected in the area in front of a device, the camera is triggered, and a sequence of images or a video is taken and recorded onto a memory card. They initially gained recognition as a useful biodiversity monitoring tool for capturing high-quality images of big cat species, which allowed individual recognition of animals based on unique pelage markings. This information could then be used to estimate population densities based on a capture-mark-recapture framework. Since then, the application of camera traps for biodiversity monitoring has greatly expanded and diversified to record the presence and behaviours of a variety of vertebrate species across the globe (Glover-Kapfer et al., 2019).

Camera traps are considered an efficient method for long-term monitoring as they can be placed in the field and left for weeks or even months to collect data. This also makes them suitable for monitoring in remote environments that may be difficult to access on a regular basis. Modern camera traps cause very little disturbance to wildlife and are relatively user-friendly and straightforward to set up, making them suitable for a range of biodiversity monitoring applications.

Alongside their use in biodiversity monitoring, camera traps have long been recognised for their potential role in public outreach and engagement. This is due to the engagement value of the images collected, the suitability for integration of camera trap data into citizen science, and the relative user-friendly technology and design of modern camera traps.

Camera traps are a versatile tool, and while their use can be context dependent – e.g. the best study design and type of data recorded depends heavily on the environment, the project aims and the research questions being addressed – they can be useful in a range of contexts. They can be adapted to different scales and can be used both in local biodiversity monitoring projects and in large-scale cross-border efforts to monitor mammals.

The technology used in camera traps is continuously being developed, resulting in better picture and video quality, increased data storage capacity, increased sensitivity and faster trigger speeds. These advances have made it possible to research an increasingly diverse range of ecological questions using camera traps. Modern developments also include integration of Wi-Fi or telephone reception, allowing camera traps to send real-time notifications when wildlife is detected. AI and citizen science integration is increasing the speed of species recognition in data sets and aiding in public outreach.

2. Case study: MammalWeb

For appropriate conservation measures to be implemented, reliable baseline data on populations, followed by ongoing monitoring to detect population changes, is needed. Data on many species is still sparse across Europe, even for common species such as the European rabbit. Mammal species can be particularly difficult to monitor due to nocturnal activity, avoidance of humans and wide-ranging patterns. Camera traps provide a viable, cost-effective long-term monitoring option for studying a variety of mammal species.

MammalWeb is a wildlife monitoring project that aims to collect data on mammal species via camera traps. Originally geographically focused on the Northeast of England, it has since expanded to cover the rest of Great Britain and Northern Ireland, as well as parts of mainland Europe through partnerships with other organisations. Since its inception in 2015, MammalWeb has collected over 1.7 million photo sequences and videos from over 2300 sites.

The process of reviewing and classifying camera trap footage is recognised as a significant bottleneck in data analysis process (Bruce et al., 2025; Delisle et al., 2021). As a solution to this, MammalWeb engages members of the public as 'citizen scientists' to aid in the reviewing and identification of species in footage. While many camera trapping citizen science projects are purely online image classification tasks, MammalWeb differs in that it engages participants to also deploy camera traps and upload the resultant footage. This approach increases the geographic range of sites from which data can be collected, including private land such as gardens which can otherwise be tricky to access.

MammalWeb has so far helped increase the number of records of mammal species, led to the safe capture of non-native invasive species (Hsing et al., 2022), and supported academic research into improving camera trap methodologies (Croose et al., 2025; Green et al., 2023; Sharpe et al., 2025). As well as aiding in the collection and processing of camera trap data, engaging citizen scientists helps MammalWeb achieve a further aim of enhancing connection to nature. MammalWeb has also been integral to several initiatives working with local schools, youth groups, and a natural history museum. The experience of participating in camera trapping citizen science has provided mental health benefits (by providing a sense of purpose and increasing social interactions) as well as increasing knowledge of native species and connection to nature (Mason et al., 2025).

3. Deployment, diffusion, amplification

The impact from camera traps can be amplified through integration with citizen science, both in terms of ability to process large amounts of data, and through the societal benefits of public participation in science. Camera trap research is well-suited for citizen science integration as each image sequence, or video, provides a voucher, which is something that can be verified if citizen science classification accuracy is questioned. Research has shown that a high level of confidence in species classification accuracy can be reached by combining classifications from multiple participants making these data sets reliable for further analysis (Hsing et al., 2018; Swanson et al., 2016). While initially focused on classification of species present in footage, research is showing that camera trapping citizen science projects can be expanded to collect a wider range of information such as age or sex of animals recorded and even individual ID. This increased the types of questions and projects that camera trapping with citizen science can be used to address.

A prominent area of current research in camera trapping is the use of AI (machine learning) for image classification (Delisle et al., 2021). This provides the potential for processing of huge data sets in fast time frames, making data ready for analysis in a much timelier manner and allowing real-time actions to be taken. Progress in this area is advancing rapidly, and there is evidence supporting the potential for highly accurate classifications. The use of machine learning for classification of footage is only likely to increase as more models and larger and more diverse training sets become available.

There are concerns that AI will replace citizen science for footage classification, risking the loss of benefits to participants from engagement with citizen science, however there is good potential for citizen science and AI integration. Machine learning models need large sets of pre-labelled data for training, which can be provided through citizen science. Citizen scientists can also aid in verifying AI classified footage (and vice-versa) reducing errors. A greater focus could also be placed on engaging volunteers/ citizen scientists in deploying camera traps in the field. Camera trap networks could be expanded by encouraging more people to place cameras at a wider range and number of locations. This could be supported by educational workshops on camera trap use and camera trap loan schemes e.g. through collaboration with charities, libraries or museums to help increase uptake.

Different types of camera trap setups are also being developed, which allow the study of a greater range of species and habitats. For example, placing camera traps in modified boxes can improve detection and identification of small mammal species such as mice and shrews, as well as mustelid species such as polecats and weasels. Arboreal camera setups are also being trialled for the study of tree-top species.

In the future, the impact of camera trap data can be amplified through the development of more shared and open access data repositories. These will aid in improving the scale and efficiency of data collection (Bruce et al., 2025). Standardising reporting of camera trap set up and other metadata, as well as standardisation of data entry format, will aid in creating shareable, usable large-scale monitoring databases.

There is a range of EU directives, frameworks, strategies and regulations that either require or support monitoring of biodiversity. As a versatile tool for monitoring terrestrial biodiversity, camera traps can be used to help meet these requirements under the Habitats and the Birds directives, as well as international commitments under the Kunming-Montreal Global Biodiversity Framework (GBF) of the Convention on Biological Diversity (CBD). They can also be used for surveillance, detection and monitoring of mammalian invasive species, thus supporting requirements of Invasive Alien Species regulations.

4. Barriers

A barrier to the use of camera traps is the funding required. While camera traps are becoming more affordable, many studies require large numbers of cameras, which can mean a significant upfront cost. Following on from this, employment of personnel to maintain the cameras, and manage, process, analyse and disseminate the data still represent significant costs. While AI or citizen scientists may aid in this, these too may have hidden costs. For example, running a citizen science platform still has web developer costs, data storage costs and the need for trained personnel to engage with and support volunteer contributors. Camera traps can record large amounts of data over their lifespan and become more cost-efficient when used over a long-period of time – but this does require long-term planning and funding to support other project costs over the long term.

As with all forms of remote monitoring, privacy issues can arise when using camera traps. Cameras often capture images of people, without the permission of the persons involved, even when the study objectives are to record wildlife. Some projects set up cameras to deliberately record human activity, e.g. to study disturbance levels or monitor illegal activity. It is common among camera trap studies for camera traps to be stolen and damaged. This not only incurs additional financial cost for replacement and loss of data but can also lead to mistrust and conflict with local communities, who may feel uncomfortable being observed. The recording of humans certainly raises ethical questions, and there are calls for clearer ethical guidelines to aid camera trap users in negotiating these issues. Suggested solutions include increased engagement and involvement with local communities to explain the purpose of the study. AI can also aid, by automatically detecting images containing humans and removing them from the data set, or by blurring features so that individuals are not recognisable.

5. References

Bruce, T., Amir, Z., Allen, B. L., Alting, B. F., Amos, M., Augusteyn, J., Ballard, G. A., Behrendorff, L. M., Bell, K., Bengsen, A. J., Bennett, A., Benshemesh, J. S., Bentley, J., Blackmore, C. J., Boscarino-Gaetano, R., Bourke, L. A., Brewster, R., Brook, B. W., Broughton, C., … Luskin, M. S. (2025). Large-scale and long-term wildlife research and monitoring using camera traps: a continental synthesis. *Biological Reviews*, *100*(2), 530–555. https://doi.org/10.1111/brv.13152

Croose, E., Wright, P. G. R., Carter, S. P., Green, S. E., & MacPherson, J. (2025). Comparing the efficacy of two camera trapping techniques for assessing the occupancy, detection and activity patterns of small Mustelids in Britain. *European Journal of Wildlife Research*, *71*(2). https://doi.org/10.1007/s10344-025-01914-7

Delisle, Z. J., Flaherty, E. A., Nobbe, M. R., Wzientek, C. M., & Swihart, R. K. (2021). Next-Generation Camera Trapping: Systematic Review of Historic Trends Suggests Keys to Expanded Research Applications in Ecology and Conservation. *Frontiers in Ecology and Evolution*, *9*, 97. https://doi.org/10.3389/FEVO.2021.617996/BIBTEX

Glover-Kapfer, P., Soto-Navarro, C. A., & Wearn, O. R. (2019). Camera-trapping version 3.0: current constraints and future priorities for development. *Remote Sensing in Ecology and Conservation*, 1–15. https://doi.org/10.1002/rse2.106

Green, S. E., Stephens, P. A., Whittingham, M. J., & Hill, R. A. (2023). Camera trapping with photos and videos: implications for ecology and citizen science. *Remote Sensing in Ecology and Conservation*, *9*(2), 268–283. https://doi.org/10.1002/RSE2.309

Hsing, P.-Y., Bradley, S., Kent, V. T., Hill, R. A., Smith, G. C., Whittingham, M. J., Cokill, J., Crawley, D., Stephens, P. A., & Stephens, P. A. (2018). Economical crowdsourcing for camera trap image classification. *Remote Sensing in Ecology and Conservation*, *4*, 361–374. https://doi.org/10.1002/rse2.84

Hsing, P.-Y., Hill, R. A., Smith, G. C., Bradley, S., Green, S. E., Kent, V. T., Mason, S. S., Rees, J., Whittingham, M. J., Cokill, J., Citizen Scientists, M., & Stephens, P. A. (2022). Large-scale mammal monitoring: The potential of a citizen science camera-trapping project in the United Kingdom. *Ecological Solutions and Evidence*, *3*(4), e12180. https://doi.org/10.1002/2688-8319.12180

Mason, S. S., Hill, R. A., Whittingham, M. J., Coghill, L., & Stephens, P. A. (2025). Ecological citizen science in schools: a case study of impact on pupils' connection to nature and knowledge of UK mammals. *International Journal of Science Education, Part B: Communication and Public Engagement*, *15*(3), 509–525. https://doi.org/10.1080/21548455.2025.2515617

Sharpe, C. R., Hill, R. A., Chappell, H. M., Green, S. E., Holden, K., Fergus, P., Chalmers, C., & Stephens, P. A. (2025). Increasing citizen scientist accuracy with artificial intelligence on UK camera-trap data. *Remote Sensing in Ecology and Conservation*. https://doi.org/10.1002/rse2.70012

Swanson, A., Kosmala, M., Lintott, C., & Packer, C. (2016). A generalized approach for producing, quantifying, and validating citizen science data from wildlife images. *Conservation Biology*, *30*(3), 520–531. https://doi.org/10.1111/cobi.12695

6. List of policy instruments

Convention on Biological Diversity (CBD), Rio de Janeiro (Brazil), 5 June 1992, in force 29 Dec. 1993

Kunming-Montreal Global Biodiversity Framework, CBD/COP/DEC/15/4, 19 Dec. 2022.

Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora [1992] OJ L206/7, as amended by Council Directive 2013/17/EU of 13 May 2013 [2013] OJ L158/193

Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds [2010] OJ L20/7.

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Biodiversity Strategy for 2030 Bringing nature back into our lives, COM/2020/380 final

Regulation (EU) 2024/1991 of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 [2024] OJ L178/1

Regulation 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species [2014] OJ L317/35

Commission Implementing Regulation 2025/1422 of 17 July 2025 amending Implementing Regulation 2016/1141 to update the list of invasive alien species of Union concern, OJ L 2025/1422

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, New EU Forest Strategy for 2030, COM/2021/572 final

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Citizen science (collaborative or co-created)

1. Introduction

Citizen science, also sometimes referred to as participatory or community science, refers to the voluntary involvement of members of the public in at least one stage of the scientific process. While most citizen science projects are contributary in nature, with volunteers/ citizen scientists contributing by submitting data through a set structure designed by scientists, other projects have greater community involvement. Collaborative and co-created projects include input from local communities in multiple stages of the process, from developing the research question to designing the study and helping to collect, analyse, interpret and disseminate the data collected. They differ slightly in that collaborative projects are generally designed by scientists, but whose design may be refined by members of the public, whereas co-created projects are designed by scientists and members of the public working together (Bonney et al., 2009).

Due to the greater level of involvement from the public in collaborative and co-designed projects, compared to contributary, participation can lead to greater impacts in terms of gaining scientific skills, understanding of the scientific process and changes in behaviours and attitudes (Shirk et al., 2012).

Co-created or collaborative type citizen science projects are usually context-specific. This is because they are designed with a community and aim to address challenges identified as being locally important to that community. These projects rely on good communication, collaboration and the development of personal relationships between community members and academic partners. The level of communication required and the ability to address community issues can be challenging at larger scales.

Co-created or collaborative citizen science projects are treated here as an innovation, as they represent a shift from the traditional academic-led research model to a more community-oriented model. This shift can help democratise the scientific process and include a more diverse set of voices in research, as well as combining scientific expertise with local and traditional knowledge to answer questions and address problems with novel approaches.

2. Case study: Co-creation of projects with historically underrepresented communities in northeast England

There are few well-documented cases of co-created environmental projects; however, co-created citizen science projects have the potential to engage diverse and historically underrepresented communities by addressing issues that they deem important. As part of the Engaging Environments programme, researchers from Newcastle University (UK) are aiming to make science more accessible for diverse communities engaged in co-creation of citizen science projects with the following four community groups:

- Sangini, a Black and minorities-led arts project committed to ending gender-based violence
- Hart Gables, which supports LGBTQ+ communities in the region
- The International Community of Sunderland (ICOS), which exists to improve the quality of life for Black and minoritised people in the Northeast of England
- North Tyneside Youth Strike for Climate, an activist group for young people aged 10 and above who are engaged in the climate emergency.

Each community worked with the Newcastle team to co-create a project that addressed its own priorities. Sangini developed an art–science collaboration that combined environmental awareness with participatory arts practice. Guided by Bangladeshi artists, co-researchers created artwork from recycled materials to express concerns about plastic pollution and climate change, culminating in a public exhibition that sparked dialogue and led to new partnerships and a long-term project. Hart Gables co-designed thematic workshops that blended environmental education with practical activities, creating safe spaces for sharing environmental and social concerns and helping to break down barriers to participation in scientific research. Youth Strike for Climate collaborated on a biodiversity monitoring project focused on rocky shore species, building scientific skills and contributing data to the National Biodiversity Network to support long-term monitoring. Finally, ICOS co-created a project tackling plastic pollution on local beaches, combining beach clean-ups and surveys with local knowledge and national datasets. Their work produced participatory maps and informed community action plans, including strategies for reducing litter and engaging local councils.

These projects showed that co-created citizen science can be an effective way to engage diverse community groups. It was also found that it is not only the final outcomes, such as the action plans or data collected, that provide value; participation in the projects themselves also creates value. Co-created citizen science can facilitate a transformative learning experience, leading to behavioural changes and changes in perception of science. Participants felt that science was now more accessible, that they had changed perceptions of who can participate in science, and that they had greater understanding of research practice (Robinson, Delany, et al., 2024).

Experiences and learning from these projects indicate that co-created citizen science should prioritise the process as much as the outcome, recognising that impact occurs throughout and beyond the project and valuing relationship-building, engagement, and lived experience over narrow academic metrics. It also requires appropriate conditions for inclusion, such as trust, equitable partnerships, safe spaces tailored to community needs, and open communication supported by shared language and cultural understanding. Finally, participatory research demands participatory evaluation, embedding co-evaluation throughout the project to ensure iterative learning, adaptation, and genuine community control, while disseminating findings widely to inform future practice (Robinson, Sugden, et al., 2024).

3. Deployment, diffusion, amplification

More documentation of co-created citizen science projects exists addressing issues such as health and well-being, but there are fewer records for truly co-created projects addressing environmental issues. The transformative potential of collaborative and co-created citizen science is becoming recognised and given greater consideration within the fields of environmental monitoring and nature conservation.

For projects to achieve greater impact, the development of trust and relationships with community groups is vital. Reaching out and connecting with minority groups can help engage historically underrepresented groups in science. Project development needs to be an iterative process with feedback and communication between academic and community researchers. As the process of participation itself creates value, the impact of a project can be amplified by creating long-term projects, provided the level of engagement and communication is maintained throughout.

While contributory style citizen science projects may be able to attract and engage larger numbers of participants compared to collaborative or co-created projects, the greater level of participation seen in the latter projects can have a greater impact on individuals. Value from each project is amplified through benefits such as increased pro-environmental behaviours and increased likelihood of participating in environmental science and research in the future.

For collaborative and co-created citizen science to be more widely deployed and scaled, a cultural shift within academia is required. Traditional research norms often prioritise researcher-led agendas, disciplinary expertise, and conventional outputs, whereas cocreated approaches emphasise shared decision-making, process-based outcomes, and the value of lived and local knowledge. Embracing these models, therefore, requires changes in academic attitudes, including recognising communities as equal research partners and valuing relationship-building, trust, and social impact alongside scientific outputs.

This shift also necessitates changes in research practice and training. Co-created citizen science requires flexible, iterative research designs and longer-term engagement, which does not always align with existing funding structures or career incentives. Supporting wider adoption will therefore depend on developing more transdisciplinary approaches and training, equipping researchers with skills in facilitation, communication, participatory methods and inclusive evaluation. Embedding these competencies within research institutions would strengthen the quality, legitimacy, and long-term impact of collaborative and co-created citizen science projects

European frameworks increasingly legitimise and resource co-created citizen/ community science. The European Green Deal and the EU Biodiversity Strategy for 2030 foreground public participation and nature-based solutions, while the Nature Restoration Regulation (2024) requires National Restoration Plans and long-term ecosystem monitoring, which mark clear entry points for community-led data and stewardship. The EU Forest Strategy for 2030 further supports participatory monitoring and closer-to-nature practices relevant to community science. On funding, Horizon Europe (Cluster 6) now includes calls that explicitly strengthen citizen science capacity for biodiversity observation, and the LIFE Programme (Nature & Biodiversity) channels implementation finance for on-the-ground projects engaging civil society and local partners.

4. Barriers

Co-created citizen science faces significant social barriers rooted in a lack of awareness and access to knowledge, and mistrust. Many communities are simply unaware that co-created research opportunities exist, or they lack clear, accessible information about what participation entails and how findings will be used. Even when interest is high, uneven access to scientific knowledge – such as literacy in research methods, data ethics, or evaluation – can limit meaningful participation and reinforce power imbalances between academic and community partners. Historical experiences of extractive research, coupled with concerns about data ownership and representation, can foster mistrust that slows engagement and requires time-intensive relationship-building to overcome.

There are also economic and practical barriers related to access to equipment and time, as well as regulatory and institutional constraints. Participatory projects often require devices (e.g., sensors, smartphones, laptops), connectivity, software, and safe venues for meetings – all of which may be unavailable or unaffordable for community partners. Time is a critical constraint for both researchers and participants: co-creation entails sustained dialogue, iterative design, and participatory evaluation that rarely align with short funding cycles, rigid deliverables, or academic workload models. On the regulatory side, requirements around ethics, safeguarding, data protection, and risk/ liability can be complex to navigate collaboratively, especially when responsibilities are shared across institutions and community organisations. Together, these social, economic, and regulatory barriers highlight the need for dedicated resourcing (equipment, stipends, facilitation), accessible training and materials, flexible funding and timelines, transparent governance of data and decision-making, and ongoing investment in trust-building to make co-created citizen science both feasible and equitable.

Despite progress in regulatory support, fragmented governance, uneven data standards/ interoperability, and short funding cycles can limit sustained co-creation and data uptake in policy. Ethics, safeguarding and GDPR compliance also add administrative burden for community partners, underscoring the need for harmonised protocols and flexible resourcing within restoration and biodiversity programmes.

5. References

Bonney, R., Ballard, H. L., Jordan, R., McCallie, E., Phillips, T., Shirk, J., & Wilderman, C. C. (2009). *Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education caise center for advancement of informal science education. A CAISE Inquiry Group Report.* www.caise.insci.org

Robinson, D., Delany, J., & Sugden, H. (2024). Beyond Science: Exploring the Value of Co-created Citizen Science for Diverse Community Groups. *Citizen Science: Theory and Practice*, *9*(1). https://doi.org/10.5334/cstp.682

Robinson, D., Sugden, H., Rao, P., Towers, A., Wysocka, J., & Delany, J. (2024). What Makes an Engaging Environment? Lessons Learnt From Co-Created Research With Diverse Community groups. *Journal of Participatory Research Methods*, *5*(4). https://doi.org/10.35844/001c.126299

Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., McCallie, E., Minarchek, M., Lewenstein, B. V., Krasny, M. E., & Bonney, R. (2012). Public Participation in Scientific Research: a Framework for Deliberate Design. *Ecology and Society*, *17*(2), 29:1-29:20. https://doi.org/10.5751/ES-04705-170229

6. List of policy instruments

Regulation (EU) 2024/1991 of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 [2024] OJ L178/1

Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, The European Green Deal, COM/2019/640 final

European Commission: Directorate-General for Research and Innovation. (2024). *Horizon Europe strategic plan 2025-2027*. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/092911.

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, New EU Forest Strategy for 2030, COM/2021/572 final

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Citizen science (online or contributory)

1. Introduction

Citizen science, also sometimes referred to as participatory science or community science, refers to the voluntary involvement of members of the public in at least one stage of the scientific process. There are many different approaches and types of citizen science projects, which now cover a vast array of topics, from discovering galaxies to transcribing historical texts. Biological recording is a particularly common theme in citizen science projects, and there is a long history of efforts by amateur enthusiasts providing valuable biological recording data (Pocock et al., 2015).

The number of citizen science projects has grown rapidly in recent times, mostly through the creation of online projects. Many of these are contributory in style. This refers to projects where scientific questions and approach are designed by professional scientists or researchers, with volunteers or citizen scientists contributing by collecting or sorting data via a set protocol, but with little or no input into study design or data analysis. These projects can attract participation from huge numbers of people from around the world. For many projects, all that is needed to participate is access to the internet via a computer or smart device. Participation can often be undertaken in short time periods to suit the time and schedule of the participant.

Citizen science and crowdsourcing projects can be an effective and efficient way of collecting and processing huge amounts of biodiversity data on scales that would not otherwise be achievable. These efforts support vital monitoring of species and habitats around the world. As well as benefits to biodiversity monitoring, citizen science can also provide benefits to participants themselves. Participation in biodiversity citizen science projects can improve skills and knowledge, have mental health benefits and increase connection to nature (Pocock et al., 2023).

The scalability depends on specific project outcomes and objectives, but the online nature of many contributary project means that they can be suitable for scaling-up. For example, image classification projects done through a website platform can be very popular, attracting thousands of participants who can participate from any location (provided they have internet access). Some projects require data collection from the field, e.g. wildlife observations, and while some of these may focus specifically on a geographic region, it is possible to scale up such projects so that observations from anywhere in the world can be uploaded.

There has been a vast increase in the number of online citizen science projects in recent years, taking advantage of the increased accessibility of the internet and smartphones. Projects have created a variety of innovative ways to engage members of the public in collecting data on biodiversity and the environment, and many utilise technology such as apps and smartphones.

2. Case study: iNaturalist

iNaturalist is an online network for sharing biodiversity information and learning about biodiversity. Network members can upload and identify records and receive help with identifications. Observations are submitted via a mobile application, and recordings consist of photographs or audio records taken by the observer with a suggested identification and metadata associated with the record, such as time and date of observation. The site currently holds over 287 million observations of more than 544 000 species from nearly 4 million observers (iNaturalist, 2025).

iNaturalist is growing rapidly in popularity, with an exponential increase seen between 2015 and 2022 in both number of iNaturalist records and number of academic articles published using iNaturalist data (Mason et al., 2025). Data from iNaturalist is most commonly used to study species distribution and range, but has also been used in studies on biology and behaviour, and biodiversity and population assessment.

To support users in identifying their observations, AI-generated suggestions are provided when observations are added to iNaturalist. Identification of species is validated by other participants who can also suggest identifications for an observation. An observation is deemed to have reached ‘Research Grade’ when it has two or more suggested identifications where at least two-thirds of suggestions agree on a species. Many iNaturalist participants only submit observations, and not identifications. This, along with the need for multiple identifications per observation, has caused identification of species to become a bottleneck in the data collection process. This has led to encouragement of professionals or those with particular species expertise to engage more with the identification stage (Callaghan et al., 2022).

While observations from iNaturalist can provide useful data on biodiversity, this is only the secondary goal of the network, with the primary goal being to help connect people to nature. iNaturalist describes itself as an online social network of people sharing biodiversity information to help each other learn about nature. Parties interested in specific taxa or geographic regions can create Projects, where relevant observations can be collated. Many citizen science projects and engagement initiatives utilise the iNaturalist platform as a useful tool for engaging people in biodiversity recording. Such initiatives include the City Nature Challenge and other bioblitz events. Participating in citizen science through iNaturalist can both help collect data and improve connection to nature for participants (Potsikas et al., 2023).

3. Deployment, diffusion, amplification

The number of citizen science projects available for people to participate in has increased rapidly in recent years. This is predominantly down to the large number of online, web-based platforms and use of mobile apps. As access to internet and smart phones and tablets has increased, these types of projects have become more accessible and can attract thousands of participants. However, the large number of online projects now available in turn means some projects must now compete to attract enough participants. Considerable research now examines motivations for participation and patterns of engagement of participants. A recurring pattern of participation in online citizen science projects is that most participants only contribute a small amount, while a small number of 'super users' contribute a large proportion of the effort. For some projects, this is not a problem, provided they can continue to attract enough new participants. For others, maintaining engagement with existing participants is valuable as they can become more skilled over time, and attracting and training new participants is more challenging. For citizen science projects wanting to quickly access a large pool of potential participants, there are platforms such as 'Zooniverse' which host many different citizen science projects and have large numbers of volunteers already registered with the platform. In order to raise awareness and attract more participants, projects often also make use of social media platforms. When used effectively, social media can reach huge audiences, engage new participants and introduce a social element to online projects, helping create an online community of volunteers which can be an important motivational factor in citizen science participation.

Reaching more people and engaging them to participate is one way of amplifying the impact of citizen science. Alternatively, impact can be increased by targeting engagement at sectors of society who have, historically, been underrepresented in citizen science. Within many citizen science projects, there is a trend for more participation from middle- to older-age people with higher levels of education and income. Engaging younger people and those from lower-income and ethnic minority backgrounds could enhance the impact of citizen science by increasing access to the benefits of participation across a broader range of society. Introducing citizen science projects into schools can help engage young people, provide unique learning experiences and help in reaching new audiences and children from underrepresented backgrounds in science.

Encouraging long-term or deeper levels of participation and engagement can also amplify the impact of citizen science for individuals. Learning and development of skills is often a key motivation for participation. Participation over a longer time-period can be beneficial for skill development, such as species identification. Developing skills can be rewarding for a participant and beneficial to the project for increasing data quality. Projects can encourage this by offering opportunities to 'level up', or other types of gamification, which can introduce a competitive element and reward people for contributing more. Greater engagement could be more likely to lead to other behavioural change, such as engaging in other biodiversity-friendly activities outside of citizen science participation. However, this can be more limited with contributory style projects, as there are limited ways that participants can provide input and often little room for progression into different roles. Deciding on the right type of citizen science project design is key to achieving the goals of each project.

Citizen science data collection can provide vital support in the monitoring required by EU policy instruments, such as the Birds and Habitats directives, the Invasive Alien Species regulation, and the Nature Restoration regulation. Citizen science not only provides data but is key to meeting requirements for public engagement set out by many policies. The Nature Restoration Regulation requires societal engagement and encourages the use of citizen science for monitoring restoration. Furthermore, use of citizen science in biodiversity monitoring is actively encouraged by the EU Pollinators Initiative and the European Green Deal. Funding support for citizen science is provided by Horizon Europe (Cluster 6) under the EU Research Framework and the LIFE Programme (Nature and Biodiversity subsection).

4. Barriers

With many contributory citizen science projects being online-based or requiring a mobile app or device to participate, the digital divide can be a significant barrier to participation for some. There are still many communities that do not have reliable internet connection or access, and so would be unable to participate in many projects. Alongside physical access to the technology required to participate, the comfort level and skills needed to use such tools and devices can be a further barrier, often for older members of the community.

Lack of awareness can also be a barrier to participation. People may not be aware that projects exist, nor that they are able to participate, believing that they do not have the skills or knowledge necessary. Reaching out to communities through novel and varied methods can help raise awareness, and provision of training and support can help projects be more accessible to all.

Not all people will want to participate in citizen science, and lack of motivation, e.g. due to lack of project relevance, can be another barrier. Contributory style projects are often designed and led by academics or researchers with little or no input from local communities or participants, so they may not always address issues considered a priority by the community.

While contributory and online style citizen science projects often require little equipment and can allow very flexible participation, lack of time can often be a barrier to participation. Access and travel can be further barriers, for example, reaching suitable areas for nature recording. There may also be financial barriers to participation if people cannot afford smart devices or other equipment or travel necessary for participation.

Concerns over the quality of data collected can also be a problem for researchers or project co-coordinators looking to use the data for reliable biodiversity monitoring.

Data quality can be improved through good study design and implementing verification techniques, such as expert validation or consensus methods (Baker et al., 2021). There is good evidence now that, with such measures in place, citizen science projects can collect high-quality biodiversity data.

5. References

Baker, E., Drury, J. P., Judge, J., Roy, D. B., Smith, G. C., & Stephens, P. A. (2021). The Verification of Ecological Citizen Science Data: Current Approaches and Future Possibilities. *Citizen Science: Theory and Practice*, *6*(1), 1–14. https://doi.org/10.5334/CSTP.351

Callaghan, C. T., Mesaglio, T., Ascher, J. S., Brooks, T. M., Cabras, A. A., Chandler, M., Cornwell, W. K., Ríos-Málaver, I. C., Dankowicz, E., Dhiya'Ulhaq, N. U., Fuller, R. A., Galindo-Leal, C., Grattarola, F., Hewitt, S., Higgins, L., Hitchcock, C., Hung, K. L. J., Iwane, T., Kahumbu, P., … Young, A. N. (2022). The benefits of contributing to the citizen science platform iNaturalist as an identifier. *PLoS Biology*, *20*(11). https://doi.org/10.1371/journal.pbio.3001843

iNaturalist. Available from https://www.inaturalist.org. Accessed [10th December 2025]

Mason, B. M., Mesaglio, T., Barratt Heitmann, J., Chandler, M., Chowdhury, S., Gorta, S. B. Z., Grattarola, F., Groom, Q., Hitchcock, C., Hoskins, L., Lowe, S. K., Marquis, M., Pernat, N., Shirey, V., Baasanmunkh, S., & Callaghan, C. T. (2025). iNaturalist accelerates biodiversity research. *BioScience*, *75*(11), 953–965. https://doi.org/10.1093/biosci/biaf104

Pocock, M. J. O., Hamlin, I., Christelow, J., Passmore, H.-A., & Richardson, M. (2023). The benefits of citizen science and nature-noticing activities for well-being, nature connectedness and pro-nature conservation behaviours. *People and Nature*, *00*, 1–16. https://doi.org/10.1002/PAN3.10432

Pocock, M. J. O., Roy, H. E., Preston, C. D., & Roy, D. B. (2015). The Biological Records Centre: a pioneer of citizen science. *Biological Journal of the Linnean Society*, *115*(3), 475–493. https://doi.org/10.1111/bij.12548

Potsikas, M., Prouska, K., Efthimiou, G., Plakitsi, K., & Kornelaki, A. C. (2023). Citizen science practice around Lake Pamvotis and the Ioannina Castle: Using iNaturalist to foster connectedness to nature in citizens and university students. *International Journal of Geoheritage and Parks*, *11*(3), 450–463. https://doi.org/10.1016/j.ijgeop.2023.07.002

6. List of policy instruments

Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora [1992] OJ L206/7, as amended by Council Directive 2013/17/EU of 13 May 2013 [2013] OJ L158/193

Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds [2010] OJ L20/7.

Regulation (EU) 2024/1991 of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 [2024] OJ L178/1

Regulation 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species [2014] OJ L317/35

Commission Implementing Regulation 2025/1422 of 17 July 2025 amending Implementing Regulation 2016/1141 to update the list of invasive alien species of Union concern, OJ L 2025/1422

Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Revision of the EU Pollinators Initiative A new deal for pollinators, COM/2023/35 final

Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, The European Green Deal, COM/2019/640 final

European Commission: Directorate-General for Research and Innovation. (2024). *Horizon Europe strategic plan 2025-2027*. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/092911.

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, New EU Forest Strategy for 2030, COM/2021/572 final

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Commons: Cecosesola – exploring commoning alternatives in food production and provisioning

1. Introduction

Commoning is treated as a socio-technical innovation because it fundamentally shifts the logic of provisioning from a commodity-based market transaction to a relationship-based governance process. While conventional food systems rely on centralised, hierarchical control and standardised industrial outputs, commoning introduces an organisational alternative based on decentralised coordination and collective monitoring. By decoupling essential goods from the sole pursuit of profit maximisation, commoning functions as a resilience mechanism that stabilises local food systems against macroeconomic volatility. Within the DAISY context, this is an innovation in social infrastructure: it provides the participatory management structures necessary to maintain the diversified, small-scale farming practices, that biodiversity policies (like the Nature Restoration Regulation) ultimately require for success.

An example for the effectiveness and long-term sustainability of commoning is Cecosesola (Central Cooperativa de Servicios Sociales de Lara), a network of grassroots organisations and cooperatives based primarily in Barquisimeto, Venezuela. Founded in 1967, it has developed into a large-scale system for organising food provisioning and related services through collective governance. Rather than operating as a time-limited intervention, Cecosesola functions as a stable organisational arrangement for the coordination of essential goods (Soetens et al., 2023; Right Livelihood, 2022).

While the network also provides healthcare and other social services, its relevance for the DAISY project lies primarily in its agri-food provisioning system. Through regularly organised Ferias de Consumo Familiar (Family Consumption Fairs), Cecosesola links regional small-scale producers directly with urban consumers (Helfrich, 2015). These markets reduce the number of intermediaries, stabilise prices and enable continuous supply relationships. In this sense, Cecosesola represents an organisational innovation within Short Food Supply Chains (SFSC) and the Social and Solidarity Economy (SSE) (Soetens et al., 2023).

Cecosesola is thus treated as an innovation not because it introduces new technologies, but because it provides a governance model for large-scale food distribution that differs from conventional market-based or state-led arrangements. Its relevance for European contexts lies in the potential transfer of organisational principles – such as collective coordination, shared responsibility and reinvestment of surplus – rather than in direct replication of institutional forms.

2. Case Study: The Agri-food Network of Cecosesola in Venezuela

Cecosesola integrates numerous community organisations and cooperatives across several regions in Venezuela. The network does not operate with a board of directors or permanent managerial hierarchy. Coordination is achieved through frequent collective meetings, rotating responsibilities and shared operational routines (Helfrich, 2015; Soetens et al., 2023). Decision-making authority is distributed and embedded in everyday practices related to logistics, pricing and coordination. This organisational structure enables flexibility and local adaptation, but it also requires continuous participation by members. Governance is therefore inseparable from daily operations.

The agri-food network is closely connected to diversified forms of small-scale agriculture. Production systems commonly involve polycultural cropping practices, often described as *conuco*-based arrangements, which combine multiple crops and contribute to soil regeneration and pest management (Venezuelanalysis, 2025).

Although biodiversity conservation is not always articulated as a formal objective, these production practices support crop diversity and ecological heterogeneity. Stable relationships between producers and markets allow for farming practices that are less compatible with standardised monoculture supply chains, thereby indirectly supporting agrobiodiversity (Soetens et al., 2023; Venezuelanalysis, 2025).

Producers associated with Cecosesola predominantly rely on local and non-proprietary seed varieties, consistent with national regulations restricting genetically modified seeds (Venezuelanalysis, 2025). Seed reproduction and exchange are integrated into farming practice rather than formalised through licensing schemes. Agronomic knowledge is exchanged through practice-based interaction among farmers, organisers and consumers (Helfrich, 2015). This form of knowledge circulation supports local adaptation and reduces dependence on external advisory services.

Cecosesola operates on a non-profit, reinvestment-oriented economic model. Prices at the food fairs are discussed collectively with the aim of balancing affordability for consumers and economic viability for producers. Financial surpluses are reinvested into infrastructure, logistics and social support mechanisms rather than distributed as profits (Right Livelihood, 2022; Soetens et al., 2023).

By reducing the role of intermediaries and maintaining stable supply relationships, the network mitigates exposure to price volatility. This contributes to food access for urban populations while offering producers predictable demand without requiring production intensification.

The logistical backbone of the agri-food network is the system of mobile farmers' markets, an initiative that began in 1984 by repurposing a fleet of obsolete buses to sell produce directly in underserved neighbourhoods (Venezuelanalysis, 2025). This decentralised distribution model has scaled to serve between 100,000 and 150,000 people weekly, approximately one-third of the population of Barquisimeto (Right Livelihood, 2022; Soetens et al., 2023). On a weekly basis, the network manages the sale of approximately 700 tons of products across 21 perishable-goods fairs (Right Livelihood, 2022). To support the ecological integrity of the supply chain, Cecosesola has implemented extensive waste-to-resource cycles, including recycling programmes that convert vegetable waste from the fairs into organic fertiliser for the associated *conuco* farms. Environmental footprints are further mitigated through the elimination of plastic bags – saving an estimated seven million bags per year – and the integration of solar panels and water-recycling systems within the network's central health and logistics hubs (Right Livelihood, 2022). Economically, the network maintains an annual turnover of approximately $100 million USD, operating on an almost entirely self-financed basis to preserve organisational autonomy.

Taken together, the scale, time span, and operational efficiency of Cecosesola differentiate it from many other commons-based initiatives. The network has operated continuously for more than five decades, supplies food to a significant share of an urban population, and maintains stable logistics and pricing under conditions of macroeconomic volatility. These characteristics position Cecosesola not as a marginal or experimental commons, but as a long-term, resilient provisioning infrastructure (Soetens et al., 2023; Right Livelihood, 2022).

In addition to food provisioning, Cecosesola operates healthcare and other social services organised through collective cost-sharing. These services reinforce long-term participation and trust within the network. For the purposes of this profile, they are treated as complementary domains that illustrate the broader applicability of the organisational model beyond food systems.

3. Deployment, Diffusion, Amplification

Cecosesola did not expand through replication or franchising. Instead, its development has been characterised by incremental consolidation within a defined regional context. Knowledge transfer occurs primarily through participation in shared routines rather than through formal documentation (Helfrich, 2015). The deployment of organisational principles relies on a process of 'free-flow rotation' rather than a fixed administrative plan (Helfrich, 2015). Members are encouraged to move voluntarily between tasks – ranging from agricultural harvesting and truck driving to administrative bookkeeping and clinical support – based on immediate community needs and personal learning goals (Helfrich, 2015). This prevents the calcification of power and ensures that technical knowledge remains a shared community asset rather than a specialised professional secret (Soetens et al., 2023). This way of organising participation is a key reason for Cecosesola's longevity. Engagement is not primarily incentivised through financial rewards or formal career paths, but through continuous learning, shared responsibility, and social embeddedness. The rotation between tasks allows members to acquire diverse skills, prevents role fixation, and maintains a sense of collective ownership over the organisation. At the same time, predictable routines, transparent pricing, and mutual reliance in daily operations create practical incentives to remain involved (Helfrich, 2015).

Decision-making is operationalised through an intensive schedule of over 3,000 meetings per year, involving different members of the network (Right Livelihood, 2022). Where individual actions are evaluated against the network's shared values in open assemblies, disciplinary measures have evolved from formal committees to a system of solution-oriented peer reflection. This behavioural innovation ensures that the system remains resilient to internal conflicts without resorting to traditional hierarchical sanctions (Soetens et al., 2023).

Amplification takes the form of increased organisational stability rather than numerical growth. Accumulated experience, shared norms and long-term relationships contribute to system robustness (Soetens et al., 2023). For European contexts, this suggests that Cecosesola's relevance lies in demonstrating how commons-based food provisioning can function as durable infrastructure, rather than as a model intended for direct scaling.

Potential adaptation pathways include integration with cooperative food networks, municipal food strategies and other SFSC initiatives where collective governance and producer–consumer coordination are already established.

4. Barriers

Trying to bring an innovation from halfway across the globe to also effectively work in Europe at this scale does bring its difficulties. However, it is important to note that the numerous benefits from commoning as practiced by Cecosesola are not bound to the unique geography and flora of Venezuela, but to the organisation of people. Yet, this must be actively cultivated rather than assumed, as implementing it merely requires the change of social constructs – no terraforming, no costly infrastructure projects necessary. In addition, a network of this scale and form can build on the diversity and experience of commoning initiatives in Europe.

A series of social, economic, and regulatory barriers can be identified. The organisational model requires sustained engagement in collective decision-making. In contexts where time constraints or individualised organisational cultures prevail, such participation may be difficult to maintain (Soetens et al., 2023).

Cecosesola prioritises price stability and accessibility over competitiveness and growth. In environments where performance is primarily assessed through efficiency or profitability indicators, these benefits may be undervalued (Soetens et al., 2023).

Finally, regulatory frameworks governing food safety, competition and public procurement in the EU are largely designed around private enterprises or public authorities (Helfrich, 2015; Soetens et al., 2023) and usually serve as a barrier to commons-based initiatives. Commons-based provisioning arrangements that combine collective governance with market activity may face legal uncertainty, particularly with respect to pricing mechanisms, liability and eligibility for public support.

5. References

Press

Right Livelihood. (2022, September 29). *2022 Right Livelihood laureates lead the way on changing broken systems.* https://rightlivelihood.org/news/2022-right-livelihood-laureates-lead-the-way-on-changing-broken-systems/

Venezuelanalysis. (2025, August 12). *Agroecology is the alternative to the climate and civilization collapse.* https://venezuelanalysis.com/interviews/esquisa-omana-agroecology-is-the-alternative-to-the-climate-and-civilization-collapse/

Literature

Aguiton, A., Brunier, S., Kotras, B., Pessis, C., & Pinaud, S. (2025). *Comment les machines ont pris la terre: Enquêtes sur la mécanisation de l'agriculture et ses conséquences*. ENS Éditions. https://doi.org/10.4000/14q3l

Helfrich, S. (2015). 'We are one big conversation': Commoning in Venezuela. In D. Bollier & S. Helfrich (Eds.), *Patterns of commoning* (pp. 377–390). Commons Strategy Group.

Soetens, A., Huybrechts, B., & Bretos, I. (2023). Collective action and institutional entrepreneurship in the social and solidarity economy: The case of the Venezuelan cooperative Cecosesola. *Journal of Business Ethics, 185*(2), 369–384. https://doi.org/10.1007/s10551-022-05187-0

6. List of policy instruments

European Parliament & Council of the European Union. (2014). *Directive 2014/24/EU on public procurement.*

European Commission. (2020). *A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system* (COM/2020/381 final).

European Commission. (2020). *EU Biodiversity Strategy for 2030: Bringing nature back into our lives* (COM/2020/380 final).

European Commission. (2021). *A long-term vision for the EU's rural areas – Towards stronger, connected, resilient and prosperous rural areas by 2040* (COM/2021/345 final).

European Commission. (2021). *Social Economy Action Plan: Building an economy that works for people* (COM/2021/778 final).

European Parliament & Council of the European Union. (2021). *Regulation (EU) 2021/2115 establishing rules on support for CAP Strategic Plans*.

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Commons: L' Atelier Paysan

1. Introduction

In times of political uncertainty, it can be risky to have critical infrastructure rely on foreign actors. Especially when it comes to agriculture, it borders on the absurd that farmers in the 21st century must buy increasingly complex machinery just to keep farming, while simultaneously losing control over knowledge, tools, and autonomy. L'Atelier Paysan, a French cooperative of farmers, technicians, and educators, responds by developing farmer-driven open tools and construction plans so that smallholders can build equipment themselves rather than rely solely on industrial suppliers (Atelier Paysan, 2018). Instead of pursuing technological novelty for its own sake, the initiative redistributes design capacity through fabrication workshops, collaborative tool development and openly accessible manuals. Pantazis & Meyer describe this as commons-based peer production using 'convivial tools' that can be modified and repaired by users (Pantazis & Meyer, 2020).

Atelier Paysan situates its work within a broader critique of agricultural mechanisation. *Observations sur les technologies agricoles* documents rising dependency on commercial machinery and erosion of practical repair knowledge (Atelier Paysan, 2021*)*, while *Comment les machines ont pris la terre* traces how mechanisation historically centralised technological control (Aguiton et al., 2025). Open-hardware designs are presented as one response to this trend, maintaining technological sovereignty at farm level and enabling low-cost, adaptable equipment to be built locally.

This profile treats Atelier Paysan as a European socio-technical innovation with relevance for agroecological transition. The following sections describe the case, its diffusion mechanisms, and barriers to broader implementation.

2. Case Study: Atelier Paysan

Atelier Paysan was formed in France to address the technical needs of small and medium-scale farms insufficiently served by commercial machinery markets. Industrial equipment is typically standardised and optimised for large-scale monoculture, while farms operating in diversified or agroecological modes require adaptable tools and the ability to repair or modify them independently (Atelier

Paysan, 2018). The initiative arose from collaboration between farmers and technicians who recognised that technical knowledge and fabrication capacity had gradually shifted away from producers to manufacturers.

The initiative operates as a cooperative bringing together farmers, engineers and educators. Members participate in tool development, workshop facilitation and documentation efforts, enabling knowledge to circulate horizontally rather than through proprietary channels. The cooperative model distributes responsibility for design and implementation, and positions farmers as active contributors rather than end-users of machinery.

Central activities include multi-day fabrication workshops in which participants build tools collectively, gaining technical skills in metalworking, assembly and adaptation. Workshops result in a finished implement and trained participants capable of reproduction. In parallel, the cooperative maintains a growing repository of manuals, schematics and technical notes. These describe dimensions, required materials and assembly procedures in sufficient detail for independent construction, and include guidance for safety and modification.

The initiative has developed a set of open-hardware designs which can be fabricated locally. Manuals and schematics function as public technical resources and form the basis of a tool commons. The emphasis is not on releasing a finished product, but on enabling adaptation and incremental improvement.

Atelier Paysan is embedded in French farming contexts characterised by mechanisation, input dependency and declining on-farm repair culture. Its publications highlight how industrialisation of equipment increased financial and technical dependency while reducing practical autonomy (Atelier Paysan, 2021; Aguiton et al., 2025). The case represents a situated countermodel in which skills and design competence remain accessible within rural communities.

3. Deployment, Diffusion, Amplification

Deployment occurs primarily through training and documentation rather than product distribution. Adoption begins when farmers participate in workshops and gain fabrication skills, enabling immediate tool use and long-term reproduction.

Workshops are the main deployment channel. Participants acquire hands-on experience and build tools suited to specific farm needs. This mode embeds technical learning within practice and avoids dependence on external machinery providers. Knowledge transfer is therefore embodied rather than informational only (Atelier Paysan, 2018).

Diffusion occurs via open documentation and peer-to-peer spread. Manuals and design files are publicly accessible, allowing tools to be reproduced by users beyond workshop contexts. Because replication does not require licensing or purchase, diffusion operates as knowledge circulation. Tool plans include material lists and technical parameters, enabling local fabrication in metal workshops or community settings (Atelier Paysan, 2018).

Diffusion expands through farmer-to-farmer exchange as users share adaptations and improvements. This horizontal dynamic enables context-specific modification instead of standardisation (Atelier Paysan, 2018). Contributions can feed back into documentation, forming a cumulative incremental improvement cycle.

Amplification depends on extending competencies rather than organisational scale. Integration into agricultural education, advisory services or rural maker infrastructures could increase uptake (Atelier Paysan, 2021). Alignment with agroecological policy environments further suggests opportunity for adoption in similar European regions. Because outputs are knowledge-based, expansion does not require manufacturing capacity but rather access to training and fabrication spaces.

European policies that could assist commoning as practiced by Atelier Paysan include the eco-schemes under the CAP and measures under the European Innovation Partnership 'Agricultural Productivity and Sustainability.'

4. Barriers

Participation requires time, interest in collective learning and access to basic workshop literacy. For farms with labour constraints or high opportunity costs, workshop attendance can be difficult. Skills required for tool modification and repair are unevenly distributed across producers, and diffusion may therefore be concentrated within communities already oriented towards agroecological or diversified practices (Atelier Paysan, 2018).

With regard to economic barriers, although open-hardware tools reduce financial dependence on commercial equipment, fabrication requires materials and access to workshops. Initial costs and technical risk may discourage uptake where economic margins are narrow. The cooperative relies on training income and membership rather than product sales, which supports autonomy but limits organisational growth capacity (Atelier Paysan, 2018; Atelier Paysan, 2021).

Self-built tools may not fit smoothly into certification systems designed for commercial machinery. Regulatory ambiguity can complicate integration into advisory services or subsidy programmes. Dominant agricultural markets continue to support proprietary equipment, and input-bundled technologies may remain economically or administratively favoured (Atelier Paysan, 2021).

Mechanisation has created long-term dependencies on specific equipment types and higher adaptability. Diffusion therefore amplifies most readily within small- to mid-scale contexts aligned with diversified production (Aguiton et al., 2025).

5. References

Atelier Paysan. (2018). Atelier Paysan – English overview document.

Atelier Paysan. (2021). Observations sur les technologies agricoles.

Aguiton, A., Brunier, S., Kotras, B., Pessis, C., & Pinaud, S. (2025). Comment les machines ont pris la terre. ENS Éditions.

Pantazis, A., & Meyer, M. (2020). Tools from below: Making agricultural machines convivial.

MacPherson, J., Rotz, S., Bronson, K., & Duncan, E. (2022). Building sustainable agricultural futures in the digital age: An integrative review. Futures, 143, 103030. https://link.springer.com/content/pdf/10.1007/s13593-022-00792-6.pdf

6. List of policy instruments

European Commission. (2020). *EU Biodiversity Strategy for 2030: Bringing nature back into our lives* (COM(2020) 380 final)

European Commission. (2021). *A long-term vision for the EU's rural areas – Towards stronger, connected, resilient and prosperous rural areas by 2040* (COM(2021) 345 final)

European Parliament & Council of the European Union. (2021). *Regulation (EU) 2021/2115 establishing rules on support for CAP Strategic Plans*

European Commission. (2020). *Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery* (COM(2020) 102 final)

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Community seed banks

1. Introduction

Community seed banks are usually small-scale institutions that store seed on a short-term basis and serve individual and neighbouring communities and citizen networks. Part of a diversity of community level seed-saving initiatives, they emerged in the early 80s in many parts of the world, with various forms and functions. Usually informal, locally governed and managed, they may handle a variety of local varieties and other crops. They aim to address the loss of agricultural diversity and enhance access to seeds adapted to local conditions. Many have a strong political aspect, aiming to regain, maintain and increase the control of farmers and local communities over seeds against the commercialisation of the food and seed system, and establish cooperation networks among farmers and those involved in the conservation and sustainable use of biodiversity (Vernooy et al., 2015). They often depend on the unpaid labour of their members and promote a participatory approach to crop management.

Community seed banks are part of informal or local seed systems. While formal seed systems appeared in the 20th century with the professionalisation of plant breeding and the emergence of the commercial seed sector, and are similar throughout the world, informal seed systems have been around since the beginning of agricultural history and are based on seed saving and customary exchanges. Formal seed systems involve a clearly constructed and regulated chain of activities, usually starting with plant breeding and selection, resulting in different types of varieties, including hybrids, and leading to variety certification and marketing. They aim to produce seed of optimal physical, physiological and sanitary quality, and to maintain the identity and purity of the variety. Seeds are usually protected by intellectual property rights, and marketing and distribution takes place through official outlets. In contrast, seeds of informal varieties may be heterogeneous and of variable quality and are in the public domain, while seed-related activities are guided by local knowledge and social norms (Tsioumani, 2020).

Modern agriculture based on commercial seeds led to monocultures and the erosion of agricultural biodiversity, while also leading to the marginalisation of farmers' innovation and seed systems. Informal seed systems, however, are still of crucial importance for subsistence agriculture in developing countries. Extensive literature shows their importance for smallholders' livelihoods, as well as their role in building ecological and socio-economic resilience, promoting biodiversity conservation, supporting community cohesion, and even sustaining peace in countries affected by conflict.

In recent years, community seed banks have attracted renewed interest in the developed world too, as a means towards conservation and sustainable use of agricultural biodiversity, access to healthy and quality food, public awareness of biodiversity values, and public participation in natural resource management. Community seed banks are a scalable tool, largely depending on local social and climatic conditions. Several diverse seed-saver groups and associations, which manage seed banks and are involved in seed exchanges, have been established in Europe, operating in Austria, France, Germany, Greece, the Netherlands, Ireland, Italy, Spain, and the UK (Koller et al, 2017). Little has been written on community seed banks in Europe, with most work having been conducted in the framework of the Horizon Diversifood project.

2. Case study: Seed Network 'Resembrando e Intercambiando' (Spain)

The Seed Network 'Resembrando e Intercambiando' (Resowing and Exchanging), an association that brings together more than 20 local seed networks throughout Spain, is a decentralised organisation with a technical, social and political dimension. Active since the late 1990s, its main objectives are the reintroduction of local, traditional and farmers' varieties in the agri-food system, in the context of agro-ecology, food autonomy, small-scale production and short supply channels. The association coordinates the activities among the local seed networks, aiming at promoting their participation in seed-related decision-making at the national and international level.

Its members, participating in the local seed networks, come from diverse backgrounds. They include farmers and farmer organisations, gardeners, students, researchers, local and activist groups, and individuals interested in responsible consumption and a fair agrifood system. Most local groups have developed community seed banks, aiming to promote access, production and exchange of seeds among farmers, promote local and traditional varieties among consumers, raise public awareness about agricultural biodiversity, and enable its conservation and sustainable use. The association organises different training activities at the national level, aiming to develop the skills and tools required for the management of the various community seed banks (Koller et al, 2017).

3. Deployment, diffusion, amplification

Community seed banks operate in diverse circumstances and legal and policy contexts around the world. They contribute to the achievement of global goals related to the conservation and sustainable use of agricultural biodiversity under the Convention on Biological Diversity (CBD) and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), and to the implementation of farmers' rights under the ITPGRFA and the UN Declaration on the Rights of Peasants (Tsioumani, 2020). In recognition of this contribution, promising policy changes have been initiated in several countries globally (Vernooy et al., 2015). This is not the case in Europe, however, where their potential remains largely untapped due to a hostile legal and policy framework, as noted in the following section. Overall, increased awareness among policymakers is needed, aiming at the integration of community seed banks into a broader framework of policies and strategies for agro-biodiversity conservation.

In this regard, policy and legal support should allow community seed banks to operate as legitimate and viable seed-sector actors, if they choose to do so. As formulated by Vernooy et al. (2024), following extensive work on the topic, policy recommendations include:

- creating a legal space for the recognition of community seed banks as a type of association or civil society organisation;
- addressing the multiple roles that community seed banks can play in national laws and policies on the conservation and sustainable use of agricultural biodiversity and related funding; and
- promoting collaboration between national genebanks and community seed banks.

As community seed banks are knowledge-, resource-, and time-intensive organisations that operate through their members' voluntary contributions, the greatest challenge they face relates to their long-term organisational viability and economic sustainability. A number of enabling conditions would support their sustainable operation: legal recognition and protection, options for financial viability, members with adequate technical knowledge and effective operational mechanisms.

4. Barriers

Vernooy et al. (2024) have identified five strategies that can support viable community seed bank development: value addition; nature-positive agriculture; national genebank partnership; networking and digitalisation; and modern, low-cost seed quality technologies.

One of the technical challenges that community seed banks face is effective seed storage for one to a few years. Most community seed banks use local materials and traditional practices for storing seeds and seedlings, and for dealing with factors that affect seed quality. These methods generally work but can be complemented by modern ones to increase efficiency and reduce the manual labour required.

Most importantly, these strategies often face economic and regulatory barriers. Development of value addition and income-generating opportunities, for instance, could build on activities directly related to the community seed bank, including seed sales. Seed sales, however, remain a challenge in many countries due to financial, organisational, and policy and legal issues. A key problem remains the difficulty or impossibility of registering farmer-selected or farmer-improved varieties in the national catalogues. In the EU, these seeds would fall under the directives on the so-called 'conservation varieties'. While these directives were designed to soften the requirements for the recognition and inclusion of such varieties in national seed catalogues, therefore allowing their sale and thus supporting the conservation and sustainable use of agricultural biodiversity, they remain too restrictive in terms of scope and allowed production and commercialisation, and involve a highly complicated approval process (Tsioumani, 2020, pp. 80-81).

5. References

Koller, B., Bartha, B., Bocci, R., Carrascosa, M., Riviére, P. & Andersen, R. (2017). *Community Seed Banks in Europe: Report from a stakeholder workshop in the* *framework of the Diversifood project*. https://diversifood.eu/community-seed-banks-in-europe/

Tsioumani, E. (2020). *Fair and Equitable Benefit-Sharing in Agriculture: Reinventing Agrarian Justice* (1st ed.). Routledge. https://doi.org/10.4324/9780429198304

Vernooy, R., Shrestha, P., & Sthapit, B. R. (2015). *Community seed banks: Origins, evolution and prospects*. Routledge. https://doi.org/10.4324/9781315886329

Vernooy, R., Adokorach, J., Gupta, A., Otieno, G., Rana, J., Shrestha, P., & Subedi, A. (2024). Promising Strategies to Enhance the Sustainability of Community Seed Banks. *Sustainability*, *16*(19), 8665. https://doi.org/10.3390/su16198665

6. List of policy instruments

Convention on Biological Diversity (CBD), Rio de Janeiro (Brazil), 5 June 1992, in force 29 Dec. 1993

International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), Rome (Italy), 3 November 2001, in force 29 June 2004

UN Declaration on the Rights of Peasants and Other People Working in Rural Areas, Resolution A/HRC/RES/39/12, adopted by the Human Rights Council on 28 September 2018

Council Directive 2002/53/EC of 13 June 2002 on the Common Catalogue of Varieties of Agricultural Plant Species [2002] OJ L 193/1

Council Directive 2002/55/EC of 13 June 2002 on the Marketing of Vegetable Seed [2002] OJ L 193/33

Commission Directive 2009/145/EC of 26 November 2009 Providing for Certain Derogations, for Acceptance of Vegetable Landraces and Varieties which have been Traditionally Grown in Particular Localities and Regions and are Threatened by Genetic Erosion and of Vegetable Varieties with No Intrinsic Value for Commercial Crop Production but Developed for Growing under Particular Conditions and for Marketing of Seed of those Landraces and varieties [2009] OJ L 312/44

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Digital communities and platforms for biodiversity education and knowledge sharing

1. Introduction

Digital communities and platforms have become increasingly important tools for biodiversity education and knowledge sharing, particularly as environmental challenges grow in scale and urgency. In this context, digital platforms refer to online spaces that host learning materials, data, and resources related to biodiversity, while digital communities comprise the individuals and organisations that access, contribute to, and interact within these spaces. Such platforms range from structured educational websites and online courses, such as PLANET4B's 'Care-Full' courses or Open University's free courses on Nature and Environment, to more interactive spaces including discussion forums, social media groups, and biodiversity-focused mobile applications.

One of the key strengths of digital platforms is their ability to connect people across geographical boundaries, enabling the formation of large, distributed communities of practice. These communities can foster a sense of collective identity among like-minded individuals who share concerns about biodiversity loss and environmental sustainability (Torres et al., 2022). Through dialogue, collaboration, and the exchange of ideas, digital communities can facilitate the sharing of solutions, support collective learning, and amplify voices that advocate for environmental action. At scale, these spaces also have the potential to influence public discourse and policy by mobilising shared knowledge and coordinated engagement.

Digital platforms also play a critical role in expanding access to education (Huang et al., 2023). By providing flexible, open or low-cost learning resources, they can reduce barriers associated with formal education systems and increase equity in access to biodiversity knowledge. This openness supports wider awareness of biodiversity, its ongoing decline, and the actions that individuals, organisations, and governments can take to address these challenges. Importantly, digital platforms can be targeted to diverse audiences, including policymakers, business leaders, educators, researchers, citizen science communities, and the general public, allowing content to be tailored to differing levels of expertise and interests.

In addition, digital communities offer opportunities to preserve and share traditional and local ecological knowledge, particularly where communities are able to document practices, observations, and narratives that may otherwise be marginalised or lost (Johnson et al., 2021). Beyond education alone, virtual research environments represent a further evolution of digital communities, providing shared online infrastructures for collaboration, data access, and analytical tools (Freitas & Gouveia, 2025). These environments support transdisciplinary research and collective problem-solving, reinforcing the role of digital platforms as enablers of both knowledge production and knowledge exchange within biodiversity conservation.

Digital communities and platforms are highly scalable as they can be adapted to address different concerns and can be accessed from any location by large numbers of people. They are considered an innovation as they are making use of the increased access to digital technology to provide novel ways of engaging communities and sharing information at large scales.

2. Case study: Global learning in Agriculture Community

The Global Learning in Agriculture Community (GLAC) is a long-running digital community of practice that supports education for sustainable development, with strong relevance to biodiversity, agroecology, and sustainable land use. Established in 2014 as part of the Global Teach Ag Network, GLAC provides an online space for educators, researchers, and practitioners to share knowledge, develop skills, and collaborate around agricultural sustainability challenges (Foster & Foster, 2024). Although global in scope, the community is highly relevant in a European context due to its focus on biodiversity-friendly agriculture, education, and knowledge exchange aligned with EU sustainability priorities.

GLAC operates primarily through digital professional development activities, including regular webinars, workshops, and facilitated discussions hosted on online platforms. These events focus on topics such as agroecology, climate change, food systems, land stewardship, and biodiversity conservation within agricultural landscapes. Participation is open and free, significantly lowering barriers to access for educators and practitioners who may otherwise have limited opportunities for professional learning, including those in under-resourced or rural contexts. For some participants, GLAC represents their only sustained access to educator-focused sustainability training.

A defining feature of GLAC is its emphasis on community-building rather than content delivery alone. The platform fosters peer-to-peer learning, dialogue, and reflection, allowing participants to exchange experiences, teaching approaches, and locally grounded knowledge. This social learning approach supports a sense of shared identity and collective purpose, reinforcing educators' roles as change agents in promoting biodiversity awareness and sustainable practices. Through repeated engagement, trust and long-term relationships are built among participants, enabling deeper learning and collaboration than one-off digital courses often achieve.

While not exclusively focused on biodiversity, GLAC integrates biodiversity conservation within broader discussions of sustainable agriculture and food systems, reflecting the interconnected nature of environmental challenges. In doing so, it supports the sharing of both scientific and practical knowledge and creates space for diverse perspectives, including local and traditional understandings of land management. Evaluations of the community highlight its success in building capacity, enhancing confidence, and encouraging participants to embed sustainability and biodiversity themes within their own educational and professional contexts (Foster & Foster, 2024).

3. Deployment, diffusion, amplification

The effective deployment of digital communities and platforms for biodiversity education depends on the design of accessible, engaging and purposeful learning experiences. Courses and learning activities must be carefully structured to suit online environments, with appropriate length, clarity of objectives, and content that aligns with the needs and motivations of learners. Short, modular formats can support sustained engagement, while clear links between biodiversity concepts and real-world challenges, such as food systems, land use, and climate change, help maintain relevance. Platforms like GLAC demonstrate the value of focusing on educator-oriented content that balances theoretical understanding with practical application.

Diffusion of digital learning initiatives is strengthened by free or low-cost access and proactive efforts to raise awareness. Open access to courses and learning resources helps reduce financial and institutional barriers, enabling participation by individuals and communities who may otherwise be excluded from formal education or professional development opportunities. Dissemination through existing networks, partner organisations, social media, and policy-aligned channels can significantly increase reach. In the case of GLAC, long-term growth has been supported by consistent communication, trust-based partnerships, and repeated contact points that maintain visibility and encourage continued involvement.

Amplification of impact further relies on flexible and adaptive learning pathways that recognise diverse learner contexts. Digital platforms are well placed to offer asynchronous participation, recorded sessions, and self-paced materials that accommodate different time constraints, learning styles and levels of prior knowledge. Adaptability also allows learning to be localised, enabling participants to interpret biodiversity concepts through their own social, cultural and environmental contexts. Incorporating elements of gamification, such as challenges, badges, progress tracking, or collaborative tasks, can further enhance motivation and participation, particularly among younger audiences, while reinforcing learning outcomes through interaction and play.

Digital communities have a crucial role to play in increasing equitable access to biodiversity education. While digital platforms alone cannot overcome structural inequalities, deliberate attention to inclusivity – such as low-bandwidth resources, accessible language, and supportive facilitation – can help broaden participation. By prioritising openness, flexibility and sustained community engagement, digital platforms can amplify biodiversity knowledge beyond individual learners, fostering wider awareness, shared understanding and collective capacity to respond to biodiversity loss

EU policy frameworks can influence the development and uptake of digital communities and platforms for biodiversity education. The European Green Deal and the EU Biodiversity Strategy for 2030 embed biodiversity awareness within broader sustainability and education agendas, encouraging the integration of digital tools for knowledge sharing and citizen engagement. The Nature Restoration Regulation reinforces this by mandating restoration targets supported by digital monitoring systems, creating demand for community-based platforms to collect and disseminate data. Complementing these environmental measures, the Digital Education Action Plan 2021–2027 promotes digital learning infrastructure and resources, enabling educators and learners to access biodiversity content through online hubs and collaborative spaces. Funding instruments such as Horizon Europe's 'Digital for Nature' calls and the Biodiversa+ Partnership provide financial and technical support for innovative digital solutions, while EU-backed citizen science initiatives standardise protocols and enhance interoperability across platforms. Collectively, these policies create an enabling environment for scalable, inclusive, and data-driven digital communities that advance biodiversity education and public participation.

4. Barriers

Digital communities and platforms for biodiversity education face a range of social and economic barriers, most notably related to the persistence of the digital divide (Huang et al., 2023). Inequitable access to digital resources, such as computers, smartphones, or suitable software, limits participation for some individuals and communities, particularly those in low-income, rural, or marginalised contexts (Johnson et al., 2021). These inequalities are often compounded by the lack of reliable infrastructure, including stable internet connections and, in some regions, consistent power supply. Such constraints can prevent meaningful engagement with online courses, webinars, or interactive learning environments, reinforcing existing disparities in access to education and environmental knowledge.

Time constraints also present a significant barrier to participation. Many potential learners – such as educators, practitioners, and community members – balance professional responsibilities, caregiving duties, and other commitments that limit their capacity to engage with digital learning opportunities. Where courses require sustained participation or long-time commitments, exclusion can occur unintentionally. Additionally, a lack of awareness of available courses and platforms reduces uptake, particularly when learning opportunities are not embedded within established professional networks or promoted through trusted channels. Cultural differences, language barriers and mistrust or disagreement over knowledge or data ownership can also prevent engagement with online platforms and communities (Huang et al., 2023; Johnson et al., 2021).

Further barriers arise from misalignment between available digital offerings and learner interests or needs. In some cases, biodiversity-related courses may be too generic, overly technical, or insufficiently relevant to learners' local contexts, professional roles, or lived experiences. Platforms that do not provide adaptable, culturally relevant, or practice-oriented content risk disengagement, even where technical access is available. From a regulatory and institutional perspective, limited recognition of informal or non-formal digital learning – such as online communities of practice – within professional development frameworks can reduce incentives to participate. Together, these barriers highlight the importance of intentional platform design, inclusive resourcing, flexible delivery, and targeted outreach to ensure that digital communities for biodiversity education are accessible, relevant, and equitable.

5. References

Foster, M. M., & Foster, D. (2024). The Global Learning in Agriculture Community: A Digital Community of Practice to Support Education for Sustainable Development. In *Digital Technologies to Implement the UN Sustainable Development Goals* (pp. 153–169).

Freitas, H., & Gouveia, A. C. (2025). Biodiversity futures: digital approaches to knowledge and conservation of biological diversity. *Web Ecology*, *25*(1), 29–37. https://doi.org/10.5194/we-25-29-2025

Huang, X., Li, H., Huang, L., & Jiang, T. (2023). Research on the development and innovation of online education based on digital knowledge sharing community. *BMC Psychology*, *11*(1). https://doi.org/10.1186/s40359-023-01337-6

Johnson, N., Druckenmiller, M. L., Danielsen, F., & Pulsifer, P. L. (2021). The Use of Digital Platforms for Community-Based Monitoring. *BioScience*, *71*(5), 452–466. https://doi.org/10.1093/BIOSCI/BIAA162

Torres, A. C., Bedessem, B., Deguines, N., & Fontaine, C. (2022). Online data sharing with virtual social interactions favor scientific and educational successes in a biodiversity citizen science project. *Journal of Responsible Innovation*. https://doi.org/10.1080/23299460.2021.2019970

6. List of policy instruments

Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, The European Green Deal, COM/2019/640 final

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Biodiversity Strategy for 2030 Bringing nature back into our lives, COM/2020/380 final

Regulation (EU) 2024/1991 of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 [2024] OJ L178/1

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Digital Education Action Plan 2021-2027 Resetting education and training for the digital age, COM/2020/ 624 final

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Forest schools

1. Introduction

Growing out of a diverse range of educational and outdoor learning backgrounds and practices, Forest School (FS) is a popular outdoor education model with international reach that develops a range of personal qualities and experiences in natural learning environments (Garden & Downes, 2023). It sits under the broad umbrella of outdoor learning and is distinguished from other outdoor learning models by a set of principles which frame it as a long-term nature-based, holistic and learner-centred process, professionally led, small group-based and supportive of risk-taking.

As a nature pedagogy, FS supports learning, behaviour, physical and emotional wellbeing, and deeper relationships with the natural world (Cree & Robb, 2021). Benefits are evidenced as wide-reaching and include increased self-confidence and self-esteem, independence, empathy, collaboration, written and spoken language skills and academic achievement, participation and focus, stamina, fine and gross motor skills, and interest in and respect/care for nature and the environment. FS is predominantly aimed at children, and while benefits cut across all ages and abilities, application and related research leans towards Early Years and primary age and additional needs groups (SEND, SEMH).

Alongside the benefits of being an inclusive child education model, FS is valued as a grassroots model aligned with various environmental and child-in-nature related movements. Studies show a correlation between FS attendance and increased care for the natural world (Harris, 2021). The importance of direct experiences of nature and a sense of care for the environment, particularly fostered during childhood, are increasingly recognised as vital on a societal level for responding to present and future climate and biodiversity breakdown.

In application since the 1950s, FS originally emerged in Denmark as a childcare solution and expanded globally with application in diverse regional and cultural settings, predominantly in Europe (particularly Scandinavia and UK), North America and more recently in Asia and Australia. Expansion has been fuelled by a growing consensus amongst educationalists, researchers, policymakers, health workers and parents that child disconnection from the natural world is rising and negatively affecting physical, mental and emotional outcomes – a trend associated with the term nature-deficit disorder (Louv, 2005).

Although widely in application, the practice has evolved with a high level of heterogeneity in its diverse range of providers (nurseries, schools, commercial and not-for-profits), its application both within and outside formal education structures and how it is structured (Garden & Downes, 2023). Variations range from full-time day-long FS nurseries to 'good practice minimum' of 1.5-2 hours weekly or fortnightly over several months, through to tokenistic FS titled experiences that are ad hoc and untrue to other core principles. This heterogeneity contributes to highly limited and inconsistent data on FS at national and international levels, including numbers of providers, settings and participants.

The rapid proliferation of FS from pioneer countries to newer regions demonstrates the potential for scaling the practice across different socio-cultural and regional contexts. Although highly place-based, FS adapts well to diverse environments and settings. Initially developed for nature-rich settings such as woodlands, forests and nature reserves, FS is routinely adapted to urban settings, including city parks, school/nursery grounds, community allotments, even cemeteries and beaches (variant called Beach School). As a continuous all-year-round and all-weather practice, FS is well suited to climatically and seasonally varied locations.

FS is a novel outdoor learning/ education model that aims to create a more equitable, holistic and nature-immersed learning experience than current mainstream education with the aim of improving human (specifically child) health, wellbeing, development and more-than-human relationships and care. It leans into growing global interest and discourse relating to declining child nature-based experience, particularly within countries where indoor and screen-based time is rising.

A highly creative and collaborative social innovation, FS is rooted in interdisciplinary methods (tool-work, games, problem solving, teamwork, arts and crafts, storytelling and physicality) and relies on direct collaboration between practitioners, participants, natural space managers/ owners, educational leaders/ managers, and/ or parents. It embraces an alternative approach to education, countering mainstream education's focus on academic progress and challenging assumptions and norms about where education can and should occur (space), how it happens (practice and structures), and why (values), by reinstating the value of play, self-discovery, Nature experience, imagination and individual agency.

2. Case Study: An ethnographic study of Forest School experiences

A 2024 novel ethnographic case study explored experiences of 25 autistic children (mean age 9.8 years) undertaking an FS programme at their specialist school in England (Friedman et al., 2024). The FS, based in school grounds, comprised two log circle areas, a variety of trees and plants and a pond. Sessions were led by a Level 3 FS Leader and Level 2 FS assistant, both school employees and experienced in FS and working with autistic children. Session format began with group circle time, followed by child-led play/ activity and concluded with final closing circle time. The FS leaders carried out site safety checks prior to sessions, and children were taught to assess for risks relating to the site and activities (climbing trees, pond, tool use). Tools were available (e.g. hammers, knives, and spades) with adult permission and supervision. Based on the research, several themes emerged, highlighting potential benefits of FS participation, as well as features that influence the enjoyment of FS participants:

Excitement and freedom of being beyond four walls: Benefits to children included the uniqueness of the environment, expectations, sense of freedom to explore and freedom from judgment and rules compared to a typical school format. Although held on school grounds, FS was viewed as 'a world of its own' and a place for adventure, imaginative play, games, and storytelling and movement, where children could satisfy their 'sensory needs in a non-stigmatising or disruptive way' e.g. using hammocks, swings, mud play.

FS affords opportunities for positive development: Different types of play (individual and group), skill development (social, practical and motor) and nature connection were observed, leading to new competencies and relatedness. 'Some parents valued Forest School 'as one of the only opportunities for their child to get outside and engage with nature' (Friedman et al., 2024, p. 208). Children experienced place attachment, becoming familiar with the site, natural features and changes (weather, other users) and gaining a sense of ownership, such as Oliver, who said, ‘I remember that in the Forest School [site], I have a tree to myself … it’s called [Oliver’s] tree.’ (Friedman et al., 2024, p. 208).

Feelings regarding nature and FS are conditional and subject to change: It was noted that the weather and mood of the children influenced FS experiences positively and negatively, whilst some (not all) felt nature helped them feel calmer if they felt emotionally down, one child stating ‘when I’m in Forest School, it makes me happy’ (Friedman et al., 2024, p. 209). Although largely positive, researchers observed examples where children did not settle, wished to leave (absconded) and moments of peer and teacher conflict. Parents' views ranged from recognising FS is not a guarantee for good days/ behaviour, to perceiving their child as happier than usual at FS, and even the happiest they ever are at school.

Rituals are important for all but must be tailored: As with these child participants, creating and maintaining rituals and related routines was key to harnessing benefits, rituals centred around fire (fire making and outdoor cooking), food (marshmallows and damper bread), recurring games and ‘movement patterns’ (starting sessions with fire circle-based circle time). FS staff were key to maintaining key Forest School rituals.

Attitudes of adults help or hinder sessions: The researchers found that adult teaching and leadership style significantly influenced FS experience for the child 'creating either autonomy-supportive or autonomy-hindering contexts' (Friedman et al., 2024, p. 211). The FS embraced the child-centred model, intentionally shifting child-teacher dynamics, encouraging child autonomy and allowing appropriate risk-taking whilst avoiding harm and removing hazards.

Over the three months, researchers found FS 'provided autonomy to children, promoted competence through scaffolded skill development, and helped to facilitate relatedness through varied types of play and interaction' (Friedman et al., 2024, p. 211) and brought a range of benefits to child participants including play opportunity, physical activity, autonomy and skills development (practical, social and motor) but also challenges. Yet the FS experience was often contingent on influences of attending adults, maintaining rituals, weather conditions, individual mood and peer interactions.

Overall, the study offers insight and nuance of different child and parent experiences and views on FS that translate to other FS programmes and studies and inform 'best practice in supporting autistic children in Forest School settings.'

3. Deployment, diffusion, amplification

FS deployment is evident through growing international numbers of settings, trained practitioners, and participants. In areas where it remains fringe, most initiatives follow small-scale models of varied quality, though ambitious expansions – such as school trusts and local authorities introducing FS across multiple sites, or charities funding their own programmes (e.g. Child and Nature Alliance Canada) - are emerging. Diffusion appears in policies and practice when schools and nurseries integrate nature-based sessions, modify grounds for outdoor learning, or adopt hybrid models like Natural Thinkers (UK) and Nature Explore (US). Healthcare inclusion, such as NHS green prescribing referrals, additionally shows broader public-health uptake. However, diffusion carries risks of dilution: hybrid, 'naturelite' approaches may fit existing systems more easily but often reduce transformative impact and can become superficial tick-box exercises.

Amplification is strongest in Denmark (Skovbørnehaver), Germany (Waldkindergarten), New Zealand, and the Republic of Korea, where forest-inspired kindergartens are integrated into mainstream early years provision through funding, legal frameworks and social norms. Yet amplification remains regionally limited, tied to shifts in national education systems, health programmes, urban planning, and legislative changes – such as Scotland's Outdoor Residential Education Bill that passed in 2025. Crucially, the transformative nature of FS pedagogy – fostering deep emotional and ecological literacy – amplifies its long-term impact: children who develop pro-environmental attitudes and behaviours during these formative experiences are likely to carry these values into adulthood, multiplying benefits for biodiversity and sustainability as they grow.

EU policy frameworks indirectly support FS amplification by embedding nature-based education within sustainability, health and child development agendas. The European Green Deal and EU Biodiversity Strategy for 2030 encourage environmental awareness and citizen engagement, creating space for outdoor learning initiatives. The European Education Area and Council Recommendation on

Learning for the Green Transition promote integrating sustainability across curricula, aligning with FS principles.

Funding streams such as Horizon Europe and Erasmus+ enable research, innovation, and educator training in experiential and nature-based pedagogy, while urban greening and NbS under the EU Climate Adaptation Strategy provide enabling environments for outdoor learning. Importantly, human rights and legal frameworks reinforce these priorities: Article 29 of the United Nations Convention on the Rights of the Child (UNCRC) establishes every child's right to an education that develops respect for the natural environment, supporting the transformative ethos of the FS. Collectively, these measures create conditions for scaling FS models and embedding nature pedagogy within mainstream education and public health systems.

4. Barriers

Based on knowledge drawn from first-hand professional experience with FS, the barriers are numerous, and understanding the full transformative potential of FS as a social innovation is challenging. On several levels, FS principles impose inherent challenges to scalability and equity. At the individual level, adherence to core principles, such as child-led learning, regular engagement, and immersion in biodiverse settings, is essential to unlock benefits. At a societal level, scalability and ripple-effect potential are shaped by complex social, economic, political, and cultural factors, particularly the degree to which FS is accessible, inclusive, and sustainable. Research remains limited and largely focused on educational and wellbeing outcomes for participants, with little exploration of FS as a driver for systemic change, such as its influence on family networks, school culture, educational systems, or biodiversity outcomes. Evidence on FS as a catalyst for rethinking spaces through nature-positive interventions, local greening projects, or dismantling structural barriers to green space access is scarce. This lack of research constrains advocacy and policy integration, leaving FS undervalued as a transformative innovation.

Dabaja (2023) identifies five challenges to FS implementation, including risk perceptions and outdoor attitudes; curriculum and stakeholder expectations; cost and logistics; site access; and administrative load (Dabaja, 2023, p.68). Access to biodiverse natural settings is the ideal, yet many schools – especially in urban areas – lack suitable spaces and face bureaucratic or financial hurdles when seeking external sites. Time constraints for teachers and families, cultural attitudes toward risk, weather, and achievement, and parental expectations for tangible outcomes further restrict uptake. Regional variations amplify these challenges: in some contexts, FS is embraced as a counterpoint to academic pressure, while in others, seasonal reluctance persists despite FS's all-weather ethos. Increasing societal disconnection from nature and the rise of digital entertainment further reduce cultural appetite for outdoor experiences.

Economic barriers compound these issues. FS is a high-value yet high-cost innovation. Delivery requires qualified practitioners, small group ratios, and resource-intensive setups, making it more expensive than conventional activities. School budgets are often constrained, and funding streams tend to be short-term or limited to small cohorts, undermining continuity – a core FS principle. Financial and logistical pressures lead schools to opt for on-site delivery rather than richer natural environments, limiting opportunities for deep nature connection, place attachment and potential ripple effects on public green space enhancement. Landowners and authorities often charge site fees to offset their own funding gaps or impose licensing arrangements, creating cost and administrative barriers. Commodification and dilution of FS practices – through low-cost, hybrid models – risk compromising quality and transformative impact. High insurance premiums and liability concerns add further costs, discouraging uptake.

Regulatory and structural barriers also play a role. Tensions between FS's child-led ethos and curriculum-driven systems limit integration within formal education (Harris, 2017). Off-curriculum positioning reduces institutional support and recognition, while monitoring and coordination remain weak. Despite widespread claims of FS prevalence in UK schools, only a small fraction are registered with the FS Association, indicating fragmented oversight and lack of systemic support. Broader structural issues – such as inequitable access to green spaces, urban safety concerns, and absence of policy frameworks for outdoor learning – further constrain scaling. Environmental degradation and climate change compound these challenges by reducing the availability of safe, biodiverse spaces for practice. Workforce capacity and training gaps add another layer: even where interest is high, there is a shortage of qualified practitioners, and training is time-intensive and costly, limiting scalability and quality assurance. Cultural norms around risk, achievement, and weather often conflict with FS principles, and parental expectations for visible outputs contrast with its process-oriented ethos. In some regions, safety concerns in urban parks or reluctance to embrace outdoor learning during winter months hinder uptake.

Collectively, these barriers highlight the need for intentional strategies to preserve FS integrity while addressing access, funding, liability, and policy alignment. Removing obstacles – such as site permissions, financial constraints, and systemic undervaluation – will be critical to realising FS's transformative potential for education, wellbeing, and biodiversity.

5. References

Cree, J., & Robb, M. (2021). *The Essential Guide to Forest School and Nature Pedagogy*. Routledge www.theoutdoorteacher.com

Dabaja, Z.F. (2023). The strands of the Forest School implementation challenges: A literature review, PRISM: Casting New Light on Learning, Theory and Practice, 6(1), pp. 63–77. https://doi.org/10.24377/prism.article667

Friedman, S., Gibson, J., Jones, C., & Hughes, C. (2024). 'A new adventure': a case study of autistic children at Forest School. *Journal of Adventure Education and Outdoor Learning*, *24*(2), 202–218. https://doi.org/10.1080/14729679.2022.2115522

Garden, A., & Downes, G. (2023). A systematic review of forest schools literature in England. *Education 3-13*, *51*(2), 320–336. https://doi.org/10.1080/03004279.2021.1971275

Harris, F. (2017). The nature of learning at forest school: practitioners' perspectives. Education 3-13, 45(2), 272–291. https://doi.org/10.1080/03004279.2015.1078833

Harris, F. (2021). Developing a relationship with nature and place: the potential role of forest school. *Environmental Education Research*, *27*(8), 1214–1228. https://doi.org/10.1080/13504622.2021.1896679

Louv, R. (2005). *Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder*. Algonquin Press.

6. List of policy instruments

Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, The European Green Deal, COM/2019/640 final

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Biodiversity Strategy for 2030 Bringing nature back into our lives, COM/2020/380 final

Council Recommendation of 16 June 2022 on learning for the green transition and sustainable development 2022/C 243/01, OJ C 243

Council Resolution on a strategic framework for European cooperation in education and training towards the European Education Area and beyond (2021-2030) 2021/C 66/01. (2021). *Official Journal*, C 66

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, New EU Forest Strategy for 2030, COM/2021/572 final

Regulation (EU) 2021/695 of the European Parliament and of the Council of 28 April 2021 establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination, and repealing Regulations (EU) No 1290/2013 and (EU) No 1291/2013, OJ L 170

UN General Assembly, Convention on the Rights of the Child, UNGA Res 44/25, UN Doc A/RES/44/25 (20 November 1989) art 29.

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Globally Important Agricultural Heritage Systems

1. Introduction

The Globally Important Agricultural Heritage Systems (GIAHS) programme was launched by the Food and Agriculture Organization of the UN (FAO) in 2002, in response to global threats to family farming and traditional agricultural systems due to climate change, urbanisation and community displacement, agricultural industrialisation and biodiversity loss. Aiming to strike a balance between conservation, adaptation to climate change and changing socio-economic conditions, and sustainable development, the programme helps mitigate the threats faced by farmers while enhancing the benefits of farming systems for environmental sustainability and community livelihoods.

In contrast to protected areas of various types that focus on the state of nature and biodiversity, including species and ecosystems, GIAHS are characterised as 'living heritage systems': they are inhabited by farming communities that have developed their agricultural ecosystem and maintain remarkable land-use systems in a close relationship with their territory. They are marked by significant agricultural biodiversity, rich traditional agricultural knowledge, distinct cultural characteristics, and community-based ecosystem management that supports food security and livelihoods.

Through the GIAHS programme, FAO has designated 104 systems in 29 countries. Of them, only 14 are in Europe: one in Andorra, two in Austria, three in Italy, six in Spain, and two in Portugal (FAO, n.d.). In many cases, GIAHS are under the management of resource-poor farmers with limited access to capital, technology or government services (Altieri & Koohafkan, 2003).

Being as it is quite context-specific, the GIAHS designation needs to satisfy a set of rigorous criteria, regarding the ingenuity, remarkability and global relevance of the agricultural ecosystem in question, its diversity, complexity and adaptive capacity, and sustainability of human-environment relations in the long term, as well as outstanding characteristics regarding biodiversity and ecosystem functioning, land and water management, food and livelihood security, social organisation and culture, traditional agricultural knowledge systems and technologies, and a proven history of sustainability. It could, however, support the last remaining and rapidly changing European agro-ecological systems in high-biodiversity areas with surviving agricultural traditions and communities, such as in the Mediterranean countries. This would require appropriate awareness building, policy, funding and capacity support.

2. Case study: Olive Groves of the Slopes between Assisi and Spoleto, Italy

Along the slopes of the Umbrian Valley from Assisi to Spoleto in Italy, a system of olive groves dating from the Roman Empire covers an area of 9213 hectares along six different municipalities. The olive-growing surface in this area is approximately 4570 hectares. It has spread uphill since the interest in olive trees resurfaced between the 16th and 17th centuries and extends in various terrace systems up the slope. The area is one of the most important areas in Italy for olive growing and is mainly based on a traditional terraces system. Different types of terraces play an important role in soil, water and landscape management, and serve as a defence against hydrogeological risk. In addition, the area's harsh micro-climate and terrain have favoured preservation. Low temperatures in winter that limit the productive potential of trees, together with the steepness of the slopes, have discouraged investments in modernising the olive groves.

The olive trees cultivated in the region come from traditional cultivars from three local varieties: Moraiolo, Frantoio and Leccino. The olive oil is produced using traditional techniques, the same that were used centuries ago (FAO, 2018). Traditional agricultural knowledge has thus allowed the farmers to produce high-quality olive oil sustainably for centuries, from seed selection and development of local varieties, to farming techniques and olive oil production.

The extra virgin olive oil produced has received an EU certification of Protected Designation of Origin (PDO) labelling. The aim of the PDO is to promote and certify the quality of the oil through the strict observance of the production regulations, ensure a greater profit for the farmer, and organise the sales chain so that the consumer has access to a quality product. The economy of olive oil production in Umbria is significant, with olive oil representing 5% of the region's gross marketable agricultural production, and involving about 27,000 farms and 270 oil mills.

In this context, a proposal for recognition of the system as a GIAHS was submitted by the Comune di Trevi in 2018, in collaboration with the responsible Ministry of Agriculture, Food and Forestry Policies of Italy, and was accordingly accepted by FAO. In accordance with the process set by FAO, an 'action plan for the dynamic preservation of the site' was developed through a participative method that involved the main regional and local institutions. It included: a preliminary analysis of threats and of the elements of vulnerability that compromised the system; strategic mitigation plans aiming to preserve sustainability of oil production; biodiversity conservation; preservation of know-how and technologies in use; preservation of crop orientation, historical memory and landscape value; and, monitoring indicators. A Management Committee was established with the participation of all relevant local and regional authorities, together with a scientific committee.

A 2025 study confirmed that this GIAHS-recognised agroecosystem provides diverse ecosystem services to local communities and protects habitats and related biodiversity while preserving landscapes of recognised cultural value. The authors concluded that the preservation of traditional agricultural landscapes with high complexity is crucial to maintain different microhabitats and to resist landscape homogenisation caused by agricultural intensification in rural areas (Piras et al., 2025).

3. Deployment, diffusion, amplification

The concept of GIAHS has gained renewed attention recently due to its contribution to sustainability while integrating environmental and socio-economic benefits. GIAHS recognition shows the relevance of cultural agro-ecological systems for biodiversity, agricultural production and livelihoods, while advocating the importance of social organisation and community innovation work for the development of sustainable human activities that have survived and co-adapt with the environment through time (García et al., 2020).

Considering that most of the European rural landscape is a cultural landscape, shaped by human agro-silvo-pastoral activities, the conservation of agricultural heritage systems should be considered as a pillar for biodiversity conservation (Piras et al., 2025), providing a viable alternative to agricultural intensification and monocultures. Cultural agro-ecological landscapes, supported by the GIAHS recognition, could further promote sustainable rural development and smallholder farmer livelihoods. This would advance key EU commitments and objectives under:

- the Common Agricultural Policy 2023-2027 - including its objectives to ensure a fair income for farmers, improve the position of farmers in the food chain, address climate change action and environmental care, preserve landscapes and biodiversity, promote vibrant rural areas, protect food and health quality, and foster knowledge and innovation;
- the Farm to Fork Strategy - including the main aim to develop a sustainable food system as essential to achieve the climate and environmental objectives of the Green Deal, while improving the incomes of primary producers and reinforcing EU's competitiveness; and
- the EU Biodiversity Strategy - including the commitment that, by 2030, at least 25% of agricultural land is under organic farming management, and the uptake of agro-ecological practices is significantly increased.

While the EU Biodiversity Strategy for 2030 does not seem to acknowledge and value the diversity of agricultural heritage systems for biodiversity, focusing rather on increasing the number and surface of protected areas (Piras et al., 2025), its provisions on agro-ecological practices can be used to promote their uptake and incentivise the increased recognition of GIAHS in Europe.

Agricultural heritage systems can also support the implementation of the 2024 Nature Restoration Regulation. Implementing the regulation, Member States need to put in place restoration measures necessary to enhance biodiversity in agricultural ecosystems, taking into account climate change, the social and economic needs of rural areas and the need to ensure sustainable agricultural production in the Union. The increased share of agricultural land with high-diversity landscape features is one of the indicators for restoring agricultural ecosystems (Art. 11). Promotion and improved deployment of GIAHS can also promote the achievement of the EU's and Member States' international commitments under GBF and the European Landscape Convention.

Designation of GIAHS in Europe remains limited, due to limited awareness, and capacity and funding constraints. On top of the rigorous criteria that the site needs to satisfy, designation depends on an onerous application process. However, policy and capacity support is currently lacking or is very much dependent upon national ministries' priorities and potential. The European Commission has recently highlighted the potential of the GIAHS programme and lessons learnt in a Commission Staff Working Document on Implementing the Strategic Guidelines on EU Aquaculture. As countries are required to improve how they plan and allocate space and water for aquaculture, it was noted that the GIAHS programme offers time-tested, community-driven examples, which show how food production can also support biodiversity conservation and cultural identity. The carp pond farming system of the Waldviertel region in Lower Austria, designated as a GIAHS in 2024, which combines low-intensity aquaculture with water conservation, flood control, and local economic development, was offered as an illustration.

Finally, the sustainability of agricultural production and community livelihoods in GIAHS can be further supported through EU quality schemes, including geographical indications, traditional specialities, and voluntary certification schemes, as illustrated by the Italian case study above. The 2024 regulation on geographical indications aims to introduce a single legal framework and a simplified registration procedure. It aims to empower producers' groups, recognise sustainable practices, and increase protection of geographical indications.

While policy and funding support is lacking, awareness could be improved by linking the GIAHS programme to existing EU policies for biodiversity conservation and rural development, such as the Nature Restoration Regulation and the EU quality schemes mentioned above. Certain funding opportunities are also available under current policy instruments, such as the Agroecology Partnership, funded by Horizon Europe. The Agroecology Partnership aims to support the agricultural sector to meet the targets and challenges of climate change, biodiversity loss, food security and sovereignty, and environmental sustainability, while ensuring a profitable and attractive activity for farmers.

4. Barriers

The GIAHS programme offers an alternative to agricultural intensification or intensive touristic development and an antidote to the abandonment of rural areas, proposing a sustainable development model for the areas satisfying the selection criteria. While the number of GIAHS has been increasing around the world, barriers to their full deployment concern the limited degree of awareness, limited capacity for project writing and implementation by the local communities concerned, and limited funding and policy support.

In addition, communities residing in GIAHS face difficulties regarding their dynamic conservation and adaptive management. A recent study has indicated common challenges related to poor monitoring across GIAHS with a potential impact on biodiversity- and livelihoods-related outcomes, highlighting: lack of monitoring guidelines; low enthusiasm of local communities about participation in management; lack of legal and financial support; and lack of technical scientific support and guidance (Jiao et al., 2022). At the same time, appropriate consultations and equitable governance arrangements are needed for the community to reap the most benefits from the arrangement and avoid conflicts.

5. References

Altieri, M. A., & Koohafkan, P. (2003). *Globally Important Ingenious Agricultural Heritage Systems (GIAHS): Extent, significance, and implications for development*. Proceedings of the Second International Workshop and Committee Meeting for the Globally Important Agricultural Heritage Systems (GIAHS) Project.

Food and Agriculture Organization of the United Nations (FAO) (n.d.). Europe and Central Asia. Globally Important Agricultural Heritage Systems. Retrieved January 17, 2026, from https://www.fao.org/giahs/regions/europe-and-central-asia/en

García, M. A., Yagüe, J. L., Nicolás, V. L. de, Díaz-Puente, J. M., García, M. A., Yagüe, J. L., Nicolás, V. L. de, & Díaz-Puente, J. M. (2020). Characterization of Globally Important Agricultural Heritage Systems (GIAHS) in Europe. *Sustainability*, *12*(4). https://doi.org/10.3390/su12041611

Jiao, W., Yang, X., Min, Q., Jiao, W., Yang, X., & Min, Q. (2022). A Review of the Progress in Globally Important Agricultural Heritage Systems (GIAHS) Monitoring. *Sustainability*, *14*(16). https://doi.org/10.3390/su14169958

Food and Agriculture Organization of the United Nations (2018). Olive Groves of the Slopes between Assisi and Spoleto, Italy. Globally Important Agricultural Heritage Systems. Retrieved January 17, 2026, from https://www.fao.org/giahs/giahs-around-the-world/italy-assisi-spoleto-olive-groves/en

Piras, F., Bazzurro, A., Fiore, B., Romano, F., & Santoro, A. (2025). Assessment of ecotone changes over the last six decades in two cultural landscapes: The case of the Prosecco Hills of Conegliano and Valdobbiadene UNESCO site and of the Olive Groves of the Slopes between Assisi and Spoleto GIAHS site. *Biodiversity and Conservation*, *34*(9), 3193–3210. https://doi.org/10.1007/s10531-023-02725-5

6. List of policy instruments

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Biodiversity Strategy for 2030: Bringing nature back into our lives, COM/2020/380 final

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A Farm to Fork Strategy for a fair, healthy and environmentally friendly food system, COM (2020) 381 final

Regulation (EU) 2024/1991 of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 [2024] OJ L178/1

Regulation (EU) 2024/1143 of the European Parliament and of the Council of 11 April 2024 on geographical indications for wine, spirit drinks and agricultural products, as well as traditional specialities guaranteed and optional quality terms for agricultural products, amending Regulations (EU) No 1308/2013, (EU) 2019/787 and (EU) 2019/1753 and repealing Regulation (EU) No 1151/2012 [2024] OJ L 2024/1143

Convention on Biological Diversity (CBD), Rio de Janeiro (Brazil), 5 June 1992, in force 29 Dec. 1993

Council of Europe Landscape Convention (ETS No. 176), Florence (Italy), 20 Oct. 2000, in force 1 March 2004, as amended by the 2016 Protocol (CETS No. 219)

Kunming-Montreal Global Biodiversity Framework, CBD/COP/DEC/15/4, 19 Dec. 2022.

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Indigenous and community conserved areas

1. Introduction

Indigenous and Community Conserved Areas (ICCAs) are natural and human-made sites, conserved and governed in a self-organised way through community values and practices, and customary norms and institutions. They include a diversity of areas occupied by Indigenous Peoples or local communities and managed sustainably for conservation and cultural purposes, with diverse manifestations and names in cultures and locations around the world. Examples include indigenous biocultural heritage territories, sacred forests and water springs, migration routes of mobile Indigenous Peoples, sustainable resource reserves and communities' fishing grounds (UNEP WCMC, 2010). For many custodian communities, the area represents identity, autonomy and freedom, connecting generations, preserving memories, imagining futures, and developing self-rule (Robson and Berkes, 2010).

The total size of such self-organised areas aiming towards conservation is poorly known. Known ICCAs are extremely diverse and protect an enormous range of natural environments, and agricultural and pastoral landscapes. They may be managed through a wide diversity of institutions and rules by either traditional or modern communities. Some have been traditionally conserved for thousands of years, while others represent the revival or adaptation of traditional practices.

ICCAs are characterised by the following features (ICCA Consortium, 2021):

- There is a close relationship between the community and the physical environment, embedded in history, identity, spirituality and/ or people's reliance on the territory for their material and non-material wellbeing;
- The custodian community makes decisions and has the power to enforce rules about the territory, resources and species through a functioning governance institution; and
- The governance decisions and management efforts of the concerned community contribute to nature conservation, as well as to community wellbeing.

ICCAs differ from state-governed protected areas, from the standpoint of who is the predominant decision-maker. However, there are many situations in which the distinction may not be clear, especially in collaborative arrangements between Indigenous Peoples or local communities and the state or local authorities (Kothari et al, 2012).

ICCAs' role in maintaining biodiversity and ecosystem processes, including carbon storage and water purification, is significant but under-documented. Existing case studies, documented in the ICCA Registry, show that ICCAs help conserve critical ecosystems and threatened species, maintain ecosystem functions, provide corridors for animal movement, including between official protected areas, and maintain synergies between human-made and natural landscapes, including by preserving agricultural biodiversity. In addition, they play a crucial role in securing the rights of Indigenous Peoples and local communities to their land and natural resources, are the basis of livelihoods and cultural identity, and help maintain and adapt traditional ecological knowledge and practices. Finally, they offer lessons on participatory governance and adaptive management (Schaaf & Lee, 2006).

In the last decade, ICCAs have started gaining recognition in international policy fora as crucial mechanisms for nature conservation, sustainable livelihoods, preservation of traditional ecological knowledge, and the realisation of the rights of Indigenous Peoples and local communities. One of the biggest opportunities to catalyse transformative change from local to global levels is to support Indigenous peoples and local communities to secure their rights to self-determined governance systems, cultures and collective lands and territories. This is arguably the key 'missing link' in efforts to address the biodiversity and climate crises that would also contribute to social justice and sustainable development priorities (ICCA Consortium, 2021). At the same time, ICCAs face critical threats and challenges by various economic and political forces, while receiving limited policy and funding support.

2. Case study: Áldujohka Sámi ICCA, Finland

The Áldujohka Sámi ICCA is an area of approximately 70 hectares situated in the northern boreal forest-peatland-stream habitat along the Ivalo River in the Inari Municipality, Sápmi (Province of Lapland), Finland, approximately 220 kilometres north of the Arctic Circle. The area is a restoration and conservation site that is a traditional fishing, reindeer herding and Indigenous land use area of the Sámi

Reindeer Community of Huuhkaja. There are approximately 10 Sámi people using Áldujohka, directly through the Sámi Reindeer Community of Huuhkaja, either all year round or seasonally. The area is also used occasionally by members of the Hammastunturi Reindeer Cooperative.

Reindeer herding is one of the main livelihoods associated with this site, in addition to traditional Sámi handicrafts, household fishery in the Ivalo River and restoration activities. Herding is not only economically important, but is also of cultural, social and linguistic value for the North Sámi involved. The Áldujohka site was chosen as one of the main reindeer calving areas in the 1970s due to the presence of peatlands, which are central to the natural feeding pastures of reindeer mothers and calves in spring.

With the Sámi being the only remaining Indigenous People in Europe, the Áldujohka Sámi ICCA is the first of its kind in the Nordic countries. The site has exceptional biodiversity and cultural values, including rare plant species such as *Diphasiastrum complanatum* (ground cedar) and several endangered biotopes (e.g., +200 years old primary post ice age forest), and a trout spawning stream. It has also produced important archaeological finds of cultural importance, including deer hunting traps and ancient reindeer fences.

Establishment of the ICCA further aimed to offer a model that could be proliferated across other Sámi forests. Operating since May 2023, activities included documentation of Sámi land and biodiversity knowledge, restoration plans for a clear-cut area of 9 hectares in the eastern part of the ICCA, biogeographical mapping, and establishment of a guardian programme for intergenerational knowledge. The impact of conservation efforts is being monitored using both Sámi knowledge and biogeographical scientific monitoring.

The ICCA is co-governed by Snowchange Cooperative and the Indigenous primary traditional owners, Bigga-Helena Magga and Sigga-Marja Magga, and their descendants. Huuhkaja Reindeer Unit is also involved in determining issues of reindeer herding on the site. There is currently no government support to help local management.

3. Deployment, diffusion, amplification

ICCAs, along with other community-based natural resource management practices, have been increasingly recognised under various international agreements and initiatives. Their deployment and amplification can thus serve towards the achievement of international goals and commitments in the context of environmental protection, human rights and culture.

The primary global agreement setting the stage for legal recognition of ICCAs is the CBD. Following a series of decisions and guidelines that promoted their establishment and recognition, alongside state-run protected areas, the GBF recognised unequivocally the rights of Indigenous Peoples and local communities to land, territories and natural resources. ICCAs, as part of biodiversity-related initiatives of Indigenous Peoples and local communities, can contribute to the implementation of the GBF's goals and targets by promoting the transformative change needed.

The GBF provisions are in line with the UN Declaration of the Rights of Indigenous Peoples (UNDRIP), an international human rights instrument that sets out the minimum standards for the survival, dignity and well-being of the Indigenous Peoples of the world. UNDRIP contains several provisions related directly to land, including Article 26(1), which provides Indigenous Peoples with a right 'to the lands, territories and resources which they have traditionally owned, occupied or otherwise used or acquired'. UNDRIP further supports Indigenous Peoples' right to self-determination and maintain control of their cultural heritage, which would also be promoted through ICCAs.

At the EU level, while there is no specific legal framework, promotion of ICCAs would support the objectives of Biodiversity Strategy 2030 and the nature-related directives, including the Birds and Habitats directives. In addition, EU Member States can promote establishment of ICCAs as part of their implementation of the Restoration Regulation. Recognising ICCAs and ensuring their coordination with other types of protected areas is crucial to promote fair and effective implementation (Stevens et al, 2016).

4. Barriers

Despite their growing importance within global conservation policy and development agendas, ICCAs face critical threats and challenges due to a diversity of social, economic and regulatory factors. These primarily include expropriation of community resources either through privatisation of land and natural resources or for 'national interest' purposes, and unsustainable development interventions for short-term economic benefit. Challenges further stem from lack of appropriate recognition and legal and economic support, which hamper community efforts and undermine their institutions and governance systems (ICCA Consortium, 2021).

A major obstacle facing ICCAs is that these areas do not look much like traditional conservation projects to agencies, officials and policy-makers whose explicit focus remains the protection of threatened and endangered species and their habitats. Despite international recognition, few countries include them in the national protected area systems while respecting their governance mechanisms. To help ICCAs fulfil their potential, government recognition mechanisms need to be backed by supportive legal reforms that spell out the costs and benefits of participation, and provide recognition but not intervention (Robson and Berkes, 2010).

5. References

ICCA Consortium (2021). *Territories of Life: 2021 Report.* https://report.territoriesoflife.org/wp-content/uploads/2021/09/ICCA-Territories-of-Life-2021-Report-FULL-150dpi-ENG.pdf

ICCA Registry Áldujohka Sámi, Finland. Available at https://www.iccaregistry.org/en/explore/finland/aldujohka-sami [Accessed January 2026]

Kothari, A. with Corrigan, C., Jonas, H., Neumann, A., and Shrumm, H. (eds) (2012). *Recognising and Supporting Territories and Areas Conserved By Indigenous Peoples and Local Communities: Global Overview and National Case Studies.* Secretariat of the Convention on Biological Diversity, ICCA Consortium, Kalpavriksh, and Natural Justice. https://www.cbd.int/doc/publications/cbd-ts-64-en.pdf

Robson, J., & Berkes, F. (2010). Sacred Nature and Community Conserved Areas. In S. Pilgrim and J. Pretty (eds). *Nature and Culture: Rebuilding Lost Connections*, pp.

197–216. https://www.iccaconsortium.org/wp-content/uploads/2015/08/example-sacred-nature-and-cca-robson-2010-en.pdf

Schaaf, T. & Lee, C. (eds) (2006). *Conserving cultural and biological diversity: The role of sacred natural sites and cultural landscapes*. Proceedings of the Tokyo Symposium, UNESCO. https://portals.iucn.org/library/sites/library/files/documents/2006-053.pdf

Stevens, S., N. Pathak Broome and T. Jaeger with J. Aylwin, G. Azhdari, D. Bibaka, G. Borrini-Feyerabend, M. Colchester, N. Dudley, C. Eghenter, F. Eleazar, M. T. Farvar, F. Frascaroli, H. Govan, S. Hugu, H. Jonas, A. Kothari, G. Reyes, A. Singh, & L. Vaziri (2016). *Recognising and Respecting ICCAs Overlapped by Protected Areas. Report for the ICCA Consortium*. https://www.iccaconsortium.org/wp-content/uploads/2016/11/publication-Recognising-and-Respecting-ICCAs-Overlapped-by-PAs-Stevens-et-al-2016-en.pdf

United Nations Environment Programme World Conservation Monitoring Centre (UNEP WCMC) (2010). *A handbook for the indigenous and community conserved areas registry*. https://wedocs.unep.org/handle/20.500.11822/8448

6. List of policy instruments

Convention on Biological Diversity (CBD), Rio de Janeiro (Brazil), 5 June 1992, in force 29 Dec. 1993

UN Declaration of the Rights of Indigenous Peoples, New York (USA), 13 September 2007, UN General Assembly Resolution A/RES/61/295

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Biodiversity Strategy for 2030 Bringing nature back into our lives, COM/2020/380 final

Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds [2010] OJ L20/7.

Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora [1992] OJ L206/7, as amended by Council Directive 2013/17/EU of 13 May 2013 [2013] OJ L158/193

Regulation (EU) 2024/1991 of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 [2024] OJ L178/1

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Large language models (LLMs): Alignment of national biodiversity targets

1. Introduction

Large Language Models (LLMs) are an advanced application of Natural Language Processing (NLP) that leverages machine learning to understand and generate human language. LLMs are part of the broader category of generative AI models, which create dynamic content, with LLMs focusing specifically on language-based outputs like text and code. Modern LLMs are built on neural network architectures, particularly transformers, which can handle billions of parameters. This gives them the ability to perform deep contextual learning, enabling them to recognise complex patterns in language, including semantics, context, and reasoning. As a result, LLMs can both read and generate text, opening up a wide range of possibilities for practical applications.

These applications include summarising or analysing information from external sources, translating documents, and producing original content in various formats, such as agendas, reports, media scripts, stories and academic assignments. To function effectively, LLMs require extensive training on large datasets to learn realistic language patterns. Users typically interact with LLMs through an interface by providing prompts that guide the model's output. In many cases, the model can also suggest next steps or alternative actions, making the interaction more intuitive and collaborative. Today, several well-known LLMs are available for public use. Examples include ChatGPT, Microsoft Copilot, Claude and Gemini. Access models vary, some are completely free, others require registration, and many offer both free and subscription-based tiers with enhanced features.

LLMs have the potential to support biodiversity conservation through increasing the efficiency of tasks, such as the synthesis of large volumes of data and research (Chang et al., 2025) or evaluation of policy measures (DeSantis et al., 2025). By improving the efficiency of such tasks, energies and funds can instead be spent more effectively on undertaking practical conservation measures. The increased speed at which tasks can be completed with the aid of language models can further benefit biodiversity by allowing more timely action to take place.

LLMs offer a scalable approach that can be used across contexts. There is an increasing body of work evaluating their utility and human preferences regarding their outputs for different purposes. We consider LLMs a recent innovation, as their development and use have been made possible by technological advancements in large computing infrastructure and machine learning.

2. Case study: Using LLMs to evaluate alignment of National Biodiversity Targets to the Kunming-Montreal Global Biodiversity Framework

The accelerating loss of biodiversity worldwide demands innovative approaches to policy alignment and implementation. This case study examines the application of large language models (LLMs), specifically OpenAI's GPT-3.5, to assess and improve the alignment between national biodiversity targets and national biodiversity strategies and action plans (NBSAPs) and the global targets of the Kunming-Montreal Global Biodiversity Framework (GBF), adopted under the Convention on Biological Diversity (CBD). Ensuring coherence between national and global targets has historically been a complex, resource-intensive process.

The project aimed to address this challenge by introducing AI-driven analysis to evaluate the similarity between 599 national biodiversity targets from 26 countries and the GBF's four overarching goals and 23 targets. Traditional manual reviews of NBSAPs are time-consuming and often inconsistent across countries. By leveraging GPT-3.5's advanced natural language processing capabilities, the initiative sought to provide scalable, efficient, and context-sensitive assessments of policy alignment. The objectives were twofold: 1) Deliver actionable insights for countries to accelerate alignment with GBF goals during NBSAP revisions and; 2) Map patterns of biodiversity policy alignment to inform strategic planning ahead of the 16th meeting of the CBD Conference of the Parties (COP16) (DeSantis et al., 2025).

The analysis combined conventional text similarity techniques (TF-IDF and BERT) with GPT-3.5's transformer-based architecture, which excels at understanding long-range dependencies and nuanced policy language. GPT-3.5 categorised alignment levels (low, medium, high) and generated tailored recommendations for improving congruence with GBF targets. Importantly, the approach was human-centred, incorporating expert review and iterative prompt refinement to ensure fairness, transparency, and contextual accuracy. Pilot testing with 26 countries validated the model's outputs and confirmed its utility for facilitating stakeholder discussions, cross-verifying national analyses, and meeting CBD reporting requirements.

The AI-assisted analysis revealed strong alignment with GBF Goals A (Protect and Restore) and B (Prosper with Nature), and with Targets 4 (species extinction), 10 (sustainable agriculture), and 14 (mainstreaming biodiversity in decision-making). However, gaps were identified in areas such as gender equality (Target 23), biosafety (Target 17), and business sector engagement (Target 15). These insights provided countries with clear priorities for updating NBSAPs and highlighted systemic challenges in integrating emerging themes into national strategies. Over 70% of analysed national biodiversity targets included measurable dimensions, and two-thirds incorporated time-bound commitments, positive trends that AI helped quantify and reinforce (DeSantis et al., 2025).

This case demonstrates the transformative potential of LLMs in the information infrastructure that transcends environmental governance. By reducing the time and cost of policy alignment analysis, AI democratises access to sophisticated tools for countries with limited resources. It also enables a whole-of-government and whole-of-society approach, embedding biodiversity considerations across sectors. However, challenges remain, including mitigating algorithmic bias, ensuring transparency, and maintaining human oversight (DeSantis et al., 2025).

This initiative illustrates how responsible, human-centred AI can enhance global biodiversity governance, offering a scalable solution for aligning national actions with international commitments and advancing progress toward living in harmony with nature by 2050.

3. Deployment, diffusion, amplification

LLMs are now widely available through major providers such as Google, Microsoft, and xAI, alongside smaller open-source and independent models that drive innovation. These tools sit within a broader generative AI ecosystem, which includes image, audio, and video generation in both stylised and photo-realistic formats, opening opportunities for multimodal biodiversity applications such as species identification, habitat monitoring, and educational content creation. The development of multimodal models (e.g., GPT-4V, Gemini) marks a significant shift, enabling integration of text, image, and audio for tasks like zero-shot species recognition, behavioural analysis, and explainable AI outputs, making advanced tools more accessible to non-specialists (Miao et al., 2025).

Diffusion of LLMs has accelerated in research contexts, with a sharp rise in publications referencing LLM use between 2020 and 2024, though uptake remains uneven across disciplines and regions (Liang et al., 2024). Similar disparities are expected in societal adoption, influenced by infrastructure, digital literacy, and resource availability. In biodiversity science, LLMs and related NLP tools are already transforming evidence synthesis, automating literature searches, screening, and coding for global reviews that would otherwise require thousands of hours of manual effort (Chang et al., 2025). These capabilities enable 'living' evidence syntheses and rapid integration of new knowledge, supporting adaptive management and policy alignment.

Amplifying impact will depend on human-centred design and oversight, ensuring fairness, transparency, and contextual nuance. Hybrid AI–expert systems are essential to mitigate risks such as bias, hallucination, and misinterpretation, particularly in conservation decision-making. Future directions include expanding applications to assess synergies between biodiversity and climate strategies, integrate economic and social dimensions, and support continuous monitoring through multimodal data streams. Open-source initiatives and parameter-efficient tuning methods offer pathways to reduce costs and democratise access, but challenges remain around computational demands, language bias, and ethical governance. By combining technical scalability with inclusive design and collaborative frameworks, LLMs and multimodal AI have the potential to accelerate biodiversity research and conservation—provided deployment prioritises transparency, equity, and alignment with global sustainability goals.

EU policy frameworks may play a role in shaping the deployment of LLMs in biodiversity conservation by providing a robust regulatory and funding environment. The EU Artificial Intelligence Act (Regulation 2024/1689) offers a risk-based framework that classifies AI, including general-purpose LLMs, requiring transparency and accountability in biodiversity applications, particularly when engaging the public or handling sensitive species data. The Data Act and Open Data Directive enhance data accessibility and interoperability by enabling sharing of non-personal and high-value biodiversity data, an essential resource for training and validating LLMs. The Digital Europe Programme invests in AI infrastructure and data capabilities, facilitating scalable implementation of LLM-based conservation tools across Member States.

Research and innovation funding streams under Horizon Europe, particularly Cluster 6 (Food, Bioeconomy, Natural Resources, Agriculture and Environment), explicitly encourage the integration of AI and data-driven approaches in environmental monitoring, evidence synthesis and policy alignment. These calls often emphasise human-in-the-loop systems, ethical AI principles, and interoperability with FAIR data standards. Similarly, the European Green Deal and the EU Biodiversity Strategy for 2030 frame digital innovation, including AI, as a key enabler for achieving restoration and conservation targets, while reinforcing commitments to transparency and inclusivity.

Policy measures increasingly call for open-source development, capacity building, and collaborative governance to ensure that AI tools, including LLMs, enhance biodiversity outcomes without exacerbating inequities or environmental impacts. Together, these regulatory and financial instruments provide a foundation for scaling AI responsibly, by embedding transparency, equity and ecological integrity at the core of innovation.

4. Barriers

The deployment of LLMs in biodiversity conservation faces significant barriers across social, economic and ethical dimensions. Access and equity remain primary concerns: effective use of LLMs requires digital literacy, reliable internet, and often subscription-based access, which can exclude users in low-resource settings. Those with the most basic ability to operate these tools may also lack the expertise to critically evaluate outputs, increasing the risk of misinterpretation. Access is further shaped by country-level infrastructure, ability to pay, and language support, where translation quality and English-centric training data can perpetuate inequities and marginalise non-English-speaking communities (Chang et al., 2025; Miao et al., 2025).

Knowledge and trust gaps compound these challenges. LLM outputs demand a certain level of subject-matter understanding to appraise accuracy, yet many users lack this foundation. Poor results from poor data remain a critical risk: biased or incomplete training datasets can lead to skewed recommendations, reinforcing systemic inequities in conservation decision-making. Concerns over algorithmic bias, hallucinations, and lack of transparency undermine trust, while the absence of clear standards for validation and explainability makes adoption difficult in high-stakes policy contexts (Chang et al., 2025; Kulkarni & Di Minin, 2021).

Economic and environmental costs also pose barriers. State-of-the-art models require substantial computational resources for training and inference, raising questions about sustainability and carbon footprint (Miao et al., 2025). Closed-source dominance limits customisation and affordability, while open-source alternatives often lag in performance. Ethical issues, including data ownership and recognition of original content creators, risks of misuse, and techno-optimism that diverts attention from proven conservation strategies, further complicate responsible deployment. Addressing these barriers will require human-in-the-loop approaches, transparent governance and equitable access frameworks, to ensure that LLMs augment rather than replace expert judgment and contribute meaningfully to biodiversity goals. At the same time, the physical infrastructure underpinning LLMs, as well as the associated water and energy consumption, raises concerns regarding negative sustainability spillovers.

5. References

Chang, C. H., Cook-Patton, S. C., Erbaugh, J. T., Lu, L., Masuda, Y. J., Molnár, I., Papp, D., & Robinson, B. E. (2025). New opportunities and challenges for conservation evidence synthesis from advances in natural language processing. *Conservation Biology*, *39*(2). https://doi.org/10.1111/cobi.14464

DeSantis, N., Supples, C., Phillips, L., Pigot, J., Ervin, J., & Wade, T. (2025). Leveraging AI for enhanced alignment of national biodiversity targets with the global biodiversity goals. *Nature-Based Solutions*, *7*. https://doi.org/10.1016/j.nbsj.2024.100198

Kulkarni, R., & Di Minin, E. (2021). Automated retrieval of information on threatened species from online sources using machine learning. *Methods in Ecology and Evolution*, *12*(7), 1226–1239. https://doi.org/10.1111/2041-210X.13608

Liang, W., Zhang, Y., Wu, Z., Lepp, H., Ji, W., Zhao, X., Cao, H., Liu, S., He, S., Huang, Z., Yang, D., Potts, C., Manning, C. D., & Zou, J. Y. (2024). *Mapping the Increasing Use of LLMs in Scientific Papers*. http://arxiv.org/abs/2404.01268

Miao, Z., Zhang, Y., Fabian, Z., Hernandez Celis, A., Beery, S., Li, C., Liu, Z., Gupta, A., Nasir, M., Li, W., Holmberg, J., Palmer, M., Gaynor, K., Arbelaez, P., Wang, P., Dodhia, R., & Ferres, J. L. (2025). New frontiers in artificial intelligence for biodiversity research and conservation with multimodal language models. *Methods in Ecology and Evolution*. https://doi.org/10.1111/2041-210X.70120

6. List of policy instruments

Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (Artificial Intelligence Act), OJ L, 2024/1689

Regulation (EU) 2023/2854 of the European Parliament and of the Council of 13 December 2023 on harmonised rules on fair access to and use of data and amending Regulation (EU) 2017/2394 and Directive (EU) 2020/1828 (Data Act), OJ L, 2023/2854

Directive (EU) 2019/1024 of the European Parliament and of the Council of 20 June 2019 on open data and the re-use of public sector information (recast), OJ L 172

Regulation (EU) 2021/694 of the European Parliament and of the Council of 29 April 2021 establishing the Digital Europe Programme and repealing Decision (EU) 2015/2240, OJ L 166

Regulation (EU) 2021/695 of the European Parliament and of the Council of 28 April 2021 establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination, and repealing Regulations (EU) No 1290/2013 and (EU) No 1291/2013, OJ L 170

Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), OJ L 108

Communication from the Commission to the European Parliament,
the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, The European Green Deal, COM/2019/640 final

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Biodiversity Strategy for 2030 Bringing nature back into our lives, COM/2020/380 final

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LLMs: Conservation CoPilot

1. Introduction

LLMs are bi-directional transformer-based neural networks trained using attention mechanism and forward and back propagation on large corpora of texts (and other media) to perform text and other media comprehension and generation tasks (summarisation, translation, extraction, classification, question answering, content creation). They are at the core of contemporary AI models such as ChatGPT. This innovation has broad relevance for biodiversity information infrastructure. For instance, LLMs act as knowledge-mediating tools, as they help to find and extract, synthesise, translate, structure, and summarise texts and data from the multilingual body of academic and non-academic literature, technical logs, regulatory texts (etc.), that underpin conservation and biodiversity decision-making.

LLMs serve as knowledge extractors in evidence syntheses (Raeissi and Knapen 2025). They can thus help address the broader epistemic problem that there is frequently too much biodiversity-relevant information out there to be of use for policymakers: LLMs can help identify patterns, or key themes, across vast amounts of data, thus helping to create decision-relevant knowledge. LLMs can also yield insights into evolution or ecosystem dynamics that might otherwise not be available. For instance, genomic LLMs, trained on genetic sequence data rather than human language, are being widely adopted to predict evolutionary pathways, including for pathogens such as SARS-CoV-2.

At the same time, the physical infrastructure underpinning LLMs, as well as the associated water and energy consumption, raises concerns regarding negative sustainability spillovers. LLMs are being actively used by industries, consumers and governments, with the commercial field developing rapidly. LLMs are highly scalable and also may be fine-tuned to specific contexts.

2. Case study: Conservation CoPilot

The 'Conservation CoPilot' is an ongoing project at the University of Cambridge to provide guidance decision support for biodiversity conservation policy. The CoPilot is intended to extract information from millions of documents from a database containing evidence on biodiversity projects across diverse ecosystems. The rationale is that policymakers need to know which types of policy interventions are most effective in halting or reversing biodiversity loss. Data collection for this project has been going on for 30 years, with conservation scientists manually curating 1.6 million scientific papers and identifying 3600 different policy interventions for biodiversity conservation. By hooking this dataset, as well as other academic datasets, into a custom-designed LLM, empirical evidence on the effectiveness of specific policies for specific purposes and ecological contexts can be rapidly identified. The ultimate aim of the project is to provide a chatbot that enables policymakers to verbally describe the environmental challenges that they are attempting to address in order to receive custom-tailored solutions based on the best available scientific evidence.

3. Deployment, diffusion, amplification

General purpose pre-trained LLMs are used by biodiversity researchers and groups for applied R&D in the form of fine-tuning, design of specific pipelines, and evaluation of their performance. In addition, custom-tailored LLMs with more narrow thematic focuses are being developed, including the Conservation CoPilot project mentioned above. Researchers have adopted LLMs for screening and data extraction in systematic reviews, for analysis and data extraction from national reports, and Party commitments to the GBF targets.

4. Barriers

Unequal access to technology is a major barrier in the diffusion of LLMs for biodiversity conservation. This is especially the case as 'out-of-the-box' general LLMs may have limited utility for conservation purposes, yet the training of custom-tailored LLMs requires financial and technical resources that may not be available in many countries and regions. As with applications of LLMs in other fields, there is thus a risk of an increasing digital divide, especially in a North-South context. The reliability of LLMs is a further impediment, as their intrinsic tendency to hallucinate may call into question their outputs and require additional human verification steps. The environmental impacts of data centres, including their water and energy consumption, are increasingly posing challenges as well. Compliance with the EU AI Act will likely increase development costs, whereas data copyright restrictions may limit biodiversity-specific fine-tuning.

5. References

Reynolds, S. A., Beery, S., Burgess, N., Burgman, M., Butchart, S. H., Cooke, S. J., ... & Sutherland, W. J. (2025). The potential for AI to revolutionize conservation: a horizon scan. *Trends in ecology & evolution*, *40*(2), 191-207.

Raeissi, M. M., & Knapen, R. (2025). Applications of Generative Large Language Models in Environmental Science: A Systematic Review. *Advances in Environmental and Engineering Research*, *6*(3), 1-15.

Troost, S., Immerzeel, R., & Krüger, C. (2025, July). Biodiversity ambition analysis with Large Language Models. In Proceedings of the 2nd Workshop on Natural Language Processing Meets Climate Change (ClimateNLP 2025) (pp. 99-112).

DeSantis, N. et al. (2025) 'Leveraging AI for enhanced alignment of national biodiversity targets with the global biodiversity goals', Nature-Based Solutions, 7, p. 100198. Available at: https://doi.org/10.1016/j.nbsj.2024.100198

6. List of policy instruments

Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (Artificial Intelligence Act), OJ L, 2024/1689

Regulation (EU) 2023/2854 of the European Parliament and of the Council of 13 December 2023 on harmonised rules on fair access to and use of data and amending Regulation (EU) 2017/2394 and Directive (EU) 2020/1828 (Data Act), OJ L, 2023/2854

Directive (EU) 2019/1024 of the European Parliament and of the Council of 20 June 2019 on open data and the re-use of public sector information (recast), OJ L 172

Regulation (EU) 2021/694 of the European Parliament and of the Council of 29 April 2021 establishing the Digital Europe Programme and repealing Decision (EU) 2015/2240, OJ L 166

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Macroscopes / global biodiversity monitoring tools

1. Introduction

Macroscopes are methods or techniques that integrate observations from multiple types of sources to monitor large- (macro-scale) biodiversity. These sources may include 'satellites, drones, camera traps, passive acoustic samplers, biologgers, environmental DNA and human observations' (Dornelas et al. 2019: 1937). Macroscopes enable nature observation at high levels of abstraction, including spatial distributions of species, temporal changes in populations, as well as evolutionary dynamics. The integration of multiple data sources to monitor biodiversity at a large scale can help to overcome intrinsic biases in biodiversity data that result from the spatial distribution of (small-scale) observations. The concept of a macroscope is enabled by the proliferation in data sources, including drones and specialised types of environmental sensors. Data input from these sources is analysed through AI/ ML techniques, for instance to detect specific species captured by camera traps, or to identify specific birds by their songs. Data analysis allows for the assessment of large-scale causal patterns (e.g. based on how changes in the levels of different populations are correlated) and to construct complex digital simulations (or digital twins) of ecosystems. In principle, biodiversity macroscopes can thus greatly enhance conservation science, with better scientific knowledge supporting conservation efforts. Notably, macroscopes can also integrate data collected by humans, providing a potential interface with citizen science.

2. Case study: eBird

eBird is a birdwatching project that is among the largest citizen-science programmes in the world. The project comprises a database of user submissions of bird sightings, pictures, sounds and other data. Bird watchers record when and where they see or hear birds and upload their observations onto the platform using a (free) mobile app. Receiving approximately 100 million submissions per year, eBird integrates vast amounts of data from different sources. The system thus fuses digital and social innovation, with humans serving as social 'sensors' that provide data that is then integrated in a digital platform (Sullivan et al. 2014).

The data provided by the eBird platform has become a crucial instrument for biodiversity policy, but also scientific research on avian biodiversity. For instance, the macroscopic nature of the data makes it possible to measure local impacts of climate change by detecting anomalies in the seasonal movements of bird populations. The eBird database presently comprises over 500 million records that are being shared through GBIF, making it one of the largest biodiversity databases worldwide. Due to the citizen science-based mode of data collection, eBird holds records from all countries worldwide, and from 97% of all known bird species. Citizen scientists have volunteered a total of more than 14.5 million hours to data collection, making this a notable example of social innovation and mobilisation.

3. Deployment, diffusion, amplification

As macroscopes are essentially about the integration of multiple data sources in biodiversity monitoring, the concept itself is not new, although more advanced implementations (that incorporate many different types of sources) are technically, accordingly, more challenging. In the field of ecology, different versions of macroscopes (of different levels of complexity) are increasingly common. The main driving factor is the diffusion of enabling technologies, including with regards to environmental monitoring, data collection and analysis, as well as the integration of inputs from multiple sensor sources. AI techniques increasingly facilitate data analysis, and the Internet of Things increases connectivity of environmental sensors. The use of citizen science methods can potentially help overcome the digital divide, facilitating diffusion in developing countries; where data collection requires no more than volunteers equipped with smartphones running free apps, very limited digital infrastructure is required for collecting large amounts of data, as in the case of the eBird project mentioned above. The macroscope is thus not just a technological innovation but crucially depends on the simultaneous adoption of social innovations.

4. Barriers

As with other digital (or partially digital) technologies, the digital divide continues to be a major barrier to the diffusion of macroscopes to the Global South. On top of this, there is a long-standing trend towards increasing North-South disparities in the production of environmental scientific knowledge itself (e.g. Karlsson et al. 2007). Accordingly, the development and application of complex, multi-sensor, data-integration platforms for biodiversity monitoring in developing countries, especially least-developed countries, may be challenging. Furthermore, with citizen science being an important element for crowdsourcing data collection through macroscopes, there are also potential social barriers to mobilisation. Without broad-based volunteer efforts, macroscopic biodiversity monitoring is bound to face challenges, particularly in countries and regions with limited technological capacities.

No dedicated policy measures for supporting the development or adoption of macroscopes appear to exist at present. In reverse, however, macroscopes in principle enhance conservation policies by providing high-quality macro-ecological data to decision-makers.

5. References

Dornelas, M., Madin, E. M., Bunce, M., DiBattista, J. D., Johnson, M., Madin, J. S., ... & Bates, A. E. (2019). Towards a macroscope. *Global Ecology and Biogeography*, *28*(12), 1937-1948.

Karlsson, S., Srebotnjak, T., & Gonzales, P. (2007). Understanding the North–South knowledge divide and its implications for policy: a quantitative analysis of the generation of scientific knowledge in the environmental sciences. *Environmental Science & Policy*, *10*(7-8), 668-684.

Sullivan, B. L., Aycrigg, J. L., Barry, J. H., Bonney, R. E., Bruns, N., Cooper, C. B., ... & Kelling, S. (2014). The eBird enterprise: An integrated approach to development and application of citizen science. *Biological conservation*, *169*, 31-40.

6. List of policy instruments

Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora [1992] OJ L206/7, as amended by Council Directive 2013/17/EU of 13 May 2013 [2013] OJ L158/193

Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds [2010] OJ L20/7.

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU

Biodiversity Strategy for 2030 Bringing nature back into our lives, COM/2020/380 final

Regulation (EU) 2024/1991 of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 [2024] OJ L178/1

Regulation 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species [2014] OJ L317/35

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Mobile apps and games for biodiversity

1. Introduction

Mobile apps and games for biodiversity constitute a distinct socio-technical innovation area because they reconfigure how biodiversity knowledge is produced, accessed, and acted upon at scale. Rather than treating biodiversity monitoring as an expert-only activity, these tools turn mass-market smartphones into distributed interfaces for (a) species identification, (b) structured observation capture, and (c) environmental learning. The innovation is therefore not only 'a new app,' but an end-to-end participation that links everyday encounters with nature to standardised data objects and feedback loops.

In the current ecosystem, two clusters are especially relevant. First, *identification and citizen science platforms* (e.g., iNaturalist/Seek, Pl@ntNet, BirdNET, Merlin, eBird) combine user-facing identification (image/audio) with workflows for submitting observations to communities and, in some cases, to broader biodiversity data infrastructures (e.g., the Global Biodiversity Information Facility - GBIF). iNaturalist, for example, is a joint initiative supported by the California Academy of Sciences and National Geographic and explicitly frames itself as a platform that supports learning and biodiversity data use in research contexts (iNaturalist, 2018, 2023; iNaturalist, 2023). It also shares research-grade observations with GBIF (iNaturalist, 2019; GBIF, n.d.-a). Second, *gamified and location-based innovations* (e.g., Pokémon GO, AR conservation games such as Wildeverse) create motivation structures that can increase attention to local environments and conservation themes by embedding biodiversity content into play and exploration (Dorward et al., 2017; Dunn et al., 2021; Smith, 2016).

This innovation area especially matters because it targets a persistent bottleneck in biodiversity governance: limited observation capacity, limited public engagement, and high transaction costs in translating local nature encounters into usable signals for monitoring and stewardship. Mobile apps/games address this by combining interface design, AI-supported recognition, participatory incentives, and data pipelines – while also introducing well-known risks (bias, privacy, validation burdens, and platform dependence) that must be managed.

2. Case studies

To describe the innovation object clearly while respecting the heterogeneity of the field, this profile uses a 'three-layer' case study structure: (i) identification and capture apps, (ii) citizen science data infrastructures, and (iii) gamified engagement pathways.

2.1 Identification and capture layer: turning smartphones into biodiversity interfaces

A core innovation is the conversion of common smartphone sensors into field identification tools that reduce expertise barriers. BirdNET Sound ID, for example, provides bird identification suggestions from short audio recordings and is described as a joint project of Cornell Lab of Ornithology (K. Lisa Yang Center for Conservation Bioacoustics) and Chemnitz University of Technology (Wood et al., 2022; TU Chemnitz, n.d.). The TU Chemnitz project page notes that BirdNET can recognise around 3,000 of the most common bird species worldwide (TU Chemnitz, n.d.). Similarly, Seek by iNaturalist uses image recognition to identify organisms and adds badges/challenges that structure user learning and participation (iNaturalist, 2023). Pl@ntNet frames identification as a citizen science activity and explicitly connects user photo contributions to scientific work on plant biodiversity (Pl@ntNet, n.d.).

These tools represent a socio-technical shift from static field guides toward interactive, assistive identification systems. Importantly, the value proposition is not 'perfect identification' but reduced friction: users can more often move from *curiosity* ('what is this?') to *action* ('recorded and shared'), which increases both educational payoff and the supply of structured observations.

2.2 Data infrastructure layer: from observations to reusable biodiversity information

The second layer is the pipeline that connects user observations to wider biodiversity information infrastructures. GBIF describes itself as an international network and data infrastructure funded by governments, aimed at providing open access to biodiversity data (GBIF, n.d.-b). iNaturalist provides public guidance describing how observations are used for research and notes that many publications rely on data shared via the GBIF iNaturalist Research-Grade Observations dataset (iNaturalist, 2023; GBIF, n.d.-a). This is a concrete example of how consumer-facing apps can become feeders into institutional biodiversity data ecosystems – subject to quality thresholds and governance rules.

In this layer, 'innovation' is best understood as a governance and standardisation achievement: heterogeneous user contributions become comparable records through metadata requirements, community validation, and export mechanisms. The practical implication for biodiversity monitoring is that some app ecosystems can support not only outreach but also downstream scientific analysis – while requiring careful attention to bias, uneven sampling, and validation burdens.

2.3 Gamified engagement layer: location-based play and conservation learning

A third strand consists of mobile games that motivate outdoor exploration and can, under certain conditions, enhance engagement with nature and conservation topics. Dorward et al. (2017) discuss Pokémon GO in conservation terms, arguing the game could increase awareness and engagement while also bringing costs/risks that need management. Smith (2016) similarly framed Pokémon GO as suggestive for biodiversity outreach and research futures . Conservation-focused AR games such as Wildeverse have been examined empirically; Dunn et al. (2021) evaluate Wildeverse as an augmented-reality game intended to generate support for ape conservation.

This cluster illustrates that 'biodiversity innovation' can emerge through motivational design rather than through direct monitoring workflows. While these games typically do not produce standardised biodiversity records comparable to citizen science platforms, they can serve as on-ramps – building interest, normalising outdoor exploration, and making species and conservation narratives salient.

3. Deployment, diffusion, amplification

The diffusion mechanism for this innovation area is structurally different from place-based interventions. App stores, platform partnerships, and education programmes allow rapid geographic spread with limited marginal distribution cost. This makes mobile biodiversity tools highly scalable in terms of reach, but not automatically scalable in terms of ecological impact or data quality.

Amplification tends to occur through three pathways:

- **Integration into citizen science events and institutions.** Apps become part of 'bioblitz' activities, school excursions, museum programming, and local NGO campaigns. The innovation here is institutional coupling: apps supply tools and feedback, institutions supply legitimacy and repeated participation settings.
- **Linkage to data infrastructures.** Where platforms export validated observations into infrastructures such as GBIF, the downstream value can increase substantially (iNaturalist, 2019; iNaturalist, 2023; GBIF, n.d.-a). This can convert dispersed participation into reusable biodiversity signals for conservation analysis (GBIF, n.d.-c).
- **Gamification and habit formation.** Seek's badge and challenge design exemplifies how lightweight gamification can turn occasional identification into repeated practice (Wood et. al., 2022). Location-based games use similar dynamics to increase time outdoors and attention to local environments (Dorward et al., 2017; Smith, 2016).

The innovation object is modular. Individual apps can be adopted independently, but the highest value often comes from an ecosystem approach: capture → validation → standardisation → export/ reuse. Transferability to EU contexts is generally high because smartphone hardware is standardised and the policy environment already contains relevant frameworks for biodiversity monitoring, digital education, data governance, and AI accountability (European Commission, 2020a, 2020b; European Parliament & Council, 2016, 2024).

A range of EU policy instruments offer policy support, including:

- The EU Biodiversity Strategy for 2030, which includes emphasis on biodiversity knowledge and action to support citizen science integration into monitoring, education, and local stewardship programmes (European Commission, 2020a).
- The Farm to Fork Strategy, including a food-system transition framing, which can be used to align biodiversity learning apps with agricultural landscape literacy and public engagement – especially where citizen science supports

awareness of species, habitats, and pressures (European Commission, 2020b).

- The Nature Restoration Regulation, which positions mobile observation and citizen science tools as complementary participation instruments that can strengthen local engagement and long-term maintenance cultures around restored ecosystems (European Parliament & Council, 2024a).
- The Digital Education Action Plan 2021–2027, which can support adoption through formal and non-formal education by embedding biodiversity apps into digital learning initiatives, teacher support, and EU-level cooperation on digital education (European Commission, 2020c).
- The General Data Protection Regulation (GDPR), by requiring privacy-by-design for location-rich biodiversity observations and providing clear guidance for schools and public bodies on lawful processing and safeguarding (European Parliament & Council, 2016).
- The Artificial Intelligence Act (Regulation 2024/1689) through its risk governance logic to encourage transparent uncertainty communication, documentation practices, and responsible deployment of AI identification features (European Parliament & Council, 2024b).
- The Open Data Directive (Directive 2019/1024), which can support interoperable reuse pathways for publicly funded biodiversity data and education outputs, while managing sensitive-species and site protection constraints (European Parliament & Council, 2019).

4. Barriers

Social and epistemic barriers relate to unequal participation and lack of trust of AI-supported identification. Citizen science participation is often socially patterned; observations can be concentrated in accessible, urban, and recreational areas, producing spatial and taxonomic bias. The innovation can therefore amplify what is easy to observe rather than what is ecologically most critical unless complemented by targeted programmes. In addition, AI-supported identification suggestions can increase participation but can also create false confidence. The socio-technical challenge is designing interfaces that communicate uncertainty and encourage verification.

Regarding economic and operational barriers, community validation and 'research-grade' filtering are resource-intensive. Scaling participation without scaling validation capacity can degrade data usability. Furthermore, many apps depend on centralised infrastructure (servers, model updates, community features). Long-term biodiversity value requires governance choices that preserve accessibility and data continuity even if business models or platform priorities shift.

In the EU context, regulatory barriers relate mainly to data protection and privacy, AI accountability, and open data alignment. Biodiversity observations can include sensitive location data (including near private property or sensitive habitats). In the EU, collection and processing of personal data must comply with GDPR requirements (European Parliament & Council, 2016). Where apps deploy AI for identification or ranking, emerging EU AI governance frameworks matter for risk management, transparency, and obligations depending on use contexts (European Parliament & Council, 2024). Finally, biodiversity innovation benefits from interoperable, reusable datasets, but reuse must align with EU rules on public sector information and open data, and with confidentiality considerations for sensitive species and sites (European Parliament & Council, 2019).

Overall, these barriers do not negate the innovation, but they define the conditions under which 'more participation' becomes 'better biodiversity outcomes.'

5. References

Identification apps and platforms

iNaturalist. (2018, June 26). *iNaturalist now jointly supported by the National Geographic Society*. https://www.inaturalist.org/blog/17333-inaturalist-now-jointly-supported-by-the-national-geographic-society

iNaturalist. (2023). *Seek by iNaturalist*. https://www.inaturalist.org/pages/seek_app

iNaturalist. (2023, July 11). *Spreading our wings: iNaturalist is now an independent nonprofit*. https://www.inaturalist.org/blog/82010-spreading-our-wings-inaturalist-is-now-an-independent-nonprofit

Pl@ntNet. (n.d.). *Pl@ntNet*. https://plantnet.org/en/

TU Chemnitz. (n.d.). *BirdNET*. https://www.tu-chemnitz.de/informatik/mi/birdnet.php

Wood, C. M., Kahl, S., Eibl, M., & Klinck, H. (2021). BirdNET: A deep learning solution for avian diversity monitoring. PLOS Biology

Data infrastructure (GBIF / iNaturalist sharing)

GBIF. (n.d.-a). *iNaturalist research-grade observations* [Dataset]. https://www.gbif.org/dataset/50c9509d-22c7-4a22-a47d-8c48425ef4a7

GBIF. (n.d.-b). *What is GBIF?* https://www.gbif.org/what-is-gbif

GBIF. (n.d.-c). *GBIF and conservation*. https://www.gbif.org/conservation

iNaturalist. (2019, November 28). *Making sure your observations are shared to GBIF*. https://www.inaturalist.org/posts/29105-making-sure-your-observations-are-shared-to-gbif

iNaturalist. (2023, December 6). *How are iNaturalist data used for research?* https://help.inaturalist.org/en/support/solutions/articles/151000170341-how-are-inaturalist-data-used-for-research-

Gamified and AR innovations

Dorward, L. J., Mittermeier, J. C., Sandbrook, C., & Spooner, F. (2017). Pokémon GO: Benefits, costs, and lessons for the conservation movement. *Conservation Letters, 10*(2), 160–165. https://doi.org/10.1111/conl.12326

Dunn, M. E., et al. (2021). Stepping into the Wildeverse: Evaluating the impact of an augmented reality game on engagement and support for ape conservation. *People and Nature, 3*(6), 1175–1188. https://doi.org/10.1002/pan3.10273

Smith, D. R. (2016). A walk in the park: Is Pokémon Go foreshadowing the future of biodiversity research and scientific outreach? *EMBO Reports, 17*(11), 1506–1509. https://doi.org/10.15252/embr.201643213

TechCrunch. (2020, April 5). *Internet of Elephants launches Wildeverse, an AR game about endangered animals and conservation*.

https://techcrunch.com/2020/04/05/internet-of-elephants-launches-wildeverse-an-ar-game-about-endangered-animals-and-conservation/

6. List of policy instruments

European Commission. (2020a). *EU biodiversity strategy for 2030: Bringing nature back into our lives* (COM/2020/380 final)

European Commission. (2020b). *A farm to fork strategy for a fair, healthy and environmentally-friendly food system* (COM/2020/381 final)

European Commission. (2020c). *Digital education action plan 2021–2027: Resetting education and training for the digital age* (COM/2020/624 final)

European Parliament, & Council of the European Union. (2016). *Regulation (EU) 2016/679 (General Data Protection Regulation)*

European Parliament, & Council of the European Union. (2019). *Directive (EU) 2019/1024 on open data and the re-use of public sector information*

European Parliament, & Council of the European Union. (2024a). *Regulation (EU) 2024/1991 on nature restoration*

European Parliament, & Council of the European Union. (2024b). *Regulation (EU) 2024/1689 (Artificial Intelligence Act)*

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Nature-based solutions: a global perspective

1. Introduction

Nature-based solutions (NbS) - interventions that protect, restore, and sustainably manage ecosystems to address societal challenges - have emerged as a critical tool for tackling climate change, biodiversity loss, and sustainable development challenges worldwide. They represent a paradigm shift in how societies address environment- or development-related challenges. Rather than relying solely on engineered or 'grey' infrastructure, NbS harness the inherent functions of ecosystems to deliver multiple societal benefits (Jang et al, 2023).

NbS have gained increased recognition in the global policy context, including the UN Framework Convention on Climate Change (UNFCCC), the CBD, and the Sendai Framework for Disaster Risk Reduction. The 2022 UN Environment Assembly formally recognised NbS as actions to protect, conserve, restore, sustainably use, and manage natural or modified terrestrial, freshwater, coastal, and marine ecosystems that address social, economic, and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits.

2. Case Study: Interurban Biological Corridors in Costa Rica: The Biodiver_City Project

From 2021-2023, the Biodiver_City project put forward an innovative approach to integrating biodiversity conservation with urban climate adaptation through the establishment of interurban biological corridors. The project aimed to: create eco-corridors that link protected areas and enable species movement across urban landscapes; reduce urban heat island effects by increasing vegetation cover; engage citizens in biodiversity monitoring using the iNaturalist mobile app; and integrate NbS into urban planning.

The project employed a multi-faceted implementation strategy, combining scientific assessment, community engagement and policy integration. Researchers mapped surface temperatures and vegetation indices across different cantons, demonstrating the relationship between green cover and cooling effects. This evidence was used to identify priority areas for corridor establishment and to communicate benefits to decision-makers and the public.

Citizen science played a central role, with thousands of biodiversity records collected through the iNaturalist platform, creating the 'Atlas Verde de la Gran Área Metropolitana'. This approach not only generated valuable data but also raised public awareness and fostered a sense of stewardship among urban residents.

The Biodiver_City project demonstrated measurable benefits, including reduced surface temperatures in areas with increased vegetation, enhanced connectivity for wildlife movement, and increased public engagement with urban nature. The citizen science component revealed surprising biodiversity richness in urban areas, challenging perceptions that cities are biodiversity deserts and building support for conservation efforts.

The case study highlighted several critical success factors for NbS diffusion, including: the potential of combining scientific evidence with citizen engagement to build support for NbS; the importance of demonstrating multiple benefits to diverse stakeholders; the value of integrating NbS into formal planning processes to ensure long-term sustainability; and the potential for technological applications to enable participatory approaches to NbS implementation and monitoring (Jang et al, 2023).

3. Deployment, diffusion, amplification

Scaling NbS from pilot projects to widespread adoption globally requires strategies which are currently lacking. While the mechanisms are largely similar to the ones discussed under the profile on NbS with focus on Europe, challenges are more complex due to the diversity of circumstances and regulatory and socio-economic realities globally, as well as the lack of a global framework for adoption.

Currently, mechanisms for diffusion concern capacity-building programmes, mainly funded by European donors; and projects involving innovative financing mechanisms, including payments for ecosystem services and green bonds.

4. Barriers

While the diversity of global circumstances should not be underestimated, barriers to NbS diffusion include the difficulty of demonstrating economic value compared to conventional infrastructure, due to the lack of assessment and valuation methodologies. Insufficient funding is consistently identified as a major barrier to NbS implementation. Lack of clear legal frameworks and policies that recognise, define and support NbS, further causes obstacles to implementation. In many jurisdictions, environmental laws, planning regulations and infrastructure standards were developed with conventional approaches in mind and do not adequately accommodate NbS.

Social barriers relate to the limited awareness and understanding of NbS among decision-makers, banks and funding agencies, uncertainty about NbS performance and differences in risk perception. In addition, NbS implementation may face resistance from communities or stakeholder groups with conflicting interests, including, for instance, agriculture- or infrastructure-related.

5. References

Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (Eds.). (2016). *Nature-based solutions to address global societal challenges*. IUCN International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2016.13.en

Cohen-Shacham, E., Andrade, A., Dalton, J., Dudley, N., Jones, M., Kumar, C., Maginnis, S., Maynard, S., Nelson, C. R., Renaud, F. G., Welling, R., & Walters, G. (2019). Core principles for successfully implementing and upscaling Nature-based Solutions. *Environmental Science & Policy*, *98*, 20–29. https://doi.org/10.1016/j.envsci.2019.04.014

International Climate Initiative > Biodiver_CITY – Establishment of Interurban Corridors https://www.international-climate-initiative.com/en/project/biodiver-city-establishment-of-interurban-corridors-18-iv-082-cri-g-interurban-corridors/ [Accessed January 2026]

Jang, N., Lo, V., Rodríguez, J. S., & Terton, A. (2023). *Enhancing Biodiversity Co-Benefits From Nature-Based Solutions for Adaptation in Practice: A Compendium of Case Studies*. International Institute for Sustainable Development. https://www.iisd.org/system/files/2024-01/case-studies-biodiversity-co-benefits-nature-based-solutions.pdf

Terton, A. (2022). Nature-Based Solutions: An Approach for Joint Implementation of Climate and Biodiversity Commitments. GIZ/IISD/UFZ.

https://www.adaptationcommunity.net/wp-content/uploads/2022/05/03-thematic-paper-NbS-biodiv-climate-implementation-giz-iisd-ufz.pdf

6. List of policy instruments

Nature-based solutions for supporting sustainable development (UNEA resolution UNEP/EA.5/Res.5), 2 March 2022

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Nature-based solutions in Europe

1. Introduction

Nature-based solutions (NbS) are understood both as actions and an umbrella concept. As actions, they address key societal challenges, including in particular climate change mitigation and adaptation, through the protection, sustainable management and restoration of both natural and modified ecosystems, benefiting biodiversity and human well-being. They are a relatively new concept, emerging within the last decade, mainly in climate-related policy processes and scholarship. NbS has gained significant traction as an umbrella concept that encompasses many approaches that can jointly address climate change and biodiversity loss while also supporting several SDGs. Use of the concept is thus currently promoted within global biodiversity and climate policy processes (Cohen-Shacham et al, 2019). Importantly, NbS are considered as a valid alternative to grey infrastructures - i.e. hard, human-engineered structures – as measures for reducing climate-related risks (Giordano et al, 2020).

The NbS concept includes five main categories of approaches (Cohen-Shacham et al, 2016; Terton, 2022):

- ecosystem restoration, for example, of a degraded forest or a polluted river basin;
- issue-specific ecosystem-related approaches, such as ecosystem-based disaster risk reduction approaches which focus on minimising the impacts of hazards, such as restoration of marshlands;
- infrastructure-related approaches, including natural infrastructure and green and blue infrastructure, such as green roofs and urban forests;
- ecosystem-based management approaches, such as integrated coastal zone management or integrated water resource management; and
- ecosystem protection approaches, such as protected areas.

The concept of NBS has gained traction in both policy and practice over the past decade. The EU has positioned itself at the forefront of NBS promotion at the global level, arguing for the integration of these approaches within major policy frameworks under the UNFCCC, the CBD, and the UN Environment Assembly.

The European Commission defines NbS as 'solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions'. NbS have recently emerged as a central innovation in European environmental policy and strategy for the future.

2. Case Study: Reducing water-related risks through NbS in the Lower Danube Region

Implemented through the Horizon 2020 NAIAD project, a case study of NbS implementation for water-related risk reduction focused on wetland restoration to reduce flood risks while generating co-benefits for local communities.

The project employed a stakeholder participatory process to design and evaluate NbS interventions, aligning with principles of sustainable development and green infrastructure as outlined in the Water Framework Directive and the Flood Directive. While wetland restoration was significant in providing reduction of floor damage, a key finding was that socio-economic co-benefits were more important for enhancing social acceptance of NbS. Meaningful engagement with local communities, enabled through local partnerships and capacity building, was also essential for implementation and monitoring. The case study further highlighted the importance of multi-level coordination for water management in transboundary contexts, and regulatory and institutional challenges with regard to local administration capacity and complications arising from private land ownership (Giordano et al, 2020; Scrieciu et al, 2023).

3. Deployment, diffusion, amplification

Research indicates that policy mixes combining regulatory, financial, and soft policy instruments are crucial for supporting the uptake and mainstreaming of NbS in Europe (Jagt et al, 2023). In addition, mainstreaming NbS requires integrating them into policies and decision-making processes across sectors, including through strategic planning.

However, achieving effective cross-sectoral collaboration faces challenges due to fragmented governance structures, difficulties in establishing and aligning institutional mandates, and lack of coordination mechanisms. While multistakeholder and collaborative approaches have been proposed and tested, challenges remain in ensuring the sustainability of interventions and the long-term interest of actors involved.

Knowledge transfer and capacity building remain critical mechanisms for NbS amplification. To enhance the knowledge base, the EU has been funding a portfolio of research projects on NbS. However, translating this knowledge into practice at national and local levels remains a challenge.

Additional financing mechanisms aiming at NbS diffusion and scaling include the European Regional Development Fund and environmental action funding schemes such as LIFE. Broader funding mechanisms would be needed, however, including through public-private partnerships, to strengthen the economic case for NbS and support their deployment.

4. Barriers

Regulatory and institutional barriers represent the most significant obstacles to NBS implementation, operating at multiple governance levels and across policy domains, with complex permitting procedures constituting a primary regulatory barrier. Policy incoherence and institutional fragmentation further hinder adoption.

Economic barriers, on the other hand, relate to funding availability, but also challenges regarding economic valuation and cost perceptions. At the same time, a lack of innovative financing mechanisms limits the mobilisation of private sector investment. The absence of insurance data and standardised metrics for assessing risk reduction benefits, in comparison to grey infrastructure, further complicates economic assessment.

5. References

Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (Eds.). (2016). *Nature-based solutions to address global societal challenges*. IUCN International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2016.13.en

Cohen-Shacham, E., Andrade, A., Dalton, J., Dudley, N., Jones, M., Kumar, C., Maginnis, S., Maynard, S., Nelson, C. R., Renaud, F. G., Welling, R., & Walters, G. (2019). Core principles for successfully implementing and upscaling Nature-based Solutions. *Environmental Science & Policy*, *98*, 20–29. https://doi.org/10.1016/j.envsci.2019.04.014

European Commission > Research and innovation > Nature-based solutions https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en [Accessed January 2026]

Faivre, N., Fritz, M., Freitas, T., de Boissezon, B., & Vandewoestijne, S. (2017). Nature-Based Solutions in the EU: Innovating with nature to address social, economic and environmental challenges. *Environmental Research*, 159, 509-518. https://doi.org/10.1016/J.ENVRES.2017.08.032

Giordano, R., Pluchinotta, I., Pagano, A., Scrieciu, A., & Nanu, F. (2020). Enhancing nature-based solutions acceptance through stakeholders' engagement in co-benefits identification and trade-offs analysis. *Science of The Total Environment*, *713*, 136552. https://doi.org/10.1016/j.scitotenv.2020.136552

Jagt, A. P. N. van der, Szaraz, L. R., Delshammar, T., Cvejić, R., Santos, A., Goodness, J., & Buijs, A. (2023). Policy mixes for mainstreaming urban nature-based solutions: An analysis of six European countries and the European Union. *Environmental Science & Policy*, 140, 42-56. https://doi.org/10.1016/j.envsci.2022.10.011

Scrieciu, A., Rotaru, S., Alexandrescu, B., Catianis, I., Nanu, F., Marchal, R., Pagano, A., & Giordano, R. (2023). Reducing Water Related Risks in the Lower Danube Through Nature Based Solution Design: A Stakeholder Participatory Process. In E. López-Gunn, P. van der Keur, N. Van Cauwenbergh, P. Le Coent, & R. Giordano (Eds.), *Greening Water Risks: Natural Assurance Schemes* (pp. 171–199). Springer International Publishing. https://doi.org/10.1007/978-3-031-25308-9_10

Terton, A. (2022). Nature-Based Solutions: An Approach for Joint Implementation of Climate and Biodiversity Commitments. GIZ/IISD/UFZ. https://www.adaptationcommunity.net/wp-content/uploads/2022/05/03-thematic-paper-NbS-biodiv-climate-implementation-giz-iisd-ufz.pdf

6. List of policy instruments

Nature-based solutions for supporting sustainable development (UNEA resolution UNEP/EA.5/Res.5), 2 March 2022

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy [2000] OJ L 327/1

Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks [2007] OJ L 288/27

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Nudges and choice architecture

1. Introduction

Nudges are interventions in choice architecture designed to influence human behaviour in a targeted manner. Under nudging, relative prices remain unchanged; in particular, the choice set of individuals is not altered (Thaler and Sunstein 2021). Thus, nudges can be distinguished from traditional approaches such as 'command and control' (mandates/ prohibitions) or market-based instruments (price adjustments). Often, nudges are relatively simple to implement and can be introduced at low cost.

Nudges encompass a variety of instruments, including, for example, default rules (e.g., automatic enrolment in programmes), framing (e.g., presenting information as a gain or a loss), the use of social norms (emphasising what most people do or should do), reminders (e.g., email/ text messages if an invoice remains unpaid), and simplifications (e.g., the use of visual figures instead of numerical data) (Sunstein 2019). Nudges are regarded as an efficient tool for behavioural change (DellaVigna and Linos 2022). They are applied in numerous sectors, such as health and finance. More recently, there has been a slight increase in the attention paid to the application of nudges in the fields of nature and biodiversity. For example, information instruments, such as the Nutri-Score, Eco-Score, the EU Ecolabel, and national ecolabels (e.g., the Blue Angel), are utilised to guide consumer choices through simplified, standardised environmental information (Primi et al. 2024). The design of these labels – including colours, scales, and symbols – is part of a regulated choice architecture aimed at promoting resource- and biodiversity-friendly consumption.

The influence of nudges is indirect and occurs through human behaviour (Wirth et al. 2024). A nudge modifies the decision-making environment, which, for instance, alters the individual's perception of the situation. In times of polycrises, there may be a saturation of negative information. With the help of nudges, information could be presented in a manner specific to target groups. Instead of burdensome negative information (e.g., species extinction and the poor state of nature), positive aspects could be emphasised more strongly, thereby motivating people to engage in biodiversity conservation. Nudges are also referred to as libertarian paternalism

(Thaler and Sunstein 2023): libertarian, because the individual's freedom of choice is fully preserved, and paternalism, because a targeted influence on behaviour is intended. This necessitates the prior definition of objectives. Consequently, if biodiversity generally receives little attention, it is possible that no target definitions – and thus no nudges – will be designed.

Nudges can be described as an innovation, as every situation is slightly different. The framework conditions, such as the political situation, social narratives, and technological possibilities, are continuously changing.

2a. Case study I: Green default policy to reduce use of printing paper

The waste of resources represents a problem for nature and biodiversity. This includes the use of printer paper. At various institutions and universities, the default setting (default policy) for printing was changed. The preset was switched from single-sided to double-sided printing. As a result, printer paper was saved, which led to fewer trees being necessary for paper production (cf. Social and Behavioral Sciences Team 2015; González-Ramírez 2024).

2b. Case study II: Persuasive messages to reduce food waste

The global population is increasing, and food security represents a major problem. Various nudges have been used with the goal of reducing food waste through persuasive messages. These include reminders in the form of anti-food-waste messages, highlighting that food is naturally imperfect and that food waste is a problem. The result was that the provision of information helped people to choose more 'imperfect-looking' food (OECD 2017; Zhang et al. 2023).

2c. Case study III: Information load can hinder the success of information labels

Biodiversity loss caused by intensive livestock farming represents a significant threat to the resilience of global food systems. Since the environmental benefits of grazing-based production are 'credence attributes' that consumers cannot directly experience, there is a lack of awareness and demand for biodiversity-friendly meat (i.e. biodiversity loss is often perceived as abstract and distant). To address this, a multi-level labelling nudge was investigated by Stampa and Zander (2022) to differentiate between various degrees of conservation measures in pasture-raised beef. The study found that while consumers appreciate local nature conservation, the effectiveness of such a nudge is challenged by low biodiversity knowledge and a market already saturated with complex labels.

3. Deployment, Diffusion, Amplification

Compared to traditional approaches such as command and control, there is significantly less literature on the relevance of nudges in the field of biodiversity. However, the link between biodiversity and human behaviour and perception is very frequently connected to elements that encompass, at least in part, characteristics of nudges. In the context of biodiversity, nudges are particularly promising when it comes to narrowing the 'knowledge-action gap' (cf. Portus et al. 2024). With the help of nudges, decision-making situations can be designed in a way that promotes biodiversity-friendly behaviour. For example, everyday routines can be influenced through nudges without having to resort to prohibitions or financial incentives.

The implementation of nudges is often cost-effective. Therefore, nudges can be transferred relatively easily to other contexts (e.g., consumption, mobility, diet, land use). Especially when financial resources are scarce, nudges can be a promising tool for biodiversity. However, it must be taken into account that behaviour is context-dependent. Before transferring nudges to people of different cultures and values, it is therefore advisable to conduct research using controlled experiments, which increases their scalability (List 2024).

Nudges offer high potential for policy measures in the field of biodiversity. This applies both to the design of the measures themselves and to the way they are communicated. Visual communication (e.g., image-based campaigns on species loss, ecosystem services, or insect decline) is employed within the framework of governmental environmental and biodiversity strategies. These campaigns aim to increase public awareness and strengthen acceptance for political measures, such as those within the context of the EU Biodiversity Strategy for 2030.

In addition, a series of labelling regulations enable information nudges by ensuring that environmental and biodiversity claims are accurate and non-misleading, thereby creating trust within the choice architecture. The EU Ecolabel regulation, for instance, translates complex environmental information into a simple visual cue. As a nudge, it reduces cognitive effort and guides consumers toward products with better environmental and biodiversity performance. Similarly, according to the organic production regulation, the organic logo functions as a heuristic nudge, allowing consumers to associate products with sustainability at a glance, though it remains too broad to signal specific biodiversity outcomes. The 0–3 egg labelling system in accordance with the Egg Marketing Standards Regulation is a clear example of a multi-level nudge that makes production conditions easily comparable. It serves as a blueprint for biodiversity nudges that communicate different levels of conservation effort in a simple, intuitive way.

4. Barriers

When designing nudges, it is essential to take various barriers into account. Social barriers encompass the low visibility and abstract nature of biodiversity loss, which complicates the perception of individual opportunities for action. Furthermore, there is a risk that people will engage in information avoidance if the information is expected to be linked to negative emotions (Golman et al. 2017). Additionally, the paternalism inherent in the design is sometimes criticised (in terms of who decides what is 'good' for people).

Economic barriers include conflicts of interest (e.g., the use of labels for purely commercial reasons), a focus on monetary prices rather than value – which should incorporate societal costs and benefits – and short-term thinking.

Regulatory barriers include a lack of political prioritisation of biodiversity. Unclear responsibilities and fragmented governance structures in biodiversity conservation hinder the coordinated application of nudges, as do conflicting interests (e.g., thinking within the constraints of election cycles).

5. References

DellaVigna, S., & Linos, E. (2022). RCTs to scale: Comprehensive evidence from two nudge units. Econometrica, 90(1), 81-116.

Golman, Russell, David Hagmann, and George Loewenstein. 2017. Information Avoidance. Journal of Economic Literature 55 (1): 96–135.

González-Ramírez, J. (2024). The effectiveness of a green default nudge in achieving resource conservation. Agricultural and Resource Economics Review, 53(2), 337-355.

List, J. A. (2024). Optimally generate policy-based evidence before scaling. Nature, 626(7999), 491-499.

Portus, R., Aarnio-Linnanvuori, E., Dillon, B., Fahy, F., Gopinath, D., Mansikka-Aho, A., ... & McEwen, L. (2024). Exploring the environmental value action gap in education research: a semi-systematic literature review. Environmental Education Research, 30(6), 833-863.

Primi, R., Grossi, G., Danieli, P. P., Vitali, A., Lacetera, N., & Ronchi, B. (2024). State of the art and challenges in the environmental labelling for animal food products. Italian Journal of Animal Science, 23(1), 1104-1123.

Social and Behavioral Sciences Team (2015), Social and Behavioral Sciences Team 2015 Annual Report, Office of Science and Technology Policy, Washington, DC.

Sunstein, C. R. (2019). Nudging: a very short guide. Business Economics, 54(2), 127-129.

Stampa, E., & Zander, K. (2022). Backing biodiversity? German consumers' views on a multi-level biodiversity-labeling scheme for beef from grazing-based production systems. Journal of Cleaner Production, 370, 133471.

Thaler, R. H., & Sunstein, C. R. (2021). Nudge: The final edition. Penguin.

Thaler, R. H., & Sunstein, C. R. (2023). Libertarian paternalism. In Research Handbook on Nudges and Society (pp. 10-16). Edward Elgar Publishing.

OECD (2017), Tackling Environmental Problems with the Help of Behavioural Insights, OECD Publishing, Paris, https://doi.org/10.1787/9789264273887-en

Wirth, C., Bruelheide, H., Farwig, N., Marx, J. M., & Settele, J. (2024). Faktencheck Artenvielfalt. oekom Verlag. https://doi.org/10.14512/9783987263361

Zhang, J., Huang, Y., Zhu, J., & Zhao, L. (2023). A meta-analysis on the effectiveness of food-waste reducing nudges. Food Policy, 120, 102480.

6. List of policy instruments

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU

Biodiversity Strategy for 2030 Bringing nature back into our lives, COM/2020/380 final

Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel [2010] OJ L 27

Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers, amending Regulations (EC) No 1924/2006 and (EC) No 1925/2006 of the European Parliament and of the Council, and repealing Commission Directive 87/250/EEC, Council Directive 90/496/EEC, Commission Directive 1999/10/EC, Directive 2000/13/EC of the European Parliament and of the Council, Commission Directives 2002/67/EC and 2008/5/EC and Commission Regulation (EC) No 608/2004 [2011] OJ L 304/18

Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel [2010] OJ L 27/1

Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May 2018 on organic production and labelling of organic products and repealing Council Regulation (EC) No 834/2007 [2018] OJ L 150/1

Commission Regulation (EC) No 589/2008 of 23 June 2008 laying down detailed rules for implementing Council Regulation (EC) No 1234/2007 as regards marketing standards for eggs [2008] OJ L 163/6

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Organic farming

1. Introduction

Organic farming is an integrated production management system that promotes and enhances agroecosystem health, including biodiversity, biological cycles and soil biological activity. It renounces synthetic fertilisers and pesticides and emphasises the use of natural inputs (i.e. mineral and products derived from plants). Acknowledging that all elements of the agricultural ecosystem are linked to each other, organic farming shares techniques with other approaches for sustainable agriculture, such as agroforestry and agroecology, including intercropping, crop rotation, and integration of trees, crops and livestock. It is, however, the use of natural inputs, the improvement of soil fertility and the use of a crop rotation plan that distinguish organic farming from other agricultural management systems (FAO, 2020).

According to the International Federation of Organic Agriculture Movements (IFOAM) – an international non-governmental organisation that has established guidelines that have been widely adopted by the organic farming community – organic agriculture practices are based on four principles: health, ecology, fairness, and care. Furthermore, according to the 2007 Guidelines on organically produced foods of the Codex Alimentarius, an organic production system is designed to: enhance biodiversity within the whole system; increase soil biological activity; maintain long-term soil fertility; recycle wastes of plant and animal origin, in order to return nutrients to the soil, thus minimising the use of non-renewable resources; rely on renewable resources in locally organised agricultural systems; promote the healthy use of soil, water and air and minimise all forms of pollution; promote careful processing methods for agricultural products; and become established on any farm through a period of conversion, the appropriate length of which is determined by site-specific factors.

Organic farming is currently practised in most countries around the globe, with 99 million hectares of agricultural land being managed following the organic agriculture principles, by at least 4.3 million farmers (Willer et al, 2025). In the EU, it has evolved from a niche practice to a policy priority, with a commitment to organic farming enshrined in multiple policy frameworks, including the European

Green Deal, the Farm to Fork Strategy, and the Biodiversity Strategy for 2030 – with a target of 'at least 25% of the EU's agricultural land under organic farming and a significant increase in organic aquaculture by 2030'.

While organic farming in the EU has been growing, its expansion is not uniform across Member States, nor without challenges. Organic farming is thus treated as an innovation, because it still represents and requires a paradigm shift: moving away from chemical-dependent agricultural production methods to knowledge- and often labour-intensive nature-based practices, based on ecological processes and integrated pest management.

2. Case Study: Italy's Organic Districts (Biodistretti)

Italy has successfully expanded its organic farming sector, a noteworthy achievement given the predominance of smallholder and family farms in the country, often in mountainous areas, and structural challenges regarding aging rural populations and farmland abandonment (Zollet, 2024).

A feature of Italy's approach is the recent legislative recognition of 'organic districts' (*distretti biologici or biodistretti*) as forms of territorial organisation focused on organic production. These areas represent integrated territorial systems where organic farming is linked to rural revitalisation and the survival of small farms. The model thus goes beyond individual farm conversion to encompass entire territories, fostering collaboration among farmers, processors, local authorities and civil society organisations. It aims to create economies of scale and strengthen local supply chains, as well as facilitate knowledge sharing and community building.

The approach has attracted a new generation of farmers, who view it as economically viable and aligned with their values. It is also linked to an expansion of food networks in the country, including farmers' markets, community-supported agriculture, and direct sales to consumers, improving farmers' access to markets. At the same time, there are ongoing challenges, including: organic certification, which remains burdensome and expensive for smallholders; the constant demand for agricultural productivity and cheap food, despite the environmental and social cost; and the incoherent policy framework, which continues to enable industrial farming and benefit corporate agri-food actors.

3. Deployment, diffusion, amplification

Policy support for organic farming has been constantly increasing in the EU, with the CAP 2023-2027 being the main pathway for financial support, channelling resources through rural development programmes, agri-environment schemes and eco-schemes. As the economic risk and high cost are among the main disincentives for transition to organic farming, such instruments provide payments for conversion to organic production, aiming to assist with the risk and high transition cost. Public procurement policies in some countries, such as Denmark, have also helped create stable demand for organic produce, while building consumer awareness through targeted campaigns and strong labelling systems. Indeed, increased consumer awareness of the environmental footprint of agricultural production has led to increased demand for organic produce in many countries, including in Europe.

At the same time, the institutional environment shapes organic farming diffusion considerably. This includes the regulatory framework, including the integration of organic farming into agricultural policies and strategies, as well as factors such as the power of organic farming organisations and dedicated policy and agronomic support, including availability of organic farm advisors and farmer-to-farmer exchange networks (Reganold & Wachter, 2016).

Dedicated knowledge production and transfer remain a fundamental element for diffusion. As an illustration, OrganicTargets4EU is a collaboration among EU-funded researchers, farmers and policy experts working to identify barriers, test solutions, and shape policy for a more resilient organic sector. In addition, it is shown that farmers are more likely to convert to organic farming together with neighbours rather than individually, to facilitate knowledge exchange as well as create a stronger local market.

In the EU, the regulatory framework provides a harmonised definition of organic production and labelling standards, aiming to facilitate trade in organic products in the block and build consumers' confidence in organic certification. Regulatory complexity and the cost of labelling and certification, however, cause uncertainty and barriers to adoption. Social movements, consumer organisations and civil society have been active in promoting organic farming, often in the face of regulatory uncertainty. Alternative food networks, including farmers' markets, community-supported agriculture, and organic box schemes, create direct connections between producers and consumers, building consumer awareness while improving market access for organic farmers.

4. Barriers

Economic barriers are the most cited obstacles to adoption of organic farming. They relate to the economic challenge of the required transition period, the higher production cost, but also, the cost of the lower yield, which is typically the result of organic production methods. In addition, investment requirements may be prohibitive for smallholders unless subsidised; the demand and market access are also often uncertain.

At the same time, for some regions, adoption of organic farming comes in a context of rural abandonment, urbanisation, and ageing of farmers, stressing the need for comprehensive policy and social solutions to address rural development. Agronomic knowledge deficits, lack of awareness, and scepticism about economic viability, may also affect rates of adoption; cooperatives can address obstacles by facilitating knowledge sharing and strengthening market access.

Limited adoption may also relate to the complexity of the regulatory framework, including the organic certification system, which is often described as burdensome and expensive. Excessive bureaucracy and uncoordinated policies are additional complicating factors.

Addressing these barriers requires comprehensive policy approaches that provide adequate public support, including through financial support, investment in knowledge transfer and market development, clear and proportionate regulatory frameworks, and policy coherence across the food and agriculture sector.

5. References

Food and Agriculture Organization of the UN (FAO) (2020). Introduction to Organic Agriculture. FAO. https://teca.apps.fao.org/en/technologies/8359/

Reganold, J. P., & Wachter, J. M. (2016). Organic agriculture in the twenty-first century. *Nature Plants*, *2*(2), 15221. https://doi.org/10.1038/nplants.2015.221

Willer, H., Trávníček, J. & Schlatter, B. (eds.) (2025). *The World of Organic Agriculture. Statistics and Emerging Trends 2025*. Research Institute of Organic Agriculture FiBL and IFOAM - Organics International. https://orgprints.org/id/eprint/54617/

Zollet, S. (2024). Organic Farming Systems and Rural Revitalization in Italy – Current Situation and Way Forward. *Journal of Rural Problems*, 60, 27. https://www.jstage.jst.go.jp/article/arfe/60/1/60_27/_html/-char/en

6. List of policy instruments

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on an Action Plan for the Development of Organic Production, COM/2021/141 final/2

Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May 2018 on organic production and labelling of organic products and repealing Council Regulation (EC) No 834/2007 [2018] OJ L 150/1

Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control [2018] OJ L 250/1

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Biodiversity Strategy for 2030 Bringing nature back into our lives, COM/2020/380 final

Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, The European Green Deal, COM/2019/640 final

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A Farm to Fork Strategy, COM(2020) 381 final

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Payments for ecosystem services: True Cost Accounting

1. Introduction

Modern environmental governance operates within economic systems that systematically privilege short-term private gains over long-term ecological stability. Land-use decisions that are individually rational often generate cumulative environmental degradation, resulting in the erosion of ecosystem services that underpin economic activity and human well-being. PES have emerged as a response to this structural contradiction by explicitly linking environmental stewardship to financial incentives (Yan et al., 2022).

The ecosystem services framework provides a functional lens through which nature is understood as a life-support system for human societies. According to the Millennium Ecosystem Assessment, ecosystems generate a wide array of services ranging from material provisioning to climate regulation, cultural meaning, and biophysical processes that sustain life (Millennium Ecosystem Assessment, 2005). Beyond its descriptive function, the framework also serves a normative role by prioritising those aspects of nature that can be aligned with socio-economic objectives.

This anthropocentric orientation has sparked extensive debate. On the one hand, monetising ecosystem services risks reinforcing a utilitarian worldview in which nature is valued only insofar as it is economically productive. On the other hand, advocates argue that economic valuation can function as a strategic translation mechanism, rendering ecological concerns legible within dominant policy and market discourses (Redford and Adams, 2009). PES thus operate at the intersection of environmental ethics, political economy and institutional design.

Conceptually, PES can be understood as part of a broader shift from command-and-control regulation toward incentive-based and hybrid governance mechanisms. Yan et al. (2022) describe PES as a novel form of land rent that reconfigures property relations by partially reallocating land-use rights in favour of ecosystem service provision. This perspective highlights that PES are not merely technical instruments but interventions that reshape social relations, power dynamics and notions of entitlement.

Historically, PES developed through pragmatic experimentation rather than as an abstract academic proposal. Early programmes, most notably in Costa Rica, demonstrated that direct compensation for conservation could alter land-use trajectories at scale. Since then, PES have diffused globally across diverse political, ecological and socio-economic contexts. This diffusion has been accompanied by increasing institutional diversity, ranging from state-led redistribution schemes to market-based and voluntary arrangements.

Despite their apparent flexibility, PES face inherent limitations in scaling. Their effectiveness depends on institutional capacities that are unevenly distributed across regions, including secure land tenure, administrative competence, and financial stability. Moreover, ecosystem services are spatially interconnected and temporally dynamic, complicating efforts to define, measure, and commodify them. As a result, PES should be seen less as universally scalable solutions and more as context-sensitive governance tools (Redford and Adams, 2009).

Beyond their instrumental function, PES contribute to a broader reconceptualisation of nature as an active component of economic systems rather than an external backdrop. By making ecological dependencies visible, PES challenge conventional growth models that treat environmental degradation as an acceptable side effect of development.

2. Case Study: True Cost Accounting and Corporate PES

True Cost Accounting (TCA) extends the logic underlying PES beyond land-use and conservation policy into global production, consumption, and trade systems. At its core, TCA seeks to correct the systematic under-pricing of goods and services by incorporating environmental and social externalities into economic decision-making. These externalities include biodiversity loss, greenhouse gas emissions, soil degradation, water pollution, and impacts on ecosystem resilience that are typically excluded from market prices (True cost accounting of food, 2021).

From a conceptual standpoint, TCA represents an attempt to realign microeconomic signals with macro-level sustainability objectives (Michalke et al., 2021). Whereas PES in general directly remunerate specific ecosystem services, TCA aims to make the absence or degradation of such services visible within accounting and reporting frameworks. In this sense, TCA can be understood as an indirect or informational form of PES that operates through transparency rather than direct compensation alone.

The adoption of TCA has gained momentum, particularly within the private sector, where corporations face growing pressure from regulators, investors and consumers, to disclose environmental risks. Corporate environmental accounting initiatives, such as Environmental Profit and Loss (EP&L) statements, seek to quantify environmental impacts across entire value chains, including upstream suppliers and downstream consumption phases. The case of PUMA illustrates how monetised environmental data can inform strategic decisions, supply-chain restructuring, and risk management (Kehring and Partners, 2019).

However, the practical implementation of TCA faces significant methodological and political challenges. Assigning monetary values to ecosystem services involves normative assumptions about discount rates, substitution possibilities, and the commensurability of ecological and economic values. Different valuation methods can yield widely divergent results, raising concerns about comparability, credibility, and potential strategic manipulation (Michalke et al., 2021).

In addition, TCA initiatives are predominantly voluntary and unevenly adopted, which limits their transformative potential. Firms that internalise environmental costs may face competitive disadvantages in the absence of harmonised regulatory frameworks. As a result, critics argue that TCA risks becoming a reputational tool rather than a driver of systemic change, unless embedded within binding policy instruments.

Carbon offsetting schemes constitute a prominent, yet contested, application of TCA principles that closely resembles PES. By financing emission reduction or carbon sequestration projects elsewhere, emitters seek to neutralise part of their carbon footprint. While offsetting can mobilise financial flows toward conservation and mitigation efforts, it also raises concerns regarding additionality, permanence, leakage and moral hazard. Critics caution that offsetting may legitimise continued emissions by framing responsibility as a compensable transaction, rather than an obligation to reduce absolute emissions.

Beyond carbon markets, emerging applications of TCA include biodiversity credits, water footprint accounting, and nature-related financial disclosures. These developments indicate a broader trend toward integrating ecosystem services into financial governance. At the same time, they highlight the risk that complex ecological relationships are reduced to standardised metrics that may obscure context-specific dynamics.

3. Deployment, Diffusion, Amplification

The rapid expansion of PES has been accompanied by a growing body of interdisciplinary research examining their environmental effectiveness, economic efficiency and social consequences (Song et al., 2023). This literature emphasises that PES outcomes are shaped as much by institutional design as by ecological conditions.

Successful PES schemes typically exhibit clearly specified objectives, conditional payments, and robust monitoring mechanisms (Ezzine-de-Blas et al., 2016). Yet, such technical criteria alone are insufficient. PES also interact with local norms, power relations, and historical land-use patterns. In contexts marked by unequal access to resources, PES may inadvertently reinforce existing inequalities or marginalise vulnerable groups.

Importantly, empirical evidence suggests that PES do not necessarily erode intrinsic conservation motivations. Instead, they often coexist with moral, cultural and identity-based reasons for environmental stewardship (Vorlaufer et al., 2025). This finding challenges simplistic assumptions about human behaviour and underscores the importance of pluralistic policy approaches.

4. Barriers

A fundamental critique of PES concerns their implicit framing of conservation as a service rendered in exchange for payment, rather than as a collective responsibility. This framing reflects broader neoliberal tendencies to govern through markets and incentives. While PES can enhance efficiency under certain conditions, they risk narrowing political debate by privileging economic rationales over ethical and ecological considerations (Redford & Adams, 2009). Moreover, the focus on discrete, measurable services may obscure the systemic and interdependent nature of ecosystems. Efforts to bundle multiple services within PES schemes offer a potential remedy but introduce additional complexity and transaction costs (Redford & Adams, 2009).

Looking forward, the role of PES is likely to expand within international climate and biodiversity governance, particularly through mechanisms such as results-based finance and transnational offset markets. Whether this expansion contributes to genuine sustainability will depend on the ability of institutions to balance economic pragmatism with ecological integrity and social justice.

Ultimately, PES should be understood not as a panacea, but as one component within a diversified environmental governance toolkit. Their greatest potential lies not only in altering individual incentives, but in fostering broader societal recognition of humanity's embeddedness within ecological systems.

5. References

Ezzine-de-Blas, D., Wunder, S., Ruiz-Pérez, M., & Moreno-Sanchez, R. D. P. (2016). Global patterns in the implementation of payments for environmental services. *PloS one*, *11*(3), e0149847.

Kering & Partners. (2019). *Environmental Profit and Loss Account (EP&L) – Kering & Puma case study*. United Nations System of Environmental-Economic Accounting (SEEA) Workshop.

Michalke, A., Kunz, J., & Gaugler, T. (2025). *True Cost Accounting: Assessing Environmental and Social Damages of Production*. Taylor & Francis.

Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Synthesis*. Island Press.

Redford, K. H., & Adams, W. M. (2009). Payment for ecosystem services and the challenge of saving nature. *Conservation biology*, *23*(4), 785-787.

Song, C., Liu, Y., Liu, L., Xian, C., & Wang, X. (2023). A scientometric analysis of payments for ecosystem services research: Mapping global trends and directions. *Sustainability*, *15*(21), 15649.

True cost accounting of food. (2021). *Nature Food*, *2*(9), 629–629.

Vorlaufer, T., Steimanis, I., & Plassenberg, J. (2025). Payment for ecosystem services and crowding of conservation behavior: A meta-analysis of lab-in-the-field experiments. *Ecosystem Services*, *74*, 101750.

Yan, H., Yang, H., Guo, X., Zhao, S., & Jiang, Q. O. (2022). Payments for ecosystem services as an essential approach to improving ecosystem services: A review. *Ecological Economics*, *201*, 107591.

6. List of policy instruments

COP30 Presidency. (2025). *Declaration on the launch of the Tropical Forest Forever Facility (TFFF)*. https://tfff.earth/wp-content/uploads/2025/11/Declaration-on-the-Launch-of-the-TFFF.pdf

European Commission. (2023). *Guidance on the development of public-private payment schemes for forest ecosystem services*. European Union. https://agriculture.ec.europa.eu/system/files/2023-07/guidance-dev-public-private-payment-schemes-forest_en.pdf

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Payments for ecosystem services: Grain for Green in China

1. Introduction

In the conventional market system, land use practices that benefit landowners the most often lead to the decline of important ecosystem services. To protect ecosystem services and counteract these socially unfavourable economic dispositions, paying for the maintenance of ecosystem services (PES) is often seen as a possible solution.

Today, the concept of ecosystem services is central for describing humanity's dependence on intact nature. According to the Millenium Ecosystem Assessment, 'ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fibre; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling' (Millennium Ecosystem Assessment, 2005, p. v).

By this definition, it is clear that the concept of ecosystem services focuses heavily on the instrumental value of nature for humans. The concept of PES remains within this perspective by giving nature an economic price tag. While some see this as a weakness of PES, others see it as a strength (Redford and Adams, 2009).

Yan et al. (2022) conceptualise PES as a new separate form of land rent: 'PES and the traditional land rent both originate from the land use rights, but the former generally aims to partly share rather than completely monopolise the rights to use the land vital to the provision of certain ecosystem services' (Yan et al., 2022, p. 4).

Costa Rica has been a pioneer in PES ever since it created one of the first such programmes in 1996. Since then, the programme has compensated landowners for conserving forests, thus significantly reducing deforestation in the country. PES has been put into use in many countries, including Ecuador, Bolivia, Kenya, Uganda, Tanzania, India, South Africa, Mexico, and the United States. In fact, in contrast to many other ideas for environmental protection, PES has not been a purely intellectual construct. To the contrary, research has often struggled to keep up with PES in practice (Yan et al., 2022).

While PES have been implemented successfully in many places, there are some reasons to be sceptical about their scalability. Scalability is not an inherent property of PES but rather is highly context-dependent. PES require clear property rights, MRV systems, and consistent contract enforcement, which can often only be achieved locally or involve considerable efforts on a bigger scale. Furthermore, ecosystem services differ from each other locally and at larger scales; there can also be financial constraints. This doesn't mean that PES are not scalable at all, but they are institutionally demanding, and their scaling-up requires substantial governance capacities (Farley and Constanza, 2010).

PES are innovative because they establish new institutional frameworks for managing the relationship between humans and nature. They constitute a reassessment of nature as a social service and a recognition of related production and opportunity costs (Yan et al., 2022). They shift environmental policy from damage limitation to proactive incentives by making externalities explicit.

2. Case Study: Grain for Green in China

Before becoming president, Xi Jinping first coined the slogan 'Lucid Waters and Lush Mountains are Invaluable Assets' (Yan et al., 2022, p. 2). This slogan encapsulates the vision of the Chinese Grain for Green programme. Implemented in 1999, it has since become the world's largest ecological restoration plan. It includes a key component based on PES (Xian et al., 2020). Embedded within a broader state-led development strategy, the programme reflects an evolving political narrative that frames ecological protection as compatible with, and even essential to, long-term economic prosperity.

The devastating floods of 1998 were one of the main reasons for the programme, as they demonstrated the need to increase forest cover on sloped cropland to prevent soil erosion. The name 'grain for green' originates from the fact that participants are not only paid in cash for the afforestation of their farmland etc., but they are also compensated with in-kind grain. Thus, unlike narrowly defined conservation initiatives, Grain for Green combined ecological objectives with rural development goals.

The programme has reportedly significantly contributed to afforestation, decreased soil erosions and mitigated China‘s carbon emissions (Xian et al., 2020). However, its large-scale implementation also reveals structural tensions inherent in PES. For example, the large plantations consumed more water locally and thus influenced the water distribution in landscapes (An et al., 2025). Furthermore, the state-defined targets incentivised rapid tree planting, often favouring monocultures that maximise short-term indicators while neglecting ecological resilience (Hua et al., 2016).

From a governance perspective, Grain for Green illustrates how PES can function as instruments of territorial management and social policy. Participation decisions were shaped not only by financial incentives, but also by administrative authority and limited alternative livelihood options, raising questions about voluntariness and distributive justice.

3. Deployment, Diffusion, Amplification

Over the past few decades, there has been a rapid increase in publications in the field of PES. Key topics in this research have included effectiveness, efficiency assessment and equity (Song et al., 2023).

Research has identified several important design features for PES schemes to work well. The ecosystem service to be provided (e.g. forest protection, water quality, carbon sequestration) must be precisely defined, because unclear target definitions lead to payments without demonstrable environmental impact (Ezzine-de-Blas et al., 2016). Payments should be strictly linked to the actual provision of the service, which also requires strict monitoring. PES should be used where there is high pressure of use or a real risk of environmental degradation. Payments must at least cover the opportunity costs of alternative use (Yan et al., 2022) and to gain acceptance for the programme, social inequalities, land rights and local power relations must be taken into account (Ezzine-de-Blas et al., 2016).

While PES schemes focus on economic incentives for environmental conservation, research has shown that they do not crowd out land users' non-monetary motivations to engage in conservation behaviour, and that conservation is not totally dependent on continuous payment (Vorlaufer et al., 2025).

4. Barriers

Just as PES does not crowd out the non-monetary motivations of land users for conservation, nor should it in the realm of policymaking. When discussing with policymakers, advocates of PES often make economic arguments about ecosystem services, which may outweigh non-economic justifications for conservation that are, in fact, often more persuasive. Multiple arguments for conservation should be made to convince policymakers and other social actors (Redford and Adams, 2009). Substitution, not replacement, is the most appropriate term for PES in relation to traditional environmental regulation. However, PES can play a role within a broader social and institutional context (Ezzine-de-Blas et al., 2016).

PES carry the risk that ecosystems are increasingly being engineered to maximise a single service, which does not always benefit biodiversity (Redford & Adams, 2009). This is evident in the above-illustrated case study concerning the dominance of monocultures within China's Grain for Green Programme. Instead of maximising single services, ecosystem services should be treated in a bundle – but that, in turn, can make monitoring and the conditionality of PES much more complex.

Another problem with the PES concept is that it considers the provision of ecosystem services to be an additional positive externality. Yet, arguably, taking care of society's natural resources is an inherent duty of everyone who utilises them. This, though, 'depends largely on one's view on property rights and entitlements, and to what extent they entail the right to unfettered exploitation of available natural resources even beyond sustainability levels'(Van Hecken and Bastiaensen, 2010).

In this sense, PES can be viewed as both a symptom of and a consequence of environmental commodity fetishism. An appropriate response would be to reaffirm the public good nature of environmental services.

5. References

An, Q., Liu, L., Staal, A., Yang, K., Cheng, Y., Liu, J., & Huang, G. (2025). Land cover changes redistribute China's water resources through atmospheric moisture recycling. *Earth's Future*, *13*(10), e2024EF005565.

Ezzine-de-Blas, D., Wunder, S., Ruiz-Pérez, M., & Moreno-Sanchez, R. D. P. (2016). Global patterns in the implementation of payments for environmental services. *PloS one*, *11*(3), e0149847.

Farley, J., & Costanza, R. (2010). Payments for ecosystem services: from local to global. *Ecological economics*, *69*(11), 2060-2068.

Hua, F., Wang, X., Zheng, X., Fisher, B., Wang, L., Zhu, J., ... & Wilcove, D. S. (2016). Opportunities for biodiversity gains under the world's largest reforestation programme. *Nature Communications*, *7*(1), 12717.

Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Synthesis*. Island Press.

Redford, K. H., & Adams, W. M. (2009). Payment for ecosystem services and the challenge of saving nature. *Conservation biology*, *23*(4), 785-787.

Song, C., Liu, Y., Liu, L., Xian, C., & Wang, X. (2023). A scientometric analysis of payments for ecosystem services research: Mapping global trends and directions. *Sustainability*, *15*(21), 15649.

Van Hecken, G., & Bastiaensen, J. (2010). Payments for ecosystem services: justified or not? A political view. *Environmental science & policy*, *13*(8), 785-792.

Vorlaufer, T., Steimanis, I., & Plassenberg, J. (2025). Payment for ecosystem services and crowding of conservation behavior: A meta-analysis of lab-in-the-field experiments. *Ecosystem Services*, *74*, 101750 https://doi.org/10.1016/j.ecoser.2025.101750

Xian, J., Xia, C., & Cao, S. (2020). Cost–benefit analysis for China's Grain for Green Program. *Ecological Engineering*, *151*, 105850.

Yan, H., Yang, H., Guo, X., Zhao, S., & Jiang, Q. O. (2022). Payments for ecosystem services as an essential approach to improving ecosystem services: A review. *Ecological Economics*, *201*, 107591.

6. List of policy instruments

COP30 Presidency. (2025). *Declaration on the launch of the Tropical Forest Forever Facility (TFFF)*. https://tfff.earth/wp-content/uploads/2025/11/Declaration-on-the-Launch-of-the-TFFF.pdf

European Commission. (2023). *Guidance on the development of public-private payment schemes for forest ecosystem services*. European Union. https://agriculture.ec.europa.eu/system/files/2023-07/guidance-dev-public-private-payment-schemes-forest_en.pdf

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Rewilding

1. Introduction

Rewilding is a broad term used for an approach to wildlife conservation that centres on restoring ecosystems through natural processes to create self-sustaining natural landscapes with little to no human intervention. Rewilding has been used to describe a variety of projects, and while this wide application and plasticity of the term can sometimes be useful, lack of clear definition can cause confusion. Rewilding projects can involve a range of measures such as reintroduction of species, taxon and megafauna replacement and land abandonment. To create better understanding of the term, a definition was developed by Carver et al., (2021) based on previous use of the term: 'Rewilding is the process of rebuilding, following major human disturbance, a natural ecosystem by restoring natural processes and the complete or near complete food web at all trophic levels as a self-sustaining and resilient ecosystem with biota that would have been present had the disturbance not occurred' (p1888).

Alongside this definition, a set of 10 basic principles for rewilding was also developed by the same authors:

- *Restore Trophic Interactions with Wildlife:* Rewilding aims to create self-sustaining ecosystems by reintroducing or reinforcing native species, especially keystone species and ecosystem engineers, to restore natural processes like predation and competition.
- *Plan at a Landscape Scale*: Effective rewilding requires large-scale planning that includes secure core areas, connectivity between habitats, and strategies for coexistence with humans and livestock.
- *Recover Ecological Processes Using Reference Ecosystems*: Restoration should be guided by reference ecosystems - either near-natural areas or historical/scientific evidence - while allowing natural disturbances and, where necessary, using ecologically similar surrogate species.
- *Recognise Ecosystem Dynamics:* Ecosystems are constantly changing due to external (storms, climate) and internal (nutrient cycles, species interactions)

processes. Rewilding should allow these dynamics to occur freely and maintain genetic and ecological diversity.

- *Anticipate and Mitigate Climate Change*: Rewilding projects should factor in climate change impacts and act as nature-based solutions (NbS) to help mitigate them, for example by enhancing carbon capture and enabling species movement along climate gradients.
- *Engage and Include Local Communities:* Successful rewilding depends on stakeholder involvement, transparent consultation, and public education to build support and address concerns about coexistence with wildlife.
- *Integrate Science and Traditional Knowledge*: Rewilding should draw on scientific research, traditional ecological knowledge, and local expertise to inform adaptive management and ensure culturally and ecologically sustainable practices.
- *Use Adaptive Management with Monitoring*: Continuous monitoring – both scientific and participatory – is essential to track progress, identify issues, and adjust strategies through an adaptive management framework.
- *Respect the Intrinsic Value of Nature*: Rewilding is rooted in an ecocentric ethic, recognising the inherent worth of species and ecosystems. Interventions should minimise human control and avoid lethal measures wherever possible.
- *Promote a Paradigm Shift in Human–Nature Relations*: Rewilding advocates transformative change in societal attitudes, aiming to restore fully functioning ecosystems, reject degradation as the norm, and create sustainable economic opportunities for people and nature (Carver et al., 2021).

Rewilding in principle is highly scalable, and indeed benefits from being applied across large scales. Creating an interconnected network of rewilded core areas and corridors is an important aspect of rewilding and creating a connected network can increase the impact of rewilding as a conservation intervention. Despite this, certain aspects of rewilding process can be very context specific. These include which measures are most appropriate – for example which species are suitable for reintroduction. Challenges such as conflict with local communities over land-use and cultural values can be highly nuanced and context specific and need to be addressed at a local level.

While some of the principles and approaches used in rewilding are well-established in, and overlap with ecological restoration, rewilding as a separate principle is relatively recent. Use of the term 'rewilding' has been around since the 1990s, but its recognition in academic literature has increased rapidly since 2015, indicating its growth in importance (Carver et al., 2025)

Rewilding can be considered an innovation because it moves beyond traditional conservation by restoring entire ecological processes rather than focusing on individual species. It embraces dynamic, adaptive management, integrates science with traditional and local knowledge, and acts as a nature-based solution to climate change. By promoting an eco-centric ethic and a paradigm shift in human–nature relations, rewilding not only revives biodiversity but also creates new sustainable economic opportunities, making it a transformative and forward-thinking approach to environmental restoration.

2. Case study: Cambrian Wildwood/ Coetir Anian, Wales

Cambrian Wildwood/ Coetir Anian is a Welsh charity that focuses on the restoration of habitats and species, while also working to connect people with wildlife. In 2017 the charity, in partnership with the Woodland Trust, acquired a 350-acre site in the uplands of Mid Wales. The site, named Bwlch Corog, consists predominantly of moorland with a small area of ancient woodland and two upland streams. The aim is for the site to be naturally recolonised by native woodland and animal species, assisted in part through planting of native trees and potential reintroduction of species such as red squirrel or pine marten.

The idea of the Cambrian Wildwood was first proposed by the Wales Wild Land Foundation (WWLF) in 2007, included plans for introduction of large carnivores, such as lynx and aimed to cover 3000 hectares of the Cambrian mountains. Despite originally being part of a rewilding movement, Cambrian Wildwood was not publicly promoted as a rewilding project. This was based on some of the challenges and conflicts that have arisen between local communities and proponents of rewilding.

This rewilding initiative has been the subject of an in-depth independent study (Wynne-Jones et al., 2018). Wynne-Jones et al., document how tensions arose between proponents of rewilding and the upland sheep farming communities in Wales. There were concerns over the increase in predators, not only from reintroductions but from population increases of existing predators, such as foxes, from the areas of rewilded land. A key point of contention was also over the cultural value of the sheep-farmed uplands, and the sense of belonging and ownership from the communities. Where rewilders described the uplands as empty and degraded, farming representatives saw a 'glorious landscape' of great cultural value (Wynne-Jones et al., 2018). Welsh language and cultural heritage deeply shape how land is understood. Terms closest to 'rewilding' imply wasteland, contrasting with Welsh traditions that view land as home, known through lived experience and pastoral practices like *cynefin* - a concept of belonging and intimate knowledge of place. Rewilding can, therefore, feel like erasing generations of cultural narratives and values tied to farming and stewardship (Wynne-Jones et al., 2018).

Strong emotions are present in both sides of the rewilding debate, yet there is space for discussion and compromise and the finding of shared values. Efforts have been made to reframe rewilding in Wales, show the importance of language and cultural heritage, with terms like *di-ddofi*, and references to Celtic mythology are used to acknowledge farming histories and foster inclusive visions of identity. WWLF has also adapted its vision to address concerns about farming livelihoods by stepping back from controversial predator reintroductions and focusing instead on less divisive species like pine martens and red squirrels. The project now emphasises coexistence with farming and positions Bwlch Corog as a site for exploring diversification, including tourism and educational opportunities to strengthen rural economies. This shift reframes rewilding as a potential solution to community vulnerability rather than a threat, aligning with broader European trends that link ecological restoration with economic sustainability (Wynne-Jones et al., 2018).

These compromises aim to reduce tensions by supporting rural livelihoods and respecting deep place-based attachments, while highlighting that recognition of cultural narratives is essential for building trust and legitimacy in rewilding initiatives. While the nuances of arguments between rewilders and local communities vary, similar tensions can be seen in projects across Europe. This case study highlights the importance of ongoing and meaningful engagement with local communities and is a lesson that can be applied broadly to conservation rewilding initiatives (Wynne-Jones et al., 2018).

3. Deployment, diffusion, amplification

New forms of rewilding are emerging, which can increase the range of habitats and scenarios where rewilding can be employed. For example, urban rewilding can help bring low-maintenance networks of natural spaces into urban environments, increasing biodiversity and improving environmental conditions for people (Pettorelli et al., 2022). Rewilding is currently used to replace agricultural systems, but the two things need not be entirely at odds. There is potential for agricultural rewilding, where wild productive systems composed of wild crops and plants are created and maintained (Vogt, 2021).

Further research on the benefits of rewilding to humans, and in particular the communities in direct proximity to rewilded areas, will help in the development of rewilding projects to help mitigate concerns and conflicts and support ethical governance of wild areas over the long term for the benefit of people and wildlife. Robust long-term monitoring of rewilded areas can help provide empirical evidence for the claims of ecological restoration benefits associated with rewilding which can help support and inform future plans.

Since 2015, global and regional policy frameworks, including the GBF, the EU Biodiversity Strategy 2030 and the EU Nature Restoration Regulation, have recognised the need for ecological restoration. Rewilding can be a key strategy in this regard. Campaigns like Nature Needs Half, Half-Earth Project, and the Trillion Tree Campaign amplify rewilding by linking it to global narratives on climate resilience and biodiversity recovery. These initiatives mobilise public awareness, private investment, and cross-sector partnerships, scaling up efforts and embedding rewilding within broader sustainability agendas.

4. Barriers

Rewilding efforts often face substantial social and political barriers, particularly where land use conflict arises. Competing demands such as agriculture, forestry, recreation, and conservation can generate tensions over how land should be managed. These conflicts are made more complex by the lack of a single agreed-upon definition of rewilding, which means different stakeholders may have very different expectations about what rewilding involves. As a result, disagreements can emerge between conservation organisations, landowners, policymakers, and local communities, especially in areas where cultural traditions and long-standing land management practices are deeply valued. In the European context, these challenges are compounded by fragmented governance structures: land governance is spread across EU institutions, national governments, regional authorities, and local municipalities, making coordinated landscape-scale planning difficult. Additionally, widespread landscape fragmentation caused by urban expansion, road networks, and infrastructure corridors creates physical barriers that restrict species movement and complicate efforts to restore ecological connectivity, one of the core goals of rewilding.

Economic and regulatory challenges also pose significant obstacles. Rewilding initiatives can require substantial financial investment, particularly when acquiring land or supporting long-term monitoring and management. Funding is often uncertain or short-term, making it difficult to sustain projects over the timescales needed for ecological change. Political resistance may arise where rewilding is perceived to threaten livelihoods or undermine local control of land, and concerns about the potential loss of cultural heritage – such as traditional farming landscapes – can further fuel opposition.

In many parts of Europe, the highly fragmented pattern of land ownership adds another layer of difficulty, as rewilding frequently requires cooperation among numerous small landholders rather than a single authority. There is also still a lack of research into economic impacts on local communities, creating further uncertainty (Faure et al., 2024). Together, these social, economic, and regulatory barriers highlight the need for inclusive planning, long-term institutional support, and landscape-level coordination to make rewilding both feasible and socially acceptable.

5. References

Carver, S., Convery, I., Hawkins, S., Beyers, R., Eagle, A., Kun, Z., Van Maanen, E., Cao, Y., Fisher, M., Edwards, S. R., Nelson, C., Gann, G. D., Shurter, S., Aguilar, K., Andrade, A., Ripple, W. J., Davis, J., Sinclair, A., Bekoff, M., … Soulé, M. (2021). Guiding principles for rewilding. *Conservation Biology*, *35*(6), 1882–1893. https://doi.org/10.1111/cobi.13730

Carver, S., Hawkins, S., Convery, I., Beyers, R., Derham, T., & Cao, Y. (2025). *Rewilding: Ten Years of Evolution and Development*. *42*, 31. https://doi.org/10.1146/annurev-environ-111523

Faure, E., Levrel, H., & Quétier, F. (2024). Economics of rewilding. *Ambio*, *53*, 1367–1382. https://doi.org/10.1007/s13280

Pettorelli, N., Schulte to Bühne, H., Cunningham, A. A., Dancer, A., Debney, A., Durant, S., Hoffmann, M., Laughlin, B., Pilkington, J., Pecorelli, J., Seiffert, S., Shadbolt, T., & Terry, A. (2022). *REWILDING OUR CITIES*.

Vogt, M. A. B. (2021). Agricultural wilding: rewilding for agricultural landscapes through an increase in wild productive systems. *Journal of Environmental Management*, *284*. https://doi.org/10.1016/j.jenvman.2021.112050

Wynne-Jones, S., Strouts, G., & Holmes, G. (2018). Abandoning or reimagining a cultural heartland? Understanding and responding to rewilding conflicts in wales – The case of the cambrian wildwood. *Environmental Values*, *27*(4), 377–403. https://doi.org/10.3197/096327118X15251686827723

6. List of policy instruments

Convention on Biological Diversity (CBD) Kunming-Montreal Global Biodiversity Framework (2022), CBD/COP/DEC/15/4.

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Biodiversity Strategy for 2030 Bringing nature back into our lives, COM/2020/380 final

Regulation (EU) 2024/1991 of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869 [2024] OJ L178/1

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Rights of Nature

1. Introduction

Recognising nature as a legal entity with rights is considered a fundamental shift in the relationship between humans and nature, albeit with origins in Indigenous cosmovisions. Cases where nature is granted legal rights are rapidly gaining traction and academic attention. In the early debates on this topic, the rights of nature (RoN) were considered to be both a philosophical legal concept – in which non-human entities are seen as inherently valuable – and a pragmatic tool for solving environmental problems (Soliev et al., 2025).

Today, rights of nature are far more than just an academic concept. Putzer et al. (2025) identify 495 initiatives across 40 countries, with local regulations accounting for almost a third of existing legislation. More than two thirds of country initiatives were identified on the American continents, with the USA having the highest concentration. This stands in line with the fact that the first modern RoN-related legislation was enacted in the USA in Borough Tamaqua in Pennsylvania, where the local government recognised ecosystems as legal persons in response to state and federal law that had rendered the local authority powerless to stop the land application of sewage sludge by corporations (Tanaescu, 2016).

Although local regulations clearly account for the dominant legal type of RoN, their specific forms are more heterogeneous than that. 12,1% of the initiatives identified by Putzer et al. (2025) are international ones. This suggests that RoN can be used as a highly context-specific tool for environmental protection while also being applicable at larger scales. However, implementing RoN on a global scale faces significant barriers. The principle of states' permanent sovereignty over their natural resources is a well-established foundation of public international law and even an integral part of the sustainable development paradigm (Gilbert et al., 2023). Furthermore, Africa and Asia account for a particularly low proportion of RoN-cases, which points towards non-Western-inspired alternatives of rights of nature thought (Putzer et al., 2025). In summary, RoN is a precise, as well as scalable innovation, but implementing it on a global scale is difficult.

Within Bruno Latour's actor-network theory, innovations are understood as a reorganisation of social relationships within networks. In this approach, non-human actors play the same role as human actors. According to Latour, innovation is the process by which new actors (both human and non-human) become capable of acting in new ways and are socially stabilised through translation and network formation (Latour, 2006). In the sense of Latour, the RoN concept is therefore a social innovation par excellence, in which the social roles of non-humans are redefined within a social network of relationships.

Case Study: Rights of Nature in the Ecuadorian Constitution

The American continents have been pioneers in RoN, leaving Europe far behind in this field (Alves et al., 2023). The Latin American country of Ecuador serves as a good example to illustrate this.

In 2008, Ecuador became the first country in the world to officially recognise RoN in its constitution (Kotzé, 2017). Article 71 of the Ecuadorian constitution from 2008 states:

> *'Nature, or Pacha Mama, where life is reproduced and occurs, has the right to integral respect for its existence and for the maintenance and regeneration of its life cycles, structure, functions and evolutionary processes.*
>
> *All persons, communities, peoples and nations can call upon public authorities to enforce the rights of nature. To enforce and interpret these rights, the principles set forth in the Constitution shall be observed, as appropriate.'*

The historical context of this new constitution lies in the presidency of Rafael Correa, who was elected in a time of political and economic crisis, with an anti-neoliberalist agenda (Kotzé, 2017). Previously, the Ecuadorian economy had been largely reliant on natural resource extraction and Indigenous groups had felt powerless against mining and drilling projects on their ancestral lands (Tănăsescu et al., 2024). Rafael Correa initiated a new Constituent Assembly to draft the new constitution. The new constitution included nature's right to preserve and regenerate its life cycles, and to recover after damage, making Ecuador the first country to formally depart from an anthropocentric interpretation of law. The result is a new constitutional model that incorporates Indigenous worldviews (Buen Vivir /

sumak kawsay) into state law, fundamentally questioning the (historically colonial) human dominance over nature (Kotzé, 2017).

But the incorporation of RoN into the Ecuadorian constitution has not been an unmitigated success. The Ecuadorian rainforest of Yasuní, an important biodiversity hotspot but also home to one of the world's largest oil reserves, shows that a legal stance of nature is not enough if there are no real-world actors defending nature‘s rights. Due to lack of financing to compensate oil companies, and despite Ecuador’s plea for international funding, Correa gave the go-ahead to drilling, thus partially sacrificing the introduced RoN. Following a successful national referendum on Yasuní in 2023, however, the oil companies had to withdraw without compensation for their investments and the already installed infrastructure (Malm and Carton, 2024).

This example shows that even though Ecuador has introduced RoN, conflicts persist because there is no hierarchy of rights, and RoN are formally on an equal footing with property rights and state resource policies (Kotzé, 2017). Therefore, RoN are an important innovation, but if no actors are fighting for them, their existence on paper is, at best, merely symbolic – albeit, without the RoN within the constitution as a basis for argumentation, the opponents of oil extraction in Yasuní might have had an even weaker stance in the first place (Ramsés-Hernández et al., 2024).

Furthermore, the lack of concretisation of RoN in the Ecuadorian constitution often means that the Constitutional Court has a special responsibility for shaping the practical consequences of RoN. As a result, several court decisions have given legal personality to rivers, for instance, although they do not seem to indicate a clear boundary between RoN and the human rights of local inhabitants (Tănăsescu et al., 2024).

In conclusion so far, RoN in Ecuador have oscillated 'between rhetoric and reality' (Kotzé, 2017). They represent a revolutionary normative approach that is often incomplete in practice. While they do not automatically result in a completely ecocentric or Indigenous-oriented legal system, they are still an important point of reference for the Ecuadorian public as well as the courts.

3. Deployment, Diffusion, Amplification

Research into RoN is still in its infancy but has grown rapidly since around 2010 (Soliev et al, 2025). The field is heavily interdisciplinary, drawing on law, political science, environmental ethics, and anthropology. Thus far, the focus has been more on normative theory than on empirical research.

Much of the research deals with the fundamental justification of RoN, often criticising the anthropocentrism of doctrinal environmental law and discussing normative-philosophical justifications for ecocentric or relational legal concepts. This line of research draws largely on environmental ethics, Indigenous cosmovisions, and Earth jurisprudence (Soliev et al., 2025).

A second line of research focuses on comparative legal analyses. The examination covers legal constructs (subject status and trustee models), legal standing and institutional enforcement. This research has shown that the formulation of the RoN is highly context-dependent, ranging from symbolic recognition to relatively strong enforceability.

Soliev et al. (2025) note that there is a lack of empirical studies that examine the actual environmental consequences of RoN. A more recent strand of research critically analyses RoN as potentially symbolic politics and as an instrument of state legitimation. This research has shown that RoN can stabilise existing power relations if they are not accompanied by structural economic reforms.

Europe lags significantly behind the Americas in terms of recognising RoN. European legal systems predominantly view nature as an 'environment' or a resource and protect it instrumentally, because of its usefulness to humans – a concept deeply rooted in Western liberal, anthropocentric legal thinking. In Europe, rights-based legal environmental protection is primarily based on environmental rights, including the human right to a healthy environment (Alves et al., 2023). Most RoN initiatives in Europe are experimental, with only a few tangible and solid RoN legislations (Ruales et al., 2024).

A binding law that has attracted significant attention in Europe is the RoN case concerning the lagoon Mar Menor in Spain. Following a popular initiative, in September 2022 the Spanish Parliament granted legal personhood to the Mar

Menor lagoon in the south-east of the country. In the decades prior to this, human activities such as fishing and agriculture had severely contaminated the waters of the lagoon with nitrates and other substances (Krämer, 2023).

A public initiative submitted a legislative draft to parliament, which was supported by all political parties, except one right-wing party. The law grants legal personality to the Mar Menor and its basin and recognises its rights to protection, conservation, maintenance and, if needed, restoration. Furthermore, it establishes several committees whose task is the management and enforcement of these rights. According to Krämer (2023), citizen initiatives such as the one in Spain are echoing pioneer changes akin to the one in Ecuador.

More RoN initiatives in Europe are in preparation and discussion. For example, in France, Italy and Germany, there are debates on regional RoN laws on rivers, mountains or forests. In Switzerland, Sweden and France, there are also parliamentary initiatives for the constitutional recognition of RoN. Furthermore, there are also several statutes, resolutions and other forms of local recognition which have primarily normative effects but, nevertheless, are still important discursive impulses (Ruales et al., 2024; United Nations Programme on Harmony with Nature, n. d.).

4. Barriers

A central problem of RoN is that nature cannot assert or enforce its rights independently. Paradoxically, this anti-anthropocentric concept is entirely dependent on human actors, and the actual decisions continue to be based on human judgements. Furthermore, 'environmental protection is not always a driver and therefore RoN does not automatically emerge from ecocentric ontologies' (Soliev et al., 2025, p. 12).

Recognising nature as a legal entity with rights is often considered a fundamental shift in the relationship between humans and the natural world. However, it is questionable whether this shift is always worth the effort. In many cases, the level of environmental protection achieved through RoN could also be attained within the framework of conventional environmental legislation (Tănăsescu et al., 2024; Kotzé, 2017). For instance, if we know that in Europe legal environmental protection is primarily based on the human right to a healthy environment, why not continue to focus on this strategy, given its partial success in the past? In this context, RoN is clearly not a substitute, but at most a supplement. Many of the problems RoN tries to cure – including especially a lack of enforcement – might simply re-emerge within this novel paradigm (Bétaille, 2019).

Whilst in some cultures, RoN can serve as the optimal approach, in others there is a need for alternative solutions. Whether RoN is a meaningful tool is highly context-specific, and determining this is fundamentally a strategic decision, rather than one amenable to a definite ethical answer. RoN are an important normative and discursive impulse, but they are not a panacea for all environmental problems.

5. References

Alves, F., Costa, P. M., Novelli, L., & Vidal, D. G. (2023). The rights of nature and the human right to nature: an overview of the European legal system and challenges for the ecological transition. *Frontiers in Environmental Science*, *11*, 1175143.

Bétaille, J. (2019). Rights of nature: Why it might not save the entire world. *Journal for european environmental & planning law*, *16*(1), 35-64.

Constituteproject.org (2022). Ecuadors Constitution of 2008 [https://www.constituteproject.org/constitution/Ecuador_2008.pdf] (accessed: 15.12.2025)

Gilbert, J., Macpherson, E., Jones, E., & Dehm, J. (2023). The Rights of Nature as a Legal Response to the Global Environmental Crisis? A critical review of international law's 'greening' agenda. *Netherlands Yearbook of International Law 2021: A Greener International Law—International Legal Responses to the Global Environmental Crisis*, 47-74.

Kotzé, L. J., & Calzadilla, P. V. (2017). Somewhere between rhetoric and reality: environmental constitutionalism and the rights of nature in Ecuador. *Transnational Environmental Law*, *6*(3), 401-433.

Krämer, L. (2023). Rights of nature in Europe: the Spanish Lagoon Mar Menor becomes a legal person. *Journal for European Environmental & Planning Law*, *20*(1), 5-23.

Latour, B. (2006). Technik ist stabilisierte Gesellschaft. *Bellinger, Krieger (Hg.): ANThology. Ein einführendes Handbuch zur Akteur-Netzwerk-Theorie. Bielefeld*, 369-397.

Putzer, A., Lambooy, T., Jeurissen, R., & Kim, E. (2025). Putting the rights of nature on the map. *A quantitative analysis of rights*.

Ramsés-Hernández, A. B., & Silva-Andrade, G. J. (2024). Derechos de la naturaleza del parque nacional Yasuní en Ecuador frente a los intereses económicos [Nature rights in Ecuador's Yasuní National Park versus economic interests]. *Verdad y Derecho. Revista Arbitrada de Ciencias Jurídicas y Sociales*, *3*(especial), 278-284.

Ruales, J. G., Hovden, K., Kopnina, H., Robertson, C. D., & Schoukens, H. (Eds.). (2024). *Rights of nature in Europe: encounters and visions*. Taylor & Francis.

Soliev, Ilkhom, Frauke Pirscher, and Marie Schreiber. 'The making of Rights of Nature: Nine patterns in a decade of empirical research on social-ecological drivers and actors.' *Environmental Research Communications* (2025).

Tanasescu, M. (2016). *Environment, political representation, and the challenge of rights*. Palgrave Macmillan.

Tănăsescu, M., Macpherson, E., Jefferson, D., & Torres Ventura, J. (2024). Rights of nature and rivers in Ecuador's Constitutional Court. *The International Journal of Human Rights*, 1-23.

United Nations Programme on Harmony with Nature. (n. d.). *Rights of nature law and policy*. Harmonizing human society and the natural world. http://www.harmonywithnatureun.org/rightsOfNature

6. List of policy instruments

2008 Constitution of Ecuador, revised in 2021. https://www.constituteproject.org/constitution/Ecuador_2021

Spanish Act 19/2022, dated 30th September granting Mar Menor and its basin status of a legal person. https://www.um.es/documents/23559040/35080450/LEY+19_2022+IN+ENGLISH.pdf

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Smart agriculture

1. Introduction

Smart agriculture broadly refers to the adoption of digital methods in the farming sector. The term also encompasses a wide technological field that combines various monitoring techniques (including satellite- and drone-based) with novel data-based management methods. Sensory inputs from different sources are combined to enable high-precision technical interventions, including the use of semi-/ autonomous drones (Ray 2017). Potential advantages include the targeted application of pesticides (thus reducing overall pesticide loads), the early detection of plant pathogens, or optimised planting by drawing on weather and soil monitoring. Smart irrigation systems can make more efficient use of water, thus reducing the water footprint of farming operations.

Smart agriculture also sometimes entails the use of digital methods in livestock farming, for instance, by outfitting animals with sensors. Finally, there are adjacent fields that are noteworthy from a transformation perspective. This includes hydroponics (i.e. soil-free cultivation methods), aquaculture, integrated agriculture-aquaculture systems, vertical farming, or agrivoltaics farming. All these methods adopt, to different degrees, techniques associated with smart agriculture.

Smart agriculture techniques have been widely diffusing in past years but are generally subject to the 'digital divide', with farmers in developing countries enjoying lower technology access than those in developed countries. In addition, the adoption of smart techniques ties into wider economic centralisation tendencies in global agriculture, with relevant technologies being owned and controlled by only a handful of (mostly US-based) companies. While smart agriculture is widely hailed as a vital tool of climate adaptation and food security, it does align with an industrial agricultural model that causes considerable negative sustainability spillover effects.

Smart agriculture is best understood not as a single innovation, but as a suite of innovations spanning robotics, machine vision, and machine learning.

2. Case study: Hands Free Hectare project

The 'Hands Free Hectare' project at Harper Adams University in the UK was a pilot project for demonstrating the utility of digital technologies, in conjunction with robotics, in the farming sector (Spencer, 2018). The project developers used a fleet of light vehicles, including tractors and drones, outfitted with open-source software and multiple types of environmental sensors. Autonomous tractors planted seeds and applied fertilisers and pesticides based on the needs identified by environmental sensors. Camera-equipped drones monitored crop development and attempted to spot plant pests. The first round of the project, from 2016 to 2017, led to the harvest of several tons of barley and brewed a limited-edition beer (Hands Free Hectare Golden Ale) for demonstration purposes. In the second growing season, from 2017 to 2018, the project successfully automated the growing and harvesting of wheat. The project thus showcased the utility of multiple sensor inputs and the shift towards swarms of smaller, autonomous vehicles, as well as the potential use of open-source software for driving changes in agricultural practices (Lowenberg-DeBoer et al. 2021).

What is particularly noteworthy about Hands Free Hectare is that it was effectively an open-source project that demonstrated the utility of digital technologies and robotics outside of a commercial agricultural paradigm.

3. Deployment, diffusion, amplification

Smart agriculture has been adopted widely in recent years, particularly in developed countries. Differences exist per crop type, with harvesting of specific fruits and vegetables being difficult to automate, and manual labour accordingly remaining economically more feasible for the moment. Adoption is high in Western Europe and mainly in North America, with labour shortages in the farming sector being one of the drivers of automation and digitalisation.

In the EU, digitalisation and automation are particularly relevant for climate-smart agriculture, due to their potential to reduce greenhouse gas emissions from the farming sector (see Chandra et al. 2018). Other regions of the world are adopting smart agriculture techniques based on national needs, for instance, to address labour shortages or to cope with rapid population growth. Overall, megatrends such as global population growth, as well as the need to adapt food systems to global warming while reducing their environmental footprint, are the main structural drivers of the diffusion and adoption of smart agriculture (Lipper et al. 2014). Desertification and land degradation, and the increased land scarcity they engender, are also potential drivers of smart agriculture, by pushing stakeholders to develop methods to increase agricultural yields while global acreage is stagnating or even contracting.

4. Barriers

Developing countries are lagging behind in the adoption of smart agriculture techniques. Barriers include insufficient access to capital, insufficient technology transfer, as well as connectivity issues in rural areas, with reliable 5G being indispensable. Moreover, there may be social barriers to adoption, as the economies of scale that smart agriculture entails can further aggravate economic centralisation tendencies in the farming sector, while also threatening employment and thus livelihoods. Insufficient interoperability between systems and sensors poses barriers as well. Patents may also (temporarily) hamper technology transfer in a North-South context. There are also questions of relative competitiveness: Stakeholders may choose to pursue cheaper methods for increasing agricultural yields, including by expanding acreage through deforestation and land conversion, or by increasing chemical inputs. Such choices become more likely in the absence of robust regulatory frameworks that align agricultural policies with long-term sustainability objectives.

5. References

Chandra, A., McNamara, K. E., & Dargusch, P. (2018). Climate-smart agriculture: perspectives and framings. *Climate Policy*, *18*(4), 526-541.

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., ... & Torquebiau, E. F. (2014). Climate-smart agriculture for food security. *Nature climate change*, *4*(12), 1068-1072.

Lowenberg-DeBoer, J., Franklin, K., Behrendt, K., & Godwin, R. (2021). Economics of autonomous equipment for arable farms. *Precision agriculture*, *22*(6), 1992-2006.

Ray, P. P. (2017). Internet of things for smart agriculture: Technologies, practices and future direction. *Journal of Ambient Intelligence and Smart Environments*, *9*(4), 395-420.

Spencer, J. (2018). Harvesting the 'Hands-free Hectare'. *Farmer's Weekly*, *2018*(18004), 52-53.

6. List of policy instruments

Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, The European Green Deal, COM/2019/640 final

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A Farm to Fork Strategy, COM(2020) 381 final

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Urban design / infrastructure

1. Introduction

Urban design and infrastructure for biodiversity and equity encompass a range of planning, architectural and infrastructural approaches, aimed at integrating nature into urban environments while ensuring social equity. This also includes NbS, such as green corridors, urban forests, rain gardens, restored waterways, and rooftop gardens. These innovations serve a dual purpose, creating green urban habitats while also improving human well-being.

Green urban design and infrastructure are widely used in contemporary urban planning (Davis et al., 2015). While the primary focus of implementation is at the city level, the frameworks are, in principle, scalable to national levels. However, effective deployment requires that solutions remain context-specific and tailored to local ecological and social conditions. The approach transforms traditional city infrastructures, creating a paradigm shift from 'grey' to 'green.' Cities thus become socio-ecological systems for the co-existence of multiple species. Pro-biodiversity urban design and infrastructure also offer powerful co-benefits, including mitigating urban greenhouse gas emissions, or by enhancing air quality and thus contributing to public health.

2. Case study: BiodiverCities project

One example of green urban design and infrastructure is the BiodiverCities project that ran between 2020 and 2023. An initiative of the Joint Research Centre and the European Commission's DG Environment, BiodiverCities developed practices for citizen engagement in the co-creation of green urban visions, exploring how to use urban green infrastructure to benefit people and nature. Working with citizens and experts in Palma, Leiden, Lisbon, Valongo, Maribor, Palermo, Vilnius, Novi Sad, Regalbuto, and Varese, the project developed guidance for the co-creation of biodiverse urban futures. Specific implementations on the ground varied, and included educational activities, awareness-raising campaigns, urban garden design, creation of dog parks, and others.

The BiodiverCities project ties into broader EU legal frameworks, notably the Green Deal and the EU's 2030 Biodiversity Strategy.

3. Deployment, diffusion, amplification

The development of urban design and infrastructure emphasises participatory methods. The goal is to involve local communities directly in the co-creation of equitable biodiversity spaces, ensuring that the integration of NbS into infrastructure planning reflects diverse social needs. This also directly connects this innovation to citizen science initiatives. In general, there is some diffusion of green urban design practices between cities, including through formal city networks such as C40 or Local Governments for Sustainability (ICLEI). Some concepts have been diffusing in highly context-specific ways. Ideas such as 'walkable' inner cities (i.e. the '15-minute city') diffused rapidly in the wake of transportation restrictions associated with COVID-19 (Mahadevia et al, 2025). The concept of 'pocket parks', meaning small green inner-city areas, diffused primarily as a result of space considerations in large urban environments.

4. Barriers

Socio-economic inequity significantly impacts the diffusion and scaling of green urban infrastructure and design. Poorer neighbourhoods frequently suffer from a 'green gap'; that is, they possess significantly less biodiversity than affluent areas. Meaningful participation in both the planning and long-term maintenance of green urban spaces appears to remain limited as well, highlighting a need for broader social buy-in. Policy silos may also impede diffusion and scaling, as infrastructure policy is frequently institutionally separate from biodiversity policy due to insufficient mainstreaming.

5. References

Molné, F., Donati, G. F., Bolliger, J., Fischer, M., Maurer, M., & Bach, P. M. (2023). Supporting the planning of urban blue-green infrastructure for biodiversity: A multi-scale prioritisation framework. Journal of Environmental Management, 342, 118069.

de Luca, C., Naumann, S., Davis, M., & Tondelli, S. (2021). Nature-based solutions and sustainable urban planning in the European environmental policy framework: Analysis of the state of the art and recommendations for future development. *Sustainability*, *13*(9), 5021.

Davis, M., Keighley, M., Naumann, S., & Graf, A. (2015). Green Infrastructure and urban biodiversity: overview and city level examples. *ETC/BD report to the EEA*.

Mahadevia, D., Delgado-Ramos, G. C., Barnes, J., Fitzgerald, J., Kamei, M., Lanza, K., Solecki, W., Pathak, M., Barata, M., Barau, A. S., Dombrov, M., & Rosenzweig, C. (2025). Learning from COVID-19 for Climate-Ready Urban Transformation. *Elements in Climate Change and Cities*. https://doi.org/10.1017/9781009527279

Laage-Thomsen, J. and Blok, A. (2020) 'Civic modes of greening the city? Urban natures in-between familiar engagement and green critique', Local Environment, 25(2), pp. 162–178. Available at: https://doi.org/10.1080/13549839.2020.1714568.

6. List of policy instruments

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Biodiversity Strategy for 2030: Bringing nature back into our lives, COM/2020/380 final

Convention on Biological Diversity (CBD), Rio de Janeiro (Brazil), 5 June 1992, in force 29 Dec. 1993

Kunming-Montreal Global Biodiversity Framework, CBD/COP/DEC/15/4, 19 Dec. 2022.

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Virtual reality

1. Introduction

Temporal and spatial distance, as well as a lack of perceived personal relevance, can result in a diminished connection between individuals and societal challenges (Liberman et al., 2007). Furthermore, the increasing loss of direct interaction with nature – often driven by growing urbanisation – can exacerbate this estrangement, a phenomenon known as the 'extinction of experience' (Soga and Gaston, 2016). Virtual Reality (VR) offers a unique opportunity to make biodiversity tangible and experiential, particularly in environments that are otherwise inaccessible, such as the deep sea or the Amazon rainforest (Nelson et al., 2020; Pimentel, 2022).

A key psychological mechanism underlying VR is the concept of telepresence: the psychological distance to environmental issues can be reduced by generating the sensation of being physically present in a location while being situated elsewhere (Riva, 2007; Kim et al., 2023). Given that humans often think in narratives rather than numbers (Shiller, 2019), VR can leverage storytelling to generate emotions that have the potential to influence both problem perception and behaviour. The applications of VR in the field of biodiversity, whilst still relatively under-researched, are potentially vast. They range from health-related benefits such as stress reduction (Gentile et al., 2023) to informing the public about the variability and dynamics of ecosystems (Chandler et al., 2022). Ultimately, VR serves as a vital bridge between complex scientific data and human psychology. By democratising access to biodiversity hotspots without the need for physical travel, it also potentially provides a tool for conservation that can help mitigate the negative environmental impacts of mass tourism.

2. Case study: Biodiversity can reduce stress levels in a VR environment

With increasing urbanisation, people are losing contact with nature, which leads to higher stress levels and psychological strain. A study utilised immersive VR simulations, incorporating both visuals and sound, to create controlled nature experiences with varying degrees of biodiversity (Meng et al., 2024). In environments with high biodiversity – a suburban park and a nature reserve – stress levels decreased significantly faster and more substantially than in a standard urban park. However, although the nature reserve was the most effective at physically reducing stress, participants subjectively rated it as less restorative than the park settings. This suggests a discrepancy: our bodies react instinctively and positively to high biodiversity, while our minds often perceive well-maintained parks as 'more beautiful' or 'more relaxing' (Meng et al. 2024). This innovation demonstrates that protecting biodiversity is not only ecologically vital but can also serve as a direct tool for public health prevention in urban areas.

3. Deployment, Diffusion, Amplification

VR is an innovative educational and communication tool that enables the overcoming of spatial, temporal and cognitive distances. It can make ecosystems that are difficult to reach or endangered, tangible for the user. By overcoming psychological distance, VR can strengthen awareness of problems and a sense of responsibility, thereby possessing the potential to reduce biodiversity loss (e.g., by increasing empathy for species and ecosystems). Through the communication of stories, complex interrelationships can be conveyed. With aligned regulation and safeguarding (e.g. avoidance of any co-occurring advertisement streaming across the visual path of headsets) VR opens up new possibilities in the fields of science communication (e.g., schools, museums) and participation, reaching individuals who otherwise have little contact with biodiversity. Furthermore, VR content can be made accessible worldwide via digital platforms and social VR spaces. Visuals and sounds can overcome potential language barriers. In contrast to physical excursions, VR also has potential to be scaled linearly – Immersive experiences can be shared globally across geographical borders – which could (e.g.) accelerate the diffusion of knowledge about endangered species.

4. Barriers

Despite the potential of VR in the field of biodiversity, there are several barriers and limitations. Social barriers include the potentially limited acceptance of VR technologies among older age groups or tech-sceptical individuals. Furthermore, concerns exist as to whether virtual experiences can replace contact with real nature outdoors (virtual nature versus real nature) and whether this might imply an alienation from actual nature in the medium term. In addition, there are economic barriers consisting of high initial investments for hardware, software development, and high-quality biodiversity-related content. This represents a particular challenge for underserved regions.

Furthermore, there are challenges in the areas of authorship and data protection (regulatory barriers). VR headsets can collect biometric data, which requires monitoring the collection and use of such data. Finally, in some cases, the institutional responsibility for integrating VR into existing educational, environmental, and nature conservation policies is not clear.

5. References

Chandler, T., Richards, A. E., Jenny, B., Dickson, F., Huang, J., Klippel, A., ... & Prober, S. M. (2022). Immersive landscapes: modelling ecosystem reference conditions in virtual reality. Landscape Ecology, 37(5), 1293-1309.

Gentile, A., Ficarra, S., Thomas, E., Bianco, A., & Nordstrom, A. (2023). Nature through virtual reality as a stress-reduction tool: A systematic review. International journal of stress management, 30(4), 341.

Kim, H., Kim, S. E., Park, K., & Tennessee, S. (2023). Exploring the role of flow experience and telepresence in virtual reality (VR) concerts. Journal of Travel & Tourism Marketing, 40(7), 568-582.

Liberman, N., Trope, Y., & Stephan, E. (2007). Psychological distance. Social psychology: Handbook of basic principles, 2(2), 353-383.

Meng, L., Li, S., & Zhang, X. (2024). Assessing biodiversity's impact on stress and affect from urban to conservation areas: A virtual reality study. Ecological Indicators, 158, 111532.

Nelson, K. M., Anggraini, E., & Schlüter, A. (2020). Virtual reality as a tool for environmental conservation and fundraising. Plos one, 15(4), e0223631.

Pimentel, D. (2022). Saving species in a snap: On the feasibility and efficacy of augmented reality-based wildlife interactions for conservation. Journal for Nature Conservation, 66, 126151.

Riva, G. (2007). Virtual reality and telepresence. Science, 318(5854), 1240-1242.

Shiller, R. J. (2019). Narrative economics: How stories go viral and drive major economic events. The Quarterly Journal of Austrian Economics, 22(4), 620-627.

Soga, M., & Gaston, K. J. (2016). Extinction of experience: the loss of human–nature interactions. Frontiers in Ecology and the Environment, 14(2), 94-101.

6. List of policy instruments

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Biodiversity Strategy for 2030: Bringing nature back into our lives, COM/2020/380 final

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Wildlife vaccinations

1. Introduction

Wildlife vaccinations generally aim to interdict the spread of pathogens between wild species of animals. Some applications of this technology find widespread use as part of conservation policies. Vaccinations are used to mitigate extinction risks in endangered species, for instance to protect Amur tigers from canine distemper virus (Gulland et al. 2024). Vaccinations are used to protect brucellosis transmission into livestock and humans (Davis and Elzer 2002). More recently, self-spreading vaccinations via infectious organisms intended for release into wild populations of species are being explored, including to prevent Lassa virus transmissions from rats into humans (see Lentzos et al. 2022).

Two broader developments stand out. First, newer approaches to wildlife vaccination increasingly draw on self-propagation mechanisms that raise complex governance and biosafety challenges. These approaches also make use of genetic modifications, for instance by inserting parts of the genetic sequence of a pathogen of interest into benign viruses that already circulate within the target population (Streicker et al. 2022). Second, wildlife vaccination is increasingly considered as a means for preventing zoonotic spillovers in the context of pandemic preparedness and response (Nuismer and Bull 2020).

There are thus complicated trade-offs and uncertainties between, on one hand, the potential benefits of novel vaccination schemes for biodiversity and public health and, on the other hand, potential risks associated with off-target effects and adverse impacts at ecosystem levels. While conventional vaccination schemes are established conservation instruments, this newer generation presently remains in earlier stages of the R&D pipeline. As vaccination instruments have high degrees of genetic specificity, it is unlikely that any given application can easily be scaled to be applied beyond the target species for which it was initially developed.

Nevertheless, self-spreading vaccinations offer potentially significant leverage for addressing severe threats to biodiversity and public health with relatively limited resource investments.

2. Case study: self-propagating Lassa vaccine

Lassa fever has been one area in which self-propagating vaccines are being explored. Lassa fever is prevalent in West Africa, spreading from rodents to humans. No human Lassa vaccination presently exists. As the Lassa virus is well-characterised and its ecology well-understood, it is considered a useful test case for the development of self-propagating vaccines (Nuismer and Bull 2020). The US Defense Advanced Research Projects Agency, the R&D division of the US armed forces, has supported research for the exploration of a self-propagating Lassa vaccine, including by developing a prototype, raising questions of potential dual use (see Lentzos et al. 2022). Public funders such as the National Science Foundation are supporting other research projects, and initial patent claims for self-propagating Lassa vaccines have been filed.

3. Deployment, diffusion, amplification

While non-transmissible vaccines have long been used for conservation purposes, next-generation approaches are either still in the developmental stages, or are undergoing limited, small-scale field trials. Research funding for the latter appears to be limited and primarily originates from public and philanthropic sources. Uptake and amplification are likely to be driven primarily by public health considerations in the context of pandemic preparedness and response. Of particular concern from a governance perspective is the risk of rushed and internationally uncoordinated deployment of self-propagating vaccines to mitigate zoonotic spillover in the context of an emerging pandemic threat. Deployment of self-propagating vaccines would likely require considerable policy changes, notably including the adoption of new guidance or rules on risk assessment and risk management.

No dedicated policy measures exist at national, European, or international levels. For self-spreading vaccines that entail genetically modified organisms (GMOs), general regulation on deliberate environmental releases of GMOs apply. In principle, however, the release of wildlife vaccinations could support conservation policies, as well as pandemic preparedness and response, although subject to significant biosafety challenges.

4. Barriers

Wildlife vaccines are typically limited in efficacy due to the difficulty of administering vaccinations to wild populations of species, outside of controlled settings, and subject to trait variation within species. This means that wildlife vaccination tends to remain partial, or to decrease over time, which may potentially induce increased pathogen virulence (Barnett and Civitello 2020). Self-spreading vaccines that amount to infectious organisms deliberately released into the environment to stimulate an immune response in target species may be subject to considerable regulatory barriers (due to the applicability of national GMO regulations, including pre-release approval processes) and may face challenges associated with social license. Economically, no plausible business case exists for wildlife vaccination (whether conventional or self-propagating), making development, implementation, and monitoring contingent on the availability of public funding. In the absence of appropriate risk assessment methods for the environmental release of self-propagating vaccines, questions of risk, harm and liability serve as further impediments to deployment.

5. References

Barnett, K. M., & Civitello, D. J. (2020). Ecological and evolutionary challenges for wildlife vaccination. *Trends in Parasitology*, *36*(12), 970-978.

Davis, D. S., & Elzer, P. H. (2002). Brucella vaccines in wildlife. *Veterinary microbiology*, *90*(1-4), 533-544.

Gulland, F. M., Barbieri, M., Cleaveland, S., Gilbert, M., Hall, A. J., & Rocke, T. E. (2024). Vaccination of endangered wildlife as a conservation tool: Hindsights and new horizons in the pandemic era. *Biological Conservation*, *300*, 110842.

Lentzos, F., Rybicki, E. P., Engelhard, M., Paterson, P., Sandholtz, W. A., & Reeves, R. G. (2022). Eroding norms over release of self-spreading viruses. *Science*, *375*(6576), 31-33.

Nuismer, S. L., & Bull, J. J. (2020). Self-disseminating vaccines to suppress zoonoses. *Nature ecology & evolution*, *4*(9), 1168-1173.

Streicker, D. G., Bull, J. J., & Nuismer, S. L. (2022). Self-spreading vaccines: Base policy on evidence. *Science*, *375*(6587), 1362-1363.

6. List of policy instruments

Convention on Biological Diversity (CBD), Rio de Janeiro (Brazil), 5 June 1992, in force 29 Dec. 1993

Cartagena Protocol on Biosafety to the Convention on Biological Diversity, Montreal (Canada), Montreal (Canada), 29 January 2000, in force 11 Sept. 2003

Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC [2001] OJ L 106/1

Directive 2009/41/EC of the European Parliament and of the Council of 6 May 2009 on the contained use of genetically modified micro-organisms [2009] OJ L 125/75

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