Engineering Ecosystem Resilience

Opportunity Space

Accessible Version 1.0

Yannick Wurm, Programme Director

CONTEXT

This document describes an early opportunity space from which we believe one or more funding programmes can emerge. We've sketched out some of our early thinking to spark your interest, and invite you to imagine relevant potential programmes with us, or suggest new directions. We'll publish updated versions of this document as our thinking evolves.

Sign up **here** to receive those updates and learn about any funding opportunities that emerge from this opportunity space.

An ARIA opportunity space should be:

- important if true (i.e. could lead to a significant new capability for society),
- under-explored relative to its potential impact, and
- ripe for new talent, perspectives, or resources to change what's possible.

SUMMARY

From soil microbes to towering forests, living organisms underpin our civilisation by supplying our food, regulating our climate, and providing the substrates for tomorrow's medicines and materials. However, ecosystems worldwide are collapsing, and current efforts to safeguard their services and resources are insufficient. By combining high-resolution measurement with targeted, resilience-boosting interventions, we could halt current declines and ultimately reverse them, enabling communities and ecosystems to prosper together.

BELIEFS

The core beliefs that underpin/bound this area of opportunity.

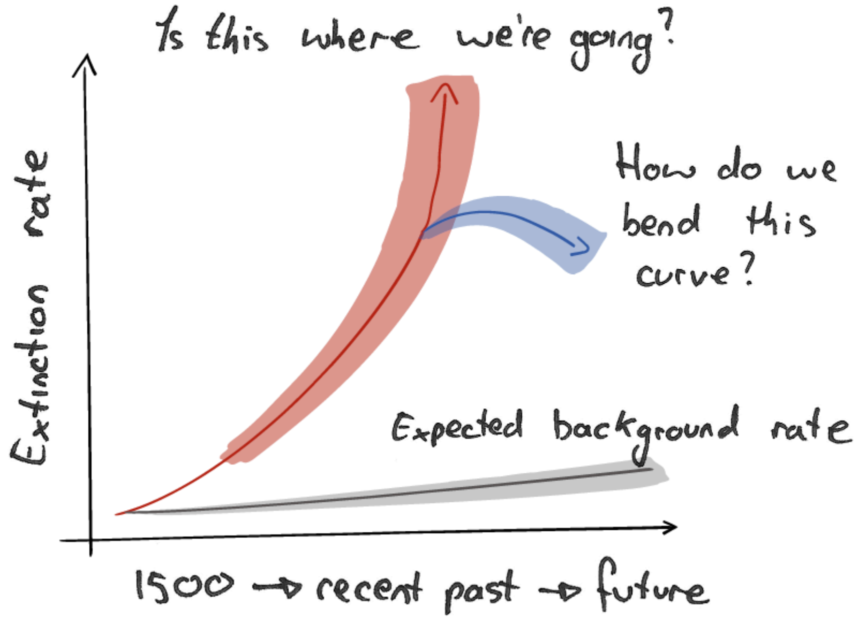
1. With ecosystem degradation accelerating globally, humanity's most vital unsolved technical capability is engineering ecosystem resilience → **success could pave the way towards unparalleled human and planetary prosperity.**
2. Our tools to measure, predict, and manage ecosystems are insufficient → **effective stewardship demands proactive deployment of fit-for-purpose technologies.**
3. Ecosystems are complex adaptive networks where small changes can have outsized effects → **with the right tools, we can design highly effective interventions that are both ethical and environmentally responsible.**
4. Converging advances in high-throughput genomics and prediction, gene editing, accelerated evolution, robotics, novel sensors, and AI analytics → **together unlock a new integrative paradigm for engineering ecosystem resilience.**

OBSERVATIONS

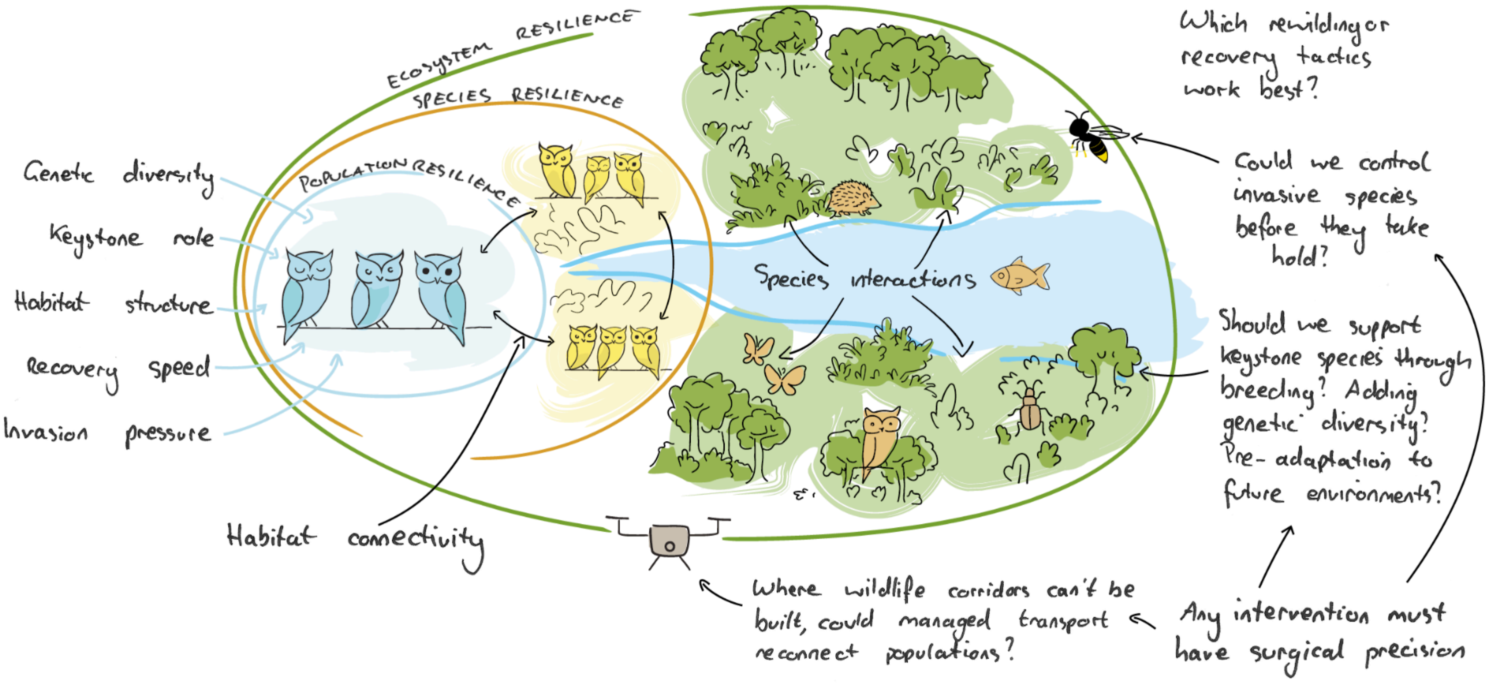
Some signposts as to why we see this area as important, under-explored, and ripe.

Nature is valuable. The services and potential it provides suffer from being underexplored, undervalued but also overexploited:

1. Over half of global GDP (£34 trillion[1]) depends on nature's services, spanning:
    a. Provisioning (food, freshwater, raw materials, pollination),
    b. Stabilisation (climate, flood, pest + disease control),
    c. Cultural benefits (recreation, tourism, wellbeing).
2. Nature is home to an immense, largely untapped reservoir of biomolecules and bioprocesses that could revolutionise pharmaceutical and materials industries[2–4].
3. Insurers are beginning to price nature-related risks, yet financial markets still capture only a fraction of nature's combined economic value[5].
4. Climate change[6], overexploitation[7], and the spread of invasive species[8] are driving stark population declines and increases in species extinction rates[9], threatening cascading collapse in both natural and managed ecosystems[4,9-14]. (What technologies or methods could enhance traditional environmental stewardship?)



5. Ecosystem stability emerges from multiple layers of interactions; their combined complexity surpasses that of most engineered systems[15-16]. (An integrated ecology-evolution-engineering modeling framework could transform decisions on if, when, and how to responsibly and effectively intervene.)

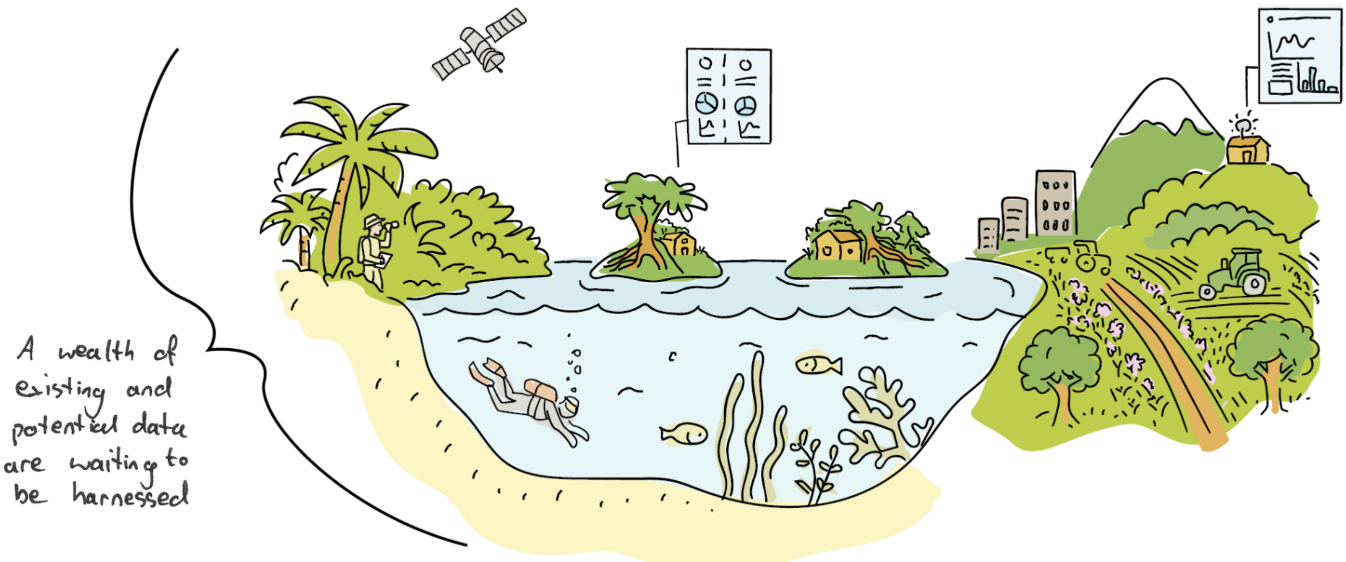


6. Targeted support of keystone species[17-18], community assemblages[19], or habitat connectivity[20] offers high-leverage opportunities to strengthen ecosystem resilience while complementing broad-scale management.

7. **The deployment of powerful new tools demands ethical considerations, inclusive governance, authentic community engagement, and long-term monitoring[21-23].** The challenge is to equitably harness the transformative benefits while preventing unintended harm[21-23]. (Any intervention must have surgical precision. We must avoid repeating past mistakes (cane toads, Nile perch, pesticide misuse, board impact decisions with insufficient risk assessment...))

8. Billions of environmental records—satellite images, field surveys, sensor feeds, and research data—remain scattered across unlinked databases.

9. Unintended large-scale experiments—from island systems, marine reserves, patchwork land-use conversions, to hurricane-stricken areas—reveal how species and ecosystems respond to disturbance.



10. AI-powered synthesis and advanced modelling could reveal hidden ecosystem resilience insights and guide smarter interventions[24]. Some key questions, which stem from the central question 'what are our knowledge gaps and which experiments are needed?', are:
    a. How well can species survive in different environments?
    b. What genes or genetic diversity are needed?
    c. Which study scales—from lab to ecotron—can reveal key parameters? Or even help some species adapt?
    d. Which diversity levels are needed for ecological resilience and function?

e. How do we future-proof for diverse climate scenarios?
f. Where are precise models needed, or approximations acceptable?
g. Which species-dependencies are strongest?

11. All ecosystems are interconnected. However, marine, terrestrial, and freshwater systems spanning tropical rainforests to urban environments to agricultural landscapes differ fundamentally due to their distinct structures, connectivity patterns, and ecological dynamics. (Which concepts and parameters apply broadly, and which vary by ecosystem? Could this inform design for off-Earth habitation?)

12. Assemblages of native species have already faced substantial environmental change. (Which combination of natural and technological approaches provide the best foundation for our future?)

13. The pace of ongoing environmental changes mean ecosystems of the future may differ from those of the past[25].

14. Prioritising short-term costs over environmental health often weakens ecosystems. Those savings can backfire, raising long-term costs and risks to companies and communities because environmental impacts are undervalued and difficult to gauge. (Could precision sensing and sharper risk forecasts clarify impacts enough to tip the balance? Or do we also need new financial instruments?)

15. Evidence from community-managed forests, regenerative agriculture, and successful marine protected areas demonstrates that when people's livelihoods improve alongside ecosystem health, both can flourish together[26-29]. (People want to preserve their environment. How do we make that the best decision emotionally and financially?)

SOURCES

A compiled, but not exhaustive list of works helping to shape our view and frame the opportunity space (for those who want to dig deeper).

1. World Economic Forum (2020). Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy.
2. Nature (1997). The value of the world's ecosystem services and natural capital.
3. World Economic Forum (2020). New Nature Economy Report II: The Future of Nature and Business. New Nature Economy Report (NNER).
4. Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being.
5. Brookings (2024). Could financial markets incorporate the value of nature?
6. Science (2022). Exceeding 1.5°C global warming could trigger multiple climate tipping points.
7. Nature (2020). Global human-made mass exceeds all living biomass.
8. Nature (2017). No saturation in the accumulation of alien species worldwide.
9. IPBES-IPCC (2021). Scientific outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change.
10. IPBES (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.
11. IPCC (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability
12. UN General Assembly (2015). Transforming our world: the 2030 Agenda for Sustainable Development
13. Science Advances (2023). Earth beyond six of nine planetary boundaries.
14. Global Tipping Points (2023). Summary Report.
15. J R Soc Interface (2023). Stability of multi-layer ecosystems.
16. Science (2007). Stability and diversity of ecosystems.
17. Functional Ecology (2022). Using ecosystem engineers to enhance multiple ecosystem processes.
18. Functional Ecology (2024). Ecosystem engineers shape ecological network structure and stability: A framework and literature review.
19. Ecology Letters (2012). Extending the concept of keystone species to communities and ecosystems.
20. Perspectives in ecology and conservation (2019). Towards an applied metaecology.

21. Bioscience (2011). Intervention ecology: Applying ecological science in the twenty-first century.
22. UNEP (2022). Kunming-Montreal Global Biodiversity Framework. Decision adopted by the Conference of the Parties to the Convention on Biological Diversity
23. Conservation Science Practice (2021). U.S. conservation translocations: Over a century of intended consequences.
24. Ecosystems (2022). An outlook for deep learning in ecosystem science.
25. Trends in Ecology & Evolution (2009). Novel ecosystems: implications for conservation and restoration.
26. Annual Review of Environment and Resources (2023). Governance and conservation effectiveness in protected areas and Indigenous and locally managed areas.
27. PeerJ (2018). Regenerative agriculture: merging farming and natural resource conservation profitably.
28. Nature climate change (2023). Community forest governance and synergies among carbon, biodiversity and livelihoods.
29. Nature Sustainability (2021). A global analysis of the social and environmental outcomes of community forests.

ENGAGE

Our next step is to formulate a programme within this opportunity space that will direct funding across research disciplines and institutions toward a focused objective. In order to ensure we select the right first challenge, we want to hear from you. Complete this form to provide feedback on the opportunity space and inform the development of our programme thesis - we will read anything you send. There, you may also register interest for our workshops.