Advanced Research + Invention Agency ARIA

Engineering Ecosystem Resilience

Opportunity space

v1

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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

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

Over half of global GDP (£34 trillion[1]) depends on nature's services, spanning:

+ Provisioning (food, freshwater, raw materials, pollination),
+ Stabilisation (climate, flood, pest + disease control),
+ Cultural benefits (recreation, tourism, wellbeing).

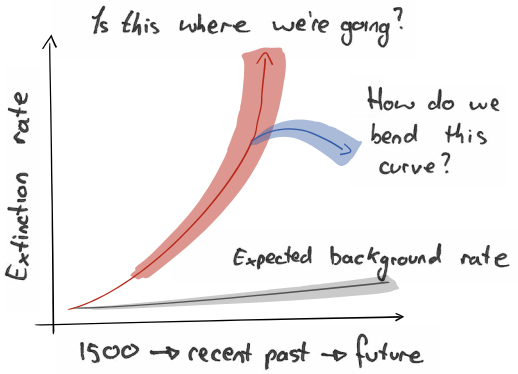
Home to an immense, largely untapped reservoir of biomolecules and bioprocesses that could revolutionise pharmaceutical and materials industries[2–4].

Insurers are beginning to price nature-related risks, yet financial markets still capture only a fraction of nature's combined economic value[5].

Underexplored and undervalued but also overexploited!

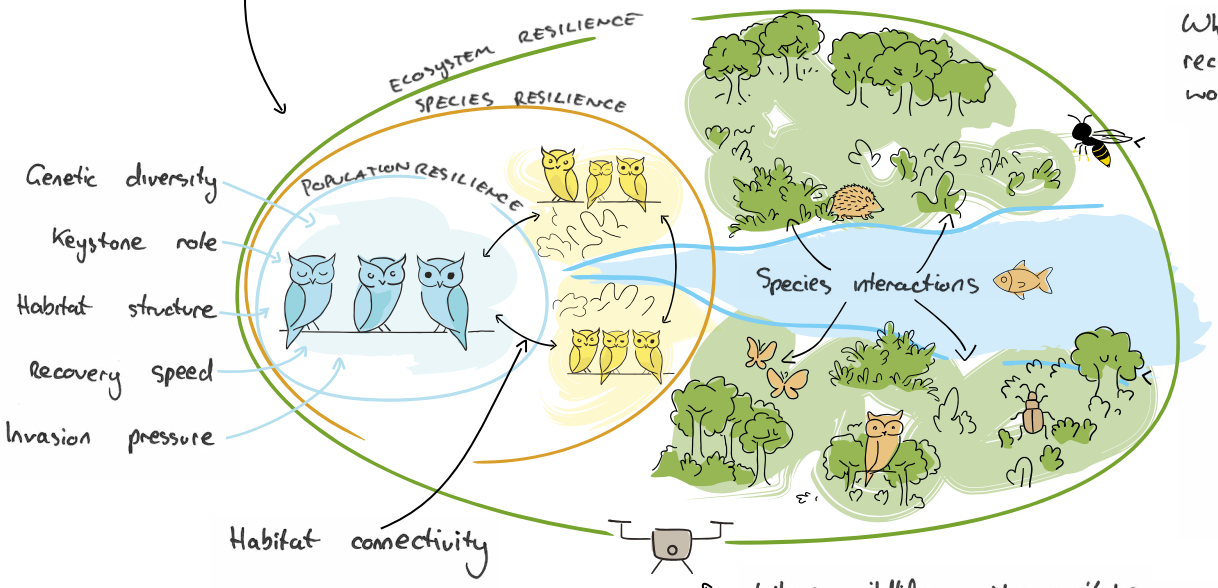
Climate change[6], overexploitation[7], and the spread of invasive species[8] are driving stark population declines and increases in species extinction rates[9], threatening cascading collapse in both natural and managed ecosystems[4,9-14].

What technologies or methods could enhance traditional environmental stewardship?



Ecosystem stability emerges from multiple layers of interactions; their combined complexity surpasses that of most engineered systems[15-16].

An integrated ecology-evolution-engineering modelling framework could transform decisions on if, when, and how to responsibly and effectively intervene



Which rewilding or recovery tactics work best?

Could we control invasive species before they take hold?

Should we support keystone species through breeding? Adding genetic diversity? Pre-adaptation to future environments?

Where wildlife corridors can't be built, could managed transport reconnect populations?

Any intervention must have surgical precision

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.

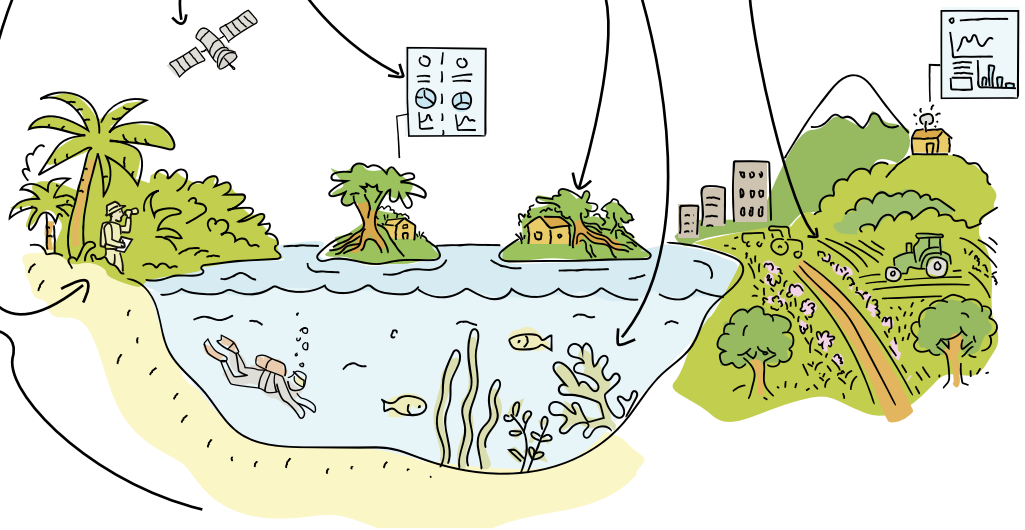
The deployment of powerful new tools demands ethical considerations, inclusive governance, authentic community engagement, and long-term monitoring[21-22].

The challenge is to equitably harness the transformative benefits while preventing unintended harm[23-24].

We must avoid repeating past mistakes (cane toads, Nile perch, pesticide misuse, broad impact decisions with insufficient risk assessment...)

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

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.



A wealth of existing and potential data are waiting to be harnessed

AI-powered synthesis and advanced modelling could reveal hidden ecosystem resilience insights and guide smarter interventions[23].

WHAT ARE OUR KNOWLEDGE GAPS, AND WHICH EXPERIMENTS ARE NEEDED?

- How well can species survive in different environments?
- Which diversity levels are needed for ecological resilience and function?
- What genes or genetic diversity are needed?
- How do we future-proof for diverse climate scenarios?
- Which study scales – from lab to ecotron – can reveal key parameters? Or even help some species adapt?
- Which species-dependencies are strongest?
- Where are precise models needed, or approximations acceptable?

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.

Assemblages of native species have already faced substantial environmental change.

The pace of ongoing environmental changes mean ecosystems of the future may differ from those of the past[24].

Which concepts and parameters apply broadly, and which vary by ecosystem?

Could this inform design for off-Earth habitation?

Which combination of natural and technological approaches provide the best foundation for our future?

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.

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[28-31].

Could precision sensing and sharper risk forecasts clarify impacts enough to tip the balance? Or do we also need new financial instruments?

People <u>want</u> 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).

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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.