tern Ecosystem Research Infrastructure

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An Australian Government Initiative

TERN Futures | Exposure Draft

Research Directions in Ecosystem Science 2025-35

Talking aloud about what matters most — outcomes of the 2025 TERN national consultation

TERN Futures Series
Research Directions in Terrestrial Ecosystem Science, 2025–2035
Exposure Draft

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Acknowledgement of sources and responsibility
This report presents TERN's interpretation of findings from a national survey of the terrestrial ecosystems research community. The survey was conducted anonymously and care has been taken to ensure that no names or other identifiable information are included in this report. It is released as an **exposure draft** to support discussion, sense-checking and further engagement. The views expressed are those of the authors and do not necessarily reflect the views of survey respondents, partner organisations or funders.

Contact
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ORIENTATION AND INVITATION

WHAT WE HEARD | Findings from the TERN Research Directions 2025–2035 Survey

METHOD AND DEFINITIONS

Taking stock before the next leap forward

We asked for your priorities

TERN has been observing Australia's terrestrial ecosystems for over 17 years. In that time, both the scientific questions driving ecosystem research and the technologies, data practices and analytical capabilities used to address them have evolved dramatically. **How can we ensure TERN continues to stay relevant, responsive and headed in the right direction for the next decade?**

In 2025, we took an intentional pause to ask the community about their changing priorities through the ***TERN Research Directions 2025–2035 Survey***. The survey ran between 11 September and 6 October 2025, inviting input from researchers, data users and stakeholders across all sectors, and garnering over 180 responses (see 'About the survey for details).

This is what we heard

- **Australian ecosystem researchers are increasingly prioritising stewardship** — focusing not just on understanding ecosystems, but on generating the evidence needed to guide timely, effective protection and restoration actions (Section 1)
- **Biodiversity and climate dominate researchers' priorities for the coming decade.** Attention is increasingly expanding to linked systems — from water, landscape, soils and vegetation to social, coastal, marine and genetic domains — reflecting a field moving toward coordinated, system-wide understanding and action (Section 2)
- **The next leap in ecosystem observation isn't about more instruments or variables — it's about integration**: linking data, models and monitoring strategies in scale-appropriate ways to answer real-world questions (Section 3)
- **Ecosystem science stands to gain the most from integration across climate, socio-economic, genomic and remote-sensing models.** Respondents signalled a need to move beyond abstract notions of interdisciplinarity, to practical, method-level integration that situates ecological observations within real-world contexts and decision-making processes (Section 4)
- **The greatest barrier to impact is the absence of a shared *theory of change*.** Without a clear pathway from observation to action, even high-quality data struggle to influence policy, investment and practice (Section 5)
- **A vision for Australian ecosystem science in 2035:** data flows seamlessly, research and decision-making are integrated, real-time insights guide action, and Australians begin to see the fruits of this collective stewardship (Section 6).

Let's continue the conversation!

As we prepare to incorporate these findings into the **TERN Strategic Plan 2026-2031**, we would love to keep you and the community engaged.

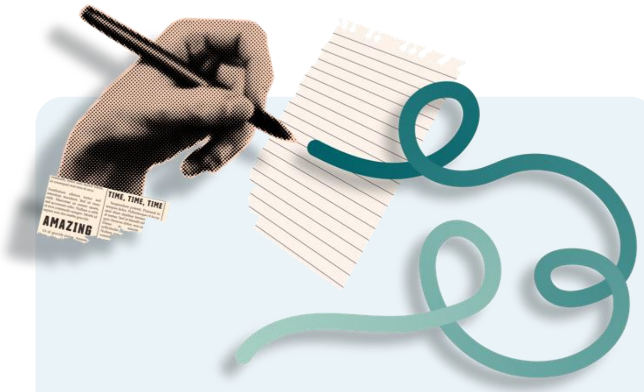
This exposure draft is our attempt to sense-check our interpretation of the survey responses and an invitation to join us in the next step: using what we have learned to inform the development of the **TERN Strategic Plan 2026–2031**.

The process:

- ✅ Sep/25 – Research Directions Survey
- ✅ Jan/26 – Survey Findings Exposure Draft
- 📅 Feb/26 – Written submissions and Roundtables
- 📅 Mar/26 – Updated TERN Strategic Plan

Have your say

In the TERN Strategic Plan 2026-2031



Send a written submission

Send your responses to the **consultation questions** (below) via email to tern@uq.edu.au by **COB Monday, 2 March 2026**.

Join a roundtable

TERN will convene a series of **roundtable discussions** throughout February 2026. To attend, register your interest here.

Consultation questions

1. Do the priorities identified in this exposure draft reflect what you are seeing across terrestrial ecosystem science in Australia? Where do they more strongly affirm or challenge your views?
2. Terrestrial ecosystem science spans many disciplines and applications. If national research infrastructure efforts must focus on a limited number of fronts, where do you see the strongest common ground? Where would coordinated investment deliver the greatest impact across the community?
3. One respondent identified the lack of a *shared theory of change* — clarity about what is measured, who uses it and how it guides decisions — as a key barrier to impact. Can you describe one or two specific national-scale data products that could be deliberately used to ‘move the dial’ for terrestrial ecosystems, science, policy and practice in Australia?

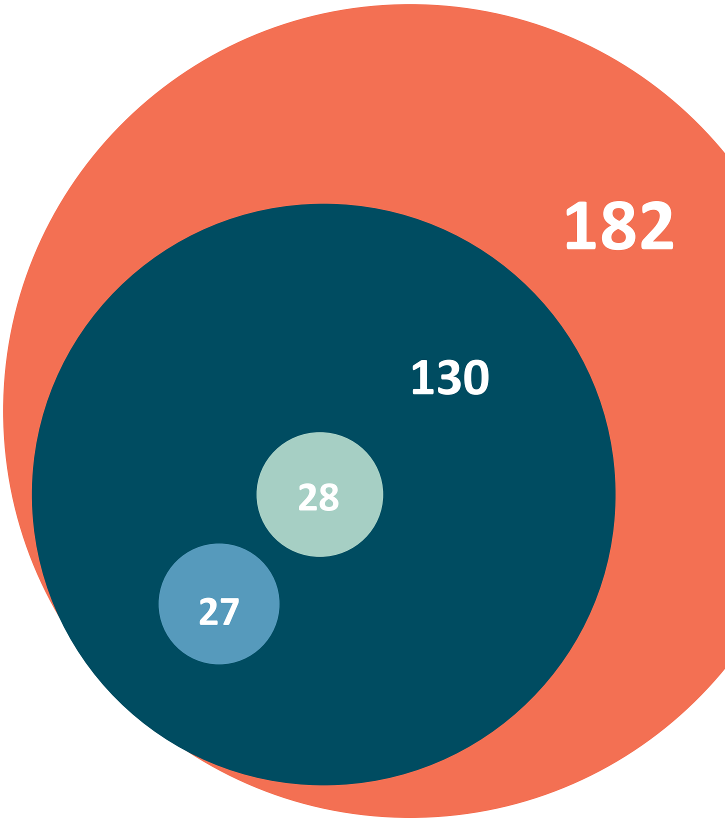
1| *Stewardship* will define the next decade of ecosystem science

When asked, *"What are the most pressing research questions you hope to answer over the next 5–10 years?"* respondents pointed to a next phase of ecosystem science increasingly oriented toward stewardship and practical impact (**Figure 1**).

While fundamental research into ecosystem functioning (●) and methodological questions around observation, data and modelling (●) remain essential, most researchers are now directing their attention to two pressing frontiers: assessing the real condition of Australia's terrestrial ecosystems on the ground (●) and finding effective, timely ways to protect and restore them (●).

Within the four broad question categories identified (**Figure 1**), the most common question *subtypes* (**Figure 2**) centred on the design and evaluation of biophysical interventions to protect or restore ecosystems (82), closely followed by questions about orchestrating effective restoration and protection actions in social contexts (68), such as determining what conservation goals to pursue (e.g., desired ecosystem condition) or how to prioritise, coordinate and optimise actions. Next were questions about quantifying impacts from anthropogenic disturbances on ecosystems (47), about detecting and predicting change (42) and about establishing reliable ecosystem condition baselines (27).

Figure 1. *Which types of questions will lead terrestrial ecosystem science in the next decade?*



Respondents could submit one or more research questions, which were separated and categorised as defined for this count (see definitions in the box).

Taken together, these responses convey a research community impatient for impact and focused on generating the evidence needed to guide timely and effective action.

Responses suggest that the coming years will be defined by translating knowledge into action, with scientific rigour guiding how Australia intervenes to protect and restore its ecosystems.

Dive into the data

Click here to explore the individual research questions posed by respondents. You can filter questions by type and subtype, as well as by topic tags such as 'biodiversity' or 'climate'. Questions have been lightly reworded for clarity and de-identified where necessary.

The four types | Questions about…

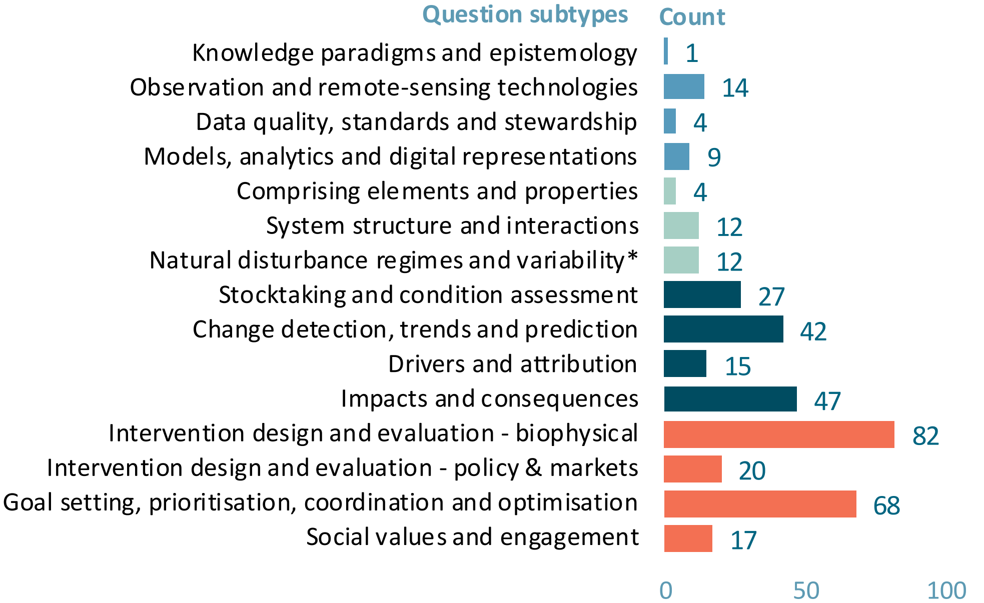
The craft of observation and modelling
Questions about *how we know what we know* — about epistemology, observation, data and modelling — focusing on the *means* of knowing rather than the *object* of knowledge.

How ecosystems work
Questions that aim to explain how ecosystems function and maintain themselves — about their structure, properties, interactions, natural variability and resilience.

Tracking change on the ground
Questions about the actual condition of Australia's ecosystems on the ground — about baselining, condition assessment, drivers, trends, and estimates of risks and impacts.

Designs and decisions for restoration and stewardship
Questions about what we *should* do — about the design, prioritisation and evaluation of interventions to protect, restore or sustainably use ecosystems.

Figure 2. *Research question subtypes (colour-coded by question type) and response count*



* Including: natural resilience, adaptations and thresholds

2 | *Biodiversity* and *Climate* are the *key* drivers of research agendas

Across the hundreds of research questions put forward by respondents, two themes dominate the research imagination for the decade ahead: **biodiversity** (129 mentions) and **climate** (84). Together, they shape the grand challenges of Australian ecosystem science: how to understand, anticipate and manage the cascading effects of species loss and a shifting climate system (counting only responses framing these issues as system-wide phenomena, not every mention of species or weather).

Following biodiversity and climate, respondents highlighted a second tier of priorities that shift the focus from global drivers to more place-based systems. These include **water** (54), **vegetation** (51), **ecosystem services and valuation of nature** (41), and **agriculture** (40). Together, they reflect concern with how Australia's landscapes — natural and managed — can sustain ecosystems and livelihoods under mounting biodiversity and climate pressures.

In addition to the dominant themes above, several smaller clusters of responses point to emerging areas of focus over the next decade. Topics such as invasives, hazards, nutrient security, microbiota and mycobiota and human systems are emerging as key interfaces through which ecosystem health, risk and recovery are being re-examined. Researchers are increasingly linking terrestrial science with marine, geological and social domains, while also turning their attention to the microscopic and genetic levels, where minute processes shape broader ecological patterns.

The emerging picture is of a research community intent on matching scientific rigour with real-world relevance: building the evidence needed not only to explain change, but to steer Australia's collective response to it.

Looking ahead, these signals point to a decade in which ecosystem science will work to trace how environmental decline reverberates across sectors, from agriculture and water resources to health and livelihoods. They also suggest an intensified interest in modelling ecosystem dynamics using inputs drawn from those interlinked systems.

Emerging research agendas

This section explores the emerging agendas within Australia's ecosystem science community, approached from a qualitative perspective. Rather than focusing on the frequency of responses, it looks to capture the breadth and direction of ideas, particularly those that point to the next frontiers of environmental research.

Building the baseline

Respondents want to know *what's really out there*. They want a complete, high-resolution picture of Australia's ecosystems and biodiversity that will inform goal-setting, monitoring and decision-making. They want to:

- Address gaps in species and ecosystem baselines: many Australian species and ecosystems remain undiscovered or poorly described
- Expand baselining beyond individual species to include ecosystem types, soils, nutrients, genetic diversity, microbiota and fungi, across terrestrial, freshwater and coastal systems
- Achieve an integrated understanding of living and non-living components — such as how geological and geomorphological features shape ecosystems (e.g., macroecological gradients, hydrogeology)
- Identify baselines for stressors and pressures — e.g., pests, microplastics or PFAS, infrastructure and land use
- Establish benchmarks for *'what should be found where'*
- Develop automated, validated gap filling methods.

Staying in step with a changing environment

Respondents want the ability to *read the health of the environment in real time,* in order to know when ecosystems are nearing collapse, where thresholds lie and what 'integrity' looks like. This includes:

- Frameworks that define and measure ecosystem integrity, thresholds and resilience
- Tracking ecological function — from species interactions to carbon, water and nutrient cycling — to detect early signs of decline
- Monitoring condition, adaptive capacity, and collapse risk across hazards (fire, flood, heat, landslides)
- Integrating Indigenous knowledge, soil and microbial genomics, and ecosystem function benchmarks into future definitions of ecosystem health.

Learning loops to accelerate environmental innovation

Australia's environmental community is seeking smarter feedback loops between environmental interventions, their evaluation, and subsequent innovation. Respondents call for a national evidence base showing which interventions are in place, how they perform, and under what conditions. Without it, innovation stalls and the nation risks repeating ineffective actions while ecosystems continue to degrade. Recommendations included:

- A strong push to establish national, shared databases of environmental intervention outcomes — the ecological equivalent of clinical-trial registries — to capture and compare what has been tried, where, and with what effect
- Urgency to accelerate learning and innovation. Time to act is limited, and without rapid, evidence-based feedback, Australia risks solving yesterday's problems
- Common frameworks and typologies to evaluate interventions consistently — aligning closely with the government's push for standardised methods in carbon and biodiversity markets
- An emphasis on measuring impact at the right scale: from paddock and property to enable local action, and across ecosystems, catchments and landscapes to capture whole-system effects

- Establishing an open, well-governed space for high-risk, high-reward experimentation. Survey responses revealed a growing recognition that incremental efforts to reverse degradation may no longer be enough in a probable future defined by extreme heat, disturbances and unpredictability. As such, there is an emerging appetite for bold and radical innovation — such as designing pest-suppressive landscapes, creating refuges and sanctuaries for at-risk species, rehydrating and re-mineralising degraded lands and other large-scale restorative experiments.

Moving forward imperfectly – Showing and telling for engagement

Respondents emphasise that waiting for perfect data is no longer an option. Australia's ecosystems — and the democratic processes that depend on shared understanding — cannot afford paralysis by precision. Imperfect but credible evidence is essential for timely decisions, transparency and collective action. Key challenges emerging at the interface of science and application include:

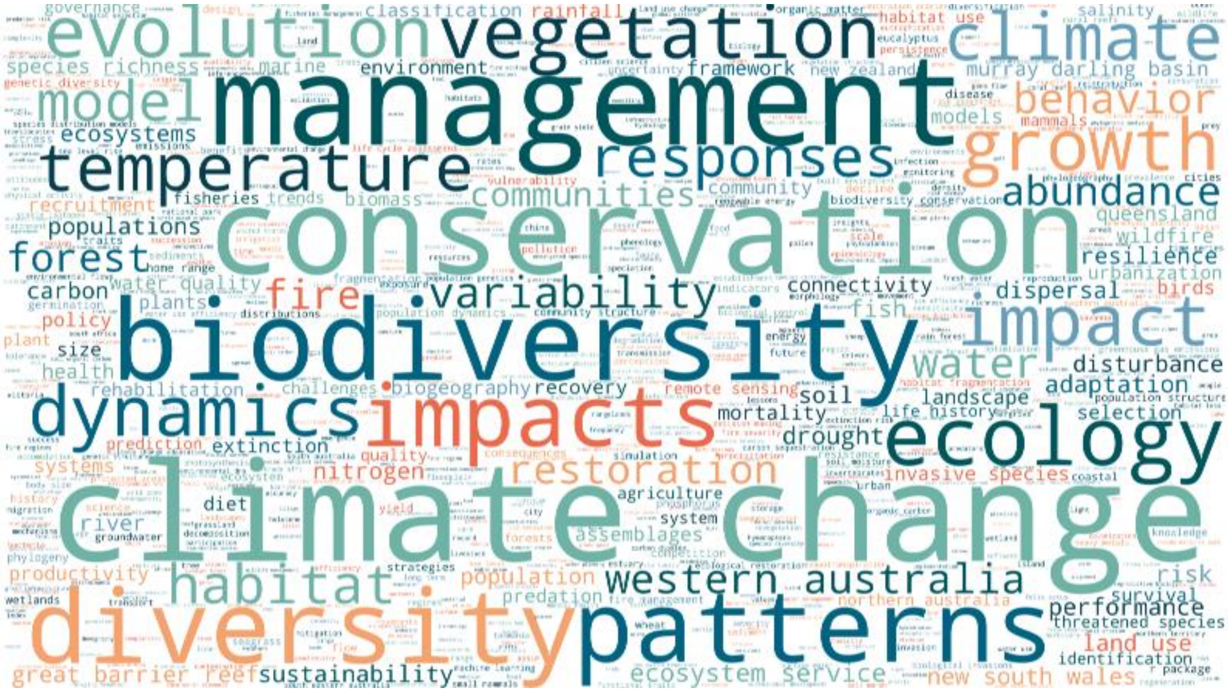
- **Knowing when available data is enough.** Researchers will need to confidently signal when available evidence can support decision-making. Doing so gives policymakers and land managers the assurance to act, while freeing effort to fill the next critical information gaps
- **Framing environmental data as a public good.** Access to environmental information is not just a technical matter; it is a civic right and shared responsibility. Respondents highlight that elevating environmental data to the level of shared public knowledge is essential for informed decisions on issues with long-term, intergenerational consequences. Without it, people are *flying blind*. Some suggest that what often looks like public disengagement or slow behavioural change may simply reflect a failure to communicate clearly what is at stake (the importance and actual condition of the systems that sustain us).

Figure 3. *Ecosystem science over time: What's enduring, what's emerging*

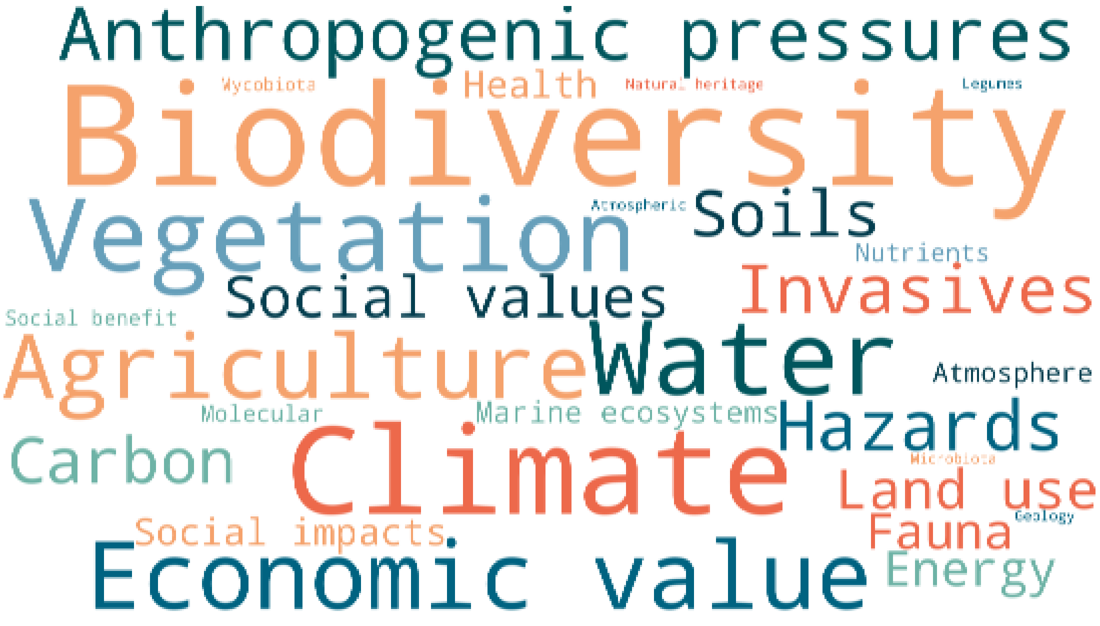
The word clouds capture how ecosystem science has evolved over time. Both show the keywords defining a decade of Australian ecosystem research, but they draw from very different sources. The first represents the past decade, built from author and database-assigned keywords in more than 23,000 research articles indexed in the Web of Science. The second looks to the decade ahead, using tags assigned by the author of this analysis to classify keywords drawn from survey responses about future research priorities.

The samples differ greatly in size and method — published literature versus survey responses about future research questions — so they are not directly comparable. Yet together they tell a clear story: biodiversity and climate remain dominant, while rising attention to water, invasives and cross-domain connections points to a field moving toward integration and systems-level understanding.

The previous decade (2015-2025)
Word cloud showing the most frequent keywords in 23,165 research articles on Australia's natural, managed and urban ecosystems published between 2015 and August 2025. Articles were retrieved from the Web of Science Core Collection. Source: TERN Australia



The next decade (2015-2035)
Domain-related themes identified in responses to question 1 of the survey: *'What are the most pressing research questions you hope to answer over the next 5–10 years?'*



3 | The next leap in observation isn't new data or instruments — it's *models* and *integration*

When asked which types of observations or scales of analysis are becoming more important in their fields, the dominant conversation wasn't about new technologies or variables: it centred on **coherence** — on finding solutions that link data and models in ways that can answer real-world questions (**Figures 4-5**).

The largest share of responses focused on improving monitoring regimes, such as *when* and *where* to observe. A hundred respondents explicitly called for data at the 'right' temporal and spatial scale to understand change. The meaning of 'right' varied, though, illuminating the fact that no single observation regime can meet every need. This points to the value of **multiple, targeted monitoring approaches**, each selected to suit a particular scale of ecosystem process or type of decision.

While the community is clear on the need for **scale-sensitive observation**, most responses remained broad and unspecific — using terms such as *"integration," "combining,"* or *"the right scale,"* but citing no particular frameworks or methods. It reveals a community highly aware of the gap, yet still without a clear solution.

The likely breakthrough for the next decade will be the rise of models that distil intelligence from environmental data for distinct purposes and the parallel refinement of observation regimes to serve those different needs.

That recognition also exposes a practical tension: doing *more* (e.g., more instruments, more coverage, more detail) may not automatically yield more insight, nor is it affordable. Environmental observation competes for finite resources, and not every question demands the same resolution. The call for integration is ultimately a call for **strategy** — to decide *what* we will observe, *how often* and *to what end*. Developing such observation and monitoring frameworks will be a defining milestone of the next decade.

Figure 4. *Emerging focus areas in environmental observation and analysis*

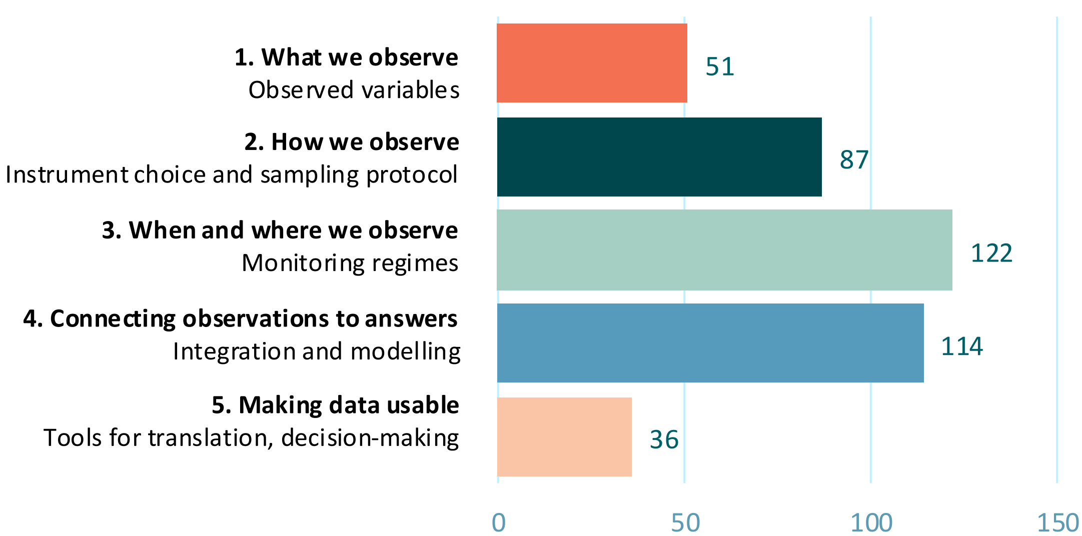


Figure 5. *Ten priorities driving future environmental observation and analysis*

Focus areas / Opportunities	Mentions
Change detection at relevant scales Monitoring change at timeframes and spatial levels that match the process of interest.	100
Ongoing environmental data streams Establishing continuous or real-time data flows from key observing systems to sustain ongoing monitoring efforts and support model development, refinement and operation.	56
Instruments to fit functional or biological resolution Selecting the right instruments for the feature studied, increasingly requiring methods that capture function, physiology or composition at micro- or molecular scales.	46
Operational models and simulation tools Models that simulate or connect ecological processes across scales and domains (e.g., carbon, hydrological, biodiversity, or pest models).	46
Creative and technological innovation Creatively harnessing existing and emerging technologies to extend reach, reduce costs and address scale gaps (e.g., AI image recognition, low-cost sensors).	41
Coverage of critical gaps Identifying under-observed regions, taxa, or processes essential to national environmental understanding (e.g., northern Australia, freshwater systems, soils, mycobiota).	37
From simple counts to complex attributes Moving from basic descriptive measures to metrics that reveal ecosystem function, health, or resilience.	29
Pressures and emerging threats Closely tracking drivers of risk or degradation—known and emerging—to support timely response (e.g., pest spread, PFAS, microplastics, radionuclides, disease, land degradation).	22
Data streams from other domains Bringing in data from social, infrastructure and climate domains to support more complete and realistic environmental models.	20
Reliable gap filling Broader application of existing methods to close observation gaps (e.g., satellite products) with clear reporting of uncertainty and limitations (e.g., ground validation).	19

4 | The greatest leverage from integration lies at the intersections of climate, society, genomics and remote sensing

Question 3 asked ecosystem science researchers which other domains they increasingly need to integrate with. Across more than 180 responses, four areas stood out: climate and weather systems (67 mentions), socio-economic, market and policy drivers (50), genomics, genetics, eDNA and trait data (45), and Earth Observations and remote-sensing models (27) (**Figures 6-7**).

The survey responses point to a decade in which ecosystem science will work more closely with climate, social, economic, genomic and remote-sensing fields, not through loose notions of interdisciplinarity, but through practical, method-level alignment.

Figure 6. *Where researchers expect integration to grow*

Adjacent fields or research / disciplines	Mentions
Climate & weather systems | Integrating ecological observations with climate models, downscaled weather and extreme-event data to understand impacts and future risk	**67**
Socio-economic, market and policy drivers | Integrating ecosystem observations with behavioural insights, policy settings and market dynamics to understand pressures and decisions	**51**
Genomics, genetics, eDNA and trait data | Integrating molecular and genetic datasets to understand populations, communities and functional processes	**45**
Earth Observation (EO) and remote sensing | Integrating satellite, airborne, and drone data—LiDAR, hyperspectral, SAR, DEMs—to map structure, change and processes	27
Agriculture, production systems and land management | Linking ecological data with agricultural production metrics, supply chains and land management practices	24
Soil, geology, terrain and energy fluxes | Foundational biophysical layers—soil properties, geology, geomorphology, energy and carbon fluxes—to explain ecosystem processes and constraints	21
Hydrology, water and biogeochemical cycles | Combining data on water movement, water quality, soil moisture, nutrients, sediments and biogeochemical fluxes across catchments and landscapes	19
AI, machine learning and advanced analytics | Applying computational tools (AI, ML, computer vision, digital twins, advanced statistics) to derive insight from complex data	14
Governance, regulation and legislative frameworks | Mapping regulations, species listings, assessment and compliance frameworks to enrich monitoring and modelling	9
Indigenous knowledge and local knowledge systems | Integrating diverse knowledge systems, cultural mapping and citizen observations into ecosystem health assessments	8
Long-term monitoring, historical archives and legacy data | Combining decades-long datasets, archived specimens and time series to detect trends and calibrate models	6
Urban and peri-urban spaces, planning and infrastructure | Linking ecological insights to dynamics and decisions in urban spaces	2

The four pillars of integration

Climate modelling is becoming an essential companion to ecological inference

Across the responses, climate modelling emerged not just as "another dataset," but as a primary context-setting system for understanding ecological change. Researchers increasingly expect to:

- Situate ecological observations against downscaled climate projections
- Align ecological sampling with climate windows and extremes
- Interpret species- or ecosystem-level trends within shifting climatic envelopes.

This implies a research direction in which ecosystem science is increasingly co-analysed with climate dynamics, and where ecological interpretation assumes at least a working familiarity with the logic, parameters and limits of climate models.

Socio-economic and policy drivers as key analytical inputs

A second clear signal was the need to integrate ecosystem data with economic behaviour, landholder incentives, market signals and policy settings. Not because ecologists are becoming social scientists, but because ecological outcomes now depend on carbon and biodiversity markets, landholder decision environments and social conditions that enable or block conservation actions.

As a research direction, this implies ecological predictions will increasingly need to factor in behavioural and economic dynamics. It also suggests that ecosystem researchers may need enough socio-economic literacy to understand what these models assume — and where their explanatory power ends.

Genomics is maturing into a mainstream ecological input

Genomics and eDNA were not mentioned as speculative additions but as expected components of future ecosystem analysis — from detecting cryptic biodiversity to assessing adaptive capacity.

Respondents highlighted the role of genomics and eDNA in fully revealing population structure, helping detect hidden biodiversity, and supporting a better understandings of how species are connected across landscapes, as well as their lineage-specific sensitivities and capacities to adapt to climate change. The signal here is not that every ecologist must become a molecular specialist, but that genomic data are becoming part of the everyday evidence base. As this happens, researchers will need a practical sense of what genomic results can and cannot tell them, so they can discern where such results add genuine ecological insight, what uncertainty looks like, and how to interpret them alongside other lines of evidence.

Remote sensing will anchor scaling, context and change detection

Remote-sensing technologies, from LiDAR to hyperspectral and drone imagery, were consistently highlighted as the scaling engine that links plot-scale ecology to landscape-scale patterns.

Two expectations followed: that ecological findings should increasingly be map-ready, and that researchers would have a clear understanding of the limitations of remote-sensing technologies.

As these tools become ubiquitous, the challenge shifts from *access* to *analytical competence*, including the ability to derive reliable ecological meaning from complex, heterogeneous and time-variable remote-sensing products.

Further implications

A hybrid workforce? Building literacy across modelling cultures

A strong undercurrent across responses was the potential need for ecosystem researchers to develop working familiarity or baseline 'fluency' in the modelling traditions of these other fields and vice versa. For example, there is a need for ecologists who can interpret climate projections, genomicists who understand landscapes, economists who incorporate ecological constraints or remote-sensing analysts fluent in vegetation and disturbance dynamics. In essence, we will need researchers that 'speak' enough climate, economics and genomics to collaborate effectively and avoid misalignment. Likewise, colleagues in other domains may need ecological context to interpret results meaningfully.

This does not imply new disciplinary specialisations, but rather understanding model assumptions well enough to combine outputs responsibly, recognising when cross-domain comparisons are valid and being able to translate ecological processes into forms those models can ingest.

Interdisciplinary research will hinge on how well models, not just data, align

One notable pattern in the responses is that researchers tended to name broad modelling families — e.g., 'climate models', 'hydrological models' — and only rarely identified specific modelling frameworks, tools or coupling approaches. This suggests that while the desire for integration is clear, the practical vehicles for doing so remain somewhat abstract. The integration frontier is therefore not only about developing interoperable datasets, but about moving from general intentions to specific, interoperable modelling architectures.

This gap points to a challenge for the decade ahead: ecosystem science will only integrate meaningfully with other fields to the extent that its models can interact with theirs. This would entail using explicit variables, scales, assumptions and uncertainty treatments that align across domains.

Such a shift will require more attention to:

- Linking climate, fire, vegetation, biodiversity, behaviour and policy through actual model chains
- Developing shared scenario frameworks rather than field-specific ones
- Exposing ecological model parameters in ways other disciplines can read and reuse
- Ensuring scales and assumptions are transparent enough to be coupled.

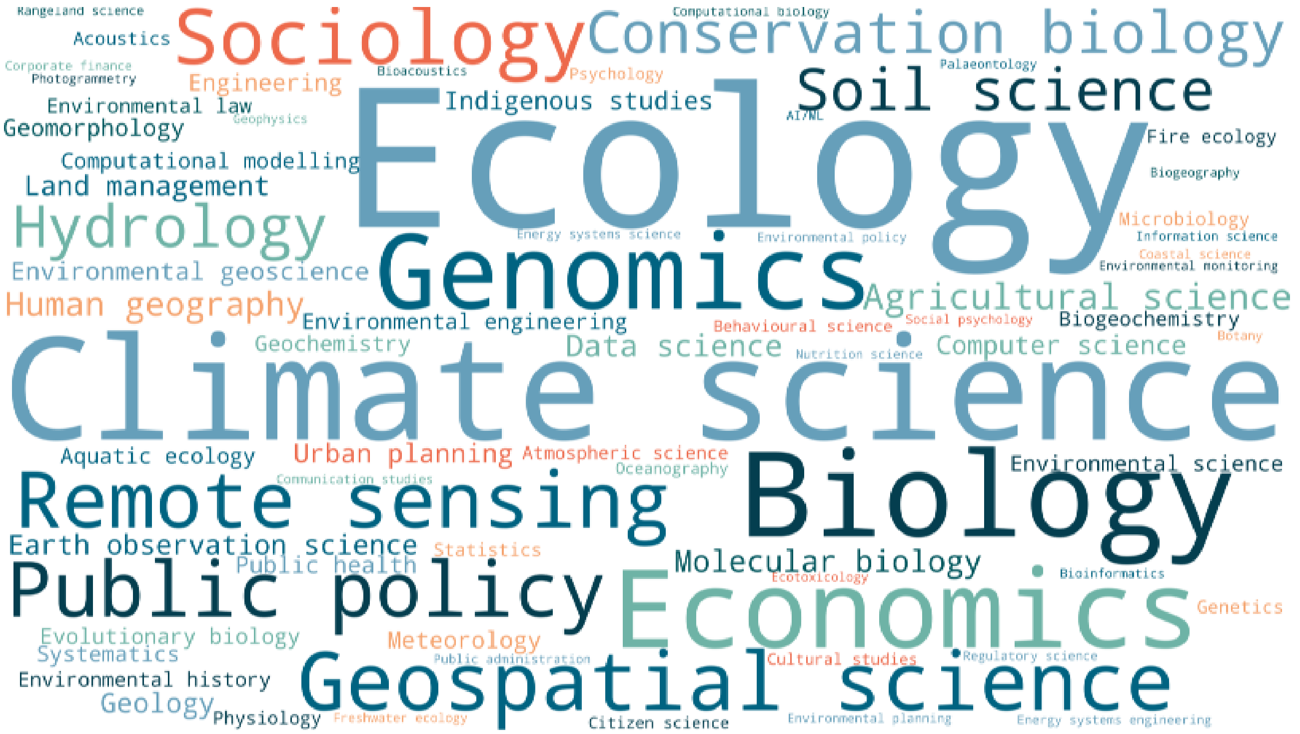
In other words, the coming decade may require more attention to model coupling, co-designed pipelines, and decision-support systems that can incorporate multiple domains. This moves the next milepost from just *data interoperability*, to *model interoperability*.

The role of AI

A recurring assumption in public discourse is that, with enough data, emerging AI systems might be able to "handle" integration across disciplines on their own. That expectation did not surface in this survey. Across more than 180 responses, AI and machine learning were mentioned only occasionally, and almost always in narrow, practical contexts: improving species identification in imagery and acoustics, automating pattern detection, scaling up data processing, or supporting existing ecological models.

When respondents spoke about interdisciplinary integration, they overwhelmingly pointed instead to the major modelling traditions they expect to align with, including climate models, socio-economic and policy frameworks, genomic and trait-based analyses, and remote-sensing analytics. AI did not appear as the anticipated engine of integration. This does not necessarily reflect explicit scepticism so much as a pragmatic view of AI: useful, but not a substitute for the structured model alignment that true integration will require.

Figure 7. *The research disciplines driving collaborations with terrestrial ecosystems science to 2035*
Word cloud showing the most frequent disciplines mentioned by survey respondents in their answers to the question *'What types of data or disciplines do you increasingly need to integrate with?'*



A central role for ecosystems science

Looking across the grand challenges facing Australia over the next decades, it is striking how many of those forces ultimately play out through terrestrial ecosystems, which are the medium through which physical, biological and social dynamics become observable and consequential. Indeed, terrestrial ecosystems are where climate patterns translate into physical impacts (heat, flood and drought), where markets and policies influence land-use decisions, where species adapt or collapse and where cultural and livelihood systems are grounded.

If climate is the change layer, society the decision layer and genomics the adaptive layer, ecosystems are the substrate linking all three. This recognition gives ecosystem science a distinctly integrative position in the decade ahead. How well we support the four types of integration discussed above will be central to how well Australia can navigate these challenges as they unfold.

5 | The biggest barrier to impact is the absence of a shared *theory of change*

In the Survey, we asked *"What's the biggest challenge you face in making ecosystem data useful and relevant for communities, policy-makers or industry?"* While some responses noted missing data or inadequate tools, the dominant concern was with the **intentionality and direction** of data collection — whether our collective efforts to produce evidence actually serve a clear purpose and can influence real-world decisions (**Figure 8**).

Multiple respondents described feeling as though Australia's environmental data community is *doing more and more, yet moving no closer to impact*. One respondent captured the underlying sentiment with unusual clarity, noting that the sector lacks *"a unifying theory of change"*, in other words, a shared understanding of how evidence is meant to travel into the worlds of policy, investment, planning and practice.

This phrasing names what many others implied: data accumulate, insights emerge, but the pathways into decisions remain fragmented. Without a deliberate architecture for influence, even exemplary science struggles to matter.

The barriers raised by respondents fall into three broad constellations: challenges at the **translation** end, challenges driven by **strategic data gaps**, and challenges arising from **misalignment with policy and institutional systems**. Underneath all three is the absence of a coherent pathway from observation to action.

Figure 8. *Barriers to research impact*

Barrier type	Mentions
Communication, Interpretation & Translation | Challenges converting complex data into insights that communities, industry and policy-makers understand, trust and use	**79**
Data Access & Availability | Challenges acquiring relevant data— e.g., timely, affordable, complete, in high-resolution, representative	**51**
Priority & Policy Alignment | Ecosystem data undervalued, sidelined or misaligned with policy agendas, organisational priorities or political realities	**44**
Data Quality, Validation & Trust | Gaps in data reliability, accuracy, uncertainty, validation or credibility	32
Analytical Capacity, Modelling & Tools | Challenges analysing data or running models to return required answers. Availability and usability of models and decision-support systems	32
Data Standards, Interoperability & Curation | Challenges merging or reusing datasets due to inconsistent formats, poor metadata, lack of standards or insufficient curation	27
Funding & Resourcing Constraints | Insufficient financial resources to collect data, analyse it, maintain infrastructure, develop tools or support ongoing programs	23
Skills, Capacity & Workforce | Insufficient skills for collecting, managing, analysing, interpreting or applying ecosystem data	19

Key insights

Rich signals, weak storylines

According to respondents, *'Communication, interpretation & translation'* (79 mentions) remains the point where the system is weakest. What respondents describe is not a simple communication deficit, but a more structural translation gap:

- **Missing connective tissue,** or mechanisms to weave existing observational data into narratives that make sense to non-specialists
- **Core indicators,** in the sense of simple, credible metrics of ecosystem condition, risk, pressure or resilience that decision-makers can come back to over time.

Addressing critical gaps

The second major barrier, 'Data access and availability' (51) concerns data gaps, but not in the simplistic sense of "we need more data"—respondents often concede Australia already collects a tremendous amount. Instead, the issue is that the missing pieces are often the ones that prevent us from telling a coherent, nationally persuasive story. Key gaps mentioned included:

- **Validation gaps.** High-resolution modelling and remote sensing remain limited by the scarcity of well-structured, ground-based benchmarks
- **Geographical and thematic blind spots.** Northern Australia, freshwater systems, soils, invertebrates, impacts from land use change, microplastics and cultural landscapes were repeatedly noted as under-observed.

Crucially, respondents were not calling for a blanket expansion in observation coverage. The deeper insight is that without said *shared theory of change*, the sector does not know which gaps could unlock credible national narratives or, if filled, dramatically amplify impact.

Further embedding evidence into processes

The third barrier, 'Priority and Policy Alignment' (44), pointed to yet another systemic translation gap: that even when robust data exist, policy frameworks do not always recognise, require or reward their use. The push for environmental accounting and market-based mechanisms at the Federal government level (carbon and biodiversity markets, national environmental accounting) is slowly shifting this dynamic. Themes included:

- **Environmental issues outweighed by short-term priorities.** Biodiversity often "tacked on at the end" or "too late" in regulatory processes
- **Discomfort with uncertainty**. Policymakers often read scientific nuance as indecision or ignore valid uncertainty by defaulting to the status quo
- **A widening trust gap.** Some highlighted declining public trust in environmental decision processes, which in turn shapes the appetite for data.

Toward a shared theory of change

Taken together, these three barrier sets suggest that the ecosystem science community is standing on the threshold of its next evolution. The challenge ahead is not primarily technical, it is architectural. A shared theory of change would clarify:

- Who the sector must influence (policy, investors, landholders, communities, regulators, markets)
- How insights should move — from observation to model, from model to indicator, from indicator to decision
- What evidence pathways require — timeliness, narrative coherence, fit-for-purpose scales
- Where domain experts must remain engaged across the pipeline — not only at the production end, but at the interpretive and decision end.

It would turn a diffuse ecosystem of observations into a coordinated system of environmental intelligence. Respondents hinted at what such a system would look like: a pipeline where credible signals, trusted intermediaries, aligned tools, and clear policy demand create a continuous loop between evidence and action.

A seat for technical experts in translation

One subtle but powerful insight emerging from the responses is that the ecosystem science sector may be missing an entire layer of capability. Respondents did not simply ask for better science writing, training materials or user-friendly tools, but also for **data professionals who can work directly with government, industry and community.**

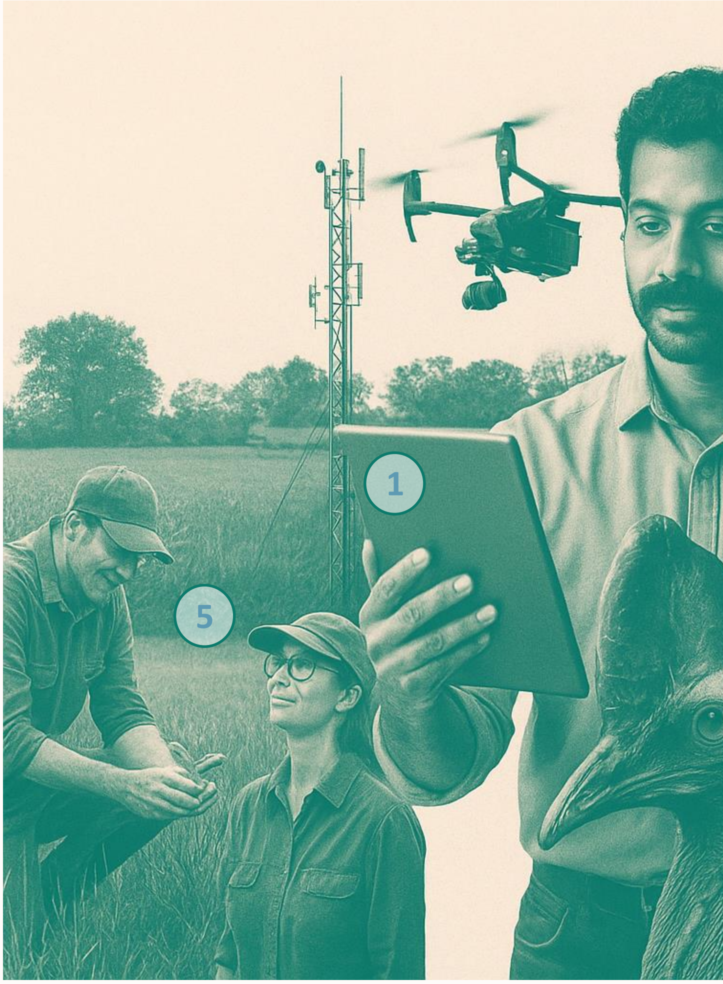
Traditionally, ecoinformaticians and data specialists concentrate at the start of the pipeline: collecting, curating and analysing data. Responses pointed to the need for them helping interpret evidence in context, understand uncertainty and apply insights to real-world decisions. Currently, such a layer of expertise is not sufficiently articulated or formally resourced.

6 | A vision for terrestrial ecosystem science in 2035

This final section distils the central themes emerging from responses to the prompt: *"Imagine it's 2035 and Australia has the right world-class infrastructure to support your work. Compared to today, what would be different?"* (**Figure 9**).

Taken together, these responses sketch a coherent environmental knowledge system where research, practice and decision-making operate as connected parts of the same enterprise, coordinated around collective missions. The emerging vision is offered here as a provocation and an invitation for what Australian terrestrial ecosystem science could become.

Figure 9. *A vision for Australian terrestrial ecosystem science in 2035*



1 No data downloads future

Environmental research is no longer a file-management sport. Researchers no longer download but plug into it. Instead of moving data to the researcher, the researcher moves their question to the data. Data linkage is already resolved — harmonised and aligned. Baselines, management actions, levels of protection, disturbances, climate trajectories and socio-ecological variables all sit in a coherent, queryable system. Government, industry, NGOs and the research sector all feed into the same national environmental data spine.

2 Infrastructure lets researchers focus on analysis and insight

Freed from most data preprocessing, researchers now begin directly at the methods stage, so their time goes into the highest-value tasks: discovering patterns, building and auditing models and testing solutions. Researchers learn their craft on high-quality data streams, digital twins and reference models. Any discipline that can use Earth Observations, sensors, AI or genomics does, because strong communities of practice have made these tools routine, not niche. Clear skills pathways and recognised credentials mean teams with the right skills can be assembled quickly to tackle issues.

3 A credible and socially-responsible national evidence base

Instead of working from partial, incompatible slices of evidence, Australian stakeholders build from a single, independent, reproducible evidence spine with provenance, First Nations knowledge and geocultural values built in. The disagreement moves from *"What is the state?"* to *"What are we going to do about it?"* — because the state is settled.

5 Knowledge and solutions are co-created across sectors

Government, researchers, industry, land managers and First Nations organisations work on the same problems from the same evidence spine. Old siloed roles have dissolved: government monitors as it researches; researchers contribute directly to real-world management; industry helps design solutions rather than reacting to them. Australian NRI is decidedly infrastructure for collaboration. Stakeholders gather around missions and solutions emerge from their collective capability.

6 A community that sees, learns and acts together

Transparent, real-time evidence shows how ecosystems, economies and communities are linked. From farmers to policymakers to households, people can see impacts as they unfold. Public data rooms, shared dashboards and community co-design tools shift behaviour faster than regulation. Students learn from the same data that guides land managers and councils, normalising data-driven thinking from the classroom onwards. Information reaches people in a form they can act on, making environmental understanding a shared civic capability.

4 Real-time data produces science that informs today's decisions

Early detection, rapid interpretation and near-real-time forecasting mean environmental management becomes proactive rather than reactive. Signals from satellites, sensors and models arrive early enough to change what happens next — not just explain what already happened. Evidence reaches researchers and decision-makers in time to matter, shortening the path from observation to action.

7 We have become better stewards of Country

Monitoring no longer just document loss — it shows recovery as it happens. High-certainty biodiversity data, reference DNA libraries and shared regional models mean problems are spotted early. Good stewardship accumulates and threats are managed before they cascade. People can point to hills, creeks, forests and farms that are measurably healthier, and know exactly which actions made the difference. People can see recovery taking shape in real places and feel, quietly but genuinely, that we are good at caring for our country.

About the survey: Reaching across Australia's ecosystem science community

The campaign

The *TERN's Research Directions 2025–35 Survey* set out to **build a picture of Australia's environmental research community—who they are, where they work and what they see ahead**. The survey was open to all, but the campaign was designed to ensure it reached the people most directly shaping environmental science across the country.

More than 12,000 people were invited by email, supplemented by broader circulation through professional and social media channels. The outreach drew on three coordinated streams, each targeting a distinct segment of the research landscape:

- First, we reached **individual researchers** directly based on their public academic profiles. To this end, every Australian university was systematically canvassed, including 43 faculties and schools and 259 research centres, institutes and networks
- The second campaign focused on the **organisations** that knit together Australia's research and environmental practice landscape — from professional societies and learned academies to Indigenous alliances, NGOs and collaborative research networks spanning ecology, agriculture, climate, data science and conservation
- Finally, we turned inward to **TERN's existing community**—inviting newsletter subscribers, data-portal users, and long-time collaborators to lend their voice.

The result was a cross-section of Australia's environmental research brains-trust.

Campaign stats

- Open rate (62%) and click rate (10%) well above industry averages (20–30% and 2–5% respectively).
- Response rate (1.5%) at the high end of typical completion rates for comparable cold email research surveys (0.5–1.5%).

Who responded

The survey received 181 completed responses, a strong result for this type of open, research-focused consultation.

Respondents represented a broad mix of disciplines, with the largest groups working in **ecology and biodiversity** (114 respondents), **environmental management and conservation policy** (60), **climate, hydrology and earth systems** (43), and **environmental observation, data and modelling** (43).

Smaller but valuable contributions came from soil and geosciences, social sciences, agriculture, genomics, urban systems, and marine and aquatic research, underscoring the breadth of disciplines connected to ecosystem science in Australia.

Most respondents (six in ten) work in **universities or research institutes**, confirming the academic sector's central role. But the next wave came from places where science meets decision-making and practice: the **community sector** (10%) and **State and Territory agencies** (10%), followed by smaller contributions from Federal government, industry and local government.

Respondents were distributed across four broad role types:

- **Researchers** (60%) — scientists and academics driving fundamental inquiry
- **Practitioners** (20%) — advisors, managers and NGO staff translating research into practice
- **Leaders** (10%) — decision-makers steering programs and institutions
- **Technicians** (10%) — data and analytics specialists who make research possible.

Together, they offer a broad snapshot of Australia's environmental research landscape — spanning the spectrum from fundamental science to applied practice, from fieldwork to data infrastructure, and from research insight to policy impact.

Glossary and Abbreviations

Glossary

Accounting (environmental)
An approach to keeping environmental records that organises observations into consistent categories, units, and reporting structures to track whether key environmental stocks or conditions rise or fall over time. Environmental accounting is emerging as a key tool for environmental governance (see: United Nations' SEEA Ecosystem Accounting), enabling countries to incorporate environmental values into existing statistical and policy systems used to track stocks of commodities or resources. In Australia, the emerging environmental accounting system is managed by the Australian Bureau of Statistics (ABS) and is designed to feed into established reporting and planning processes such as State of the Environment reporting.

Anthropogenic
Resulting from human activity rather than natural processes. In environmental science, it is commonly used to describe changes or impacts on ecosystems, the atmosphere or land cover that result from human actions, such as greenhouse gas emissions, deforestation or urban development.

Analytical capabilities, Analytics
In the context of national research infrastructure (NRI), these are tools, services and systems that support the analysis, interpretation and visualisation of data. For terrestrial ecosystem observations, these capabilities can range from data visualisation platforms and workflow pipelines to decision-support systems, helping researchers and stakeholders explore patterns, trends and relationships within complex datasets.

Biodiversity
The variety of life at genetic, species, and ecosystem levels. In contemporary environmental science, discussions of biodiversity are closely linked with the management of invasive species, pests, climate and other human-influenced pressures that affect the integrity and resilience of ecological systems.

Biophysical intervention
A deliberate action that alters physical, chemical or biological aspects of an ecosystem to achieve a specific management or restoration outcome. Examples include reforestation or controlled burns.

Conservation
The practice of managing ecosystems to protect or restore species and genetic diversity and maintain ecological integrity and resilience. Conservation is inherently contested, as it involves deciding not only *what* to conserve but also the standard or reference condition to aim for, decisions that are often complicated by limited or no baseline data and uncertainty about historical states (e.g., pre-colonial ecosystems). This underscores the central role of environmental data in guiding conservation choices.

Cryptic species / organisms
Species or individuals that are difficult to detect due to camouflage, small size, hidden habitats or elusive behaviour. Monitoring them effectively requires complementary observation methods, such as environmental DNA (eDNA) or acoustic monitoring (a.k.a. ecoacoustics), which can detect species that may be missed by cameras or field surveys.

DNA Library
A curated reference collection of DNA sequences from identified organisms, organised so that unknown genetic material can be compared against known sequences. In biodiversity monitoring, DNA libraries allow researchers to match environmental DNA (eDNA) from soil, water or air samples to specific species. Australian-specific DNA libraries are critical for reliable and faster species identification across projects and monitoring programs nationally.

Earth Observations
Measurements of the Earth's surface and atmosphere derived primarily from satellites and other remote-sensing technologies. Their usefulness depends on being checked and interpreted using observations collected on the ground. In Australia, TERN provides on-the-ground reference measurements to support EO products.

Ecosystem

A system formed by living organisms and their physical environment, whose condition cannot be understood by looking at single species or variables in isolation. Ecosystems function through the interaction of many elements — such as biodiversity, climate, soils, water and disturbance — and it is at this system level that benefits people rely on, such as food production, water regulation and climate buffering, emerge. Ecosystems are also constrained by limits to change, with pressures accumulating over time and potentially reducing their resilience or triggering abrupt shifts. At TERN, we aim to collect data across these key ecosystem components. We consider terrestrial ecosystems to broadly include inland, coastal, freshwater, productive, and urban environments.

Epistemology

The study of knowledge — how we know what we know, what can be known and the limits of that knowledge. In terrestrial ecosystem research infrastructure, epistemology is a practical concern: it shapes how we design observations, choose instruments, interpret data, quantify uncertainty and understand the limits of models and predictions. It also underpins decisions about how observations from one site can be transferred or extrapolated to others, and how confidently we can infer ecosystem condition and trends from available evidence.

Fluxes (energy, carbon, water, nutrients)

The rates at which energy or materials move between components of an ecosystem or between ecosystems and the atmosphere. Fluxes are measured because they reveal how ecosystems function, including productivity, water cycling, nutrient dynamics and greenhouse gas exchange, and how these processes respond to environmental change. TERN measures carbon, water and energy fluxes at its Supersites, providing key information to understand ecosystem health, productivity and resilience.

Function (ecosystem)

The processes through which ecosystems operate, including energy flow, nutrient cycling, and decomposition, which underpin productivity, resilience, and the services ecosystems provide to people.

Genomics

The study of the complete set of DNA within an organism or population, capturing the sequences, structure, and variation that define life at its most fundamental level. In environmental research, genomics reveals hidden patterns in species diversity, population health, and adaptation, and helps scientists link those patterns to ecosystem processes and environmental change. While TERN's genomics capabilities are still developing, its rich, layered environmental and ecological data provide the essential context for interpreting DNA, allowing us to see not just what is changing in ecosystems, but why — and to anticipate the forces shaping Australia's terrestrial landscapes.

Macroecological gradients

Systematic changes in environmental conditions or biological traits across large spatial scales, such as temperature, rainfall, or species richness from the equator to the poles. They help explain patterns in biodiversity, productivity and ecosystem processes, and indicate where monitoring efforts are most valuable.

Modelling (data), Model (data)

A simplified representation of reality used to understand, simulate, or predict ecosystem processes. Models range from process-based simulations to statistical and predictive approaches. Their reliability depends on high-quality, long-term, and systematic data, such as the observations TERN provides for Australian terrestrial ecosystems.

Natural disturbance / variability (ecosystem)
The range of changes in ecosystem structure, composition, or function caused by natural events or processes, such as fire, floods, storms, disease outbreaks, or seasonal cycles. These dynamics set the natural bounds of ecosystem behaviour, revealing the limits of resilience and the capacity to absorb change. Understanding this variability is essential for interpreting long-term trends, predicting ecosystem responses, and assessing risks from human activities. TERN's systematic, long-term observations capture both regular patterns and rare events, providing the context needed to distinguish natural fluctuations from anthropogenic impacts.

Nutrient cycling
The movement and transformation of elements like nitrogen, phosphorus and carbon through ecosystems. Nutrient cycling drives plant growth, supports food webs, maintains soil fertility and influences water quality. Understanding these cycles helps explain why some ecosystems thrive while others struggle, how they recover from disturbance and how human activities like farming, pollution or land clearing can disrupt the balance of life.

Remote-sensing (technologies)
A range of technologies for collecting information about the Earth's surface or atmosphere from a distance. Common examples include: optical sensors, which detect reflected sunlight to reveal vegetation or land cover; thermal and infrared sensors, which measure heat or plant stress; radar and LiDAR, which emit signals and measure their returns to map terrain and vegetation structure; and multispectral and hyperspectral sensors, which capture reflected light across many wavelengths to uncover chemical or physiological properties.

Stewardship (of ecosystems)
The responsible management and care of ecosystems and natural resources to sustain their value and function over time. In environmental science, stewardship involves monitoring, informed decision-making and actions that balance human use with conservation.

Abbreviations

eDNA
Environmental DNA. Genetic material shed by organisms into soil, water, air or other substrates, used to detect and monitor species.

DEM
Digital Elevation Model. A 3D representation of the Earth's surface used to study terrain, catchments and habitat patterns.

IoT
Internet of Things. Networked sensors and devices that collect and transmit environmental data automatically, in real time.

LiDAR
Light Detection and Ranging. A remote-sensing technology that emits laser pulses and measures their return to map terrain, vegetation or structural features in 3D.

NCRIS
National Collaborative Research Infrastructure Strategy. Australia's program for funding and coordinating shared research facilities and infrastructure across the country.

PFAS
Per- and polyfluoroalkyl substances. Persistent synthetic chemicals used in consumer and industrial products that can accumulate in the environment and affect ecosystems and human health.

SAR
Synthetic Aperture Radar. A type of radar remote-sensing technology that produces high-resolution images of terrain or vegetation, day or night, in all weather conditions.

TERN
Terrestrial Ecosystem Research Network. Australia's national infrastructure for collecting, integrating, and sharing terrestrial ecosystem data to support research, management and policy.