Royal Botanic Gardens

Kew

Science Strategy

2021–2025

Foreword

Life on Earth is in peril. Never before have so many challenges manifested themselves so clearly and intensively. Every year, millions of hectares of forest are lost; fire devastates huge swathes of natural habitats; floods and hurricanes hit our cities; heat and drought reduce our harvests; people struggle to feed their children and combat disease; and species suffer a silent death, never to return.

These challenges are a direct or indirect result of unsustainable human activities, which are causing the depletion of natural resources and the widespread loss of biodiversity, our life-support system. The 'Great Acceleration' that characterises human development since the 1950s is also a time of 'Great Decline' for nature – a decline I have witnessed first-hand in the tropical ecosystems of my home country, Brazil. The devastating and intertwined impacts of biodiversity loss and climate change are affecting each one of us on this planet, some more than others. The decline of biodiversity means the reduction or loss of the many ecosystem services we rely on: the provision of natural products such as water, food, medicine, fuel and other materials; processes such as flood prevention and nutrient cycling; and cultural benefits such as recreation.

Science can provide answers to many of the challenges we face. Achieving sustainable human development across the globe requires fundamental understanding and practical solutions. The useful properties of plants and fungi are largely untapped and hold the potential to bring equitable benefits to people and nature.

In this document, we at the Royal Botanic Gardens, Kew present our ambitious plan to help stop biodiversity loss and develop sustainable nature-based solutions to some of our biggest global challenges. The next few years provide a closing window of opportunity for societies to protect and sustainably use Earth's remaining biodiversity and to restore what we have degraded.

My colleagues and I hope you will want to join forces with us in achieving this vision.

Sincerely,

Professor Alexandre Antonelli
Director of Science, Royal Botanic Gardens, Kew

Kew Gardens, our UNESCO World Heritage Site in south-west London.

Executive summary

We at the Royal Botanic Gardens, Kew (RBG Kew), in partnership across disciplines and sectors, aim to help stop biodiversity loss and develop sustainable nature-based solutions to some of humanity's biggest global challenges. This document sets out how we will refocus our science to fulfil RBG Kew's new mission outlined in *Our Manifesto for Change 2021–2030* – **To understand and protect plants and fungi for the well-being of people and the future of all life on Earth.**

Our structure, our research and our resources now align to five Scientific Priorities, to help us achieve transformative change and maximum positive impact. These Priorities are:

Priority 1

Ecosystem Stewardship

Conducting innovative research into evidence-led protection of biodiversity and ecosystem services, while seeking nature-based solutions to societal challenges.

Priority 2

Trait Diversity and Function

Understanding plant and fungal traits, to aid conservation, increase resilience to global change, and explore potential uses and benefits for human health and well-being.

Priority 3

Digital Revolution

The large-scale digitisation of specimens and integration of data systems to increase the global value and use of RBG Kew's collections for science, conservation and education.

Priority 4

Accelerated Taxonomy

Using new technologies to push the frontiers of taxonomic research, accelerating the characterisation and identification of species.

Priority 5

Enhanced Partnerships

Cultivating current and new scientific, educational and commercial partnerships within the UK and across the world to maximise scientific excellence and on-the-ground impact.

Within each Priority, we set out our vision to innovate (research and explore), inspire (motivate, train and educate) and influence (engage externally) to achieve our goals. Our work will be delivered through a programme of Initiatives, as summarised on pages 67–68. Our vision is ambitious; what we can achieve will rely on the experience and resources we already hold, in combination with increased income and investment in our world-class collections and science.

Wakehurst, our site in West Sussex, home to the Millennium Seed Bank.

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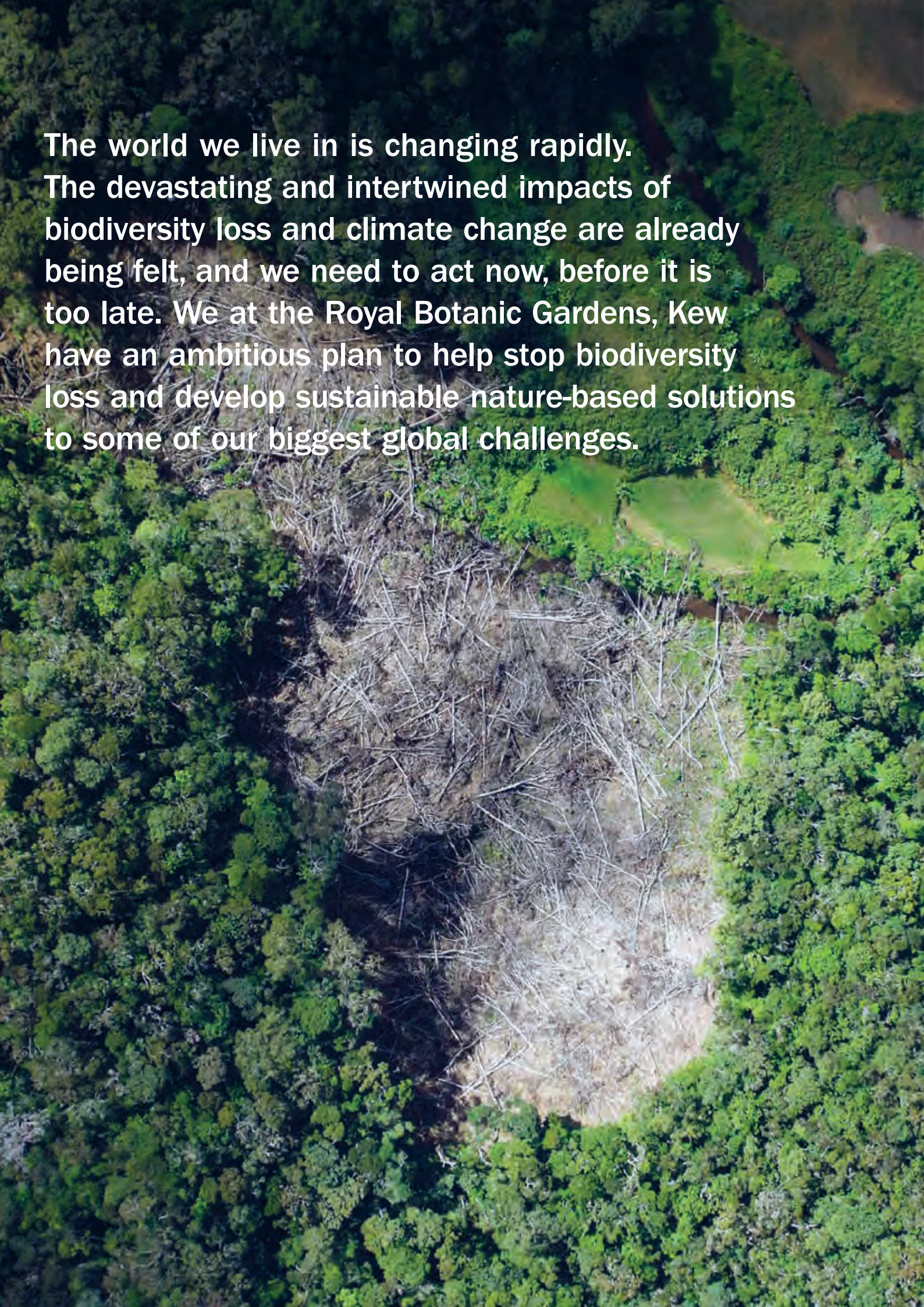
Introduction



The world we live in is changing rapidly. The devastating and intertwined impacts of biodiversity loss and climate change are already being felt, and we need to act now, before it is too late. We at the Royal Botanic Gardens, Kew have an ambitious plan to help stop biodiversity loss and develop sustainable nature-based solutions to some of our biggest global challenges.

RBG Kew's contribution

For more than two centuries, our scientific work has focused on exploring nature, finding and describing species of plants and fungi, investigating their uses, and sharing their wonders and beauty with people. But the world has changed. The plants and fungi we depend upon, either directly or indirectly, are now disappearing faster than ever before. We would have to go back 66 million years to find a similar wave of extinctions – then caused by a meteorite, but today a result of human activities.

Scientists have long recognised that humanity is operating beyond the 'Planetary Boundaries' of sustainability and this message is now clearer than ever. The *Global Risks Report 2021,* produced by the World Economic Forum, highlighted that biodiversity loss is one of the top three global existential threats, and the RBG Kew-led *State of the World's Plants and Fungi 2020* report estimated that 40 per cent of all plant species are currently threatened with extinction.

Despite these stark messages, there is hope. It is within our collective power to remedy the loss and decline of biodiversity before it is too late, but we must act now. RBG Kew, in partnership across disciplines and sectors, has an outstanding opportunity to push the frontiers of fungal and plant science and make substantial contributions to solving the biggest challenges facing humanity, through a new mission and renewed focus.

This document provides an outline of the scientific ambitions and vision of RBG Kew, in collaboration with partners across the world. Building on our unique wealth of experience, we set out five Scientific Priorities to help us achieve transformative change and maximum positive impact. We also strengthen our commitment to equity and inclusion in science, whether in working with our global network of partners, making our digital resources freely available, or in researching and sharing our history. What we have achieved to date has had a significant impact, but given the challenges that face humanity, it is critical to step up investment for the future of biodiversity and people.

Our mission

To **understand and protect plants and fungi** for the well-being of people and the future of all life on Earth

In partnership with our global network of collaborators, we aim to understand, protect and restore biodiversity at taxonomic, genetic, functional and ecosystem levels, and at all spatial scales. Our expertise will contribute fungal and plant knowledge to partnerships aimed at safeguarding all biodiversity, and our exploration of the useful properties of plants and fungi will provide significant benefits to society. Protecting biodiversity will contribute substantially to one of the critical UN Sustainable Development Goals – Life on Land (SDG 15) – and will also directly support several other goals, contributing to sustainable livelihoods (SDGs 1, 8, 11), food security (SDG 2), sourcing new medicinal plants (SDG 3), protecting watersheds (SDG 6), exploring alternative energy sources (SDG 7) and increasing resilience under climate change (SDG 13). Our biodiversity research will also support other crucial areas, such as building the research capacity of countries (SDG 9) and developing international partnerships (SDG 17). Within the United Kingdom, our work will help the government to achieve its 25-Year Environment Plan for England, as well as supporting the environmental commitments of the devolved nations and the UK Overseas Territories.

Our Scientific Priorities

Five Scientific Priorities

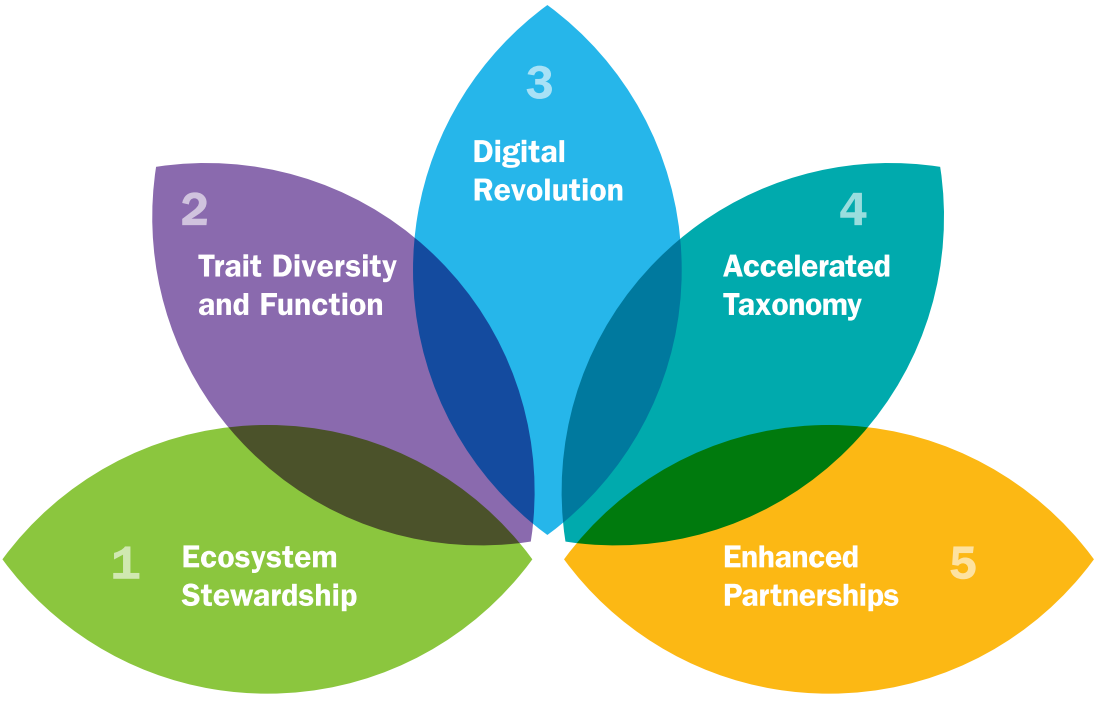
To fulfil our mission, we will build and share robust scientific evidence, greatly accelerate the identification and naming of fungi and plants, mobilise our collections, expand our training portfolio, enhance the influence of biodiversity considerations in discourse across sectors, and maximise positive impact through working with communities, governments, companies, land managers and other practitioners.

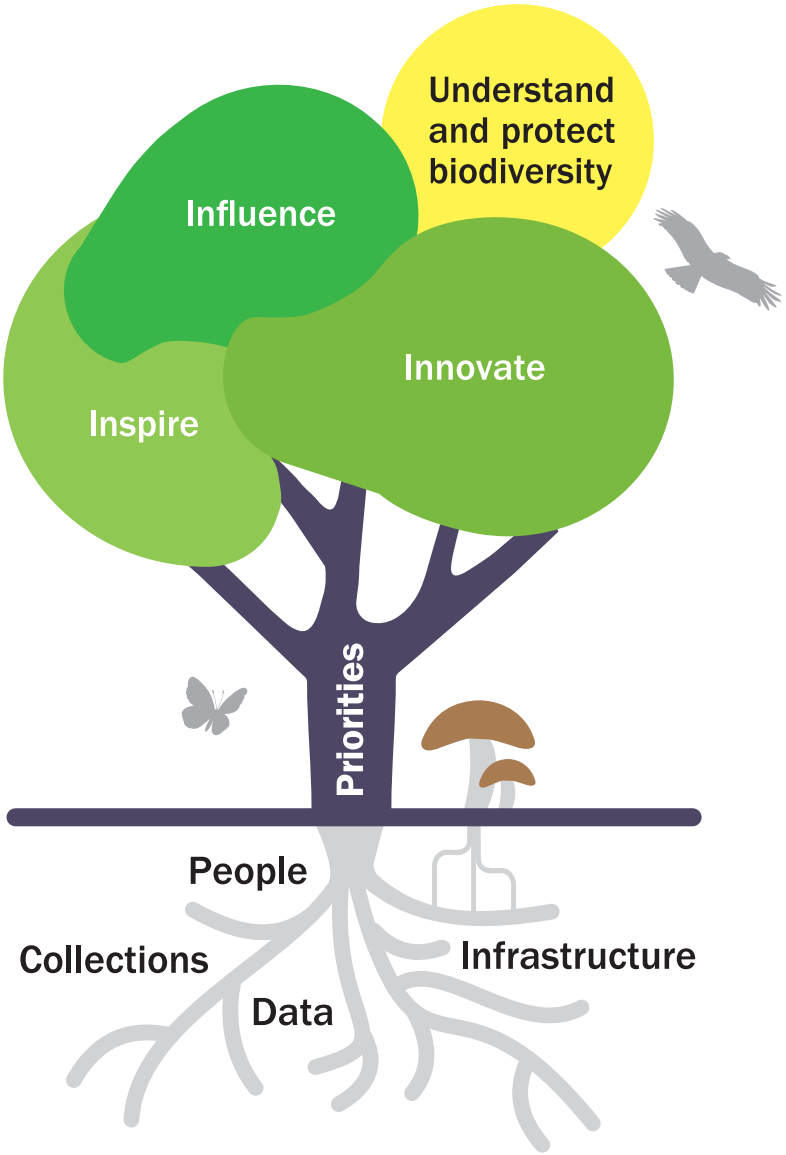
We will capitalise on, and further develop, our greatest assets – our collections and expertise – to pursue five key Scientific Priorities: Ecosystem Stewardship; Trait Diversity and Function; Digital Revolution; Accelerated Taxonomy; and Enhanced Partnerships. We will deliver each Priority through three modes of action. Here, we outline our vision and how we will innovate (research and explore), inspire (motivate, train and educate) and influence (engage externally). Our vision is ambitious; what we can achieve will rely on the experience and resources we already hold, in combination with renewed investment in our world-class science.

Underpinning all five Priorities, our living and preserved collections will be further developed to increase the diversity of reference material and data. Our collections are essential for supporting hypothesis-driven research, and our collecting activities will be guided by an analysis of gaps in geographic and taxonomic coverage and their relevance to our Priorities.

Our horticultural and scientific programmes will be coordinated both for scientific endeavour and *ex situ* conservation of key species. Physical and digital curation of the collections will be maintained at the highest standard to ensure the scientific robustness of our biodiversity data. Our infrastructure will be enhanced and developed so that we have state-of-the-art physical and digital environments to support our critical work.

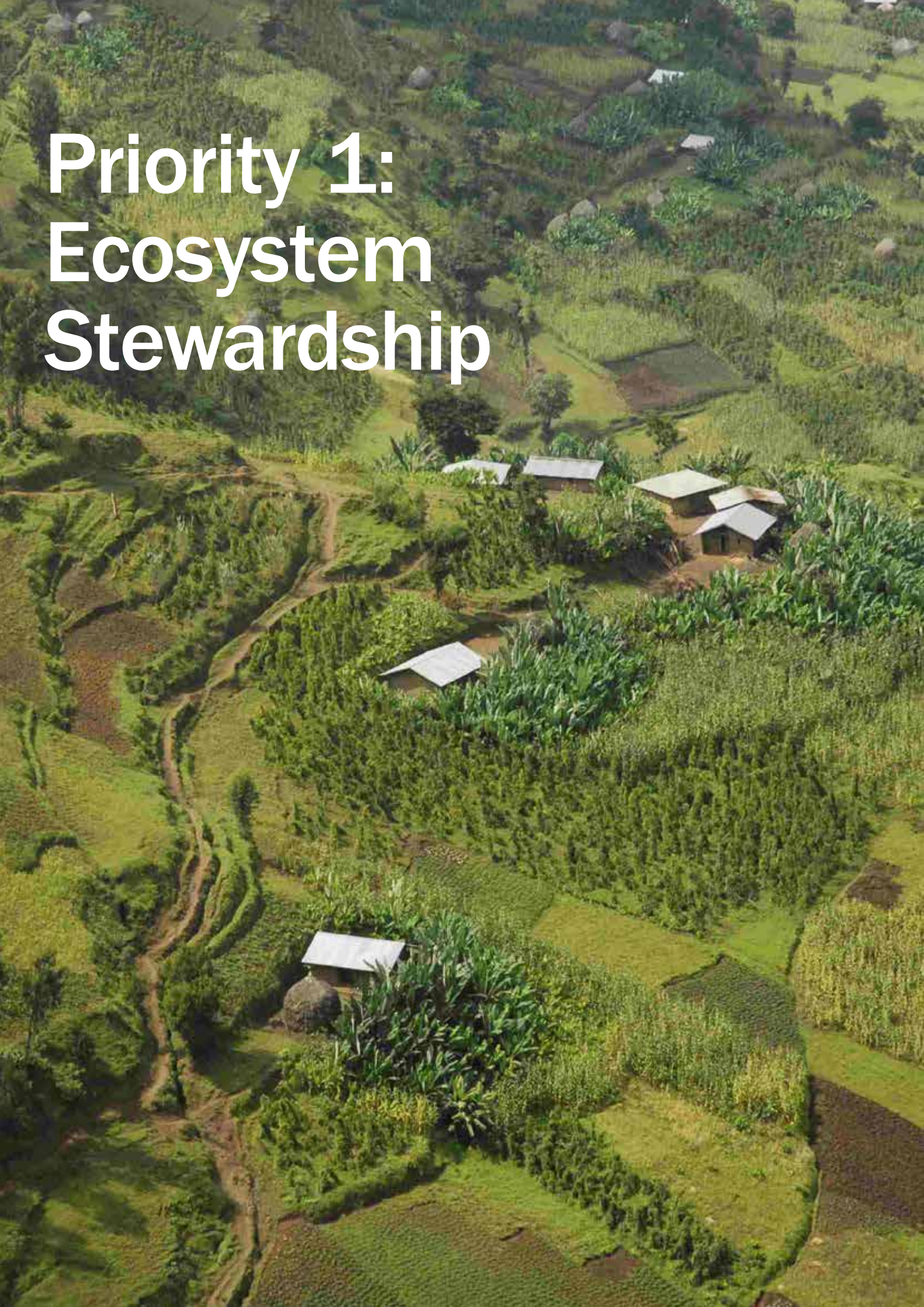
People are a fundamental resource. Drawing upon activities and expertise across the five Scientific Priorities, we will raise our ambition to train the next generation of fungal and plant scientists and horticulturists through in-person and virtual training. We will continue to strive for a culture of scientific excellence at the heart of what we do, attracting and retaining new talent through competitive recruitment, evaluating performance through regular reviews of our scientific staff, and developing the skills of our staff, students and associates, in particular through our Future Leader Fellowship (FLF) programme, our MSc courses, and other opportunities for education and professional development. We will work with RBG Kew's Equality, Diversity and Inclusion programme to remove barriers to recruitment and promotion. This work will build critical capacity to help develop and implement sustainable nature-based solutions to the challenges we face today.





Underpinned by our collections, data, people and infrastructure, and guided by our Priorities, we will innovate (research and explore), inspire (motivate, train and educate) and influence (engage externally) to achieve RBG Kew's mission.

Priority 1: Ecosystem Stewardship



Priority 1: Ecosystem Stewardship

Ecosystem stewardship combines the *in situ* (on-site, in-country) protection of biodiversity with its sustainable use. Good ecosystem stewardship generates knowledge and practices that sustain, promote and restore natural and cultural capital. RBG Kew's unique contribution in this area encompasses the collection and analysis of plant and fungal diversity data (from genes and species through to whole ecosystems), informed by and giving insights into evolutionary processes, ecological interactions (including pollination systems and mycorrhizal fungi), diverse and sustainable agriculture and agroforestry, ecological restoration, and ecosystem health and productivity.

Our approach will involve conducting innovative research into evidence-led protection of biodiversity and ecosystem services, while seeking and implementing diversity-derived solutions to societal challenges. Using our extensive collections alongside insights and further data obtained on the ground, we will apply the breadth of our knowledge to provide a holistic approach for maximum impact and benefits.

Our vision:

We will **innovate** by developing novel tools for the rapid quantification and assessment of biodiversity, identification of priority areas for conservation and restoration, and implementation of sustainable nature-based solutions to global challenges. To achieve this, we will integrate fieldwork, curation and collections-based research, using and generating multiple data sources, including genomic, trait, ethnobotanical and spatial data, and drawing on artificial intelligence (AI) and predictive modelling techniques to enhance our analyses. We will develop new participatory approaches with local communities and in-country partners to enhance livelihoods and ecosystem services. This will include work across semi-natural and managed landscapes, including agro-ecological systems, clearly linking biodiversity to human benefits. We will also conduct additional research into understanding the causes of biodiversity loss and use these new insights to inform efforts to stop this trend.

We will collaborate with and train partner scientists in the evaluation of habitats and species and **inspire** citizen scientists, land managers, conservationists, development organisations and the academic community to understand, sustainably use, protect and promote the recovery of native species and the ecosystems in which they occur. To achieve this, we will build on existing partnerships, develop new ones with relevant organisations, and assemble a network of citizen scientists to broaden our engagement with communities in the UK and across the world.

We will **influence** national and international governments, by providing information and advice that encourages responsible access and equitable use of biodiversity. We will also encourage the public and private sectors to increase investment in the protection and restoration of the world's most valuable and vulnerable ecosystems. Our evidence base will move beyond simple species counts to integrate other metrics of biodiversity and their contributions to human well-being, including economic value and health benefits. To achieve influence in these sectors, we will promote our science through our external affairs and science policy teams and our collaborative partners overseas.

Ecosystem stewardship combines evidence-led protection of biodiversity with its sustainable use.

Initiative 1.1: Ecosystem Assessment

Aim: To develop innovative tools enabling protection and prioritisation of ecosystems, species and natural resources

Urgent action is required to assess the condition of the world's ecosystems and their constituent species, and to set priorities for effective conservation. We will meet this challenge by developing an ecosystem assessment pipeline (a data-driven and reproducible analytical process) to objectively assess and monitor ecosystems. This will involve the integration of multiple approaches and datasets, including AI, genomics, ecology, remote sensing and spatial analyses. The pipeline will be used to identify, monitor, understand and prioritise units of biodiversity at all scales – from landscapes and ecosystems to species, populations and genetic diversity. Its outputs will inform *in situ* conservation and the implementation of nature-based solutions to global, regional and national challenges.

The pipeline will provide an evidence base to underpin responses to environmental change, enabling identification of key centres of diversity that represent concentrations of vital resources, as well as characterising ecosystems and groups of organisms of particular societal importance or those facing the highest risk of extinction – determining where they are found and which processes are driving change. This knowledge will be used to develop enhanced protection for biodiversity and the ecosystem services it provides.

We will also develop tools to optimise allocation of resources in the stewardship of ecosystems, pinpointing where specific monitoring or management actions are likely to be most effective under current and future climate scenarios. Immediate beneficiaries will include those in the fields of biodiversity and conservation science, and conservation practitioners. We will also work extensively with stakeholders from governments, non-governmental non-profit organisations, and the private sector to promote and influence the protection of biodiversity and its sustainable use.

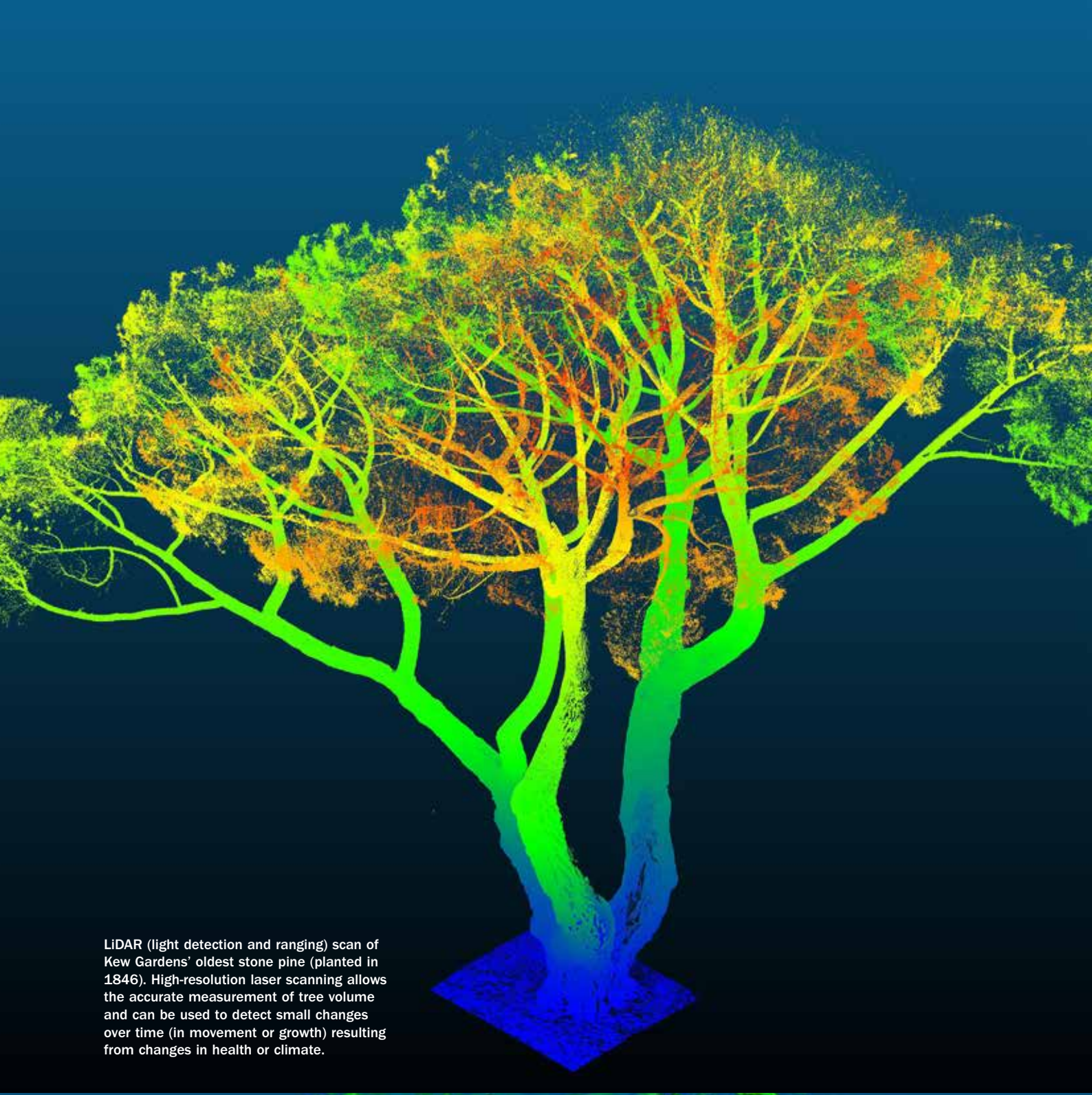
Deliverables:

- **An inventory of priority ecosystems and landscapes for conservation, monitoring and recovery.** This will be carried out in at least eight countries, including Bolivia, the Turks & Caicos Islands, Guinea, and Indonesian New Guinea. Site management will be underpinned by dynamic (change-tracking) supporting information that will drive stewardship and guide the provision of targeted resources aimed at maximising avoidance of ecosystem collapse, species extinction, genetic loss and deterioration of ecosystem services.

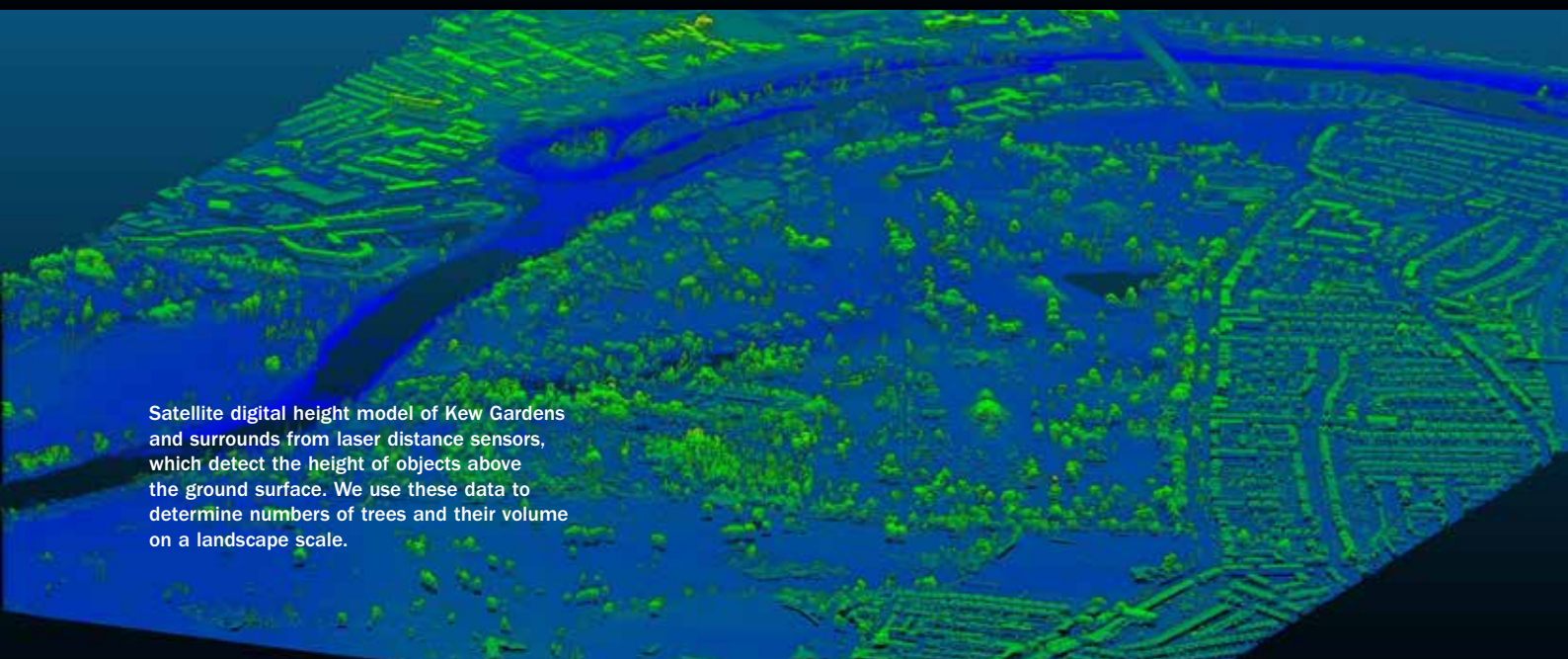
- **Innovative methods and tools to identify, assess, monitor, model and understand units of biodiversity at multiple scales.** Examples include data pipelines to provide accurate and dynamic interpretation of biodiversity; delivery of the next generation of online tools to drive species conservation assessment; and, where data are limited, next generation AI-driven analysis for the identification of species and areas at risk.

- **Information on the ongoing and projected threats faced by different units of biodiversity.** This will be gathered using protocols including those of the International Union for Conservation of Nature Red List of Threatened Species (IUCN Red List). Outputs incorporating estimates of resilience and the scale and severity of threats will be translated into on-the-ground conservation planning. They will include current and predicted distribution maps, thresholds of change, hotspots of taxonomic and phylogenetic (evolutionary) diversity, and indicator taxa of ecosystem condition, for example mycorrhizal fungi communities in dominant habitats across the UK and elsewhere in Europe.

We aim to identify, monitor, understand and prioritise units of biodiversity at all scales.



LiDAR (light detection and ranging) scan of Kew Gardens' oldest stone pine (planted in 1846). High-resolution laser scanning allows the accurate measurement of tree volume and can be used to detect small changes over time (in movement or growth) resulting from changes in health or climate.



Satellite digital height model of Kew Gardens and surrounds from laser distance sensors, which detect the height of objects above the ground surface. We use these data to determine numbers of trees and their volume on a landscape scale.

Initiative 1.2: Nature-based Solutions

Aim: To generate evidence on how biodiversity can help solve societal challenges, and to implement solutions

'Nature-based solutions' (NbS) is an umbrella term for actions that work with and enhance nature to address environmental and societal challenges for the benefit of both society and nature. Researching, implementing and refining NbS is a critical part of enabling effective *in situ* conservation, as it highlights knowledge of the benefits arising from nature and puts the resources in place to encourage people to engage in its protection and sustainable use.

We will seek to understand and enhance the capacity of diverse ecosystems and landscapes to contribute to solving challenges in the UK and globally, in urban and rural settings, and investigate how plants and fungi can provide and support NbS. Key interventions to protect or enhance natural capital (the benefits and services provided by nature) will include research into ecosystem restoration, agroforestry, agricultural and horticultural innovation, and management of wild-harvested resources and their associated traditional knowledge. To inform interventions and monitor their effectiveness, our research will span topics from grassland and fire ecology to novel crops, high-resolution mapping, modelling of carbon storage, and pollination services. NbS will be implemented and monitored in partnership with communities, researchers, governments and non-governmental non-profit organisations.

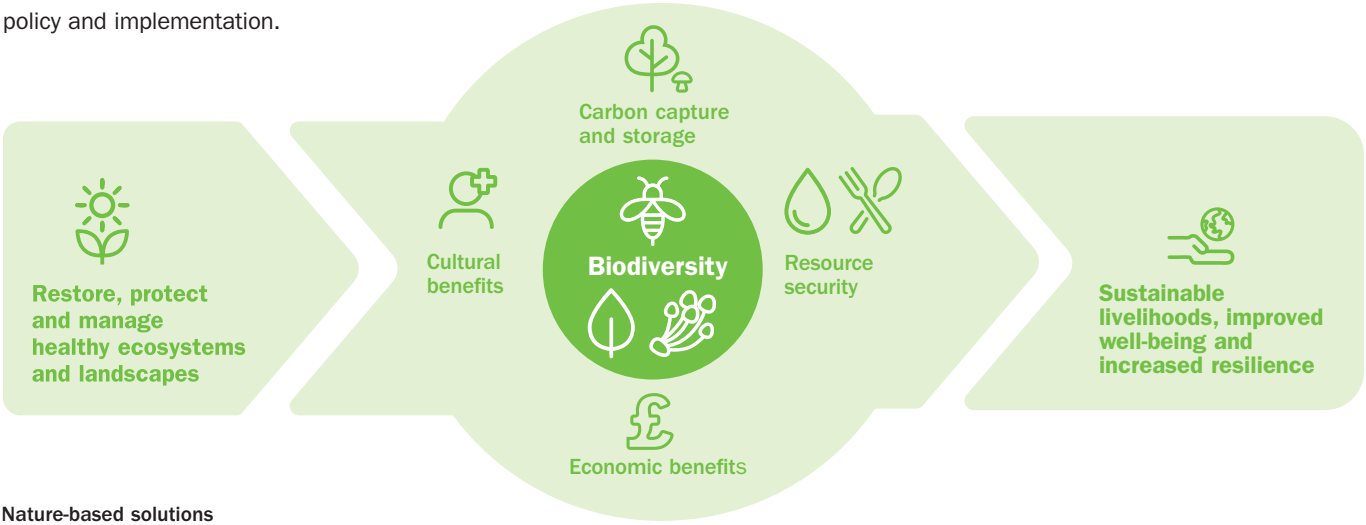
We will also work with partners on ethical and international-policy-compliant mechanisms to secure funding to protect biodiversity and ecosystem services. Possible avenues include carbon finance, ecotourism, biodiversity assessment and/or certification and sustainable marketing of plant and fungal products. This Initiative focuses on benefits for people, but will also provide data, models and methods for use by the rapidly developing interdisciplinary NbS research communities. Outreach and engagement with stakeholders will increase awareness and maximise the impact of NbS policy and implementation.

Deliverables:

- **Monitoring and evaluation of which NbS work where, for wider application and scalability.** For example, at our Wakehurst site, we will develop indicators to measure natural capital and associated ecosystem services under environmental change, and we will explore their value. We will focus on carbon sequestration above and below ground (especially via fungi and their interactions with plant roots and soils), nature connectedness, and water and pollination services.

- **Evidence contributing to the development of more resilient landscapes and ecosystems in which biodiversity is better protected, enhanced and sustainably utilised, especially where human need is greatest**. We will deliver this in countries and territories including Madagascar, Peru, Mexico, Colombia and St Helena, working to enhance natural capital to protect biodiversity, sequester carbon and improve livelihoods.

- **Tools and interventions to help implement NbS.** For example, in selected locations we will model how global warming will impact seed germination and seedling establishment of wild edible plants, and develop conservation and propagation protocols for community-based reforestation. We will identify the most suitable plants and fungi for use in NbS by using annotated species catalogues, AI tools to identify key species providing ecosystem services, and outputs focused on prioritising the world's edible plants.



Nature-based solutions

Initiative 1.3: Biodiversity Metrics

Aim: To develop and apply innovative ways of quantifying and monitoring biodiversity to enhance its protection

Targets and metrics are fundamental to the effective stewardship of biodiversity and ecosystems. They are vital for biodiversity protection and monitoring, and provide evidence to guide management action to maximise the societal benefits that nature provides through ecosystem services. Such metrics have been principally applied to charismatic groups of organisms or to ecosystems and landscapes in high-income countries. In this Initiative, we will embed plants and fungi in global biodiversity and natural capital metrics, promoting their inclusion in nationally and internationally agreed indicators and targets, and evaluating their congruence with metrics used for other major groups of organisms.

To achieve this, we will develop datasets, inventories, analytical tools, maps and models at different scales – from population genetic diversity via species and ecosystems to global approaches – and use these to quantify status and trends at spatial and temporal scales appropriate to policy development for management of, and investment in, biodiversity.

Outreach and working in partnership will be vital, to ensure that we meet the needs of potential beneficiaries, who range from governments and international bodies to sub-national entities and the private sector. For example, in the UK and UK Overseas Territories, we will contribute to measuring and valuing natural capital assets and generating assessments to meet stewardship needs. These approaches will enable the incorporation of natural asset values into the economy. Internationally, we will work to extend our influence and impact on metrics that support global- to landscape-level biodiversity protection.

Deliverables:

- **Novel or enhanced stewardship metrics at a global scale, including and building on IUCN Red List products.** This will include Evolutionarily Distinct and Globally Endangered (EDGE) metrics for all species of flowering plants, and applications of the Species Threat Abatement and Restoration (STAR) metric to plants. At a finer scale, we will fast-track Red List assessments to respond to emerging threats, such as for the plant genus *Dalbergia* (rosewoods), listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). We will also generate a UK fungi Red List Index and an asset register.

- **Natural capital metrics and methodological innovation incorporating specific benefits provided by biodiversity.** These include food source availability for pollinators, above- and below-ground carbon storage, and regulation of water flow by trees. Selected metrics will incorporate human well-being and prosperity.

- **Metrics to measure resilience to environmental change in species that supply provisioning ecosystem services.** This will enable the identification of resilient species with the potential to contribute to the development of nature-based solutions. Develop and test metrics for resilience to environmental change, which will include at least one covering environmental change in fungal soil diversity.

Ectomycorrhizas of *Xerocomellus pruinatus* on the roots of sessile oak, *Quercus petraea*.

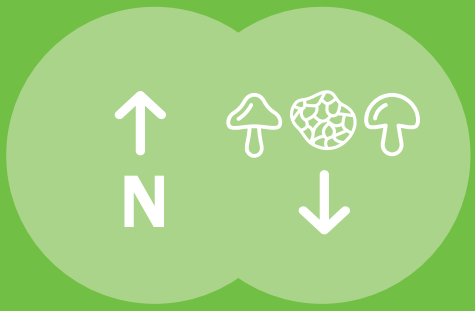
CASE STUDY:
The effect of nitrogen pollution on fungi and forest function

Mycorrhizas are an association between fungi and the roots of plants. In exchange for carbon, the fungi supply their plant hosts with essential nutrients that enhance their growth and strengthen defences against pests and diseases. Ectomycorrhizas, where the fungus forms a sheath around the root, are common in trees and other woody plants, and are important in the functioning of European forests. To look at the effect of nitrogen pollution on mycorrhizas, and therefore trees and forest functioning, we analysed nearly 40,000 mycorrhizas in combination with long-term soil, tree, pollution and climate data from 137 forests across the UK and 19 other European countries.

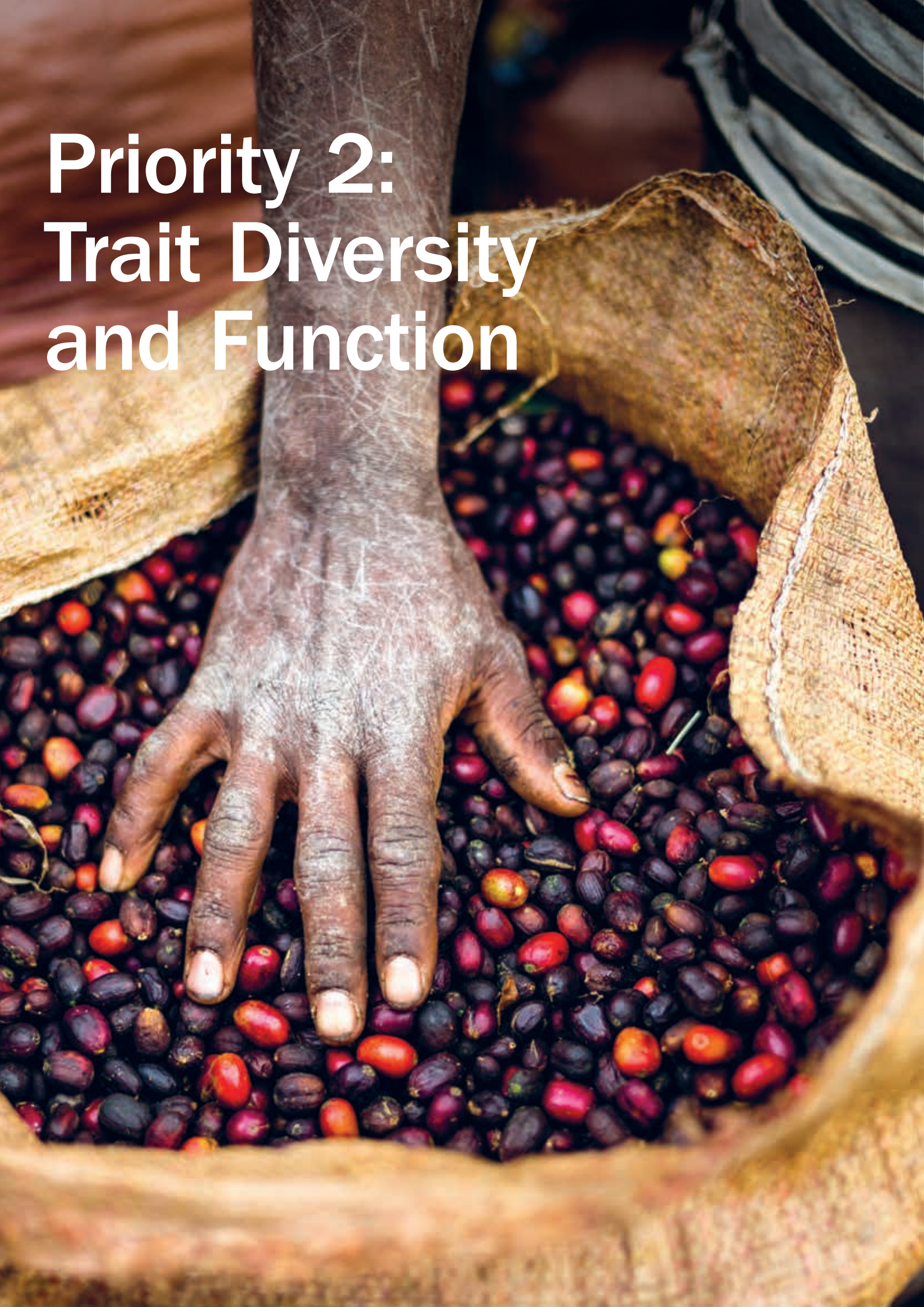
We revealed that nitrogen pollution negatively affects mycorrhizas at a much lower threshold than previously estimated; diversity decreases sharply, and fungi with limited soil exploration and carbon sequestration abilities increase. We linked these large-scale below-ground changes to a tipping point in forests leading to alarming tree nutritional imbalances, with major ecological and economic consequences. These findings call for re-evaluation of nitrogen critical loads in ecosystem assessments and can inform environmental policy. We now aim to test how mycorrhizas and environment change over time, and how these changes are linked with tree and forest condition. We can then include such data in a forest model to predict how changes in mycorrhizal communities will influence forest functioning, tree growth, and soil carbon capture along environmental gradients, and how these are influenced by global change.

40,000
mycorrhizas

137
forests



Sampling mycorrhizal roots from the forest floor.



Priority 2: Trait Diversity and Function

Priority 2: Trait Diversity and Function

Plants and fungi hold the key to addressing many of the challenges facing the natural world. But there is still much we do not know about the properties that have enabled them to survive in the environment. The specific suite of characteristics and properties of a species – its 'traits' – can reveal how it has adapted to particular environments, and how resilient it may be to future change. Understanding these traits, their function and how they have evolved, will enable us to better conserve plants and fungi, both within and outside their natural range or habitat, and to identify species and molecules we can use sustainably and equitably for the benefit of humankind.

RBG Kew's collections, particularly the Seed Collection at the Millennium Seed Bank and the Living Collections at Kew Gardens and Wakehurst, provide a priceless reserve we can mine to drive this process of discovery, in line with the Nagoya Protocol, related legislation and best practice. The exploration of biodiversity offers a wealth of opportunities for improving human health and well-being and may provide new solutions for sustainable development.

Our vision:

We will **innovate** in the use of new technologies and methods to explore the properties of plants and fungi, and their potential applications, as well as researching the underlying evolutionary forces driving change and resilience in genomes, species and ecosystems. To achieve this, we will draw on our unique collections in addition to newly collected material. Notable applications of this research include increasing the success of ecological restoration and species reintroduction programmes, and developing a broader range of species to improve nutrition and provide a range of other nature-based solutions. In particular, we will explore traits that can be useful for agriculture, both for improving major crop species and developing minor crops that may be more resilient to environmental change. We will also explore the molecular basis of useful traits, combining genomics and chemistry, and identify new biomolecules with potential to enhance human health, livelihoods and well-being. Innovative plant health research will reveal the genetic basis of resistance to major pests and pathogens in economically and ecologically important species.

We will **inspire** governments, companies and our visitors to think about the benefits of exploring and harnessing the power of biodiversity to deliver solutions to the world's needs, and to appreciate the value of protecting it for the benefit of future generations. To achieve this, we will showcase economically important plants in our gardens, give our visitors the chance to experience unfamiliar plant-based products at our Science Festival, and educate our on-site, online, professional and commercial audiences about the ecosystem services provided by plants and fungi and the potential for them to be used in new ways for health and well-being.

We will **influence** the development of international policy (for example, through the Convention on Biological Diversity – CBD) to ensure that the benefits of this work are equitably shared across the globe. To achieve this, we will contribute to development and implementation of the CBD and its associated protocols, advising the UK government and contributing to discussion among scientists, communities and policymakers to maximise access to and use of physical and digital materials.

Understanding plant and fungal traits can aid conservation and lead to benefits for human health and well-being.

The skeletal forms of dead or dying ash trees (*Fraxinus excelsior*) stand out in a woodland affected by the ash dieback fungus (*Hymenoscyphus fraxineus*) in Sussex, UK. Some trees appear to remain healthy despite the epidemic, which fits with evidence generated by RBG Kew scientists that heritable resistance exists.

Initiative 2.1: Adaptation and Resilience

Aim: To understand and utilise plant and fungal traits to increase resilience

Rapid adaptation is needed to protect and enhance natural and human systems in a changing world. This Initiative will provide a fundamental understanding of how plants and fungi evolve to overcome physical, environmental and biological challenges, especially those due to climate change and infectious diseases. We will explore variation in the genomes, morphology, physiology and chemistry of plants and fungi, as well as the diversity and characteristics of plant microbiomes (their associated suite of microorganisms, which include fungi). This information will provide insights into how different species adapt and survive in different environments. We will also examine how these factors influence the evolution and distribution of biodiversity and how they affect resilience to change.

This knowledge will be used to detect and predict adaptation and to recommend interventions to enhance resilience in a variety of environments, from natural and semi-natural habitats to landscapes heavily impacted by humans. We will generate and apply big data to genomic prediction and the discovery of the genetic basis of traits. Expansion of RBG Kew's C-values database containing the largest compilation of genome size data for plants will allow novel exploration of how genome size impacts the ability of species to adapt, while comparative evolutionary approaches will be used to predict the presence of advantageous traits as well as future pest and pathogen risks.

Through increased understanding, we will develop, model and test approaches to enable and accelerate adaptation to stress through actions such as climate-smart seed selection (selecting seeds that will respond to predicted changes in climate), microbiome manipulation (selecting advantageous microorganisms), and introducing adaptive diversity into species and populations through selective breeding or the translocation of plants from one area to another. In addition, novel methodologies will be applied for cost-effective monitoring of adaptation using DNA sequencing. New growth facilities at Wakehurst will support experimental modification of environments to enhance understanding of adaptation. We will work in partnership with Defra to deliver the new 'Centre for Forest Protection' together with Forest Research, within which RBG Kew will apply the approaches developed in this Initiative to UK tree and woodland health.

Deliverables:

- **Transformative growth facilities and research.** We are actively seeking funding to build the Wakehurst Conservation and Research Nursery, which will include over 750 m^2 of new controlled growing environments. This will allow the cultivation of plants for enhancing conservation programmes, and enable key experiments to determine adaptation and resilience potential under different environmental scenarios.

- **Accurate predictions of adaptation potential in diverse plant and fungal systems based on genomic and trait data.** These will include genome–environment association analyses (with a special focus on enset – a tropical herb in the banana family – and northern European oaks); and the generation of genome size data for over 90 per cent of the UK native flora, to unlock the role of genome size diversity as a driving force in influencing the adaptive potential of species. We will also use genomic data to accurately predict fungal–plant interactions across different landscapes.

- **Recommended interventions to accelerate adaptation to climate change and infectious diseases.** This will include planting recommendations for subsistence farmers in the southern highlands of Ethiopia and woodland creators in the UK.

Initiative 2.2: Biointeractions and Bioactive Molecules

Aim: To explore biological interactions and bioactive molecules to unlock useful properties in plants and fungi

The interaction of plants and fungi with other beneficial and antagonistic organisms – such as pollinators, herbivores, disease agents and mycorrhizal fungi – is a main driver of biological and chemical processes that mediate defence, attraction, adaptation and diversification. This Initiative will explore this biological interface to reveal the bioactive molecules and mechanisms that underpin these processes and modify these interactions. This Initiative will also uncover how interactions between the different kingdoms of life influence processes of speciation and diversification, which will inform conservation strategies at the community/habitat level.

In addition, we will investigate the molecular basis of useful traits, combining the power of phylogenetic prediction, genomics, chemistry and AI to identify bioactive molecules with potential to enhance human health, livelihoods and well-being. By understanding the molecular basis and evolutionary patterns of useful properties, this Initiative will unlock the potential of plants and fungi for the development of nature-based solutions with environmental and societal benefits: from food and medicines to enhanced ecosystem services and landscapes.

We will also endeavour to unlock the market potential of useful plant and fungal traits by collaborating with businesses to help them develop sustainable and ethical products, especially those that support biodiversity conservation or deliver livelihood benefits and opportunities in low- and middle-income countries. These include environmentally benign inputs and interventions in agriculture, and nature-based healthcare products.

Deliverables:

- **Information on the composition, function, evolution and impact of fungal microbiomes.** This will include screening the diversity of fungal microbiomes in seeds that have been collected in the wild (e.g., from crop relatives and conifer species) to assess the risk of introducing new diseases or, conversely, the potential benefits to plant health. These data will enable the design of effective mitigation strategies and contribute towards future-proofing plant health.

- **Identification of the chemical benefits of pollen and nectar for pollinator health.** This will include analysing pollen compounds from across the 200 most important plants for pollinators in the UK, uncovering the link between the diversity of sterol compounds in their pollen and the degree of specialisation by bees on the different food plants. We will also identify and quantify which pollen sterols are required by wild bees, and estimate the capacity of the landscape to support different bee species.

- **Increased understanding of the functioning of traits with the potential to enhance human health and livelihoods.** This will include using predictive approaches and RBG Kew's extensive knowledge of plant evolutionary relationships to accelerate the discovery of potential new medicines, and to provide new insights into dietary plants that contain bioactive molecules relevant to reducing cognitive decline in ageing or dementia.

Initiative 2.3: Enhancing Survival

Aim: To discover key survival traits for plant and fungal preservation and sustainable use

A crucial human contribution to the survival of our planet is the successful protection of plants (mainly through seeds) and fungi in biobanks, so they can be used as assets for nature-based solutions and the restoration of threatened species and habitats. Biobanked material also provides a key resource to enable the discovery of new traits and properties of value to humans and the environment. Yet, to ensure effective preservation, deep understanding of how plants and fungi protect themselves from environmental stresses is required.

This Initiative will undertake multidisciplinary research to discover and understand the key genomic, chemical, morphological and structural traits of diverse plant and fungal tissues (e.g., seeds, spores, plant embryos) that impact their reproduction (e.g., seed dormancy and germination), lifespan, persistence and hence survival under different environmental stresses (e.g., temperature, moisture, oxygen).

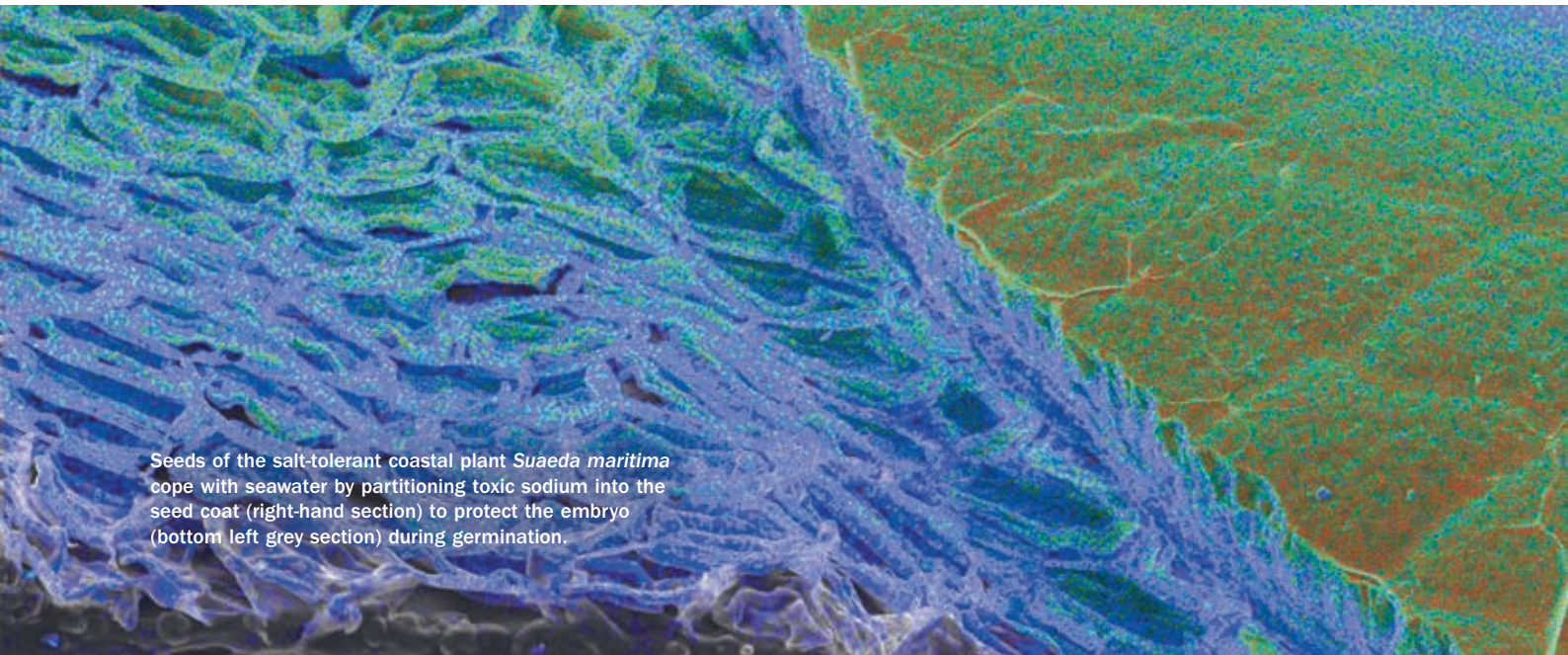
This work will be enhanced through the delivery of a new state-of-the-art facility, the Kew Cryosphere, which will significantly extend the ability to save threatened plant and fungal species and hence reduce biodiversity loss. The work will take a global partnerships approach, closely linked to our Science Collections and conservation and commercial partnerships, to maximise end-user engagement. The research findings will be communicated through training courses for the next generation of scientists and practitioners and will inform future conservation and seed-use strategies, including for species that are not suitable for standard seed-banking approaches and neglected and underutilised crop and crop wild relative species.

Deliverables:

- **Increased understanding of low temperature stress tolerance of cells and tissues to enhance *ex situ* conservation.** This will guide the delivery of successful *ex situ* storage of plants and fungi and will include recalcitrant-seeded species (those that cannot withstand the drying and freezing process used for standard seed banking). The research outputs will be enabled through the design and resourcing for a 200-m^2 high-tech laboratory for research, training and biobanking – the Kew Cryosphere.

- **Increased understanding of oxygen, temperature and moisture stress tolerance for seed storage and use.** This will lead to improved conditions for seed storage and use in the agricultural trade and elsewhere. Predictive models to establish the environmental limits of seeds for storage and growth will be developed and validated for hundreds of species.

- **The first Global Seed Information Facility on seed traits.** This will be a research resource and serve a range of end-users in horticulture, agriculture, forestry, conservation and sustainable use. The multidimensional facility, incorporating information on chemical, physiological, physical, biophysical and microbiome traits, will be co-designed and co-delivered with the international seeds community, including the Crop Trust, Organisation for Economic Co-operation and Development and the International Society for Seed Science.



Seeds of the salt-tolerant coastal plant *Suaeda maritima* cope with seawater by partitioning toxic sodium into the seed coat (right-hand section) to protect the embryo (bottom left grey section) during germination.

Initiative 2.4: Sustainable Agriculture

Aim: To identify and utilise traits to develop crops for sustainable agriculture

Agriculture is essential for human existence but faces considerable challenges, particularly in an era of accelerated climate change and increasing pressure on land due to the growing global population. Conversely, agriculture is a major cause of greenhouse gas emissions, environmental pollution, and biodiversity loss, which also needs to be addressed. This Initiative will combine innovative research with RBG Kew's expert knowledge on plant and fungal diversity and data from our extensive collections.

In collaboration with partners around the world, we will fast-track the identification of beneficial crop traits, such as environmental stress resilience, high yield, high nutritional value (for human and animal health), and pest and disease resistance. We will investigate the presence and potential of these traits in major and minor crop species, crop wild relatives and other useful plants. In turn, this knowledge will be applied to provide key benefits to society, such as in sustainable food production, climate change adaptation, and biodiversity and ecosystem conservation.

Genomic approaches, coupled with chemistry, anatomy, physiology, climatology and agronomy research, will be used to investigate the specific properties, mechanisms and function of plant traits relevant to agriculture, across species and populations. For example, the use of genomic tools will enable the identification of candidate genes for water use efficiency (reducing the need for watering), nitrogen use efficiency (reducing the need for fertiliser), and heat stress resilience (allowing plants to be grown at higher temperatures). Other genomic approaches will be applied to identify signatures of local adaptation to particular conditions, and to recommend future crops and agricultural strategies in an era of climate change and other pressing global challenges.

Deliverables:

- **Identification of useful plant and fungal traits for crop plant development and sustainable agriculture.** This will include characterising climate requirements and key traits, using genomic methods and other approaches, for protein crops (field beans, soybean and other legumes), cereals (wheat, rice etc.) and beverages (coffee, tea). The work will also include the search for candidate genes for water use efficiency, drought resilience and heat stress.

- **Increased understanding of the underlying mechanisms and functions of useful traits.** This will include understanding the functioning of traits that are pertinent to the success of crop plant development and sustainable agriculture in a changing environment. Study species will include soybean, wheat, rice, selected crop wild relatives and candidates for neo-domestication (contemporary domestication of species not previously used in agriculture).

- **Dissemination of crop plant and trait data to drive decision- and policymaking for the benefit of biodiversity.** We will generate data and case studies demonstrating the critical value of biodiversity, to drive coherent and meaningful conservation action and policy change. Examples include national assessments of coffee natural capital (wild species diversity) in Africa for protected area conservation, and the identification of focal species and landscapes for the conservation of crop wild relatives and neo-domesticates, both *in situ* and *ex situ*.

Lowland heathland in Lower Saxony, Germany.

CASE STUDY:
The hidden health benefits of heathlands for bumble bees

Pollination services of bumble bees support crop production and natural habitats, but there is increasing concern about population declines in many species. Among the multiple pressures facing bumble bees are diseases and parasites, which can have direct impacts at individual, population and community levels but can also exacerbate the effects of other stressors. Ling heather (*Calluna vulgaris*) nectar is an abundant food source for bumble bees in the UK. Our recent work on the chemistry of this species shows that heather nectar also contains a natural medicinal compound, **callunene**, which is bioactive against a widespread bumble bee parasite, *Crithidia bombi*. At ecologically relevant concentrations, callunene dramatically reduces infection, and its presence in the landscape could help bumble bees manage their parasite load and optimise pollination services. Heather is a common flower of heathlands, but this habitat is in serious decline in the UK. The loss of our heathlands therefore reduces the potential for heather to lessen the detrimental effects of parasites on the health of the UK's bumble bees. By understanding the wider value of floral resources in the landscape, we can prioritise conservation targets to maintain efficient pollination services.

***Bombus terrestris* feeding on *Calluna vulgaris*.**

Priority 3: Digital Revolution

X-ray of *Harpagophytum* (devil's claw) fruit with seeds inside.

Priority 3: Digital Revolution

RBG Kew holds a globally unique, substantial and growing collection of fungal and plant specimens, illustrations, data, databases, scientific literature, and archives of unpublished material, the legacy of more than 260 years of plant and fungal science. Yet our collections still hold vast quantities of uncaptured data from physical specimens (including DNA and biomolecules) and their labels, and from our archive collections and information on illustrations. Combined with other information (on taxonomy, traits, geographic distribution, and use), these data provide a deep reserve of information and implicit knowledge for the generation of scientific hypotheses in biodiversity and conservation research.

RBG Kew already plays a leading role in maintaining resources in which information about plants and fungi is assembled, curated and disseminated. The large-scale digitisation of our major collections and their integration with these resources will release this information, helped by new innovative online tools for data retrieval, analysis and visualisation. This digital revolution will facilitate more efficient curation and management of data and specimens, while increasing the global value and use of the collections by scientists and the wider public. Digitisation and digital innovation will allow virtual repatriation of images and data to countries of origin, while unleashing new opportunities for large-scale data mining and analysis for scientific discovery and innovation.

Our vision:

We will **innovate** by producing, synthesising and distributing fungal and plant data, to unlock the vast resource of information held within our collections and advance global research on the causes of biodiversity loss and factors conferring resilience. To achieve this, we will put the digitisation of our collections at the heart of our science, aggregate our digital assets and integrate our data with the most up-to-date plant and fungal evolutionary trees and networks of life.

We will **inspire** millions of people to learn more about the wonders and benefits of the natural world through interaction with our digital resources. To achieve this, we will make our research, data and publications open, communicate fungal and plant knowledge on diverse online platforms, and integrate citizen science and machine learning methods into the collection, translation and analysis of specimen data.

We will **influence** and be influenced, leading by example in the dissemination of biodiversity data in globally agreed formats. We will encourage the sharing of data sets for mutual benefit and coordination of efforts, working towards common digital outputs. To achieve this, we will participate in multilateral partnerships for data synthesis in fungal and plant diversity knowledge, developing global standards and protocols to facilitate the interchange of biodiversity data, reducing duplication of effort and encouraging the exchange of data for mutual benefit. We will engage with the users of our data both to widen awareness of the economic and social value of biodiversity and to gather evidence of the impact of the information we distribute.

Through digitisation, RBG Kew's collections and expertise can underpin and enhance biodiversity research worldwide.

We will image and database our 7 million herbarium specimens, as part of our freely available resource of plant and fungal information.

Initiative 3.1: Digitisation of RBG Kew's Collections

Aim: To transform our Science Collections into a global online resource

We will digitise RBG Kew's 8.5 million plant and fungal specimens, along with targeted complementary material from among our 200,000 illustrations, 7 million archival documents and 300,000 printed items. We will create a complete catalogue of the collections, making specimen records and images freely available online and accessible to researchers across the globe. The result will be a unique, world-leading resource providing access to our internationally significant plant and fungal collections. It will open up data (images, taxonomic classification and information about collecting events) from more than 260 years of scientific exploration, placing them at the centre of efforts to combat urgent global challenges such as habitat degradation and climate change.

Increased digitisation will allow us to contextualise our collections, anchoring them in time and space, and to facilitate changes in how the collections are curated and used. Our well-curated records will serve as a gold standard for the development of machine learning algorithms, and will reveal, for example, new links between morphology and occurrence, while facilitating automated approaches for the rapid definition of new taxa and identification of plants and fungi in the field.

Digitisation will enhance both the management and curation of our collections, and we will develop new 'digital first' workflows, ensuring that all new collection objects have a digital record on arrival and increasing the amount of curation that can be automated. We will sample the Herbarium and Fungarium collections for targeted DNA sequencing to help elucidate evolutionary relationships and provide clear reference sequences for type specimens. This is especially important for fungi, where morphological features are often unclear. Collectively, these changes to our working practices will ensure the sustainability of our collections while maximising their usefulness to researchers.

Deliverables:

- **Full digitisation of our major collections.** Digital records for over 7 million herbarium and 1.25 million fungarium specimens, along with targeted items from our archive and art collections, accompanied by high resolution images.
- **Molecular digitisation of our 50,000 fungal type specimens, the world's largest collection.** DNA sequencing of our fungal type specimens will allow the accurate description of the collection, provide new insights into fungal biodiversity, and provide a framework of data and methods for its future exploration. This will be the first major collection of fungal type specimens to be characterised at a molecular level.
- **Digital curation and management embedded into RBG Kew's collection management procedures.** This will include objects being 'born digital' at the point of entry to RBG Kew, with some subsequent curation occurring online. Digitisation provides the opportunity to open up curation to a broader pool of experts and enables the annotation of specimens with information gleaned through machine learning and other computational processes.

Transverse section of the leaf of a maritime pine (*Pinus pinaster*).

Initiative 3.2: Knowledge Integration

Aim: To integrate RBG Kew's plant and fungal knowledge management to facilitate its integrity, curation and use

Understanding biodiversity and the threats to its survival are central to tackling the biodiversity and climate crises, but much of the information describing it is highly fragmented and dispersed. This is also true within RBG Kew, where, in addition to information about our collections, we hold publications, images and databases containing information on the taxonomy, traits, distribution, phylogeny, DNA and conservation of species. The stewardship and dissemination of this information will be enhanced by new systems for data management integration and increased interoperability between our data and complementary resources worldwide.

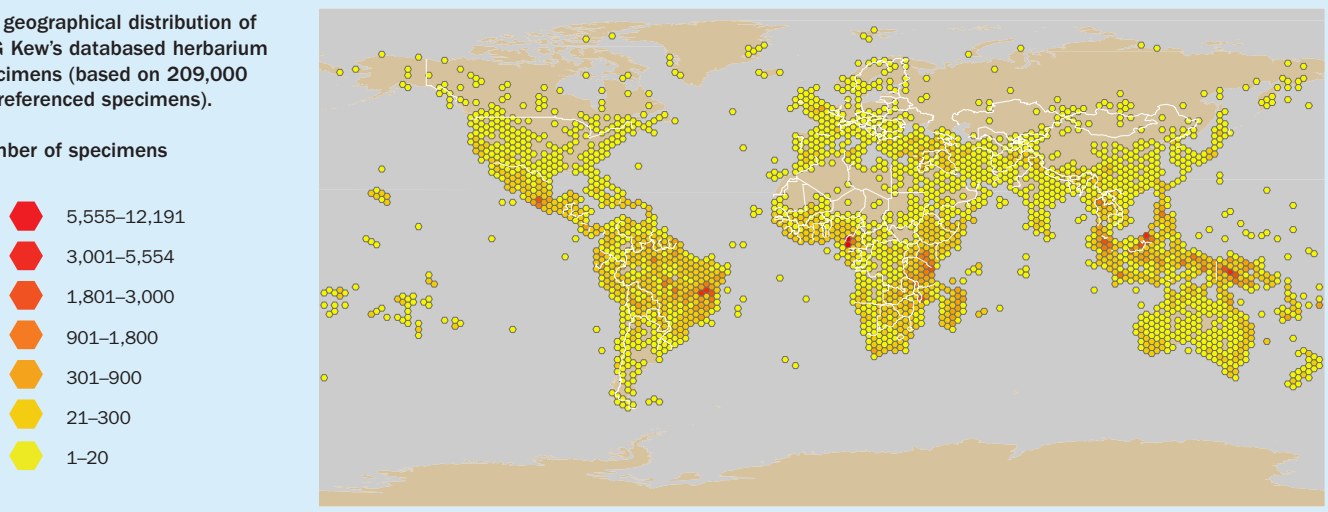
We will modernise and transform our internal systems for data management, bringing all our collections data into a single database. This will improve the efficiency of data curation and allow the tracking of material at the level of individual specimens or collection events. The curation of names and taxonomy is fundamental to this endeavour Our new systems will support the consistent and correct description of the specimens in our collections and in publications. We will work with other taxonomic authorities and experts worldwide towards the common goal of establishing an unambiguous species list for all life on Earth.

We will evaluate our data and assess our holdings in a global context, while monitoring our progress towards digitisation, deployment and use. We will use and contribute to the development of shared data standards through international standards organisations. We will engage a broader community of citizen and professional scientists to contribute knowledge and expertise, and to get credit for doing so, and facilitate the integrated use of our data in global efforts to synthesise knowledge for all life.

Deliverables:

- **Publication of an enhanced World Checklist of Vascular Plants comprising taxonomy and geography.** Coordinated by RBG Kew, this is a global consensus of all known vascular plant species (flowering plants, conifers, ferns, clubmosses and firmosses), to which we will add associated information on their geographic distributions.
- **RBG Kew's name and taxonomic data incorporated into global systems for species naming and taxonomy.** These include the Catalogue of Life, the World Flora Online and the Global Biodiversity Information Facility (GBIF). We will roll out a new system for self-registration of plant names in support of the *International Code of Nomenclature for Algae, Fungi and Plants*. We will also work with our collaborators to provide a global political and technical framework for the integration of diverse expertise and the update of reference data.
- **A single integrated collection management system linking all our data.** The data will be made available within and beyond RBG Kew through standardised data releases and programmatic interfaces. Material will be traceable on its journey from the site of harvest through different collections (e.g., seed, living plant, herbarium voucher, DNA) and linked to relevant metadata at each stage.

The geographical distribution of RBG Kew's databased herbarium specimens (based on 209,000 georeferenced specimens).



Initiative 3.3: Knowledge Sharing

Aim: To deliver plant and fungal knowledge and the tools for its applied use in research, conservation and innovation

RBG Kew's core information resources (such as our names and taxonomy resources, the Medicinal Plant Names Services, and Plants of the World Online) play a central role in addressing a broad range of environmental, regulatory and conservation issues. But technologies such as remote sensing and DNA sequencing are rapidly expanding the volume and precision of the information available globally to measure and model the environment. The challenge now facing us is to deliver our data in a full environmental context at speed and scale, such that a global community of professional researchers, citizen scientists and regulators can contribute to, learn from and use RBG Kew's knowledge and expertise.

We will create a new portal, bringing together our collections with image, taxonomic, trait and geographic data about all species of plants and fungi, integrating our own knowledge with data produced elsewhere. We will partner with organisations and research communities that develop policy, lead global conservation initiatives or catalogue and regulate how plants and fungi are used by humans, and design our services around critical needs.

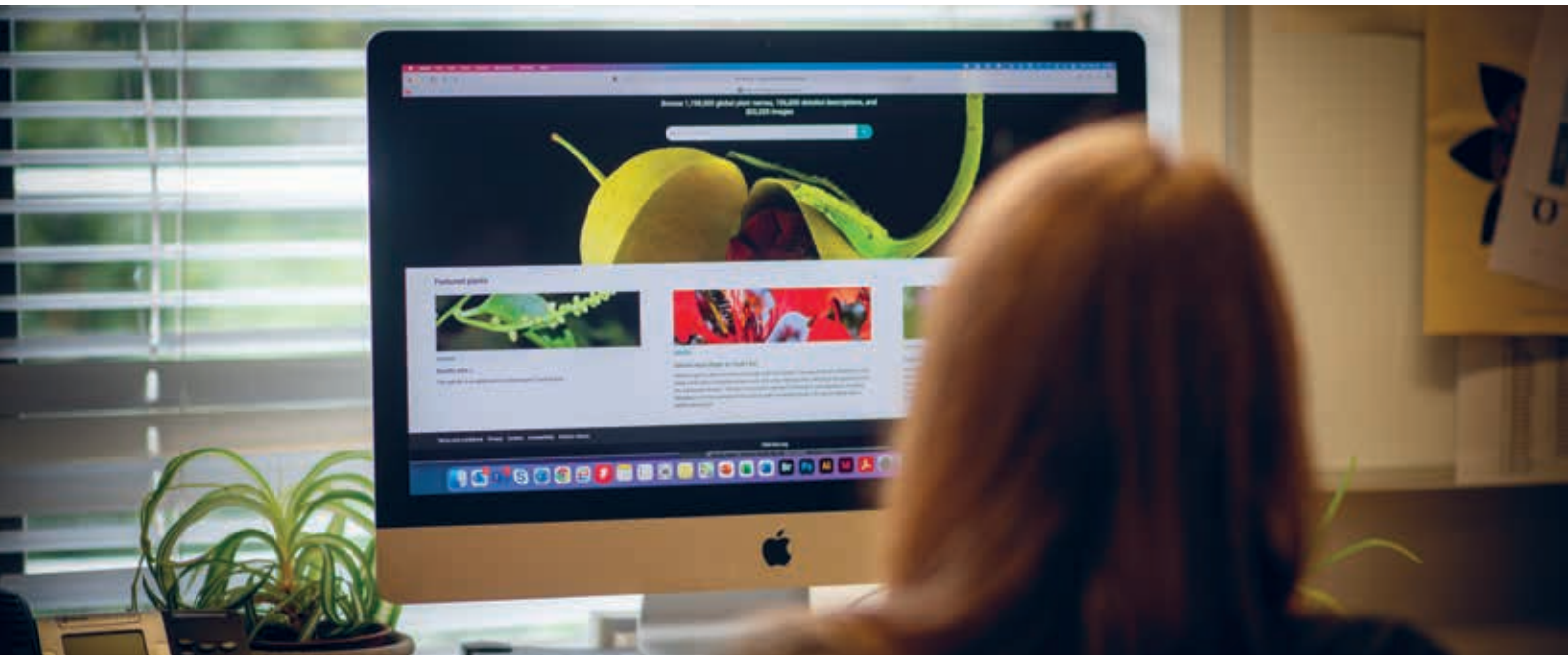
We will enable novel research and enhance the quality of decision-making in multiple disciplines by making our scientifically rigorous data accessible through well-designed digital channels. We will ensure that our data are findable, accessible, reusable and interoperable, to empower researchers and drive knowledge discovery. We will help develop, and use, standard formats for data description, provide programmatic interfaces to all our data, and deploy analysis software to facilitate its use. We will collaborate with other organisations that also manage information about plants and fungi to build a truly global information resource.

Deliverables:

- **A central information portal for use by the global research and conservation communities.** The portal will provide direct access to RBG Kew's botanical and mycological knowledge and will build on and be integrated with the World Checklist of Vascular Plants, Species Fungorum and the integrated names and collections data. It will describe 400,000 taxa, containing 1.6 million scientific names, and provide access to all our digitised images and taxon descriptions.

- **A 'Plants for Health' portal and data service.** This will address the needs of health regulators, practitioners, industry and research, with information on 0.25 million health and nutritional products derived from c. 50,000 plants and fungi. Incorrect or ambiguous terminology will be corrected and clarified prior to inclusion in the resource, enhancing the scientific rigour of health regulation and practice and enabling novel research. An interdisciplinary network of institutions (in food and medicines regulation, nutrition, patents, sustainable development and scientific publishing) will enrich, deploy and sustain this Initiative.

- **Analysis tools, data distributions and programmatic interfaces.** These will allow researchers from a broad range of disciplines to add to and infer from a global knowledge base, dynamically interlinking RBG Kew's reference information with authoritative data on species occurrences, soils and climate.



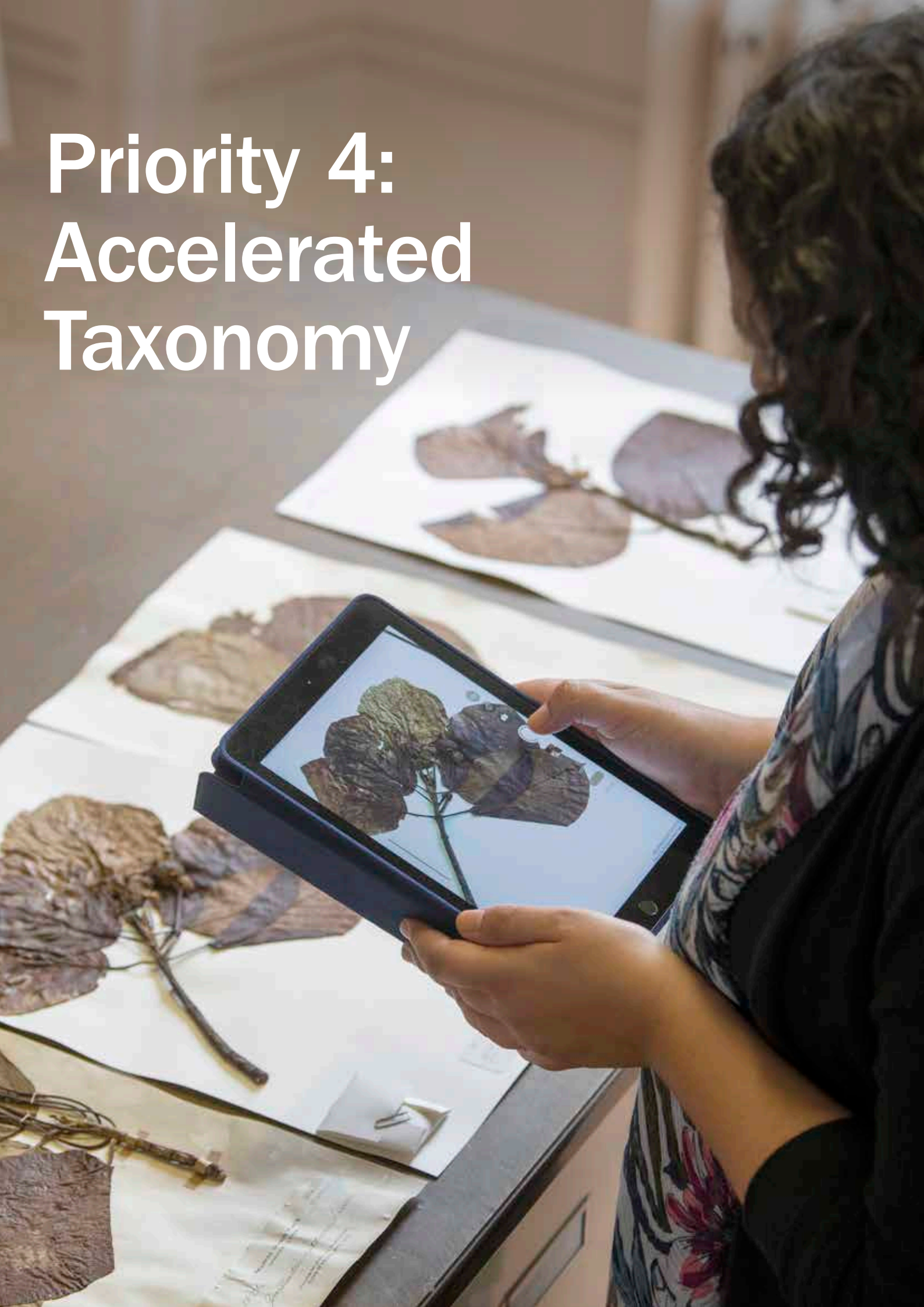
Ginkgo biloba, one of hundreds of plant species used as both medicine and food supplement.

CASE STUDY:
Plants for Health

RBG Kew's Medicinal Plant Names Services (MPNS) has catalogued plant-based medicinal products (regulated drugs, traditional remedies and plants used by indigenous and rural communities) and the c. 33,000 plants from which they derive. Globally, across many disciplines, over 0.6 million names are used imprecisely, ambiguously and inconsistently for both plants and their products. MPNS has mapped these names to RBG Kew's authoritative plant names resources – the International Plant Names Index and World Checklist of Vascular Plants – enabling regulators, scientists, health practitioners and patients to find information and navigate regulations and research reliably. MPNS is the global 'standard'. It supports global health regulation (e.g., International Organization for Standardization, World Health Organization, United States Food and Drug Administration) by enhancing the data integrity and interoperability of these agencies. It enables novel research (e.g., understanding the distribution of medicinal species across the tree of life and analysis of their conservation) while enhancing protection of traditional knowledge and the efficacy of plant patents. In the next five years, we will expand MPNS into 'Plants for Health', an enhanced resource covering food supplements, allergens, cosmetics and medicines, supporting the correct use and regulation of plants used for these purposes.

Selecting safe and appropriate health products is challenging, partly because of the ambiguous and inconsistent labelling in use. Plants for Health addresses this by deploying RBG Kew's botanical terminologies to validate and harmonise the names of thousands of plants and plant products employed by regulators, health practitioners, manufacturers and researchers.

Priority 4: Accelerated Taxonomy



Priority 4: Accelerated Taxonomy

Taxonomy is the science of naming, identifying and classifying living organisms. It is the bedrock for the scientific study of life: any research involving living organisms needs a taxonomic point of reference. Taxonomy has been the backbone of RBG Kew's scientific research throughout our history, and our collections and taxonomic experts are essential to the processes of describing and conserving biodiversity. Drawing on increased data availability and new tools and technologies, including phylogenomics and machine learning, we will push the frontiers of taxonomic research to accelerate the characterisation and identification of species in near real-time.

We will also develop methods for speeding up the discovery of hidden diversity in natural history collections. In delivering the aims of this Priority, our focus will be on taxonomic groups and regions where progress is most needed, and our outputs will include detailed taxonomic publications, online tools, and other resources tailored to the specific needs of our stakeholders.

Our vision:

We will **innovate** in the identification, naming and classification of fungi and plants, accelerating the description and understanding of the world's biodiversity. To achieve this, we will lead a paradigm shift in taxonomy to embrace machine learning, trait research (including genomic, chemical, morphological and ecological) and citizen science. Our activities will be guided by our expertise and collections in key families, our knowledge of conservation threats, and a consideration of socio-economic benefits. Working in collaboration with our global partners, we will identify key taxonomic gaps, and apply and develop new approaches to refine our knowledge of the plant and fungal trees of life at scale and speed.

We will train a new generation of students and professionals and **inspire** them to dedicate their careers to biodiversity studies in the context of a changing world, focusing on a solutions-oriented approach. To achieve this, we will deliver modern taxonomic training focused on transferable skills, integrative techniques and expertise in the fields of highest value to employers. Going beyond the fundamental science, we will showcase the relevance of taxonomy to agriculture, industry and people's lives.

We will **influence** funding bodies, governments, companies and research organisations around the world to take an informed approach to the conservation, management and use of biodiversity. To achieve this, we will conduct and share evidence-based analyses and highlight the importance of the inventory, description and monitoring of biodiversity. Working with our key stakeholders, we will demonstrate how taxonomic knowledge on selected taxa and geographical regions can inform decisions to be taken under a responsible Ecosystem Stewardship model (Priority 1), providing benefits across science and society.

Our collections and taxonomic experts are essential to accelerating the description and conservation of biodiversity.

Initiative 4.1: Documenting Biodiversity

Aim: To accelerate the description, naming and classification of plants and fungi

It is estimated that at least 20 per cent of plant species and over 95 per cent of fungal species remain unknown to science, and documenting this undescribed diversity is crucial. Without a name, it is difficult to share knowledge and impossible to assess extinction risk, design conservation measures, or explore the potential a species might hold. As part of this Initiative, we will work to speed up the analytical process – the 'pipeline' – from unnamed species to DNA-based taxonomic classification, and we will ensure the results are readily available to the widest possible audience.

We will identify opportunities for efficiencies in specimen data handling, and embed a 'DNA first' approach in plant and fungal taxonomy to identify and classify specimens. We will also develop a 'modular monograph' process, whereby comprehensive systematic publications called monographs – the gold standard in the classification and description of biodiversity – are completed by assembling component datasets for maximum efficiency and flexibility (modules include taxonomy, phylogenetics, nomenclature, traits, photographs and botanical illustration). We will work with our scientific partners to produce taxonomic outputs such as identification keys, checklists and inventories where biodiversity is most threatened, building on our exceptional collections and taxonomic expertise to accelerate progress.

Analysis of the coverage of plant genera at RBG Kew and other herbaria will be used to prioritise collecting activities. For fungi, we will focus on increasing knowledge and collections from our focal systematic groups and regions, including the UK. We will produce open, accessible taxonomic outputs for the varied audiences who depend on taxonomy.

Deliverables:

- **Taxonomic triage: a global gap analysis of herbarium collections to inform future collecting efforts.** This will enable us to complement existing specimen coverage and fill knowledge gaps, recognising the potential for jointly curated meta-collections across the global collections network. It will focus our collecting and taxonomy partnerships on the most at-risk systematic groups, as well as plants and fungi with useful properties and adaptations.

- **Geographic prioritisation: documentation and description of plants and fungi in regions of exceptional biodiversity.** These will include Important Plant Areas – encompassing the RBG Kew-led Tropical Important Plant Areas programme – and other areas where high biodiversity and threats coincide. We will focus on priority countries such as Bolivia, Indonesian New Guinea and Cameroon, where we are working with our local scientific partners to document their natural resources.

- **A new taxonomic pipeline to speed up the description of plant and fungal diversity.** This will allow us to progress specimens from the status of potential new species to fully named and described species more quickly. It will involve a 'DNA first' classification approach to rapidly and accurately place unidentified specimens on the tree of life, followed by open, accessible outputs (such as checklists, monographs, and other resources), with British fungi and selected plant groups as case studies.

The deserts of southern Africa are exceptionally rich in unique biodiversity. We are working with partners to name, classify and study these remarkable floras.

We will collaborate with partners to document and describe plants and fungi in the most diverse regions and where the threat of extinction is greatest.

Initiative 4.2: The Tree of Life

Aim: To expand and populate the tree of life for plants and fungi

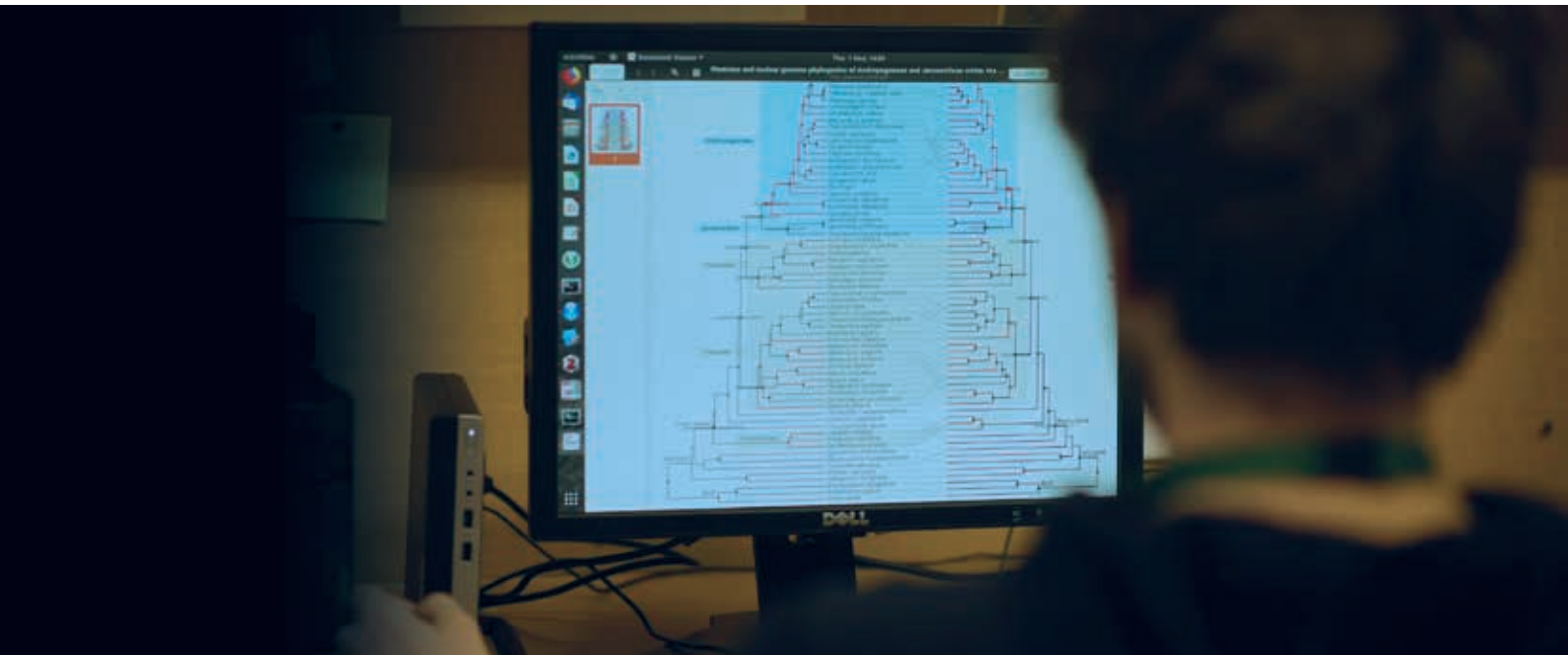
The tree of life is the fundamental biological roadmap for navigating the evolution and properties of life on Earth, and yet the details of its branches remain largely unresolved. Most of the fungal tree is unmapped and even the flowering plant tree is fraught with data gaps, despite the critical role these groups play in sustaining ecosystems. This Initiative will build on the successes of the RBG Kew-led Plant and Fungal Trees of Life (PAFTOL) project to deliver a further step change in our knowledge. It will equip us with the tools to accelerate efforts to document, identify and classify life on Earth, to explore its useful properties, to understand its origins and evolution, and to predict how species will respond to future environmental change.

High-throughput DNA sequencing has already significantly deepened our understanding of evolutionary relationships, yet has the potential to accelerate it further. RBG Kew has a proven track record of leadership in tree of life research based on the DNA sequencing of our collections, such as the Fungarium and Herbarium collections, Living Collections, Millennium Seed Bank samples and even ancient archaeological artefacts. We aim to intensify these efforts to accelerate our taxonomic and monographic work, to expedite species description by rapid phylogenetic placement, and to provide the essential comparative framework for evolutionary and applied research, such as phylogenetic prospecting for biomolecules.

We will dive deeper into focal lineages, such as threatened and species-rich groups from priority regions, and crop wild relatives. Our DNA sequence data and plant and fungal trees of life will be made rapidly available, following an open data approach within an innovative and dynamic online setting.

Deliverables:

- **A complete tree of life for both plants and fungi at the genus level.** This will include all 14,000 angiosperm genera and 50 per cent of the 8,000 fungal genera, using RBG Kew's unrivalled collections. It will be achieved in collaboration with our partners around the world and will serve as a global phylogenetic backbone for comparative research at any taxonomic scale.
- **The application of analytical tools to the tree of life, for research on taxonomy, evolutionary biology, trait discovery and ecosystem stewardship.** We will use the tree of life to resolve taxonomic uncertainties, understand evolutionary histories and predict traits of interest in our priority groups (e.g., palms, orchids, grasses, legumes, tropical myrtles, succulent plants, and selected groups of macrofungi and lichens).
- **A dynamic, integrative tree of life digital platform.** This will provide open and innovative delivery of the most up-to-date view of the tree of life for plants and fungi. Anyone with an internet connection will be able to view, search and download the tree of life and the sequence data we generate.



Initiative 4.3: Innovating Species Identification

Aim: To develop and implement new identification tools for recognising species

Accurate species identifications are essential for biodiversity to be explored, studied and conserved for the future. This Initiative will transform how our collections and those around the world (including herbarium, seed and living specimens) are used to identify plants and fungi. New technologies will be harnessed to accelerate and democratise the identification of plants and fungi growing in their natural habitats, or in RBG Kew's specimen collections, and in trade or other contexts in which only fragments of material are available.

We will develop automated specimen identification systems, simultaneously facilitating curation and research in our collections, by applying our taxonomic expertise to improve the accuracy of algorithms trained to recognise specimens. The sequencing of all fungal type specimens as part of Priority 3 (Digital Revolution) will set the foundation for unambiguous fungal identification, providing a baseline for detecting species new to science.

Reference DNA sequence datasets for species in selected plant groups will be developed for confident identification and authentication of plant material, which are important resources for the enforcement of laws and conventions protecting plants. We will mobilise digital datasets to facilitate identification of plants and fungi in the field, focusing on the regions of high biodiversity and threat identified with our scientific partners.

Deliverables:

- **Accelerated specimen-naming workflows with automated identification of specimens.** Using our collections and expertise, we will introduce machine learning for the identification of digitised plant specimens, and 'DNA first' approaches for fungal specimens – using DNA sequence data to determine where they sit in the tree of life. This will greatly reduce the time needed to accurately name specimens arriving in our collections and determine whether any are new to science.

- **Curated specialist reference datasets of DNA sequences for selected groups of plants and fungi.** These will include Kew's taxonomic specialist groups as well as plants in trade and type specimens of fungi. This will facilitate the molecular identification of unknown specimens – useful for the fundamental description of plant and fungal diversity but also with important applications in areas such as the enforcement of CITES. We will test different DNA sequencing approaches (e.g., Angiosperms353, customised target capture) to bring new tools and reliability to the identification process for commodities such as rattans and aloes, which are often illegally traded.

- **Enhanced plant and fungal identification for field-based inventories.** We will share the variety of datasets and information resources from RBG Kew's collections to support the naming of plants and fungi, with the ambition to develop apps for specialists to identify species in the field from texts and photographs assembled from our collections.

Agrisystems in Ibity, central Madagascar, are centred around rice cultivation, with numerous other crops grown alongside rice in small plots.

CASE STUDY:
How grass taxonomy can help build smallholder food production resilience in Madagascar

Weedy grasses have the potential to impact food security, livestock and agrisystems, and require accurate species identification to be managed. *Digitaria* grasses in Madagascar damage crops and reduce yields. They are difficult to control because they look confusingly similar to one another and are hard to eradicate by manual removal. RBG Kew scientists are working with partners at the University of Antananarivo, Madagascar's National Center for Applied Research on Rural Development, and communities in Ambihidray, Ibity, and Itremo to understand the origins of *Digitaria*, upgrade its classification and enable smallholders to better manage *Digitaria* grasses in their agrisystems. DNA barcodes will allow species to be identified when plants are not in flower outside the wet season. This is the first time DNA barcode identification will be used for Malagasy agriculture. These new identification methods will ensure the most appropriate weed control can be applied without compromising the growth of the nutritious species that are suitable for grazing.

Digitaria ciliaris **(right) is an annual weedy plant, while** ***Digitaria longiflora*** **(left) is a resilient stoloniferous perennial that persists in burned fields.**

Priority 5: Enhanced Partnerships

Priority 5: Enhanced Partnerships

The aims outlined throughout this strategy are ambitious, and we cannot achieve them alone. Effective, structured partnerships, focusing on impactful goals, are essential to the continued success of our collecting, research and conservation activities. Our partnerships enable us to have a better understanding of the complex issues that impact biodiversity loss. They also enable us to extend our reach to the indigenous peoples and local communities that are the key custodians of biodiversity and are often the groups whose livelihoods are negatively impacted by biodiversity loss.

To build effective partnerships, we will strengthen our relationships with our UK biodiversity partners, including the Natural History Museum, Zoological Society of London and the Royal Botanic Garden, Edinburgh, along with our large network of international partners in over 100 countries worldwide. We will also build our business partnerships to demonstrate the economic importance of biodiversity. In addition, we aim to develop multidisciplinary and cross-disciplinary partnerships in the UK and across the world, strengthen education, research and commercial activities, and build on the success of the Millennium Seed Bank Partnership (MSBP). Enhanced Partnerships will weave through all of the other four Priorities to build on our current network of partners and collaborators and maximise our real-world impact.

Our vision:

We will **innovate** and build bridges across science and society to protect, sustainably use and conserve biodiversity and to find solutions to urgent global challenges. To achieve this, we will enrich our partnerships to include professionals in disciplines such as arts and humanities, environmental economics and the broader social sciences, medical and food sciences, and climatology. We will focus the MSBP on species conservation and support for habitat restoration, and we will expand our commercial and innovation activities relating to biodiversity.

We will **inspire** scientists, governments, commercial entities and non-governmental organisations to join forces in new, transdisciplinary programmes, increasing the impact of applied and fundamental science. This will be implemented through key themes of societal importance, including drug discovery and improving food security. We will also support compliance with international policy, for example through the development of robust methods that support the identification and monitoring of timber entering trade. Building on our scientific strengths and the evolving needs of society, we will continue to deliver cutting-edge training (postgraduate and professional) to a growing audience, through MSc and PhD programmes, and a combination of online, on-site and off-site courses.

We will **influence** politicians, policymakers and industry to invest in biodiversity research and infrastructure. To achieve this, we will facilitate partnerships that measure, evaluate and improve biodiversity and demonstrate the well-being and livelihood benefits of nature-based solutions, communicating our findings and engaging in best practice and policy discussions. Joining with others we will shape public debates and be a credible voice internationally.

Diverse partnerships maximise scientific excellence, understanding and real-world impact.

Initiative 5.1: Interdisciplinary Research

Aim: To extend our reach and impact in science and public engagement through interdisciplinary research

Humans and plants are inextricably linked, whether through the use and conservation of plants, or through the role of botanic gardens such as RBG Kew as spaces for encounters with the natural world. Our long history of plant collecting further enriches and complicates the story.

The arts, humanities and social sciences offer powerful tools to study the human element of biodiversity and to engage with people, through research questions, methodologies, language, and communities of practice. They can address some of the most pressing questions facing RBG Kew: how to integrate support for biodiversity and human well-being; understanding links between cultural and biological diversity; how to achieve impact at diverse levels including community and government; how to deliver access to and new understandings of RBG Kew's collections; and how to broaden our reach, both within and outside the gardens.

This Initiative builds on a successful ongoing programme of research and collaboration that has already demonstrated our capacity to make a distinctive, high-quality contribution in this area. We will further develop our research to closely align to the Scientific Priorities set out in this document, to new strategies relating to RBG Kew's history and heritage, and to RBG Kew's extensive public engagement programme. We will strengthen key partnerships, for example building on our multidisciplinary work with Royal Holloway, University of London, and develop partnerships of similar ambition with other institutions. By 2025, we aim to be internationally recognised as a leader in the embedding of interdisciplinary approaches in a botanical and mycological institute.

Deliverables:

- **New interdisciplinary partnerships.** Working closely with existing and new collaborators in the arts, humanities and social sciences, we will bring new perspectives and methods to RBG Kew's science, history, collections and public engagement. We will work with collaborators to gain significant funding for research projects and PhD students. Our new partnerships will be truly interdisciplinary, bringing together new skillsets for innovative and impactful research.

- **Establishment of a Centre for Plant Humanities.** The centre will be a focal point for interdisciplinary work, highlighting relevant work across directorates and drawing together researchers to enhance innovation and raise visibility. It will build on our vibrant research programme in the arts and humanities, drawing further on RBG Kew's history and collections, scientific research, and network of partners.

- **Interdisciplinary approaches to the conservation and use of food crop heritage.** Working with collaborators, we will use historical and ethnobotanical methods for the study of neglected food plants, supporting the conservation and use of endangered crop diversity, neglected food species and food heritage.

Researchers from the Federation of Indigenous Organizations of Rio Negro visiting our collections as part of a long-term project on the biocultural heritage of the Amazon rainforest with partners in the UK, Germany and Brazil.

Initiative 5.2: Millennium Seed Bank Partnership

Aim: To strengthen the global plant conservation network delivering solutions to biodiversity loss

We will maintain and enhance the MSBP, continuing to work across and within our partner countries and territories to inform, sustain and strengthen impacts. We will ensure no plant is beyond protection – banking seeds of rare, threatened and useful plants (among others), increasing our understanding and use of cryopreservation, maintaining our position as a world leader in seed biology and diversity research, and supporting global conservation initiatives.

Collection quality, driven by the MSBP Seed Conservation Standards, will be at the forefront of our efforts, ensuring high-quality collections and optimum storage conditions and helping partners to develop capacity in this area through sharing of knowledge and expertise. Our targets will be driven by the principles of prioritising quality and diversity within collections and supporting hypothesis-driven research. We will also increase the ease of access and use of our collections, maintain accurate and accessible seed bank records, and engage with future users of collections during project planning.

We will grow our impact in restoration, developing restoration-related expertise (e.g., identifying priority wild species, sharing propagation protocols, researching seed priming, scaling up native seed supply chains) and engaging with the restoration community. We will support partners to develop restoration-ready materials, improving understanding of the use of wild plant seeds in restoration, forestry and agriculture. We will support active restoration work in the UK, and the conservation of plant diversity worldwide, through the development of seed conservation projects that emphasise natural capital, sustainable development and improved livelihoods.

Deliverables:

- **Increased *ex situ* conservation of the world's flora.** With a focus on the UK and areas of high biodiversity and high threat, we will excel at the long-term conservation of the world's flora. We will bank 2,000 seed collections per year, and add their data to the MSBP Data Warehouse, along with data for an additional 300 seed collections held only in the country of origin. These will include multiple seed collections per species, wherever possible, to increase the genetic diversity conserved. We will also explore options for the conservation of 'exceptional' species that do not produce seed or cannot be stored under standard seed-banking conditions, and support the development of the Global Seed Information Facility (Initiative 2.3).

- **Improved restoration outcomes.** Through the mobilisation of MSBP collections, data and nursery propagation knowledge, we will help improve restoration outcomes through: i) a portal for access to global accession data on seed and other living material from wild plants, and ii) developing workflows for large-scale delivery of seed of native, threatened and important species for restoration.

- **Expanded training and technical support.** We will run annual Seed Conservation Techniques training and undertake an annual review and update of MSBP Seed Conservation Standards based on latest best practice. Standards reviews will be undertaken with all active MSB partners within a rolling five-year timeframe complete for 50 per cent of partners.

Initiative 5.3: Education and Training

Aim: To deliver world-class postgraduate education and training through partnerships

The combination of RBG Kew's extensive collections, databases, scientific expertise and global partnership network gives us a unique opportunity to play a leading role in education and training. Our current interdisciplinary programme combines taxonomy and evolutionary biology with conservation science and the evaluation and enhancement of natural capital, thus enhancing understanding of plants and fungi, the interactions between them and their relevance to human lives and livelihoods. We aim to expand this to broaden our training of the next generation of plant and fungal scientists, both in the UK and globally, and to encourage and inspire our students to meet the challenges that society faces.

We aim to further develop a comprehensive programme of university-level and professional training while ensuring fair access to our courses, delivering consistent approaches to training using the most appropriate technologies and resources, providing support for the delivery of high-quality teaching and supervision, and ensuring accessible approaches to learning across our Scientific Priorities.

We will enhance the status of RBG Kew as a postgraduate education provider, delivering biodiversity specialists that can work across disciplines and geographies to help stop the decline in global biodiversity. Working with leading universities, we will develop a Postgraduate Training Centre, delivering highly trained professionals in the fields of plant and fungal science, taxonomy, conservation and sustainability, with an emphasis on cross-disciplinary training.

Deliverables:

- **New professional training opportunities.** This will include the development of a one-year International Graduate Trainee Scheme for Kew Science, delivering six professional biodiversity specialists per year with key skills in delivering biodiversity science support.
- **Expansion of our Master's degree programme.** We will continue delivery of the MSc with Queen Mary University of London, and create additional MSc courses in partnership, training over 50 MSc graduates per year. We will also increase the reach of our courses, making them accessible to a wider and more diverse pool of students.
- **Development of RBG Kew's Doctoral Training Programmes.** We will enhance our offer to UK and overseas PhD students, expanding the delivery of key skills and training in biodiversity science through doctoral supervision, training, and access to RBG Kew's resources. Our target is for staff to be co-supervising 100 doctoral students by 2025.

Initiative 5.4: Enhancing Commercial Partnerships

Aim: To support the sustainable use of biodiversity entering trade

The Commercial Innovation Unit supports the development of innovative ideas with the potential to lead to commercial ventures that benefit societies and economies through the sustainable use of plant and fungal biodiversity. These ideas are developed through industrial and academic partnerships. They build on the extensive knowledge in plant and fungal biodiversity at RBG Kew but also tap into our global network of collaborators, so that source countries benefit from the use of their biodiversity.

Projects vary in scope, from drug development to habitat restoration. One area we specialise in is the authentication of commercially sold plants and associated plant-derived products to help companies deal with adulteration and poor-quality material entering the trade. This makes use of our extensive collections of expert-verified specimens and benefits from the diversity of disciplines that we specialise in, including taxonomy, molecular identification, natural product chemistry and evolutionary biology.

Changes in land use and aspects of climate change are impacting the supply of many products derived from plants and fungi. We can help companies to find new sources of species with particular chemistries, and to identify how they can optimise their supply chains while ensuring sustainable and ethical practices and compliance with international conventions and protocols.

Deliverables:

- **Expansion of key commercial relationships.** We will increase the diversity of companies we work with on products derived from plants and fungi to include those in different sectors, including pharmaceutical, restoration, pest control, personal healthcare and natural extract suppliers.
- **Increased diversity of plants and fungi used in products.** Through collaborations with commercial partners and with source-country suppliers, we will increase the diversity of sustainably sourced plants and fungi being used commercially in products.
- **Establishment of an innovation platform for commercial opportunities.** We will build a portfolio of biodiversity-focused projects that cut across the different science Initiatives and involve different types of partnerships through consultancy and commercially focused Research and Development. Through these partnerships, we will increase public awareness of the importance of nature, the biodiversity crisis and potential solutions.

The Millennium Seed Bank buildings at Wakehurst.

CASE STUDY:
The Millennium Seed Bank Partnership

Two in five plants are threatened with extinction, and we are losing plant diversity at a rate 500 times faster than the background extinction rate for plants. Unfortunately, many threats facing plants do not respect the borders of protected areas (e.g., climate change, pollution, invasive species), meaning conservation is required beyond natural habitats. The Millennium Seed Bank has been providing an insurance policy against extinction in the wild for over 20 years, and together with our partners we have conserved over 48,000 species through seed banking. Training is at the heart of our partnership, with more than 2,000 practitioners trained and technical support provided to over 97 countries and territories and more than 250 organisations. By protecting national floras, including threatened, useful and endemic species, we are providing a solution to the biodiversity crisis now, and options to develop solutions to other global challenges for generations to come.

48,000
species banked

2,000
practitioners trained

Seed Conservation Techniques training course at the Millennium Seed Bank, enabling partners from around the world to share their experiences.

Delivering our Scientific Priorities

Alignment and infrastructure

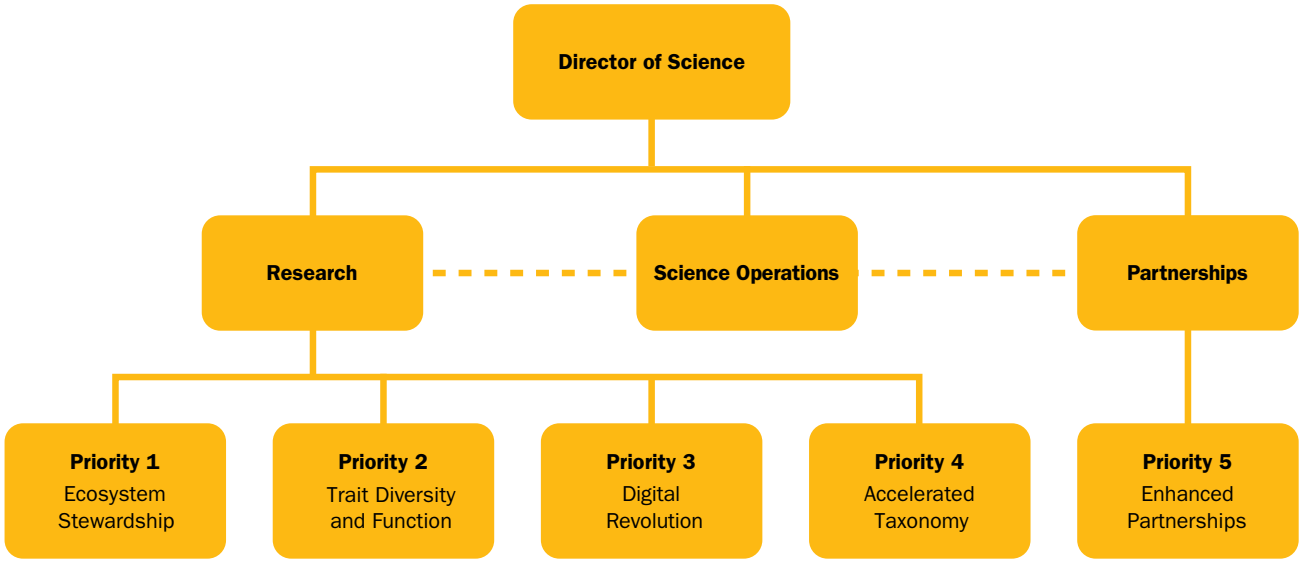
The alignment of our departmental structure to the Scientific Priorities is the optimal way to maximise delivery of our mission through scientific innovation, excellence and real-world impact.

The five Scientific Priorities will be delivered through three departments, established in the first year of the current strategy (2021): Research, Partnerships, and Science Operations. The Research department is responsible for the delivery of Priorities 1 to 4, while the Partnerships department delivers Priority 5. The Science Operations department is focused on the collections, infrastructure and services necessary to achieve the goals of the Scientific Priorities, and partner strategies such as the *Science Collections Strategy 2018–2028*. Staff contribute their expertise across Priorities, ensuring that the knowledge and experience embedded in Kew Science is used to its full potential.

Key components of the Science Operations department are Science Collections, Library and Archives, Science Services and Laboratories (See Box 1), and Kew Madagascar Conservation Centre Operations – the latter supporting our team in Madagascar, where RBG Kew has a long-term base fighting biodiversity loss in a critically threatened, megadiverse environment.

Operational priorities for the delivery of our strategy include:

- Progressing the development and funding of the Science Quarter (see Box 2).
- Streamlining and digitising the key operational processes that support RBG Kew's science, to allow effective working on and off site.
- Working towards achieving accreditation for our laboratories recognised by the International Organization for Standardization (ISO).
- Developing and implementing a new grant management system to support continued growth in RBG Kew's external research income.
- Providing new online learning and training courses in areas including health and safety, fieldwork skills, conservation policies and research grants.
- Implementing a Research Ethics Policy, including equitable approaches to language, publication, open data, authorship and plant naming.
- Establishing networks to influence national and international biodiversity policy.
- Establishing a Plant Science Ambassador Programme at Kew, bringing plants and fungi to life for young people and inspiring the next generation of scientists.



Science organisational structure at RBG Kew launched in 2021. The structure aligns with the five Strategic Priorities and our operational needs, to maximise impact and delivery.

BOX 1:

Science Services and Laboratories

High-quality, high-impact research in plant and fungal sciences requires world-class laboratory infrastructure and efficient and effective science services. Consequently, we are embarking on a programme of innovation and improvement in all RBG Kew's science services, streamlining their delivery and enabling more remote operation.

We will continue to work with key partners and networks in delivering services, including UK Research and Innovation (UKRI) for accessing research and training funding, and providing scientific advice to Defra and the Animal and Plant Health Agency (APHA) in relation to licensing activities for the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), in our role as the CITES UK Scientific Authority for Flora.

With planned new investment using dedicated science capital funding, we will enhance research capabilities through provision of new laboratory technologies and controlled growth facilities (e.g., the Wakehurst Conservation and Research Nursery) that are critical for the delivery of the Science Strategy. Each of our laboratories – molecular biology, small molecule analysis, bioimaging, and seed biology – will provide analytical solutions for all our Scientific Priorities.

Building on RBG Kew's *Sustainability Strategy*, published in 2021, we will take action to reduce the environmental impact of our laboratory operations, setting out best practices and targets for reduction in energy and water usage, usage of chemicals and materials, and waste and recycling.

BOX 2:

Science Quarter

As part of our outlook to the future, we have committed to seek investment for the infrastructure and technology needed to establish a global hub of excellence for the future of plant and fungal science. This vision will be realised through the Science Quarter, a development to create innovative new spaces for our collections, resources, scientists and students across our Kew and Wakehurst sites. This will bring a long-term step change in the quality and global impact of our science, in order to deliver our mission and strategy.

The Science Quarter will provide a platform for collaborative, discovery-driven plant and fungal science to find solutions to the critical challenges facing the world today. Providing a working environment that values and supports all of its occupants, it will become a magnet for world-class scientists and students, reinforcing the unique role of Kew Science in the global plant and fungal research arena, and supporting Defra and wider government in their goal to secure the UK as a global leader in scientific innovation.

The development of the Science Quarter goes right to the heart of RBG Kew's objectives and statutory functions – protecting the national collections and ensuring they are accessible to all and being used for the benefit of humankind.

Sharing our science

Science communication is intertwined with everything we do, and is the mechanism by which we transmit our mission and research to society. Effective and inclusive internal and external communication of our science is integral to the success of the Priorities and to achieving impact. Science staff will continue to work closely with colleagues across the organisation to expand the reach of our scientific research and the communication of the importance of our mission. Our aim is to inspire a diverse audience to understand, value, sustainably use and protect biodiversity. We are all part of the solution as we strive to achieve a more sustainable future.

We are committed to sharing our knowledge equitably and fairly and increasing transparency, and to using science communication as a strategic tool to achieve this. We will explore new and innovative ways to communicate our science and inspire and influence all sectors of society across the globe. We will endeavour to maintain and increase our active social media presence with a focus on interactive online platforms, and to use our science to engage audiences more effectively through both virtual and in-person events. As a public-facing organisation with 2 million visitors per year and a significant online presence, we have the potential to revolutionise the way plants and fungi are talked about and valued the world over.

Our aim is to inspire a diverse audience to understand, value, sustainably use and protect biodiversity.

The Science Collections

Collections-based research

The exceptional Science Collections held at RBG Kew document plant and fungal diversity through time and space and provide an unrivalled evidence base that can be used to address contemporary issues, ranging from climate change to food security and human health. Our collections-based research is therefore fundamental to the overall mission of the organisation, which is to understand and protect plants and fungi, for the well-being of people and the future of all life on Earth.

Research does not happen in a vacuum, and knowing what happened in the past is crucial to understanding the present and predicting what might happen in the future. Our specimen collections include dried plant and fungal specimens, seeds, DNA and tissue samples, wood cross-sections, samples in spirit and growing *in vitro*, microscope slides, and economic botany artefacts documenting the uses of plants by people. They provide evidence of plant and fungal diversity and use in the past and present and allow us to understand how the diversity and distribution of species might change in the future.

Alongside the scientific specimens, the Library and Archives Collections provide the context – how they came to be collected and why. They document hundreds of years of human knowledge about plants and fungi and their distribution, properties and uses. The Archives also document the history of the organisation and its role at the centre of a global network of botanic gardens and individuals. RBG Kew's Living Collections complement these resources, providing historical context and contemporary sources of material for research, conservation and education. The full breadth and depth of Kew's collections is described in Kew's *Science Collections Strategy* (2018–2028), *Living Collections Strategy* (2019), and the *Library and Archives Strategy* (currently in preparation).

Managing the collections for the future

Collections of the size and scope of those at RBG Kew have national and global significance and relevance. They must retain this relevance into the future, facilitating the delivery of our mission while continuing to serve the diverse needs of the wider research community and other stakeholders. We will:

- Produce a Collections Development Policy covering Kew's Science, Library, Illustrations and Archive collections to relate current collection activity to the Priorities and Initiatives set out in this document. It will also outline the principles for responsible and ethical acquisition and management.
- Ensure the diverse countries and cultures that partner with RBG Kew and contribute to our collections are accurately and equitably represented and are able to access our collections data.
- Move quickly to re-examine our collections to acknowledge and address any exploitative or racist legacies, and to develop appropriate narratives around them.

Our collections are a long-term investment. They require care and maintenance and, if damaged or destroyed, cannot be replaced. We will ensure appropriate standards are in place across the collections by aiming for Museum and Archive Service Accreditation and we will apply similar standards and processes to collections that are ineligible for accreditation, including the Library, Seed and DNA/tissue collections. Accreditation provides a benchmark to help assess curation and management, formalises procedures and policies, facilitates responses to users' needs and interests and helps develop the skills of staff. We will also formulate plans for the development of collections managed by the Kew Madagascar Conservation Centre. Our long-term aim in Madagascar is to collect comprehensive and high-quality georeferenced samples of all species of plants and fungi, with duplicates available to researchers in Madagascar and other countries.

As legislation governing access to genetic resources and benefit sharing evolves, we aim to develop best practice with partners and to adopt new methods to streamline administrative requirements, ensuring a fast, efficient, equitable and transparent process. We will also establish best practice for handling preserved collections under evolving plant health legislation. We will work with our partners in the UK and EU through the Distributed System of Scientific Collections research infrastructure to develop common standards in collection management and digitisation.

Deliverables:

- Improved digital access to the collections (in conjunction with Priority 3), while still providing physical access to specimens when required.
- A plan for targeted collections (in conjunction with all five Scientific Priorities), based on a thorough gap analysis in the context of other collections-based institutions worldwide (with Priority 4).
- Enhanced use of the collections to inform the conservation and restoration of species and ecosystems.
- Enhanced *ex situ* conservation through the development of the Kew Cryosphere (in conjunction with Priority 2).
- Sub-strategies and policies for the collections and their use, including a Library and Archives Strategy (2022), Collections Development Policy (2022), Institutional policy on offensive language in collections (2022), Herbarium Handbook (2022), Development Plan for Madagascan Collections (2023), Plant health guidelines for preserved plant and fungal collections (2023), and a Repatriation and Data Sharing Policy (2023).
- Museum Accreditation for Herbarium, Fungarium, Economic Botany and Illustration collections (2025), and Archive Service Accreditation for Archives (2025).

What we will achieve

What we will achieve

The ambitious plans for understanding, protecting and sustainably using biodiversity that we have outlined in this strategy incorporate many goals that we are already on track to achieve with current resources and funding. To deliver our vision in full requires investment in our people, resources and infrastructure, and we will actively pursue a range of funding opportunities for our world-class scientific research.

What we aim to deliver:

Priority 1: Ecosystem Stewardship

Initiative 1.1: Ecosystem Assessment

- An inventory of priority ecosystems and landscapes for conservation, monitoring and recovery.
- Innovative methods and tools to identify, assess, monitor, model and understand units of biodiversity at multiple scales.
- Dissemination of the ongoing and projected threats faced by, and resilience of, different units of biodiversity.

Initiative 1.2: Nature-based Solutions

- Monitoring and evaluation of which nature-based solutions work where, for wider application and scalability.
- Evidence contributing to the development of more resilient landscapes and ecosystems.
- Tools and interventions to help implement nature-based solutions.

Initiative 1.3: Biodiversity Metrics

- Novel or enhanced stewardship metrics at a global scale
- Natural capital metrics and methodological innovation incorporating specific benefits provided by biodiversity.
- Metrics to measure resilience to environmental change in species that supply provisioning ecosystem services.

Priority 2: Trait Diversity and Function

Initiative 2.1: Adaptation and Resilience

- Transformative growth facilities and research as part of the Wakehurst Conservation and Research Nursery.
- Accurate predictions of adaptation potential in diverse plant and fungal systems based on genomic and trait data.
- Recommended interventions to accelerate adaptation to climate change and infectious diseases.

Initiative 2.2: Biointeractions and Bioactive Molecules

- Information on the composition, function and evolution of fungal microbiomes and their impact on plants and the environment.
- Identification of the chemical benefits of pollen and nectar for pollinator health.
- Identification and understanding of the functioning of bioactive molecules and other traits that have the potential to enhance human health and livelihoods.

Initiative 2.3: Enhancing Survival

- Establishment of the principles of low temperature stress tolerance of cells and tissues to guide the delivery of successful *ex situ* storage of taxa.
- Establishment of the principles of oxygen, temperature and moisture stress tolerance.
- The first Global Seed Information Facility on seed traits.

Initiative 2.4: Sustainable Agriculture

- Identification of useful plant and fungal traits and how they may be applied to crop plant development and sustainable agriculture.
- Information on the underlying mechanisms and functions of useful traits and their application in crop plant development and sustainable agriculture.
- Dissemination of crop plant and trait data to drive decision- and policymaking for the benefit of biodiversity.

Priority 3: Digital Revolution

Initiative 3.1: Digitisation of RBG Kew's Collections

- Full digitisation of our major collections.
- Molecular digitisation of our 50,000 fungal type specimens, the world's largest collection.
- Digital curation and management embedded into Kew's collection management procedures.

Initiative 3.2: Knowledge Integration

- Publication of an enhanced World Checklist of Vascular Plants comprising taxonomy and geography.
- RBG Kew's name and taxonomic data incorporated into global systems for species naming and taxonomy.
- A single integrated collection management system linking all our data.

Initiative 3.3: Knowledge Sharing

- A central information portal for use by the global research and conservation communities.
- A 'Plants for Health' portal and data service.
- Analysis tools, data distributions and programmatic interfaces.

Priority 4: Accelerated Taxonomy

Initiative 4.1: Documenting Biodiversity

- Taxonomic triage: a global gap analysis of herbarium collections to inform future collecting efforts.
- Geographic prioritisation: documentation and description of plants and fungi in regions of exceptional biodiversity.
- A new taxonomic pipeline to speed up the description of plant and fungal diversity.

Initiative 4.2: The Tree of Life

- A complete tree of life for both plants and fungi at the genus level.
- Application of analytical tools for research on taxonomy, evolutionary biology, trait discovery and ecosystem stewardship.
- A dynamic, integrative tree of life digital platform.

Initiative 4.3: Innovating Species Identification

- Accelerated specimen-naming workflows with automated identification of specimens.
- Curated specialist reference datasets of DNA sequences for selected groups of plants and fungi.
- Enhanced plant and fungal identification for field-based inventories.

Priority 5: Enhanced Partnerships

Initiative 5.1: Interdisciplinary Research

- New interdisciplinary partnerships.
- Establishment of a Centre for Plant Humanities.
- Information to enable us to understand, conserve and use food crop heritage.

Initiative 5.2: Millennium Seed Bank Partnership

- Increased *ex situ* conservation of the world's flora.
- Improved restoration outcomes.
- Expanded training and technical support.

Initiative 5.3: Education and Training

- New professional training opportunities.
- Expansion of our Master's programme.
- Doctoral training programmes developed at RBG Kew.

Initiative 5.4: Enhancing Commercial Partnerships

- Expansion of key commercial relationships.
- Increased diversity of plants and fungi used in products.
- Establishment of an innovation platform for commercial opportunities.

The next few years provide a closing window of opportunity for societies to protect and sustainably use Earth's remaining biodiversity and to restore what we have degraded.

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Citation

This document should be cited as:
Royal Botanic Gardens, Kew. (2021). *Science Strategy 2021–2025*. Royal Botanic Gardens, Kew, Richmond.
DOI: https://doi.org/10.34885/rbgkewsciencestrategy2021

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