



State of Wet Tropics 2020–2021

*Growing opportunities—landscape restoration
for biodiversity and ecosystem recovery*



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Purpose of the report

This State of Wet Tropics report satisfies the requirements of Queensland's *Wet Tropics World Heritage Protection and Management Act 1993* and the Commonwealth's *Wet Tropics of Queensland World Heritage Area Conservation Act 1994*.

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Acknowledgement of the Rainforest Aboriginal Peoples of the Wet Tropics

The Wet Tropics Management Authority acknowledges Rainforest Aboriginal Peoples as the Traditional Custodians of the Wet Tropics World Heritage Area and recognise their connection to this cultural landscape. We pay respect to Elders past, present and future. We recognise Rainforest Aboriginal Peoples' ongoing and essential connections to the Wet Tropics land, sea and sky country and their rights and responsibilities under customary obligations and Aboriginal lore. The Wet Tropics Management Authority supports the active roles of Rainforest Aboriginal Peoples in the ongoing management and governance of the Wet Tropics World Heritage Area.

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Feedback

The report is an important document representing communication and accountability. The Authority values comments and welcomes feedback from readers.

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Further information



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A black and white photograph of a smiling person wearing a cap and a work shirt, holding a large stack of bricks. The person is standing in a field with tall grass and trees in the background. A green map of Queensland is overlaid on the left side of the image, with three locations marked: Cooktown, Cairns, and Townsville.

It has never been more
important to remind
ourselves of the value and
benefits of restoring our
Wet Tropics landscapes.

Cooktown

Cairns

Townsville

Message from the Chair

This year marks the beginning of the 2021–2030 United Nations Decade of Ecosystem Restoration. The decade is an international rallying call to protect and revive ecosystems and restore them, recognising the importance of healthy ecosystems to people's livelihoods and wellbeing, to counteract climate change and provide resilience, and to stop the collapse of biodiversity.

It has never been more important to remind ourselves of the value and benefits of restoring our Wet Tropics landscapes. Replanting, rehabilitating and repairing rainforests offers opportunities to heal past ecological injuries, especially for high-priority areas where our biodiversity once thrived.

We have a responsibility to the Wet Tropics community to take better care of our extraordinarily diverse natural asset. The Area contains the world's oldest continuously surviving tropical rainforests, is home to ancient living cultures, and is ranked the second-most irreplaceable World Heritage site on Earth, according to the International Union for the Conservation of Nature (IUCN) because of its unique concentration of endemic, rare and ancient species.

When we restore rainforests we limit and even reverse the declines of wildlife and ecosystem services by establishing new faunal corridors, creating protective buffers around parks and restoring key ecological functions.

To conserve our soils, plants and animals and ecosystems we strengthen the partnership between western science and the knowledge of Rainforest Aboriginal Peoples.

We applaud the restoration practitioners who have devoted their lives to restoration across the Wet Tropics over the past four decades, and, in many cases, produced significant restoration gains. To achieve greater areas of restoration in a useful timeframe, reforestation needs to be scaled up.

Ensuring the health of Wet Tropics forests is already a core goal of World Heritage management. Landscape restoration is one of the most effective ways we can achieve that goal. Now under a changing climate, we must act strategically, together, and immediately. It is important to make the Decade of Ecosystem Restoration the focus of meaningful conservation and ensure a legacy that extends far beyond a 10-year period.


Ms Christine Grant
Chair


Ms Leslie Shirreffs PSM
Outgoing Chair

Terms and abbreviations used in this report

Assisted regeneration	Natural regeneration that is actively encouraged by methods such as grass suppression.
Biodiversity	Living organisms and the ecosystems of which they are a part.
Biodiversity planting	High density planting of locally sourced native species.
Buffer planting	Biodiversity planting established along a forest edge.
Chronosequence	A set of sites using the same method of reforestation that differ in the time since they were established.
Climax species	The most shade-tolerant species of tree to establish in the process of forest succession. The seedlings of climax species can grow in the shade of the parent trees, ensuring their dominance indefinitely.
Corridor	Habitat, usually narrow (<200m wide), connecting isolated habitat patches.
CRRP	The Community Rainforest Reforestation Program which ran in the Wet Tropics from 1992 to 2000.
Ecological succession	Change and replacement of species at a site over time due to changes in site conditions.
Ecosystem	An assemblage of interacting living and non-living components. Ecosystems may be natural, as in forest ecosystems, or comprised largely of introduced species as in agricultural and urban ecosystems.
Ecosystem restoration	Actions to assist recovery of a natural ecosystem.
Ecosystem goods and services or ecosystem services	Contributions of ecosystems to human communities.
Endemic	A native species restricted to a geographic area.
Environmental markets	Mechanisms that aim to leverage environmental protection or conservation through market means.
Frugivorous	Feeding on fruit.
Habitat	The natural environment in which a species or suite of species occurs.
Habitat restoration	Actions to assist recovery of habitat for a species or suite of species.
Landscape restoration	Processes that aim to recover ecological value and function in a degraded landscape.
Matrix	The areas that surround patches of remnant vegetation.

Monitoring	Systematic data collection over time to evaluate progress toward an objective.
Old growth/ intact/ mature forest	Forest that has never been cleared.
Plantation forestry	Low density tree planting managed for commercial timber production or other economic benefit. May include native and/or introduced species.
Practitioner	Person engaged in planning, implementing, and monitoring landscape restoration projects.
Rainforest Aboriginal Peoples	Traditional Owners of the Wet Tropics of Queensland World Heritage Area and wider Wet Tropics region. Includes more than 20,000 people from at least 20 tribal groups, 120 clans and eight language groups.
Reforestation	Establishment, by any means, of forest on land that was previously forested. The species may or may not be native.
Refugia	An area in which a species' population can survive through climate change.
Regeneration or regrowth	Forest growth that occurs after stock are removed without trees being planted.
Restoration	Actions to assist recovery of a natural ecosystem usually including biodiversity planting.
Restoration industry	Collective term for providers of goods and services related to landscape restoration.
Revegetation	Establishment, by any means, of vegetation cover. May use native or introduced species.
Stepping stones	Patches of natural habitat within a modified matrix.
Taxa	A taxonomic group of any category, such as a species, family, or class.
Traditional Custodians	The specific group of Rainforest Aboriginal Peoples who have cultural responsibility for a particular area.
Traditional Owner/s	Aboriginal person/s who is/are a member/s of a local descent group having certain rights and responsibilities in relation to a tract of land or area of water.
TREAT the Area	Trees for the Atherton and Evelyn Tablelands.
The Plan	Wet Tropics of Queensland World Heritage Area.
Wet Tropics region	Wet Tropics Management Plan 1998.
Wet Tropics region	Geographic region that encompasses the Wet Tropics of Queensland World Heritage Area and surrounding landscapes along Queensland's tropical east coast.
WTTPS	Wet Tropics Tree Planting Scheme (1988-1994).

Executive summary

Stretching 450km along the northeast coast, the Wet Tropics of Queensland World Heritage Area (the Area) encompasses almost 900,000ha of mostly tropical rainforest and supports the highest biodiversity of any region in Australia.

This unique biodiversity and its significance in understanding evolutionary history also makes the Area one of the most important and irreplaceable regions in the world.

Covering just 0.12% of Australia, the Area is home to an exceptionally high proportion of the nation's biodiversity for example: 3,300 plant species, 700 vertebrate species, 30% of the nation's marsupial species, 45% of bird species, 60% of butterfly species, 65% of fern species and 15 of the world's 26 ancient lineage of flowering plants—the highest concentration in a single protected area on Earth.

In the Area, there are at least 20 Rainforest Aboriginal tribal groups, made up of 120 clans and eight language groups—over 20,000 people—with ongoing traditional connections to the landscapes of the Area. Across these groups there is a huge body of rich and diverse traditional knowledge about the Wet Tropics environment.

More than 100 years of European colonisation has seen large areas of former forest logged, cleared or converted to crops and pasture. This legacy of deforestation coupled with accelerating climate change threatens the natural values, ecosystem services, and quality of life that the Area and surrounding landscapes and seascapes support. Many of the region's unique species have already declined and Wet Tropics communities are experiencing more extreme weather including longer drought periods, greater bushfire risk and more frequent coastal flooding.

Landscape restoration is practical, on-ground action that can repair past damage and improve the resilience of both natural ecosystems and human communities. By expanding and connecting habitat, successful reforestation can bolster species populations and enable their movement. It can store carbon, help regulate local climate and precipitation, regulate stream-flows and water quality, and reduce streambank and coastal erosion. It can also improve crop production through pollination and pest control, and contribute to community income, employment, and wellbeing.

Most reforestation activities rely on community groups and other organisations across the Wet Tropics to undertake voluntary and funded restoration activities. There have been many successful projects, and techniques have been refined over 30 years of practice.

But there are setbacks. Groups have often struggled to maintain continuity within and between projects, due to dispersed sources of limited life funds. They have had limited capacity to undertake risky or innovative projects, or to monitor and analyse outcomes. Short-term, project-based funding has thus produced many small, widely scattered restoration sites. It has also hampered development of a vibrant restoration industry.

Costs

Traditional biodiversity planting comes at a high cost per hectare and consequently most on-ground restoration action has been focused on individual sites, each typically less than 10ha. Biodiversity planting introduces advanced native tree seedlings of a diverse selected mix of local species suited to the site. It requires ongoing site maintenance to ensure rapid canopy closure to create conditions that suit forest species and native tree recruitment. Long-established plantation forestry techniques use fewer trees per hectare and a relatively new approach is using scattered ‘tree islands’ to attract seed dispersing birds and foster natural tree recruitment.

There are also a wide range of emerging approaches to reforestation that do not involve planting trees. These include direct seeding, assisted natural regeneration by suppressing grasses or other forest inhibiting species, tolerating some non-native trees, and targeted management of livestock, wildlife, or fire.

These less intensive approaches are important complementary strategies for returning large areas of forest to the Wet Tropics and need to be incorporated into site assessment.

To date, the costs and benefits of reforestation in the Wet Tropics have been inadequately monitored and opportunities to gain valuable insights and learn from them have been missed.

Scientifically designed monitoring is needed to compare the relative outcomes of different methods, their relative cost-effectiveness for achieving different goals, and the factors leading to variation among restored sites.

Strategic investment

Assessment of investment strategies for any specific site must consider what the best combination of approaches are in a landscape. This may involve trade-offs between cost per hectare and quality or speed of outcome.

Costs may also be reduced through new opportunities being developed to fund or generate revenue from reforestation. These include carbon markets and payments for ecosystem services. Growth of a sustainable restoration industry, promoted by these new opportunities, will help support landscape-scale reforestation.

Scaling up landscape restoration

To achieve greater areas of restoration in a useful timeframe, reforestation needs to be scaled up.

Landscape scale planting is a bigger picture approach to reforestation and examines ways to share costs, employ multiple approaches to reforestation and integrate multiple land uses—including nature conservation or environmental protection—across landscapes. Achieving it requires commitment and collaboration between government, business, researchers, and community. This often involves consultation across different sectors to understand priorities, complementary and incompatible combinations of land uses, as well as future needs of communities.

Recommendations

Landscape restoration is a practical action to buffer the Wet Tropics World Heritage Area and the region's waterways, distinctive biodiversity and nature-based economy from the worst effects of deforestation and climate change.

This report reviews the benefits of maintaining and increasing forest density; the types of reforestation approaches available; cost effectiveness of reforestation and the ways and means to generate funding; and how we can learn from and improve monitoring and data collection of site projects. It provides the following recommendations:

Policy and planning

- prioritise landscape scale reforestation in Wet Tropics regional and local planning
- increase investment in reforestation
- encourage new sources of revenue for reforestation such as environmental markets and payments for ecosystem services, and
- revise the National Carbon Accounting System methods to better represent the amount of carbon stored in Wet Tropics restoration sites.

Innovation and scaling

- support innovation and collaboration to develop and refine promising alternative reforestation techniques
- support future landscape scale projects with planning and project design, monitoring, interpretation and communication by trained personnel, and
- develop the capacity of the regional restoration industry to operate at large scales and over the longer term.

Monitoring and evaluation

- implement better-coordinated monitoring of landscape-scale changes in forest cover, quality and location
- encourage quantitative measurement and support monitoring of the costs and benefits of alternative approaches to reforestation in the Wet Tropics
- develop methods for evaluating the social outcomes of different reforestation types, and
- support the ongoing collection, management and interpretation of reforestation data including records of interventions, cost accounting and field measurements.

Introduction

Why restore Wet Tropics ecosystems?

In tropical areas worldwide, forest clearing has created vast areas for pasture and cropland, many of which have become degraded and unproductive over time.^[1] During the past decade, international organisations have responded with a range of global initiatives to address the pressing need for landscape-scale forest restoration.^[2] The United Nations has resolved that 2021–2030 is the ‘UN Decade on Ecosystem Restoration’, aiming to put the world on track for a sustainable future by ramping up restoration efforts.^[3]

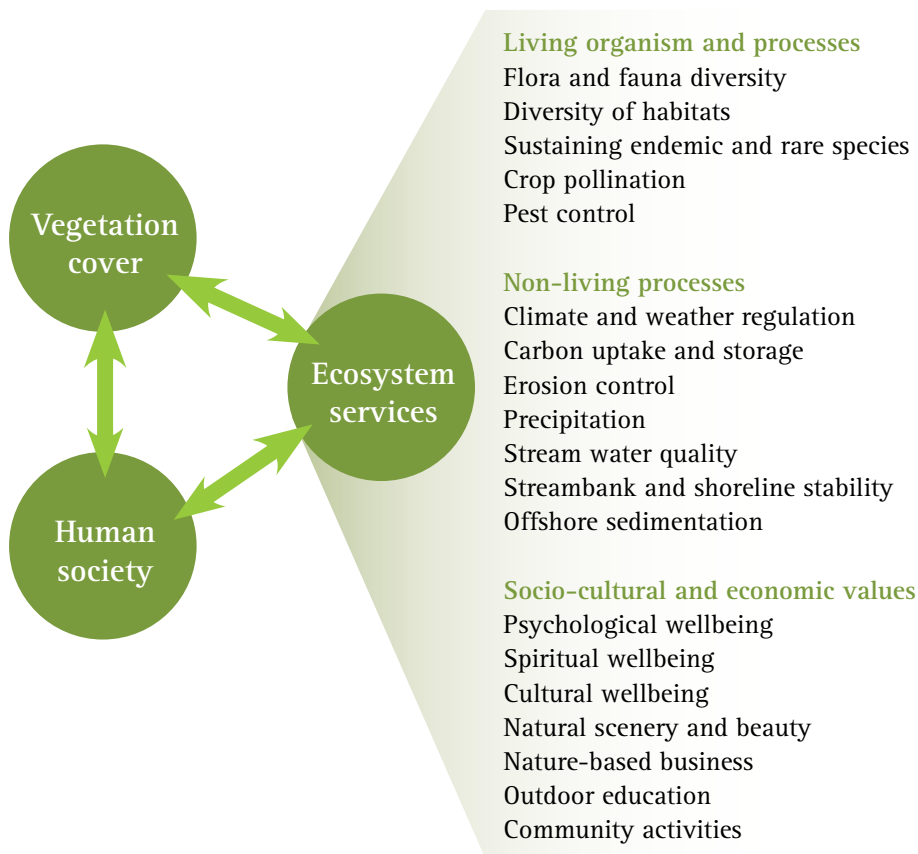
Prior to European settlement, Rainforest Aboriginal Peoples lived in the Wet Tropics region many thousands of years, and their livelihoods and culture were, and still are, intertwined with the landscape’s natural features.^[4] The Wet Tropics is the only place in Australia where Aboriginal people have permanently inhabited a tropical rainforest environment.^[5]

When the first allocation of lands were opened to settlers in the 1800s, they were required to clear and cultivate as a condition of occupancy. Over the past 160 years, successive waves of new people have settled in the Wet Tropics region and cleared native vegetation and replaced it with cropland or pasture. In recent decades, a legacy of unforeseen losses and costs has become apparent.^[6]

Vegetation is the most visible aspect of the ecosystem. It comprises the wide array of different living species within it (plants, animals, fungi and microbes) and the ecological processes that enable it to persist and regenerate. These are all linked to its non-living surrounds by a range of different chemical and physical processes. These continual interactions mean human actions which affect one part of an ecosystem can induce far-reaching changes to other parts. Because they are indirect these changes can take years or decades to become apparent, and they can be difficult to predict.

What is known is that wholesale clearing of native forests in parts of the Wet Tropics has contributed to species’ declines and local extinctions, loss of scenic, aesthetic and spiritual qualities, land erosion and degradation, streambank slumping and collapse, loss of timber resources, and increased extremes of heat and cold.^[7] Additionally, indirect effects in other parts of the landscape include limitations to species’ movements, reductions in water quality (in-stream and offshore), precipitation and water flows, increases in runoff during heavy rain, and in atmospheric CO₂. Elevated CO₂ in turn contributes to climate change, with a wide range of further undesirable effects on both ecosystems and people.^[8]

Figure 1. Ecosystem services and their inter-relationships with people and vegetation



Rainforest Aboriginal Peoples' concept of cultural landscapes emphasises the inseparable and independent nature of Country and People. This concept inherently recognises the consequences for people brought about by damage to ecosystems. Landscape restoration is an important part of healing both Country and Rainforest Aboriginal Peoples. But the health of Country can encompass more than reforestation and weed management and may include aspects such as access to traditional medicine, being on Country, learning from Elders, language, and ownership.^[9]

In Western society, ecosystem services is a term often used to encompass the many ways in which an ecosystem (as represented by its vegetation) provides benefits to human societies and economies. Converting native vegetation to pasture, cropland and human settlements will inevitably affect the ecosystem goods and services which were once assumed to be eternally available.

Globally, conservation biologists agree that protecting remaining old growth and remnant forest will not on its own avert further declines in its biodiversity and ecosystem services. Restoration of rainforest cover is a vital tool for recovering ecosystems and human benefits.^[10] Landscape restoration is a practical action to buffer the Wet Tropics World Heritage Area and the

region’s waterways, distinctive biodiversity, and nature-based economy from the worst effects of deforestation and climate change (see Table 1).^[11,12]

Reforestation can be compatible with human settlements and productive land uses. The challenge is in how and where to undertake reforestation actions. Financing, land availability, community participation and tracking reforestation outcomes can be achieved with concerted effort and support from governments and communities.

Table 1: Benefits of restoring forest cover to landscapes

Benefits of restoring forest cover to landscapes	
	<ul style="list-style-type: none"> • Limit further declines in rare, endemic or threatened species that depend on forest by enlarging the area of suitable habitat • Help reverse species’ declines by buffering forest remnants and by linking them with stepping-stones or corridors of forest habitat • Help forest-dependent species survive climate change by providing more habitat in formerly cleared climatic refugia • Improve crop productivity in nearby farmlands by providing habitat for crop pollinators and natural enemies of crop pests • Improve scenic values, ambience, and experiences of nature for people thereby providing potential employment and income sources to the region from visitors • Increase opportunities for community activities, engagement, education, new social experiences, and philanthropy • Remove carbon from the atmosphere because growing trees sequester and store carbon both above and below ground • Improve the dry season supply of water in streams and rivers, both by creating runoff through cloud condensation onto leaves, and by gradually releasing soil-stored water • Mitigate against floods, by encouraging rainfall infiltration into soil instead of surface runoff • Protect watersheds from erosion, and streams from sedimentation, by encouraging rainfall infiltration into soil instead of surface runoff • Improve habitat quality for aquatic plants and animals within streams, both through improved water quality and streamflow, and by shading the streambed • Improve the quality of water and species’ habitats in offshore marine areas such as coral reefs and fisheries.

A snapshot of reforestation efforts in the Wet Tropics

Historically, reforestation in the Wet Tropics has consisted mainly of tree planting in two forms – biodiversity plantings and plantation forestry. These approaches differ in their primary goals, design and management. Both approaches have been supported by an array of government initiatives. Plantation forestry began with state government projects in the 1920s and has consisted mostly of single, or limited species plantings, sometimes of native rainforest trees, but often directly replacing intact rainforest.^[13]

Tree planting in the Wet Tropics was boosted by two government schemes that aimed to provide employment for retrenched forestry workers following the World Heritage listing. These were the Wet Tropics Tree Planting Scheme (WTTPS, 1988–1994), which focused mainly on streamside biodiversity plantings,^[14] and the Community Rainforest Reforestation Program (CRRP, 1992–2000), which focused on mixed-species agroforestry plantations on degraded farmland.^[15] The WTTPS established a network of native plant nurseries with local governments that continued to manage the nurseries after 1994. In the decade 1991–2001, the WTTPS planted 1,000ha of biodiversity plantings.

From 1991 to 2001, 2,000ha of mixed species cabinet timbers were planted under the CRRP scheme.^[16] The CRRP was transferred to state government management after 1994 and shifted towards single-species non-rainforest plantations.^[17] Five local governments in the Wet Tropic region continue to operate native plant nurseries and undertake reforestation.^[18]

Two important Commonwealth Government schemes funded reforestation projects—the Natural Heritage Trust (NHT, 1997–2008) and Caring for Our Country (CFOC, 2008–2018). They fostered the establishment and development of Landcare and catchment management groups, other community groups and regional natural resource management organisations. Biodiverse tree planting on former agricultural land continues to be strongly dependent on these organisations. Their reforestation techniques have been refined and developed over more than 30 years of practice and the methods are well documented in the search for improved efficacy and efficiency.^[19]

For millennia, Rainforest Aboriginal Peoples have used techniques such as cultural burning and direct seeding to manage forest regeneration processes. The need for landscape-scale restoration is an artefact of colonisation and—like the concept of threatened species—was not part of traditional cultural practice or knowledge systems.^[20] Dispossession and exclusion from decision making about Country have been barriers to Rainforest Aboriginal Peoples engagement in landscape restoration historically.^[21] Nevertheless, Rainforest Aboriginal Peoples have led landscape restoration in recent decades, for example, through the Healing Country program (Indigenous Land and Sea Country Ranger programs) (refer Appendix I) and the Commonwealth's Working on Country program.

Restoring communities

In the 1970s, the Wet Tropics community began to see the importance of restoring native species to maintain the long-term health of the environment.

Trees for the Evelyn and Atherton Tablelands (TREAT) was started by botanist Joan Wright and rainforest ecologist Geoff Tracey, who recognised the need for a community-based tree planting organisation to revegetate degraded lands and create corridors for wildlife on the Tablelands. Its principal objective was to encourage people to plant native rainforest trees. Along with Tony Irvine, they worked tirelessly with the Queensland National Parks and Wildlife Department to encourage native tree planting on private lands, and to build a nursery to support their efforts. In 1982, the TREAT nursery commenced construction. The nursery continues to operate today and TREAT has over 500 members (around 900 individuals) contributing to land restoration.

Over time, other nurseries began to establish across the Wet Tropics. There are now more than 10 not-for-profit and community nurseries across the region (Appendix II).

Staff and volunteers across these nurseries continue to work together to restore and maintain the forests in the hope that the unique natural values of the Wet Tropics are conserved for future generations.

More recently, landscape restoration efforts have become increasingly concerned with buffering and supporting the Wet Tropics World Heritage Area, improving the quality of water in agricultural run-off to the Great Barrier Reef and mitigating climate change. Recent funding schemes, such as the Queensland Government's Land Restoration Fund,^[22] focus on carbon farming and associated co-benefits, which further support reforestation efforts.

A number of land and conservation philanthropic organisations also provide significant regional funding for habitat restoration. Possible alternative funding arrangements—such as market credits for carbon, other ecosystem services and biodiversity—are also gaining attention.

How can forest cover be restored?

Forests can, and do, naturally regenerate.^[23] Natural regeneration relies solely on dispersal to restore native plants and ecological processes to a site. Although no planting is involved, other interventions may be required to manipulate, assist or accelerate the successional process. This method is often appropriate for locations adjacent to an expanse of established rainforest vegetation. The first step is to manage any factors limiting natural regeneration such as stock grazing, fire and weeds.

Natural regeneration in the Wet Tropics of Queensland World Heritage Area

The recently reviewed Wet Tropics Management Plan (the Plan)^[24] divides the Wet Tropics World Heritage Area into zones that broadly reflect ecological integrity and management intent. Prior to the review, Zone A, areas of high ecological integrity, comprised 52% of the Area. This recognised that significant sections of land were recovering from past disturbances such as logging.

Since World Heritage listing in 1988, substantial tracts of land have recovered.

As part of the review of the Plan^[25] the Wet Tropics Management Authority—with endorsement from Rainforest Aboriginal Peoples, the tourism sector, local government, and the conservation community—increased Zone A to 92.5% of the Area, in recognition of the success of the previous management plan in rehabilitating large, previously disturbed areas.

Ecological barriers and facilitators

In landscapes where large areas of former forest were cleared and then converted to either cropland or grazed pasture grasses for some decades, it can be more difficult for forest to regenerate naturally.^[26,27] When the land is retired from productive use and livestock are removed, invasive woody weeds and tall pasture grasses take over, inhibiting growth of native trees.

Many rainforest trees have short-lived seeds, and therefore agricultural soils rapidly lose their bank of stored seeds.^[28-30] Regrowth can only occur if new seeds are dispersed into an area, which depends on the presence and movements of fruit-eating birds and bats.

Many factors can act to limit seed and seedling survival. Seeds and seedlings may be eaten by invertebrates such as the larvae of beetles and other insects, granivorous birds, and mammals such as rodents, marsupial browsers, or stray livestock.^[31] Exposed seeds in open areas may either fail to germinate, or they may dry out soon after germinating. Growing seedlings need a supply of light, water and nutrients.^[32]

These barriers can be overcome when forest cover is actively restored through tree planting,^[33, 34] because the planted tree saplings (around 30–50 cm tall) grow past these early stages in nurseries. Unless regularly maintained for several years, a range of factors can also kill the young trees or greatly slow their growth. These include drought, frost, extreme weather events, fire and competition from uncontrolled growth of grasses and other pasture species.

Socio-cultural-economic barriers and enablers

The decision to set aside land for restoration may involve giving up the option to use the area for grazing, cultivation, or other productive land uses which could mean accepting a reduction in income. This opportunity cost comes on top of the cost of restoration itself, which can be high, particularly for biodiverse planting. While restoration costs may be partly covered by grants, usually from government programs, they are typically small, inconsistent, and often do not cover the costs of ongoing maintenance.

Funding insecurity also constrains the ability of nurseries to supply seedlings for replanting; while there is sufficient nursery infrastructure in the Wet Tropics to double current output, most nurseries are unable to employ enough staff to manage increased operations. Financial issues equally apply to Indigenous-owned land which is often held by the Prescribed Body Corporate for Rainforest Aboriginal groups which typically have minimal resources for management of Country. On-ground management of these areas often depends on partnerships (for example with the Queensland Parks and Wildlife Service and Partnerships) and with philanthropic organisations.^[35]

20 There are additional, substantial barriers to restoration that are not related to costs. The first is the contest between dedicating land for restoration and retaining land for infrastructure, suburban and other development, as well as primary production. Integrated regional planning that explicitly prioritises opportunities for restoration, as well as other land uses, is an important way to address these tensions. Second, landholders' attitudes influence their engagement in practices such as restoration. For example, farmers in the Wet Tropics express a strong and positive stewardship ethic, including concern about soil health and weed control,^[36] but may be concerned about being seen as 'greenies' and losing credibility among their peers if they undertake restoration.^[37]

Restoration can and does boost the economic value of agricultural areas, potentially offsetting opportunity costs. For example, restoration can stabilise soil, provide shade for stock, increase populations of crop

pollinators and/or increase amenity value. New and emerging ecosystem services and biodiversity markets (e.g. Reef Credits, Cassowary Credits) have the potential to cover restoration costs as well as generate additional income.

Philanthropic organisations increasingly fund restoration in the Wet Tropics region and may represent a more reliable funding support over time. Restoration practitioners are continually seeking lower cost methods^[38] as well as new sources of funding for restoration.

On-ground landscape restoration is often driven by community organisations supported by a base of dedicated volunteers. This community involvement contributes hundreds of hours of work every year in nurseries (e.g. potting up seedlings), at restoration sites (e.g. planting seedlings, installing tree guards, providing food for other volunteers), as well as managing projects, developing funding applications, participating in regional planning processes and increasing community awareness and support for restoration.

Landholder attitudes to restoration can be changed through access to advice and support, especially through industry-based organisations, as well as regional natural resource management bodies, landcare and catchment care groups. Reframing restoration as a legitimate way to earn income such as through ecotourism, payments for carbon abatement, or production benefits can also foster participation in restoration.^[39]

Sharing know-how with the general community through brochures/fact sheets, hands-on training, demonstration sites, field days and opportunities to participate (e.g. volunteer tree planting) can build understanding of the reasons to undertake restoration, as well as practical knowledge of how to do it.

Types of reforestation

Forest restoration is more than simply planting trees.^[40] Real forest ecosystems are sustained by complex interactions among different plants, animals, microbes, chemicals (in various states of transformation between organic and inorganic) and the physical properties of the air and soil. Ecological restoration is not only a process (i.e. an activity) but also the outcome sought.^[41]

Biodiversity plantings

In the Wet Tropics, biodiversity planting can potentially produce the fastest and most extensive recovery of all approaches to reforestation on former agricultural land because it removes many of the barriers to regeneration.^[42]

Core components include: site preparation to remove pasture grasses/herbs; planting advanced native tree seedlings of a diverse selected mix of local species suited to the site (including adequate representation of slow-growing trees typical of mature forest); ongoing maintenance to suppress grass/herb competition so that the trees survive and grow; and rapid canopy closure to create conditions that suit forest species and native tree recruitment (to add

new seedlings and other organisms over time). Planting may include other early actions to aid tree survival and growth (ensuring moisture, adding mulch).

Plantation forestry

In plantation forestry approaches, wood or carbon production is maximised by planting tree species selected for their wood (cabinet) quality and rapid growth, in either monocultures or limited mixtures of several species. Costs are reduced by planting smaller seedlings at lower density than for traditional biodiversity plantings.^[43,44]

Figure 2. A successful seven-year-old biodiversity planting, seen from the edge



Figure 3. This 10-year-old biodiversity planting has failed to develop, due to lack of maintenance (grass and weed suppression) after planting



Figure 4. A seven-year-old mixed species timber plantation, containing a few tree species, spaced-out and pruned



Other techniques

A range of other techniques is now being developed worldwide to facilitate tropical forest restoration by overcoming some of the regeneration barriers on a particular site. In some situations, forest regrowth can occur spontaneously over large areas through natural dispersal by weather, birds and fauna.^[45,46] For example, this may be the case if intensive productive land use has not occurred for long periods (less than a decade), and sufficient patches of mature forest are present nearby.

Outcomes of reforestation

Maintaining biodiversity and improving resilience

Restoring native vegetation cover in the landscape aims to reverse the consequences of habitat loss and fragmentation by increasing the amount or quality of habitat for native species and enhancing movement between habitat patches. The outcomes are affected by a range of factors including individual species' characteristics, habitat quality and quantity, time since clearing, the methods used, the shape and placement of revegetated areas and the nature of surrounding land use (see Table 2).

Table 2: Factors affecting the outcomes of reforestation for biodiversity

Scale	Factor	Presumed value for biodiversity	
		lower	higher
Site	Number of species planted	few	many
	Number planted per hectare	low	high
	Mix of species planted	wind-dispersed seeds	fleshy fruits
	Site maintenance	limited	comprehensive
	Patch size	small	large
	Time since clearing	long	recent
Landscape	Proximity to remnant forest	close	far
	Landscape forest cover	low	high
Time	Age	new	established

Traditional ecological knowledge held by Rainforest Aboriginal Peoples has not been widely used to monitor biodiversity outcomes of reforestation in the Wet Tropics, although cultural indicator species are part of traditional monitoring of the health of Country and may help to build understanding of the values of reforested areas for biodiversity and ecosystem services.^[47, 48]

Structure and function of reforested habitat

Regrowth forests in the Wet Tropics region develop slowly, their progress constrained by dispersal and recruitment limitations. Although canopy cover and the number of trees in regrowth forest can reach similar levels to rainforest within 40 years,^[49] species composition still differs. Climax species, wind-dispersed species, those with large, animal dispersed seeds, and plants with ancient ancestries are under-represented in regrowth forest.^[50–52]

Likewise, old timber plantations can have a similar structure to intact forest where they have developed a rainforest understorey but lack climax species.

In comparison, biodiversity plantings typically develop rapidly when well maintained. Although hundreds of different species are used, those selected for restoration plantings in the Wet Tropics are dominated by small seeded, fast-growing species that accelerate site succession.^[53] Canopy cover and tree density comparable to intact forest can be achieved within 10 years and the height of planted trees may approach those of intact forest in 25 years.^[54] Rapid canopy closure provides suitable conditions for rainforest plant recruitment and, consequently, native tree and shrub species richness may also approach that of rainforest within those time frames.

Plants with ancient ancestries, and those with wind-dispersed or large seeds are better represented in biodiverse plantings than in regrowth. However, like regrowth, biodiversity plantings are slow to develop an overall forest-like species composition and to recover diverse life forms such as vines, epiphytes, and ferns.^[55] Distance to a seed source affects recruitment of intermediate and late-successional species. Restoration sites close to forest tend to have higher numbers of later-successional native recruits than isolated plantings.^[56]

Birds

Bird use of reforested habitat has been relatively well-studied in the Wet Tropics, partly because of the important relationship between frugivorous birds and the dispersal of rainforest fruit and partly because of their utility in monitoring. Less specialised rainforest bird species are common in regrowth forest and across the range of reforestation styles.^[57] Initial recovery of forest bird species is rapid in biodiversity plantings. By 10 years after planting, biodiverse rainforest restoration sites can have about half the number of rainforest-dependent bird species that characterise old growth forest.^[58]

Whether or not a bird species recolonises a rainforest restoration site is related to how specialised it is in terms of its habitat requirements, whether it utilises edges, and how mobile it is. Proximity to remnant rainforest may also allow rainforest specialists to extend their home range to incorporate replanted areas while retaining access to rainforest resources not available in plantings.

Even when close to old growth forest, some rainforest birds make little use of reforested habitat, including old regrowth forest and maximum diversity plantings.^[59] These recalcitrant species include most of the climate sensitive endemics. This is concerning when a main goal of landscape restoration in the Wet Tropics uplands is to increase the extent of cool refugia for endemic species threatened by climate change. Determining how to assist these species requires additional study to reveal species-specific resource requirements that are not met in replanted sites.

Mammals

Mammals, though less well-studied than bird communities, show similar patterns of recovery in reforested Wet Tropics landscapes. The species of small mammal in a restoration site have been shown to change from those of a grassland to those more characteristic of rainforest with increasing age of rainforest restoration.^[60] There is also typically an increase in common brushtail possum (*Trichosurus vulpecula*) and giant white-tailed rat (*Uromys caudimaculatus*) abundance.

Some iconic mammal species do readily recolonise replanted habitat. For example, Lumholtz's tree-kangaroos (*Dendrolagus lumholtzi*) have established in the Peterson's Creek Wildlife Corridor, despite plant species that differ substantially from their typical habitat.^[61] The Corridor also supports green ringtail possums (*Pseudochirops archeri*).^[62] However, the musky rat-kangaroo (*Hypsiprymnodon moschatus*), a rainforest specialist restricted to north-eastern Queensland, typically avoids restoration sites.^[63]

Reptiles

There is limited data on the use of reforested sites by reptiles. In one study, rainforest reptiles were recorded in old timber plantations and biodiversity plantings but not in young timber plantations or regrowth. Specialist species associated with complex habitat, such as the prickly forest skink (*Gnypetoscincus queenslandiae*) which lives in and under decaying logs, were poorly represented in reforested sites.^[64]

In some restoration plantings, practitioners have successfully enhanced habitat for fauna by adding structural features, referred to as 'habitat stacking'. An example is coarse woody debris, added as microhabitat for reptiles and other taxa. For example, prickly forest skink (*Gnypetoscincus queenslandiae*) numbers increased in restoration sites where salvaged log and fence post piles had been added to facilitate the species return.^[65]

Invertebrates

The outcomes of reforestation for invertebrates are poorly known. This is partly because taxonomic and biological knowledge of most invertebrate groups is lacking. Beetles and ants are an exception.

Ground beetle assemblages in regrowth, timber plantations and biodiversity plantings have been found to have a species composition in between that of pasture and rainforest.^[66, 67] Beetle assemblages become more similar to those of old growth forest as reforested sites get older and more structurally complex.^[68] Of restoration plantings, older sites and sites next to forest tend to have a beetle species composition most like old growth forest. Even these closer and older sites, however, have a lower abundance and richness of rainforest-associated beetles compared to old growth rainforest.^[69]

An Ant Forest Indicator Index, based on 10 indicator species, has been used to assess ant community changes in forest restoration sites on the Atherton Tableland. In sites more than 5 to 10 years old that had a relatively closed

canopy, ant communities were found to converge on those of mature rainforest.^[70]

Linking landscapes using riparian corridors

Many Wet Tropics restoration projects are located along waterways, benefiting native aquatic species including freshwater fish. Reinstating native vegetation in riparian zones can also assist land animals, as these cool, moist places are often areas where terrestrial fauna concentrate. Reinstating streamside vegetation suppresses growth of exotic pasture grasses, reduces in-stream light levels, improves water flows and trap terrestrial sediments and nutrients. These factors can all affect aquatic species survival and reproduction.^[71]

Connecting habitat

Reforestation does not only increase the available habitat for a suite of species. It also changes the spatial configuration of the landscape, improving connectivity and the capacity of individuals or genes to move within and through it. Other advantages for wildlife of restoring corridors are increasing foraging areas and resources.

The degree to which reforestation combats habitat fragmentation is difficult and time consuming to assess for fauna because animals must be caught. It is also likely to be different for each species and each landscape context. Genetic analysis has detected long distance mammal movements at Donaghy's Corridor.^[72] Some forest attributes such as canopy cover and stem density, along with a sizable proportion of the original fauna, can recover rapidly in reforested sites. The value of reforestation for fauna generally increases with increasing structural complexity, increasing plant species richness, functional diversity and proximity to intact forest.

Though it significantly benefits biodiversity, landscape-scale restoration cannot fully compensate for loss of original habitat.^[73]

Outcomes for ecosystem services

Forest restoration at a landscape scale can potentially provide a wide range of the ecosystem services that are provided by intact mature forests. These include regulation of local climate and precipitation, contributing to global climate regulation through carbon storage, regulating stream-flows and water quality, reducing streambank and coastal erosion, improved crop production (through pollination and pest control) and contributing to community wellbeing, income and employment opportunities. The best available information relates to carbon sequestration and water. Forest restoration can also increase the resilience of tropical landscapes and livelihoods to unavoidable climate change through a variety of mechanisms.^[74]

All forms of reforestation in the Wet Tropics can sequester and store carbon, both above and below ground.^[75-77] However, the carbon in any forested

site depends on the tree density, individual stem diameters and species-specific wood densities.^[78] Therefore, the amount of carbon benefit varies according to the structure and management of a reforested area, and its tree species composition. Large-diameter trees in reforested sites contribute disproportionately large amounts of stored carbon. Similarly, the large amounts of carbon stored by remnant rainforests are mainly held in the largest-diameter trees,^[79,80] which are many decades to centuries old.

Reforesting strips of riparian land along streams in the Wet Tropics uplands and lowlands can bring a variety of benefits in limiting erosion and improving stream condition and water quality and the quantity of runoff. Some of these benefits stem from the shading provided by a tree canopy, which suppresses grasses and weeds that otherwise choke watercourses. Their suppression enables the accumulated sediment to be washed out, thus restoring a stream channel.

In 1998 it was estimated that 38km of lowland streams were choked with para grass (*Urochloa mutica*) in the lower Johnstone River catchment alone. Reforesting the riparian zones of waterways such as these is a clear environmental priority. Achieving the necessary outcomes will require extensive continuous effort across a catchment's network of waterways for a decade or more.^[81]

Research in Australian subtropical landscapes showed that soil properties (nitrogen and carbon cycling, soil microbial activity, physical attributes and fine root biomass) recover to varying degrees following different forms of rainforest restoration on former pasture areas—the fastest being for biodiversity plantings.^[82]

Benefits to regional communities

Community involvement in landscape restoration is beneficial not only for the scale and success of restoration efforts but also for the individuals, organisations and communities involved. Individuals, families, and communities that grow and plant native trees and take part in other landscape restoration activities benefit in various ways from their involvement. For many members of community organisations, it contributes to their identity, sense of place and community. Volunteer activities are typically social, cater to a wide range of abilities, and enable participants to make an important contribution to the environment while boosting their own well-being. The local community and visitors alike can play a key role in the future of sustainable tourism and delivery of conservation priorities in the Wet Tropics.^[83]

"There is an atmosphere of comradeship in a constructive project".

Joan Wright, Founder of Trees for the Evelyn and Atherton Tablelands.^[84]

Reforested areas can enhance recreational opportunities for residents and visitors alike. For example, at Allumbah Pocket near Yungaburra, the Yungaburra Landcare Group has transformed a riparian area that was inaccessible due to exotic grasses and dense lantana (*Lantana camara*). It is now a popular place to look for platypus (*Ornithorhynchus anatinus*) and Lumholtz's tree-kangaroos (*Dendrolagus lumholtzi*) along its several kilometres of walking tracks.^[85] Such opportunities can have flow-on effects for local economies helping to support businesses such as accommodation providers and tour guides while taking pressure off high-use visitor sites in the World Heritage Area.

The Wet Tropics region is home to more than 250,000 people and is a popular visitor destination. As such, roads, powerlines and communications towers are necessary human elements that can impact significantly on the visual amenity of its natural landscapes. Reforestation can help remediate habitat disturbance caused during infrastructure construction and may also help to screen or distract from visual impacts.

Landscape restoration also offers opportunities for employment within the restoration industry. There is a growing demand for native tree seedlings in the Wet Tropics driven not only by tree planting for environmental purposes but also by expanding opportunities in the carbon market, plantation forestry and bush tucker sectors. Indigenous Land and Sea Ranger groups are a great example of employment and economic benefits deriving from restoration and other management activities (see Appendix I). Payments for ecosystem services (e.g. carbon sequestration, improvement of reef water quality) are also delivering economic outcomes from restoration in the Wet Tropics.

Landscape restoration can benefit regional communities through less tangible positive effects on spirit, identity, and well-being.

Protecting and enhancing the Wet Tropics outstanding values

Beautiful undeveloped scenery is very important to overall quality of life for residents and to visitor's decisions to visit the Wet Tropics region.^[86] Natural beauty is also experienced through sound, smell, emotional connection and appreciation of natural values.

Although the iconic vistas and scenery for which the Wet Tropics is renowned are protected and managed, these values nevertheless face threats. As the climate changes, the Wet Tropics region is expected to experience an increase in the severity of extreme weather events such as floods, drought, heat waves and fire. The intensity of cyclones is also expected to increase.^[87] These events can affect visual amenity by degrading habitat and altering waterflows, impacting on the aesthetic values of the region's cloudy mountain tops, expansive forests, coastal scenery, rivers and waterfalls.

Rainforest Aboriginal Peoples and landscape restoration

Rainforest Aboriginal Peoples are actively engaged in landscape restoration across the Wet Tropics through the work of Indigenous Land and Sea Ranger groups, through representative bodies, family and clan groups at property level, as well as in their roles as employees of government, community organisations or research institutions and as members of community groups. This has predominantly taken the form of participation in programs and schemes that emphasise the biophysical aspects of restoration.

Increasingly, Rainforest Aboriginal Peoples are taking the lead in the development and implementation of management frameworks informed by their perspectives on Country health and healing Country.^[88] For example, in their roles as rangers, Rainforest Aboriginal Peoples may undertake reforestation, weed control and monitoring on the ground, as well as facilitating Elders' time on Country, reviving language, and continuing cultural practices.

There are practical demonstrations of respectful and equitable collaborations with Rainforest Aboriginal Peoples, including several in the Wet Tropics. The Our Knowledge Our Way guidelines^[89] use case studies from around Australia to scope best practice ways of working with Rainforest Aboriginal Peoples and Indigenous knowledge to manage Country. The Department of Agriculture, Water and Environment's approach to writing the 2021 State of the Environment report with First Nations representatives as co-authors of each chapter demonstrates respect for cultural knowledge and also benefits from these perspectives.

Increasingly, Rainforest Aboriginal Peoples are taking the lead in the development and implementation of management frameworks informed by their perspectives on Country health and healing Country.^[88]

Investment in Wanjuru Traditional Owner leadership and catchment management

Training in natural resource management often focuses on developing on-ground technical skills. These are obviously very important, but a sustainable restoration industry in the Wet Tropics depends on having people with the range of complementary skills needed to develop and run restoration enterprises.

Jaragun EcoServices is training Wanjuru Traditional Owners from the Russell River catchment to develop independence and leadership in natural resource management.

Through the Queensland Government's Reef Assist program^[90] staff have developed practical skills in native plant and weed identification, weed control techniques, seed collection for revegetation, methods for propagating plants and potting seedlings in the nursery, record-keeping and project monitoring, as well as technical skills and licences in weed spraying, chainsaw use, machinery and the operation of boats and drones.

In addition, Wanjuru Traditional Owners have gained knowledge and understanding of the broader context and opportunities for management of Country, including regulatory frameworks, programs and policies, as well as the science underpinning practice.

Wanjuru staff have also learnt management skills, including team supervision, project management processes and tools, operational policies, job hazard assessment and risk management, and engagement and negotiation with landholders. The program has also supported ongoing learning and application of cultural knowledge by facilitating visits by Elders to project sites and inclusion of cultural knowledge in the workplace.^[91]

Although landscape restoration aligns with the aspirations of Rainforest Aboriginal Peoples to heal Country, restoration using certain methods or in particular places may not be culturally appropriate. Several Rainforest Aboriginal groups have produced protocols setting out culturally appropriate processes for seeking advice and permission.^[92]

Joint management has an important place in conversations with Rainforest Aboriginal Peoples about landscape restoration in the Wet Tropics. The 2005 Wet Tropics of Queensland World Heritage Area Regional Agreement^[93] (the Regional Agreement) was a landmark moment in realising their aspirations to manage Country. One of the important actions in the Regional Agreement was to formally recognise cultural values of the Wet Tropics. In 2012, the Indigenous heritage values of the Wet Tropics World Heritage Area were incorporated into the Area's National Heritage Listing.

The Regional Agreement is currently being refreshed to include contemporary aspirations of Rainforest Aboriginal Peoples and to overcome some of the difficulties faced by partners in delivering on some aspects. Despite real progress, Rainforest Aboriginal Peoples have limited influence over decisions about much of their Country, including restoration. While Rainforest Aboriginal Peoples may be consulted and engaged in planning and decision-making processes, there is limited opportunity to co-operatively scope, design and co-deliver these processes.

Joint management has an important place in conversations with Rainforest Aboriginal Peoples about landscape restoration in the Wet Tropics.

Growing our evidence base

Monitoring biodiversity

Monitoring aims to evaluate the outcomes of on-ground works and to provide information from which to learn and improve techniques. However, the outcomes of Wet Tropics reforestation projects have rarely been systematically monitored. Tree planting has mostly focused on “getting trees in the ground,”^[94] rather than systematically tracking a project’s progress.

There is typically an expectation that any form of reforestation will result in an improvement in biodiversity value, and that reinstating vegetation will provide suitable conditions for the return of diverse flora and fauna: an “if we build it, they will come” assumption.^[95] Monitoring of how much biodiversity has returned may therefore seem unimportant.

Information about the biodiversity outcomes of reforestation in the Wet Tropics is largely limited to independent scientific studies during the past two decades. There are few examples of the use of Rainforest Aboriginal Peoples’ cultural indicators in monitoring biodiversity outcomes of reforestation.^[96, 97]

The complex and diverse ecosystems of the Wet Tropics present many possible aspects to monitor. The first decision is which groups of species to monitor. Then a method must be chosen. Many ecological and logistical factors drive these decisions, including the site’s size, accessibility and condition, and the resources, expertise and approvals required.

The Monitoring Revegetation Projects in Rainforest Landscapes Toolkit (the Monitoring Toolkit)^[98] describes methods for monitoring vegetation structure and the composition of plant and bird species. The methods were designed to be as simple as possible while still yielding meaningful data.

Plants and birds are often targeted because they are functionally diverse, contain suites of species distinctive to specific habitats, and are responsive to environmental change, making them good indicators of a site’s progress (refer Table 3). They are also relatively well-known and straightforward to sample. Measuring vegetation structure can also indicate progress in a site’s habitat values over time.

Failure to adequately monitor reforestation projects across the Wet Tropics has meant that there have been few opportunities to learn from past successes and failures. Consequently, the data needed to plan and prioritise future landscape restoration is also limited. Dedicated resources are needed for monitoring to better understand how biodiversity values are affected by different forms of reforestation, in different places, and at different stages.

Monitoring vegetation structure and ecosystem services

Forest structure is the overall outcome of a large number of individual attributes, including the density, size and variety of tree stems, their canopy cover and height, the number of vertical foliage layers, shrub densities, the presence of particular plant life-forms (such as epiphytes, vines and hollow trees), the amount of dead wood (standing trees or fallen logs) and the ground cover (for example, the proportions of litter, bare soil, grasses and herbs).^[99,100] It is much easier and faster (and hence less costly) to measure attributes such as these than to quantitatively survey animal and plant communities, or to measure ecosystem processes such as decomposition, hydrology or pollination.

Increased canopy cover is arguably the most useful single indicator of early development,^[101] as is declining grass cover (refer Table 4).^[102] A well-developed tree canopy (more than 70% cover) has important functions of providing habitat for fauna, shading the ground and regulating local climate.^[103] Shady ground, with fallen leaf litter, inhibits the growth of light-demanding pasture grasses and herbs, while creating conditions that suit the germination and growth of rainforest seedlings.^[104] Sites with low grass cover and high canopy cover support high diversities of rainforest fauna. Many other aspects of a rainforest-like vegetation structure develop more gradually (for example, stem size diversity), and are better indicators of progress during mid-stage development, after canopy closure. Some other important attributes, such as tree hollows and large fallen logs, develop very slowly and are therefore most useful when assessing development in the most advanced sites.^[105]

Table 3: Options for monitoring biodiversity values in Wet Tropics reforestation sites

Group	Methods	Utility
Plants	Observational field surveys with laboratory identification of collected specimens.	Plants are stationary and therefore relatively easy to measure and identify in the field. However, rainforest tree species are exceptionally diverse, and their identification requires a high level of expertise and experience. Surveys that target recruited seedlings can indicate a site's future development.
Birds	Observational field surveys such as transects or point counts. Acoustic loggers.	Birds have high diversity in their habitat preferences and are relatively easy to observe making them useful indicators. Acoustic loggers can be left in-situ extending sampling time. However, processing data is time consuming, species identification difficult, and the area sampled by loggers ambiguous.
Reptiles	Observational field surveys (e.g. active searches). Traps placed in the field (e.g. pitfall traps, funnel traps).	Many reptiles have specific habitat preferences and may be easily observed if the weather is suitable, making them useful indicators. Reptiles are expensive and time consuming to monitor with traps. Using traps requires experience, permits and ethics approval and there can be safety concerns with venomous snakes.
Mammals	Observational field surveys (day and night) for animals or their scats (faeces). Traps or other sampling devices placed in the field (e.g. pitfall traps, box traps, hair tubes, camera traps). Acoustic loggers to detect bats in the field with laboratory identification of recorded calls.	Mammals have relatively low diversity in their habitat preferences limiting their value as indicators. They are usually expensive and time consuming to monitor due to the equipment involved. Using traps and hair tubes requires experience, permits and ethics approval. Camera traps and bat detectors are non-invasive and can be left in-situ. However, processing data is time-consuming and species identification can be difficult. Transect searches can be useful for detecting larger mammals such as pademelons, possums, and tree-kangaroos, as can searching for scat.
Invertebrates (e.g. beetles, ants, others)	Extraction from litter. Traps placed in the field (e.g. pitfall traps, light traps, baited stations).	Invertebrates are abundant, diverse and important in ecosystem functioning making them potentially useful indicators of ecosystem change. Sampling invertebrates does not generally require permits or ethics approval on private land. All methods require equipment and time-consuming processing. A high degree of expertise in identification is required and ecological data with which to distinguish habitat preferences is lacking for most invertebrate taxa.

Table 4: Across reforested sites of different ages and types, species richness of rainforest-dependent fauna is associated with a variety of components of vegetation structure

Vegetation attribute		Birds	Reptiles	Beetles
Decreased:	Grass cover	****	***	**
Increased:	Canopy cover	****	****	***
	Tree density	**	**	**
	Large tree density	***	***	*
	Tree height diversity	**	**	*
	Special life forms	**	**	*
	Shrub density	***	**	**
	Woody debris	*	**	**

Data from 35 sites; numbers of asterisks show strength of association (correlation coefficients * $r = 0.40-0.49$, ** $r = 0.50-0.59$, *** $r = 0.60-0.69$, **** $r = 0.70-0.79$). Modified from (z28,z35).

At the landscape scale, the development of many ecosystem services (including those connected with climate modification and water quality) is also strongly influenced by the cover, quality and location of forest. Cover (the percent of land occupied by forest) is the simplest possible measurement for any given forest type. Quality could refer to the baseline type of native forest, or to its state of degradation or recovery (ranging from intact to absent). Measurements of location may include aspects of position (such as along streams or on hills), elevation and context (for example, a site's proximity to, or links with, other forest areas).

These aspects of landscape-scale structure, and their changes over time (refer Figure 5) can be measured using an expanding range of techniques based on remotely sensed imagery (typically either aerial photography or satellite imagery). Informative and publicly assessable imagery is available on the internet through Google Earth, which also can be used to assess historical changes, as far back as the 1980s. For the Atherton Tableland, an integrated 1978 aerial photo coverage can be compared with more recent images via the online e-Atlas.^[106]

Designing projects and tracking outcomes

Learning from current and future reforestation efforts requires a scientifically rigorous approach; one that is structured to provide information about the relative merits and costs of different restoration techniques, and the reasons for these differences. The process involves a combination of project design, monitoring, interpretation of results and their communication, all undertaken by suitably trained personnel.

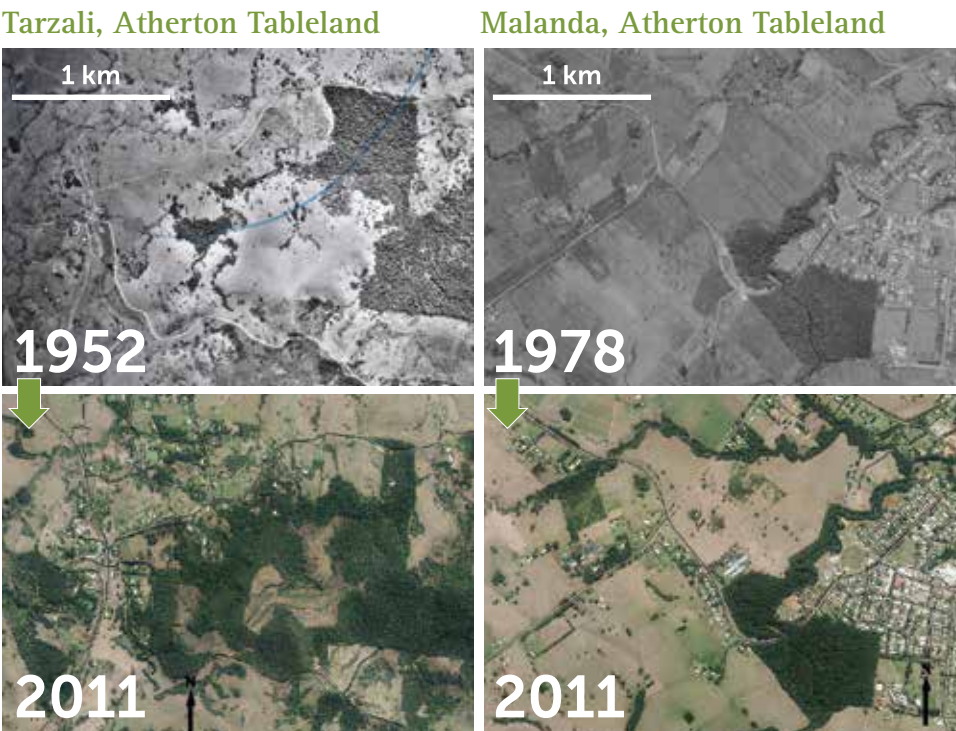
For best results, monitoring needs to be designed into a project before on-ground works commence. Integrating Rainforest Aboriginal Peoples

perspectives on monitoring would give two-way understanding of the outcomes of reforestation.^[107]

Elements include documenting basic information about where a project is located, its area, prior land cover and goals. Resources are required for both field measurements and data management (comprising electronic record-keeping, a central long-term data repository, and the extraction and interpretation of results). Under these conditions, monitoring can yield valuable new insights and information to feed back into improved approaches and management.^[108]

For any method of reforestation, well-designed monitoring can reveal whether outcomes at a given site are on track, together with one or more reference sites that represent the target type of mature forest. Patterns of development over time can be investigated without multi-year surveys, if there are enough sites that vary in the time since restoration actions began. These different-aged sites form a chronosequence, which represents the likely pathway of change over time.^[109]

Figure 5. Changes in forest cover resulting from unassisted regrowth following reduced grazing at Tarzali and biodiversity planting along a stream at Malanda



Scaling up landscape restoration

Planning and prioritising restoration in the Wet Tropics

There are often multiple contesting land use options for a given place in the Wet Tropics. Landscape planning tries to identify ways to integrate multiple land uses (including nature conservation or environmental protection) across landscapes. This often involves consultation across different sectors (e.g. various local government planning schemes, Rainforest Aboriginal Peoples' Country-based Plans)^[110, 111] to understand priorities, complementary and incompatible combinations of land uses, as well as future needs of communities. In the Wet Tropics, landscape planning has also been used to distinguish where in the landscape to target protection measures (e.g. under conservation agreements or acquisition) and where to undertake restoration for biodiversity and ecosystem services.^[112]

Prioritising restoration aims to achieve the best outcomes for biodiversity and ecosystem services. Solutions vary depending on the intended outcome. For example, prioritisation to assist the endangered mahogany glider (*Petaurus gracilis*) emphasises restoration between forest patches in coastal regions around Cardwell, while prioritisation to increase climate refugia highlights cool, upland areas.^[113] Rainforest Aboriginal Peoples cultural values are usually incorporated into prioritisation approaches in Healthy Country or Country-based planning led by Rainforest Aboriginal Peoples.^[114]

Restoration in the Wet Tropics has also been prioritised to achieve ecosystem services benefits at the same time as biodiversity, for example carbon sequestration,^[115] water quality, or coastal protection.^[116]

Principles of landscape ecology are often used to predict where restoration could have the most benefit by building on current spatial patterns of forests. These approaches typically prioritise restoration close to existing forest (e.g. fringing the World Heritage Area) or between forest patches (e.g. corridors along watercourses). However, today's forest patterns ultimately reflect human decisions about clearing or development, rather than biological or ecological importance. Rainforest Aboriginal Peoples hold sophisticated ecological knowledge that may supplement gaps in scientific understanding of species biology or community ecology, and potentially identify other locations where restoration would have particular benefit for biodiversity.^[117]

Whatever the intended benefit or approach, on-ground application of strategic restoration plans depends on practical considerations such as the availability of funds, landholder willingness, purpose (i.e. habitat or

Supporting strategic restoration decisions

In 2017, Terrain Natural Resource Management (Terrain NRM) and Central Queensland University facilitated a participatory workshop with management and planning agencies and people involved in decision-making about restoration. Its aim was to support strategic decisions about rainforest restoration on the southern Atherton Tableland.

They developed an interactive mapping tool to help prioritise restoration that has benefits for forest biodiversity, climate refugia and carbon sequestration, as well as for specific biodiversity values, ecosystem services, and social values. The tool brought together a wide range of spatial layers that combined to generate a total score for each one-hectare unit.

Use of the interactive tool made it easy for decision makers to see the effects of different factors on the prioritisation results, increased understanding of the drivers behind these results and consequently built trust in the tool.^[120]

carbon abatement), community engagement and costs associated with site characteristics such as slope, proximity to water, soil type, weed infestation, fencing and distance to town. Including social values in prioritisation can increase the chances that it will be put into practice.^[118, 119]

Collaborative approaches

There is no shortage of cleared land suitable for restoration in the Wet Tropics, but it is distributed in relatively small parcels among many different land holders and types of land tenure. Achieving landscape-scale restoration must consider the opportunities and constraints associated with these differences, along with the varying biophysical and administrative characteristics of different sites.

Across the Wet Tropics, numerous local community groups and organisations (see Appendix II), independently coordinate forest restoration activities, and educate others. Much of this effort has involved substantial contributions by volunteers, valued at some hundreds of thousands of dollars per annum. Some groups manage nurseries for growing rainforest trees, and volunteers contribute to the work of nurseries run by local and state governments.

Additionally, the processes of monitoring outcomes, developing effective techniques, making decisions about prioritising and positioning projects, and then implementing them on the ground requires coordinated inputs from government, landholders, Traditional Custodians, community groups, practitioners, policy makers, and scientific researchers and advisers.

Therefore, collaborative efforts are an essential part of success in landscape restoration. Collaborative approaches to restoration are most successful when project partners have clear agreed goals and well-established lines of communication, and when they have secure funding and resourcing together with flexible timeframes.^[121,122]

Five questions to ask when future-proofing restoration

The need to restore landscapes is more urgent than ever but the changing climate brings questions and challenges for practitioners.^[123]

1. Should species for plantings be selected for future climate conditions rather than historical conditions?
2. Should planting time be adjusted to avoid the warmest months when seedlings can be lost due to extreme heat?
3. How will seasonal patterns of rainfall be affected, and what effect will that have on the planting season and the need for irrigation?
4. Should more ground cover such as grass and herbs be retained, or sites more heavily mulched, to offset soil loss through heavy rainfall and flood events?
5. Can methods change to ensure plantings are more robust to cyclone damage, given that cyclones will become more intense and be more likely to affect plantings further inland?

Emerging approaches to forest restoration in the Wet Tropics

To increase landscape-scale forest cover, it will be necessary to expand the menu of commonly practised techniques (such as traditional biodiversity plantings) and develop and test less-intensive interventions that can be economically applied over larger areas. Globally, there is a wide range of potential approaches, each of which is suited to a particular environmental situation and site history.^[124]

Developing lower cost techniques

In a technique recently developed in central and southern South America (the neotropics), the number of trees planted per hectare was reduced by placing them in scattered ‘tree islands’—each a small clump of fast-growing trees about 0.5–0.1ha. Such tree clumps act as core foci for further spontaneous recruitment of a wider variety of tree species, causing clumps to progressively expand.^[125,126] This expansion occurs because new forest seeds are imported into tree clumps by frugivorous birds and because conditions in the shady tree islands favour subsequent seed germination and seedling growth. In a similar manner, some plantation forestry areas can develop a diverse understorey of local forest tree saplings if ground vegetation is not suppressed.^[127,128]

Direct seeding

As an alternative to tree planting, direct seeding aims to efficiently deliver sufficient forest tree seeds across large land areas, under conditions where they are likely to survive, germinate and grow. Direct seeding has been extensively and successfully developed for mono-species agriculture and plantation forestry seed delivery by mechanised vehicles (either ground or aerial) may be accompanied by seed burying and/or chemical agents to improve survival and growth.

Seed dispersing birds could also be harnessed to deliver seeds by installing perch structures to attract them. An important limitation is that many seeds and emerging seedlings die due to competition from pasture grasses and herbs, effects of exposure, and consumption by wildlife.^[129] Aerial direct seeding with diverse rainforest species, together with herbicide control of the previous ground cover, has been used to restore Brazilian rainforest, with some success.^[130]

Assisted natural regeneration

Another emerging technique avoids planting any trees by focusing on areas where there is already some natural regeneration of seedling trees which are struggling to grow amidst grasses.^[131] Actions are taken to release these trees from the grass competition, by suppressing or killing the grass, either mechanically or chemically with herbicides.^[132] In older sites, if a mature regrowth tree canopy has developed that consists mostly of non-native or a single native species, a more diverse natural regeneration can be accelerated by removing or killing these dominant trees (often termed ‘bush regeneration’ in Australia).^[133]

Other techniques

A range of techniques to promote forest regeneration have been tested in other parts of the world.^[134] These include targeted management of livestock (in some cases their removal, in others introducing controlled grazing), managing fire regimes and managing wildlife. The latter includes actions to attract seed dispersers or to suppress the small to medium-sized mammals that consume seeds and seedlings. This, in turn, could be achieved either directly or indirectly by encouraging large carnivores that may formerly have been persecuted (‘rewilding’).^[135]

Some of these approaches are still in an experimental stage and have not been widely extended to enable economies of scale. Most also produce slower development of forest ecosystems than is possible through biodiversity planting, and may have a higher risk of failure, especially if inappropriately applied. Nevertheless, there is a pressing need for innovation and development of the most promising alternative techniques for the Wet Tropics.

Non-native trees

Some potentially useful innovative approaches require adopting a more evidence-based approach to managing non-native trees and shrubs, which are often the first to appear in disused agricultural land.^[136] These can facilitate subsequent rainforest regeneration by acting as tree islands or nurse trees, beneath which grow a more diverse understorey of native tree saplings and which may also be used by forest-dependent wildlife.^[137] In other situations, non-native trees may slow further forest development if they form a dense canopy which could slow or suppress the growth of the rainforest seedlings beneath. Understanding and working with this balance is a major emerging challenge in rainforest restoration.

Catalysing natural forest regeneration on disused pasture

The kickstart trials in the Wet Tropics uplands^[138] are a concept experiment begun in 2011. These trials test whether natural regeneration of rainforest trees can be catalysed without tree planting, by killing and suppressing dense pasture grasses in sites adjacent to mature rainforest. These trials are accompanied by monitoring of actions, costs, vegetation structure, seedling recruitment, seed rain and bird surveys.

Initial grass suppression with herbicide sprays stimulated abundant recruitment of non-native wild tobacco (*Solanum mauritianum*), together with some fast-growing pioneer native tree species in the first year. Best native tree recruitment occurred beneath scattered pre-existing trees and shrubs (whether native or non-native), which then developed into progressively expanding multi-species tree islands.

Beneath the wild tobacco trees, a broader range of native trees also recruited over time, but more slowly. Some of these were native pioneers which grew to small trees over the 5 to 10 years, starting new positive feedback cycles of further forest regeneration, while the tobacco trees died back. The overall outcome is a spatial patchwork of more and less-advanced forest regeneration. The estimated establishment cost per hectare is 25%–30% that of biodiversity tree planting.^[139]

Figure 6. Adaptively-timed repeat selective herbicide application



Developing the restoration industry

Several factors support expansion of the landscape restoration industry in the Wet Tropics region. First, its warm climate and high rainfall promote fast tree growth. Next, with relatively high unemployment there is a need for more jobs. Most importantly, there is much that landscape scale restoration can do to protect the natural values and therefore the economic values of the region.

Around 54,000ha of land in the Wet Tropics is estimated to be of poor agricultural quality (14,403ha), over 20% slope (9,649ha) or along a waterway (30,072ha).^[140] Most of this is private tenure. Landholders are finding an increasing array of opportunities to cover costs or profit from reforestation on this land.

Carbon credits

Options are emerging to generate revenue from reforestation by the sale of carbon credits. In the Wet Tropics region, a range of organisations including Green Collar and GreenFleet work with landholders to engage them in carbon markets. However, at current carbon prices, carbon farming may only provide a supplementary income stream where low-density tree planting is combined with other land uses.^[141]

Field data from the Wet Tropics has shown that the methods used in the Commonwealth Government's National Carbon Accounting System do not adequately represent the amounts of stored carbon in this region's forest restoration sites because it is based largely on data from non-tropical areas.^[142]

Projects that restore native vegetation cover in the Wet Tropics region deliver significant social and environmental benefits as well as rapid carbon sequestration. The Queensland Government's Land Restoration Fund seeks to price in environmental and social 'co-benefits' by paying a premium over and above the carbon credits generated by funded projects. Some other developing ecosystem service market models also offer payments for biodiversity benefits, for example the Cassowary Credits scheme.

Corporate social responsibility

Expanding interest in corporate social responsibility offers further potential to fund and support landscape restoration in the Wet Tropics. A growing number of businesses are demonstrating their social and environmental credentials by investing in projects that offset their carbon footprint and deliver social and biodiversity benefits.

Nursery capacity

The Wet Tropics Management Authority's recent survey of nursery capacity estimated the region's annual production of seedlings for biodiverse plantings at 300,000 to 400,000 with most seedlings produced by conservation organisations and local governments. Most nurseries have the space to produce more seedlings, and it would be possible to double

Developing an environmental market for restoration: Cassowary Credits

Terrain Natural Resource Management (Terrain NRM), supported by the Queensland Land Restoration Fund, has been working with regional technical experts, potential participants (e.g. landholders), Rainforest Aboriginal Peoples and organisations representing potential investors (e.g. GreenCollar, EcoMarkets Australia) to design a new, voluntary market-based scheme to attract investment in biodiverse rainforest restoration across the Wet Tropics. An initial feasibility study of a Cassowary Credit scheme was conducted in 2019–2020 and work continues with market testing and refining methods for measuring and crediting restoration.^[143]

The Cassowary Credit scheme is designed to attract very large investment in restoration of rainforest across the Wet Tropics, delivering benefits for biodiversity, regional communities and Rainforest Aboriginal Peoples. The scheme targets restoration in areas classified as rainforest and scrub. The southern cassowary (*Casuarius casuarius johnsonii*) is being used as a flagship because it has a large geographic distribution across the bioregion, is a widely recognised, iconic species and plays a crucial role in seed dispersal and forest regeneration. Methods for calculating Cassowary Credit earnings needed to be credible and evidence-based to inspire confidence in investors but also simple to implement to avoid prohibitively high participation costs. In order to foster high rates of participation by landholders, the current scheme design also includes methods that deliver returns (i.e. credits) that reflect the real costs of biodiverse restoration and deliver these early to cover the high up-front costs of restoration.

Preliminary analyses are promising in terms of the ability of projects to generate Cassowary Credits in the first 1 to 5 years. Since carbon accounting methods tend to generate credits comparatively slowly, projects that are registered as both carbon farming and Cassowary Credit projects could potentially earn income over a sustained period.

annual seedling production in the region if nurseries had additional staff.^[144] Businesses responding to the survey indicated they could increase seedling production substantially in response to increased demand.

Various government schemes such as the Green Army (2014–2018) temporarily boosted the number of workers in landscape restoration projects in the Wet Tropics. This additional staffing has been useful for the projects in which trainees have been deployed but their participation has generally not translated into permanent employment in the sector.

This is expected to change as developing carbon and ecosystem services markets expand landscape restoration-related business opportunities for landholders, conservation organisations, restoration practitioners and allied services.

Conclusions

With the increasing challenges of climate change, it is not enough to protect and manage what is left of old growth forest. Efforts must be increased to repair past damage, increase coverage by encouraging regrowth, and subsequently bolster resilience of both natural ecosystems and human communities.

Successful reforestation can improve species populations and enable their movement. It can store carbon, help regulate local climate and precipitation, regulate stream-flows and water quality, reduce streambank and coastal erosion.

It can also improve crop production through pollination and pest control, and contribute to community income, employment and wellbeing.

This report has focused on the ecological and socio-cultural barriers facing restoration, the methodology of reforestation and its various merits, how to grow evidenced-based reforestation practices, how to reduce costs, and importantly how to increase the practice of landscape-scale planning by using a combination of reforestation approaches.

Clearly, in the Wet Tropics region, areas of policy, innovation, monitoring and evaluation, and existing funding models need review, revision and expansion.

The continued reliance on the vital work established by community groups and volunteers is not sustainable. A collaborative approach for landscape scale reforestation is needed. If we are to grow the reforestation industry and meet and mitigate future climate challenges, this must include the voices of local, state and federal government planners and agencies, Rainforest Aboriginal Peoples, landholders, environment groups, researchers, scientists and the community.

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Appendix I

Land and Sea Ranger Operations in the Wet Tropics region (as at September 2021)

Ranger operation	Location/Traditional Owner groups	Host organisation
Yuku Baja Rangers	Archer Point/Cooktown surrounds/Yuku Baja Muliku people	Yuku-Baja-Muliku Landowner & Reserve Ltd
Jabalbina Rangers	Mossman to Wujal Wujal/Eastern Kuku Yalanji people	Jabalbina Yalanji Aboriginal Corporation RNTBC
Djabugay Bulmba Rangers	Mona Mona and Kuranda/Djabugay speaking people	Buda:dji Aboriginal Corporation
Dawul Wuru Rangers	Cairns to Port Douglas/Yirrganydji people	Dawul Wuru Aboriginal Corporation
Dulabed Malanbarra Yidinji Rangers	Goldsborough Valley and Gordonvale region/Dulabed and Malanbarra people	Dulabed and Malanbarra Yidinji Aboriginal Corporation RNTBC
Girringun Rangers	Ingham to Mission Beach including hinterland areas west to Mount Garnet/Nywaigi, Gugu Badhan, Warrgamay, Warungnu, Bandjin, Girramay, Gulnay, Jirrbal and Djiru peoples	Girringun Aboriginal Corporation
Djubunji Land and Sea program	Trinity Inlet, Greys Peak National Park/Mandingalbay Yidinji people	Mandingalbay Yidinji Aboriginal Corporation RNTBC
Gunggandji Rangers Yarrabah	Gunggandji people	Gunggandji Aboriginal Corporation RNTBC

Appendix II

Examples of groups and organisations active in reforestation in the Wet Tropics. (*Indicates nursery capacity)

Community Groups

Cairns Urban Landcare*

Community for Coastal and Cassowary Conservation (C4)*

Kuranda Conservation Community Nursery Inc.*

Kuranda Envirocare*

Terrain Natural Resource Management (Terrain NRM)

Tree Kangaroo and Mammal Group (TKMG)

Treeforce Association Inc.

Trees for the Evelyn and Atherton Tablelands (TREAT)*

Yungaburra Landcare Group Inc.

Catchment and Landcare groups

Barron River Catchment Management Association Inc. (BRCMA)

Holloways Beach Coast Care

Johnstone Landcare and Johnstone Catchment*

Malanda and Upper Johnstone Landcare (MUJL)

Mulgrave Landcare and Catchment Group Inc.

Russell Landcare and Catchment Group

Local Government Authorities

Cairns City Council *

Cassowary Coast Regional Council*

Douglas Shire Council*

Hinchinbrook Shire Council*

Tablelands Regional Council*

State government agencies

Queensland Department of Environment and Science (includes Queensland Parks and Wildlife Service and Partnerships*)

Wet Tropics Management Authority

Research and educational organisations

Commonwealth Scientific and Industrial Research Organisation (CSIRO)
Griffith University
James Cook University
The School for Field Studies
The University of Queensland

Philanthropic/not for profit organisations

Rainforest Conservation Foundation*
Rainforest Rescue*
South Endeavour Trust

Industry, business and innovation (^Aboriginal organisations)

Abiculture**
Biome5 Pty Ltd
Biotropica
Brettacorp Inc.*
Conservation Volunteers Australia*
Jarragun Ecoservices**
Native Conifer Carbon Sink Pty Ltd
North Queensland Land Management services
Girringun Aboriginal Corporation **
Greening Australia*
Rainforest Reserves Australia*



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The Wet Tropics Management Authority is able to undertake its work in the Wet Tropics of Queensland World Heritage Area with the assistance of the Australian and Queensland Governments.