REIGN OF FIRE

With recent strides made in understanding the complex ecological cycles of our rainforests, scientists are now better aware of the severe effects of both climate change and creeping development on forest ecosystems. **Julian Cribb** reports on a growing call for an urgent change to management thinking and practice for rainforest areas.

Researchers expect climate change to dry rainforests out, making them highly susceptible to intense, devastating fire. Rainforest fragments now cover just 0.3 per cent of the country.
CSIRO Tropical Forests Research Centre

Most devastating of all the foes of the rainforest is fire. Each year through human action, intentional and unintended, fires obliterate huge areas of the world's remaining rainforests.

And, in a subtle interaction which has scientists deeply concerned, global warming is quietly stoking the fires. As the climate warms, El Niño events become more intense and more frequent, bringing with them the droughts which turn moist forests to tinder.

Researchers at the Australian Rainforest CRC have identified a more disturbing signal still. Rainforests are typically vast sponges for the CO_2 that is driving global warming. Investigations using a flux tower located in lowland tropical rainforest suggest that, under in normal conditions, a hectare of Australian tropical rainforest pulls around 31 kg of carbon out of the atmosphere every day.

But when conditions turn dry, says the CRC's Deputy CEO, Dr Steve Turton of James Cook University, the forest 'flips' and becomes a net carbon emitter, each hectare liberating around 12 kg a day – equal to a small car – as moisture-stressed trees close their stomata and cease to absorb carbon from the air, and the CO_2-emitting microbes in the forest litter remain active. Just what this means for global warming is not yet clear but the possibility exists that more frequent droughts will cause the forests to shed more carbon which will, in turn, fuel climate change, leading to further droughts, fires and carbon release.

It is this intimate linkage of forest, atmosphere, biodiversity and human activity that is the focus of Australian rainforest science, as researchers grapple with a vast and complex system. Spurred by the smoke clouds that blanket the ruined forests of Sumatra, Borneo and the Amazon, there is an acute sense that time is running out for us to fully understand what is going on, and what needs to be done if even a fraction of the world's tropical rainforest is to be saved.

Once, fire was largely kept at bay by the forests: their wet microclimate and rapid decomposition of litter left little for fires to work with, Dr Turton says. The great change came about as humans began to drive roads through the forest for logging and clear large areas for farming. Every road was a highway of death, bringing not only logging trucks but also the hot, sere winds that prepared the way for fires.

'When the rainforest is fragmented, it is much more vulnerable to 'edge effects' – drying, invasions of pests and weeds, human activities. The more fragmented it is, the more it dries and the greater the risk of fire,' he says. Unlike sclerophyll (fire-tolerant) forest, rainforest trees are notably poor at regenerating after a fire, and those only lightly scorched often die.

On a map, Australia's tropical rainforest appears extensive and intact, covering some 750 000 hectares

Looking up at the Australian canopy crane, which has been a boon to researchers' understanding of the higher rainforest ecosystem.
Rainforest CRC/Birgit Kuehn

from Douglas Shire in the north to Hinchinbrook on the central north Queensland coast. (It is estimated that some 210 000 hectares has been cleared since European settlement.) In reality, the remainder is carved through and through with 1427 km of roads and 324 km of powerline clearings, as well as railways, phone lines, gas and water mains, tourist trails and former logging tracks, every one of them an invasion route for fire, weeds, feral animals, diseases, roadkill, noise and other forms of pollution. Roads themselves may directly impact only two per cent of the forest area – but their effects touch up to 20 per cent, Dr Turton warns.

Fracturing the forest and occupying the richest soil is a century of agriculture, to which runaway urban, infrastructure and tourist development is adding its own, more recent, impacts.

Understanding how to maintain a sustainable forest in the face of this battery of assaults, from the local to the global, represents an extraordinary scientific challenge. Fragmentation is already so widespread it seems almost impossible to reverse and the 650 hectares of tropical rainforest that has been restored with great care and labour in recent years seems like a sandcastle set against the tide. For a while managers and the public consoled themselves with the thought that reserves would save representative fragments of forest in perpetuity, but the scientific evidence is already amassing that this hope is over-optimistic.

This is illustrated in the work of CSIRO's Dr Dave Wescott and Dr Andrew Dennis into tree 'seed shadows', which has revealed that more than 65 species of birds and animals are involved in distribution the seeds of rainforest plants, hundreds of metres and even kilometres from the original tree.

The pattern in which seeds are distributed is known as a 'seed shadow', Dr Westcott explains – and is one of the major processes which govern the fate of the forest. The others include water flow, nutrient cycling, predation and competition – all in their way affected by fragmentation and edge effects. This Australian research is believed to be the first time scientists have attempted to describe seed dispersal in all its complexity at the landscape scale.

'In fragments of rainforest, we find there are far fewer animal species to disperse the seeds,' Westcott explains 'Some trees have their seeds dispersed and others don't, so the mix of trees in the forest also changes.'

'As a result, rainforest fragments don't regenerate in the same way as intact forest. Over time, the number

The Ulysses butterfly, *Papillo ulysses josea*, is a north Queensland rainforest icon. Its range extends from Cape York to Mackay.
CSIRO Land and Water/Willen van Aken

Rainforest CRC researcher, Dr Steve Turton, of James Cook University's Cairns Campus, checks carbon flux equipment attached atop the canopy crane. His team's work has discovered that forests are likely to become net emitters of CO_2 under hotter conditions.
Rainforest CRC/Birgit Kuehn

and diversity of trees declines. This suggests that in the long-run, fragmented reserves will not be effective in conserving the forests in a state with which we are currently familiar.'

'The point we need to grasp is that rainforests are dynamic. They shift constantly, in space and time. This process is vital – especially when the environment is changing round them. If we humans interfere with it, then it will imperil the forests' future survival.'

Among the first trees to suffer when the rainforest fragments are those with large seeds, he says. These require sizeable birds and animals to disperse them – and these dispersers are often the first to forsake the fragmentary forest patches. As a result the patches become simplified over time, losing their large-seeded trees as small-seeded species take over.

In some cases, he says, this can result in a catastrophic loss of the biodiversity which makes up the rainforest. To overcome it, Dr Westcott suggests, it will be necessary to think beyond the system of reserves, and make allowances for the natural tendency of forests and their species to move in space and time.

Scientists expect that climate change will exacerbate the vulnerability of reserves. In a recent, influential report to the Queensland Government, the Rainforest CRC issued a grave warning about the consequences for rainforest biodiversity. If trapped within geographically static boundaries, the forest will be unable to colonise the new ecological zones that open up under climate change, as it has for eons.

The consequences include deterioration of ecosystem function – as forests are forced to subsist in less than ideal climatic conditions – and the contraction of ideal habitat for a wide array of species. This effect is highlighted by the plight of the Bellenden Ker nursery frog, *Cophixalus neglectus,* one of several species isolated in cool mountain-top forests with no means of reaching similar havens: a one degree average annual warming is expected to eliminate its ecosystem. Current forecasts suggest the tropics may warm by between 1.4 and 5.8°C by 2100.

The effects of climate change on the forest will have a direct impact on society, the report warns. As it declines, so too will its 'ecosystem services' – the filtration and purification of water, the retention of nutrients and soil, the prevention of floods and the preservation of native species throughout the landscape. This effect is already strongly marked in the damage to the 750 inshore reefs of the Great Barrier Reef and loss of tourism amenity from 14 million tonnes of sediment, 49 000 tonnes of nitrogen and 9000 tonnes of phosphorus that annually runs off the land as a result of forest clearing and human activity.

The report identifies several classes of country as being at especially high risk of biodiversity loss under climate change conditions. The first is the arid and semi-arid western fringe of the forest, already a marginal habitat and highly susceptible to fire and other disturbances. The second is the dense vine thickets which resemble most people's ideas of a rainforest, and which are highly susceptible to fire in particular. Third are the cool mountain-top regions which seem fated to lose their microclimates altogether as warm conditions seep gradually upwards. Fourth are wetlands, river systems and riverbanks which are especially at risk from clearing activity followed by floods.

The report also warns that high temperature extremes expected under greenhouse conditions may also lead to deaths and possible extinction for some species, such as the cool-adapted mountain possums.

The researchers called for urgent actions to address the challenge, including:

- an end to clearing of rainforest
- strategic land acquisitions which allow forest to regenerate according to the dictates of changing climate
- greater effort to conserve forest outside reserves, and to link reserves together across the landscape
- protection of regrowth vegetation

Right: Cassowaries are one the rainforest ecosystem's crucial large seed dispersers.
CSIRO Land and Water/Willen van Aken

Far right: The fringed tree-frog, *Litoria eucnemis*, occurs in the wet tropics rainforest of far north Queensland.
Alex Thomas

- recovery plans for endangered species, including the establishment of DNA banks
- better fire and water management
- on-ground monitoring of biodiversity.

Recognising that it will take time for such proposals to be adopted and implemented in the higher echelons of government, the Rainforest CRC is already turning its findings into specific local actions. These form the core of the new Regional Natural Resource Management Plan for the Wet Tropics – a complete manual, updated with state-of-the-art science – for how to live sustainably in the wet tropics.

'No NRM plan in Australia has this level of detail,' exclaims Rainforest CRC CEO, Professor Nigel Stork. 'It takes in the whole biosphere, from top to bottom. It shows government where it needs to invest – and what results it can expect to achieve.'

'There are a whole lot of things we can do about sustainability in the tropics by getting all landholders doing their bit on their place.'

A particular feature of the plan is its focus on preserving human culture, as well as natural ecosystems. An entire section deals with ways to protect and sustain Indigenous rainforest cultures, whose knowledge of the forest and its species extends back tens of thousands of years. Some 100 Aboriginal tribes from 18 tribal groups, representing 20 000 individuals are now working with the Wet Tropics Management Authority through the newly formed Aboriginal Rainforest Council, in what is widely regarded as a first for engagement of Indigenous people in the future care and management of a region.

The work of rainforest science extends far beyond the forest itself. In recent time one of the most enthusiastic adopters of its findings have been farmers and graziers, anxious to control the runoff, soil and fertiliser losses that clearing and agriculture can generate.

'We now have a proven approach for putting property planning on a business footing,' says CSIRO's Professor Brian Roberts. 'There are a whole lot of things we can do about sustainability in the tropics by getting all landholders doing their bit on their place.'

The new approach starts with intensive mapping of land capability, so farmers know what can and cannot be done with it. Catchment plans are then drawn up on the basis of soil type, and these are converted into individual property plans. Researchers and advisers then help the farmer to choose the right mix of indicators from which to assess the effectiveness of their measures, and set practical, achievable targets.

These may start with straightforward measures of soil and nutrient loss, Professor Roberts says, but then extend to more subtle measures such as biophysical stream health or stream bank vegetation health. Such advice is now readily accessible to farmers in guides such as *Keeping it in Place*, a manual for controlling erosion on grazing properties in the Burdekin catchment, developed by CSIRO, Queensland Primary Industries and Fisheries and Meat & Livestock Australia. Similar advice is available for sugarcane and other farmers.

Apart from helping farmers to manage their own

The submarine in the sky

Hanging over the green billows of the rainforest canopy like a giant steel wading bird, the canopy crane at Cape Tribulation is to rainforest science what the deep-sea submersible is to marine exploration, the dish array to radioastronomy or the hadron collider to particle physics.

The crane allows scientists to venture into a new dimension in the exploration of Earth: the real life of the forests which takes place far above the ground, where trees meet the clouds and biology looks very different from ground level.

Researchers have been shinning into trees for decades – at some personal risk and discomfort – but the canopy cranes have exposed the intimate life of the forest at a level of detail and complexity never possible before. Twelve of them now tower above the world's forests.

The 47-metre Australian crane is a platform for spellbinding new insights into the life of trees, arboreal animals, birds and insects, the forest as an organism and as a vast reciprocating engine linking the atmosphere and earth.

It enables the detailed study of a cylindrical region of forest 110 metres in diameter and 40 metres high. This takes in more than 80 tree species in a region once damaged by a cyclone, where the forest is renewing itself.

Suspended in their gondola, investigators can plunge into the canopy like divers to take readings, collect samples and monitor equipment with an ease and freedom denied to rope-bound research.

The crane is playing its part in breakthrough insights into rainforest function and biodiversity, says Rainforest CRC CEO, Professor Nigel Stork, whose own entomological studies have found more than 1500 beetle species in the canopy and on the ground beneath. Of these, he says, probably half or more are new to science.

'The crane is our equivalent of a deep-sea submersible. Before such vehicles came along, we had a very constricted view of what we were studying. We are completely revolutionising our understanding of how forests function and what is in them.

'In order to understand rainforests, we desperately need this information about the canopy. We still know next to nothing about its insects and microbes, its carbon and water fluxes, its interactions with the atmosphere.'

In work by Griffith University's Professor Roger Kitching, the canopy crane has provided new insights into the complex processes of pollination – knowledge vital if rainforests are to be protected or re-established.

Researchers use the gondola of the canopy crane to sample life at the top of the Daintree rainforest. Rainforest CRC/Michael Cermak

Right: The caterpillar of the spectacular Hercules moth, *Coscinocera hercule*, found in the rainforest of northern Queensland and New Guinea. Measuring up to 27 cm, it is one of the largest moths in Australia.
CSIRO Entomology

landscapes and restore native vegetation along stream banks, around wetlands and by creating links between isolated patches of native forest, such advice is also bringing about a rapid rise in individual and industry consciousness of the plight of the rainforest itself and a wish to do something about it, Professor Stork says. However, noting the sudden eruption of the canal development phenomenon in the tropical north, he acknowledges there is still a long way to go before such views are widespread in the community, especially the cities.

'One of the messages we have taken to heart is that people don't want science – they want knowledge they can use,' he says. 'So knowledge brokering has become a critical role for rainforest scientists – as much as actually generating the science in the first place.

As the only developed nation with a significant area of intact tropical rainforest, Professor Stork argues that Australia has an opportunity – and some say a duty – to lead the world not only in rainforest science, but it its application and adoption. A large part of the CRC's work has focussed on opportunities to do just that, and to build new industries in areas such as plantation agroforestry, eco-friendly tourism and bush foods.

'There are currently three billion people living in the world's tropics, who are in need of the sort of knowledge which we are generating in Australia. By the middle of this century there will be close to six billion – equal to the total world population at present.

'This suggests there is not only an urgent need to understand and solve our own challenges in living sustainably in the tropics – but also that we work now to help devise solutions that will assist others to do so.'

Professor Stork contends that sustainable tropical knowledge, the offspring of rainforest science, will become one of Australia's most promising new exports by the end of the present decade.

In time, he hopes, this knowledge industry will come to distinguish the north of Australia in the eyes of the world as much as its rainforest and reef on which it is founded do today.

More information:
CRC for Rainforest Research: www.rainforest-crc.jcu.edu.au
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