RAINFOREST

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DISPATCHES FROM EARTH'S MOST VITAL FRONTLINES

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In the spring of 1990 Friends of the Earth placed an advertisement in *New Scientist* magazine inviting applications to lead the organisation's tropical rainforests campaign. I'd done some campaign work with the International Council for Bird Preservation (now BirdLife International) trying to save the world's most threatened parrots from extinction, had a couple of science degrees and a passion since childhood for wildlife. It seemed like the job me, so I applied. To my delight I was offered the role and six weeks later reported for duty.

Friends of the Earth operated out of a shabby office building in a then run-down part of Shoreditch, close to the City of London. It was a 1950s building, built on a V2 bombsite amid a row of Victorian warehouses. It struck me as a fitting location from which to wage the campaign for these wonderful ecosystems. First thing that Monday morning I met my new team to talk about strategy and where we needed to focus our efforts. There were boxes of papers everywhere, covering every conceivable subject linked with tropical forests. I was told how the archive was organised and how it was maintained. Then my new boss, Campaigns Director Andrew Lees, took me up onto the roof to tell me roughly what he had in mind.

Andrew was a charismatic and gritty figure, oozing fighting spirit. He smoked cigarettes and consumed a large mug of sweet black coffee while giving me a precis of the campaign to date, and where he thought it should head next. He wanted to raise political pressure for more action and that would come from a combination of research, media coverage, lobbying and public backing for our goals. These included ending unsustainable tropical timber imports to Europe, changing the policies of the World Bank (which had funded a lot of tropical forest destruction) and altering the practices of multinational companies, such as those in the oil and gas sector that were entering indigenous territories in the Amazon. There was also an ongoing campaign on Third World debt, which had been identified as one of the underlying economic drivers of the problem.

We'd need to raise the money to do all this, he explained, and build up the capacity of the Friends of the Earth International network, so that campaigners in the rainforest countries were better equipped for the epic struggle that lay ahead.

'Is that all?' I said. 'No,' replied Lees. 'But it's enough to be getting on with.' 'I'd better get started then,' I said, and so began my career as a campaigner for the tropical rainforests.

I've been at it ever since.

* * *

Back in 1990 awareness about the plight of the tropical rainforests was growing fast in relation to the threats to indigenous people and wildlife, especially across the Amazon. There, native societies were being driven into oblivion, their languages, culture and ways of life being lost forever, and so too were many species of animals and plants, including untold numbers still to be described, haemorrhaging into extinction right before our eyes.

There was far more limited awareness of the rainforest's hugely important role in combatting climate change (a phrase then yet to reach general currency), through the absorption of carbon dioxide. A few months after I joined the team we issued a report on the scale of climate-changing emissions caused by deforestation. Having worked with leading climate change and deforestation experts, our estimate was that about a fifth of emissions were then being caused by tropical rainforest destruction – a figure confirmed later by better-resourced research agencies. The report got hardly a mention in the media.

And there was even less popular knowledge – or indeed much available scientific research – of the role of the forests in replenishing oxygen, or driving the circulation of fresh water, and how deforestation in South America might impact on the frequency and intensity of droughts in places as far afield as North America's Great Plains, Africa and Europe. In short, we didn't know the half of it. Rainforests were far more important than we had imagined.

What we did know, though, was that rainforests were already in crisis. The scale of forest loss in some regions was already extreme, in south-eastern Brazil and West Africa, for example, and was indicative of what could soon lie ahead for other tropical rainforest regions. During the 1970s scientists had for the first time begun to compile comprehensive data sets on forest losses and in 1981 the UN published its findings in its first Tropical Forest Resources Assessment Project, detailing the huge scale of forest loss then taking place. In 1990 a more sophisticated analysis using satellite data estimated that the compound rate of tropical forest loss was running at nearly 1 per cent per year.

That trend, if it remained static, would see the disappearance of all of the tropical forests within a century. There was a real sense of urgency, increasingly high stakes, and with that a huge responsibility to succeed. In the way of success, however, lay some very deep challenges. Not least of these were the rapidly growing populations of many rainforest countries and the related need, as many political and business leaders saw it, to expand economic growth so as to help ensure the expanding numbers of people didn't live in poverty.

Against this backdrop my Friends of the Earth predecessor Charles Secrett had in 1984 launched the world's first campaign to slow down and halt the destruction. In the pages that follow I tell the story of the battle for the rainforests, what I have seen at the frontlines, what has worked and how progress has sometimes been made. We start, though, with more on why these rainforest ecosystems are so important and extraordinary, and the crucial roles they play in the rise of truly twenty-first-century challenges – water security, climate change and conserving the Earth's staggering natural diversity.

Tony Juniper, Cambridge, 2018

PART ONE

EARTH`S MOST VITAL SYSTEMS

1 RAINFOREST – A CLUE IN THE NAME

How tropical rainforests make clouds and recycle water, sustaining farming far away from where they stand

If there is one factor that unites the diverse set of ecosystems we call tropical rainforests, then it is rain. This seems obvious. Rainforests take their name from the fact that a lot of rain falls upon them. But it is vital to know that they can also create it, and not only that, but help to move it far away from where the rainforests themselves are. The whole cycle is powered by photosynthesis, and how rainforests pump water into the air as part of the process of converting the sun's energy into chemical energy. In many rainforests it is possible to see them doing this on an almost daily basis.

I've observed this for myself a number of times, including on a trip to the Amazonian lowlands of Peru, sitting on a ridge looking toward the green expanse of a rainforest canopy close to the steep slope of the Andes. There I watched for a couple of hours the effects of the sun beating down on the sea of trees that stretched far into the distance. Birds flew back and forth, monkeys called and insects buzzed, and behind all of it a fundamental process took place. As solar radiation powered photosynthesis in the trillions of leaves held aloft on that canopy of trees, so they released more and more moisture until the sky above gradually turned from clear blue to hazy blue, and then grey. The moist air rose and condensed and the outline of trees on the distant higher slopes blurred, as cloud and forest seemed to become one. And this fusion between trees and atmospheric moisture was not just an impression. For when the clouds that evening discharged their loads of rain from beneath a dark crashing thunderstorm, the water would not only run down rivers in the rainforest, but also back up the stems of the trees, to emerge once more through those solar-powered leaves, and again flow into the atmosphere.

The first writer to suggest that there were connections between forests, the humidity of the atmosphere and climate was the German naturalist Alexander von Humboldt, who explored the Americas during the early 1800s. He saw rainforests while travelling along the Orinoco and the Casiquiare, the latter linking with the Rio Negro in the catchment of the Amazon, thereby connecting these two vast river systems.

At a time when knowledge was increasingly sought through more and more specific scientific disciplines, von Humboldt was a rare thinker who took the wider view, looking at the whole system as well as the individual species or components, such as trees or animals. He believed that the Earth was one great organism within which everything was connected and that the forest was a complex system, based not only on interactions between the many hundreds of thousands of distinct lifeforms that comprised it, but also with the atmosphere and water. He saw how forests released humidity into the air to form clouds, and then rain.

Despite von Humboldt's equatorial observations leading him to see the fundamental connections that exist between forests, clouds and rain, the phrase 'tropical rainforest' was first used only about a century later, in 1898, by a German botanist called

Humid air rises over a tropical rainforest, Tambopata-Candamo reserve, Amazon, Peru (TM)

Andreas Schimper. It took half a century more before Schimper's phrase (*tropischer Regenwald* in his native German) entered mainstream use, triggered by the publication of Paul Richards' 1952 book *The Tropical Rain Forest*. In the wake of Richards' work came a long-running debate among botanists, geographers and ecologists as to the definition of a rainforest. Generally speaking it was taken to be forest receiving more than 200 cm (80 inches) of rain or condensed mist per year, with that more or less spread throughout the year. Many humid tropical forests were included in the category, even though for some part of the year they had less rain or mist.

As time has gone by we've had more and more opportunities to gain a practical appreciation of how tight the connections between forests and rainfall often are. Take, for example, the 3,000-kilometre-long rabbit-proof fence built across the interior of Australia in 1907 to control rodents that had by then taken on plague proportions. On the side of the fence where the native vegetation remained, abundant cloud formed, whereas on the side with millions of rabbits, grazing animals and crops, the skies were clearer and there was less rain.

The recycling of water back to the air via vegetation is the result of a process called transpiration. On the underside of leaves are tiny pores that open to enable carbon dioxide to be extracted from the air. When plants do this, then through those same pores they lose water. As water is lost from leaves, so more is drawn up from the forest floor, through bundles of tiny tubes called xylem. These connect leaves all the way down to the microscopic hairs at the end of the roots.

There is no heart or other pump to push the water up and it moves from the soil and up to the leaves, including those on the ends of twigs, 50 metres up, via suction. As water is pulled up to the top of the tree via what are the equivalent of very long narrow straws, more is brought up from below, carrying the dissolved nutrients that are needed in the solar-powered manufacture of the molecules necessary for growth and reproduction. Water pressure inside the bundles of tubes is up to about fifteen times that of the atmosphere. When water reaches the tiny pores on the underside of leaves, the sudden reduction in pressure means the water can become a gas – water vapour.

Alongside water vapour the trees discard another gas – oxygen – a by-product of plants using sunshine to split water so as to get hold of the hydrogen they need to make sugars. Of all the oxygen released on Earth through photosynthesis, the tropical rainforests contribute about 20 to 30 per cent of the total; most of the rest comes from photosynthetic plankton in the oceans.

Photosynthesis goes faster in brighter light, causing leaves to open their pores wider to permit the entry of more carbon dioxide while at the same time letting more water vapour out. Water also flows out more quickly when it's warmer, and when it's windier. So long as there is a lot of water, as there generally is in a tropical rainforest, the plants can avoid the wilting effects that accompany water scarcity.

Those thin green leaves to which most of us pay hardly a second thought are thus not only manufacturing complex organic molecules using sunshine, water and carbon dioxide caught from the atmosphere, but also releasing life-giving oxygen and water that makes new rain. When it comes to that latter function, the most extreme example of the synergy between vegetation and moisture is seen across the vast block of tropical rainforests that lie in and around the Amazon basin.

Amazon: the Earth's largest freshwater system

Stretching for thousands of kilometres from the Atlantic Ocean on the eastern side of South America to the slopes of the Andes in the west, the Amazon basin is the world's largest freshwater system. Rain falling on the Andean mountains on the western side of South America is recycled several times after it first fell on the far side of the continent, where clouds roll in with moisture evaporated from the distant Atlantic. Even though it is in the tropics, some of the water falling on the high Andean slopes does not do so as rain, but as snow.

From December to May there is an annual melt that usually coincides with torrential rains over the forests. When this happens the depth of the Amazon's main river channel increases by between about 9 and 14 metres. Huge tributaries back up and vast areas are inundated, creating a particular kind of flooded rainforest called *várzea*. During February and March, when the water is at its deepest, it is possible to glide in a boat through the forest canopy. The huge slow-flowing swamp that is the result is the habitat of a range of specialist animals, including huge fish. During this wetter season, an area of forests bigger than New Mexico (around 350,000 square kilometres) is under deep water, with the main channel swelling to some 40 kilometres across. Even during the dry season the main river in its middle reaches is still about 11 kilometres wide.

The *várzea* is but one component in a complex system, whereby the trees and water work in concert. At over 6,000 kilometres from source to sea, the Amazon basin river system drains nearly half of South America, a catchment of more than 7 million square kilometres. From streams arising on the slopes of the Andes to the sparkling rivulets flowing beneath trees in the forests, the capillaries drain into rivers that eventually aggregate into massive veins such as the Rios Negro, Madeira, Purus, Tapajos, Xingu, Caquetá and Putumayo, which in turn fill the great vena cava of the Amazon itself, that each day discharges some 15 billion tonnes of freshwater – all of which first fell as rain – to the Atlantic Ocean.

During the course of a year the Amazon system moves about one fifth of all the freshwater travelling in all of the Earth's rivers. Where this vast continental river reaches the sea, its mouth is over 325 kilometres wide – greater than the distance between London and Paris – projecting a vast plume of freshwater hundreds of kilometres out into the Atlantic. So huge is the river that ocean-going ships can navigate inland to Peru – around two thirds of the way up toward its source. The Amazon system is connected from end to end not only by water and shipping, but also wildlife, including a species of catfish that makes an annual migration in the headwaters on Andean slopes all the way to its mouth and then back again.

The rivers will of course only maintain flow so long as the rain continues to fall from clouds. That in turn depends on a supply of new water getting into the air and to the slopes of the Andean mountains. As might be expected, the proportion of water entering the air from leaves, rather than that evaporated from the surface of the ocean, increases with distance from the Atlantic, and with increasing distance from the sea, so the importance of the forest in maintaining rainfall goes up.

Why the rainforest is like a green ocean

In the tropical rainforests, where the organic green engine of photosynthesis hums at high speed, a single large tree can pump up over a thousand litres of water per day from the soil to the air, and in so doing dramatically changes the humidity above the forest where it grows. The vapour is lighter than the rest of the air and this triggers convection currents that take it skyward. At higher altitudes the air is cooler and this causes the vapour to turn back to tiny liquid droplets via condensation. The return to the liquid phase requires not only lower temperature, however, but also a non-gas surface upon which the return to liquid can be precipitated. You can see this taking place on a cool window in a steamy kitchen, or on grass at the dawn of a new day that follows a warm but cloudless summer evening. There are no windows or grass stems high above the rainforests, though, so other surfaces facilitate the return to liquid.

Whatever gets up to the cooler altitudes, where condensation can most readily take place, will of course be very small, and also very abundant. The materials that do this take the form of tiny floating non-gas particles called aerosols. These are the microscopic nuclei upon which water vapour condenses to create the tiny water droplets that come together in clouds. There are many different sources of these cloud-seeding materials, including dust kicked up from storms over deserts, salt grains from sea spray and various organic materials. Among the latter are compounds released through those pores on the leaves themselves, including terpene and isoprene.

At millionths or even billionths of a metre across, numberless trillions of these minuscule particles drift up from the forest in the humid air and in the presence of sunshine unite with oxygen to form very fine dust particles that have an affinity for water. These are among the tiny surfaces upon which condensation occurs. This tree-generated cloud fuel is augmented by billions of trillions of pollen grains rising into the air every day from the vast number of flowers, as well as fungal and bacterial spores. The result is a vast bank of cloud-seeding material being released by the rainforest itself, magic dust feeding into rising moist air to generate cloud, and then rain – lots of it.

So it is that the Sun's energy is harnessed by plants to lift water into the atmosphere, uniting with microscopic particles to create the rain that replenishes the headwaters of rivers, refills the aquifers that give rise to springs and moisten the soils that enable plant growth, and on a colossal scale. Each day some twenty billion tonnes of water vapour is emitted from the Amazon basin rainforests – more even than the huge quantity of liquid water that flows each day along the Amazon river itself. That vapour is a globally significant source of freshwater and a major proportion of the 90 per cent of all the water that reaches the atmosphere via plant transpiration on land each day. The fact that only about 10 per cent of the water arriving in the air from land is via simple evaporation (in other words isn't mediated by plants, and instead is coming directly from soils or concrete) underlines the vital roles played by vegetation in recycling freshwater.

Having said this, it is important to remember that most of the water vapour that goes into the air is from the surface of lakes and oceans (which are of course pure water). The oceans are more extensive than the land, but surfaces covered with forests can evaporate at least as much water as an equivalent area of lake or ocean. Dense stands of trees with understoreys of shrubs and covered in epiphytes present multiple layers of vapour, emitting surfaces, whereas the sea or a lake has just one.

Recent research suggests that strong parallels can be drawn between how rainforests and oceans work. One study using images generated by cameras borne on satellites and aircraft found that Amazonian clouds have a striking resemblance to maritime clouds, leading some researchers to describe the rainforest as a 'green ocean'. The parallel is seen in the expansive forest surface covering millions of square kilometres, stretched out beneath the atmosphere, vast, wet and exposed to the winds that move moisture, very much like an actual ocean.

How the rainforests pump water around the planet

Significant areas of the green oceans of rainforests that once covered so much of the humid tropics have, however, been drained, and (as we'll see later) with increasingly serious implications for humans. This is because the rainforests not only replenish cloud and thus freshwater, but, it seems, also help drive large-scale air movements, effectively pumping moisture-laden air inland. This is the result of the condensation of the vapour released by the forest, which causes dense clouds to form above the sea of trees. The condensation leads to a drop in air pressure, causing warm moist air to be sucked in from over the ocean. This brings with it the airborne water that creates the rains that moisten the forests in the first place – and which is then recycled by the forest into new clouds.