



# The Planet's Laundromat

*The Amazon region cleans the atmosphere, keeps the global atmospheric cycle running and stores water on a grand scale. These are just three reasons why the **MAX PLANCK SOCIETY** maintains a branch in **MANAUS**, in the heart of the Amazon region. For **MEINRAT O. ANDREAE**, they are also reasons for regarding the Amazon as a global “service provider” – one in whose protection every country in the world should invest. Doing so need not even hamper the economic development of the region.*

**M**y first encounter with the Amazon was in 1985, from the window of a research aircraft. The view lasted several hours: forest, clouds, water, more forest .... Yet a glance at the map showed that we had crossed only a tiny portion of the vast Amazon ecosystem. The Amazon Basin has 17 times the area of Germany; it could accommodate the whole of Europe from Poland to Portugal without difficulty. During my long flight over the tropical rainforest, I was struck by two thoughts. First, an area of such proportions, containing so much life, must surely play a key role in the Earth system. And second, what I am looking at is so huge that mankind will not be able to destroy it.

However, anyone who flies further, for instance southwest from Manaus toward the Brazilian state of Rondônia and then over the Bolivian border, will quickly reject at least the second assumption: instead of forest and clouds, thick veils of smoke cover pastureland and soybean fields where, only a few years earlier, tropical rainforest still stood. Since the 1960s, some 16 percent of the Amazon has been deforested; roads have increasing-

ly been built and people settled – and the trend continues. If it is not stopped, it is estimated that half of the forest will have disappeared by the middle of the century. In the eastern part of the Amazon Basin, the forest will have been replaced by savanna or put to agricultural use, with the exception of a small number of nature reserves. Only in the extremely rainy and poorly accessible northwest will truly large tracts of forest still be preserved. However, again: What exactly is the problem with that? Why do we need the Amazon rainforest?

## *Planet Earth – an indivisible habitat*

To answer that question, I like to use the analogy of “Spaceship Earth.” Spaceship Earth conveys the notion that humanity inhabits an indivisible planet, and that it relies on the components from which this celestial body is constructed to keep working together properly. Together with all other forms of life, humanity is a part of the Earth system. What, then, is the role of the humid tropics in general and the Amazon rainforest in particu-

lar as life-support systems for Spaceship Earth? I would like to look at four particular functions here: the boiler, waterworks, laundromat and library. As it will be shown, these functions are all closely interrelated, and none can exist completely without the others.

The climate system has a lot in common with a steam locomotive. The temperature is increased at one point and reduced at another, and the resulting thermal gradient causes movement. Put simply, the Earth is warmed by the Sun in the tropics, but cooled in the higher latitudes by radiation of the heat into space. The movements of the atmosphere and the oceans transport heat and equalize the energy balance. Just as in a steam locomotive, the conversion from heat to movement is caused largely by the evaporation of water and the condensation of steam.

Together with the Congo Basin and the continent of Oceania around Indonesia, the Amazon Basin constitutes one of the boilers that supply the atmosphere with steam and energy. When warm air and steam rise and, in the process, are cooled, clouds are formed that, in turn, generate further uplift. This uplift around the tropical belt is what causes the atmosphere to circulate over vast distances. The result of all of this is what we experience worldwide as weather and climate.

Were the tropical rainforest to be replaced by grasslands – or worse, by wasteland – the energy balance would change. Grass and bare earth are lighter in color than rainforest, and thus absorb less solar heat – in exactly the same way that a light-colored automobile warms up less quickly than a dark one. In addition, less water evaporates from the reduced vegetation, and more of the absorbed solar energy must therefore be given off in the form of hot air rather than as water vapor. Anyone who has ever worked in a deforested area knows the difference. It is more humid in the rainforest, but not nearly as hot as on the adjacent pasture.

Let us now consider the second function, the waterworks. As already described, the tropical regions have the function of a steam boiler, in that water evaporates and, as in a steam locomotive, gives off energy when it condenses. The condensed water then falls in the form of rain. Each water molecule that is transported from the Atlantic Ocean into the Amazon Basin passes through this cycle some five times before it leaves the basin again. In other words, it remains for a relatively long time within the rainforest system, where it can be exploited repeatedly for the biological processes of the vegetation. In a sense, therefore, the rainforest has the capacity to optimize its own water supply. Since plant photosynthesis and the availability of water are closely interconnected, this system is also able to absorb and store large quantities of carbon from the atmosphere. At present, the living, above-ground biomass of the Amazon rainforest contains some 93 billion tons of carbon – approximately one-fifth of the total carbon in the terrestrial biosphere.

If we imagine eliminating large parts of the forest, all the components of the water cycle are changed: evaporation is reduced, the water flows away down the rivers more rapidly and less water remains in the system. At the same time, the dynamics of atmospheric convection – the upward movement of air and water vapor, which is driven by heat and which is responsible for the formation of clouds and rain – also change. Global climate models predict that a total deforestation of the Amazon would result in regional precipitation being reduced by around a quarter. These models are, unfortunately, of little use for real-case predictions: their scale is too coarse to give adequate consideration to a realistic scenario of partial deforestation and to the interaction between vegetation and the water cycle.

For both plants and human beings, the crucial question is not only how much it rains, but how much of the precipitation remains available. Where water rapidly runs off soils with little vegetation, or evaporates immediately owing to a warmer climate, less water may be available even when precipitation rises. Less water, in turn, reduces fertility, and in extreme cases, the forest vegetation may give way locally to steppe. This development is further favored by fires, which close a vicious circle: in years of low precipitation, for example during an El Niño, parts of the tropical rainforest are more prone to fire. Should fires then also break out more frequently as a result of increased human activity, they spread throughout the forest.

This does not cause the forest to die immediately; its canopy, however, is opened, and it is able to retain less

water as a result. With the onset of the next cycle, it is drier and even more susceptible to forest fires. After two or three such cycles, the forest is destroyed, becomes transformed into a savanna landscape, and has little long-term prospect of recovery. Thus, in conjunction with fire and climatic cycles, even light exploitation by roads or selective tree harvesting may lead to deforestation.

In chemical terms, the tropics can be regarded as the Earth's laundromat. Day by day, man and nature pump enormous quantities of substances into the Earth's atmospheric layer. The use of fossil fuels in power plants and automobiles causes billions of tons of carbon to be released in the form of carbon dioxide (CO<sub>2</sub>), together with millions of tons of nitrogen oxides (NO<sub>x</sub>). Emissions of natural hydrocarbons, particularly from plants, are also on the order of several billion tons per year. If these substances were not repeatedly removed again from the atmosphere, we would quickly be surrounded by a suffocating cloud of trace gases.

Most such gases are poorly soluble in water, and are thus barely washed out by rain. The self-purification of the atmosphere therefore requires chemical reactions by which the trace substances are brought into a water-soluble form. These reaction chains normally begin with an initial oxidation step in which the trace gas is attacked by a highly reactive molecule, such as ozone (O<sub>3</sub>) or the hydroxyl radical (OH). Production of these atmospheric detergents requires UV radiation and water vapor, both of which are present in generous quantities in the tropics. It thus comes as no surprise that the tropics are the region in which atmospheric trace gases are largely eliminated. For many years, these oxidation reactions were believed to take place primarily in the middle troposphere, being suppressed by the hydrocarbons from the rainforest. However, the latest measurements conducted by the Max Planck Institute for Chemistry suggest that chemical chain reactions directly above the rainforest regenerate the OH “detergent” and contribute to effective self-cleaning of the atmosphere.

Should the atmospheric cleaning mechanism be disturbed by human activity, for example by additional emissions of nitrogen oxides from industry and the slashing and burning of forest, the laundromat can turn into a witches' cauldron: photochemical smog with high concentrations of ozone and other atmospheric pollutants, and large quantities of fine aerosols – which in turn influence the formation of clouds and precipitation and thus modify the water cycle.



However, the atmospheric trace gas that is currently causing the greatest concern – namely carbon dioxide – cannot be eliminated by any atmospheric detergent. The part of this gas that is not dissolved in the ocean or bound in

the terrestrial biosphere must remain in the atmosphere, which surrounds the planet like a warm blanket. Effective climate protection thus requires protection of the terrestrial biosphere, in which approximately three times as much carbon is stored than in the atmosphere. Rather than this store being preserved, however, it is being over-exploited: globally, deforestation currently accounts for around one-fifth of the carbon input into the atmosphere – approximately half of which is attributable to South America, primarily the Amazon Basin.

### *Diversity must be preserved*

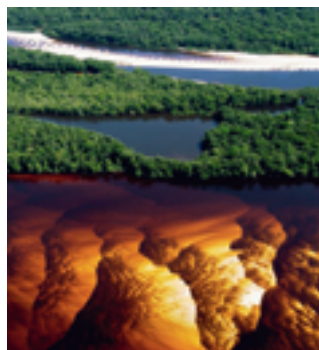
Major progress in climate protection could thus be made here. Conversely, if action is not taken swiftly enough, the momentum of the system could cause us to lose all control over the situation: some coupled climate-vegetation models predict that global warming is destabilizing the ecosystem of the tropical rainforest and could cause it to tip toward the creation of a savanna. The carbon dioxide that would be released as a result would then lead to yet further warming.

Finally, the rainforest's function as a library: each hectare of rainforest is home to around a hundred species of trees. Altogether, there are estimated to be some 6,000 tree species in the Amazon, compared to around 50 in Europe. Some 2,500 species of birds and mammals and many tens of thousands of plant species in the Amazon Basin have been described scientifically. The number of invertebrate species runs into the hundreds of thousands, and insect species into the millions. Altogether, some 17 percent of all species of organisms on Earth live in the Amazon. Of these, the great majority have not yet been described scientifically, and possibly never will be. The variety of species in the Amazon Basin is directly related to the variety of habitats, and is consequently threatened by any form of exploitation that is accompanied by habitat destruction, in particular by clearing and deforestation. The genetic information stored in these ecosystems and their biodiversity is barely measurable and may be of enormous economic significance.

The life of plants involves continual defensive action against feeders and pathogens. Since they can neither escape nor bite back, plants have perfected chemical

### *Without the forest, water will become scarce*

Deforestation thus changes the local climate: instead of being humid and reasonably cool, it becomes hotter and drier. However, owing to the changes in the energy balance, a large-scale rise in temperature also disrupts the atmosphere's energy balance on a global scale. As yet, we do not fully understand the consequences of these effects. Predicting them is difficult because temperature, precipitation, vegetation coverage, radiation balance and the water cycle are closely interlinked, and the complex interaction within this system of causes and effects remains far from adequately researched.



warfare and have developed a powerful arsenal of defensive substances. These may also be exploited by mankind as medicine: many of our pharmaceutical products are based on plant substances, and a great many more may be awaiting discovery in the plants of the Amazon. It is not without reason that the countries of the Amazon Basin fear biopiracy – the illegal prospecting for genetic treasures and their theft.

Ethically, I equate slashing and burning in the Amazon with the arson of a library of unique volumes: once torched, the endemic species of the Amazon would be lost forever – burnt pages torn from the book of evolution.

The Amazon thus provides a number of ecosystem goods and services to the planet: it acts as a form of global service provider in its regulation of the climate system and the water cycle, helps keep the atmosphere clean, stores carbon, and houses an enormous archive of genetic information. That is the situation as seen from outside. For the people living within the Amazon, it is somewhat different. They expect from their region what we expect from our own country: it should provide them with the means for economic activity – and keep them fed. In the Brazilian Amazon Basin alone, the population rose from around 5 million to over 20 million between 1960 and today. Most of these people are poor and live on less than we can even imagine. And herein lies the real challenge for the future of the Amazon: how can the economic interests of the region's inhabitants be satisfied while at the same time delivering the global ecosystem goods and services?

### *How much is the Amazon worth to us?*

The traditional approach to land use in the Amazon is being followed in Brazilian states such as Mato Grosso, on the southern edge of the basin: deforestation on a grand scale and extensive agricultural activity, particularly pasture agriculture; and more recently, also intensive crop farming, particularly of soybeans. On the one hand, this activity destroys the tropical rainforest and its resources; on the other, it serves the mass production of goods that are relatively low in added value and that benefit primarily the wealthy classes. An alternative can now be seen in Amazonas state, in the center of the Amazon Basin. This state is rife with contradictions: it exhibits the strongest economic growth anywhere in Brazil (almost 14 percent in 2004), yet at the same time the lowest rate of deforestation, at only 2 percent.

Amazonas is a huge territorial state, one that is dominated by urban forms of settlement and whose economic production is generated almost exclusively by a single city, Manaus. This is precisely where the government of Amazonas,

under the leadership of Governor Eduardo Braga, sees an opportunity: it proposes that Manaus' development be continued as a high-tech center, and that goods with high added value be produced with relatively low exploitation of resources. At the same time, it suggests the hinterland should be exploited gently and sustainably, and with a low population density. The protection of the native population of Amazonas, and the conservation of nature and thus also of the ecosystem goods and services, is to be of key importance in this strategy.

Virgilio Viana, the Secretary of State for Environment and Sustainable Development of Amazonas state, presented this vision on the occasion of a visit to Manaus by German President Horst Köhler, which was also attended by representatives of the Max Planck Society. Viana also raised a pertinent and very valid question: if Amazonas were to make the services of its forest available to the world, how much would the world be prepared to pay for it, and in what form? As yet, no economic, political or legal models for such a trade exist. How much is the Amazon worth to us? A great deal, no doubt; otherwise we would not be asking ourselves these questions. But how much would we be prepared to pay? Where is the market on which these services could be traded? Carbon credits regulated by climate-protection agreements are an example, albeit not a particularly convincing one.

The Amazon presents us with a fascinating challenge, both economic and political. It teaches us how closely the components of the Earth system are interwoven; how, for example, the biosphere, climate, and carbon and water cycles influence each other reciprocally. These were the questions that first led us there. At the same time, the Amazon shows the extent to which mankind is dependent on an intact Earth system – and how easily it can be destroyed. This dependency presents a major challenge to the social and natural sciences. Together, they must develop concepts that permit and safeguard sustained development of this region.

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