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Sustainable management of tropical forests

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Introduction

Tropical forests account for half of the world's forests, hold over half of all forest carbon and are home to more than 80% of terrestrial biodiversity. They also play a fundamental role in climate regulation on both regional and global scales, not to mention protecting soils from erosion, regulating water systems, lowering temperatures and providing countless products for local populations: meat, fruit, materials and medicinal plants. Unfortunately, tropical forests are disappearing at an alarming rate. Over the last thirty years, the planet has lost just over four hundred million hectares (400 Mha) of tropical forests, an average of 13 Mha per year. This total loss of forest cover is mainly due to the conversion of tropical forests to farmland, pasture or industrial plantations (oil palm, sugar cane, fast-growing trees). This deforestation is compounded by forest degradation which, in certain regions of the world such as Amazonia, affects as much land as deforestation. There is no single, universal definition of forest degradation. Generally speaking, it is a reduction in the forest's capacity to provide goods and services, due to human or natural disturbance. However, this definition does not take into account the temporal and quantitative aspects of degradation, which remain key elements. In fact, depending on the type, intensity and frequency of the disturbance suffered, the degradation will be more or less significant and long-lasting. The more intense and frequent the disturbance, the longer it will take for the forest ecosystem to recover its functions. In extreme cases,

the disturbance is so severe that the ecosystem cannot regenerate and shifts to a different stable state, such as scrubland.

The two main causes of forest degradation are the uncontrolled, and usually illegal, exploitation of timber or firewood, and fragmentation, which is again linked to deforestation and exacerbated by the effects of climate change. Degradation causes varying degrees of disturbance depending on the causes and practices. The ability of a forest to recover, i.e. to return to a state comparable to its initial state, will depend essentially on the intensity and frequency of these disturbances.

As early as 1992, the United Nations Conference on Environment and Development warned of the need to preserve and conserve tropical forests for the good and survival of mankind; today, this issue has become an absolute priority. To achieve this goal, two complementary but often contrasted approaches exist. The first prioritizes strict conservation by creating protected areas, minimizing human exploitation of resources. In contrast, the second approach supports sustainable resource management, allowing controlled use for the benefit of local communities and society as a whole. Foresters chose the second method, based on the principle that a managed forest that provides goods and services for the population, the State and society will be protected and conserved.

Unfortunately, the reality on the ground continues to contradict this principle. Illegal logging, which is still widespread in many tropical countries, causes major damage to forest stands and diminishes their ability to regenerate and withstand the effects of climate change. Tropical countries and the international community are still slow to consider the problem of tropical forest degradation as an absolute emergency, in the same way as deforestation.

The aim of this essay is therefore to provide an overview, accessible to non-specialists, of the impact of timber harvesting on tropical forests. It also suggests ways in which timber harvesting can be made sustainable, thereby helping to conserve tropical forest ecosystems and improve the living conditions of millions of people who depend on them.

After a career spanning more than thirty years at the *Centre de coopération internationale en recherche agronomique pour le développement* (CIRAD), during which I travelled through the main tropical forest massifs to study the impact of logging on the capacity of tropical forests to recover, I decided to write this essay to share my experience with as many people as possible. Throughout my long career as a tropical forest ecologist, I have worked tirelessly to explain and convince people that selective logging of tropical forests can be an effective and complementary means of creating protected areas and conserving large areas of forest for the benefit of the people and countries of the global South.

Before diving into the heart of the matter, it is important to correct some misconceptions about tropical forests. They remain largely unknown to the Western public and are often idealized as a lost paradise—one where humans have no place, except as conservationists, as if they were incapable of living there without actively preserving them (Chapter 1). Yet, since the very beginning of humanity, humans have inhabited forests, whether temperate, boreal or tropical. Today, the 'indigenous' peoples, small-scale farmers and local populations are increasingly demanding the right to live in and from their forests, i.e. to use them while conserving them.

Timber harvesting, which is often blamed for all the harm done and considered to be the main source of deforestation, deserves to be objectively 'explained' rather than rehabilitated.

The aim of this essay is to clarify the principles of selective logging (Chapter 2), then to describe its real impact in a factual manner, and finally to lay the foundations for sustainable logging (Chapter 3). This exercise required a comparison of the realities on the ground with the results of the research and the recommendations arising from it. In the final chapter, therefore, I have tried to suggest ways of promoting and extending sustainable management practices, taking account of the environmental, social, economic and political dimensions. Finally, the conclusion looks at possible paths towards greater sustainability.

TROPICAL FORESTS

Tropical forests are found in a band on either side of the equator bounded by the Tropic of Cancer and the Tropic of Capricorn. The characteristics of this band are that in each of the tropics, the Sun appears at its zenith once a year, at the summer solstice in June for the Tropic of Cancer and at the winter solstice in December for the Tropic of Capricorn. Outside this zone, the Sun is never vertical to the ground. So when it is at its zenith over the Tropic of Cancer, it is summer in the northern hemisphere and winter in the southern hemisphere, and vice versa when it reaches its zenith over the Tropic of Capricorn. Between these two seasons, the Sun is at its zenith at the equator twice a year, on the equinoxes of March and September. In this vast bioclimatic zone, the average temperature in the coldest month rarely falls below 20°C, except occasionally at altitude. It is also the region of the planet that receives the highest light intensity.

A VAST DIVERSITY

The term 'tropical forests' covers a huge diversity of ecosystems, whose variation is mainly based on three factors: differences in rainfall within the tropical zone, altitude, which influences temperature, and the nature of the soil, which sometimes requires great adaptation by the trees (Figure 1).

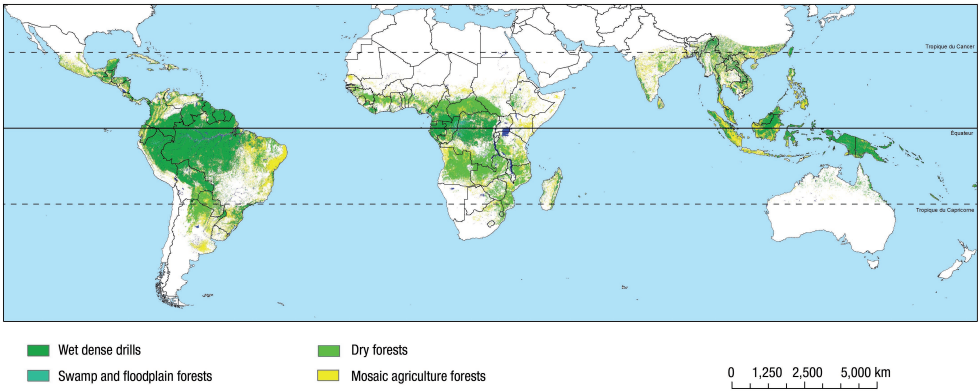

Figure 1. Distribution of the main types of tropical forest in the world (source: Global Forest Cover, *in* Sist *et al*., 2021).

Within the tropical region, the climate is not uniform. Rainfall is highest at the equator, often exceeding 2,000 to 2,500 mm/year, and the dry season is short (2–3 months). The further north or south one moves away from the equator, the longer the dry seasons and the lower the rainfall become. Tropical forest ecosystems have therefore adapted to this climatic variability. Near the equator, tropical rainforests dominate (Figure 2A). This type of tropical forest is often called 'evergreen', because the trees remain green all year round, although this does not mean that they do not lose their leaves but simply that new ones are being produced continuously. The air is saturated with moisture most of the time, and rainfall is abundant throughout the year, except for one or two months of respite during the dry season. These are the richest terrestrial ecosystems on Earth in terms of plant and animal species. More than 300 species of trees have been counted in a hectare of forest in the Peruvian Amazon at the foot of the Andes. The richest forests in France rarely have more than 20!

The largest and tallest trees in the tropics can also be found in evergreen tropical rainforests. The canopy (the roof of the forest) reaches between 35 and 60 m, and some trees go beyond this to reach heights of over 70 m. The height record belongs to a tree of the Dipterocarpaceae family in the forest of Borneo, a red meranti (*Shorea faguetiana*), measured at 100.8 m. This makes it the fourth tallest living tree in the world, with the Sequoia (*Sequoia sempervirens*) of the American West (115.7 m) in first place.

When rainfall decreases and the dry seasons extend in length and intensity, evergreen tropical rainforest gives way to semi-deciduous tropical forest, so called because some of the trees lose all their leaves during the dry season to better withstand the drought. It is from their leaves that the trees lose the most water, making them their weakest part during extreme periods of drought. This semi-deciduous forest develops under annual rainfall patterns between 1,500 and 2,000 mm. In terms of structure and biodiversity, it is very similar to evergreen tropical rainforests, and these two types of forest have many species in common.

Dry forests are found in regions with annual rainfall of between 800 and 1,200 mm. The trees are smaller and rarely reach 20 m in height, except along rivers, where a more luxuriant forest can develop. The longer and more intense the dry seasons, i.e. the further away from the equator, the less dense the forests. There is a gradual transition to wooded savannah. Trees are also more widely spaced, and most lose their leaves in the dry season. The vegetation is also adapted to frequent fire. Many tree species in the Brazilian Cerrado have developed thick bark to protect the living wood carrying the sap from fires.

In mountain environments, forest species must adapt to temperature and humidity conditions, which change considerably with altitude. These forests are often referred to as 'cloud

forests' (Figure 2B). The air here is saturated with water, and as altitude increases, temperatures not only drop but also vary greatly between day and night. High in the mountains, above 2,000 m, the forests are home to many temperate climate plants such as rhododendrons, heathers and conifers.

Soil plays a crucial role in characterising tropical forest types. Hydromorphic soils, characterised by their poor drainage capacity, are frequently found near large rivers like the Amazon. These rivers experience constant or periodic flooding depending on the season, leading to the development of so-called 'flooded' forests, which can either experience periodic flooding during the rainy season or remain permanently flooded. (Figure 2C). In flooded forests, the trees have their feet in the water for a large part of the year. However, to ensure that their absorption functions properly, the roots need oxygen, which is in short supply in waterlogged marshy soils. To remedy this, many trees in flooded forests develop pneumatophores, portions of their roots that grow towards the surface of the water and then rise above both soil and water to capture the necessary oxygen.

Mangroves (Figure 2D) are special forests that should be distinguished from the other flooded forests mentioned above. They are found along coasts and estuaries, where they are influenced by the tides and develop in brackish water whose salinity varies considerably according to the tidal cycle. In addition to oxygen depletion during high tide, the soil is muddy and unstable. Mangroves, which reign supreme over these forests, have found a solution to ensure their stability on such a soft substrate: they grow on stilt roots, which form an often inextricable tangle. Many mangrove species are viviparous, meaning that the seed germinates in the fruit while it is still on the tree. Once the root is sufficiently developed, the fruit, which is not really a fruit anymore, but rather a 'propagule', falls and is planted in the mud