EXPERIENTIA

Volume 43/No. 3 Pages 221–346 15 March 1987

The dynamics of the Amazonian terra-firme forest

The Editors wish to thank Dr. I. Walker for coordinating this review.

Introduction

by H. O. R. Schubart* and I. Walker

INPA, Caixa Postal 478, 69.000 Manaus, AM (Brazil)

Under the pressures caused by the existence of roughly 5 million km^2 of primeval forest in the north and increasing population pressure from the south, the Federal Government of Brazil, in the early 1970s, gave a massive boost to the Instituto Nacional de Pesquisas da Amazônia (INPA, National Institute for Research in Amazonia), an institute of the National Council for Development of Science and Technology, CNPq. At the same time, in 1974, it set up the National Environmental Agency (SEMA, Secretaria Especial do Meio-Ambiente), which, up to date, has secured over 2 million hectares of endangered ecosystems, including Amazonian forest habitats[1]. Furthermore, in 1976 Brazil adopted a special conservation plan for the Amazonian region, based on scientific studies of vegetation types and faunal patterns which, by now, protects 11.6 million ha (ca 2.3%) of the Brazilian Amazon Basin. This includes 24 separate reserves, including the SEMA ecological reserves[2].

Until then, INPA, with its modest means, had been primarily orientated towards tropical medicine, systematic botany (INPA's herbarium contains circa 130,000 specimens), plant chemistry, sylviculture and limnology. The little that was known at the time had already led to the suspicion that the luxurious vegetation cover of the Amazonian forest was not indicative of luxurious soil fertility, and the question 'Should not the tropical forest be a renewable resource?'[3] took shape and grew with every bit of new information. This is essentially an ecological question and the effort to answer it led to the expansion of INPA's Department of Ecology from 1 Ph.D., 1 M.Sc. and a handful of B.Sc.s in 1974 to 12 Ph. D.s, 14 M.Sc.s and a number of B.Sc.s (who are actually engaged in post-graduate studies) in 1985. This expansion of manpower in the Department of Ecology, as well as in the other departments of INPA, allowed INPA to set up separate post-graduate courses in ecology, entomology, botany, limnology and fisheries research, in sylviculture, and recently also in nutrition and food science. Ecology's graduate program started in 1976, and has so far produced 2 Ph.D.s and 24 M.Sc.s who are, for the most part, working in the Amazonian region. Indeed, the majority of the authors of the following articles are not only researchers, but also post-graduate teachers in INPA's Ecology Department.

While INPA's staff of 236 researchers is financed by the Brazilian Government, several larger, multidisciplinary research projects in forest ecology, which are the main topics of this review, have been developed with the aid of foreign agencies such as BID (Bank of Inter-American Development), OAS (Organization of the American States), WMO (World Meteorological Organisation of UNESCO) and IAEA (International Atomic Energy Agency). Moreover, INPA maintains research agreements with a number of international institutions which include, for example, ORSTOM (Institut Français de Recherche Scientifique pour le Développement en Coopération), the WWF (World Wildlife Fund) and the Max-Planck-Institute for Limnology, Plön (much of this last-mentioned cooperation is evidenced in the recent book 'The Amazon'[4]). Of particular importance for INPA's effectiveness is the interaction with other Brazilian institutions, notably with the Amazon State University (FUA), the University of São Paulo, CENA (Centro de Energia Nuclear na Agricultura), INPE (Instituto Nacional de Pesquisas Espaciais), SEMA (see above), IBDF (Instituto Brasileiro de Desenvolvimento Florestal), among others.

The final selection of authors and articles in this review series is partly due to opportunity and partly to deliberate choice. Almost inevitably, all authors are either INPA staff or researchers engaged in cooperative projects between INPA and one or the other of the above-mentioned institutions (as seen from the authors' addresses). Not all potential authors were (from the coordinator's point of view) in the ideal situation of being able to write up their research at the time when they were approached. However, the review should permit the reader to synthesize as coherent a picture of basic Amazonian forest ecology as is presently possible.

The first paper (Leopoldo et al.) describes the general climatic situation of the Amazon basin, estimates of the water cycle and data on nutrient cycling through the forest habitat. Chauvel et al. explain the dynamics of pedogenesis in the course of geological time, and Guillaumet summarizes the evidence for Amazonian forest structure as a function of the soils thus evolved and their topography. Kahn proceeds to a detailed analysis of the population dynamics of palms in relation to overall forest

structure and topography of the terrain, palms being a prevalent feature in Amazonian forests. Luizão and Schubart show the importance of litter decomposition and of the soil organisms as decomposers for the recycling of nutrients and thus for the maintenance of the forest, while Rylands gives a detailed account of monkeys as consumers of the living biomass in the forest canopy. Walker, finally, integrates the biology of streams into the general ecological process of forest dynamics.

It is hoped that the review conveys one aspect in particular with penetrating clarity: namely, that of the mutual interdependence of all the described processes and patterns from which the multiple dangers to and fragility of this gigantic ecosystem directly follow. The consideration of this balance is indispensible for any land use by man in the Amazon Basin.

* Director of the Instituto Nacional de Pesquisas da Amazônia.

1 Nogueiro-Neto, P., Getting Brazil's network of ecological stations on the ground. Wld Resour. Inst. J. (1985) 27–34.
2 Rylands, A. B., Conservation areas protecting primates in Brazilian Amazonia. Primate Conserv. *5* (1985) 24–27.
3 Schubart, H. O. R., Manejo ecológico da floresta tropical: o programa do INPA. Acta amazon. *12*, suppl. (1982) 5–6.
4 Sioli, H. (Ed.), The Amazon. W. Junk Publ., Dordrecht 1984.

0014-4754/87/0221-02$1.50 + 0.20/0

Towards a water balance in the Central Amazonian region

by P. R. Leopoldo*, W. Franken**, E. Salati*** and M. N. Ribeiro**

**Facultade de Ciências Agronômicas, UNESP, Campus de Botucatu, 18600 Botucatu SP (Brazil), **Instituto Nacional de Pesquisas da Amazônia (INPA), 69000 Manaus AM (Brazil), and ***Centro de Energia Nuclear na Agricultura, USP, 13400 Piracicaba SP (Brazil)*

Key words. Hydrological cycle; Amazon River; evapotranspiration; canopy interception; water budget; precipitation; Amazon Basin; deforestation effects.

1. Introduction

The possible effect of the Amazonian forest ecosystem on the regional, or even on the global, climate, is a subject discussed with much polemical ado.

Until the 1960s the Amazonian forest cover remained essentially intact[4]. However, with the construction of roads in the 70s colonization, accompanied by deforestation, set in with ever-increasing speed. Under the auspices of the 'Instituto Nacional de Colonização e Reforma Agrária', the government alone removes an average of 25,000 km^2 of forest per year[50].

As a result of this process, national and international concern has intensified. In the absence of hard scientific data, and nurtured by conjecture and hypotheses only, the discussion has acquired a rather unrealistic and perhaps even polemical tenor, and contradictory views are defended with equal conviction.

Thus, some authors claim that the energy liberated by the condensation of water vapors from the Amazon Basin, which is transported in the higher atmospheric strata to the polar regions, represents an important contribution to the thermal equilibrium of the earth[35]. If this were proven to be true, the deforestation of this region would result in a higher temperature contrast between polar and more central latitudes of the globe.

Others hypothesize that even complete deforestation would have little global impact. Sellers[47] estimates that the effect would merely be a reduction of the annual rainfall in Amazonia by 250 mm, and, on the other hand, the arid Brazilian Northeast would benefit from increased precipitation. Conclusions of global irrelevance have also issued from the Centre for Informatics, Goddard Institute, New York, which is considered to be one of the most sophisticated agencies for simulation prognostication. In this model, the climatological parameters of the forest, such as surface temperature, evapotranspiration, light reflection, etc. were replaced by the respective values for tropical pastures. The model[51], however, omits important factors such as the release of CO_2 by the burning of the forest; this is one of the major preoccupations of climatologists, because it might lead to higher global temperatures and thus could even cause partial melting of the polar ice caps[47]. As for regional effects, the Goddard futurologists admit that pastures would retain less rainwater and that, therefore, erosion would intensify and cause an equivalent increase of sediments in rivers, and that this, in turn, could endanger the plankton and the entire aquatic fauna[51].

Fortunately, though, matters have moved beyond mere conjecture and dispute. National and international agencies have cooperated in setting up a number of research programs on the interaction between vegetation and atmosphere throughout the northern Brazilian states and through the Amazon Basin as a whole, including the neighboring countries (fig. 1). For example, the Instituto Nacional de Pesquisas da Amazônia (INPA), the Centro de Energia Nuclear na Agricultura (CENA), the Instituto Nacional de Pesquisas Espaciais (INPE), ORSTOM (France), the American States Organization (OEA), the International Atomic Energy Agency (IAEA), and the IVIC (Venezuela-San Carlos), are only a few of them. Some results of the OEA-project, at Model Basin, are summarized by Walker and Franken[53].

However, in view of the enormous problems, that would arise from a possible destabilization of the Amazonian