DEFORESTATION IN THE AMAZON: PAST, PRESENT AND FUTURE

Wim Sombroek
International Soil Reference and Information Centre (ISRIC), Wageningen, The Netherlands

Niro Higuchi
Dept. de Silvicultura Tropical, Instituto Nacional de Pesquisas da Amazônia (INPA), Manaus , Brazil

Keywords: Amazon region, deforestation dynamics, climate change, agricultural frontier, tropical road construction, Amer-Indian land use, Terra Preta, carbon stocks, carbon sequestration, El-Niño, Clean Development Mechanism (CDM).

Contents

Summary

The forest coverage of the Amazon region may have had its largest extension and highest biodiversity in the Late Tertiary. During the Pleistocene epoch, climatic conditions varied considerably, resulting in a much less abundant forest cover during the last Glacial Maximum. In the present Holocene epoch the forest coverage may have extended well beyond the present-day biome. Since then there have, apparently, been many minor oscillations in rainfall and some macro-droughts.

Human presence in the region started at least 11 000 years ago, and Amer-Indian settlement had its maximum intensity between 500 and 1500 AD, with settlements in large, permanent communities. It is estimated that by the year 1500 AD about 10% of the Amazon forest was either deforested, or had undergone changes in vegetation characteristics due to land use practises of Amer-Indian chiefdoms. Around their settlements they had gradually created fertile soils called *Terra Preta*, with high ethno-agro-biodiversity value.

Upon the arrival of the Europeans, the Indian population was decimated by contagious diseases, by warfare and the hunt for slaves, and by forced re-settlement. Many areas

then reverted to some form of forest, even during the time of the famous rubber boom, around 1900 AD.

In the Brazilian part of the Amazon region the situation changed drastically around 1960, with the construction of highways and access roads for small-holder settlement, mining, ranching, soybean growing and indiscriminate logging of valuable timber species. Especially in the southern and south-eastern edges of the region the deforestation rate was very high. By the year 2000 in total 14.6% of the original forest coverage of the Brazilian part had been burned down completely, while forest-floor fires in logging areas may have caused substantial hidden environmental damage in addition. National and international programmes to reverse this trend have thus far had little success.

Some recommendations are formulated on the future use of the lands and forests of the Amazon region, in view of the implementation of the Kyoto Protocol of the Framework Convention on Climate Change.

1. Introduction

The Amazon forest region comprises roughly 6 000 000 km^2—larger than all of Europe—and is spread over nine countries but with about 70% in Brazil. The region provides 18% of the world's fresh water input to the oceans and has a regulatory function for the present-day South-American climate system. It contains about 430 Gt. carbons in its vegetation and soils, which is 6% of the world's terrestrial carbon storage; it houses about one-third of the global plant and animal bio-diversity, has a multitude of terrestrial and aquatic ecosystems, and great ethnic diversity.

Contrary to popular opinion, the Amazon forest has not been a uniform and stable ecosystem over many millions of years. Most researchers of tropical paleo-climates agree that in the Pliocene the Amazon forest-covered area may have had its largest extension and highest bio-diversity. During the Pleistocene, which started some 2.5 million years ago, climatic conditions varied considerably, with lower temperatures during the northern hemisphere's ice ages, and alternations of dryer and wetter conditions in parts of the region every 20 000 years or so.

During the early part of the Last Glacial Maximum, starting about 50 000 years ago, there was first a wet period of 25 000 years, followed by a dry one with 40% lower rainfall between 21 000 and 13 000 years ago, one-third lower atmospheric CO_2 concentrations, and temperatures 4-5 ^oC lower than today (Van der Hammen and Hooghiemstra, 2000). The Pleistocene temporal dynamics of the spatial extent of the forest cover is exemplified by the frequent occurrence of fossil stream channels, deep mouths of tributaries (*rias)*, river terraces, convex slopes, gravel beds and stone lines in an elevated position, white-sand savannahs with fossil dunes, etc. There is also some, but disputed palynological evidence of the predominance of grassy vegetation types on the northern and southern fringe areas of the present-day forested region. The occurrence of discrete centres of high bio-diversity and endemism would also point to refuge areas of the humid forest, surrounded by seasonal forest or savannah vegetation.

The Holocene warmer period started about 11 000 years BP with a definite wet period from 11 000 to 5000 BP, when tropical forest coverage may have extended well beyond the present-day biome. During the last 5000 years there have been minor oscillations in the rainfall conditions, in the form of El-Niño dry years every 5-7 years, macro-droughts every 70 years or so, and “mega” El-Niños every 300-500 years. They must have had strong plant-physiological and vegetation-flammability effects in the fringe areas of the forest region.

There are many natural differences in the types of vegetative cover within the geographic forest region, due to differences in the strength and duration of the dry season in the eastern and southern parts of the region, altitudinal effects in the western fringe—the *Selva Alta*—and strong differences in soil conditions in all parts. The latter vary from sand to heavy clay, from nutrient-rich to very acid, from well to imperfectly or poorly drained, and from very shallow to extremely deep. Especially the arkosic sandstone plateaux and the intermittently poorly drained Late Pleistocene terrace lands of central Amazonia, with their sandy topsoils abruptly overlying an impenetrable layer of iron-humus or *plinthite* (pre-laterite) material, have given rise to intra-forest savannah vegetation types of different physiognomy and species composition (*campo, campina, campinarana, caatinga amazônica* in the Brazilian literature). They total at least 8% of the region, and are sometimes mistaken as the result of human-induced deforestation.

Human-induced deforestation was very prominent during the last 40 years of the twentieth century, and continues unabatedly. It is only recently that major international concern has arisen on this deforestation. This is because of the importance of the old-growth forest as a stock (and sink) of greenhouse gases influencing the global climatic system, and the value of its bio-diversity.

However, there have been several earlier phases of human effects on the forest vegetation, connected with cycles of population pressure and economic demand for one or more products of the forest or its deforested land. Until recent years, deforestation was considered a valorisation of the land concerned. The historical dynamics and non-linearity of the human influence on the Amazonian environment, and the degree of resilience of the forest system, is discussed in the following sections.

2. Deforestation in the Amer-Indian Period (Before 1500 AD)

The first irrefutable presence of man in the region is from archaeological evidence in the Lower Amazon uplands (Caverna-da-Pedra-Pintada at Monte Alegre, 11 000 BP; Taperinha near Santarém, 8000 BP), southern Pará (Caverna-de-Gavião near Carajas, 8000 BP) and the Middle Caquetá river area in Colombia (Peña-Roja site near Araracuara, 9000 BP). Rudimentary agricultural practises may have started around 4000 BP (Araracuara), and intensive horticultural types of land use started about 2000 BP, as based on fossil seed analysis of archaeological settlement sites in the Araracuara, Manaus, Santarém, and Monte Alegre areas, and anthropogenic mounds on the island of Marajó in the mouth of the Amazon river (see Figure 1).

Settlement reached its maximum intensity in the period 500-1500 AD. It is nowadays accepted by most anthropologists and archaeologists that, immediately before the

Colombian conquest of Latin America, between five and ten million Amer-Indians were living in the lowland region of the Amazon (Cleary, 2001). At the time, they were not roaming in small nomadic bands through the vastness of the forests, but were settled in large, permanent communities, often on high bluffs overlooking the major rivers and their floodable lowlands (Orellana expedition). They also settled on the higher terrains of upper river catchments where ample defence works were constructed, as in the upper Xingu area. The Llanos-de-Mojos plains of Bolivia at the south-western fringe of the forest region contain fossil drainage canals, raised beds, and flood-control dikes that give evidence of early agricultural production systems and organised fish cultivation.

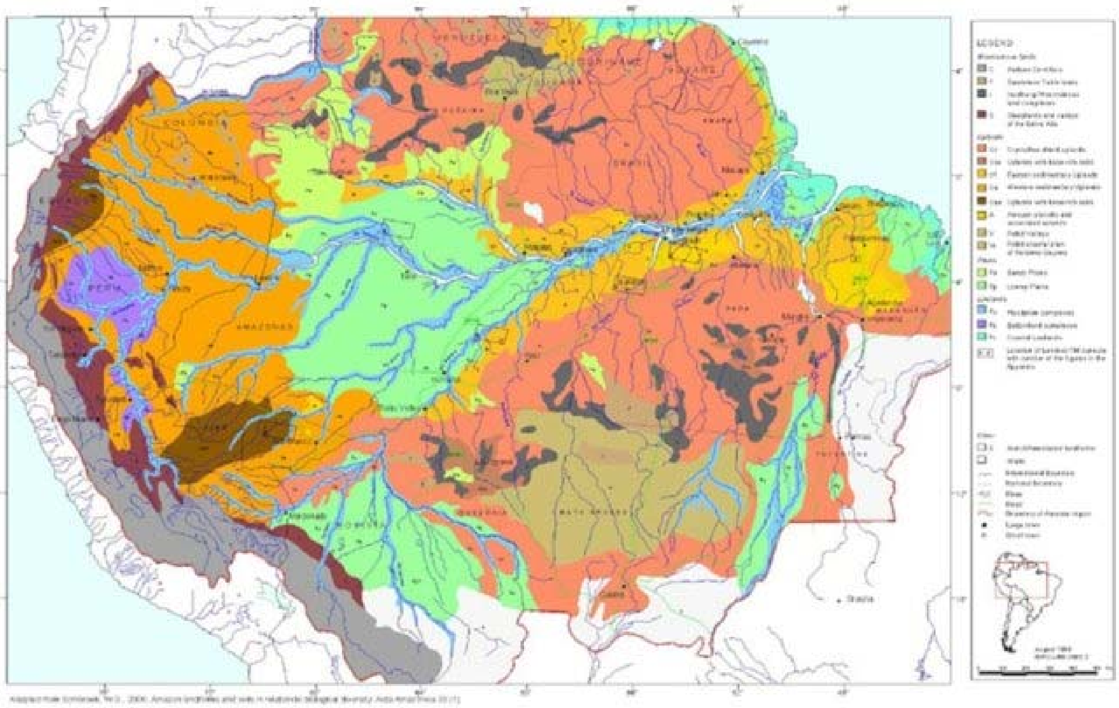

Figure 1. Situation map of the Amazon region, with main landforms, and location of Landsat image cut-outs.

The recent accidental discovery of large, perfectly circular or rectangular Indian defence works, in the form of ramparts and moats, under the forests of eastern Acre, now transformed into large cattle ranches, is another indication of substantial pre-Conquest Amer-indian occupation and deforestation.

Large-scale agricultural land use as a means of livelihood for the Indian tribes in the central area is less visible from the air. However, ongoing geographic inventories and associated laboratory research on the occurrence of anthropologically enriched black or dark-brown earths—called *Terra Preta (-de-Indio)* soils in Brazil when containing ceramics, or *Terra Mulata* when without artefacts—point to the sustained presence of large Indian communities with specialised production of ceramics and garden-like land use around the settlements. *Terra Preta* sites count in the thousands, maybe one per 100 km^2 in many areas, varying in size from 5 to 400 ha or more. This implies that large tracts of land will have been deforested at around 1500 AD, inter-connected through permanent forest tracks and river transport for inter-tribal commerce of implements, such as stone hand axes as essential means of forest clearing.

In the dryer areas with unfavourable soil conditions, the lasting effects of this early Indian deforestation can be seen in aberrant forest regeneration in the form of tall bamboo forest in central Acre and adjoining parts of Amazonas and Peru (Figure 3), low bamboo (*Guadua* sp)-dominated vegetation in the Açailandia area of north western Maranhão (*tabocal)* and in the interior of Suriname (*pini-pini*); liana forest (*cipoal)* on the plateau stretches west of the lower Xingu (Figure 2) and fire-resistant *babaçu* (*Orbignia* sp) palm forest concentrations in the middle Xingu area.

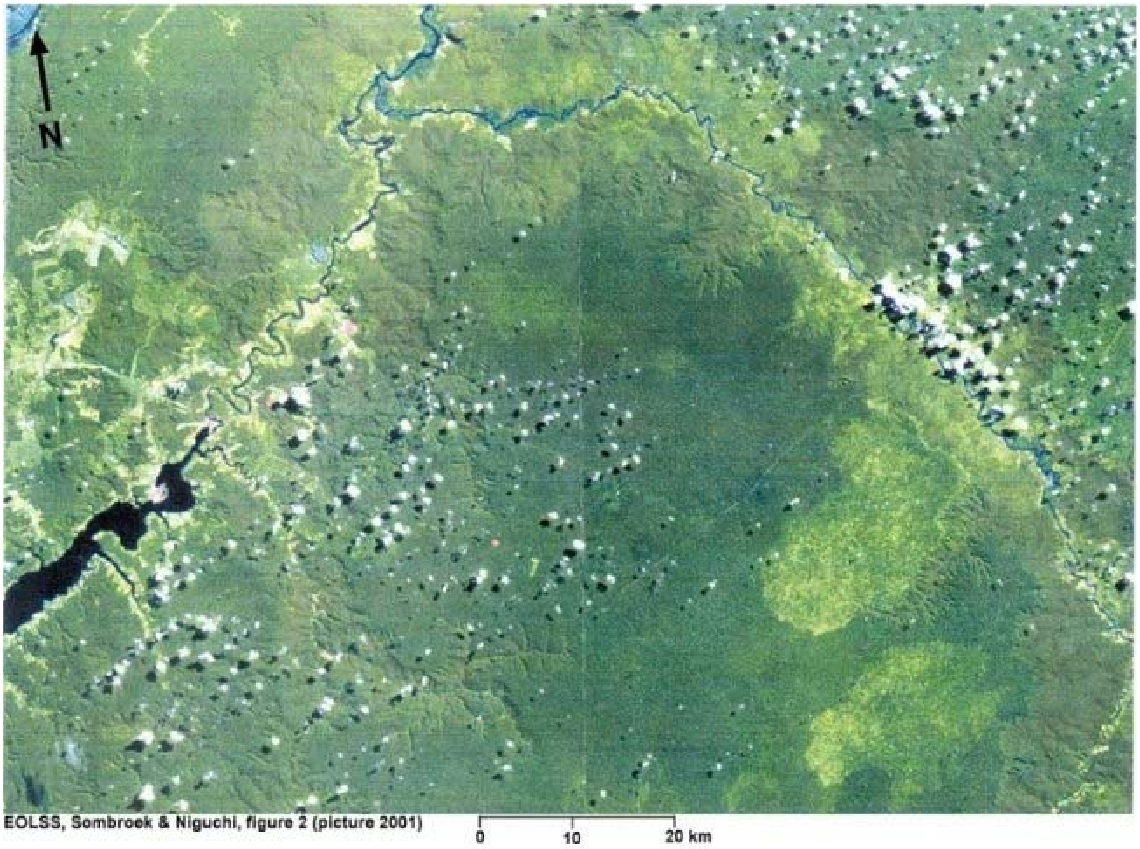

Figure 2. Liana forest, an aberrant Amazon vegetation type, as the likely lasting effect of former Amer-Indian land use.

On the lower right, this Landsat-TM cut-out shows light green areas that are concentrations of dense liana forest (*cipoal)* on the Plio-Pleistocene plateau parts (*planalto Amazônico)* in the region of Rio-Curuá-do-Sul, between the lower rivers Tapajós and Xingu. These light green areas have a sharp boundary with the surrounding dark green primary forest, and field observations by William Balée (MPEG, Belém) have confirmed the presence of patches of anthropogenic *Terra-Preta-de-Indio* soils in these *cipoal* areas. It is therefore assumed that in pre-Columbian times such areas were densely settled. The compact heavy-clay soils (*Xanthic Ferralsols*) on these plateaux, and the strong dry season in the area, will have prevented regular forest re-growth after the 16th century decimation of the Indian population.

On the left is the dam and artificial lake of Curua–una, providing hydro-power to the town of Santarém.

[Landsat –TM # 227/062, August 1995]

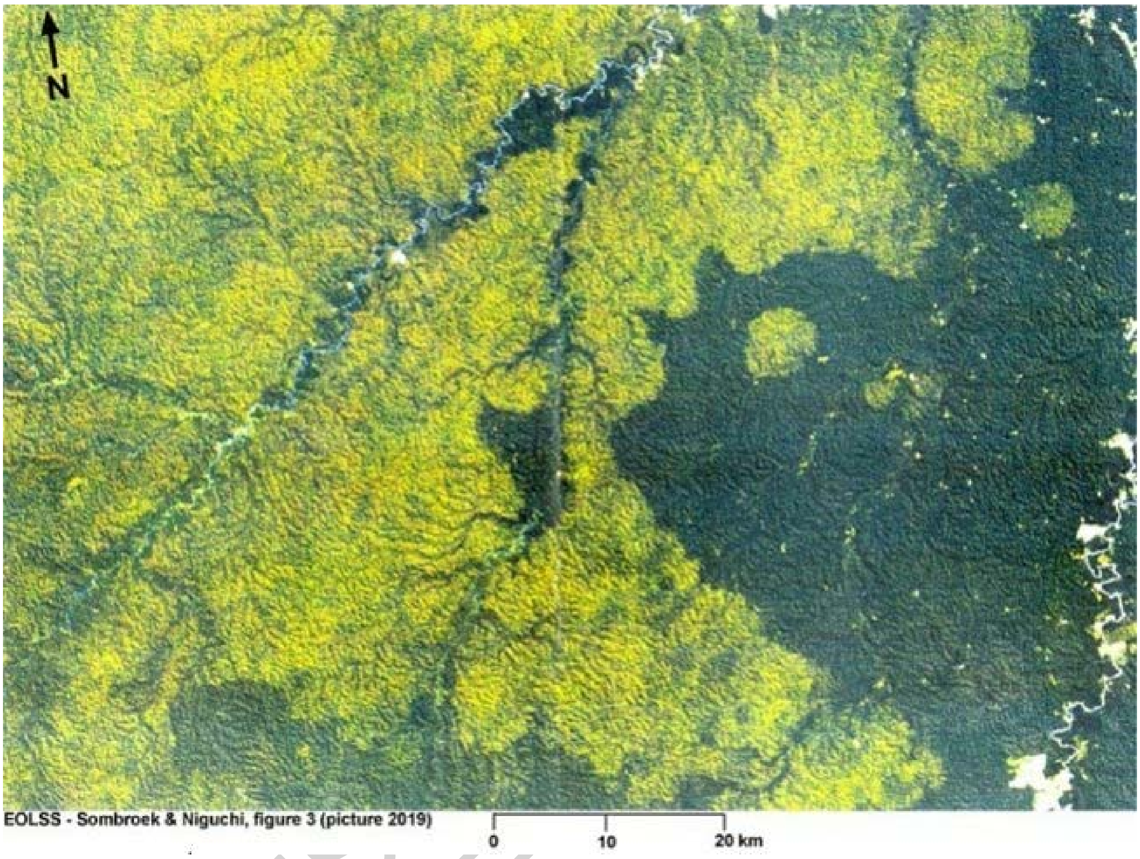

Figure 3. Concentrations of bamboo forest (*bambuzais, Guadua superba)* in the transition zone of Acre and Amazonas States.

These areas, showing up as light green, may be the lasting result of early Amer-Indian occupation. Periodic large-scale burning after flowering of the bamboo and preferential re-growth of its rootstocks will have caused the sharp boundaries with the dark green multi-species primary forest. The dissected upland in this area has predominantly fertile, but unstable and shallow soils with swell-shrink features *(Vertic Cambisols)* which may be detrimental to the re-growth of tree species. The precise origin and dynamics of these *bambuzais* are being studied by Bruce Nelson and co-workers of INPA, Manaus.

At the right side of the picture many tiny white dots within the primary forest can be recognised. They are the home gardens of still active rubber gatherers (*seringeiros*), in the centre of their individual collecting areas *(colocações).* [Landsat-TM # 003/066, July 1992]

In some parts, such as the present-day open savannah area of Tenharim near the southern dip of the Trans-Amazônica highway, which is surmised to be the source area of the Tupi group of Indian languages, there was apparently an over-intensive use of the land, resulting in widespread water and wind erosion during some past time. In the more humid areas, on the other hand, certain useful tree and shrub species such as the Brazil-nut tree, appear to have higher densities in the forest fringes of concentrations of *Terra Preta* sites, as is the case in the area of the lower Aripuaná-Manicoré tributaries of the Madeira river (Figure 5).

All these features—the frequent occurrence of *Terra Preta* and *Terra Mulata* soils, the discovery of earthen defence structures, the presence of raised beds for crop production and dams for aquaculture, and the occurrence of large areas of aberrant vegetation types with sharp boundaries to the old-growth forest—have recently led to the hypothesis that at least 10% of the Amazon forest biome was either completely deforested, or had undergone major changes in canopy structure, species composition and soil conditions, by the time of the arrival of the Europeans.

-
-
-

Bibliography

Chambers, J.Q., Higuchi, N., Tribuzi, E.S. and Trumbore, S.E. (2001). *Carbon sink for a century: Intact rainforests have a long-term storage capacity*. Nature. 410: 429 [This paper discusses the potential length of the CO_2 sequestration in old-growth Amazon forests]

Cleary, D. (2001). *Towards an environmental history of the Amazon: From pre-history to the nineteenth century*. Latin American Research Review 36 (2). 65-96. [This substantial text provides new insights on the influence of early Indian civilisations on the landscape and the forest ecological conditions in the region].

Fearnside, P.M. (1993). *Deforestation in Brazilian Amazonia: The effects of population and tenure.* Ambio 22 (8): 537-45. [One of many articles of this author with long-time and first-hand experience in the region on problems of deforestation and land use change. See also his article in EOLSS chapter 1.5.8 on “Combating Deforestation in Brazil”]

Gash, J.H.C., Nobre, C.A., Roberts, J.M. and Victoria, R L. (1996). *Amazon deforestation and climate.* John Wiley & Sons, New York. pp 611. [A series of articles about the results of the first set of soil, vegetation and atmospheric data field data of the ABRACOS project and their use to calibrate land surface sub-models of the General Circulation Models, which are used in climate change predictions]

Hall, A., ed. (2000). *Amazonia at the crossroads: The challenge of sustainable development.* Institute for Latin American Studies, London. 257p. [This book examines past patterns of destructive resource extraction in Amazonia and critically analyses a series of new initiatives that would offer more sustainable options]

IPCC (2000). *Land use, land use change and forestry: A special report*. Edited by Bob Watson et al., Cambridge University Press. 377p. [This special report of the Intergovernmental Panel on Climate Change compiles and analyses all worldwide available data on land cover and land condition changes and their influence on global climate change, with recommendations on policy changes in relation to the Kyoto Protocol of the Framework Convention on Climate Change]

Nepstad D.C. *et al* (11 co-authors) (1999). *Large-scale impoverishment of Amazonian forest by logging and fire.* Nature, 398: 505-508. [This describes the increased flammability of many of the Amazon forests after logging when current practises are continued]

Nobre, C. (2001). *The Amazon Basin and land use change: A future in balance?* Proceedings Third International Conference on Land Degradation. Embrapa-CNPS, Rio de Janeiro. [This discusses the early findings on CO_2 sequestration by the Amazon forest system of the international programme Large-scale Biosphere-Atmosphere experiment on Amazonia (LBA)]

Phillips, O., Mahli, Y. and Higuchi, N. (1998). *Changes in the carbon balance of tropical forests: Evidence from long-term plots*. Science, 282: 439-442. [This article describes the recently started renewed growth of old-growth Amazon forest as a consequence of increased atmospheric CO_2 concentrations]

Richey, J.E., Melack, J.M., Aufdenkampe, A.K., Ballester, V.M. and Hess, L.L. (2002). *Out-gassing from Amazonian rivers and wetlands as a large tropical source of atmospheric CO_2.* Nature, 416 (11): 617-620. [This reports on the out-gassing of CO_2 from sediment-rich Amazon rivers and their floodplains]

Smith, N.J.H., Serrão, E.A.S., Alvim, P.T. and Falesi, I.T. (1995). *Amazonia: Resilience and dynamism of the land and its people.* UNU Studies on Critical Environmental Regions 3. UN University Press, Tokyo, New York and Paris. 253 p. [This book examines the driving forces behind the rapid ecological and socio-economic changes, which result in threats to the forests and their biodiversity, with strategies for their conservation and adapted cropping systems such as agro-forestry and improved pasture management]

Sombroek, W.G. (2001). *Spatial and temporal patterns of Amazon rainfall: Consequences for the planning of agricultural occupation and the protection of primary forests.* Ambio, 30 (7/01): 388-396. [This article, with 4 maps on the rainfall conditions from newly available data of 800 pluviometric stations, examines the effects of the emerging spatial and temporal patterns on the ecology and agricultural settlement trends]

Sombroek, W.G., Kern, D. Rodrigues, T., Cravo, M da S., Cunha., T.J., Woods, W. and Glaser, B. (2002). *Terra Preta and Terra Mulata: Pre-Columbian kitchen middens and agricultural fields, their sustainability and their replication*. Transactions 17th World Congress Soil Science, August 2002, Bangkok, Thailand, Symposium 18 (Dudal, ed). Pp 1935-1 to 1935-9 on CD-Rom. <www.17wcss.ku.ac.th>. [This article gives an overview of the present-day knowledge about the anthropogenic black earths of the Amazon region, and the aims and requirements of an interdisciplinary research and development programme for modern replication of these fertile soils].

VanderHammen, Th. and Hooghiemstra, H. (2000). *Neogene and Quaternary history of vegetation, climate and plant diversity in Amazonia*. Quaternary Science Reviews 19, 725-742. [An article on the likely climate changes of the past, on the basis of pollen analysis from the Andean Cordillera and some of lowland Amazonia].

Walker, R. (ed) (1996). *Land use dynamics in the Brazilian Amazon*. Special issue, Ecological Economics, 18, pp 80. [Contains valuable articles of Serrão, Smith, Scatena, Moran, Beaumont, and Walker on land use changes in the Brazilian part of the region, with special attention to their environmental economic aspects].

Biographical Sketches

Wim Sombroek holds a Ph.D. in agricultural and environmental sciences from Wageningen University. From 1959 to 1969 he participated in tropical soil survey, and land evaluation projects in Latin America, including Brazilian Amazonia, and in Africa. Thereupon, he became director of the International Soil Reference and Information Centre in Wageningen until 1991, when he joined FAO, Rome, as director of its Land and Water Division and focal point on Climate Change matters. He returned to the Amazon region in 1996, as a team member/consultant in a Manaus-based project on natural resources policies, within the Pilot Program for the Protection of the Brazilian Tropical Forests of the G7 countries and Brazil (PP-G7). At present he is a part-time visiting scientist at the Museu Paraense Emílio Goeldi in Belém, under a fellowship of the Brazilian National Science Foundation CNPq.

Niro Higuchi holds a Ph.D. in Forestry from Michican State University. Since January1980 he has worked in the department of tropical forestry of the National Institute for Research in the Amazon

(INPA), located in Manaus, Brazil. His major research interest is management on sustainable yield basis of the Amazon rainforests. Currently this includes the dynamics of the vegetation in relation to global climatic change.