IMPORTANCE OF TROPICS TO GLOBAL CARBON CYCLE

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Keywords: Carbon cycle, tropical ecosystems, green house gases, biogeochemical cycles.

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Summary

The climate on Earth naturally changes continuously, over time scales going from days, months, years, and either millennium to millions of years. Variations in the amount of physical variables, as the amount of solar radiation received by the planet and small

variations of the Earth orbit, within the Planet the occurrence of volcanic eruptions, changes in ocean currents and atmospheric circulation, geographical distribution of the landscape, cause climate variability in a suite of patterns. In the recent history of the planet Earth, the changes in the greenhouse gases and aerosols concentration in the atmosphere and the profound changes in the land cover of the planet provide strong evidences that the rapid rates of environmental change observed in the last 250 years are likely result of a complex interplay of human-related and natural causes.

Terrestrial environment refers to an enormous suit of ecosystems, which includes water bodies, above and below ground communities and a complex mosaic of land covers, that are pools of carbon, nutrients and other chemical species that exchange fluxes with the atmosphere, eventually originating green house gases. In tropical ecosystems the anthropogenic control of the regional carbon budgets is dominated by emissions from fire and deforestation, accounting up to 75% of the total emissions, depending on the country in this region. Other contribution comes from fossil fuel combustion, energy production, changes in soil carbon stocks, changes on land cover, among others.

The carbon emissions are bounced back, as sinks, by re-growth of secondary forest, increasing area of reforestation, increase of net primary productivity and so forth. The natural variability of energy, water and, thus, carbon exchanges between the terrestrial ecosystems and the atmosphere is controlled by a suite of processes. Those processes are constrained essentially by controlled by local meteorological fluctuations and climatic variability, water and nutrient availability.

1. General Overview

Climatic conditions including precipitation, seasonal water balance, length of growing season, extreme and mean temperature can strongly influence life on Earth, therefore changes in the climate can deeply impact global ecosystems, animal and plant species, in particular tropical regions. Several studies have shown that the evolution of geological and climatic variations is associated to the distribution and composition of terrestrial ecosystems. Analogously, the scenarios for future climate, due to increase of green house gases in the atmosphere, can produce important changes in the composition of the terrestrial biosphere. While the link of climate and ecosystem composition and function can be clearly stated, the feedbacks from ecosystem to the climate are identified, on physical and biophysical processes, as energy and water fluxes (evapotranspiration, latent and sensible heat), biogeochemical cycles (carbon and nutrients).

The general effect of Global climate change can be just slight perceived in the ecosystem level, but changes due to human activities like: land use, lost of biodiversity, physical and chemical degradations (for instance, sewage in water systems), among others, is clearly noted at this level. The natural variability of terrestrial ecosystems and atmosphere exchanges are controlled by a suite of processes, related to surface temperature, CO_2 concentration, soil moisture and nutrient availability, which reflect on soil and plant physiological responses. Therefore, the carbon cycle and dynamic are connect, and reflect, the changes in atmosphere elemental composition and in the ecosystem processes. For tropical regions deforestation and replacement of natural vegetation by pasturelands and agriculture, or impoundment of river systems, are good examples of changes in ecosystem processes reflecting on the carbon dynamic.

2. The Biosphere and Tropical Regions

The heterogeneity of the biosphere is enormous, thus well the dynamic of the carbon cycle in this compartment of the Earth system. Over one third of the Earth's terrestrial surface is situated in the tropics, encompassed between Cancer and Capricorn tropics (Figure 1), with environments ranging from hot deserts to tropical rain forests.

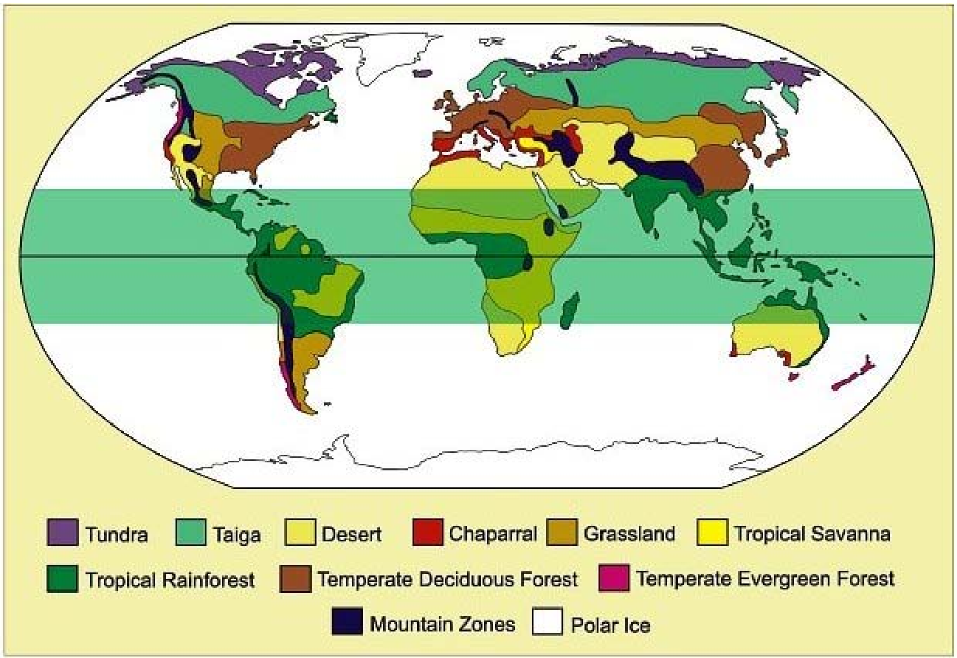

Figure 1. World map indicating Biomes types. Biomes are classified according to the predominant vegetation and characterized by adaptations of organisms to that particular environment. The highlighted area indicates the region between the tropics of Cancer and Capricorn.

Major terrestrial ecosystems in the tropics are tropical rainforests and tropical savannas, basically separated by soil type and by period of the year when evapotranspiration is lower, the precipitation being 9-10 months for forests and 6-8 months for savannas, which define substantial differences in vegetation physiognomies. Translating that to numbers, tropical forests cover an area of 17 million km^2 with $340x10^9$ tons of C stored in the above and below ground biomass, and tropical savannas cover 15 million km^2, with $24x10^9$ tons of C. Therefore, tropical systems account for a substantial portion of the carbon stored in the atmosphere, highlighting the importance of these systems in the global carbon balance (see IPCC 2007).

3. Carbon Linking Ecosystems

Carbon is found in nature as a chemical structure of a single element (i.e., graphite, diamond) or as molecules, combined with other elements. At the molecular state, carbon is found in several compartments of the Earth system assuming different states of oxyreduction. As CO_2, a high oxidation state, carbon is an abundant element in the atmosphere (although compromising only 0.04% of its composition). The photosynthetic process, from autotrophic organisms, reduces the CO_2 in a sugar molecule (CH_2O) transferring carbon from the atmosphere to the biosphere and providing energy to the other forms of life on Earth. As methane (CH_4), the most reduced state, carbon is found in low oxygen environment (deep ocean, floodplains, lake sediments, ruminant animal’s stomachs, etc).

Carbon is distributed in several compartments in the Earth. The lithosphere is a major carbon reservoir (estimated at $70x10^6$ Pg C), although the fluxes between this and other compartments are very small and the residence time very high. Most of the carbon in this compartment is stored as carbonate (mainly calcite and aragonite), but the presence of fossil carbon is important. The recent transfers promoted by human activities are transforming significantly the dynamics of this pool, specially changing its residence time, which means transferring carbon from a long storage time, as petroleum or coal, to a much faster cycling molecule in the atmosphere (CO_2). The terrestrial atmosphere is a fairly homogeneous compartment and holds about 0.04% of its composition as carbon molecules, and mainly on carbon dioxide (CO_2). This percentage represents a total mass of approximately $7.5x10^2$ Pg C.

Another important compartment is the Hydrosphere, which is the compartment that encompasses rivers, lakes, reservoirs and oceans, with carbon compounds commonly found as dissolved organic and inorganic carbon (DOC and DIC), particulate organic carbon (POC) and the organic carbon associated with the living organisms. The oceans hold a major portion of these carbon forms and are extremely important in the global carbon cycle. The influx of carbon into aquatic system happens basically through the following mechanisms: photosynthesis, terrestrial input and rock weathering (for the inorganic forms). The inorganic dissolved carbon (DIC) in aquatic ecosystem is composted by CO_2, H_2CO_3, HCO_3 and CO_3. The concentration of each form of carbon is directly related with the pH. In pH 7.3, for instance, the HCO_3 concentration is 10 times higher than CO_2 concentration and 100 times higher than CO_3 concentration. In rivers, the inorganic carbon is dominated by HCO_3, and the ultimate source of this carbon is the atmosphere.

Carbon is a key element linking ecosystems. In the tropics, the ecosystems diversity is as high as biodiversity itself (community sense); the spatial organization is a complex mosaic of different kinds of aquatic ecosystems, soils and vegetation. Dense forests are structured over a weathered soil profile, composed of a thin nutrient rich layer at the surface (see representation on the right side of Figure 2). Roots are, thus, superficial, with a dense microbe community associated with them providing a synergy for better and efficient nutrient absorption by the vegetation, avoiding dissolved elements to percolate into deep soil layers as a consequence of dense amount of rainfall. A savanna is represented, on the left side of the figure, with short and scarce vegetation. In this representation the vegetation has deep root system, exploring deeper soil layers for nutrients and water. The figure also illustrates the human action over the systems (deforestation, dams, for example).

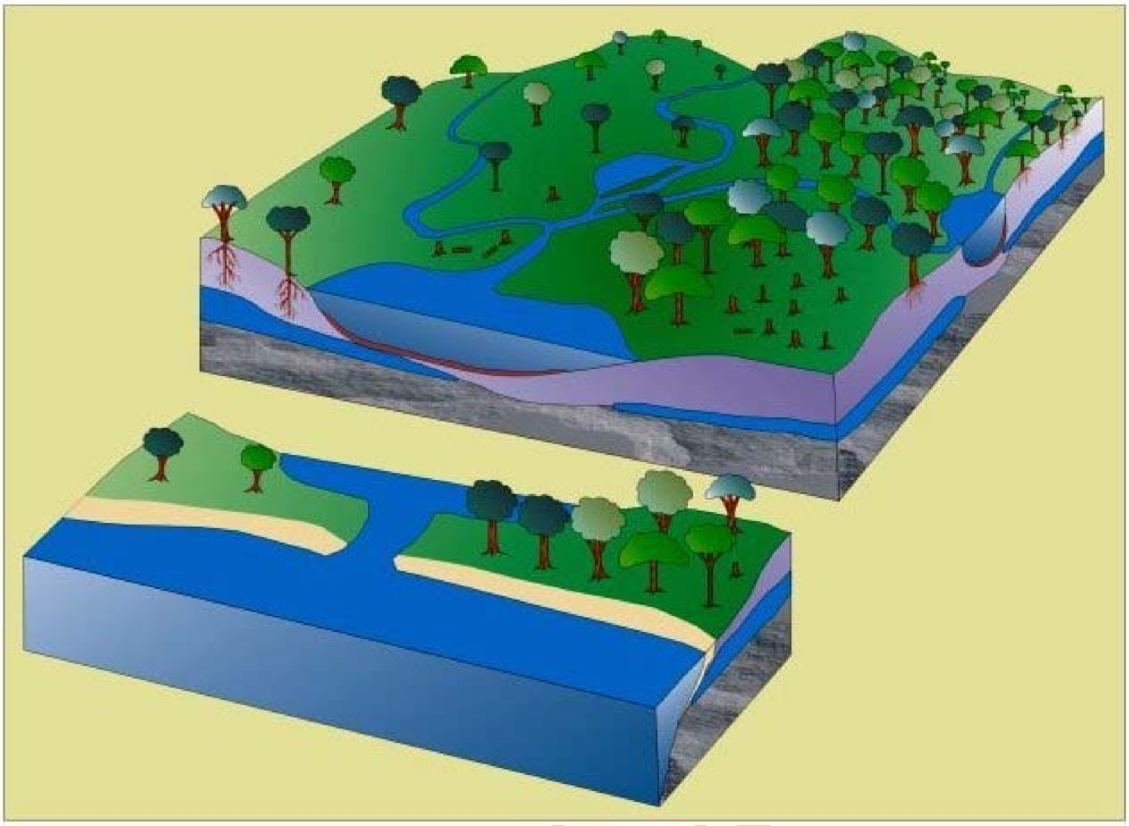

Figure 2. Tropical zone represented as a complex mosaic of ecosystems.

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Biographical Sketches

Fabio Roland is Associate Professor of Ecology and the Head of the Graduate Ecology Program at the University of Juiz de Fora. His PhD thesis focused on phytoplanktonic production in an impacted Amazon lake and his Post-Doc was developed at the Institute of Ecosystem Studies, EUA. He has been coordinating projects focusing (a) Carbon Budget in Hydropower Reservoirs, (b) Management and conservation of aquatic biodiversity in tropical freshwaters (c) Monitoring and restoration of an impacted Amazonian floodplain lake. Dr. Roland, recently, was the President of Brazilian Society of Limnology.

Jean Pierre Ometto is associated to IGBP (International Geosphere-Biosphere Programme). His PhD thesis focused on ecological and nutrient dynamics in stream ecosystems under different levels of anthropogenic perturbation and his Post-Doc was developed under the scope of the LBA project in the Brazilian Amazon. Interested in carbon, water and nutrient cycle within and among ecosystems, Jean has used the stable isotopes to study ecosystems functioning in several regions of Brazil and collaborated with various international institutions among which NOAA, University of Washington, UCLA, IAEA. During the past five years he has worked with the Stable Isotope Ecology at the University of Sao Paulo and University of Juiz de Fora. His recent work with IGBP has strengthened the network for scientific collaboration and questions related to contemporary global environmental changes

Nathan Barros is a scientist and researcher at the Aquatic Ecology Laboratory, at the University of Juiz de Fora. By the same University, he had the degree in Biology in 2006 and a Masters degree in 2008. Nathan's master thesis was based on the interactions between viruses and bacteria and the implications to these communities in an Amazon lake. His main interest is in carbon and nutrients cycles, microbial processes and greenhouses gases. Barros has experience in Ecology, focusing on Aquatic Ecology and in the last five years he has been working on the implication of hydropower reservoirs to the greenhouse gases emissions, as well as on the impact of bauxite tailing to an Amazonian lake.

Felipe S. Pacheco is student at the Graduate Ecology Program at the Federal University of Juiz de Fora, Brazil, and a scientist at the Aquatic Ecology Laboratory, at the same University. His Master thesis approaches studies of water movement using Lagrangean drifts and its implications to understand ecological process in tropical ecosystems. Felipe is interested in explaining the importance of hydrodynamic and modeling to tropical ecosystem and how it regulates nutrient cycle, phytoplankton ecology, gas emissions and other ecological process. He has been working on reservoirs at the project 'Carbon Budget in Hydropower Reservoirs' and on the restoration of an Amazonian lake.

Raquel F. Mendonça is student at the University of Rio de Janeiro, Brazil. Her master thesis was based on applying stable isotope techniques for tracing the carbon pathways in the scope of two projects, approaching carbon budget in hydropower reservoirs and analyzing a latitudinal gradient in South America lakes. She has been cooperating with scientists from Wageningen University (The Netherlands) and now she is a researcher at the Aquatic Ecology Laboratory, at the University of Juiz de Fora, Brazil. Currently, Raquel's research approaches the mechanisms of carbon storage and immobilization within freshwater system sediments.

Arcilan T. Assireu is an associated researcher at the Remote Sensing Division of Brazilian National Institute for Space Research and at the Graduate Ecology Program at the Federal University of Juiz de Fora. He is currently working on a multi-institution project based on periodical field campaigns and hourly data acquisition of limnological and meteorological parameters by a buoy system instrumented for real time transmission through a satellite link. This project aims to understand and quantify the role played by Brazilian electric reservoirs in the global CO_2 and CH_4 greenhouse gases budget. His PhD thesis deals with the oceanic surface and sub-surface circulation using satellite tracked drifters. His interests are varied, from geophysical time series analysis, to geophysical fluid dynamics (mostly ocean, lake and reservoir circulation).

Luiz Antonio Martinelli is scientist and researcher at the Laboratory of Tropical Ecosystems Ecology, at the University of São Paulo. His PhD theses focused on the spatial variability of mineralogical, chemical and organic composition of sediment on flood plains of Amazon river. Dr. Martinelli teaches, as visitor professor, at the Center for Latin America Studies, at the Stanford University, SU, USA. At this University he teaches "Biogeochemistry of the Amazon Basin" and "Causes and Consequences of Amazon Deforestation". Dr. Martinelli has experience in Ecology with emphases in Dynamics of Tropical Ecosystems, working essentially on nutrient cycles in the Amazon tropical forest.