EFFECTS OF POLLUTION AND WILDLIFE TOXICOLOGY IN TROPICAL ECOSYSTEMS

Yaico Dirce Tanimoto de Albuquerque
Universidade Federal de Uberlândia, Instituto de Química, Campus Santa Mônica,, Uberlândia, MG, Brazil

Flávia Nogueira de Sá and **Maria Teresa Raya Rodriguez**
Universidade Federal do Rio Grande do Sul; Departamento de Ecologia, Instituto de Biociências, Porto Alegre, RS, Brazil

Keywords: tropical forests, benefits, impacts of chemical pollution and deforestation.

Contents

Summary

This chapter describes the general aspects of the functioning of the forests and the importance of these ecosystems for the life and the planet's climate control. The remaining tropical forests support about of half of the biodiversity of the world and they constitute a huge and invaluable reservoir of foods and products of economical value, besides constituting a complex chemical storehouses of bioactive compounds. The tropical forests also contribute to a multiplicity of ecological services, such as:

hydrological cycle, availability of drinking water, biological control of plagues and of vectors transmitters of diseases as cholera, schistosomiasis, yellow fever, malaria, besides contributing for the climate control of the forest areas and in global scale. The accelerated rate of the deforestation added to the climatic changes and chemical pollution caused by the anthropogenic activities are putting in risk the benefits offered by remaining tropical forests because the recovery of the destroyed areas is a very slow process and it can be irreversible depending on the habitats and of the biodiversity destroyed. Nowadays, the preservation of the remaining tropical forests makes part of the discussions and international agreements to control the global warming because these ecosystems are important converters of atmospheric carbon dioxide, an important greenhouse gas, into starch, cellulose, carbohydrates, proteins, and other organic compounds. This gas is being emitted into the atmosphere in much larger amounts than the absorbing capacity of the terrestrial ecosystems. The global warming causes changes in the pattern of distribution of the rains affecting the integrity of the forests, their biological diversity, and the carbon cycle. The immediate damage is the impoverishment of communities that live in the forests and in their proximities, relying on the resources produced by the forests for their survival, and the extinction of organisms that participate in the biological control of vectors of diseases.

1. Introduction

Over one third of the terrestrial surface is situated in the tropics, with environments ranging from hot deserts to tropical rainforests. The tropical and sub-tropical regions are the richest in biodiversity, supporting more than 70 per cent of the vegetable species and animals of the world. Biodiversity refers to the vast variety of wild plants, animals, fungi and others microorganisms that live on our planet. The biodiversity in these regions is the result of evolution over millions of years under stable climatic conditions involving complex networks of ecological interactions.

The tropical forests can hold several hundreds of plant species and animals per hectare, constituting very narrow ecological niches. Tropical rainforests are the Earth's oldest living ecosystems and they occupy a narrow band centered about the equator (Figure 1). The remaining rainforests are found in Latin America, Asia and Africa and occupy 7% of the world's land surface. More than half of the world's intact tropical rainforests are in three countries: Brazil, Democratic Republic of the Congo and Indonesia. The largest continuous rainforest lies in South America, where about 2.7 million square miles (6.9 million square kilometers) of forest cover the Amazon Basin.

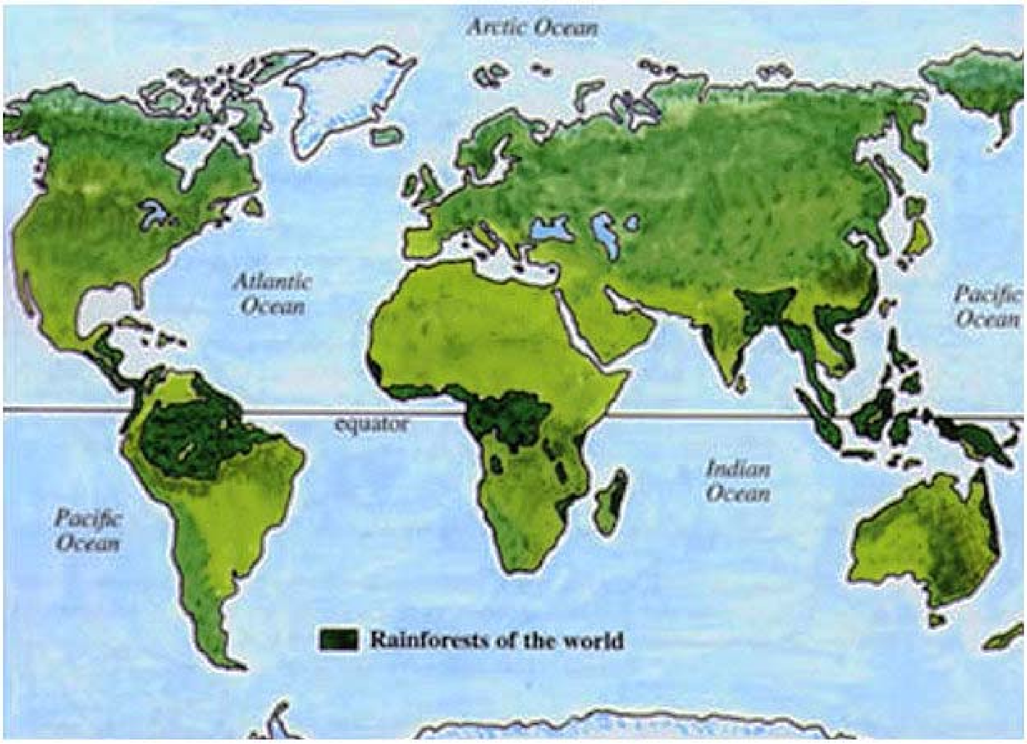

Figure 1: World distribution of tropical rain forests.

In the terrestrial ecosystems, biological diversity plays an important part in the flow of energy, in the recycling of nutrients and, mainly, in the capacity that these ecosystems have to resist external disturbances or of recovering from them. The soil of the forests is the habitat for several groups of microorganisms, such as, algae, bacteria, fungi and others invertebrate organisms like earthworms and termites, which have been involved in maintaining oxygen production and soil fertility. Cyanobacteria and some fungi species contribute to the fertility of soils because of their ability to fix atmospheric nitrogen. The algae in the soil, the trees and other plants act as primary producers and are the food source of a great variety of species existing in the forests. The decomposition of the biomass by microorganisms in the soil make it possible the devolution of the energy and mineral ions such as sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}), calcium (Ca^{2+}), phosphate (PO_4^{3-}), nitrate (NO_3^-), ammonium (NH_4^+), sulfate (SO_4^{2-}) to the environment, which are essential for the productivity of trees and plants of the terrestrial ecosystems, and to sustain the diversity of microorganisms and organisms.

So, the variety of wildlife controls the capacity of the forests to produce foods such as grains, fruits and other products of great economical value for the society, such as: wood, fibers, resins, latex, drugs for medicines and essential oils. The variety of species is part of the countless alimentary chains existent, in which each species population has its importance in the control of the population of other species and in the energy transfer or decomposition of the biomass and/or in the recycling of nutrients. Therefore, the increase or the decrease of the population of a certain species can cause significant alterations in the populations of the other species.

The tropical forests still carry out other important functions on the global scale such as the control of the hydrologic cycle and the production of molecular oxygen (O_2) through photosynthesis by algae and plants. The tropical forests are recognized as the "*sinkhole of carbon*" because they are responsible for great amounts of carbon stored as chemical compounds, which are essentials for the sustenance and the development of the trees, vegetation and animals, including the humans. The hydrologic cycle and the CO_2 concentration in the atmosphere are essential for the control of the temperature and climatic conditions of the region, as well as of the Earth as a whole. In this context, the importance of the preservation of the forest ecosystems is, besides the ecological tourism, of the immense value in providing economical resources to the humans. In spite of this importance, the tropical forests experience tremendous pressure of human action, especially by deforestation, because they occupy areas in undeveloped countries, which have nearly half of the world's human population. The deforestation causes immediate reduction in the offer of goods and services and it affects the climatic conditions of the region, such as, the regime of rains that feed the rivers and the aquifers, as well as the temperature and the fertility of the soil. Deforestation also destroys the chemical reservoir that can be explored in the production of medicines. Actually, about twenty five per cent of the medicines produced should use substances extracted from plants and animals originating from tropical forests. This percentage can increase with the discovery of new animals and plant species. It is estimated that there are about five to thirty million of animal species in the planet, but only 1.4 million were described by the science.

2. Soil and Biodiversity of the Terrestrial Ecosystems

The layer of the soil in contact with the atmosphere and the hydrosphere (0.5 to 3.0 m of thickness) is where settle down the geological and biological processes that control the chemical storage and the recycling of nutrients and minerals necessary for the productivity of the natural biomass and cropland. This layer is the result of the weathering of parent rocks by climate action, water, dissolved atmospheric gases and microorganisms. In the humid tropical areas, the minerals result mainly from the action of the rainwater on the parent rocks that involves hydration processes, dissolution and hydrolysis. This action is intensified by the presence of atmospheric gases dissolved that acidify the water, as, for instance, CO_2 and organic acids, and microorganisms that can attack directly the rocks and minerals by enzymatic oxidation or reduction of metal ion (ex, Fe^{2+} to Fe^{3+}; Mn^{2+} to Mn^{4+}) or by action of acidic substances metabolically produced, such as, CO_2 or H_2SO_4.

Weathering of minerals in the terrestrial ecosystems can also be enhanced due to microbial decomposition of dead animals and vegetal biomass. A diversity of inorganic and organic compounds can be produced during the stages of the biomass degradation, such as: mineral nutrients (nitrogen as NH_3, carbon as CO_2, inorganic anions and metallic ions), organic acids (ex. 2-ketogluconic acid) and biopolymers chelating. Some of these compounds can dissolve or transform the minerals through acid-base reaction or complexation with metal ions from minerals, or by modification of the superficial properties of the mineral particles involving adsorption or ionic exchange processes.

The biogeochemical processes, photosynthesis and the mineralization of the biomass play a fundamental role in the soil as shows the Figure 2. These processes are essential for the cycling of the macronutrients such as nitrogen (N), phosphorus (P), sulfur(S), sodium (Na), calcium (Ca) and magnesium (Mg); micronutrients such as copper (Cu), cobalt (Co), zinc (Zn) and molybdenum (Mo) and other essential nutrients such as carbon (C), hydrogen (H) and oxygen (O), specially such as carbon dioxide (CO_2), molecular oxygen (O_2) and water (H_2O). CO_2 can be released into the atmosphere or dissolved in the aqueous phase of the soil and water bodies and contribute to the photosynthesis processes, as well as it can dissolve minerals like $CaCO_3$. O_2 can also be dissolved in the aqueous phase of the soil and water bodies and can contribute to the degradation of dead biomass by aerobic microorganisms.

The abundance of nutrients in the soil controls the fertility and the productivity of the trees and vegetation, as well as the photosynthesis rate by autotrophic microorganisms in the soil, which are the main primary producers of foods for a countless species in different trophic levels of the alimentary chains. Thus, the terrestrial ecosystems should be understood as integrated systems, involving complex interactions among the living organisms-rock-water-air.

Microorganisms function as living catalysts in a vast number of chemical processes, particularly those involved in the decomposition of biomass and oxidation-reduction processes. The rate of biodegradation is strongly influenced by temperature, availability of molecular oxygen (O_2) and quantity of water. In highly oxygenated soils, the organic matter is oxidized in several stages while O_2 is reduced to H_2O. In flooded soils the anaerobic microorganisms prevail, which decompose the 1organic matter using substances such as the nitrate and sulfate ions as electron acceptors. Therefore, in waterlogged soils with low availability of these inorganic species, the organic matter accumulates and it may reach up to 90 per cent of the solid fraction of the soil.

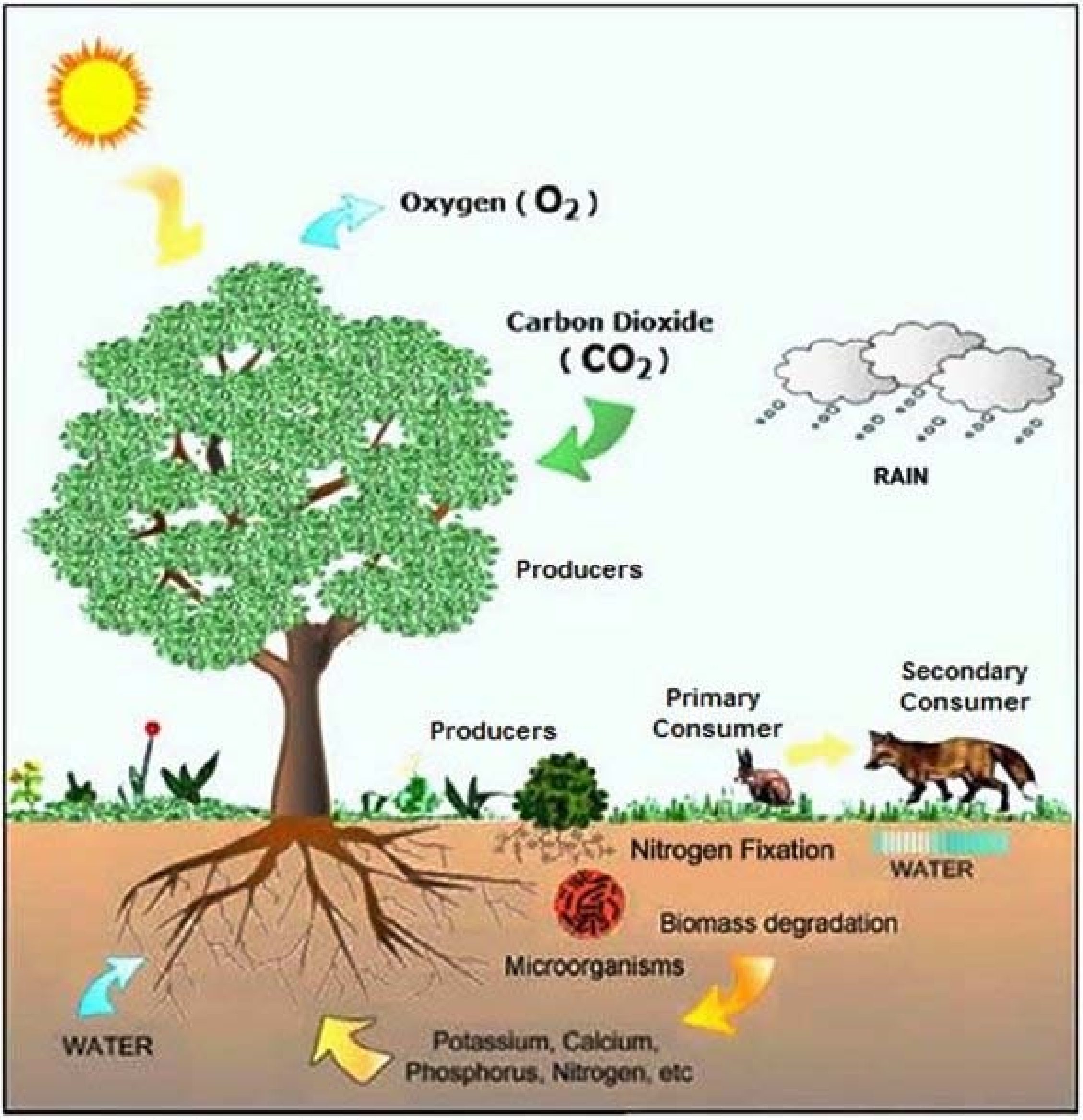

Figure 2: Major components of ecosystems in functioning (adapted from MILLER, 2001).

The climatic conditions affect the physical, geochemical and biological processes that settle down in the soil, affecting, as consequence, the availability of nutrients in the soil. These factors control the population and the diversity of plant and animal species existing in the ecosystems. The climatic conditions relatively stable, under high medium temperatures, and the precipitation of abundant rain are responsible for the great biodiversity of the Amazonian Forest (the most part located in Brazil), the largest of the world. The biodiversity's richness of the tropical rain forests also depends on the nitrogen fixation processes. Among the nitrogen (N_2)-fixing species, the rhizobia bacteria that exist in symbiotic associations with roots nodules of leguminous contribute to the great amounts of biologically fixed nitrogen in agriculture. Besides, there are the cyanobacteria (blue-green algae), ubiquitous in tropical soils, which occur both as free-living species and in association with a variety of plants, and the actinomycete *Frankia* species, which form active N_2-fixing symbioses with some host tropical plant species. Another nitrogen fixing species is that of certain fungi that exist in symbiotic association with plant roots, referred as mycorrhiza fungi. Mycorrhiza fungi provide a greater absorptive surface than root hairs and thus help in the absorption of relatively immobile ions in soil such as phosphate, copper and zinc. Thus, mycorrhizae play an important role in plant growth in the tropical ecosystems and savanna woodlands that occur on generally poor soils.

3. Tropical Forests and Ecological Services

3.1. Biodiversity and Benefits

The tropical forests are shelter and sources of livelihood for the vast and diverse communities of organisms that live in and for the communities that live around them, including the humans. Unfortunately, nobody knows exactly how many species were already extinguished and how many species exist still beyond those already named and described. Most estimates of the number of species range anywhere between 5 and 30 million, with an estimate more probable of somewhere near 10 million.

Plants and algae in the soil are the base of most food chains existent in the forests. The abundance of species controls the quantity, quality and variety of foods supplied by forests. The abundance of foods controls the population and the diversity of wildlife of the forest ecosystems, including the microorganisms in the soil, insects, birds, fish, amphibians, and reptiles. The productivity of forests depends of several factors, such as, nitrogen fixation, cycling nutrients and their availability for growth and development of the vegetation, conservation of pollinators and predators, as well as the biological control of pests. The tropical forests provide innumerous products of economic value, such as foods, timber, dyes, fibers, resins, latex, essential oils, shellac, and drugs for a great variety of applications. Besides, according to World Health Organization (WHO), a great variety of plants, microorganisms and animals are also source of powerful and important drugs, which are widely used to control diseases in humans and animals. Common examples of plant-based drugs include quinine, used to treat malaria; morphine, an analgesic; penicillin, the most famous antibiotic, which is derived from a common fungus called *Penicillium;* acetylsalicylic acid, an analgesic detected in native trees of the Europe and western Asia, and the taxol, an anti-cancer drug that has been found in the bark and foliage of a small coniferous tree. Other examples are the broad spectrum antibiotics, tetracycline and erythromycin, derived from tropical soil microorganisms, besides the drugs used in the treatments of acute childhood leukemia and other forms of cancer. For this reason, the tropical forests are recognized as complex chemical storehouses of many undiscovered biodynamic compounds for use in future medicines.

Estimates indicate that less than 1 percent of millions of species of the tropical rainforest have been studied in terms of their bioactive constituents for medicinal uses or in the production of foods and drinks. For this reason, the preservation of the tropical forests is a great economical investment for the humanity's future. In the same way, the preservation of the knowledge about the innumerous medicinal uses of plants by indigenous people and herbal healers that live in the forests has considerable importance.

Ecological benefits are also provided by tropical forests. Innumerous invertebrate animals and microorganisms play important function in the degradation and recycling of wastes, which are essential to maintain the health and the productivity of wildlife. The soil of the tropical forest is sandy and it is covered with a thin layer of leaves, twigs and dead animals, which shelters invertebrates and microorganisms which quickly consume the biomass layer returning the mineral nutrients in the soil. Without the trees and vegetations, the soil quickly loses its ability to support plants resulting in its desertification. Other ecological benefits provided by some invertebrate and microorganisms are the immobilization of toxic heavy metals or the mineralization of toxic organic pollutants. The forests also sustain species communities involved in the biological control of plagues that affect the productivity of plants and trees, as well as in the control of the population of intermediate host of biological agents responsible for many diseases as dengue, cholera, malaria and schistosomiasis. The studies cumulatively suggest that the maintenance of forests has important implications in the health management of the region. Then, the destruction of habitats affects directly the biodiversity involved in biological control of diseases transmitted by intermediate host, the processes of purification of the water of the rivers and reservoirs, affecting the quality of the water that is consumed by humans and animals.

Tropical diseases affect half a billion people each year, killing around 20 million. Malaria, which is transmitted by mosquitoes, is a major killer in tropical countries. About 500 million people suffer from malaria, with 70 per cent of cases occurring in Africa. The relationship between diseases and forests is highly complex. The clearance of forests followed by establishment of farming or grazing cattle favors epidemics such as malaria and yellow fever because it creates standing water where mosquitoes can breed. In South America, the clearance of forests for farming and cattle ranching has also led to dramatic increases in the populations of vampire bats, a natural host for rabies.

Dam building and use of irrigation's systems in forest areas intensifies plague's population and diseases such as malaria, guinea worm, and dengue fever. Because the forested regions are rich in minerals, mining activities are also established in these areas causing the contamination of the soil and water bodies by acid drainage and/or heavy metals originating from these activities.

3.2. Hydrological Cycle and Climate Control

The vegetal covering of the soil and the abundance of plants and organisms existent in the tropical forests are essential for maintenance of the cycle of the water in the environment, known as the hydrological cycle. This cycle plays decisive role in the productivity of the biomass and in the control of the climate of the planet. The hydrological cycle begins with the incidence of solar radiation that reaches the surface of the Earth causing its heating. The Earth's warming causes the evaporation of the water of the soil, of the rivers, reservoirs, seas and oceans. It also causes the melting of the glaciers, which feeds the rivers and seas, altering the sea level and threatening islands, coastal areas and cities in estuaries. The water vapor in the atmosphere can form the clouds originating the rains or it can be moved for other areas under the influence of atmospheric currents originated from the warming of the atmospheric air (Figure 3). Another important contribution for the hydrological cycle comes from the tropical forests because the dense vegetation can lose great amounts of water vapor through of the evaporation and transpiration processes, known as evapotranspiration. Due to this phenomenon, in very hot days, the rainforests strongly influence the climatic conditions and the hydrological cycle of the region.

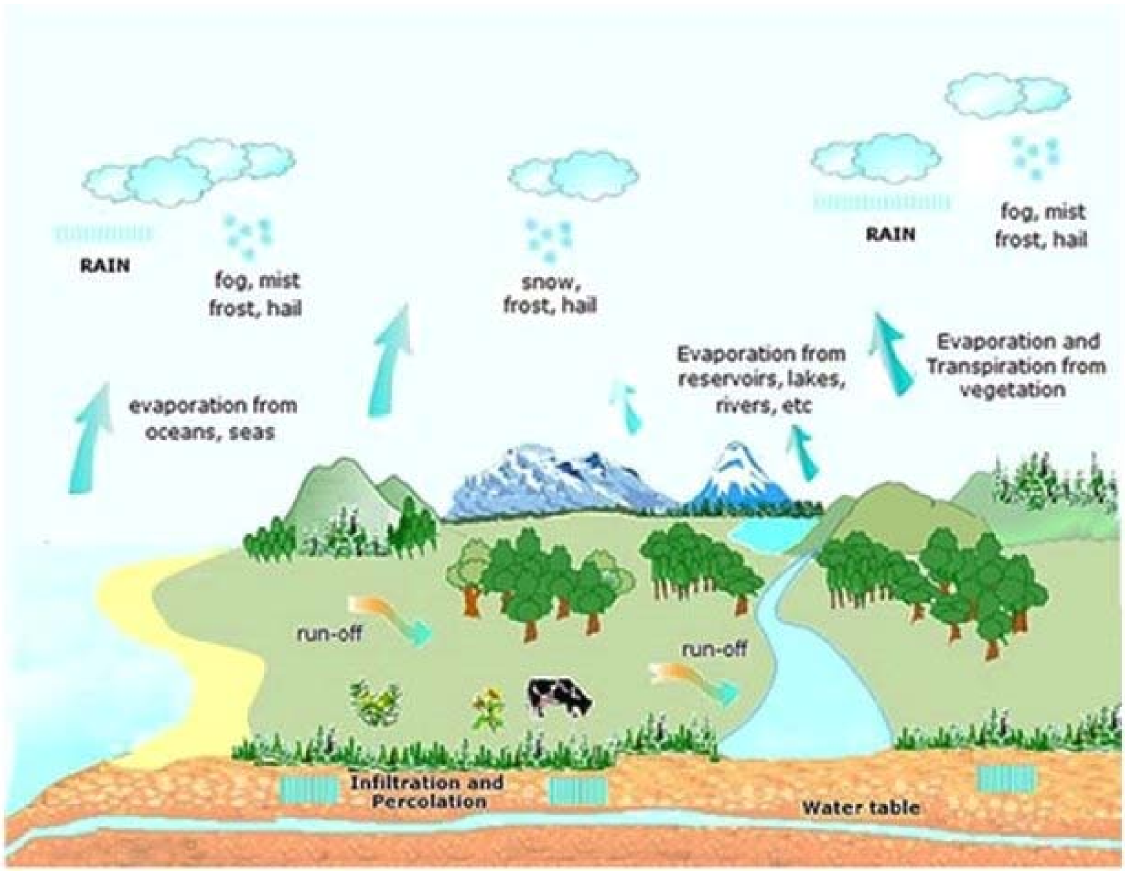

Figure 3: Simplified model of the hydrological cycle.

In the Amazonian Forest it is estimated that the evapotranspiration contributes to about half of the precipitation that falls in the forested area. Then, the clearing away of trees and plants quickly diminishes the moist canopy of the tropical rainforest reducing the evaporation and leaving the local atmospheric air hotter in the hottest days. The water vapor returns to the terrestrial surface in the form of water liquid (as rain, fog, mist) or solid precipitation (as snow, frost, hail). The rain can precipitate directly on the seas and oceans or on the fields and grasslands forming the torrents that drain into the rivers and reservoirs. The rainwater can still be absorbed by mineral particles in the soil or infiltrate through the soil and to recharge water tables and the aquifers that feed the nascent of the rivers. The water in the soil plays a decisive role in the photosynthesis process, as well as in the availability and transport of the nutrients in the plants, carrying out important function in the conservation of the biological diversity.

The water vapor together with other gases in the troposphere, mainly the CO_2, plays important role in the control of the temperature of the Earth planet. Of the total of incident solar radiation (ultraviolet, visible and infrared) that enters in the atmosphere of the planet, about 50% reaches the Earth's surface (see Figure 4). A part of the incident solar radiation is absorbed by plants in the photosynthesis processes. Other 20% of the incoming solar radiation is absorbed by gases in the stratosphere and in the troposphere: Ultraviolet radiation (wavelengths < 0.4 μm) is absorbed by gases in the stratosphere (mainly oxygen diatomic and ozone), and infrared radiation (wavelengths of 0.8 to 4 μm region) is absorbed by gases in the troposphere, mainly water vapor and CO_2.

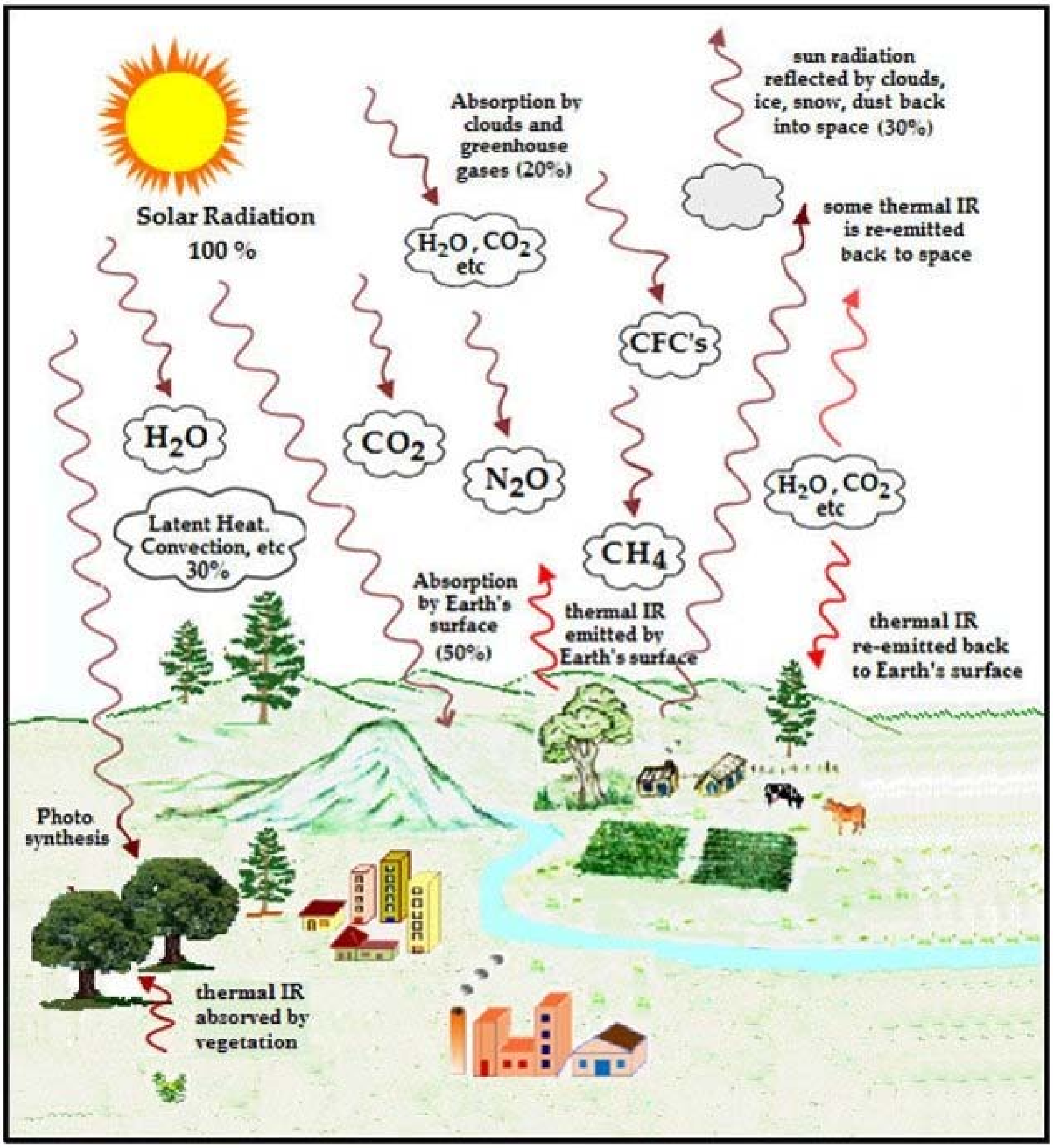

Figure 4: Fluxes of solar radiation in and out of the Earth's atmosphere.

Others minor gases in the atmosphere, such as, methane (CH_4), nitrous oxide (N_2O), Ozone (O_3), chlorofluorocarbons (CFC's), also contribute to the control of the temperature of the planet. About 30 percent of the incoming radiation is reflected back into space by clouds, ice, snow, sand and reflecting bodies, without being absorbed. The energy absorbed by gases in the atmosphere and Earth's surface is released as longer wavelength infrared (IR), from 4 to 50 μm, called thermal infrared or heat. A small proportion of this thermal infrared (10%) escapes directly into space, but most part may be absorbed by gaseous molecules in the atmosphere, such as water vapor, carbon dioxide and other minor gases. The thermal IR radiation absorbed by gases in the troposphere can be re-emitted in all directions. A significant part of them is directed back towards the Earth's surface, where they may be absorbed again.

Then, the atmosphere acts like the glass cover in a greenhouse, retaining the heat released by Earth's surface and re-emitting back. For this reason, this phenomenon is called natural greenhouse effect and it is responsible for the medium temperature at the Earth's surface around $+15^0$C. Among the processes involved in the control of the temperature of the planet is the great amount of heat expended in turning ice into water and water into vapor. The heat involved in these transformations is known as latent heat. The heat absorbed is lost when water vapor condenses or when the water liquid solidifies. The condensation of the water vapor is the major responsible by warming of the surrounding air, impeding the abrupt fall in the temperature at night when there is not incidence of sun radiation. Others phenomenon related with heat transfer are the displacement of masses of air and ocean currents from warm tropics to the cold polar regions.

Since the water in the terrestrial surface absorbs heat at different rates depending on the sources, the diurnal temperature changes are larger on land than in rivers, lakes, seas and oceans. Trees and plants of the forests participate actively of the control of the temperature during the day as a blanket that absorbs and reflects thermal radiation. The heat absorbed by vegetation is responsible for the losses of water vapor by evapotranspiration process, which returns as rainfall. The maintenance of the patterns of rainfall is important to feeding of the rivers, lakes, reservoirs and recharge of the aquifers.

Although the greenhouse effect is important to maintain the life in the planet, the intensification of this phenomenon is undesirable. Like this, the anthropogenic emissions of greenhouse gases should be controlled by all of countries, developed and in development. Among the greenhouse gases - carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), chlorofluorocarbons (CFC's) - the emissions of CO_2 are the most representative and preoccupying.

The vast vegetation of the rainforests has important contribution in the control of the CO_2 levels in the atmosphere through of the photosynthesis processes. The photosynthesis removes continuously carbon dioxide from the air and stores it as chemical substances in their leaves, wood, roots and soils, while oxygen (O_2) is produced (Figure 2). The Amazon rainforest, the greatest natural resource remaining on the planet, has been described as the *"lungs of planet"* that continuously recycles carbon dioxide into O_2 by photosynthesis process. As the Amazon rainforest absorbs slightly more carbon dioxide than the respiration process releases carbon dioxide, this forest is considered a net producer of oxygen (O_2). It is estimated that more than 20 percent of Earth's oxygen is produced in this area. Algae in the soil also contribute to the production of O_2 and removal of CO_2 from the atmosphere by photosynthesis.

The carbon sequestration involves conversion of the atmospheric carbon dioxide into terrestrial carbon pool in the form of organic compounds in the biomass (of the plants, organisms and microorganisms, above and below-ground), soil humus, biogenic carbonates and geological materials. Then, forests and soil with vegetal covering, rivers, lakes, reservoirs, seas and oceans represent efficient mechanisms of sequestration of atmospheric carbon through photosynthesis and biogeochemical processes.

-
-
-

Bibliography

BAIRD, C. (1999). *Environmental Chemistry*. 2nd Edition. New York: W.H. Freeman and Company, 528 p. [This book presents a comprehensive text about the chemical processes that occur in the natural environmental and as these processes control the functioning of the aquatic and terrestrial ecosystems. Effects of anthropogenic pollutants on these ecosystems and on materials are discussed in the perspective of solving the impacts and preventing them]

BAWA, K.S. and DAYANANDAN, S. (1998). “Global climate change and tropical forest genetic resources”. *Climatic Change*, Springer Netherlands, vol. 39, no. 2-3, pp. 473-485. [This paper discusses as the global climatic changes may directly affect the distribution of biomes, ecosystems, and the genetic diversity. Effects on plant genetic resources through effects on phenology events, breeding systems, and plant-pollinator and plant seed disperser interactions, are also discussed].

BAZZAZ, F.A. (1998). “Tropical Forests in a future climate: Changes in biological diversity and impact on the global carbon cycle”. *Climatic Change*, Springer Netherlands, vol. 39, no. 2-3, pp. 317-336. [A valuable discussion is presented regard to possible impacts of the deforestation, elevated atmospheric CO_2 and temperature rise, on tropical forests’ integrity. The deforestation combined with the climatic change may reduce the biological diversity drastically because the global change can decouple the strong co-evolutionary interactions and to change forests’ functioning and the ecological services offered by these ecosystems]

BEGON, M.; TOWNSEND, C. and HARPER, J.L. (2005). *Ecology: From individuals to ecosystems*. 4th edition. Oxford: Blackwell Publishing, 752 p. [This book provides a comprehensive treatment of the principles of ecology, species interactions, and nature of the community and influence of population interactions on community structure, food webs, and patterns in species richness. All topics are enriched by extremely clear illustrations and a rich use of examples of human relationships with the environment]

BRAGA, B.; HESPANHOL, I.; CONEJO, J.G.L.; BARROS, M.T.L.; SPENCER, M.; PORTO, M.; NUCCI, N.; JULIANO, N. and EIGER, S. (2003). *Introdução à Engenharia Ambiental*. São Paulo: Prentice Hall, 305 p. [The book provides the concepts basic of ecology, biogeochemical cycles, and hydrological cycle. Fundamental aspects of environmental pollution and management of solid residues, and environmental legislations are also discussed]

BURGER, J. (1997). “Ecological effects and biomonitoring for mercury in tropical ecosystems”. *Water, Air and Soil Pollution*, Springer Netherlands, vol. 97, no. 3-4, pp. 265-272. [A profound discussion is presented regarding the contamination of Hg and like it can affect the population of top predators of the tropical forests. The author suggest that top predators may also be more vulnerable either because they have smaller niches, or because they are at the top of longer and more complex food webs. In longer food webs, toxicants such as Hg may be bioamplified].

CAPE, J.N.; FOWLER, D. and DAVISON, A. (2003). “Ecological effects of sulfur dioxide, fluorides, and minor air pollutants: Recent Trends and Research Needs”. *Environment International*, Elsevier, vol. 9, pp. 201–211.[The effects of the reduction of the emissions of the 'traditional' primary air pollutants (fluorides, sulfur dioxide) on ecological systems, close to the emission sources and in remote areas, are discussed. They alert for the need in understanding the pathways by which airborne pollutants enter and react within ecosystems to improve the predictions of the response to future emission changes, both locally and globally]

COLFER, C.J.P.; SHEIL, D. AND KISHI, M. (2006). “Forests and human health: Assessing the evidence”. Occasional Paper published by Center for International Forestry Research (CIFOR), Bogor, Indonesia, no. 45, 111 p. [This publication offer four issues related to tropical forests and human health: first, emphasizing the forest as a food-producing habitat, human dependence on forest foods, the nutritional contributions of such foods, and nutrition-related problems that affect forest peoples; second, dedicated to disease, tropical diseases and health problems related to forests other health problems; third, with focus in the medicinal products and related indigenous knowledge, with a discussion of the benefits of forest medicines and conflicts over their distribution; and the fourth topic about the cultural interpretations of human health found among forest peoples, including holistic world views that impinge on health and indigenous knowledge].

CORREDOR, J. E.; HOWARTH, R. W.; TWILLEY, R. R.; MORELL, J. M. (1999). “Nitrogen cycling and anthropogenic impact in the tropical inter-American seas”. *Biogeochemistry*, Springer Netherlands, vol. 46, no. 1-3, pp. 163-178. [The authors discuss the mechanisms that lead to nutrient limitation in tropical marine systems, with particular emphasis on nitrogen cycling in Caribbean ecosystems. They discuss the pathways for which both nitrogen and phosphorus exert substantial influence on biological productivity and structure of tropical marine ecosystems]

DIVAN JUNIOR, A.M.; OLIVA, M.A.; MARTINEZ, C.A.; and CAMBRAIA, J. (2007). “Effects of fluoride emissions on two tropical grasses: chloris gayana and Panicum maximum cv. Colonião”. *Ecotoxicology and Environmental Safety*, Elsevier, vol. 67, no. 2, pp. 247-253. [This paper describes the injuries on the two grasses species caused by fluoride emission from an aluminum smelter. The ionic permeability, photosynthetic rates, stomatal conductance, transpiration, chlorophyll a fluorescence and chlorophyll, soluble carbohydrates and fluoride contents were evaluated and compared with the respective contents of control plants situated at 78km from the fluoride source]

DOMINGOS, M.; KLUMPP, A.; RINALDI, M.C.S.; MODESTO, I.F.; KLUMPP, G.; DELITTI, W.B.C. (2003). “Combined effects of air and soil pollution by fluoride emissions on Tibouchina pulchra Cogn., at Cubatão, SE Brazil, and their relations with aluminum”. *Plant and Soil*, Springer, vol. 249, no. 2, pp. 297-308. [The authors evaluated the F and Al uptake from fluoride-contaminated soil, supposedly as AlF_x complexes, in the increase of foliar F and Al contents in saplings of tree Al-accumulators species, which were concomitantly exposed to fluoride-contaminated air. The seasonal variations in F and Al accumulation and possible metabolic changes in the plants due to F and Al accumulation were also investigated].

EDWARDS, C.A. (2002). “Assessing the effects of environmental pollutants on soil organisms, communities, processes and ecosystems”. *European Journal of Soil Biology*, Elsevier, vol. 3, no. 3-4, pp. 225-231. [The ecological impacts of pollutants on soils of natural and managed ecosystems are discussed based on the following effects: at the organism population level; at the community level in terms of effects on plant-plant, plant-microbial, or plant-faunal interactions, species diversity and on soil food webs; at the ecosystem level, in terms of effects on primary and secondary productivity, organic matter breakdown and nutrient cycling]

FEARNSIDE, P. M. (2001). “Global warming and tropical land-use change: greenhouse gas emissions from biomass burning, decomposition and soils in forest conversion, shifting cultivation and secondary vegetation”. *Environmental Pollution*, Elsevier, vol. 112, pp. 163-169. [The author shows that the total net emission of carbon from the tropical land uses calculated for the 1981-1990 period may be 50% higher than the value used by the Intergovernmental Panel on Climate Change. The continued deforestation would produce greater impact on global carbon emissions and the impact from tropical land uses on global warming should be approximately 29% of the total anthropogenic emission from fossil fuels and lad-use change]

FREY, B.; STEMMER, M.; WIDMER, F.; LUSTER, J.; SPERISEN, C. (2006). “Microbial activity and community structure of a soil after heavy metal contamination in a model forest ecosystem”. *Soil Biology and Biochemistry*, Elsevier, vol. 38, pp. 1745–1756. [The authors studied the effects of chronic heavy metal contamination on soil microbial communities by using a model forest ecosystem consisting of several tree species (*Norway spruce, birch, willow*, and *poplar*) maintained in open top chambers. They observed that the heavy metal contamination strongly impacted the microbial biomass and function of the soil microbial communities and that the effects are more pronounced when in combination with acid rain]

FURLAN, C.M.; DOMINGOS, M.; SALTINO, A. (2007). “Effects of initial climatic conditions on growth and accumulation of fluoride and nitrogen in leaves of two tropical tree species exposed to industrial air pollution”. *Science of the Total Environment*, Elsevier, vol. 374, pp. 399–407. [The study was performed with saplings of *Tibouchina pulchra* and *Psidium guajava* in two sites at Cubatão, São Paulo, southeast Brazil: one, virtually unaffected by air pollution and other, severely affected by pollutants released mainly by chemical, fertilizer, iron and steel industries. The results obtained from measurements of chemical composition, growth and biomass allocation, for both species in the two sites, suggested that seasonal conditions of the first months of sapling exposure (summer or winter) modulate the intensity of responses to pollution stress]

GILLER, K.E.; WITTER, E.; MC GRATH, S.P. (1998). “Toxicity of heavy metals to microorganisms and microbial processes in agricultural soils: a review”. *Soil Biology and Biochemistry*, Elsevier, vol. 30, no. 10-11, pp. 1389-1414. [The review summarizes the results of the effects of heavy metals on soil microorganisms and microbial mediated soil processes accumulated from studies from both laboratory studies and field experiments. The enormous disparity between these results shows the urgent need for studies that provide a better understanding of the long term effects of heavy metals toxicity to microorganisms in field soils, and how such effects are regulated, which can be used to guide future policies for the environmental protection of soils]

GRANTZ, D.A.; GARNER, J.H.B.; JOHNSON, D.W. (2003). “Ecological Effects of Particulate Matter”. *Environment International*, Elsevier, vol. 29, pp. 213– 239. [This paper discusses the different pathways for which the particulate matter can cause damages to the vegetation and to the ecosystems depending on the chemical loading and size distribution of the particles. Impacts on the vegetation and ecosystems, especially through its effects on the rhizosphere bacteria and fungi in the soil, were discussed in details]

HERNANDEZ, A.J.; ALEXIS, S.; PASTOR, J. (2007). “Soil Degradation in the Tropical Forests of the Dominican Republic's Pedernales Province in Relation to Heavy Metal Contents”. *Science of the Total Environment*, Elsevier, vol. 378, pp. 36–41. [The authors observed that the fertility (organic matter, N, P, K) and available heavy metal contents (Cu, Cr, Pb, Cd, Ni, Zn mean) were almost invariably higher in the natural forest soils compared to those given over to human activities, especially cultivated soils. The authors suggested the uptake of metals by the crops and, to a lesser extent, by animals feeding on crop remains and grassland plants, to explain the differences]

HOLTGRIEVE, G.W.; JEWETT, P.K.; MATSON, P.A. (2006). “Variations in soil N Cycling and Trace Gas Emissions in Wet Tropical Forests”. *Oecologia*, Springer, vol. 146, pp. 584–594. [The authors evaluated how change in mean annual precipitation affects the processes resulting in the loss of N as trace gases. They observed that mean annual precipitation exerts strong control on N cycling processes and the magnitude and source of N trace gas flux from soil through soil redox conditions and the supply of electron donors and acceptors.]

HOPKINS, M. (2007). “Carbon Sinks Threatened by Increasing Ozone”. *Nature*, Nature Publishing Group, vol. 448, no. 7152, pp. 396-397. [The author alerts for the rising levels of ozone pollution over the coming century that can affect the ability of plants to absorb carbon dioxide from the atmosphere. Ozone is known to be a minor greenhouse gas, but the new calculations suggest an indirect way of influencing the global warming by 2100]

HUANG, P.M.; WANG, M.K.; CHIU, C.Y. (2005). “Soil Mineral – Organic Matter – Microbe Interactions: Impacts on Biogeochemical Processes and Biodiversity in Soils”. *Pedobiologia*, Urban & Fisher, Elsevier, vol. 49, pp. 609-635. [This paper describes as the mineral–organic matter–microorganism interactions interfere control the biogeochemical reactions, the biodiversity, species composition, and sustainability of the terrestrial ecosystem. The authors show as the frontiers of knowledge are essentials to understanding the dynamics and mechanisms of terrestrial ecosystem processes, and to developing innovative management strategies to sustain ecosystem health on the global scale]

IPCC, (2007). *Climate Change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom, 851 p. [The Climate Change 2007 volumes of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) provide the most comprehensive and balanced assessment of climate change available. This IPCC Working Group III volume provides a comprehensive, state-of-the-art and worldwide overview of scientific knowledge related to the mitigation of climate change]

KLUMPP, A.; ANSEL, W.; KLUMPP G.; and FOMIN, A. (2001). “Um novo conceito de monitoramento e comunicação ambiental: a rede européia para a avaliação da qualidade do ar usando plantas bioindicadoras (EuroBionet)”. *Revista Brasileira de Botânica*, Sociedade Brasileira de Botânica, São Paulo, vol. 24, no. 4, pp. 511-518. [The paper presents the scientific and communicative aims and methods of the EuroBionet project. This program uses bioindicator plants to assess air pollution effects within a network of cities and through a specific communication concept the scientific results are translated and communicated in a way that addresses the public and raises environmental awareness]

LAURENCE, J.A. (1998). “Ecological Effects of Ozone: Integrating Exposure and Response with Ecosystem Dynamics and Function”. *Environmental Science and Policy*, Elsevier, vol. 1, pp. 179-184. [This paper discusses the effects of the ozone exposure on plant growth, development and productivity. Under sufficient exposure to ozone, normal plant-parasite interactions may be modified and disrupt normal development of forest stands resulting in shifts in composition, changes in genetic structure and biodiversity and in impaired ecosystem function]

MANAHAN, S. E. (2001). *Fundamentals of Environmental Chemistry*. 2nd Edition. New York: Lewis Publishers, 1003 p. [This book provides the foundations for understanding the processes that occur in atmosphere, hydrosphere, and lithosphere, which affect the living systems, under natural conditions and polluted. The effects of organic and inorganic pollutants on living systems are discussed within a context that goes besides simply to understand the processes involved but mainly to direct efforts towards the preservation and enhancement of an equilibrate environment, rather than simply exploit it]

MATSON, P.A.; McDOWELL, W.H.; TOWNSEND, A.R.; VITOUSEK, P.M. (1999). “The Globalization of N Deposition: Ecosystem Consequences in Tropical Environments”. *Biogeochemistry*, Springer, vol. 46, pp. 67–83. [The authors assessed that the effects of increasing anthropogenic N inputs on tropical ecosystems processes may be quite different in relation to the ecosystems of temperate zones. They concluded that anthropogenic inputs of N into tropical forests may decrease the productivity due to indirect effect such as acidity of soil or limitation of other resources, such as availability of phosphorus or others nutrients].

MILLER Jr, G.T. (1998). *Living in the Environment: Principles, Connections, and Solutions.* 10th Edition. Belmont: Wadsworth Publishing Company, 761 p. [This book provides a critical overview of ecosystems and how they work, the connections and interactions that sustain the biodiversity and ecosystems’ stability. A critical discussion is also presented about the major environmental problems, such as, deforestation of tropical forests and loss of biodiversity, destruction of the ozone layer, global warming and alternative energy resources, atmospheric pollutants, and pollution of natural resources with organic and inorganic pollutants. Finally, aspects economic, politics, and ethics and sustainable use of renewable and non renewable resources are critically discussed]

MORAES, R.M.; KLUMPP, A.; FURLAN, C.M.; KLUMPP, G.; DOMINGOS, M.; RINALDI, M.C.S.; and MODESTO, I.F. (2002). “Tropical fruit trees as bioindicators of industrial air pollution in southeast Brazil”. *Environmental International*, Elsevier, vol. 28, no. 5, pp. 367-74. [The authors assessed *Psidium guajava* L., *Psidium cattleyanum* Sabine and *Mangifera indica* L. as possible tropical bioindicators of air pollution by industrial emissions. The study was performed around the industrial complex of Cubatão, SE Brazil, which comprises 23 industries, including fertilizer, cement, chemical, petrochemical, and steel plants, with 110 production units and 260 emission sources of pollutants]

O’NEILL, P. (1994). *Environmental Chemistry*. 2nd Edition. London: Chapman & Hall, 268 pp. [The environmental chemistry is discussed through of the processes involved in cycling of major and minor elements between living matter, water bodies, atmosphere, and soil. The effects of the pollutants constituted by these elements on materials, human health, and other living systems of the terrestrial ecosystems are discussed within each topic to provide a critical vision about the environmental problems involved]

PHILLIPS, O.L. (1997). "The changing ecology of tropical forests". *Biodiversity and Conservation*, Springer, vol. 6, pp. 291-311. [The author alerts for the possible mistakes of evaluation of the remaining forests through the satellite images. Besides deforestation, an array of direct effects that probably interact synergistically with one another may threat the humid tropical forest biodiversity, such as: selective extraction of plants, selective extraction of animals, biological invasion, fragmentation, climate change, changing atmospheric composition, and increasing tree turnover rates]

RAYA-RODRIGUEZ, M. T. (2000). *O uso de bioindicadores para avaliação da qualidade do ar em Porto Alegre*. In: ZURITA, M. L. L. and TOLDO, A. M. (Ed.). *A Qualidade do Ar em Porto Alegre*. Porto Alegre: SMAM, 103 p.[This book presents several chapters about typical situations of the air quality in Porto Alegre city, Rio Grande do Sul state, Brazil. The mentioned chapter discusses the results obtained in a program of evaluation of the pollution in several places of the city, using plants as bioindicators]

SCHARLEMANN, J.P.W. and LAURANCE, W.F. (2008). "Environmental Science: How green are biofuels?". *Science*, American Association for the Advancement of Science, vol. 319, no. 5859, pp. 43-44. [The authors alert for the full environmental costs associated to the biofuels, such as ethanol from corn (maize) and sugarcane, which have been increasingly associated with lower greenhouse-gas emissions than fossil fuel. For the evaluation of benefits of biofuels should be considered the loss of rich tropical forests in stored C, that elevates the emissions of gases greenhouse and causes alterations in the hydrological cycle, the environmental costs associated with amounts water and energy that are necessary for the biofuel crops productivity, besides greenhouse gas emissions from nitrogen fertilizers by biological activity in the soil, besides others costs]

SCHOLES, R.J. and Van Breemen, N. (1997). *The Effects of Global Change on Tropical Ecosystems*. Geoderma, Elsevier, volume 79, pages 9-24. [The authors evaluate that the land use will continue to be the dominant driver of environmental change in the tropics for the next several decades. The combined effects of changes in the vegetable covering of the soil with others global changes, including climate changes, affect the functioning of several processes, principally those related to carbon cycling and nutrients assimilation, resulting in alterations on structure and productivity of tropical ecosystems]

SILVANO, J. and RAYA-RODRIGUEZ, M.T. (2003). "Evaluation of metals in water sediment and fish of azul lake, in a open-air originally coalmine (Siderópolis, Santa Catarina state, Brazil)". *Acta Limnologica Brasiliensis*, Sociedade Brasileira de Limnologia, vol. 15, no. 3, pp. 71-80. [The aim of this study was evaluate the concentrations of Chromium, Manganese, Nickel, Zinc, and Iron in water, sediment, and muscle and liver of some fish species from a lake originated from the mineral coal mining. The metal contents in these samples were discussed and compared with results obtained in no-contaminated sites]

SILVER, W.L. (1998). "The Potential Effects of Elevated CO_2 and Climate Change on Tropical Forest Soils and Biogeochemical Cycling". *Climatic Change*, Elsevier Netherlands, vol. 39, no. 2-3, pp. 337-361.[This paper presents the pools and fluxes of carbon in tropical forests, and the relationship of these on nutrient cycling and climatic conditions. The annual net primary productivity, the carbon flux from soil respiration, and the soil organic carbon storage of the dry and humid tropical forests, were used to examine the sensitivity of biogeochemical cycling to incremental changes in temperature and rainfall]

TOWNSEND, C.R.; BEGON, M. and HARPER, J.L. (2006). *Fundamentos em Ecologia*. Porto Alegre: Artmed, 592 p.[This textbook offers the essential concepts of ecology, populations, communities and ecosystems. Also topics are discussed as flow of energy through the ecosystems, sustainability and pollution]

US-EPA, Environmental Protection Agency. (1996). *Air Quality Criteria for Ozone and Related Photochemical Oxidants*. Washington, DC: Office of Research and Development, National Center for Environmental Assessment. [The purpose of this is to critically assess the scientific data associated with exposure to the concentrations of ozone and related photochemical oxidants found in ambient air. Emphasis is placed on the presentation of health and environmental effects data; however, other scientific data are presented and evaluated in order to provide a better understanding of the nature, sources, distribution, measurement, and concentrations of O_3 and related photochemical oxidants and their precursors in the environment]

VAN DOBBEN, H.F.; WOLTERBEEK, H.T.; WAMELINK, G.W.W.; TER BRAAK, C.J.F. (2001). "Relationship Between Epiphytic Lichens, Trace Elements and Gaseous Atmospheric Pollutants". *Environmental Pollution*, Elsevier, vol. 112, pp. 163-169. [The authors used lichens as accumulator organisms to estimate concentrations of these pollutants in the environment, and multivariate statistic to determine the relation between the abundance of the species and pollutant concentrations. Atmospheric SO_2 and NO_2 appeared to be the most important factors determining lichen biodiversity]

WALL, D. H. and VIRGINIA, R. A. (1999). "Controls on Soil Biodiversity: Insights from Extreme Environments". *Applied Soil Ecology*, Elsevier Netherlands, vol. 13, no. 2, pp. 137-150. [The authors purpose that research in low biodiversity extreme environments allows separation of the climatic, soil and biological interactions that determine the soil biodiversity and the community's structure. The insights reached in these studies may also provide information on soil biodiversity and community structure in more complex, temperate, and tropical ecosystems under increasing global changes]

WELLBURN, A. (1994). *Air Pollution and Climate Change. The Biological Impact*. 2nd Edition. Singapore: Longman Singapore Publishers Ltd, 268 p. [This book provides a critical overview on processes in the atmosphere involving the traditional primary pollutants as sulfur dioxide, nitrogen oxides, ammonia and sulfides, and secondary pollutants as acid rain, ozone, PAN, photochemical smog and their respective effects on plants, health human, animals and materials. Evaluation of the effects of stratospheric ozone depletion and global warming are also presented].

Internet Sources

http://www.srl.caltech.edu/personnel/krubal/rainforest/Edit560s6/www/where.html

http://www.wwf.org.uk/core/wildlife/fs_0000000017.asp

http://chge.med.harvard.edu/publications/

http://www.rain-tree.com/facts.htm

http://www.rainforestinfo.org.au/background/causes.htm

http://rainforests.mongabay.com/0101.htm

http://www.countrysideinfo.co.uk/biodvy.htm

http://carbono.isnet.com.br/

Biographical Sketches

Yaico D. Tanimoto de Albuquerque is chemist by Universidade de São Paulo (Brazil) and doctor in Analytical Chemistry by the same University, in which was developed research related to evaluation of atmospheric pollution in São Paulo city and surroundings. She works in Universidade Federal de Uberlândia (Brazil), where acts in the teaching of contents related to the Analytical Chemistry and Environmental Chemistry, and coordinates researches related to the development of analytical methodologies that are applied to the control of environmental pollutants. She also develops researches related to the treatment and management of solid chemical residues produced in chemical laboratories.

Flávia Nogueira de Sá is biologist, graduated in Universidade Federal do Rio de Janeiro (Brazil), and doctor in Ecology by Universidade Estadual de Campinas (Brazil). She conducted a post-doctoral research at Macquarie University (Australia) on interaction of insects and plants, and has published papers in international scientific journals and chapters in technical books. She works in Universidade Federal do Rio Grande do Sul (Brazil), where teaches various Ecological subjects for undergraduates and graduates and supervises research projects in this area.

Maria Teresa Raya Rodriguez is chemical engineer and chemist, graduated in Universidade Federal do Rio Grande do Sul (Brazil), and doctor in Ecology by Universidade Federal de São Carlos (Brazil). She works in Universidade Federal do Rio Grande do Sul (Brazil), where teaches Applied Ecology and Ecotoxicology subjects for undergraduates and graduates and coordinates the environmental assays of Centro de Ecologia of the Universidade Federal do Rio Grande do Sul.