

Climate change and human activities in Brazil with emphasis on the coastal zone

Roberto Luiz do Carmo

roberto@nepo.unicamp.br / IFCH/NEPO/UNICAMP

Luci Hidalgo Nunes

IG/UNICAMP

Abstract *The human activities have always impacted the climate. Conversely, climatic change also impacts human life, since adaptation is needed for those changes. These factors enhance the dialectic relationship between human activities and climate change. The paper pointed out the most important aspects of climate change and their impacts in human activities, emphasizing the Brazilian case, in special in the coastal zone. It also called attention for the contribution of human activities in promoting climate change in both rural and urban areas. The evaluation emphasizes the need in improving our knowledge in the feedback processes involving the physical mechanisms of the atmosphere and the population dynamics into the territory, in order to subsidize public policy to minimize the adverse effects of climate change and to increase the population resilience to this problem*

Introduction

Human activities have always impacted the climate, but since the Industrial Revolution these impacts have been rapidly growing. Conversely, climate change also impacts human life, since humanity must adapt to these changes. Variations in precipitation patterns, duration of droughts and an increase in extreme events, for instance, have created a new set of threats and a new group of vulnerable populations. These factors enhance the dialectic relationship between human activities and climate change.

The purpose of this paper is to highlight the most important aspects of climate change and their impacts on human activities, emphasizing the Brazilian case, focusing on the coastal zone. It also intends to call attention to the contribution of human activities in bringing about climate change in both rural and urban areas.

1. Climate and climate change

The atmosphere is a thin layer of gases and particles that envelops the globe, protecting the

planet and sustaining life and physical processes. Atmospheric eddies are driven by differences in the distribution of the sun's radiation, the main source of energy for the planet, whose emissions are mainly made up of short waves, whereas terrestrial radiation is made up of long waves.

Because the energy received in a given place is controlled by latitude, land-water contrasts, ocean currents and other local attributes, there are different climatic regimes all over the world. The climate in an area can be seen as a set of prevailing weather types, which in turn is the local state of the atmosphere in periods of time from minutes to days. Both climate and weather vary through time and space, but while weather varies over smaller periods, climate varies from decades through thousand of years. But the climate of an area can change when modifications in the averages or in the variability in the climatic pattern are registered, a fact that has occurred many times in the history of the planet, as can be attested by evidence such as ice cores, glaciers and tree rings.

The planet must shed energy into space at the same rate at which it absorbs it from the sun to maintain its current average temperature

(15°C)*¹ But since the middle of the 18th Century, a sharp increase in the atmospheric levels of greenhouse gases has been registered due to activities such as industrialization, deforestation and land use changes: from 1800 to the beginning of the 1990's carbon dioxide (CO₂) went up from about 280 ppmv (parts per million by volume) to about 358 ppmv, methane (CH₄) increased from roughly 0.8 ppmv to more than 1.7 ppmv, and nitrous oxide (N₂O), from about 0.275 ppmv to 0.310 ppmv. CFC-11, a powerful greenhouse gas that did not even used to exist, nowadays makes up 268 pptv (IPCC Report, 2007; Marengo, 2006). Their residence time in the atmosphere are, respectively, 50-200, 12, 120 and 50 years, and their relative contribution radiative forcing are 64%, 19%, 6% and 11%. As a result, instrumental measurements taken around the world and monitoring from satellites have exposed a warming of 0.3 to 0.6°C since the 19th Century. This trend could be partly attributed to natural causes, such as strong El Niño events - which occur due to the warming of the ocean - or even small variations in the radiation output from the sun; however they alone would not be sufficient enough to explain the magnitude and the patterns found. The Intergovernmental Panel on Climate Change Reports (1996, 2001 and 2007) admitted that human influences on global climate, mainly due to the contribution of greenhouse gases in the atmosphere and land use alterations, were responsible for changes during the last decades. This effect will lead to changes in the earth's radiation balance, increasing its average temperature, which might change the climate in a host of other potentially serious ways.

The natural variability of the climate and the long-term effects of rising greenhouse gas levels are only partially understood. It is not known how much time it could take until equilibrium is approached for a given enhanced level of greenhouse gases, and much of this uncertainty stems from poor knowledge of the behavior of the atmosphere and especially of the ocean. These uncertainties increase due to imprecise knowledge of important sources of feedback involving water vapor, clouds, ice, snow and biological fluxes, all of them quite difficult to measure. But humankind is certainly

the most uncertain factor in the system.

A warmer atmosphere tends to enhance evaporation, increasing the water vapor content of the troposphere, which in turn amplifies warming, since water vapor is a greenhouse gas. These mechanisms may increase convective processes, mainly in humid tropical regimes, bringing more precipitation. In addition, snow and ice might melt at higher rates and because they reflect much of the sunlight which reaches the Earth back into space, a reduction in these types of cover is likely to enhance warming. Another effect would be changes in the sea level in Polar Regions due to thermal expansion of water in the oceans and melting of glaciers and ice-sheets. Furthermore, if temperatures increase, the risk of some tropical diseases such as malaria and dengue fever may increase as well, since warmer temperatures reduce the time it takes for the parasite to develop to maturity, increasing so the odds that a mosquito will pass the mature parasite along to a new host before it dies.

2. Brazil in the context of climatic change

Brazil occupies roughly 6.3% of the world's surface and its population is approximately 2.8% of the global total, 80% of which live in urban areas (United Nations Population Division, Population, Resources, Environment and Development: The 2005 Revision). The country has 4.7 million km² of forests (World Bank, 2007), concentrates about 13% to 17% of the world's biodiversity (Levinshon & Prado, 2005) and 15% of the planet's fresh water (OMM/UNESCO, 1997). During the last decades, the Brazilian economy has become one of the largest in the world: its current GDP is estimated at US\$796 billion and its GNI, at US\$661 billion (World Bank, 2007).

The settlement of the territory for strong economic production in Brazil started in the beginning of the 16th Century, driven by the production of some important items for Europe such as pau-brasil tree and sugar cane, both produced near the coast. Therefore, the pattern of settlement in the country came about from the shore inland; since the beginning of Brazilian history, the coast is a place with unquestionable advantages because of its natural resources and its location, which provides benefits for transportation. Until the 16th Century, only São Paulo of the 18 pioneer settlements was

*¹ Earth radiates mostly in the infrared spectrum, sending roughly 390 W/m² upwards, from which 240 W/m² eventually escape to space whereas the rest is captured by clouds and greenhouse gases, keeping the planet warmer than it otherwise be.

out of the coastal area, although even São Paulo was not too far from the coast (Vitte, 2003). In the 18th Century, mining activities became economically important but they did not bring about a real shift in the ways in which the population spread across the territory, since the decision centers were established in coastal cities and the railways and other infrastructures in these areas for transporting inland production provided additional advantages to the coastal area. Only late in the 19th Century did the growth in the agro-exporting economy of coffee lead to the occupation of western areas. But the model of coastal occupation still remains, as we will discuss later.

During the second half of the 20th Century, Brazil faced a very intense process of urbanization. The changes in rural areas and industrial development played important roles in this process. At present, despite the weight of agriculture and related activities, the importance of industry is tantamount.

In the middle of the 20th Century, transnational corporations came to Brazil, setting up mainly near the coast due to infrastructure benefits, creating industrial complexes such as Cubatão (State of São Paulo) and Camaçari (State of Bahia). In the last decades the phenomenon of second homes for the middle and upper classes has gained velocity, and the growth of civil construction and other related economical activities which attracted an important population contingent of immigrants to the area.

These phenomena brought in turn both benefits to the economy and deficits in the infrastructure, and created a population segment that occupied the unstable hillsides of the Serra do Mar Escarpment and mangrove areas. Slums appeared rapidly and this occupational pattern and pollution generated by industrial complexes - for decades without any control - accelerated the incidence of landslides, mudslides and urban floods, triggered by precipitation which is heavy in the coastal zone, especially in the summer.

The ways in which the territory has been settled, poverty among significant numbers of people, and inadequacy of basic infrastructure, technological and organizational systems have been important contributors to the continuous growth of society's vulnerability to natural events in the coastal zone; the intense urbanization process introduced impermeable surfaces, changed hydrological regimes, concentrated people in risk-prone locations and developed a heat-island effect in several cities, whose

effects might be added to the temperature increase from greenhouse gases. The warming processes would contribute to the increase of hazards such as floods and landslides, exposing more people to the risk of death and injury, destroying crops and fields, promoting salt-water intrusions in fertile soils and rivers erosion, contamination of water and outbreak of diseases.

Moreover, climate is a factor of utmost relevance in determining the distribution of biomes, so that climate alterations would deeply affect them. Brazil has the most important biodiversity on Earth, in great part due to the Amazonian and the Atlantic Rainforests, the latter following the shoreline. Forests represent a large store of carbon, and deforestation releases enormous amounts of carbon into the atmosphere: it is estimated that the country produces approximately 3.5% of world carbon emissions, with a large participation in deforestation (70% of CO₂ emissions) through burning forests (Marengo, 2006). Further, as underlined by Houghton (2003), trees are long-lived and take a long time to reproduce, so that some changes could occur much faster than the time required by these ecosystems to adapt to the new environment as a result of climatic changes. Additionally, deforestation reduces the water retention capacity of the soil, increasing continental runoff and precipitation recycling through evapotranspiration; it also contributes to biodiversity losses and makes lowland areas more vulnerable to flooding.

The Brazilian contribution to the emission of greenhouse gases is mainly due to the burning of forestland, especially in the Amazon region. Recent studies (Marengo, 2006) showed that 70% of Brazilian contribution comes from this process. On the other hand, it is important to stress that some activities and some population groups might be very vulnerable to climate change.

3. Climate changes in Brazilian rural areas

From the economic viewpoint, the proportional value added to the country's economy by agriculture was 8.1%, in the year 2005 (World Bank, 2007). Spatial modes of crops could be affected if the current patterns of temperature and precipitation change, and despite the fact that technological improvements (genetic manipulation and other techniques) would make it easier for crops

to adapt to new environmental conditions, their sensitivity to climate variations are different and much investment should be used for this purpose, deviating valuable resources from education, health and other important social areas in Brazil to support agriculture mainly for exportation purposes and based on machines, which has the additional negative consequence of unemployment in rural areas.

Land use and land cover change contribute substantially to the Brazilian emissions of greenhouse gases. The most important factor is the burning of Amazon Forest. Meanwhile, in the last few years soybean production is the activity with the largest potential of pressure for the forest. The international commodities market is the driving force of the expansion of these crops. The characteristic plantation system of this agricultural process needs a large amount of investments in equipment and implements. Therefore, soybean production can be considered one of the causes for the Brazilian contribution to global warming. In social terms, soybean production has led to significant economic migration. In addition, soybean crops require small numbers of workers.

In relative terms, Brazilian soybean production raised from 1% to 24% of World production between 1961 and 2004 (FAOSTAT, 2004), as can be seen in Figure 1. Many factors can be listed to explain this growth, among them the governmental investments in technology to create new varieties adapted to the country conditions, the land availability and the attractive prices in the international market. The soybean adaptation was successful and the productivity of the crops is among the largest of the world. The capacity for mobilizing capital for investments is very high due to expectations for fast returns, which makes soybean expansion difficult to control. However, some studies show that climate change might affect the spatial pattern of soybean production either in a positive or negative way, in terms of increasing or decreasing the suitable area for production (Siqueira et al., 2000; Pinto et al., 2002).

Another activity which is also related to rural production, raising cattle to meet demands, which also has a strong impact on global environmental changes as a result of methane emission from the animal's digestive system.

There are two important tendencies in terms of meat production: firstly, there is an increase in world meat production as a result of a change

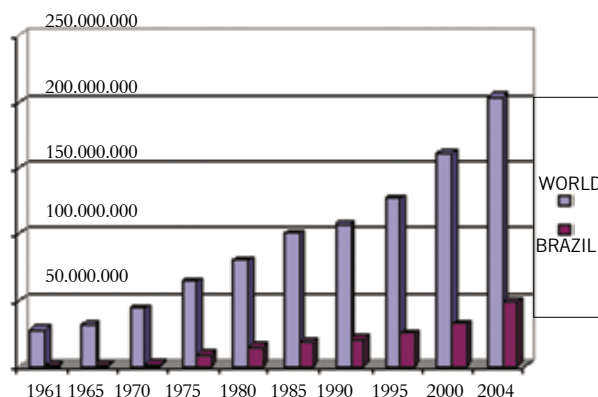


Figure 1 - Soybean Production, world and Brazil, 1961-2004 (Mt). Source: FAOSTAT data, 2005.

in dietary habits, along with an important rise in animal protein consumption. Figure 2 presents the growth of meat production. The second tendency is related to the Brazilian participation in the international meat market, which is growing expressively. Table 1 compares meat production in Brazil and in the USA, showing that Brazilian current production corresponds to around 8% of world production. Considering exportation,

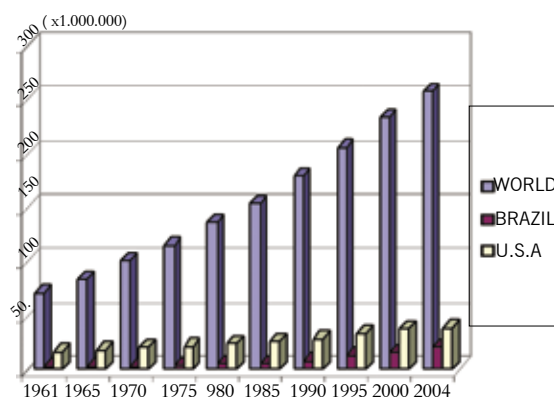


Figure 2 - Meat Production, World, Brazil and United States of America, 1961-2004. Source: FAOSTAT data, 2005.

Brazil might lead world meat exportation in the coming years.

Two other economic activities might also be affected by global environmental changes: industry and tourism. Industries in Brazil built up in urban areas, near the consumption market and available labor force. During the first half of the 20th Century

Table 1 - Distribution of World meat production (%). Source: FAOSTAT data, 2005

Country	Year									
	1961	1965	1970	1975	1980	1985	1990	1995	2000	2004
Brazil	3.0	2.9	3.1	3.1	3.9	3.8	4.3	6.2	6.6	7.7
The United States of America	23.1	21.6	21.2	18.7	17.9	16.7	15.9	16.4	16.0	15.0

they were particularly concentrated in São Paulo city, as emphasized by Negri (1996). But into its seventh decade, industries were redistributed over the territory: first in São Paulo State hinterland and more recently in other parts of the country, mainly Rio de Janeiro and the Northeastern States (Diniz and Diniz, 2004).

The impacts of global environmental changes on Brazilian industry follow the same trends projected for other areas of the world and a number of problems may arise, among them: 1. industrial concentration might promote an increase in competition for environmental resources, especially water. Carmo (2005) stressed that the growing demand for water for domestic and industrial use is one of the most important problems in some metropolitan regions in Brazil. Additionally, the increase of temperature might aggravate this problem and even change the water cycle; 2. impacts of extreme climatic events on public and private infrastructure must demand extra resources, and conflicts and/or strength might arise due to the competition for these resources; 3. sea level rise must affect strategic areas such as Cubatão (São Paulo State) and Camaçari (Bahia State), where many oil refineries and petrochemical factories are located. In addition, the salt level in freshwater streams could increase and affect huge areas; 4. further investments will have to be made for adapting to the growing impacts of extreme climatic events 5. urban heat islands, generated by human activities, will probably be aggravated due to industrial pollution.

In 2003, tourism-related activities in Brazil generated approximately US\$ 17.3 billion (IBGE - Instituto Brasileiro de Geografia e Estatística). However, global environmental change also poses a threat to tourism activities. Areas with beautiful landscapes, especially near the coastal zones and islands, may be significantly affected and transformed (Hein, 2007; World Tourism Organization, 2007). In addition, changes in the precipitation distribution pattern could also affect the flow of tourism in some areas.

4. Climatic changes in the Brazilian coastal zones

About half of humanity lives in the coastal zone, so these locales and their inhabitants are particularly vulnerable to any increase in sea level. Besides, these areas also contain much of the world's biodiversity (fishes, animals, birds, marshes and swamps, tropical rainforest), which could be lost with unprecedented consequences. Additionally, water supply could be negatively affected, and hazards such as storm surges, tropical cyclones, floods and landslides would increase in intensity and frequency, bringing further problems to these places and their inhabitants. It must be stated that the real effects of global change will be felt by people at the local level.

The Brazilian coastal zone is more than 7,400 km long, ranging from 4° N to 33° S, with a rich mosaic of ecosystems (MCT 2004). It is a place of interactions between terrestrial, marine and atmospheric environments, with resources that have potential to generate large amounts of profit. These resources are both attractive conditions for competitive production and scenic or original landscapes (Vitte, 2003).

According to a recent survey published by the Brazilian Government Agency for Statistics, (IBGE, 2005), in 2002 there were 478 coastal municipalities (8.5% of the total), with an estimated population of 53.7 million inhabitants (30% of the total country's population, estimated at 174.6 million inhabitants, 2002), including 9 state capital cities, where 14.5 million people live. Despite the large population of coastal cities, in many people live far away from the shoreline. In order to have more accurate information on the number of people who might be affected by sea level rise, a study focusing on the census tracking level is necessary.

Another important fact is that the effect of sea level rise could be indirect, as in the North Region, mainly due to interactions with rivers. In the Ama-

zon River estuary, the Marajó Island is an example of climate change in a vulnerable region. Marajó is the largest fluvial island in the world, with an area of almost 50,000 km², 12 municipalities and 283,000 inhabitants. The interaction of the sea and the Amazon River, in the context of climate change, might affect people's standard of living in terms of decreasing the availability of fish, important for local subsistence. In addition, sea level rise might be critical for the island. Considering that there is sewage collection in only 10% of the households and that there is no sewage treatment at all, one can conclude that these aspects should affect the local population dramatically.

In addition, the process of "second homes" in some areas of Brazil's coast by the richest groups of population has been intensive (Deschamps et al, 2000). However, some aspects could affect the occupational pattern in the area: for instance, the impacts on the land market of some recent negative events affecting coastal zones (the strong tsunami in Asia in 2005, surges in many parts of the Brazilian coast and the threat of sea level rising) are still difficult to be measured, but might influence future occupational trends.

Final remarks

One must consider two aspects of the effects of climate change: the ways in which human activities affect climate change and how these changes affect human life.

Furthermore, these changes present a potential affect on human life in various ways, such as the increase of severe storms that bring landslides, flooding and potential diseases, the threat of sea level rise, etc. All these aspects result in death, illness, migration to safer areas and economic losses.

For Brazilian, the most significant factor that causes climate change is the burning of the Amazonian rainforest. Every year tons of CO₂ are launched into the atmosphere due to the process of economic occupation of the Amazon. Despite government efforts, this process remains uncontrolled.

Urban related activities make up 30% of Brazilian emissions from transport system and industrial processes. Urbanization is spread across Brazil, with megacities and many Metropolitan Regions that concentrate population and economic activities which in turn affect both atmosphere and land use.

Comprehensive knowledge of all these dy-

namic aspects is a necessity in view of improving our knowledge of the feedback processes involving the physical mechanisms of the atmosphere and humankind in order to influence public policy to minimize the adverse effects of climate change and to increase people's resilience to this problem.

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