Impact of climate change on health and disease in Latin America

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1. Introduction

Climate change is a widely known problem and consequence of multiple interacting phenomena. Nobody can deny it, and several issues are identified as cause and implications of this global problem. Among these causes there is a basic important element, its anthropogenic origin. Many styles and quality of modern life, explained by the use and abuse of contaminating energy sources, including the forms of generating, producing and distributing it. Additionally, demographical changes of the World have intensified this climate change crisis, including the increase in the magnitude of the global population, its utilization of more equipment and electrical devices.

Climate change has multiple effects on society, including direct and indirect influences on human health and is one of the spheres that has been recently highlighted by multiple research reports in regard to the importance of climatic change for global public health (Martens et al, 1997).

General effects of climate change have been already detected; physical sciences have shown it clearly, the earth is warming up. If the trend of global warming continues, man will face many threats, diseases and deaths related to natural disasters: hurricanes, torrential rains, heat waves and other climate anomalies. In some regions of the world numerous populations will be displaced by the increase of the level of the sea or will be seriously affected by droughts and famines, decrease of suitable lands for the agriculture, increase of the food-borne diseases, water-borne diseases, vector-borne diseases as well as an increase of premature deaths and diseases related to the air pollution (Mills, 2009; PAHO, 2008; United Nations, 2006).

Global warming and climate change are products of many physical imbalances but also from biological and social ones in the way of evolution of mankind. Apparent modern quality of life, assumed in the last years and particularly during the last century, as well as population growth and overpopulation in some areas of the World, have lead to modern societies that have significantly increased the consumption of energy and waste production (Mills, 2009; PAHO, 2008; United Nations, 2006; Diaz, 2006).

2. Basics about Environmental Changes and Health

The elements and inputs for other acquaintances and accepted as traditional and necessary for a good health are: drinkable, constant and safe water, safe and sufficient food, immunizations, epidemiological alertness of the morbidity and response to this one, safe and effective fight against disease vectors and the sufficient preparation against disasters. All of them are indispensable and decisive components of the practices of public health that also constitute the best adjustments and adaptation to climatic change (PAHO, 2008; United Nations Development Programme, 2008; United Nations, 2006).

Population segments with higher poverty will be the most affected by climate change. The physical effects of the climatic change will be different in diverse geographical localities, and social conditions will make the poorest areas more vulnerable to climate change. Repercussions, influences or impacts in human health will be determined and modified by such conditions. Herein we should include the level of development (importantly measured by the Human Development Index, HDI), poverty (currently measured by many indicators such as the Poverty Index and the Unsatisfied Basic Needs index), education (included as a variable of the HDI,) the infrastructure of public health, the landscape use and the political structure, among others. Initially, developing countries will be the most vulnerable and affected. Countries with high levels of poverty and malnutrition, fragile health infrastructures and/or political instability will be the most vulnerable in facing the multiple impacts of climate change (PAHO, 2003; United Nations Development Programme, 2008).

It is vital to prepare ourselves and face these phenomena as well as the elements that contribute to the problem. One of the most important consequences, global warms, as well the climate variability and environmental effects influence human health. Already, multiple research reports have described the effects of climate change on multiple biological imbalances within in many diverse forms of life. As many diseases are consequences of a complex interplay of biological organisms (microbial organisms, insects or vectors, animals and human beings), significant environmental changes can originate displacements of serious endemic and epidemic diseases. These include malaria, leishmaniasis, hemorrhagic transmissible fevers and dengue, among many others, from the original endemic areas in South East Asia, neo-tropical Americas and Africa, to southward and northward. Additionally, increase in global temporary and definitive migration will also contribute to the increase of such diseases in endemic areas and will be seen in non-endemic areas in other, even developed, countries (PAHO, 2003; United Nations Development Programme, 2008).

Many communicable or infectious diseases are sensitive to the climate variability. Climate change represents an additional risk which must be dealt with in order to take the corresponding preventive measurements. In the last 20 years significant evidences have been generated from multiple science fields demonstrating how the climate change affects, directly and indirectly, disease vectors (particularly mosquitoes) (Diaz, 2006; Parry et al, 2007). Climate change can accelerate biological development and increase vectors population available to transmit pathogens and diseases. This is a consequence of climate change on the environment, altitude, cold and heat, and water reservoirs and, particularly, wetlands.

With a more spread and greater population of vectors, disease risk spectrum is a consequence of more time of exposition. In some affected areas of the World climates have become more suitable for disease vectors survival. Until approximately twenty years ago

(1990), slightly more than 30% of the World's population was living in regions at risk for dengue and malaria. Today it is known that with the climate change this percentage has been increased, and it is foreseen that between 50 and 60% of the World's population will live in zones at risk for transmission of dengue in future years. This translates to mean, among other things, that the poorest populations will be less able to resist than others. This is mainly due to the lack of drinkable water and the need to collect water, which in the case of dengue is particularly suitable for the vector (*Aedes aegypti*) development (Gubler et al, 1981; Sukri et al, 2003; Rifakis et al, 2005; Halstead, 2006).

Other infectious diseases discussed later are also significantly influenced by the climate change. Many of them can change patterns to come into levels of epidemics when significant climate anomalies occur. These include torrential rains, water-courses, hurricanes, which originate floods, collapse of structures and faults in the basic services, with severe consequences in the populations. When these phenomena occur in poorer regions, other problems are generated and explained by the losses of activities and the climate change. Finally this will generate major direct losses to the health, to the economy and to the family and social structure of the affected regions and countries (Parry et al, 2007; PAHO, 2008).

As previously stated, major impacts will be felt in developing countries. This is explained due to the high levels of poverty and the few response capacities of the health systems and the lack of drinkable, constant and regular water supply services, as well as waste disposal systems (United Nations Development Programme, 2008).

It becomes imperative and of utmost relevance to study, the impacts of climate change on health. This knowledge must be used for monitoring and preparing for diseases, early alert and response, spreading knowledge, educating, strengthening the population, and concentrating efforts on the formal education of the populations more at risk in the basic education and students of health sciences. These new approaches in preventive medicine, tropical medicine, travel medicine, epidemiology, among other medical and health disciplines, should be considered and taught, in order to prepare for damages and diseases related to the climate change (United Nations Development Programme, 2008; PAHO, 2008).

We must improve the preparedness and all the systems of early alertness, to be more effective and to better approach the possible increase in the number of environmentally related disasters like hurricanes, torrential or copious rains, floods, fade, among others (PAHO, 2008). Additionally, climate change can originate emotional and psychiatric personal and collective conflicts related to the fight for water resources, the availability and access to drinkable water, food production, and in the generation of diseases related to nutritional deficits. In the long term, the climate change will alter natural economic and social systems that help to support acceptable levels of health (Ortega Garcia, 2007; Ebi & Paulson, 2007).

To protect the health and reduce the risks related to the climate change, we must intensify and promote innovative measures of education as well the epidemiological alertness and control of infectious diseases, the employment of safe sources of water and the efficient coordination of the health teams' response to the related emergencies (PAHO, 2008).

Challenges before the imminent natural dangers and the subsequent impact in the countries and populations who need major protection, will always exist. We must work to assure that the reduction of risks due to initiatives of health, including medical primary assistance, safety of patients, women, children and workers, should be sustainable in time (PAHO, 2008).

In the future years, climate change will increase the risks before disasters, making them not only more frequent, intense and risky, but also population vulnerability will be greater than currently exists. More frequent and intense storms, floods and long-lasting droughts can concern the communities, the attitude to be prepared, answer and reconstruct after events. Other adverse impacts on the public health, ecosystems, food safety, migrations and the most vulnerable groups like children, the elderly and women, will increase the vulnerability of communities to natural dangers of all the types (PAHO, 2008).

In the last 20 years, the number of disasters has doubled from 200 to more than 400 per year. Floods are more frequent (of approximately 50 in 1985, it increased to more than 200 in 2005). Damage areas are increasingly more extensive than twenty years ago. These trends indicate a future where the variability of extreme climate and its consequences probably will become the norm. The human implications are significant, with more rains, hurricanes, and increasing sea levels which will increase the risk of floods, and vulnerability will be higher (Liverman, 2009).

Between the years 1991 and 2005, 3,470 million persons were affected by disasters, 960,000 persons died, and the economic losses were estimated in US $1,193 billion. The poorest countries have been more affected, which is due to their internal vulnerabilities, capacity of response with effective measures in reducing risks. Small developing countries are indeed more vulnerable. For example: losses in Granada from hurricane Ivan in 2004 totalled US $919 million. That amount equalled 2.5 times Granada's gross domestic product (GDP). Similar figures were seen in other Central America countries such as Honduras, Nicaragua, Guatemala, El Salvador and Belize, in which hurricane Mitch, in 1998, caused around 9,550 deaths, destroyed 13,785 homes and affected a population of 3,174,700 people in those countries (Liverman, 2009; McMichael et al, 2003). Although developing countries in Latin America are most vulnerable to the impacts of natural disasters (related, or not, to climate change), there are a clear internal differences between the development of its countries that make them very different in their vulnerability, consequences (in morbidity, mortality and incapacity) and responses against them. For example: recently, two significant earthquakes in Latin America affected two countries, Haiti (January 2010) and Chile (February 2010), respectively. However, effects were remarkably different. In the Haitian earthquake, general and health consequences were practically devastating. In the Chilean earthquake, although it affected a large geographical area with a stronger intensity, general and health consequences were much lower.

The risk for conflicts may increase, especially in already fragile social environments. The risk of discrimination and violation of the most fundamental rights: human, economic, social and cultural, would need special attention. Many challenges will be raised, and as a consequence of this, forced migrations from the changeable climate areas will occur (PAHO, 2008).

Adaptation and mitigation of the effects of climatic change will need special analysis of vulnerability. Development of risk maps, contingency plans, and other measures will be needed. Better communication is needed with societies and governments from academia and research organizations regarding the impact of climate change on public health. Additional financial and human resources will be needed to fight against the effects of climate change on health and disease (PAHO, 2008; Lapola et al, 2008).

Multiple strategies and mechanisms for the reduction of risks should be implemented before the disasters and the human consequences of the climate change affect the World. In order

to protect the human safety, this must include social and economic development, the preparation before the emergencies, and the proper response and mechanisms of recovery at all the levels (United Nations Development Programme, 2008).
It is also important to have materials, human resources and reliable financial resources to address the risks related to disasters and the management of them in this setting of climate change (PAHO, 2008).
As previously stated climate change will affect health and disease in multiple ways and is currently impacting communicable and non-communicable disease epidemiology in many areas of the World. This includes Latin America. In this important Neotropical area, multidisciplinary biomedical research, particularly from the public health perspective, has shown that climate change has significantly impacted the epidemiology of tropical, and in general, of communicable diseases.

3. Climate change and Communicable diseases in Latin America

3.1 Communicable diseases endemic in Latin America

As previously described, it is well established that climate is an important determinant of the distribution of vectors and pathogens, such as those of malaria (*Anopheles spp.-Plasmodium falciparum, P. vivax, P. ovale, P. knowlesii*), dengue (*Ae. aegypti*-Dengue viruses), and leishmaniasis (sandflies *Phlebotomus spp. and Lutzomyia spp.-Leishmania spp.*), among many others in different areas of the World, including Latin America. This is particularly true in its tropical regions but also in its subtropical areas (Rodriguez-Morales, 2005).
In this Neotropical region, recent contributions in the field have demonstrated strong and significant links between climate variability, climate change, emerging and re-emerging infectious diseases that represent public health issues for the region. Many diseases have varied their morbidity, mortality and even chronic consequences, such as disabilities, as a consequence of climate variability and change (Rodriguez-Morales, 2009).
Countries such as Venezuela, Colombia, Mexico, Ecuador, Brazil, Argentina, Peru and Bolivia, among others, have evidenced and suffered the impacts of climate change in the socioeconomic systems, such as agriculture and fishing. These impacts are a consequence of the phases of the El Niño Southern Oscillation (ENSO) phenomena, but also in specific health conditions, such as tropical and infectious diseases including malaria, dengue, leishmaniasis (cutaneous and visceral), yellow fever, cholera and diarrhoeas, and probably Chagas disease (Figure 1) (Rodriguez-Morales, 2005; Araújo et al, 2009) are a result of climate change. Tropical areas of Latin America have been suitable for those diseases; these are endemic, and climate change is now triggering its increase, persistence, re-emergence in non-previous endemic areas or in areas where they were eliminated, eradicated or controlled (Figure 1).

3.2 Approaches to the Study of Communicable diseases in Relation to Climate

Different statistical analyses, most based on linear regressions, have linked extreme climatic anomalies with significant alterations in the epidemiological patterns of diseases and are sometimes coupled, directly and indirectly, on time and space (McMichael et al, 2003). Additionally to statistic techniques, geographical information systems (GIS) and remote sensing (spatial epidemiology) have supported these observations and are helping in the development of systems for predicting and forecasting such diseases based on climate variability and climate change (McMichael et al, 2003). Now availability of data, images and software, and new technologies for the region (including satellites) allows better defining of the impact of climate change on health and disease (Rodriguez-Morales, 2008). In Argentina, there is now an aero-spatial institution with an area dedicated to satellite epidemiology, use of data from remote sensing (satellites) applied to the study of diseases (Rodriguez-Morales, 2005; Beck et al, 2000).

3.3 Evidences regarding Climate Change and its Potential Effect on Disease: Cutaneous and Visceral Leishmaniasis

In this regard, evidences from Latin America have accumulated useful qualitative and quantitative information that indicates how climate variability and change influenced particular tropical diseases (McMichael et al, 2003; Arria et al, 2005). The impact of El Niño Southern Oscillation climatic fluctuations during 1985–2002 in the occurrence of leishmaniasis in two north-eastern provinces of Colombia (North Santander and Santander) was reported. During that period, it was identified that during El Niño, cases of leishmaniasis increased up to 15.7% in disease incidence in North Santander and 7.74% in Santander, whereas during La Niña phases, leishmaniasis cases decreased 12.3% in Santander and 6.8% in North Santander. When mean annual leishmaniasis cases were compared between La Niña and El Niño years, significant differences were found for North Santander ($p<0.05$) but not for Santander ($p=0.05$) (Cárdenas et al, 2006). During the same study period in southern provinces, effects of climate variability and change were also studied regarding leishmaniasis incidences. In this study, 11 southern departments of Colombia were analyzed: Amazonas, Caquetá, Cauca, Huila, Meta, Nariño, Putumayo, Tolima, Valle, Vaupes and Vichada. Climatic data were obtained by satellite and epidemiologic data were obtained from the Health Ministry. National Oceanographic and Atmospheric Administration (NOAA) climatic classification and SOI (Southern Oscillation Index)/ONI (Oceanic Niño Index) indexes were used as indicators of global climate variability. Yearly variation comparisons and median trend deviations were made for disease incidence and climatic variability. During this period there was considerable climatic variability, with a strong El Niño for six years and a strong La Niña for eight years. During this period, 19,212 cases of leishmaniasis were registered, for a mean of 4,757 cases/year. Disease in the whole region increased (mean of 4.98%) during the El Niño years in comparison to the La Niña years, but there were differences between departments with increases during El Niño (Meta 6.95%, Vaupes 4.84%). The remainder showed an increase during La Niña (between 1.61% and 64.41%). Differences were significant in Valle ($p<0.01$), Putumayo ($p<0.001$), Cauca ($p=0.03$), and for the whole region ($p<0.01$), but not in the remaining departments (Cárdenas et al, 2008). This information shows how climatic changes influence the occurrence of leishmaniasis in north-eastern and southern Colombia.

Similar results have been described in Venezuela. Between 1994 and 2003, a study in 2,212 cutaneous leishmaniasis cases also linked climate variability to disease incidence in an endemic area of the country, Sucre state. During that period, three important El Niño phases were observed: 1994-1995, 1997-1998, and 2001-2003. The 1997-1998 phase was the most relevant one and was followed by a chilly and rainy season in 1999 (La Niña). During 1999-2000, 360 cutaneous leishmaniasis cases were recorded in Sucre, with an important variability within a year, and a 66.7% increase in cutaneous leishmaniasis cases ($F=10.06$, $p<0.01$) associated with the presence of a weak La Niña phenomenon (not too cold and rainy). Models showed that with higher Southern Oscillation Index (SOI) values, there was a reduced incidence of cutaneous leishmaniasis (r^2=0.3308; p=0.05). The increase with respect to the average trend in rain was associated with increases in trends for cutaneous leishmaniasis in the period from 1994 to 2003 (p=0.036) (Cabaniel et al, 2005).

Although not described in such detail, the Suriname cutaneous leishmaniasis is a seasonal disease. The rainy seasons are from November to January and from May to July. In a recent study (2008), most patients with this disease were registered during the short dry season in March (35%) (van der Meide et al, 2008). In Brazil, studies made on leishmaniasis vector have characterized spatial distribution of them. In Mato Grosso, the vector sandfly *Lu. whitmani* s.l. have been positively correlated with deforestation rates and negatively correlated with the Brazilian index of gross net production (IGNP), a primary indicator of socio-economic development. Authors found that favourable habitats occur in municipalities with weaker economic development. This confirms that vector occurrence is linked to precarious living conditions found either in rural settlement of the Brazilian government's agrarian reform program, or in municipalities with intense migratory flows of people from lower social levels (Zeilhofer et al, 2008). In Colombia, another entomological study in 5,079 sand flies collected (*Lu. spinicrassa* represented 95.2% of them) have linked population densities to climate. The climatic period where the collection of vectors was done corresponded to a dry season of El Niño (highest Oscillation Niño Index in the last 2006 trimester). In general, the main components analyses evidenced a significant inverse relation between *Lu. spinicrassa* abundance and the relative humidity ($p<0.05$) and rainfall ($p<0.05$), but not for the average temperature ($p>0.05$) (Galvis et al, 2009). In Costa Rica and Bolivia, recent studies have also linked social and climate changes with cutaneous leishmaniasis (Chaves and Pascual, 2006; Gomez et al, 2006).

In the case of visceral leishmaniasis, other studies in Latin America have linked its incidence to climate. Prolonged droughts in semi-arid north-eastern Brazil have provoked rural-urban migration of subsistence farmers and a re-emergence of visceral leishmaniasis (Confalonieri, 2003). A significant increase in visceral leishmaniasis in Bahia State (Brazil) after the El Niño years of 1989 and 1995 has also been reported (Franke et al, 2002).

3.4 Evidences regarding Climate Change and its Potential Effect on Disease: Malaria

For malaria, many studies in the region have linked climate to disease. Classically, after the onset of El Niño (dry/hot) there has been described a risk of epidemic malaria in coastal regions of Colombia and Venezuela (Poveda et al., 2001). Even new patterns of disease have been described in association with climate variability, as in the so-called phenomena of highland malaria described in Venezuela and Bolivia. In November 1999, in an Andean area of Venezuela, there was an epidemic outbreak of highland malaria in the Parish of Guaramacal, Trujillo state. This was an area historically classified as without malaria, with altitudes up to 2200 meters above the sea level (masl). Nine cases of malaria were reported from this area: two of these were classified as introduced and seven were classified as imported. Four species of mosquitoes of the genus *Anopheles*, subgenus *Kerteszia*, probably implicated in this outbreak were collected; they were identified as *Anopheles homunculus* (n=27; 65.9%), *Anopheles lepidotus* (n=9; 21.9%), *Anopheles neivai* (n=3; 7.3%) and *Anopheles pholidotus* (n=2; 4.9%). These mosquitoes were not previously reported as vectors of malaria in Venezuela or from Trujillo State. The most important breeding sites were the epiphytic bromeliads (*Tillandsia spp*). The presence of introduced cases was probably brought about by frequent migrations of people to and from La Laguneta, La Fernandera, Agua Fría in Guaramacal Parish, and the village of San Juan de Dios in Portuguesa state. These people worked in culturing corn and yucca during an epidemic outbreak of malaria in that region; however, these social issues coupled with intense climate changes and particularly intense rainfall during the year of the outbreak would explain this occurrence of highland malaria (Benitez et al, 2004).

In Peru, recent studies have described the relation between climate and disease. This has been explored in Loreto, a north-eastern Amazon jungle area of Peru, during a 13 year period. In this ecological study conducted with data from the monthly average temperature (ºC), relative humidity (%), precipitation (mm) and level of the Amazon River (meters), malaria was linked to climate variables. Authors found significant negative correlation between temperature and cases of malaria for five years: 1997, 1999, 2003, 2005 and 2006; river level for four years: 1997, 1998, 2003 and 2005; and humidity for three years: 1996, 2005, 2006. No association was found for any years with rainfall. The multiple regression models were significant in three years (1999, 2003 and 2006) with r^2 values between 0.870 and 0.937 (Ramal et al, 2009). In Brazil and Ecuador, malaria has been studied in regard to the influence of climate variability (Kelly-Hope & Thomson, 2008).

3.5 Evidences regarding Climate Change and its Potential Effect on Disease: Other Parasitic Diseases

In Brazil, other parasitic diseases such as schistosomiasis have been linked to climate variability (Kelly-Hope & Thomson, 2008). In Venezuela, some evidences suggested that onchocerciasis (river blindness) would also be associated to climate (Botto et al, 2005). In this country, ascariasis has been linked to climate (Benitez et al, 2005). Chagas disease probably will be influenced by climate change; however, there is no significant number of reports that have shown relevant evidence supporting this theory. Other trematode infections different to schistosomiasis, such as fascioliasis and paragonimiasis would be susceptible to the impacts of climate change given their complex parasite life cycles. Regard cestodes few studies on taeniasis and cysticercosis, hydatidosis, hymenolepiasis, among others have also been fewly studied in relation to climate change and climate variability.

3.6 Evidences regarding Climate Change and its Potential Effect on Disease: Dengue

Dengue, as described before, has been significantly linked to climate change, including evidences generated from Latin America. Many countries in Latin America are endemic for this disease which is particularly important in urban centres, such as Caracas, the capital city of Venezuela. In this location between 1998 and 2004, a study found significant associations between dengue hospital morbidity and climate variability. This study used microclimatic data such as rainfall and maximal and minimal monthly temperatures. Macroclimatic indexes such as NAO (North Atlantic Oscillation), SOI (Southern Oscillation Index) and ONI (Oceanic Niño Index), were used. Seasons were categorized as positive or negative for El Niño phenomenon (the latter were classified as neutral and La Niña). Linear regression models were used for determining the associations. Results indicated that for the studied period, 2,187 confirmed cases of dengue fever were recorded, and the annual mean was 268 cases (± 371). The highest case toll was in year 2000 (up to 214 cases per month), and this had a climatic correlation with La Niña. Years negative for El Niño had the highest number of cases (1999, 2000, 2001, and 2004) which was 60.26% higher than the mean number of cases. This compared with the years where El Niño phenomenon occurred (1998, 2002, 2003) where there was a reduction in the case number compared with the mean values (−67.56%) (χ^2=21.76; $p<0.01$). Linear regression models found a statistically significant association between dengue fever and rainfall abnormalities in Caracas (r^2=0.01199; F=4.635; p=0.032), as well as with maximum temperatures recorded (r^2=0.1345; F=59.37; $p<0.001$) (Rifakis et al, 2005). Other studies in Venezuela have reported similar results (Barrera et al, 2002; Herrera-Martinez et al, 2009). Annual variations in dengue/dengue hemorrhagic fever in Honduras and Nicaragua appear to be related to climate-driven fluctuations in the vector densities (temperature, humidity, solar radiation and rainfall) (Patz et al, 2005). In some coastal areas of the Gulf of Mexico, an increase in sea surface temperature (SST), minimum temperature and precipitation was associated with an increase in dengue transmission cycles (Hurtado-Díaz et al, 2007). Other studies in Mexico have reported similar results (Peterson et al, 2005). In Barbados, Puerto Rico and Dominica, climate variability has been linked to dengue incidence (Depradine and Lovell, 2004; Schreiber, 2001; Rodriguez-Morales, 2005).

3.7 Evidences regarding Climate Change and its Potential Effect on Disease: Other Viral Diseases

Parasitic and other infectious diseases in Latin America have been linked to climate variability and climate change. This is the case of other viral diseases that are different to dengue, such as yellow fever, influenza, Hantaviruses and rabies, among others. A study conducted during 2002-2004 linked rabies occurrences in Venezuela to climate variability. Rabies in Venezuela has been important in the last years, affecting dogs, cats, other animals and humans and it is a reportable disease. In Zulia state, it is considered a major public health concern. Recently, a considerable increase in the incidence of rabies has been occurring, involving many epidemiological, ecoepidemiological and social factors. These factors were analyzed in 416 rabies cases recorded during the study period. The occurrences have been increasingly significantly, affecting mainly dogs (88.94%). Given this epidemiology it was associated ecoepidemiological and social factors with rabies incidence in the most affected state, Zulia. This area has varied environmental conditions. It is composed mostly of lowlands bordered in the west by a mountain system and, in the south, by the Andes. The mean temperature is 27.8ºC, and the mean yearly rainfall is 750 mm. ĉlimatologically, year 2002 corresponded with El Niño (drought), middle 2003 evolved to a Neutral period and 2004 corresponded to La Niña (rainy). This change may have affected many diseases, including rabies. Ecological analysis showed that most cases occurred in lowland areas of the state and during the rainy season ($p<0.05$) (Rifakis et al, 2006). For Hantaviruses, outbreaks of Hantavirus pulmonary syndrome have been reported for Argentina, Bolivia, Chile, Paraguay, Panama and Brazil after prolonged droughts (Williams et al., 1997; Magrin et al, 2007). This may be due to the intense rainfall and flooding following the droughts, which increases food availability for peri-domestic (living both indoors and outdoors), rodents (Magrin et al, 2007). In Brazil and Venezuela, yellow fever outbreaks have been linked to climate variability (Vasconcelos et al, 2001; Rodriguez-Morales et al, 2004).

3.8 Evidences regarding Climate Change and its Potential Effect on Disease: Bacterial Infections

Bacterial infections have been associated to an increase linked to climate variability, climate change and global warming. *Staphylococcus*, *Streptococcus*, and enteric bacteria tend to colonize humans more readily in warmer climates. In addition, some authors have studied the changes in incidence of Gram-negative carriage from three skin sites in a climate controlled chamber at 35°C and 90% humidity for 64 h. Their findings showed that high temperatures and humidity increased the overall frequency of isolation of Gram-negative bacteria, although there were individual differences. If global warming continues, health care workers may one day encounter outbreaks of infectious diseases with these pathogens. As these organisms have a significant potential for inherent resistance to antimicrobials or for the development of antimicrobial resistance and the treatment of these patients will impose a huge challenge to medical sciences (Thong & Maibach, 2008). A study attempted to link gram-positive cocci (GPC) to climate variability in Venezuela. During the study period (1992-2001), 501 GPC infections were diagnosed and identified. The year with the highest incidence was 1999 (La Niña year), while the year with lowest incidence was 1992 (El Niño year). It was observed that during La Niña years (1998-2001) a more significant number of cases occurred compared with El Niño years (1992–1994, 1997) (15%, χ^2=25.96, p<0.01). During annual rainy seasons we found significantly more incidences (months of July and August) than in dry seasons (January and February) (75%) (F=29.85, p<0.01). However, this was affected by ENSO classification, because comparing La Niña and El Niño years, incidence was higher for the first during January to June, and for October and November; while for the second, incidence was higher for July to September (Rodriguez-Morales et al, 2006). Other bacteria, such as *Leptospira* has been linked to climate variability. Flooding produces outbreaks of leptospirosis in Brazil, particularly in densely populated areas without adequate drainage (Kupek et al, 2000). In 1998, increased rainfall and flooding after hurricane Mitch in Nicaragua, Honduras, and Guatemala caused a leptospirosis outbreak, and an increased number of cases of malaria, dengue fever, and cholera (Costello et al, 2009). In Peru, an autochthonous disease, Carrion's disease (*Bartonella bacilliformis*) has been linked to climate variability (Huarcaya et al, 2004). *Vibrio cholerae* is another bacterial pathogen in which its incidence has been linked to climate variability. As ocean temperatures rise with global warming and more intense El Niños, cholera outbreaks might increase as a result of more plankton blooms providing nutrients for *Vibrio cholerae*. Studies in Peru, Ecuador, Colombia, Mexico and Venezuela have shown evidence of these relationships (Patz et al, 2005; Farfan et al, 2006; Chavez et al, 2005; Franco et al, 1997; Lama et al, 2004).

3.9 Evidences regarding Climate Change and its Potential Effect on Disease: Zoonoses

For veterinary public health, climate change may be associated with seasonal occurrence of diseases in animals rather than with spatial propagation. This is the case for pathogens or parasitic diseases, such as fascioliasis, in areas with higher temperatures. When disease seasonality is extended as a consequence of the increased survival of the parasite outside the host or, conversely, shortened by increased summer dryness that decreases their numbers. For other pathogens, such as parasites that spend part of their life cycle as free stages outside the host, temperature and humidity may affect the duration of survival. Climate change could modify the rate of development of parasites, increasing in some cases the number of generations and extending the temporal and geographical distribution. New World screwworm is frequently found in South America, with infestations increasing in spring and summer and decreasing in autumn and winter (Rodriguez-Morales, 2006; Paris et al, 2008). West Nile Virus is a disease in which both long-distance bird migration and insect population dynamics (*Culex*) are driven by climate conditions. Vesicular stomatitis (VS) affects horses, cattle and pigs and is caused by various vesiculoviruses of the family Rhabdoviridae. Seasonal variation is observed in the occurrence of VS; it disappears at the end of the rainy season in tropical areas and at the time of the first frosts in temperate zones (Pinto et al, 2008).

3.10 Climate Change and Communicable Diseases: Public Health Perspectives

Given the substantial burden of disease associated with climate change in developing tropical countries, such as most of Latin America, it is of utmost relevance to incorporate climate changes into public health thinking, including health authorities and systems, as well as the whole public health education and faculties.

Although many studies may have some limitations, such as a lack of incorporation of other meteorological factors into the analysis (temperature, rainfall, sun radiation, transpiration or evotranspiration, relative humidity, vegetation indexes [Normalized Difference Vegetation Index, NDVI and Enhanced Vegetation Index, EVI] among others) (Cárdenas et al, 2006), it has been suggested that such findings are relevant from a public health perspective to better understand the ecoepidemiology of different communicable diseases (Rodriguez-Morales, 2005).

However, further research is needed in this region and other endemic areas to develop monitoring systems that will assist in predicting the impact of climate changes in the incidence of tropical diseases in endemic areas with various biological and social conditions.

4. Climate change and Non-communicable diseases in Latin America

4.1 General Aspects: Environmental context and Climate change

Anyone pursuing the science of medicine must proceed accordingly. First he ought to consider what effects each season of the year can produce. Seasons are not all alike and differ widely within themselves and their changes. The next point is the hot winds and the cold, especially those that are universal, but also those that are peculiar to each particular region (as described by Hippocrates, regard airs, waters, places) (PAHO, 1988).

Since ancient times, men have been aware of the importance of climate changes in their health. What is important from these ancient evidences from our prime medical doctors to our westernized world, we must pay much attention to climate changes which certainly has increased during last 50 years due to the greenhouse effect.

The following excerpt from the World Health Organization (WHO), collected from the web, about Facts on Climate Change on Health, December 2009, seems to indicate that non-communicable diseases (including injuries and malnutrition) represent an important burden of the human health around the World and will be increased in the following years even more dramatically due to the climate change. Aspects of quality of life and living conditions will be directly affected due to limited food production and shortage, and air pollution. Also it is important to highlight that disasters associated to climate changes will provoke death and more disability. Definitely this will diminish social-economic development, especially in the developing countries.

"Climate and weather already exert strong influences on health: through deaths in heat waves, and in natural disasters such as floods, as well as influencing patterns of life-threatening vector-borne diseases such as malaria. Continuing climate change will affect, in profoundly adverse ways, some of the most fundamental determinants of health: food, air and water, according to WHO Director-General Dr. Margaret Chan. Areas with weak health infrastructure – mostly in developing countries - will be the least able to cope without assistance to prepare and respond. From the tropics to the arctic, climate and weather have powerful direct and indirect impacts on human life. Weather extremes – such as heavy rains, floods, and disasters like Hurricane Katrina that devastated New Orleans, USA in August 2005 – endanger health as well as destroy property and livelihoods. Approximately 600 000 deaths occurred worldwide as a result of weather-related natural disasters in the 1990s, some 95% of which took place in developing countries. Pollen and other aeroallergen levels are also higher in extreme heat. These can trigger asthma, which affects around 300 million people. Ongoing temperature increases are expected to increase this burden. Water scarcity encourages people to transport water long distances and store supplies in their homes. This can increase the risk of household water contamination, causing illnesses. Increasing temperatures on the planet and more variable rainfalls are expected to reduce crop yields in many tropical developing regions, where food security is already a problem. Steps to reduce greenhouse gas emissions or lessen the health impacts of climate change could have positive health effects. For example, promoting the safe use of public transportation and active movement - such as biking or walking as alternatives to using private vehicles - could reduce carbon dioxide emissions and improve public health. They can not only cut traffic injuries, but also air pollution and associated respiratory and cardiovascular diseases. Increased levels of physical activity can lower overall mortality rates" (WHO, 2009).

There is a positive message in the above paragraph: human prevention and information can help to reduce the climate change impact in order to improve public health, from individual and collective efforts.

In the Region of the Americas, human and health indicators have advanced over the past decades. Life expectancy at Birth has gone from 68.8 in 1980-1985 to 74.9 in 2005-2010; fertility rate (children/woman) from 3.1 to 2.6, infant mortality (per 1,000 live births) 37.8 to 16.5; urban population (%) from 69 to 79. An important aspect that has changed, showing a clear epidemiological transition, is that rates of mortality from communicable diseases (rate/100,000 inhabitants) dropped from 109 in 1980-1984 to 55.9 in 2000-2004. Meanwhile, mortality from diseases of the circulatory system (rate/100,000 inhabitants), a most important representative of non-communicable disease, dropped from 280 to 229.2, clearly a minor change in comparison to the former group of communicable diseases.

The Region of the Americas continues and will continue in the next years to experience three major demographic shifts: population growth, urbanization, and aging. Weather disasters are increasing in a significant proportion due to the climate change. These disaster pattern changes will be contributed to by the increase of the climate change and will be implicated with strong human activities–climate interaction with a heavy anthropogenic origin (PAHO, 2007).

Assessment of human health during the 21st century, without considering the environment and its implications, is forgetting the social and environmental determinants of health and quality of life of human beings. During the last few decades, the damage caused by human activity and demographic explosion has accelerated the degradation, although they are not the only reasons for this situation.

Deterioration of the environment, already made, recognition of global environmental changes, the hard lessons from human-caused disasters or mistakes such as incidents like Seveso, Bhopal, Minamata, the Chernobyl nuclear accident, the Exxon Valdez accident in Alaska, cholera epidemics in Latin America, globalization, migrations and tourism, travelling across the globe, obligate us to consider the relationship between human health and a changing environment.

Public policies are difficult to manage in order to warranty the basic need for human health as a human right which includes potable water for hygiene and cleanliness. Ethics are needed to guide decision making to gain human rights (Tavares, 2005).

Main contributors to climate change and its consequences in health include now: degradation of good quality water, deposits of toxins and chemical pollutants, the impossibility to treat these products of human activities, and the wide spectrum of synthetic chemical substances in circulation in the environment without control or even knowing their consequences to human beings in the long term.

In terms of the environment, a WHO report found that most of the major diseases were at least, partially caused by exposure to environmental risks and that environmental causes contributed to about one-fourth of disability-adjusted life years lost (DALYs) and one-fourth of associated deaths (Prüss-Üstün & Corvalán, 2006).

A study done by the Pan American Health Organization (PAHO) about inequality in the access, distribution and expenditure in potable water in Latin America and the Caribbean found interesting results. With more than 11 countries of the region in 2001, the study showed that the poorest are generally those that do not have water systems and have to pay more to get potable water. Also, urban populations have more access to intra-domiciliary water than rural communities. But more concerning is that associated with poor disposition of potable water, the climate changes in terms of drought accompanied by fires and air contamination, and heavy rainy seasons produce even more problems with tropical rain, flooding, mudslides, and contamination of water (OPS, 2001).

4.2 Non-communicable Diseases Globally and in Latin America

Last decades, non-communicable diseases (NCDs) are spreading around the world and imposing their predominance in developing countries. Of real concern is that this changing of morbidity and mortality will put more pressure and a heavier burden of infectious and non infectious diseases in a poor environment characterized by poor health systems. Non-communicable diseases will cause 7 out of every 10 deaths in developing countries. Many of these diseases can be prevented by attacking associated risk factors (Boutayeb & Boutayeb, 2005).

According the World Health Organization's statistics, chronic NCDs such Cardiovascular Diseases (CVDs), diabetes, cancers, obesity and respiratory diseases, account for about 60% of the 56.5 million deaths each year and almost half of the global burden of disease. In 1990, 47% of all mortality related to NCDs was in developing countries, as was 85% of the global burden of disease and 86% of the Disability Adjusted Life Years (DALYs) attributable to CVDs. An increasing burden will be born, mostly by these countries, in the next two decades. The socio-economic transition and the ageing trend of the population in developing countries will induce further demands and exacerbate the burden of NCDs in these countries. If the present trend is maintained, it is predicted that by 2020, NCDs will account for about 70 percent of the global burden of disease, causing seven out of every 10 deaths in developing countries, compared with less than half today (Boutayeb & Boutayeb, 2005).

In 1990, approximately 1.3 billion DALYs were lost as a result of new cases of disease and injury, with the major part in developing countries. In 2002, these countries supported 80% of the global Years Lived with Disability (YLDs) due to the double burden of communicable and non-communicable diseases. Consequently, their people are not only facing higher risk of premature life (lower life expectancy) but also living a longer part of their life in poor health. These remarks indicate that NCDs are exacerbating health inequities existing between developed and developing countries and making the gap more profound between rich and poor within low and middle-income countries (Boutayeb & Boutayeb, 2005).

Globally, non-communicable diseases are more important in terms of frequency, absolute and relative, representing the vast majority of deaths. According to a main prediction from WHO data globally, Project Global Burden Disease (GBD) from Murray and Lopez have provided an important contribution to understanding mortality and burden of disease projections into the future and selected indicators and DALY. Most recently, Colin D. Mathers and Dejan Loncar made further projections of Global Mortality and Burden of Disease from 2002 to 2030 taking into account HIV/AIDS which, according to these authors, were underestimated by Murray and all (Boutayeb & Boutayeb, 2005; WHO, 2009).

A traditional typology of disease is tripartite—communicable disease, non-communicable disease and injury. A first generation of diseases is linked to poverty—common infections, malnutrition and reproductive health hazards mostly affecting women and children. These mostly (but not entirely) communicable diseases are concentrated among the poor in developing countries. A second generation of primarily chronic and degenerative diseases—such as cardiovascular disease, cancer, stroke and diabetes—predominate among the middle-aged and elderly in all countries. Susceptibility to these non-communicable diseases is linked to lifestyle and health-related behaviour. Injury should be added to these two groups of diseases and is prevalent in both rich and poor countries.

Disease and injury causes of death are classified (simplified) in the GBD using a tree structure in which the first level comprises three broad cause groups: Group I (communicable, maternal, perinatal, and nutritional conditions), Group II (non-communicable diseases), and Group III (injuries). A large decline of all causes of Group I with the exception of HIV is projected between 2002 and 2030. Although age-specific death rates for most Group II conditions are projected to decline, ageing of the population will result in significantly increasing total deaths due to most Group II conditions over the next 30 years (Figure 3). Global cancer deaths are projected to increase from 7.1 million in 2002 to 11.5 million in 2030, and global cardiovascular deaths from 16.7 million in 2002 to 23.3 million in 2030. Overall, Group II conditions will account for almost 70% of all deaths in 2030 under the baseline scenario (Mathers & Loncar, 2006).

Another important group (external causes of death) project to increase (40%) due to injury between 2002 and 2030 mainly due to the increasing numbers of road traffic accident deaths, together with increases in population numbers more than offsetting small declines in age-specific death rates for other causes of injury. Road traffic accident deaths are projected to

increase from 1.2 million in 2002 to 2.1 million in 2030, primarily due to increased motor vehicle fatalities associated with economic growth in low- and middle-income countries. (6)
The rapid rise of non-communicable diseases (NCDs), mental disorders, injuries and violence represents one of the major health challenges to global development in the 21st century. However, the staff across WHO's Cluster for Non-communicable Diseases and Mental Health believes that affordable solutions exist today to prevent millions of premature deaths each year in developing countries, mainly through policy change, effective surveillance and monitoring, initiatives to reduce common risk factors, and the strengthening of health systems. A stronger commitment to tackle NCDs and malnutrition and forge new partnerships are critical to making progress (WHO, 2009).
Socio-economic deterioration meaning poverty, rapid urbanization and social fragmentation has contributed to greater inequalities and unhealthier environments. Urban areas are characterized by violence, poor housing conditions and lack of basic sanitation. Directly in terms of climate change and global warming, the 2001 report of the United Nations Intergovernmental Panel on Climate Change mentioned that two countries of Latin America are among the world's largest carbon-dioxide emitters. These countries are Brazil and Mexico (PAHO, 2007).
Among the most important emerging challenges confronting the Americas are non-communicable diseases and violence due to aging of the population and unhealthy lifestyles and risky behaviours. Overweight and obesity, diabetes, alcoholism, malignant neoplasm, diseases of the circulatory system, mental health problems, road traffic and violence injuries and death are consequences of this unhealthy and unsafe social environment and lifestyle (PAHO, 2007.

4.3 Chronic Non-communicable diseases in the Americas

Cardiovascular diseases, chronic obstructive respiratory diseases, cancer and diabetes are the chronic non-communicable diseases of greatest interest for public health in Latin America and the Caribbean. In both sub-regions, non-communicable diseases are responsible for two out of three deaths in the general population and nearly one-half of deaths among those under 70 years old. Of the 3,537,000 deaths registered in Latin America and the Caribbean in 2000, 67% were caused by these chronic diseases. Ischemic heart disease and cancer accounted for the majority of deaths in those 20-50 years old. Non-communicable diseases contributed 76% of DALYs to the overall disease burden. In addition, early mortality and complications, sequels and disability limit functionality and productivity. These represent huge medical and health expenditures with financial and social costs that undermine resources in both the health systems and social security. (13)
Cardiovascular diseases (which include ischemic heart disease, cerebrovascular disease, hypertensive disease, and heart failure) represent 31% of the mortality. Data from 2000-2004 shows that mortality from diseases of the circulatory system was higher in men (223.9 per 100,000 population) than in women (179.3 per 100,000), although there are important difference in magnitude between sub regions. Many of these deaths are consequences of improper diet, obesity, lack of physical activity, and smoking, and include ineffective hypertension control and disease management. Hypertensive diseases are a major risk factor for heart disease and cerebrovascular disease and an important cause of mortality. However, there are major differences between countries of mortality rates from above 30 (age and sex adjusted rate per 100,000 population) in Bahamas, Dominican Republic and

Trinidad and Tobago to mortality rates lower than 10 in Panama, Uruguay, El Salvador and Canada (PAHO, 2007).

The most common malignant neoplasm's are of bronchus and lung, stomach, cervix, the breast and prostate. Diabetes was the fourth cause of death in Latin America and the Caribbean in 2001 accounting for 5% of total deaths. In Mexico, diabetes was the leading cause of death in the total population in 2002, with 12.8% of deaths (PAHO, 2007).

Chronic respiratory diseases caused 3% of all deaths, mortality incidence (2000) range between 16 and 25 per 100,000 populations; and, in most countries it was higher in men. Asthma, chronic obstructive pulmonary disease, emphysema, and chronic bronchitis are the most common (PAHO, 2007).

External causes of deaths: Violence, intentional and unintentional. Homicide is the most common intentional violent cause of deaths. A complex interaction of individual, relational, social, cultural, and environmental factors makes the Regions of the Americas one of the most violent in the world. Traffic accidents are most common, unintentional violence cause of death (PAHO, 2007).

Other violent, unintentional causes of death are related to disasters. The Americas constitutes one of the World's regions most exposed to natural disasters, and this vulnerability increases the potential risk of destructive effects caused by events of any nature (PAHO, 2007).

Between 2001 and 2005 the impact of these destructive phenomena has left a toll of some 20,000 death, 28 million victims, and billions of dollars in property losses. It is estimated that every year an average of 130 natural disasters of varying degrees of magnitude occur in the Region. Around 79% of the population is at high risk of damages and death, mainly due to living in large urban areas not prepared to cope with disasters such as earthquake, rain falls, flooding, and mudslides. Most dwellings are in high risk locations, unplanned, poorly built , and do not follow appropriate construction standards (PAHO, 2007).

4.4 Integrative Communion: Climate Change and Non-communicable Diseases

The most recent report of the Intergovernmental Panel on Climate Change (WHO, 2009) confirmed that there is overwhelming evidence that humans are affecting the global climate, and highlighted a wide range of implications for human health. Climate variability and change cause death and disease through natural disasters, such as heat waves, floods and droughts. Many important diseases are highly sensitive to changing temperatures and precipitation. Climate change already contributes to the global burden of disease including malnutrition, and this contribution is expected to grow in the future. Continuing climate change will affect, in profoundly adverse ways, contamination and shifting some of the most fundamental determinants of health in lacking or adverse way: food, air and water. Also, individuals and social mental health will be affected due to the very fast dynamics of change, traumatic experiences which moves at a different scale the ways of life and the surrounding environment. Sanitary infrastructure deterioration and destruction will challenge governments and populations to provide the minimum of medical and health care services, and probably even access to sanitation and health care will be an issue for most in developing countries. Most advances done in this area within developing countries during the last few decades would be confronted earlier with a fast climate change and its consequences represented by natural disasters. Surveillance and information systems are essential for prevention and medical preparation to cope, appropriately, with consequences of disasters related to climate change

(Alfaro & Rivera, 2008). There are many public and private organizations that bring support and information about disasters and health, including the *Red Centroamericana de Información sobre Desastres y Salud* which provides scientific information, research, products and services related to its mission (Cespedes, 2007).

Many authors have reported regional assessments of health impacts due to climate change in the Americas and show that the main concerns are heat stress, malaria, dengue, cholera and other water-borne diseases. Other investigators have published and estimated relative risks (the ratio of risk of disease/outcome or death among the exposed to the risk among the unexposed) of different health outcomes in the year 2030 in Central America and South America. The highest relative risks are for coastal flooding deaths (drowning), followed by diarrhea, malaria and dengue (Kovats & Haines, 1995; Parry et al, 2007). Air pollution or contamination is an important issue related to urban areas and modes of transportation and automobiles are implicated as the main cause in cities like Buenos Aires and Argentina where some research has been done in comparison with other cities of Latin America (Fernando et al, 2001).

Climate change is likely to increase the risk of forest fires. In some countries, wildfires and intentional forest fires have been associated with an increased risk of out-patient visits to hospital for respiratory diseases and an increased risk of breathing problems (WHO, 2009; Mills, 2009). However, it is not easy to register, but a study in Florida during 1998 made this important remark after studying a fire event that occurred in several counties: rapid surveillance of non-reportable diseases and conditions is possible during a public health disaster. In urban areas exposed to the 'heat island' effect and located in the vicinity of topographical features which encourage stagnant air mass conditions and the ensuing air pollution, health problems would be exacerbated, particularly those resulting from surface ozone concentrations (PAHO, 2003; PAHO, 1988; PAHO, 2007).

Natural and technological disasters involved many casualties occurring in a short period of time and emergency actions and controls, pre and post events, (planning and preparation) are crucial for good management. The increasing number of disasters in the region has been noticed during the last three decades, events such as electric tropical storms and hurricanes, flooding, mudslides and droughts has affected more frequently. There are bases to consider the effects in terms of deaths, displacements and lost properties of disaster related to poor housing, unplanned settings, low income, lack of social security and labour, deforestation, primitive practice of agriculture, lack of planning territorial order, and poverty (Alfaro & Rivera, 2008).

During the last decades, due to intense rain precipitation in short periods of time, there have been described many events such as mudslides and landslides all over Latin America (described in Guatemala, Nicaragua, San Salvador, Brazil, Bolivia, Peru, Columbia, Argentina, Ecuador, Venezuela, Mexico) and the Caribbean. Especially vulnerable are unplanned urban settlements located on mountains and hilly ground, where soil texture is loose and not prepared for construction. Hundreds of people living in poor-quality buildings and houses have been affected by injuries, losing their properties and even death. These situations have become common since main infrastructure projects have been planned but not done. However, a lot of effort has been made to educate and inform people about pre, during and post natural disasters due to abundant rain occurring (Parry et al, 2007; PAHO, 2007). Also, these types of events and their frequency will affect tourism to certain areas that are very popular in Latin America such as Machu Picchu, Amazonas River and plains and will be even worse for the populations that live close to this natural monuments, predominantly indigenous and minority groups.

Problems related to skin control of temperature and water, cancer, photosensitivity and damage related to exposure to ultraviolet radiation or ozone have been described in other areas of the world. In Latin America, at least one reported example has been reported: Highly unusual stratospheric ozone loss and UV-B increases have occurred in the Punta Arenas (Chile) area over the past two decades, resulting in the non-photo adapted population being repeatedly exposed to an altered solar UV spectrum. This causes a greater risk of erythema and photocarcinogenesis. The rate of non-melanoma skin cancer, 81% of the total, has increased from 5.43 to 7.94 per 100,000 (46%) (PAHO, 2007).

Some investigators, environmentalists, nature protectors, biodiversity advocates, public health practitioners and many others are concerned that not much attention has been given to the roots of the problem of climate change, and ecosystems that should be protected are forgotten in the care of this natural barrier to many natural disasters related to tropical storms, hurricanes and flooding. A more integrative, environmental approach should be taken by national and regional governments. Plans to protect all natural barriers such as seas, rivers, water, forests, mangroves, biological diversity, and nature in general are supported by an increasing number of politicians, representative, communities, scientists, laypeople. It is the focus of attention nowadays for this new millennium and evidenced by world agreements such as those made in Kioto, Japan and Brazil.

5. Figures

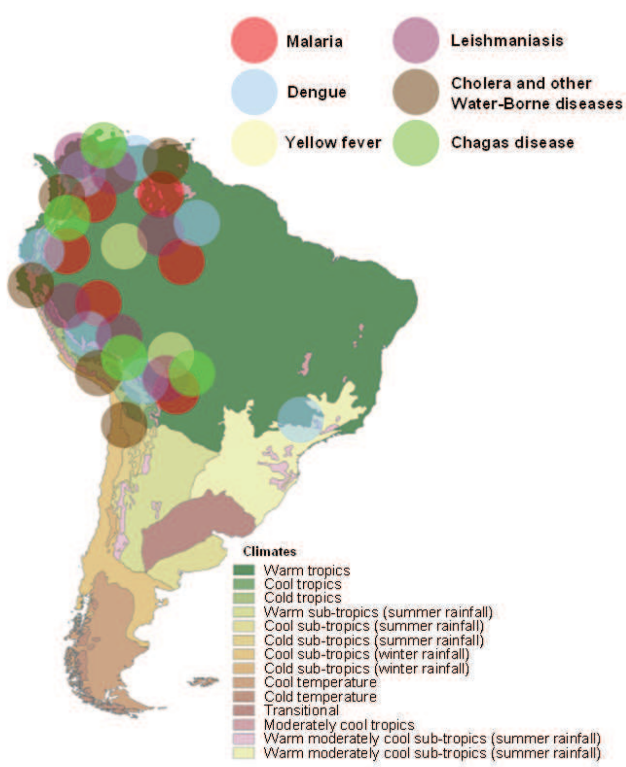

Fig. 1. Climates of South America and spots for the distribution of reports of endemic ties of communicable diseases that are prone to be affected by climate variability and climate change (adapted from World Book (2007). – South American climates. Available at: http://www.worldbook.com/wb/Students?content_spotlight/climates/south_american_climate).

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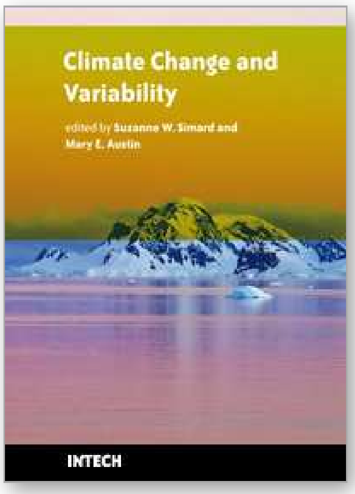

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Climate change is emerging as one of the most important issues of our time, with the potential to cause profound cascading effects on ecosystems and society. However, these effects are poorly understood and our projections for climate change trends and effects have thus far proven to be inaccurate. In this collection of 24 chapters, we present a cross-section of some of the most challenging issues related to oceans, lakes, forests, and agricultural systems under a changing climate. The authors present evidence for changes and variability in climatic and atmospheric conditions, investigate some the impacts that climate change is having on the Earth's ecological and social systems, and provide novel ideas, advances and applications for mitigation and adaptation of our socio-ecological systems to climate change. Difficult questions are asked. What have been some of the impacts of climate change on our natural and managed ecosystems? How do we manage for resilient socio-ecological systems? How do we predict the future? What are relevant climatic change and management scenarios? How can we shape management regimes to increase our adaptive capacity to climate change? These themes are visited across broad spatial and temporal scales, touch on important and relevant ecological patterns and processes, and represent broad geographic regions, from the tropics, to temperate and boreal regions, to the Arctic.

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