DRAFT

Climate Change in the Americas: Synthesis, Integration, and Assessment

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I. EXECUTIVE SUMMARY

This work is the result of a collaborative effort by graduate students and post doctoral researchers from North, Central, and South America who gathered at The Pan-American Advanced Studies Institute held in La Paz, México, June 4-14, 2007. The goal of this paper is to provide a context for a systemic and interdisciplinary understanding of the issue of climate change currently affecting the Pan American countries, and to provide recommendations for the undertaking of actions to prevent, mitigate and adapt to the detrimental impacts by global warming. The vast majority of scientists agree that increasing concentrations of carbon dioxide and other greenhouse gases in the Earth's atmosphere are causing changes in global climate. These increases are generally attributable to burning of fossil fuels and changes in land use. As scientists we agree that these facts are immutable and that the focus for this group should be on recognizing impacts and recommending strategies to reduce further changes to the atmosphere.

For the purpose of this paper, the Pan American countries were divided in three regions: North America (Canada and the United States), Mesoamerica and the Caribbean, and South America. For each region a discussion of the anticipated impact of global warming as well as strategies for prevention, mitigation and adaptation are provided. We also provide a synthesis of recommendations that encompass all the Americas. Because research and information on the impact of global warming differs in availability for different regions, each regional chapter will have a slightly different emphasis. Recommendations stemmed in part from this differential availability of information.

The best available resources on climate change have been summarized as part of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) report released in 2007. The IPCC has generated a number of future climate scenarios based on several possible emissions trends. In South America, in terms of temperature, there is a broad agreement between models that the entire continent will warm by up to 5ºC. In northern South America, the months of June, July and August (the current dry season) will become drier than normal, and rainier with the exception of the La Plata region which will likely experience more precipitation. In the months of December through February, the entire continent will likey experience wetter than normal conditions, with exception of the Patagonia region and the southern Chilean coast. In Mesoamerica and the Caribbean, temperature is expected to increase by up to 2.5ºC, and broadly, precipitation levels will decrease by an average about 6%, with varying impacts depending on the region. In the United States and Canada, an increase of about 7ºC can be expected by the end of this century, with the most extreme temperature changes expected in arctic regions. Precipitation in North America is thought to increase in northern regions by up to 50% and will likely decline in the southwestern and central regions of the United States.

Projected changes in climate are expected to have a variety of impacts on natural, economic, and social systems. Across all regions, we expect to see an increase in natural hazards such as drought, extreme heat and storm events; sea level rise; flooding; decline of agricultural systems; melting of permafrost and glaciers; and tropical disease spreading. These impacts will vary in their distribution and intensity. In South America, perhaps the biggest concern is loss of the Amazon rainforest due to predicted conversion of tropical forest to savannah, with its associated impacts on biodiversity loss, local and regional hydrology and weather, and social systems. In Mesoamerica and the Caribbean, impacts on climate are expected to range from extreme drought to very intense and perhaps more frequent tropical storm events, with devastating impacts on economic, social and ecological systems, including possible loss of significant land area in island nations due to sea level rise and coastal erosion. In North America, the hardest impacts to overcome will be decreasing water availability and an increase in extreme weather events, such as droughts, heat waves, and tropical storms. An important consideration to note is that changes in atmospheric and oceanic temperature do not respect national boundaries, and impacts on these properties will impact the entire earth, with often poorly understood consequences.

A major outcome of this institute is the drafting of broad recommendations for mitigation and adaptation to climate change and its impacts. The most important thing that individuals and governments can do to mitigate the impacts of climate change is to reduce overall emissions of greenhouse gases, through energy conservation, exploration of alternative energy sources, and increasing carbon sequestration. Another extremely important recommendation is to increase public knowledge about climate change by bridging the gap between scientists, policymakers, and the public. More research is needed to explore the specific impacts of climate change on ecosystems in developing country, which can be facilitated by international collaborations such as the PASI.

We hope to continue the collaboration we have begun here by combining our various expertises in the geochemistry, hydrology, climatology, anthropology, education, policy, and economics aspects of climate change by fostering future collaborations to expand the base of knowledge in these areas.

PART II: INTRODUCTION

The emission of greenhouse gases as a result of human activities is causing climate change (IPCC 2007). Therefore, it is widely recognized by scientists, governments and civil society that climate change is one of the major issues of global concern for our time and that we need to take immediate action to mitigate detrimental impacts on our ecosystems. As a result of this recognition, 141governments have ratified the Kyoto protocol agreement, which became legally binding as of February 16, 2005. The now legally binding Kyoto protocol has effectively established a legal framework for the reduction of the emission of greenhouse gases by 5.2% by the year 2012. To effectively address the causes and prevention of climate change requires a systemic and interdisciplinary perspective, while the tackling of issues of prevention, mitigation and adaptation requires integrative, interdisciplinary and collaborative efforts between by academics, governments and civil society.

The IPCC notes that as a result of increasing worldwide scarcity of water there are about 1.7 billion people who do not have adequate water supplies, and it predicts that by 2025 this number will increase to 5 billion people because it is projected that stream-flow and water recharge in many of the water stressed countries will decrease further. In addition, increases in temperature and water shortages are forecasted effects of climate change on agricultural production. Agricultural yields will decrease as a result of temperature increases especially in tropical and sub-tropical regions, while in the continental interior moisture deficits (dryness) will be the main effect; both will lead to food supply and food security problems (IPCC 2001, 2007).

Although there is uncertainty to the projected duration, intensity and overall impacts of climate change, what is fairly certain is that societies will be affected through changes in the ecosystems on which they depend for their livelihood (Githeko et al. 2000). According to the IPCC (2001, 2007), the effects and impacts of climate change are not uniform and those societies who are most vulnerable (those who are least able to cope with the impacts) will be affected the most. Therefore, it has increasingly been acknowledged that the adaptive capacities of societies with regards to impacts of climate change need be placed into a broader socio-economic context—including poverty, economic development, population growth and local adaptive strategies and capacities—so that the strategies for mitigation and adaptation developed are informed by this broader context.

The dominant economic paradigm promoted by developed countries and international organizations like the World Bank and the IMF promotes economic globalization and trade liberalization based on the idea that improvement in the standard of living for the least well off countries is directly and positively linked to increases in economic growth. Industrialization and/or trade liberalization of these economies is therefore encouraged and supported. This model of economic development places a high level of faith in science and technology as the solution to most of our ecological problems. Yet, as illustrated in Figure 1, our economic activities in the pursuit of economic growth are now well beyond the capacity of ecosystems.

Figure 1: Human demand and the Earth's biocapacity

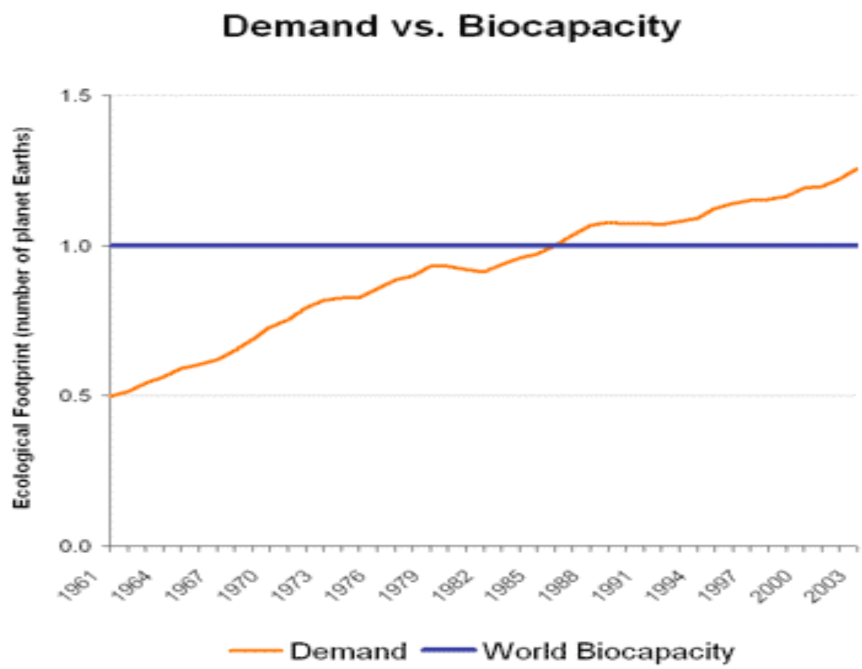


Figure 1 shows the ratio between the world's demand and the world's biocapacity in each year and how this ratio has changed over time. Expressed in terms of "number of planets," the biocapacity of the Earth is always 1 (represented by the horizontal blue line). This graph shows how humanity has moved from using, in net terms, about half the planet's biocapacity in 1961 to over 1.25 times the biocapacity of the Earth in 2003. The global ecological deficit of 0.25 Earths is equal to the globe's ecological overshoot (source: Global Footprint Network).

Although there is growing awareness that climate change poses a significant threat to human wellbeing and ecological sustainability, many of us continue to live unsustainable lifestyles. The Stern Review (2006), a study commissioned by the U.K. government and headed by Sir Nicholas Stern, provides an analysis of the economic costs of the impacts of climate change and the possible avenues for mitigation and adaptation and their associated costs. This report states that the causes of climate change are the results of the emissions of greenhouse gases including CO2 and others, from past and current economic activities particularly in energy, industry, transportation, and land use. According to the report, the concentration of CO2 in the atmosphere prior to the industrial revolution was 280 ppm (parts per million) compared to the current level of 430 ppm. To stabilize the concentration around 440 - 500 ppm "would require global emissions to peak in the next 10 - 20 years, and then fall at a rate of at least 1 - 3% per year. By 2050, global emissions would need to be around 25% below current levels" (Stern Report 2006, Ch. 8, p. 8).

The mitigation of and adaptation to global warming cannot be solved through technology alone. Responding to climate change requires a shift in our understanding of the "relationships among ecological, social, and economic systems and the application of this understanding to the mutual well-being of nature and people, especially that of the most vulnerable including future generations" (ISEE, Article II). Only through this approach can we (re)position our social system in a more interdependent and responsible relationship with the ecological and economic systems. This perspective recognizes that there are limits to the capacity of the world's natural systems to support economic growth, repositioning economic development as a subsystem of the ecosystem (Constanza et al1997).

PART III: NORTH AMERICA

Methodology: While there are many areas of inquiry about how global warming will impact North America that are in need of investigation, scientists and social scientists have a broad understanding of predicted impacts. Based on the availability of resources on the science of climate change, the North America group decided to focus efforts in particular on working to synthesize existing information in order to make policy recommendations. Drawing on the strength of our group's interdisciplinary composition (including hydrology, biogeochemistry, atmospheric science, geology, anthropology, and land and food systems) we present a very broad overview of what is known about current and future climate scenarios as well as strategies for mitigation and adaptation before detailing specific policy recommendations.

1.0 Current and future climate

Despite the prediction that North America, on the whole, will experience continued warming over the next century (IPCC 2007 Chapter 11), the seasonality of warming and the predictions for changes in precipitation are regional. Most regions are predicted to experience similar changes in climatic conditions as concentrations of atmospheric greenhouse gases continue to increase. The majority of the information in this section is derived from the 2007 IPCC report, and the National Assessment Synthesis Team report (2000).

Regional average annual temperature increases, ranging from 2 to 6 °C, are predicted and are based on the A1B scenario outlined in the AR4 report (Table 1). Winter (December, January, February) temperatures are expected to increase the most in the northern section of the Northeast and across Canada and Alaska, while temperatures during the summer months (June, July, and August) will increase the most across the rest of North America (Table 1). Predictions of fractional changes in precipitation across North America are more variable with up to a 15% decrease predicted for the Southwest and Great Plain states of the United States of America and up to a 30% increase in precipitation predicted for Canada and Alaska (Table 1).

Table 1. Differences between annual temperature and precipitation and the seasonality of the largest temperature changes from 1980-1999 and 2080 to 2099 as predicted using the average results of 21 models forced with the A1B (AR4) scenario. Note that the B1 scenario (AR4) predicts even greater increases in temperature. This information is largely drawn from the IPCC (2007) report for policy makers but precipitation information for the Southwestern states of the United States of America is also based on research by Seager et al. (2007).

Region	Temperature change (°C)	Season experiences greatest change	Fractional change in precipitation

Northeast	3 to 3.5°C increase	Winter for most northern areas but summer for the more southern areas	5-10 % increase
Southeast	2.5 to 3.0 °C increase	summer	5-10% increase (southwest) to a 5% decrease (northern)
Midwest	3.5 °C increase	summer	5 to 10% increase
Southwest	3 to 3.5 °C increase	summer	0 to 15% decrease
Great Plains	3 to 3.5 °C increase	summer	0 to 15% decrease (becomes more pronounced further south)
Pacific Northwest	2.5 to 3.5 °C increase	summer	0 to 5% increase
Polar regions (Alaska and Canada)	2 to 6 °C increase	winter	5 to 30 % increase

Due to the surface albedo feedback, North American polar regions have seen and will continue to experience large surface air temperature changes associated with climate change. Average annual projected changes from the multi-model data set vary from 2ºC to 6ºC for the B1 scenario to 4ºC to 10ºC for the more extreme A2 scenario (AR4). Seasonally, these changes are expected to be the largest in winter, as receding sea ice produces results in significant sensible heat transfer from open water to the atmosphere. These oceanic heat losses may have a significant effect on both Arctic and global atmospheric circulation (Rinke, et al., 2006). However, it is unclear exactly how the atmospheric circulation will respond to these changes (AR4).

2.0 Major expected impacts of climate change

2.1. Changes in precipitation and fresh water availability:
Increasing pressure on water resources due to climate change are going to be exacerbated by projected population increase in the USA and Canada. Impacts of climate change are expected to have varying consequences for the availability of freshwater supplies in the US and Canada (IPCC Fourth Assessment (2007). According to the most recent IPCC Report, northern regions are likely to experience longer winters whereas the southwest of the USA will experience longer summers. Predicted increases in temperature across the whole of North America will significantly impact the distribution of rainfall. Precipitation is expected to increase in the northern states of the USA and Canada. Conversely, rainfall amounts are likely to decrease in southwest USA (Seager et al., 2007). Snow

depth and season length are very likely to decrease in most of North America except in northern areas of the continent, parts of Canada, where maximum snow depth is very likely to increase over the next century.

Diminishing precipitation over parts of the United States, which will affect the quantity and quality of fresh water, will have significant impacts on ecosystems, energy, human health and agriculture. Increasing population will add extra pressure on the already depressed surface and subsurface water sources. Projections show a growth in population in the USA reaching 420 million people by the year 2050 (wwww.numbersusa.com), with most of the population growth occurring in the southwestern states. Canada will experience a slower population growth with projections showing a total of 43 million inhabitants by the same year (www.sustreport.org). Higher temperatures are expected to increase evaporation from natural and artificial reservoirs and from bare soils, which will diminish soil productivity and augment irrigation demands.

Reduced sea ice, increased temperatures, and an intensification of the Aleutian Low will result in an increase of atmospheric water vapor, and thus precipitation over the majority of the polar regions (AR4). Recent observations point to a trend of increasing precipitation in the Arctic (Hinzman, et al., 2005).

Models indicate that sea level pressure in the northern North America will decrease by 1.5 to 3 hPa due to atmospheric warming (AR4). Recent multi-model analysis shows a decrease in frequency of high pressure circulation patterns and in increase in low pressure patterns along the North Atlantic storm track in the winter season for the A1B scenario (Cassano, et al., 2006).

While snow depth is expected to decrease in much of northern North America, snow depth is projected to significantly increase in some coastal areas along the North Slope and Canadian Arctic Archipelago due to increased projections of winter precipitation (AR4).

In regions where rainfall is expected to increase, the cost associated with the construction and maintenance of flood control infrastructures will consequently rise. Intensification of surface runoff is likely to increase sediment build up in reservoirs with the consequent reduction of water storage for consumption or hydroelectric generation.

Tropical storm formation is also expected to increase as a result of changing weather patterns and increasing sea surface temperature. Storms are also expected to be more intense, with more rainfall and faster sustained winds. This has serious implications for coastal ecosystems and human settlements, especially on the southern Atlantic and Gulf of Mexico coasts in North America. There is also some evidence that tropical storms will move polewards in response to climate changes, thereby threatening northern communities not previously affected.

2.2. Potential water conflicts:

In the literature on environmental conflicts, some authors argue that the degradation of the environment (land degradation, deforestation, depleted fish stocks, scarce water supplies) is the root cause of conflicts (wars, disputes, border crossings), whereas others argue that it only exacerbates existing conflicts (Sondorp and Patel, 2003). However, both views agree that competition over scarce water supplies and increasing droughts as a result of climate change can directly or indirectly lead to conflicts.

It has been proposed that water markets will help resolve conflicts over water availability and increase water efficiency since water rights will be allocated to the highest demand and to social sectors that are more willing to pay. This solution has been argued to be most effective in water-stressed regions such as the southwest region of USA where water markets will bring most needed water resources to this rapidly growing region. Although water market mechanisms can relieve some highly stressed ecosystems, there is also the underlying concern that it will deeply affect the most impoverished communities who will not have the economic power to compete for the resources in the market such as Mexican-American, indigenous and agricultural communities (Dellapenna, J.W., 1999).

The allocation of water in the USA is dictated by two major doctrines for surface water: the Prior Appropriation Doctrine, which prevails in 19 states east of the 100th meridian (roughly west of the Mississippi River) and the Riparian Doctrine, which prevails in 31 states in the east part of the country. The Riparian Doctrine prevalent in the east part of the country dictates that water rights is based on ownership of adjacent land, whereas the Prior Appropriation Doctrine establishes that users that demonstrate earlier uses of the water for beneficial use acquire the rights.

Stress will increase in already overexploited aquifers in the southwest where the rights of access to groundwater is poorly regulated or not regulated at all (Jacobs et al, 2000). Many Native American Communities are located in the southwest where a great majority practice subsistence agriculture and economic activities related to fisheries and tourism. Also, most tribal communities are culturally tied to a specific place and depend on natural resources for their livelihood. Tribal Nations have been granted water rights over the streamflows of the Colorado River and other minor tributaries. However, historically local communities have not used those water rights and emerging demands could potentially pose new stress to already overexploited surface and subsurface water resources.

A 2004 Environment Canada report, “Threats to water supply in Canada,” states that climate change impacts of most concern in Canada include changes in the hydrological cycle caused by increased rates of evaporation and evapotranspiration, in spite of a forecasted increase in precipitation in some regions. In addition to a general increase in water demand—as reflected by the increase in water demand from agriculture, industry and municipalities—the decrease in the supply of fresh water will threaten the health of aquatic ecosystems. Moreover, potential water conflicts as a result of increased scarcity of water supply could arise from governance issues associated with national and international water agreements, in-stream water values associated with ecosystems health, and water rights of First Nation communities (Environment Canada, 2004).

2.3. Impacts on aquatic ecosystems:

Increasing global temperatures due to greenhouse gas emissions pose a threat to freshwater and marine resources including fisheries, coral reefs, and water quality. Warming of surface waters can affect fish and shellfish populations in several ways. Temperature has an effect on the physiology of fishes, and in response to warming, fish populations may migrate to waters with more optimal conditions for growth. Temperature increases may also cause a shift in the range of aquatic diseases which will spread at rates too rapid for populations to adapt. Certain species may find themselves exposed to new predators who moved in response to unsatisfactory conditions. Also, changes in hydrology such as increased or reduced freshwater inflow and changes in salinity can alter fish habitat such that certain species may be threatened. It is important to note that the negative impacts of climate change are expected to have the greatest impact on fisheries that are already threatened by overexploitation. Given that marine and freshwater fish are a significant portion of protein in the North American diet, impacts on fisheries will have food security repercussions for some people.

Climate change is also implicated in global decline of coral species, which are areas of rich biodiversity as well as important cultural and biological resources. Corals are notoriously sensitive and have a low tolerance for environmental change. Increasing ocean temperatures are implicated in coral bleaching, a process by which algae are expelled from the coral skeleton. This process is also accelerated by acidification of seawater, caused in part by rising dissolved CO_2 concentrations. Widespread coral mortality and collapse of coral reef ecosystems is expected to occur if climate change continues unabated.

Another important impact of climate change on aquatic ecosystems is that of increasing occurrences of toxic phytoplankton species, also known as harmful algae blooms (HABs). Increasing ocean temperatures can lead to rapid increases in population of these toxic species, which are often more easily adapted to changing environmental conditions than slower-growing species such as seagrasses or kelp. These toxic algae are a threat to their ecosystems and can have a negative impact on human health, either by contamination of drinking water, declines in air quality, or massive fish kills. While increasing temperature can have a negative impact on fish populations, coral health and toxic algae populations, it is only one of several threats to the integrity of aquatic ecosystems in North America. Chemical and agricultural runoff, overfishing, and habitat degradation are also serious threats to aquatic ecosystems, and global warming will likely exacerbate existing ecological problems. This is especially important in North America, where populations are continuing to migrate coastward and put pressure on delicate marine ecosystems.

2.4. Melting of permafrost:

Permafrost has already shown significant signs of warming, approximately 3ºC since the mid 1980s, and GCM simulations indicate that this trend will continue over the next fifty years (Hinzman, et al., 2005). Melting permafrost will have significant ecological and human impacts in northern North America. From an ecological standpoint, thawing permafrost can result in saturated soils, flooding and destroying root systems and causing forests to be replaced with meadows and bogs. From a human impact perspective, melting permafrost can have a devastating effect on infrastructure such as pipelines, buildings, and roads. The runway at Prudhoe Bay, for example, has already been reconstructed once due to melting permafrost (Hinzman, et al., 2005).

Because much of the western United States depends on snow for water storage, climatic changes resulting in reductions in snowpack are of particular concern for this region. Recent analysis indicates that western snowpack is already declining, and the majority of this decline can be attributed to climatic reasons (as opposed to decadal variability) (Mote, et al., 2005). This trend is expected to continue with a warming climate due to earlier spring melts and later autumn snowfall (AR4).

In northern regions, changes in the snowpack have direct implications for local residents. For example, air and off-road travel are the main options for intercommunity transit in the largely roadless Alaskan North Slope. Off-road travel is only permitted when enough snow is on the ground to protect vegetation and the active soil layer is completely frozen. Therefore, the length of time available to travel off-road is greatly influenced by the changes in the snow pack and changes in the growing season. Oil and mineral exploration opportunities, which require off-road travel, are also limited by reductions in snow pack (Hinzman et al., 2005).

Many northern North American residents practice subsistence hunting, and changes in the hunting seasons and patterns have a direct effect on this way of life. Because traveling inland requires snowpack, changes in the duration of this snowpack affects the available time for hunting. For example, in Barrow, Alaska, the spring goose hunting season is advancing as the snowpack melts earlier and earlier. This timing shift conflicts with bowhead whale hunting which is conducted from the ice pack (Hinzman et al., 2005).

2.5.Impacts on forests:

The IPPC (2001) states that in North America the effects of climate change will result in the areal expansion and forestry productivity over the next 50-100 years, but extreme or long-term scenarios will lead to decline. However, the IPCC 2001 report notes that climate change is likely to cause disturbances such as fire and insect outbreaks, and the outcome of these disturbances will heavily depend on the management practices implemented.

Modeled predictions of climate change in boreal forests such as northern and upslope migration of treeline, moisture-stress related tree dieback, infestation and wildfire disturbances are currently observed in boreal forests in Alaska, Canada and Russia (Soja et al. 2007). Northern and upslope migration of the treeline is observed in regions across Siberia, white spruce moisture-stress related dieback in Alaska, extreme forest fires over the last 7-9 years in Siberia, Alaska and Canada, and multi-year outbreaks of spruce beetle. Amber et al (2007) suggest that this is evidence of the response of the boreal terrestrial environment to effects of climate change.

Pine beetle infestations attributed to climate change are devouring large areas of pine forests in Western Canada and Alaska, which could contribute to a vicious cycle of reduced forest cover, increased CO2 emissions and further climate change (Philip 2004).

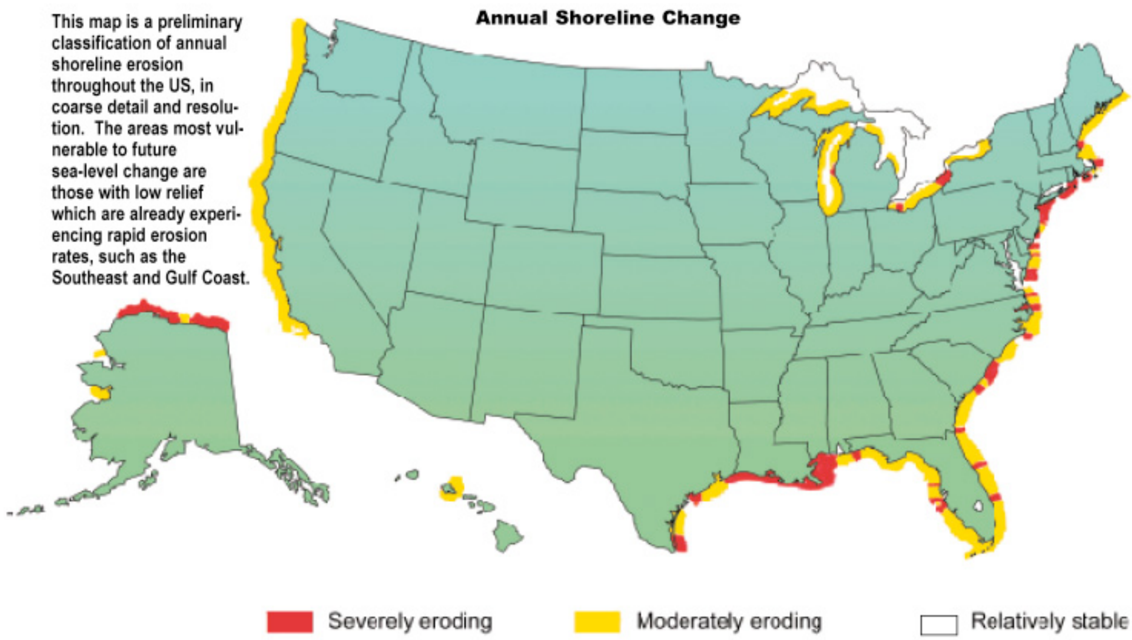
The Ministry of Natural Resources of Canada states that the pine beetle epidemic in the province of British Columbia, the largest producer of wood products in Canada, has been spreading at an alarming rate. By 2005, the pine beetle epidemic had extended to 8.7 million hectares and killed 450 million cubic meters of pine, and it is forecasted that by 2013, some 80 percent of the province's mature pine may be affected.

2.6.Impacts on agriculture:

The IPCC projects that moderate climate change in the early part of the 21st century will result in increased aggregate yields of 5 to 20 percent for rain-fed agriculture in North America, but that there will be significant variability among regions. Crops that are at the warm-end of their suitable range as well as those that depend on over utilized water resources will face challenges (IPCC 2007). Although there is potential for expansion of cropland as a result of warmer temperatures, there are regions that are very sensitive to temperature changes such as the southern provinces in Canada and the north-western and north-central states of the United States, while the great plains of the US are sensitive to changes in precipitation (Ramankutty, 2002). Therefore, the net result of climate change for agriculture in North America is unpredictable. Many of the most important North American summer crops like corn, grains, cotton, sorghum, and rapeseed go through some moisture or temperature sensitive stage of development during the summer months (JJA) and thus, are likely to be sensitive to changes in temperature and precipitation regimes, and the associated net decrease in soil moisture (USDA).Therefore, some people will benefit because they are located in regions where agricultural expansion will occur, whereas others will face food security challenges because of the impacts on resources sensitive to temperature increases and water scarcity on the regions where they live.

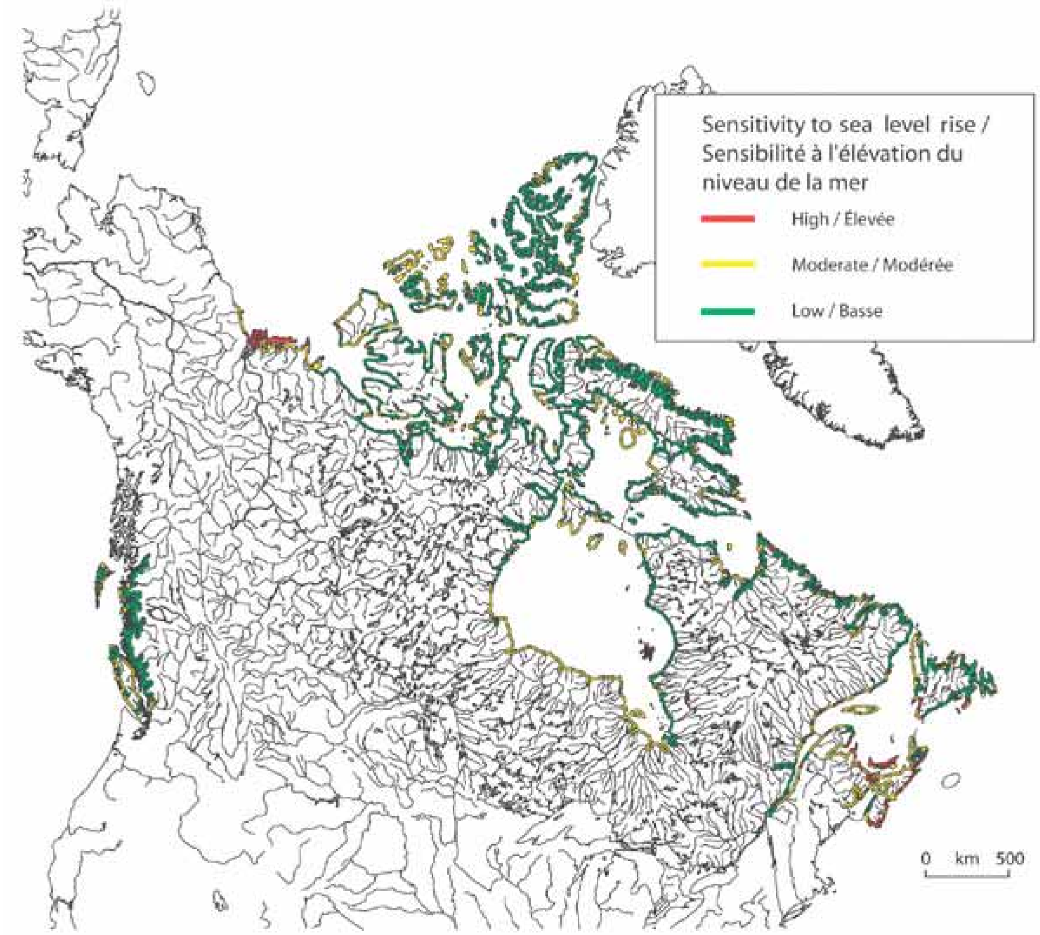
2.7.Coastal impacts:

Approximately one half of the U.S. population (153 million people) lives in coastal counties. Melting of the Greenland ice sheet is predicted to cause a rise in sea level of 4 to 6 meters or more (IPCC 2007). Therefore, a significant portion of the population of North America is likely to be displaced in the coming decades and centuries. Coastal communities and habitats will be negatively impacted by sea level rise, especially in the face of increasing pollution and development. Population growth and the rising value of infrastructure in coastal areas increase vulnerability to climate variability and future climate change, with losses projected to increase, especially if the intensity of tropical storms increases.



(Source: US Global Change Research Program 2000).

Canada has more than 240 000 kilometers of ocean shoreline, more than any other country in the world. Roughly seven million Canadians (21 percent of the total population) live in coastal areas, and many people in small communities depend on coastal resources. In addition to coastal areas, the Great Lakes are often included in discussions of coastal zones because the interface between human and natural systems is similar and because lakes will also be significantly impacted by climate change. Climate projects for the current century suggest that coastal impacts will include changes in water levels, wave patterns, the magnitude of storm surges, and the duration and thickness of seasonal ice coverage. Along marine coasts, global sea level rise will be the primary influence, while for the Great Lakes, water levels are projected to decline (Natural Resources Canada 2004).



(Source: Natural Resources Canada 2004).

2.8. Impacts on vulnerable populations

2.8.1. People living in poverty:

Poor communities are especially vulnerable to the effects of climate change because they have limited adaptive capacities and often are more dependent on climate-sensitive resources such as local water and food supplies (IPCC 2007:9). In addition, those living in poverty are more likely to live in high risk areas including marginal lands and poor quality housing and are less likely to have financial resources or insurance, leaving them at a significant disadvantage in terms of adapting to climate change (Stern 2007:131). Moreover, it should be noted that those who stand to be most affected by climate change are least responsible for the greenhouse gas emissions that cause the problem—both globally and within the United States.

The poverty rate in the United States is among the highest in the developed world. In 2005, the official poverty rate was 12.6 percent, or 37 million people. Among children under age 18, 17.6 percent – 13 million children -- lived in poverty (US Census Bureau 2005). These rates represent an average for the entire population. People of color and people living in urban environments in general have higher rates of poverty. Poverty rates also vary significantly by state; from 2003– 2005, the District of Columbia, Louisiana, Mississippi, and New Mexico all had poverty rates of 17 percent or more, while New Hampshire's poverty rate was the lowest at 5.6 percent.

Canada does not have an official measure of poverty. Instead, the Statistics Canada publishes what it calls "low income cut-offs" which identify "those who are substantially worse off than the average" but not necessarily poor. These measures are, like the US's poverty rate, based upon income levels. In 2005, Canada's low-income population based on pre-tax income levels was 15.3 percent of the population, or 4.8 million people. For children under the age of 18, 16.8 percent were considered low income (Statistics Canada 2005).

The Canadian Centre for Policy Alternatives—a research institute concerned with issues of social and economic justice—in a recent publication (CCPA, 2007) states that although Canada is one of the richest G8 countries, there are a substantial number of families living under the poverty line and that the gap between the rich and poor families is increasing. According to CCPA, “In 2004, the average earnings of the richest 10% of Canada’s families raising children was 82 times that earned by the poorest 10% of Canada’s families. That is approaching triple the ratio of 1976, around 31 times. Close to 1.2 million children — almost one child out of every six in Canada — still live in poverty. Low-income families need, on average, an extra $7,200 a year just to reach the poverty line” (CCPA, 2007, p. 2).

Although the vulnerabilities of Canada's low income residents may be different than those in the United States because of the different local effects of climate change, nevertheless, in both nations those with less access to resources will face greatere challenges related to mobility and adaptation than those with greater wealth.

2.8.2. Indigenous Peoples:

Indigenous peoples in North America are particularly vulnerable to the impact of climate change because their close association with the environment through hunting, fishing, and agricultural practices affects not only the livelihood of many groups but also their cultural identities. For example, hunting among the Inuit is not only a source of food for subsistence, it is also an important mechanism for the transmission of cultural values from elder, experienced hunters to youth. Inuit communities in Canada and Alaska have been documenting changes in sea ice, weather patterns, and permafrost that have already impacted animal populations as well as their ability to hunt safely. Current estimates suggest that over half of all sea ice may disappear by 2100, with devastating impacts on mammal populations as well as Inuit and others who depend on these animals for subsistence (Stern 2007). Because subsistence activities are integral to their cultural identity and continuity, many indigenous communities feel that global warming infringes their human rights to life, physical integrity, and security, their human right to enjoy property, and their right to enjoy the benefits of culture. Nobel Prize nominee Sheila Watt-Cloutier, former Chair of the Inuit Circumpolar Conference, recently led a delegation of Inuit in presenting a case in front of the Inter-American Commission for Human Rights. Watt-Cloutier suggests: "When viewed in the context of the cumulative impacts of all the other cultural, economic and environmental degradation that indigenous peoples face, climate change threatens our very survival as peoples" (Watt-Cloutier 2007).

2.9.Impacts on human health:

Climate change may impact health in several important ways, through direct temperature effects including extremes of heat and cold and extreme events such as hurricanes and floods which can result not only in injuries and deaths but also in increased infectious disease rates as well as increased psychological stress. Increases in precipitation and temperature can increase incidence of vector-borne diseases.. Vector-borne diseases that are common in warm regions including malaria, dengue fever, yellow fever and encephalitis may move north and may reappear or increase in incidence in North America. Also, climate change is expected to contribute to air quality problems including smog and particulate air pollution leading to increasing incidence of respiratory disorders (WHO 2003).

In some temperate and northern regions of Canada and the United States, mortality may initially decrease due to fewer severely cold days.

Health Impacts will be more severe for those already characterized by poor health. For example, the 2003 heat wave in Europe that caused 35,000 deaths disproportionately affected the elderly and the sick (Stern 2007).

3.0. Prevention, Mitigation, and Adaptation

In general, the best way to prevent the aforementioned impacts of climate change is to dramatically and immediately reduce greenhouse gas emissions to the atmosphere in an attempt to slow global warming. Experts on climate change agree in general that this is the most critical and important step to take in the prevention and mitigation of climate change impacts. Economic projections indicate that this is the most cost effective means of protecting resources in the face of climate change.

Because the United States is the largest producer of greenhouse gasses in the Americas, a particular emphasis should be placed on identifying ways of reducing emissions in the US. Several factors that influence the amount of United States greenhouse gas emissions are government structure, population, economics and energy consumption.

1. *United States government structure:* The United States has a democratic republic structure that empowers local, state and federal oversight of natural resource use as well as enabling economic development and infrastructure needs for the population. The United States includes 9,192,000 square kilometers of land that is mostly owned privately (60%), with 28% owned by the federal government and managed by the national parks service, and the remaining 2 percent is held in trust by the Bureau of Indian affairs (Lubowski et al. 2006). The private sector leads the development and management of the natural resources while the government regulates the activities and provides educational support.

2. *Population growth*: The population determines the amount of energy consumption, housing density, transportation needs and land use patterns. The 2005 population statistics list the three most populous countries in the world as China, India and the United States with populations of 1.315 billion, 1.103 and 296.4 million persons respectively. United States population growth from 2000 to 2005 was 1 percent or 15 million persons with immigration representing 42 percent of the growth (US Doc/Census 2006). The warmer climate states of California, Arizona, Texas and Florida experienced the largest population increases from 2000 to 2005 (US Doc/Census 2006), growing from 72.7 million to 77.4 million people collectively. Energy consumption implications of this increase in population in the southern states is that less heating energy will be needed in the winter, and more energy will be used in the summer for cooling systems. Another trend in population distribution is the movement of persons form rural communities to relocate in suburbs associated with urban centers. This increase in suburban populations creates a larger suburban sprawl land use around urban centers. The transportation impact of expanding suburban populations is a longer commute and more heavy reliance on cars for transport.

3. *Economic structure:* The United States has the largest economy of all other nations with a GNP in 2005 of $11.1 trillion dollars in (constant 2000 dollars). Economic projections are for continued growth at a rate of 2.9 percent. The recent trend of decreasing revenue from manufacturing to an increase in service sector revenue (as a percent of GNP) has facilitated a decrease in the production of greenhouse gasses.

4. *Energy*: The consumption of energy for heating and cooling in the continental United States varies geographically and according to seasonal temperatures. The largest source of energy produced in the United States is coal, which when compared to other energy sources has the highest emissions of carbon dioxide per unit of energy. In 2005, coal provided about half of the energy used to generate electricity, however with increasing oil and natural gas prices there is a preference to use more coal for electricity, regardless of the higher emissions. Natural gas is the fossil fuel with the lowest emissions of carbon dioxide and represents the third largest energy source producer in the US.

Mitigation and adaptation of later impacts of climate change will be exponentially more costly than reducing emissions in order to prevent further changes. That being said, we are already seeing changes in many parameters such as temperature and precipitation patterns, and even with reduction in emissions these trends will continue. Climate models predict that even if we ceased greenhouse gas emissions, temperatures would continue to rise by 0.5 to 1 degree Celsius over the next several decades due to past emissions (Stern 2007). Because of this, it is necessary to consider mitigation and adaptation strategies in addition to immediate reduction in emissions.

3.1. Precipitation and fresh water availability:

In locations where decreased water availability is predicted, cities and regions should prepare to mitigate these impacts by encouraging residents to reduce water usage. This can include reducing water use for gardening, parks and commercial uses. One way to encourage water conservation is by introducing increased fees for use and imposing limits on residential and commercial water use. In dry regions, residents, city planners, and developers should be encouraged to landscape with native plants that use minimal water resources. Areas that are projected to have increased precipitation, snow melt, or significant weather activities should prepare for potential flooding by arranging evacuation plans and considering construction of levees and seawalls (See also agriculture section).

Examples of some adaptation strategies to address water scarcity include the building of storage reservoirs to supply water for agriculture and industrial consumption in Arizona and California, in the USA, and in the provinces of Alberta and Saskatchewan in Canada. However, the implementation of these strategies is costly because of the massive infrastructure required, and controversial because of their impacts on ecosystems and the people who depend on these ecosystems as a result of extensive flooding. Frederick and Schwarz (1999) calculated that the annualized water-related cost due to population increase in the United States will approach 14 billion dollars by the year 2030.

Costs associated with the construction and maintenance of flood control infrastructures will increase in regions where rainfall is expected to increase. Also, the intensification of surface runoff is likely to increase sediment build up in reservoirs with the consequent reduction of water storage for consumption or hydroelectric generation.

3.2. Water conflicts:

Some provinces in Canada in their attempts to manage water resources more sustainably and to reduce the potential for water conflicts, have began to implement water management strategies to address the needs of competing users. One example of these strategies is the Water Management Plan for the South Saskatchewan River Basin (WMPSSRB) developed by Alberta Environment. This Plan attempts to address water management issues consistent with Environment Canada's concerns raised in their report 2004 with regards to threats to the Canadian water supply and the impacts on the various water sectors. Taking into account the increasing scarcity of the local supply of water, the Plan intends to provide policy directions in order to minimize potential conflictive scenarios as a result of unresolved water issues with First Nation communities and the fulfillment of inter-provincial and international water agreements (Alberta Environment, 2006, p.5).

3.3. Aquatic ecosystems:

One way to mitigate the impacts of climate change on commercial fisheries is to reduce the already present overfishing pressure on many of these systems. A reduction in fishing intensity will enable fish and shellfish populations to better adapt to changes in their physical environment. A reduction in pollution of these ecosystems will also lend more flexibility for these populations to adapt. In general, our marine and freshwater resources, including coral reefs, need to be better protected and studied in order to minimize the impacts of global change. We should also be prepared for geographic shifts in economically important wild populations in the face of increasing temperatures, by carefully studying their distribution as a response to climate change.

3.4. Permafrost:

There is very little that can be done to mitigate the impact of permafrost melting. Adaptation plans should focus on relocating communities settled in the Arctic and subarctic regions of Alaska and Canada. North American governments should budget adequately for resettlement planning and implementation. Communities that are already planning for relocation such as Shishmaref, Alaska, should be carefully documented as case studies for future planning.

3.5.Forests and forestry:

The 2006 Stern report states that worldwide deforestation yearly contribution to global CO2 emissions is greater than transport sector's; thus reducing deforestation is an effective avenue for reducing CO2 emission and therefore large scale international programs to reduce deforestation should be implemented immediately.

The Canadian Forest Service's mitigation and adaptation plan include focusing research on the reduction of the uncertainty regarding future climate change impacts, testing adaptation and mitigation strategies and integrating biological/ecological social sciences (Canadian Forest Service).

3.6. Agriculture:

Given the heterogeneous nature of agriculture as a result of the variety of ecosystems in which agriculture is practiced and the crop types cultivated, the 2007 IPCC report on mitigation and adaptations states the mitigation measures will vary according to these two factors. In general, mitigation potential from agriculture includes soil carbon sequestration as a result of sustainable agricultural practices such as no-tillage and the use of agricultural residues for bioenergy purposes, although this will depend on the demand for this type of energy from sectors such as transportation (IPCC, 2007).

The Canadian Ministry of Agriculture and Agri-Food Canada (2001) recognize that environmental challenges in agriculture, including climate change, are the result of complex social, environmental and economic systems. Therefore, the Ministry addresses environmental challenges by committing to support sustainability principles and best practices in agriculture through programs, research and development, and educational campaigns that support the protection and enhancement of soils, water supplies and biodiversity. A statement by the Minister of Agriculture with regards to the issue of climate change illustrates the sustainability approach in agriculture: "adopting farming practices that reduce greenhouse gas emissions associated with climate change often improves other aspects of sustainable agriculture, such as biodiversity, energy efficiency, and water quality" (Agriculture and Agri-Food Canada, 2001, p. II)

3.7. Coastal sea level rise:

Current adaptation is uneven and readiness for increased exposure is low. Sea level rise and associated erosion and freshwater intrusion need to be anticipated. Some states have enacted policies to limit further development in areas expected to be impacted by sea level rise. Engineering-based options to mitigate the negative impacts of sea level rise include adding sand to beaches to minimize erosion and construction of seawalls and levies. Protection of natural barriers such as dunes and berms is essential to protect coastal communities against marine encroachment. Fresh water resources are also at risk to salt water intrusion, and management strategies need to be in place to deal with reduction of drinking water resources in coastal areas.

3.8. Vulnerable populations:

3.8.1: People living in poverty:
The development of strategies of adaptation to climate change impacts for vulnerable sectors of society requires an approach consistent with the concept of sustainability, whereby their assets (stores, resources, claims and access) and activities required for a means of living…[are maintained so that they can]…cope with and recover from stress and shocks, maintain or enhance [their] capabilities and assets, and provide sustainable livelihood opportunities for the next generation" (Chambers and Conway, 1991, p. 6).

Although poverty issues are not commonly associated with developed countries, there are significant numbers of people living under the poverty line (enough income to provide for housing, shelter and food) in the US and Canada, and therefore lack the adaptive capacity to cope and recover from socio-economic and environmental shocks including climate change impacts.

Governments at the local and national levels in Canada and the US need to decrease the number of families living under the poverty line by developing comprehensive programs that are aimed at increasing the levels of social assistance for poor families, increasing the levels of training and capacity development and job creation. Additional strategies include developing policies that improve access to healthcare, transportation, and information. Adaptation strategies should include evacuation planning with a special focus on those who lack private vehicles and improving the housing infrastructure for low-income citizens. Because low-income individuals are more likely to live on environmentally marginal lands that will be affected by storms, flooding, and drought, regional planners should consider ways to create mixed-income housing and should develop infrastructure to protect at-risk areas.

3.8.2: Indigenous Peoples:
Indigenous peoples should be party to efforts to determine policy solutions to climate change and their concerns and recommendations should be incorporated into planning efforts. There are many groups that exist within international bodies that focus on indigenous issues that might serve as resources on climate change, including: the Inuit Circumpolar Conference (ICC), The Working Group on Indigenous Populations under the Subcomission of Prevention of Discrimination and the Protection of Minorities of the UN; The Working Group on Indigenous Populations under the Subcommission of

Prevention of Discrimination and the Protection of Minorities of the UN; The Working Group on the Draft Declaration of Indigenous Peoples of the Commission on Human Rights of the UN; The Working Group on Article 8 (j) and Connex Articles of the Convention on Biological Diversity which includes, among other issues, systems of traditional knowledge; the recognition of traditional knowledge systems in the Intergovernmental Dialogue on Forests (including the Panel, Intergovernmental Forum and the United Nations Forum on Forests); and The Permanent Forum on Indigenous Affairs of ECOSOC in the United Nations.

3.9. Human health:

The World Health Organization has noted that the impact of climate change on public health will depend not only on environmental changes but also on the ability of the health care system to adequately respond to greater incidences of disease or injury. More research is needed to understand how social and natural systems will interact in North America to create regional and local differences in human health impacts.

In the United States, unless the health care system is restructured to provide better care for those who are uninsured or underinsured, this may mean that the health impact of global warming will be disproportionately born by those living in poverty, including people of color and indigenous communities. As such, adaptation efforts should focus on providing equitable access to health care.

Summary of Potential Impacts and Mitigation and Adaptation Strategies:

Potential impact	**Projected effects**	**Mitigation/adaptation strategy**
Changes in availability of fresh water/precipitation patters	1. Increasing precipitation in northern regions 2. Decreasing rainfall in arid regions 3. Transition to larger and more frequent tropical storms	1. Flood control infrastructure, preparation for increased sedimentation in reservoirs 2. Construction of freshwater reservoirs, implementation of water conservation plans
Water conflicts	1. Decreasing water availability in dry areas will lead to increased conflicts among states, nations and ethnic groups	1. Sustainable management and development of water resources
Aquatic ecosystems	1. Decline in fisheries 2. Coral reef decline 3. Harmful algal blooms	1. Reduce existing cultural pressures of aquatic resources (e.g., overfishing, pollution, eutrophication 2. Aquaculture to replace wild catch
Permafrost melting/reduced snowpack	1. Changes in arctic ecosystem function 2. Unstable ground for human infrastructure	1. Relocation of prone Arctic communities 2. Development of alternative freshwater resources

	3. Lack of reliable water source in spring	
Vulnerable populations	1. Low-income populations will be disadvantaged in terms of adaptation to climate change 2. Indigenous peoples will lose natural resources and opportunities	1. Decreasing the number of people living in poverty 2. Planning for management of disadvantaged peoples in face of natural disasters 3. Indigenous input needed on policy and management strategies
Forest ecosystems	1. Initial increase in forest productivity followed by later decline 2. Increased disturbance due to fires and insects	1. Reducing deforestation helps forest ecosystems and leads to sequestration of CO2. 2. Further research on effects of climate change on forests
Human health	1. Extreme weather events 2. Tropical diseases 3. Unhealthy people at greater risk	1. Increase capacity of health care system to respond to increased demand due to climate change 2. Adaptation of systems to better serve disadvantaged populations.
Agriculture	1. Yield increases in areas expected to see increasing rainfall 2. Many crops may decline due to temperature increases 3. Many areas will face increasing water shortages	1. Changing practices to increase soil C sequestration. 2. Sustainable farming to support future concomitant climate change and population increase
Coastal communities	1. Sea level rise 2. Vulnerability to increased hurricane activity 3 Freshwater intrusion	1. Limit further development in coastal areas 2. Engineering options such as seawall construction or adding sand to beaches 3. Protection of natural barriers (reefs, dunes, berms)

4.0. Policy Recommendations for North America

4.1. Use Energy More Wisely and Develop Alternative Energy:

Energy conservation is the most cost efficient method of reducing North American energy usage. A variety of governmental programs and incentives for industrial and consumer energy reduction are effective ways to reduce consumption. For example, credits for energy efficient products, consumer education programs, and energy reduction mandates all have proven track records of reducing consumption. However, the United

States government continues to be the largest consumer of energy in the United States. The US government has made an effort to reduce emissions, but has met with limited success. Executive Order 13123 signed by President Bill Clinton established goals for the Federal government sector that went beyond requirements from the National Energy Conservation Act. From 1990 to 2004 the government has reduced emissions by 19.4% with a goal of reducing emissions by 30% by 2010.

Fossil fuel burning contributes to the inventory of greenhouse gases in the atmosphere by burning of carbon that had previously been removed from the global carbon cycle for millennia. By using sources of energy that do not rely on deposits of old carbon, we can reduce the input of greenhouse gases to the atmosphere. Examples of alternative energy sources that may contribute to a reduction in emissions if they are used to replace fossil fuels include nuclear, hydroelectric, geothermal, biofuels, wind, wave, solar, and hydrogen power. The United States and Canada have the technical capability to fully develop these sources of energy and help distribute them to other countries.

We can also learn to use our existing fossil fuel infrastructure more efficiently which will help reduce North American greenhouse gas emissions. On a per capita basis, the United States and Canada use far more fossil fuels than other Latin American and Southern American countries. The use of fossil fuels, however, is vital to both the North American and the world economy and will continue to be an important part of the economy for years to come.

Given this context, we must immediately begin a two-pronged approach: First, we must begin investing time, thought, and research into fossil fuel carbon sequestration and reduction methods. Examples of this include: carbon trading programs specific to the United States and Canada, new technologies to minimize carbon emissions, and industrial incentives for energy companies to invest in these new technologies.

While the United States did not ratify the Kyoto Protocol, emissions trading programs such as the regional northeastern sulfur trading program have been successful in recent history. We recommend that the United States combine the strong points from four commonly referenced carbon trading options (the Kyoto Protocol, the Bush Administration Climate Initiative, the Bingaman Climate and Economy Insurance Act of 2005, and the McCain-Lieberman Climate Stewardship and Innovation Act of 2005) into a national (not international) policy so that the funds stay within the U.S. economy. This recommended policy would use the numbers from the Kyoto Protocol toreduce raw emissions to 5% below 1990 values, which would be approximately a 7% reduction from current (2006) U.S. emissions. Like the Bingaman policy, this proposal would have a gradual increase in strictness, allowing time for companies to slowly change their technology, yet still rapid enough to provide immediate incentives for change. Under this recommended plan, in 2008 the U.S. as a whole would have to reduce emissions by 0.5% of the 2006 value and continue to reduce by 0.5% of the 2006 value each year from 2009-2011. From then on emissions would be reduced to 1% of the 2006 value for years 2012-2016 for a total reduction of 7% from 2006 levels by 2016. Each year, a committee would re-evaluate the act to see if emissions standards should be stricter due to unexpected breakthroughs in technology. After 2016, the committee would set forth a new goal to reach and start implementing carbon sequestration technologies into the policy. Penalties for non-compliance will be funneled directly to the National Renewable Energy Laboratories (NREL) to be put directly towards research, development, and implementation of low greenhouse gas emitting technologies.

Dependence on any one method of energy production is unrealistic, and energy diversification is vital for the continued development of North American economies. Funding for North American research and development programs related to alternative energy is superficial, hypocritical, and subject to political lobbying. For example, several weeks after President Bush announced his support of research and development of renewable energy in his 2006 State of the Union address, the National Renewable Energy Lab (NREL) laid off 32 people due to a $28 million budget shortfall.

Given the immediate need for alternative energy development, knowledge transfer of existing alternative energies must be considered. For example, Denmark excels at localized wind energy production, France is a leader in nuclear fuel reprocessing and nuclear reactor design, and Scotland and Portugal are experienced in wave energy production. Rather than reinventing proven technologies, we could most efficiently use limited funding by adapting and improving existing alternative energy technologies from other countries. Research should additionally be directed at reducing impacts of new energy sources on other nations and peoples. We recommend following principles of environmental justice that state that the impacts of expanding and developing technologies should not be displaced onto communities living in poverty, developing nations, orpeople of color (NPCELS 1991).

4.2. Improving Transportation

Transportation is and will continue to be absolutely vital to the North American economy; energy consumption within this sector has been growing at approximately 2% per year for the last several years. The transportation sector consumes 28% of total energy consumed in the US and emits 33% of the greenhouse gases in the country. The largest component of the transportation sector (68%) is attributed to cars and light duty vehicles (U.S. DOE/EIA 2006e).

4.2.1. Passenger Vehicles. Research shows that consumers often choose to drive vehicles that have low fuel efficiency. The number of SUVs and vans on the road has increased by 31% from 1997 to 2004 and represents 31% of all the energy consumed in the transportation sector. Consumers often choose these types of vehicles on the basis of safety and capacity rather than energy efficiency. Therefore, a targeted effort to make these vehicles more energy efficient would have a major impact on North American transportation energy consumption. Another important strategy is to invest in the safety of smaller, less polluting vehicles and to educate the public about the relative safety, efficiency and cost-effectiveness of these vehicles in order to shift consumer trends towards purchase of smaller cars.

California and eleven other states have made efforts to reduce carbon emissions from the transportation sector, yet these efforts have met resistance at the federal level. A concerted effort by the federal government to improve vehicle efficiency for all vehicles through mileage standards, incentives for consumer purchase, and industry production of these vehicles is needed. Higher mileage standards will also help U.S. auto makers remain competitive in a global marketplace. In addition, commercial, construction and shipping vehicles must be subject to higher mileage standards. Technologies to improve fuel efficiency already exist, and as such we have a moral obligation to utilize them to increase fuel efficiency of vehicles.

4.2.2. Airline travel. The airline industry is an important part of the North American transportation sector. While airline passenger traffic saw a drop following the attacks of September 11, 2001, traffic has now rebounded and the industry continues to grow. Air travel now represents 7% of the energy consumed in the transportation sector. It is recommended that a carbon emissions tax be instituted on an energy used per passenger kilometer basis for airlines. This tax would be passed on to consumers and would be used for two initiatives. First, the carbon tax would be used to partially offset greenhouse gas emissions produced by aircraft. Second, this tax would be used by the airline industry directly to improve aircraft efficiency.

4.2.3. Train travel. Carbon efficient transportation options must be improved within North America for the transportation sector to significantly reduce greenhouse gas emissions. For longer distances, rail is one form of transportation that has the potential to be both carbon and cost efficient. Long distance rail travel is two to three times more fuel-efficient than long distance air travel. Unfortunately, because North American countries have not invested adequately in rail infrastructure it is often more expensive and less convenient to travel by rail as opposed to air. Europe has many well-utilized high speed rail systems that make travel cheap and fast. For example, France's high speed TGV trains have reached speeds of 357 miles per hour, while the fastest train in the United States has only reached speeds of 150 miles per hour. There is no reason that the same level of service could not be implemented in North America.

4.2.4. Bus travel. At the regional level, investing in improved bus service is crucial. The current major United States bus provider has a monopoly on bus service and as a result service has suffered. Regional service is known for frequent delays, poor quality of bus infrastructure (broken seats and lights), and prices that can at times approach the cost of renting a car. Bus terminals are often in poor condition and located in unsafe areas of cities. Federal help allowing for the introduction of competitors to regional bus service would allow for market forces to improve bus service. For example, the competitiveness of the Chinatown Express service between major northeastern U.S. cities has resulted in more frequent service, lower costs, and more passengers traveling by bus between these cities.

4.2.5. Other local transportation options. Fossil fuel dependency needs to be reduced at the local level. Many of these types of changes will need to be done at the local governmental level, although federal incentives should provide direction. In the United

States, federal and state transportation dollars are often available to municipalities for automotive related road improvements. These dollars could easily be tied to making roads more pedestrian and bicycle friendly. For example, municipalities could be required to add bicycle lanes when accepting federal or state money. Improving sidewalks, crosswalks, and adding greenway space are additional ways for municipalities to improve bicycle and pedestrian transportation. Professional societies, engineers, and transportation designers should be encouraged to incorporate these design recommendations into their baseline plans.

At the local level, fossil fuel dependency can also be reduced by encouraging mass transportation options. Denver, Colorado, is a leader in the United States in mass transportation. Many private and governmental employers in the Denver area issue bus and train passes to employees as a means of encouraging public transportation and decreasing the employer's cost. For example, the recently constructed NOAA David Skaggs Research Center in Boulder, Colorado, was able to minimize parking lot construction costs by issuing transportation passes to employees. This has the added benefit of encouraging mass transportation across all socioeconomic classes.

Green Design: Planning for Growth and Development

Suburban sprawl results in increased carbon emissions through increased transportation needs and less efficient housing. Suburban sprawl can be combated by encouraging methods to increase population density and mixed use development. For example, zoning regulations encouraging redevelopment of cities is be one way to minimize sprawl. Portland, Oregon, in the United States has been a leader in introducing urban growth boundaries to increase density within the city limits. These types of regulations result in decreased infrastructure needs of outlying suburbs, decreased carbon emissions associated with transportation needs, and preservation of open space in outlying areas.

Communities desiring to use federal, state, or provincial money to redevelop should be required to incorporate smart growth principles into development plans. Smart growth principles are outlined below:

Smart Growth Principles
• Create a Range of Housing Opportunities and Choices • Create Walkable Neighborhoods • Encourage Community and Stakeholder Collaboration • Foster Distinctive & Attractive Communities with a Strong Sense of Place • Make Development Decisions Predictable, Fair and Cost Effective • Mix Land Uses • Preserve Open Space, Farmland, Natural Beauty and Critical Environmental Areas • Provide a Variety of Transportation Choices • • Strengthen and Direct Development toward Existing Communities

At an individual building level, programs such as the Leadership and Energy in Environmental Design (LEED) rating system should be incorporated and encouraged in all new growth. These types of programs encourage the design, construction, and operation of high performance green buildings and rate building water savings, energy efficiency, material selection, indoor environmental quality, and sustainable site development (Pew 2006). Any building that is built with taxpayer money should be required to meet minimum environmental standards. In addition to minimizing fossil fuel emissions, other benefits of this approach include promoting green building practices of developers, helping promote research into more environmentally sound building methods, and reducing long term building operating costs. The table below shows estimated financial savings of green building design:

Category	**20- year Net Present Value**
Energy Savings	$5.80
Emission Savings	$1.20
Water Savings	$0.50
Operations and Maintenance Savings	$8.50
Productivity and Health Benefits	$36.90 to $55.30
Total savings	**$52.90 to $71.30**

Summary of the financial savings of green buildings (per ft^2). Kats et al. (2003) compared 33 green buildings from across the United States of America to conventional designs for the same buildings. The 2% increase in initial additional costs associated with building green were found to be recuperated in energy savings alone within the first 20 years.

4.3. Improving Climate Change Education

Actions to mitigate and adapt to climate change by North Americans have not been proportional with the actual threat posed by climate change. Improved education on climate change plays a vital role in closing this gap. Many of these recommendations have been adapted from the proceedings of the 2005 Yale School of Forestry and Environmental Studies conference entitled “Americans and Climate Change” (Abbasi 2005).

One major reason for a lack of action by North Americans is that there has not been a unified attempt on the part of organizations and agencies to provide cohesive leadership on climate change prevention, mitigation, and adaptation. Instead, there are a multitude of governmental organizations, non-governmental organizations, political lobbying groups, and individuals each with varying messages.

We recommend that North American governments take an active role in climate change leadership and begin an educational campaign akin to the U.S. government “just say no” and “this is your brain on drugs” anti-drug campaigns. To date, the official message from the United States government has been mixed and confusing, ranging from doom and gloomscenarios to outright denial. The message and position of climate education must be simple, clear, consistent, and understandable. While the complexity and severity of the climate situation needs to be emphasized, individuals need to know both what they can and should do and what these actions or lack of actions will accomplish. Slogans similar to those adopted by the anti-drug campaign might be employed. The campaign must be well financed and include input from a wide variety of community members, ranging from commercial representatives, public interest groups, and private citizens. It would be reasonable to integrate the campaign with the Canadian and U.S. Earth Day on April 22 as there is already environmental momentum associated with this day.

Climate Change Campaign Slogan Ideas
In the ocean of life we can all make a difference. Saving energy isn't the only thing, it's everything. Go the earth friendly way and save a gallon a day. Sea level matters. Sea level is life.

A second reason for lack of public awareness and action in response to climate change is that there is a significant disconnect between the public and the scientific community. While there is a vast body of scientific and social science literature and policy papers about climate change in North America, the science of climate change is often communicated to the public inadequately. Scientists are often used as the messenger with poor results: Scientists retain scientific terminology in communicating and are unable to clearly explain the uncertainty and complexity of scientific problems in a language that everyone can understand. The net result is a confused public. Therefore, there is a need to engage credible non-scientists to publicly discuss climate change. We recommend that the governmental education campaign should also include an effort to organize conferences and workshops to educate journalists and science writers about climate change as a way to foster better communication to the public.

One method to raise awareness of climate change in the public eye is to link climate change with pressing North American problems such as energy policy. Energy policy has many facets that correlate well with actions needed to combat climate change. For example, in recent years energy security has generated significant national interest Methods to improve North American energy security will have positive benefits from a climate change mitigation perspective. Specifically, developing and improving domestic alternative energy sources will improve energy security as well as providing additional positive benefits such as job creationto and reduction of regional air pollution. All of these positive benefits should be highlighted.

Additionally, an educational campaign should specifically target K-12 education. Climate change information should be offered as part of a standardized science curriculum and integrated into testing. Curriculum materials should be developed with K-12 teachers in mind; much of the currently available information is not written with that target audience and is beyond the scope of what a K-12 teacher requires.

Finally, there is a disconnect between science and ethical values in North America. There are many significant ethical issues associated with climate change impacts such as the disproportionate impact on people living in poverty, species extinction, and increased disease. One way to help connect scientific understanding of these problems to ethics is through religious organizations. For example, in the United States, evangelical Christians have a strong belief in earth stewardship. This type of perspective should be encouraged and those knowledgeable on climate change issues should engage religious leaders and organizations. The influence of these leaders may also help to overcome initial resistance to a wide-spread education campaign on the part of those who remain skeptical about the anthropogenic basis of climate change.

4.4. Water Planning

With changing precipitation patterns and increasing temperature, water resources will diminish in many North American regions, particularly in the southwestern United States. This will affect both individual consumers and agriculture.
Although Canada possesses 20% of the earth's fresh water, the average daily personal water usage for Americans and Canadians is 100 gallons per day. Additionally, approximately 14 percent of municipal water is lost through leaks. Thus, improved conservation efforts are absolutely necessary to manage and ensure adequate resources for future generations.

Several governmental programs and incentives can be utilized to promote water conservation. For instance, one approach is to require the installation of water meters in all well water fed residential, commercial, and government buildings. Buildings that presently rely on well water may not be metered for water consumption. As resources become depleted, well water users should form groundwater management zones to collectively manage their resources. The transition into management zones could be eased by requiring installation of water meters now.

Many water districts across the United States and Canada employ a tiered block rate system, and this method should be utilized by all districts. In this type of system, water rates increase with usage thus encouraging water conservation by the end user. The additional funds gained through tiered rate programs can be used to upgrade and improve existing water distribution systems. Another financially-based approach that should be considered in order to make the best use of water resources is to set water rates according to local water availability. This approach would also be useful as a measure to encourage water intensive businesses to locate in water rich areas.

Water used for agricultural practices in the United States is highly subsidized by the federal government. The Bureau of Reclamation has issued long-term irrigation contracts, some of them for next 25 to 50 years, which are being used to expand the agriculture frontier in water stressed states such as Arizona and California. In the case of Arizona, estimates indicate that approximately 70 percent of water is used for agricultural purposes. We suggest that water conservation in this sector can be funded and implemented as subsidies tied to the most efficient irrigation technologies currently available.

Landscaping residences and cities with native plants, shrubs and trees can have social, economic and environmental benefits. Planting native trees around a home can reduce energy use by keeping the home cool during the summer and provide wind protection in the winter (greenopolis.ca). Native plants also reduce water use because they are more drought-tolerant. In some cities in Canada there are incentives and programs that support the use of native plants for residential landscaping. In Toronto, the Urban Forestry Services plants trees on city owned street allowances fronting residential properties for free and a local non-profit offers subsidized backyard tree planting (City of Toronto). In the city of Ottawa, the Tree, Reforestation and Environmental Enhancement (TREE) Program aims to enhance the urban and rural forests by planting of 100,000 trees between 2007 and 2010. In the United States, the Florida and Texas both require “Xeriscape” landscaping on new construction projects on state property, a method that incorporates specific principles for water saving (www.xeriscape.org). Given that these programs show successful social, economic and environmental benefits, other cities in North America should follow this practice.

Water resources extend beyond state, provincial, and national boundaries, and therefore discussion of these resources must become a top priority. As resources become increasingly strained, water rights and water quality have the potential to ignite both local and international conflict. We recommend implementing a suite of agreements, laws, and incentives to ensure sustainable water resources and to help minimize conflict.

4.5. Planning for Resettlement

Mitigation of climate change impacts is important to ease humanity’s transition into a warmer world but adaptation also must be considered. In some cases, adaptation will involve resettlement as coastal lands erode, permafrost melts, and arid regions face increasing dryness. This is not a futuristic “what if” scenario;several villages in Alaska are currently facing this reality. For example, the village of Shishmaref ispart of a barrier island chain that has had severe erosion causing damage to both commercial and residential properties. In 2006, residents voted to abandon the island – which has been inhabited for 400 years -- and relocate their village. Moving costs have been estimated at $180 million (Revkin 2007).

The Native Alaskan village of Newtok is currently planning a move due to melting permafrost and erosion. While the Army Corps of Engineers estimates that the move will cost $130 million (or $413,000 per resident), village leaders believe the move will cost much less. Because there is no formal process or federal agency charged with dealing with applications for resettlement funding due to climate change, for the time being the town has been working to find funding in a piecemeal fashion (Yardley 2007).

States should develop detailed resettlement plans for towns predicted to be affected by climate change, particularly those in coastal areas, areas that will be affected by permafrost melt, and areas that will be severely stressed by lack of water resources. While some towns may able to relocate their citizens on an ad hoc basis to larger urban areas, for others such as indigenous communities, resettlement as a whole community is important to cultural identity and survival. Decision-making about resettlement should be made by local communities as part of broader, coordinated state-led efforts to develop comprehensive planning for climate change adaptation.

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PART IV. MESOAMERICA AND THE CARIBBEAN

1. CURRENT AND FUTURE CLIMATE

Figure 1: The Mesoamerican region includes eight countries; Belize, Costa Rica, Guatemala, El Salvador, Honduras, Mexico, Nicaragua and Panama.

The Caribbean region includes 24 countries and dependencies: Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, British Virgin Islands, Cayman Islands, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Montserrat, Netherlands Antilles, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, Turks and Caicos Islands, and United States Virgin Islands.

1. SOCIAL SYSTEM

1.1. Total Population

Approximately 190 million people live in the Mesoamerica and Caribbean Region. About 56% of these live in Mexico and about 22% live in the Caribbean (Fig. 2).

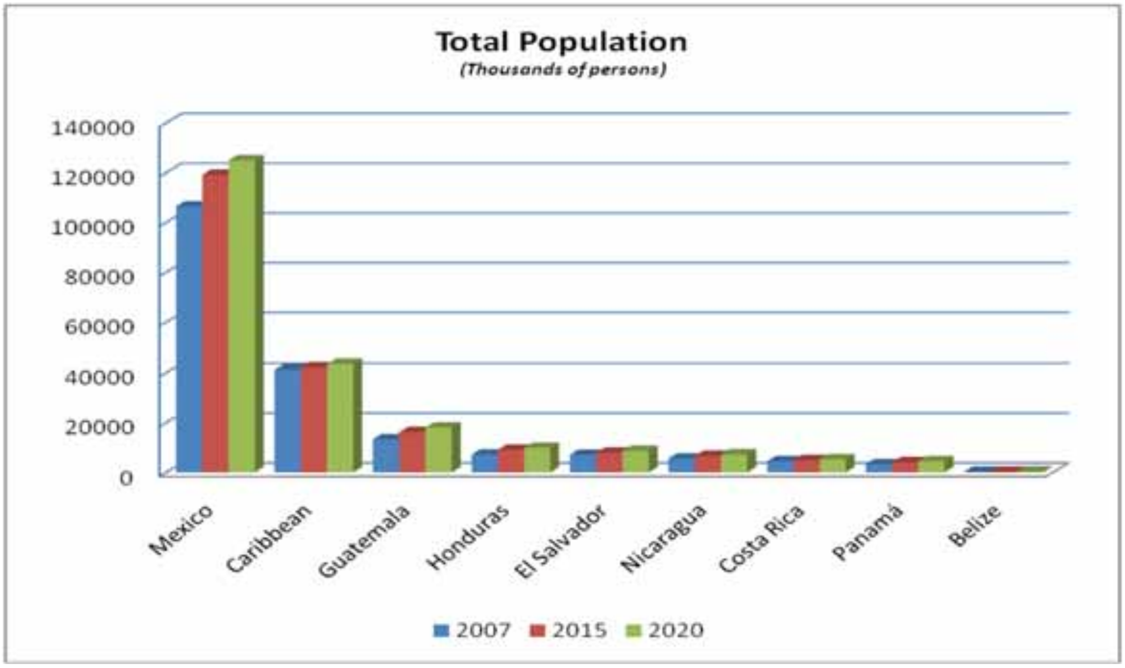


Figure 2. Total Population in Mesoamerican and the Caribbean (UNPOP, 2006)
(*NOTE: This figure corresponds to a projection, which involves the use of an average fertility hypothesis*)

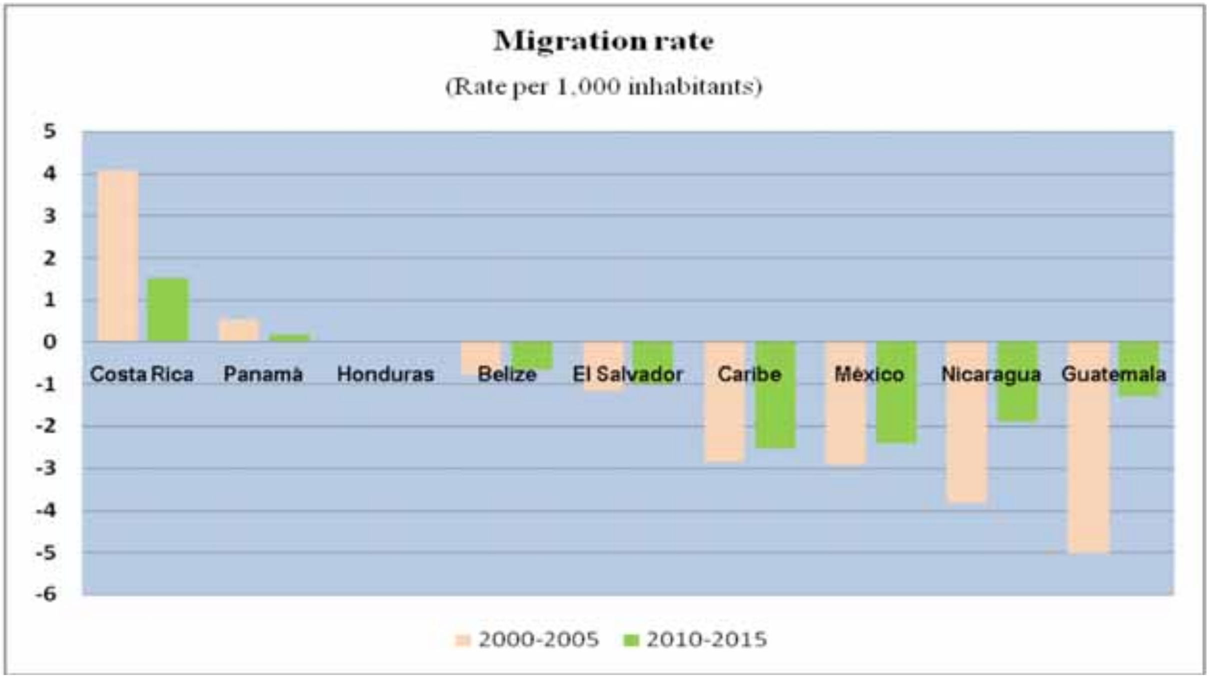
In 2005, urban areas (defined as communities of 1000 or more people) made up 58% of region's total population. Mexico City, the region's largest city, comprised 10.6% of all urban population. In 2020, the fraction of people in Mesoamerica and the Caribbean living in cities is projected to increase to 66.5%, higher than any other region in the world.

There are 148 indigenous groups in Mesoamerica, 62 of them in Mexico and 29 in the Caribbean (UNPOP, 2006).

1.2. Migration

Migration rates are found by subtracting immigration from emigration. The balance is positive when immigration is higher than emigration and negative when the emigration surpasses immigration. The countries receiving population in the region are Costa Rica and Panama. In the period 2000-2005, Costa Rica showed an increase in population due to immigration of 4.07 people per 1000. Caribbean, Mexico, Nicaragua and Guatemala are the main countries with a negative balance of migration (Fig. 3).

Figure 3. Mesoamerica and Caribbean migration rate (UNPOP, 2006)



The statistics that exist in the Caribbean are in general less accurate, since they gather only part of the actual emigration statistics.

1.3. Education and Health

We use two statistical indicators from CEPAL to measure education and health in Mesoamerica: adult literacy rate and infant mortality rate (UNPOP, 2006). We could not include statistics from the Caribbean because data is not available from all countries, only from less than half of the countries in the Caribbean region.

Nicaragua and Guatemala have the highest percentage of illiteracy in the region, with more than 25% of people older than 15 that cannot read. Mexico, Panama, Belize and Costa Rica have lower rates of illiteracy, near 10%, whereas Costa Rica has the lowest. CEPAL predicts that illiteracy will diminish in all countries of Mesoamerica by 2015. In relation to Global climate change education programs, there are not formal educational programmes as a part of the curricula in any of the national education systems.

Guatemala and Honduras have the highest infant mortality rate (higher than 40 per 1000 births), whereas Costa Rica are the country with less children mortality which is less than

15 per 1000. Water related morbidity in the Central American isthmus is very high. The rates per 100,000 inhabitants are 0.4 to 18.8 for typhoid fever; 0.7 to 13 for paratyphoid fever; 0.5 to 786.2 for bacillary dysentery; and 17.9 to 555.6 for amebiasis. Several international health organizations have warned about the increasing prevalence of tropical illness in Mesoamerica because of global warming. The World Health Organization predicts that increasing temperature will produce a rise of tropical illness due to enhanced parasite survival and reproduction in subtropical latitudes.

While Cuba and the Dominican Republic have the best education and health indicators in the Caribbean, there is a huge inequity between countries because of different policies among the 24 countries. There is also a large variation at the sub-national scale, with indigenous people suffering the worst economical, educational and heath conditions.

1.4. Economy

Most of Mesoamerican economies have begun the millennium with good results. In 2005, GNP per capita increased in all countries except in Haiti, where was constant. Dominican Republic had the highest rate of growth (UNPOP, 2006).

In Mesoamerica and the Caribbean, Mexico has the highest income per capita, followed by the Caribbean region (consolidated) and Costa Rica, the country with the lowest poverty rate in Mesoamerica at less than 10%. Nicaragua and Honduras are the poorest countries in this region, with poverty rates higher than 60%.

The most recent data available for the Mesoamerican - Caribbean countries (for 2007) show that 34% of the region's population are living in poverty and 13% of the population was extremely poor, or indigent.

Between 2000/2002 and 2003/2005, Mexico also saw significant decreases in poverty levels, in the first case of 1.6%. The percentage of indigents declined appreciably in these countries, as well as Costa Rica, El Salvador and Panama. At the other extreme, the Dominican Republic is the only country where both poverty and indigence rates worsened between 2002 and 2005.

According to UNESCO, the Caribbean has the most unequal economic distribution in the world. Haiti is the country with highest fraction of poor and homeless. However, there is a general trend toward the reduction of poverty rates in Mesoamerica, especially in rural areas.

1.4.1. Economic sectors

Growth patterns differ in relation to both the origin and the allocation of the exceptionally large volume of resources that are currently flowing into the region (owing to increased remittances and improved terms of trade) and opening up a gap between GDP and income growth rates.

In Central America and some of the Caribbean countries, the faster growth in income is being driven by remittances from emigrant workers and is being received by the private sector. From the standpoint of income distribution, these resources are going mostly to households, particularly those with relatively lower incomes (i.e., the population segment whose consumption level is the most dependent on current income). This being the case, national saving may be expected to be lower, with consumption acting as the engine of demand.

In the Caribbean, the most important economic sector is tourism (wholesale and retail trade, restaurants and hotels (PIB 2005 5,754.2 dollars), followed by construction (mining and quarrying) and the less important economic sector is Energy, gas and water (PIB 2005 971.8 dollars).

Although industry and transport are not the primary economic sectors in this region, and its CO_2 emissions as a whole represent less than 10% of world emissions, there are several countries with important CO_2 emissions per capita. In 2000, Mesoamerica emitted 400 million tones of CO_2 whereas emissions of the Caribbean were below 100 million tones. In the same year, Mexico was the country with major CO_2 emissions: 100 millions tones of carbon mainly due to fossil fuel combustion rather than land use change (UNEP 2003).

Agriculture and Forestry

The overall use of arable land for agriculture in the region over the last 40 years has increased by about 15%. Since 1961, Costa Rica has doubled its use of land for agriculture, and Belize and Cuba have also increased nearly as much. From the available data, the use of land for agriculture in Granada and Saint Kitts and Nevis has been reduced by more than 30% since 1961.

Forest coverage differs among the countries in this region. Barbados and Haiti have less than 5% of their territory covered by forests, whereas Belize, Dominica and Panama are more than 60% forested.

The Mesoamerican forest area was reduced from 82.7 million hectares (ha) in 1990 to 73 million ha in 2000 (almost 971 000 ha of forests annually), with a deforestation rate of 1.25 per cent annually — the highest in the region, and almost six times the global rate (FAO, 2000). The biggest losses were in Mexico (6.3 million ha) and Nicaragua (1.2 million ha); Belize, Nicaragua and El Salvador suffered the greatest relative losses of, respectively, about 20.9 and 37.3 per cent of the 1990 forest cover (UNEP, 2003).

Fisheries

Mexico and Cuba have the largest fishing fleets of the region, with captures of 1,400,000 t and 50, 830 t for 1995 respectively. In the case of Mexico this industry generates approximately 250,000 direct jobs, with a total gross export income on the order of 800 million dollars.

2. NATURAL SYSTEMS

2.1. Precipitation and Temperature

Global climate change impacts on annual average precipitation and temperature in Mesoamerica are assessed in this section. Data from 17 global circulation models run under different green-house gases induced Global climate change scenarios is used to derive estimates of precipitation and temperature change in 5°x5° cells on the earth surface for years from 2000 to 2100. The data has been obtained from the *Model for the Assessment of Greenhouse gas Induced Climate Change* (MAGICC 4.1) and SCENGEN software applications (Wigley, 2004; Hume et al., 2000). All models except the W&M are from the *Coupled Model Intercomparison Project 2* (CMIP2) database. For more information regarding the GCMs see Covey et al. (2003). The average projection of the models has been analyzed for four representative scenarios: A1-MES, A2-MES, B1-MES and B2-MES, defined by the Intergovernmental Panel on Climate Change. Results from scenarios A1 and A2 are presented following (Fig. 4-11):

Scenario A1-MES:

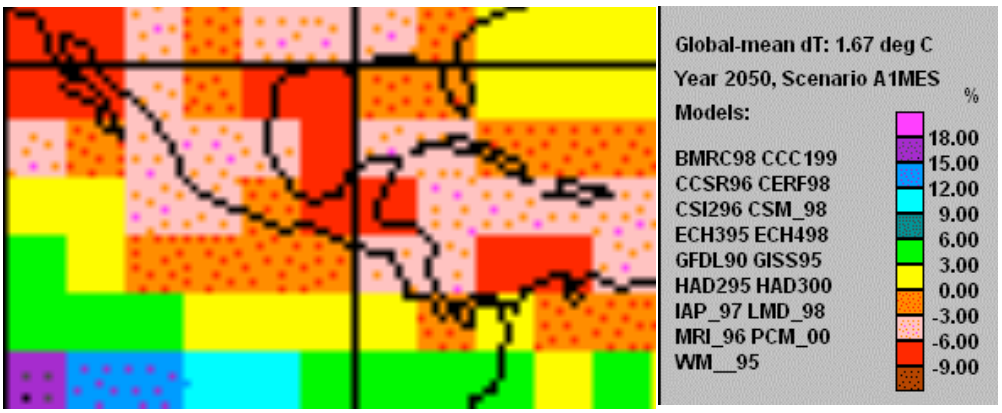


Figure 4. Rain projections for 2050 according to scenario A1-MES

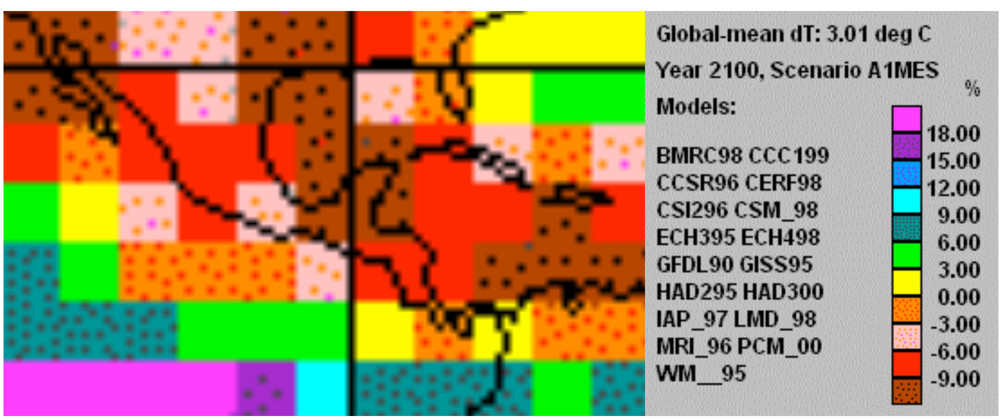


Figure 5. Rain projections for 2100 according to scenario A1-MES

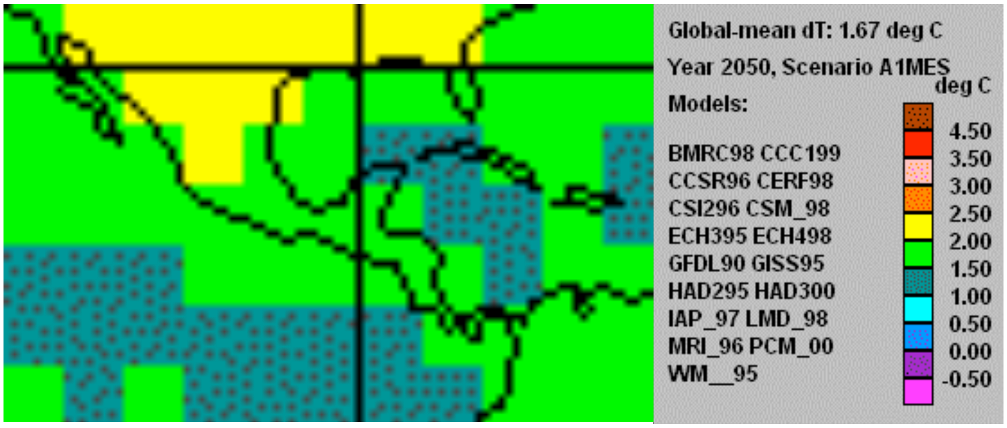


Figure 6. Temperature projections for 2050 according to scenario A1-MES

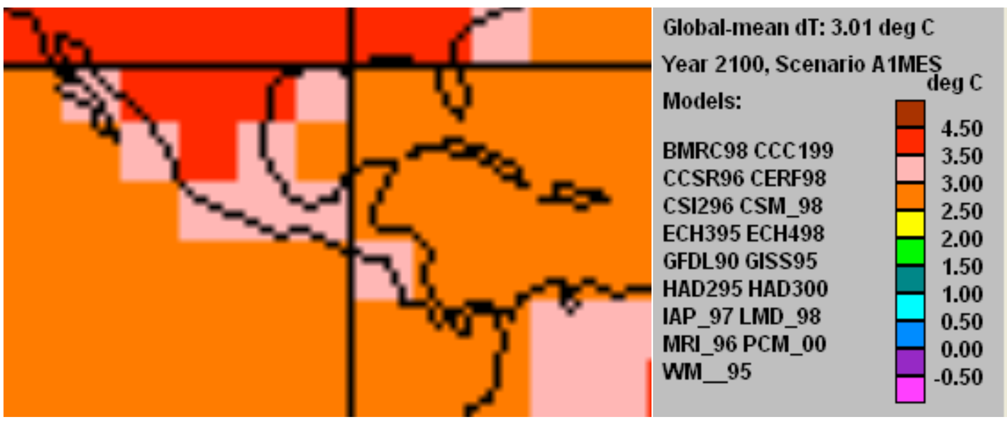


Figure 7. Temperature projections for 2100 according to scenario A1-MES

Scenario A2-MES:

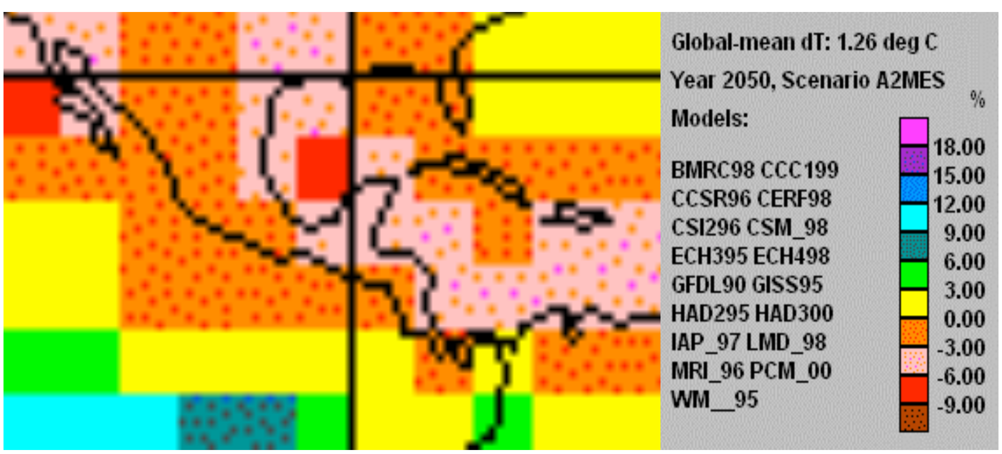


Figure 8. Rain projections for 2050 according to scenario A2-MES

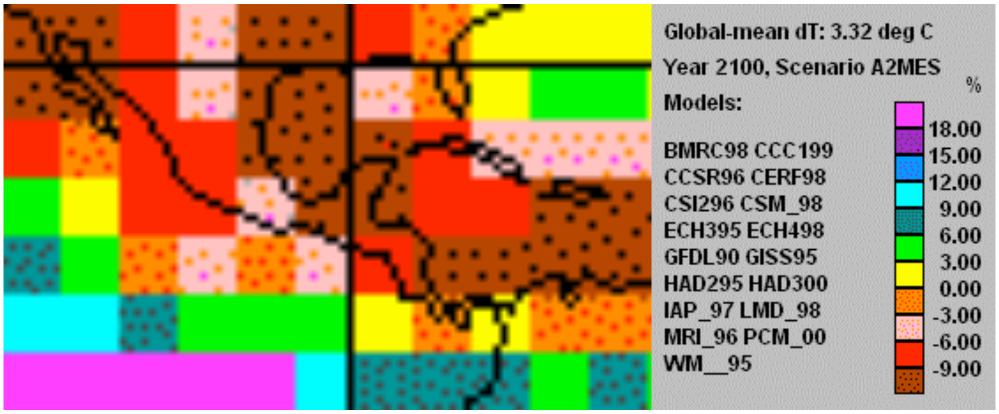


Figure 9. Rain projections for 2100 according to scenario A2-MES

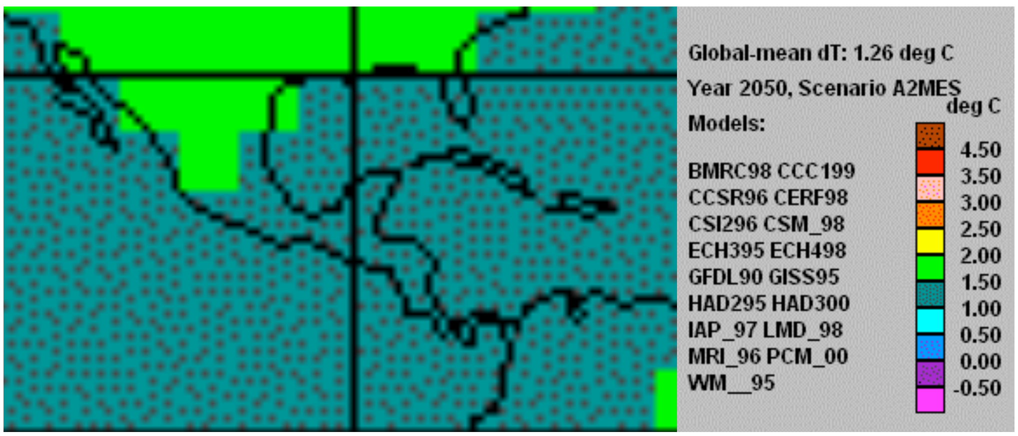


Figure 10. Temperature projections for 2050 according to scenario A2-MES

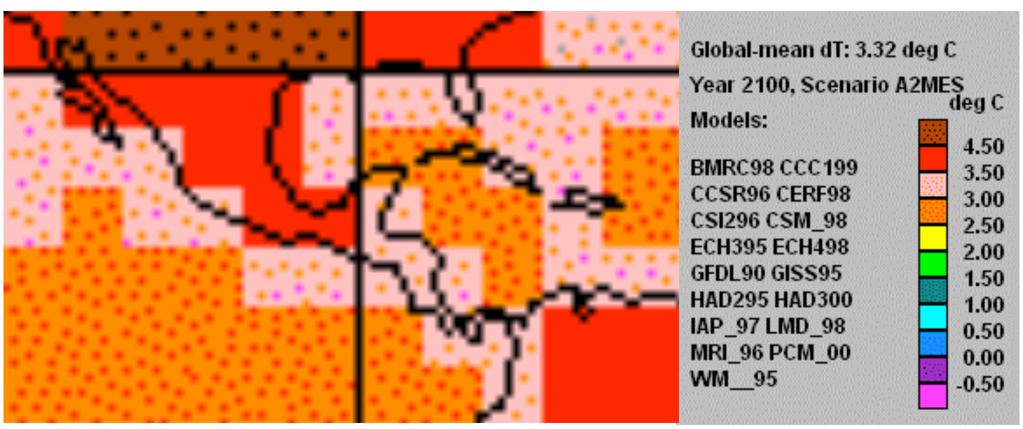


Figure 11. Temperature projections for 2100 according to scenario A2-MES

As can be seen in the projections above, annual average precipitation in Mesoamerica is expected to decrease over the next 100 years. The region will get drier especially in the already dry months (IPCC AR4 WG1 ch 11.6). Global climate models predict a decrease of between 0 and 9% by 2050 and of 3 to 10% by 2100. The monsoon system from which northwest Mexico derives much of its annual rainfall is somewhat more difficult to assess, as it is subject to a number of complex tropical and subtropical interactions, although this area is projected to receive some of the largest percentage decreases of precipitation. In mountainous areas, changes in atmospheric circulation on local levels could go against larger regional trends. Changes in tropical cyclones will affect annual precipitation totals in the Caribbean. Droughts are also expected to become more common throughout the entire region, as well as intense rainfall events.

Temperature is expected to increase and estimates range from 1 to 2.5 degrees Celsius for 2050 to 3.5 to more than 4.5 degrees Celsius by 2100. Temperature is expected to continue increasing throughout the region at an approximately linear rate, though slightly faster than the overall global rate (IPCC AR4 WG1 ch 11.6).

The above results point towards a significant decrease in water availability. Increases in temperature will cause a general increase in evapotranspiration (ET). Thus, since precipitation (P) is decreasing, the term P-ET will decrease significantly. Average annual streamflows will be lower as well as the amount of water recharged into the aquifers. It is unclear in detail how the frequency, intensity and spatial-temporal distribution of precipitation events will change in the future, but most recent research points towards and intensification of extreme events, be it droughts or floods. Teleconnections such as the El Nino Southern Oscillation may also be affected in a warmer climate. (IPCC AR4 WG1 ch 10.3) although there is considerable uncertainty on the nature of such effects. The ENSO strongly affects the Mesoamerica and Caribbean region, so any modifications to its behavior will also affect this region strongly.

2.2. Cyclones/Extreme Events

Changes in the behavior of tropical cyclones are likely due to increasing sea surface temperatures and changes in ocean-atmosphere dynamics, though the exact effects are somewhat uncertain as discrepancies exist within projections of future frequency, intensity, duration, and distribution in the Caribbean. The most certain consequences will be an increase in peak tropical cyclone intensity and rainfall rate. Although the last few hurricane seasons have seen a dramatic increase in frequency, it is not clear whether the long term frequency of tropical cyclones will change (WMO 2006).

2.3. Oceans

Ocean temperatures will continue to rise throughout the region. Ocean temperatures in and around the Caribbean are highly correlated with the North Atlantic Oscillation, which has been trending steadily more positive (warmer) over the past several decades. (IPCC AR4 WG1 Ch5) A rise in sea level will strongly affect the Caribbean and its many islands, and the potential for rapid sea level rise (with the breakdown of Greenland or the West Antarctic Ice Sheet), would be disastrous. Vulnerability studies indicate that a projected increase of 0.5m of sea level will cause flooding of more than 50% of Caribbean beaches in the next 50 to 100 years (PNUMA 2006).

2.4. Ecosystems

The region is geographically located between the parallels 7° and 32° of North latitude approximately, and Tropic of Cancer and the Equator. Coupled with an irregular topography with different elevation areas, this situation leads to a great variety of tropical and temperate ecosystems in the region. In agreement with the classification made by the

FAO (2000) in the report from Forest Resources Assessment Programme, the ecological zones and terrestrial ecosystems are: tropical rain Forest, tropical moist Forest, tropical dry Forest (arid and semiarid lands), tropical mountain systems, subtropical steppe, subtropical desert, Subtropical.

Because forest areas represent an important area of Mexico and Central America, the necessity to know and to evaluate the resources of such ecosystems, diverse international institutions have worked in conjunction with the governmental authorities, among them the Latin American Economical Commission (CEPAL), the United Nations Environmental program (UNEP) and Food and Agriculture Organization (the FAO). Considering the Kyoto Protocol requirements, the FAO follows the recommendations of the Good Practice Guidance for Land Use, Land-Use Change and Forestry (GPG-LULUCF) from the IPCC (2003), so that in the report of Forest Resources Assessment Programme, it includes the estimations of biomass to the calculations of carbon reserves. Through this report, we can know land cover, rate of change, and loss of forest among other things. The knowledge of these numbers allows the evaluation of the impacts on the atmosphere and the deforestation, whose main preoccupation is related to the global heating and loss of environmental services of forests and the forests themselves (SEMARNAT, 2005). This report has been applied to all the countries of Mesoamerica and the Caribbean (FAO, 2005). However information from many countries is not fully available.

Mesoamerica and the Caribbean contain an exception variety of species and genetic varieties, as well as ecosystems. In the region, Mexico is outstanding in this respect; of 704 species of reptiles, 393 are endemic (56%), 179 of 282 species of amphibians (62%) and 139 of 439 species of mammals (32%) (INE, 1995). Because it is insular, the Caribbean shows a high level of endemism, with 23.5 endemic plants for each 100km2, surpassing by 3, 4 and 12 times, respectively, the density in the Brazilian Atlantic forest, the tropical Andes and Mesoamerica. In the Caribbean there are 7,000 endemic plants, all of them under protection, whereas in Mesoamerica there are 5,000 endemic species of plants (UNEP, 2003). This biological wealth is undoubtedly one of the region's main assets, and its loss, one of its principal environmental problems.

In the Caribbean, less than 10 per cent of original island vegetation is still intact. Worse still, only a part of that 10 per cent is protected by parks and reserves. As the small intact areas are generally found in the smaller islands, they are under greater pressure. In addition, the smaller the island, the more endemic species it has so that there is less margin for error in maintaining the biotic heritage of small islands than there is in preserving it in larger islands or on continents (UNEP, 2003).

2.5. Aquatic Resources

Mesoamerica and the Caribbean are influenced by two great oceanographic zones, the Pacific and the Atlantic. These can be divided in each coast by: The Occidental Baja California Pacific Ocean, The California Gulf, The Tropical Pacific Ocean; The Gulf of Mexico and The Caribbean Sea. These countries have a lot of coasts in the Pacific, Atlantic and the Caribbean, which are dominated by mangles, coastal lagoons, estuaries, communities of marine grass and coral reefs. The coral reefs are usually on the Atlantic side and especially in the region of the Caribbean.

With respect to the coral reefs, at an international level, evaluations have been made to know the state of conservation. Among them, the World Resources Institute (WRI) formed a group with diverse participations, where an analysis of the degree of threat by anthropogenic impacts was made (coastal development, marine contamination and overexploitation, fish non sustainable, erosion and terrestrial pollutions). However analyzed threats did not include the direct physical destruction of reefs and the global climate change (SEMARNAT, 2005).

The coastal places more vulnerable to the Global climate change are mainly located in the Gulf of Mexico and the Caribbean Sea. Other ecosystems showing potential of flood damage in Mesoamerica are estuarine systems, coastal lagoons, estuaries and important river systems and its deltas.

3. POLICIES

Mexico shows significant differences in comparison with the other countries of the region: It has also recently established a National Policy for Climate Change.

The Mexican government strategy proposes that global warming along with the degradation of ecosystems and the lost of biodiversity are transcendental problems for the 21st century, and one of the greatest challenges for humanity. Global climate change is a problem of national security, and it demands efforts towards mitigation (CO_2 emissions) and the development of adaptation capacities to prepare for the impacts. For these reasons the government assumes the coordination and pursuit of efforts that society must make towards different approaches for mitigation, adaptation and prevention. These efforts are summarized in the National Strategy which includes 3 approaches:

1) Emissions of GHG and opportunities for mitigation (generation and use of energy, vegetation and land use, progressive valuation of carbon in the national economy),

2) Vulnerability and Adaptation (Management of hydrometeorological risks and handling of water resources; Environmental biodiversity and services; Agriculture and cattle ranch; Coastal zone; Slums; and Generation and Use of Energy).

3) Research and communication of global climate change.

The strategy also involves international cooperation and treatment of global climate change as an opportunity to enforce the transition to sustainable development.

It is assumed that emissions would begin stabilizing at 550 levels of ppm of CO_2 (twice the pre-industrial level). Nevertheless any limitation of GHG emissions would be based on implications for development of the region, ensuring equitable schemes of allocation of future quotas of GHG emissions.

2. IMPACTS, CHALLENGES AND CONCERNS

1. IMPACTS AND CHALLENGES

The major impacts of Global climate change identified for Mesoamerica and Caribbean region are: 1. Increasing temperature; 2. Sea level rise; 3. Water stress; 4. Extreme events. Global climate change impacts are affecting both natural and social systems, and its consequences involve the recognition of challenges in ecological, economical and political dimensions that we describe in the following chapter.

1.1. Agriculture

Agriculture in the region is a relevant economic activity and it is vulnerable to the effects of Global climate change primarily due to water stress (IPCC, 2007). According to the predictions, rainfall will decrease in the whole region and extreme events – floods and droughts - will have higher impacts.

South of Mexico, Central America and the Caribbean will be affected by more intense hurricanes. Increase of rainfall intensity can cause an increase of erosion rates especially in mountain regions where the terrains being cultivated have high slope reducing productivity. Central and northern areas in Mexico will be drier than at present because rainfall will decrease. Under these conditions, we expect that agriculture production will decrease due to lack of water and modification of temperature and water availability.

It is possible that some (or many) varieties of traditional crops can be lost due to Global climate change because they are used only on small regions, and it is possible that some traditional cultures could be highly impacted, putting their traditional livelihoods in danger.

1.2. Forestry

Global climate change impacts as increasing temperature and water stress will affect forest populations and species distribution in the region. Species and communities may not be able to migrate to new areas where conditions could be adequate for them due to the rapidity of changes. Global climate change will also increment forest fire frequency and plagues. Under these conditions forestry production may decrease and the human pressure on new forest areas would increase as well as land use change. Therefore, CO_2 capture will be diminished.

People whose livelihoods depend on forest resources are vulnerable due to lack of other opportunities for satisfying their needs, thus migration to cities may be favoured. Challenges in forestry have to focus on avoiding land use change into agriculture and controlling forest fires and plagues, as well as developing forest management plans.

1.3. Fisheries

Observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000 m and that the ocean has been absorbing more than 80% of the heat added to the climate system (IPCC, 2007).

For the terrestrial climate in Mexico, the Global climate change would result in temperature increases and rain decreases (Magaña et al., 2000, cited by Lluch-Cota, 2004). The El Nino events will also be affected. Regionally, El Niño reduces the phytoplankton biomass, modifies the massive distribution of resources, and is common detriments of benthic resources of high value. The capture of shrimp tends to enlarge, however the general balance of these events seems negative for the national fishing (Lluch-Cota et al., 1999).

The effects of the Global climate change upon the fishing are in the context of an activity that frequently faces problems of sustainability. Over fishing, overcapacity, conflicts among fleets and with other activities, a management that ignores environmental variability and the incapacity to enforce regulatory measures in practice, are aspects occurring worldwide that, according to the IPCC (Everett et to the. 1995 it cited by Lluch-Elevation, 2004), will tend to be aggravated with Global climate change.

With higher temperature, the variability of the ocean superficial circulation is basically the result of the magnitude and rapidity with which the changes from summer to winter happen, as well as of its extension and geographical location (Gallegos-García, 2004). The previous effect determines among others the position, rapidity and direction of the current superficial navies and the location, extension and frequency of episodes of wind upwelling; these phenomena are of sum importance for the marine productivity.

The increase of the sea surface temperature has been suggested to change the distribution and the abundance of several species, some of which are the base of massive fisheries as is the case of the pelagic small fish (sardines and anchovies) that are important to the fisheries. In the cases of benthic resources with little or no capacity of displacement, the gradual increase of the temperature of the sea would bring consequences regarding changes in the structure and composition of ecosystems.

In the case of the Mexican Pacific, information from the temperature multi-scale characterization of the sea, a suggested change may occur for the species that live together with the abalone, upon rise in 1.3 ºC sea surface temperature respect the first decades of the century XIX (Ponce-Díaz et al., 2003). For the case of the Caribbean, the occurrence of El Niño has also been associated with the affectation to the fisheries activity.

Regarding the Global climate change and the effect suggested of increase of the medium level of the sea, this phenomenon himself will affect to the adjacent infrastructure in the coast.

1.4. Tourism

The main coastal tourist destinations in the region will be threatened because of the increasing frequency and intensity of tropical cyclones. In addition, the sea level rise will affect lodging industry located near the sea. This will have severe affectations in economic profits, employment of local people and local trade, also the investments required for the infrastructure protection and backfill of the coastal zones and specifically the beaches (Sanchez-Salazar, 2004).

1.5. Biodiversity

Impacts of global climate change on biodiversity in Mesoamerica and the Caribbean may be important and are described following.

Temperature increase and sea level rise may cause the loss or change of ecosystems, altering population distribution and affecting the species that compose them. This will also have strong implications for migratory species, as their sanctuaries to help them migrate will be altered or will disappear. In the coastal zones, coral reef, mangroves, marshes will be affected.

Disturbances such as fires, diseases, water stress and others may cause dispersion and isolation, patterns of distributions and fragmentation, facilitating ecosystem changes, the introduction of invasive species, overall affecting genetic biodiversity.

Impacts of extreme events have been mainly identified on coastal and riparian zones. Regarding the ecosystems and its diversity, we identify the decrease in the abundance of populations and the capacity of adaptation of the species.

1.6. Health

Some health impacts are readily quantified as deaths due to storms and floods. The increase on the frequency and intensity of storms and hurricanes increases the risk of the coastal human populations to suffer physical damages. However, others are more difficult to quantify, e.g., the health consequences of food security. The feedbacks between social vulnerability (poverty) and climate change impacts also tend to increase mortality risks.

A greater incidence of infectious diseases related to the temperature increasing, bad quality of the water and floods affecting the municipal drainage, or the sanitary conditions, increases the risk of epidemics from infections. Malaria, today, is mostly confined to tropical and subtropical regions. The disease's sensitivity to climate is illustrated by desert and highland fringe areas where higher temperatures and/or rainfall associated with El Niño may increase transmission of malaria. Dengue is the most important arboviral disease of humans, occurring in tropical and subtropical regions, particularly in urban settings. Many diarrhoeal diseases vary seasonally, suggesting sensitivity to climate. In the tropics diarrhoeal diseases typically peak during the rainy season. Both floods and droughts increase the risk of diarrhoeal diseases (WHO, WMO and UNEP, 2003).

Other consequence of the temperature increase is the excess deaths during times of thermal extreme in persons with pre-existing disease, especially cardiovascular and respiratory disease. Exposure to high extreme temperatures could produce mortality by heat stroke.

1.7. Urbanization

Megacities and medium urban cities in the region significantly contribute to global climate change. Environmental problems which are already very serious in cities will increase as a result of global climate change. Cities absorb resources from all over the world, generate vast amounts of waste and sewage, and contribute considerably to the pollution of the environment. Due to their rapid growth, large cities often fail to satisfy their basic needs and are thus confronted with severe problems of adaptation and mitigation of environmental issues.

The major expected impacts are the increased damage to urban infrastructure and the people; intensification of "heat islands" in the cities, higher risks of flooding and overload in drainage networks and in the coastal and riparian areas, higher risks of landslides in slopes, more atmospheric pollution in urban basins, higher costs of insurance policies, higher energy requirements for temperature control, affectation of environmental services of urban green zones (Sanders, 1986; Nolan *et al.*, 2006).

Poor people are concentrated in high-risk areas, because there is not available land for the construction of housings at low cost. Therefore, they are very vulnerable to the impacts of Global climate change. Then it is possible that migration to the cities and other countries will increase significantly. The internal and external migration of the countries of the region will require the satisfaction of basic necessities for people that leave its original place to settle in the cities demanding jobs and the satisfaction of its primary necessities (feeding, dress, transport, sanitation system, electrical energy, etc.), which also repels in the growth of the informal and not controlled economy, for example Mexico City and San Jose. Due to their rapid growth, large cities often fail to satisfy the basic needs of the poor population and are thus confronted with severe problems related to poverty, unemployment and social exclusion.

Likewise, urban centers accommodate human capital to solve sustainability challenges. However, most of the society is not aware of the importance of an adequate individual environmental behavior and following environmental policies.

2. MAIN CONCERNS

In the region, there is a lack of research and information generation at local, regional and national level. It is necessary to achieve basic data and generate regional models about Global climate change future scenarios. There is also a lack of capacity building for researchers and policy makers, and the whole society is not well-informed about all the causes and consequences of Global climate change.

The implementation of policies is particularly scarce in the smallest and poorest countries of Mesoamerica and Caribbean region, which often depend on external funding (loans or grants) to design and implement their programs. In addition to a lack of economical resources, policies are usually announced without taking into account all the government and non-government organizations and institutions, as well as local communities.

The evolution of the institutional setting increases capabilities for supporting innovation and technological upgrading thus fostering the supply of it. Hence, reinforced knowledge and innovation demand and supply patterns could induce Mesoamerican and Caribbean countries to extend the scope of policies and to design and implement vertical and selective policies amid horizontal ones while strengthening mechanisms for policy coordination and articulation.

3. APPROACHES AND RECOMMENDATIONS

3.1. PRINCIPLES

In their national response strategy, the developing countries of Mesoamerica must be guided by the principles of Article 4 of the Intergovernmental Panel on Climate Change (IPCC), and subsequent Conference of Parties (COP) decisions, wherein the developed country parties have committed to assisting the developing country parties in the implementation of response measures to combat the negative effects of climate change. Some of the instruments more used in this context are the Global Environmental Facility (GEF) and USAID.

The analyses by sectors indicate the wide-ranging nature of the potential adverse impacts that anthropogenic climate change can have on Mesoamerica, notwithstanding the high levels of uncertainty as to the timing, nature and extent of these possible changes in climate parameters and consequently their impacts.

However the Precautionary Principle enshrined in the Convention points out that one does not have to await full scientific certainty before initiating measures to combat climate change.

Given the scarcity of resources however, the regional approach is not based on climate change considerations only. The measures to address the likely, or potential, impacts of climate change are linked to wider considerations, such as approaches towards reducing existing vulnerabilities and risks to present day weather and climate variability, as well as advancing wider sustainable development objectives.

The measures address all the main aspects of climate change i.e.

- Reduction in emission of greenhouse gases.
- Adaptation to the many sources of vulnerability that have been identified.
- Forests management and agriculture.
- Biodiversity and environmental services.

It must be noted however that given the low levels of greenhouse gas emissions that this region contributes to the global total, the emphasis must be placed on adaptation aspects, as this is the area where the region will experience the most serious adverse impacts. In the next section general strategies will be given to accomplish the responsibilities required by the Kyoto Protocol.

2. MITIGATION OF GREENHOUSE GAS (GHG) EMISSIONS

Based on the results of the GHG Inventory, the focus on mitigation activities will be on those sectors that are responsible for the most significant emissions - the residential sector, the transport sector and the energy industries sub-sectors within the energy sector, which together are responsible for 86% of the carbon dioxide emissions.

Mitigation activities for the non-carbon dioxide emissions are not considered, as the quantities emitted are minimal.

2.1. Residential Sector

Mitigation of greenhouse gases in this sector is premised on the creation and promotion of an enabling financial and fiscal environment for the adoption of appropriate energy efficient, renewable and sustainable technologies in the buildings sector.

Within this context, the following measures must receive priority consideration:

- the introduction of tax concessions for the adoption of energy efficient and renewable technologies.
- the sensitization of financial institutions and governmental agencies to the environmental and other benefits of these technologies.
- regulatory measures relating to mandatory energy-efficiency standards, within the context a national building code.[1]
- utility demand side management (DSM) that would provide incentives for the purchase of energy-efficient products, and specially solar energy generators.
- manufacturer incentive programs that would reward companies for the development and commercialization of high-efficiency low-energy-use products may be implemented
- procurement programs, where large purchases may make the acquisition of energy-efficient products affordable and the adoption of cost-effective energy efficiency measures in exchange for technical support and marketing assistance.

2.2. Transport Sector

Mitigation of greenhouse gases in this sector must be approached in the context of a comprehensive transportation plan aimed at regularizing and minimizing traffic flow and consequently reducing the greenhouse gas emissions.

Some of the initiatives that must be considered include:

- incentives, through licensing fees for instance, to encourage the purchase of energy efficient vehicles.
- incentives, such as price control, to encourage the use of alternative fuels, such as natural gas or bio-fuels, that are less polluting.
- energy use efficiency improvements, through the use of less carbon emitting fuels such as natural gas.
- legislation of fuel economy standards, including compulsory fitting of speed limiters.
- the mandatory installation of pollution removal devices such as catalytic converters in vehicular exhaust emission systems, in the context of strong legislation relating to exhaust emissions.
- the restriction of the importation of older foreign used vehicles. Ideally, the first approach to controlling or reducing CO2 emissions from tail pipes is to restrict the age of the vehicles on the roads to those that may meet better emission

[1] As forest the authors include shrublands, temperate and tropical forests, mangrove and wetlands

standards. In this context, policy directed at discouraging the importation of foreign-used cars and heavy vehicles more than 5 years old would be put in place. Such measures will provide much needed control to the increasing population of older vehicles on the roadways.

- policies that make more efficient the public transportation and encourage the wider use of more comfortable and safer buses and non-motorized systems such as bicycles and push-carts, together with supporting infrastructure such as dedicated lanes and improved signaling. This will be accompanied by public education to the environmental benefits of using public transportation.
- greater use of some non-transport options such as overall land use planning, improved urban planning, and transport substitution using modern telecommunications options, which will lead to reduced vehicular trips and thus GHG reductions.

2.3. Energy Sector

The options that will be considered for emissions reduction in this sector include:

- The optimization of existing power plants for more efficient fuel use, and consequently lower emissions, by implementing a regime of preventative maintenance.
- The retro-fitting of existing plants with modern efficient technologies.
- The use of less carbon-intensive fuels, such as switching from liquid fossil fuels to natural gas, or simply the use of cleaner liquid fuels where costs can be justified.
- The greater use of renewable energy technologies for power generation such as solar and wind energy and the development of micro-scale hydro power plants. They could be approved big hydro power plants, if they do not cause any significant environmental and/or social impacts.
- The provision of incentives for investment in renewable energy and the removal of policies that hinder the application and use of renewable energy.
- the adoption of measures that facilitate the penetration of less carbon-intensive technologies, such as provisions for accelerated depreciation of new equipment and negotiated agreements with industry that favor the use modern and more efficient equipment.
- The institution of regulatory measures, voluntary agreements with the power generating utilities and infra-structural measures aimed at removing institutional barriers and the development of a comprehensive and efficient energy system planning.

2.4. Other Sectors

For industrial sector some policies to be applied are:

- Promoting energy co-generation using potentiality of concrete, metallurgic ,and sugar industry.
- Auditing of industrial facilities for evaluating environmental and energy performance

3. ADAPTATION MEASURES

Future social and economic development in Mesoamerica depends not only on climate change issues, but also on many others factors including political considerations.

This preliminary assessment of the adaptation options will therefore focus on measures and policies that are of the "*win-win*" or "*no-regret*" type. This means that these measures would be desirable and positive even in the case of no climate change. In many cases, reduction in poverty levels can provide benefits across many areas to reduce vulnerability to climate change impacts.

It must be noted however, that more in-depth vulnerability analyses are urgently required, in order to ensure that the countries develop a more rigorous response program to the potential negative impacts of climate change. The focus areas are: Water resources, Agriculture, Tourism, Human Health, Institutional Framework and Capacity Building.

3.1. Water Resources

Water resources are vulnerable to sea level rise and temperature increase leading to higher evaporation rates. In scenarios derived from the HADCM2 and many other models water resources are additionally vulnerable to sizable reductions in precipitation levels. Given the centrality of ground water sources to the national water supply, the problem of water resources is primarily one of keeping and protecting the underground water resources.

This would include the following actions:

- Rational use of available water enforced by the national water authority;
- Controlled rate of pumping from aquifers with compliance and penalties measures;
- Conservation of protective forests that allows a high rate of infiltration of rainfall to the aquifers; and
- Protection of contamination of underground water from pollution sources - agricultural, human settlements and others.
- Processing the used water according to different pollution sources.

The use of measures for minimizing runoff of freshwater to the ocean environment would have to be done in agreement with the requirements of the coastal ecosystems, which thrive on definite levels of salinity and organic sediments from land areas.

3.2. Agriculture

- Incentives to develop sustainable agriculture practices.
- Incentives to diversify the agricultural crops and introduce policultivars.

3.3. Tourism

Adaptation options for this sector include:

Developing and enforcing environmental policies and regulations (including building regulations) for tourism activities that take into account the issues of sea level rise and climate change.

Ensuring that the risks associated with sea level rise (coastal flooding, increased action of waves and coastal erosion, enhanced storm surges and rising water tables) are taken into consideration in the building and development of new tourism resorts.

Redirecting tourism from activities that adversely impact on natural fragile ecosystems, toward more societal activities of historical, traditional and cultural nature that will not be associated with climate change, so as toward ecological tourism.

3.4. Human Health

Climate influences on health are most directly related with epidemiological issues and preventive medicine. This two features, epidemiological control and preventive medicine, should be enhanced in the country's health system.

Adaptation measures for this sector would include the following,

The development of a Health Forecast System for acute respiratory, intoxication, insulation, dehydration and many other diseases, for which weather and climate conditions constitute the triggering mechanism.

Strengthening of data collection and reporting systems.

Vaccination campaigns for all possible diseases.

Sustained and improved sanitary conditions in human settlements.

Sustained and improved disease vector control.

3.5. Institutional Framework

The measures required here are the establishment of a coordinating authority for the management of climate change and the institutionalization of climate change considerations into the policy making process.

Coordinating Authority - A National Coordinating Authority is needed, as in the majority of countries, no institution has the responsibility of managing the process of adapting to climate change.

Policy Making – It is necessary that climate change considerations within the sustainable development, be placed at the centre of national development planning.

3.6. Capacity Building

The human resource capacity in Mesoamerica is deficient in the knowledge and skills required for assessing and responding to the impact of climate change. It is therefore imperative that these deficiencies be redressed.

This requires upgrading at two levels:

The development of a cadre of trained professionals who can provide technical leadership and guidance to the climate change process. Such training is usually obtained through formal university programs.

The upgrading of the technical capacities of the management and technical personnel in the institutions and sectors that will be most affected by the impacts of climate change.

4. PRIORITY ACTION PLAN

It is not possible to immediately address the large number of response actions identified in this document. It is therefore necessary to identify key areas for the initiation of a structured response to climate change.

In this context, a priority action plan could address certain core areas for attention, which can be expected to have multiplier effects. These could be:

- Strengthened Institutional Capacity for Climate Change
- Public Awareness
- Coastal area management
- Improved Freshwater Management

4.1. Institutional Strengthening

A special Authority must be established to deal with the climate change. The responsibilities of this Authority will include:

- Database management of climatological time series.
- Being a source of certified climatological data for governmental or private development and investment programmes.
- Being a part of the institutions involved in the issuing of environmental permission and licensing.
- Giving systematic specialised services to small farmers and agricultural institutions.
- Creating and servicing a National Climate Forecast System with the capabilities of producing forecasts for periods of 1 - 12 months.
- Strategic environmental assessment of Policies, Plans and Programs government in order to ensure that environmental concerns, including climate change issues, are considered for planning.
- Developing and strengthening emergency disaster response plans in vulnerable localities.
- Creating and servicing a National Drought Surveillance System and a National Early Warning System for Agricultural Drought.
- Ensuring that climate variability and climate change issues are included in all country development and planning actions, with special emphasis on the most vulnerable groups.
- Coordinating research issues and create scientific networks in the fields of climate variability, climate change, desertification and sustainable development.

This institutional strengthening must be accompanied by the provision of relevant training in climate change impacts and assessments, to technical and senior managerial personnel in the key institutions in all of the sectors that will be adversely impacted by climate change. This training must include methodologies for data collection and analysis related to assessing and responding to the threat of climate change.

4.2. Public Awareness

Greater public awareness of climate change will be essential since actions will be required by stakeholders at all levels – individual, household, community, sectoral and national. This can only be possible when persons involved have a greater awareness of the problems associated with climate change. That is why different information campaigns must be developed according to age, residence, scholarship, involvement level.

This will require the education of agencies and organizations involved in public outreach and information dissemination (particularly the news media, NGOs, and community based organizations) on matters relating to climate change impacts and adaptations. This level of awareness will be targeted at the infusion of basic knowledge of climate change at the mass level. It will also require the provision of specialized training and sensitization for decision makers and resource managers to provide them with the information base they will need to advance sustainable development in their respective sectors.

The ultimate objective of these public awareness programmes would be to sensitize stakeholders as to the likely impacts of climate change and the measures that can be taken to ameliorate adverse impacts.

The priority lines of the awareness campaigns must include:

- Information on causes and impacts of the climate change, specially oriented to the most vulnerable population groups.
- The availability and the incentives to use the alternative energies.
- The incentives for the purchase of energy-efficient products, and specially solar energy generators, and involving local communities, mainly in small-sized energy supply projects.
- The development of human and institutional capacities, in the implementation and management of policies aimed at promoting renewable technologies, by for instance, providing information and training to key Government officials and local stakeholders.
- Sensitization of the business sector about the links between future utilities and sustainable development.
- Educational and promotional health related issues.
- Educational and promotional environmental services issues.
- To include global climate change in the basic education school curricula at multidisciplinary level with theoretical contents and practical activities.

4.3. Coastal Area Management

Various hard and soft technologies exist for responding to IPCC projected scenarios of sea level rise and accelerated storm surge. These fall into a range of Retreat, Accommodation and Protection options. These types of responses are generally best accomplished within the framework of some sort of integrated coastal management framework. Action will therefore be taken to enhance coastal resource management, bearing in mind the need to incorporate climate change data and trends, emphasizing the identification of most vulnerable areas.

The uncertainties surrounding timing and extent of climate change and the existing stresses on the coastal and marine environment means that adaptation options adopted would be also targeted at promoting sustainable resource use in coastal and marine areas. Sectoral beneficiaries will include the important tourism and fisheries sectors.

4.4. Improved Freshwater Resource Management

Model results from the Climate Model Intercomparison Project (CMIP) indicate a significant uncertainty in the results and fairly disparate projections for future impacts of climate change on Mesoamerica's rainfall regimes. Nevertheless, the average of all the models indicates a clear decrease in the rainfall over the region.

Given the importance of freshwater supply to economic sectors (health, agriculture, tourism) there is a need to work to ensure security of water supply, especially in the most vulnerable zones, taking into consideration water requirements of natural ecosystems.

A combination of resource enhancement activities (reforestation, agro-forestry) and management measures (water conservation, efficient water use technologies, land use policy, zoning) are required if sustainable approaches are to be achieved. The possibility of desalinization is an option that an increasing number of small island countries are also being forced to examine, despite the high costs involved. It is also very important to create watersheds management plans for urban zones, which could include two or more countries.

Future measures to address freshwater management will therefore incorporate climate change considerations into forecasting and management planning.
For reducing population vulnerability, solid waste and wastewater must be treated before discharging them into the natural system.

4.5. Research

Additional research must be geared towards:

- Prediction and forecasting modelling at regional level
- Regional data base development for calibrating models
- A more in-depth analysis of the vulnerability of the various sectors in Mesoamerica to the potential negative impacts of climate change.
- The potential for developing and introducing crop cultivars resistant to the projected climatic conditions.
- The setting up of a clearinghouse to track new and emerging technologies that address energy efficiency improvements, including the transport sector.
- Technological development for efficiency improvement of alternative energies especially for reducing investment costs.
- Research at regional level about hydrological balance and the effects due to climate change at landscape scale.
- Development of diffusion and communication strategies for different social sectors about climate change.
- Epidemiologic research about disease that can be favoured by climate change.

- Effects on biodiversity, ecosystem dynamic and environmental services and their feedback mechanisms with global climate change.
- Assessment of social and economic impacts in the region.
- The use of insurance for adaptation to extreme climatic events.
- Is basic to establish genetic and germplasm banks for the preservation of vulnerable species.
- Costs evaluation of adaptation policies and measures.
- Costs evaluation and risk assessment of extreme events consequences and their repercussions on insurances policies.
- Development of mariculture and aquaculture technologies for adaptation to climate change effects on fisheries.
- Indicators and index for assessing the performance of climate change policies applied in each country.

4.6. International cooperation

It is necessary to promote international cooperation for solving regional issues related to climate change:

- To promote coordination among the national climate change authorities.
- Public health and emergency plans for extreme events emphasizing vulnerable groups and areas of attention.
- Research on climate change issues focusing at a regional level. Exchange of data, information and human resources.
- Technological development.
- Establishment of national and regional commitments on equity basis for forcing developed countries to strengthen their responsibilities about climate change.
- Develop environmental education programmes at interregional level (exchange).

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PART V: SOUTH AMERICA

1. CURRENT AND FUTURE CLIMATE

1.1 Current climate

Precipitation Temperature and Weather Extremes

The IPCC 4th assessment report indicates that across South America (SA), increasingly wet conditions were observed over the southeastern South America, including Patagonia, while negative trends in annual precipitation were observed over Chile and parts of the western coast of the continent from 1901-2005.

An important feature of SA climate is the South American Monsoon System (SAMS) which is evident in the austral summer [Barros et al., 2002; Nogués-Paegle et al., 2002; Vera et al., 2006]. It is a key factor for the warm season precipitation regime. In northern Brazil, different precipitation trends have been observed over northern and southern Amazon, showing a dipole structure [Marengo, 2004] that suggests a southward shift of the SAMS. The mean wind speed of the low-level jet, a component of the SAMS that transports moisture from the Amazon to the south and southwest, showed a positive trend [Marengo et al., 2004].

Sea Surface Temperature (SST) is also determinant factor in SA climate. Positive SST anomalies in the western subtropical South Atlantic are associated with positive rainfall anomalies over the Southern American Convergence Zone (SACZ) region [Doyle and Barros, 2002; Robertson et al., 2003]. Barros et al. [2000] found that, during summer, the SACZ was displaced northward (southward) and was more intense (weaker) with cold (warm) SST anomalies to its south. The convergence zone is modulated in part by surface features, including the gradient of SST over the equatorial Atlantic [Chang et al., 1999; Nogués-Paegle et al., 2002], and it modulates the interannual variability of seasonal rainfall over eastern Amazon and northeastern Brazil [Nobre and Shukla, 1996; Folland et al., 2001].

Evidence shows that besides precipitation distribution, frequency of extreme events has also changed worldwide, as for example substantial increase of heavy precipitation events and greater occurrence of droughts, especially in the tropics and subtropics. SA has recently experienced rarely recorded, if ever, climate and weather events like the extreme drought in the Amazon in 2005 and the South Atlantic “hurricane” Catarina of March 2004.

Although, it has been accepted that hurricanes could not form over the South Atlantic Ocean due to a couple reasons, these being a very intense climatological vertical wind shear and not sufficiently warm sea surface temperatures, in March of 2004 the Hurricane Catarina was registered in southern of Brazil. This is not to say that a phenomenon like Catarina had not existed in the past, but there is very strong evidence that at least during the satellite era this is unprecedented. Pezza and Simmonds [2006] point out the question: was Catarina a result of natural climate variability only, or could it also be related to climate change due to anthropogenic influences? The authors stated it is uncertain as to whether Catarina is or is not related to climate change. However, a global climate model simulation study by Sugi et al.[2002] for the period 1979-1988, shows that in an environment with double CO_2, ocean and atmospheric conditions favorable to hurricane formation in the South Atlantic could develop, near the region where Catarina was formed (Fig1.).

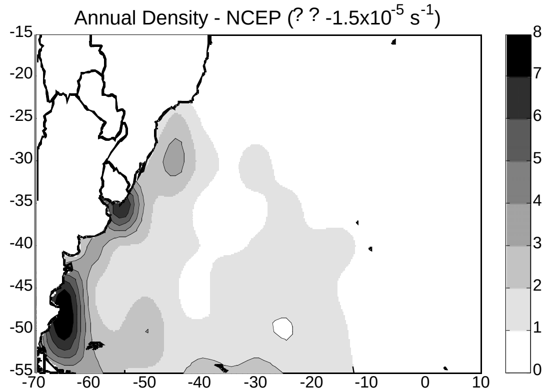

Figure 1. Tropical cyclone tracks for a ten-year period. (a) Observed tracks for 1979–1988 based on the US Navy Best Track Dataset. (b) Tracks in the 2 x CO2 experiment (Source: Sugi et al., 2002).

Not only tropical cyclogenesis can be affected by climate change, but extratropical as well. According to Reboita et al. [2007] there are 3 favorable regions for extratropical cyclones genesis in the eastern coast of SA, shown in Fig.2. Studies for the entire Southern Hemisphere show that decrease in low level temperature gradient between the polar and equatorial regions [Sinclair and Watterson (1999)], would result in lower baroclinicity reducing in 2% the number of systems [Watterson (2006)]. On the other hand daily rainrates would double, as anticipated by an increased moisture capacity of a warmer atmosphere.

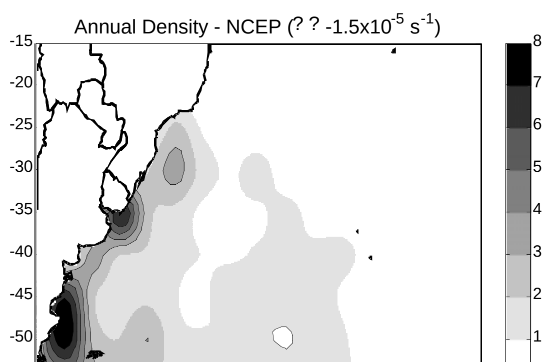
Annual Density - NCEP (? ? -1.5x10^{-5} s^{-1})

Figure 2. Extratropical cyclones density (rate of number of systems in a 5x5 grid by its area times 10^4) from 1990 to 1999 based in the NCEP reanalysis. Cyclones with lifetime higher or equal 24 hours and relative vorticity higher or equal -1.5 s^{-1} were identified.

In terms of temperature, significant increasing trends were found in the occurrence of warm nights and decreasing trends in the occurrence of cold nights, but no consistent changes in the indices based on daily maximum temperature. In northern South America however, both minimum and maximum temperature have increased.

1.2 FUTURE CLIMATE

In South America is uncertain how annual and seasonal mean rainfall will change over northern South America, including the Amazon forest. In some regions, there is qualitative consistency among the simulations (rainfall increasing in Ecuador and northern Peru, and decreasing at the northern tip of the continent and in southern northeast Brazil). The systematic errors in simulating current mean tropical climate and its variability and the large differences between models in future changes in El Niño amplitude preclude a conclusive assessment of the regional changes over large areas of Central and South America. Most models are poor at reproducing the regional precipitation patterns in their control experiments in particular over most of the Amazon. The high and sharp Andes Mountains are unresolved in low resolution models, affecting the assessment over much of the continent. As with all landmasses, the feedbacks from land use and land cover change are not well accommodated, and lend some degree of uncertainty. The potential for abrupt changes in biogeochemical systems in the Amazon remains as a source of uncertainty. Large differences in the projected climate sensitivities in the climate models incorporating these processes and a lack of understanding of processes have been identified (IPCC, 2007).

1.2.1 TEMPERATURE

The projected warming is approximately linear with time during the XXI century, but the magnitude of the change and range among models are greater over the Amazon than over southern South America. The annual mean warming under the A1B (1.7-4.4ºC temperature increase) scenario between 1980 to 1999 and 2080 to 2099 varies in the Amazon (southern South America) region within 1.8°C (1.7°C) to 5.1°C (3.9°C) with a median of 3.3°C (2.5°C). This median warming is close to the global ensemble mean in southern South America, but about 30% above the global mean in the Amazon Region. The simulated warming is generally largest in the most continental regions, such as inner Amazon. The warming in central Amazon tends to be larger in JJA than in DJF, while the reverse is true over the Altiplano where, in other word, the seasonal cycle of temperature is projected to increase.

Similar results were found by three regional models (horizontal resolution of 50 km) forced with SST anomalies provide by the Oceanic component of the HadCM3 coupled model (Figure 3) [Ambrizzi et al., 2007]. The ensemble of the models shows increase of temperature in South America, specifically in Central Amazon.

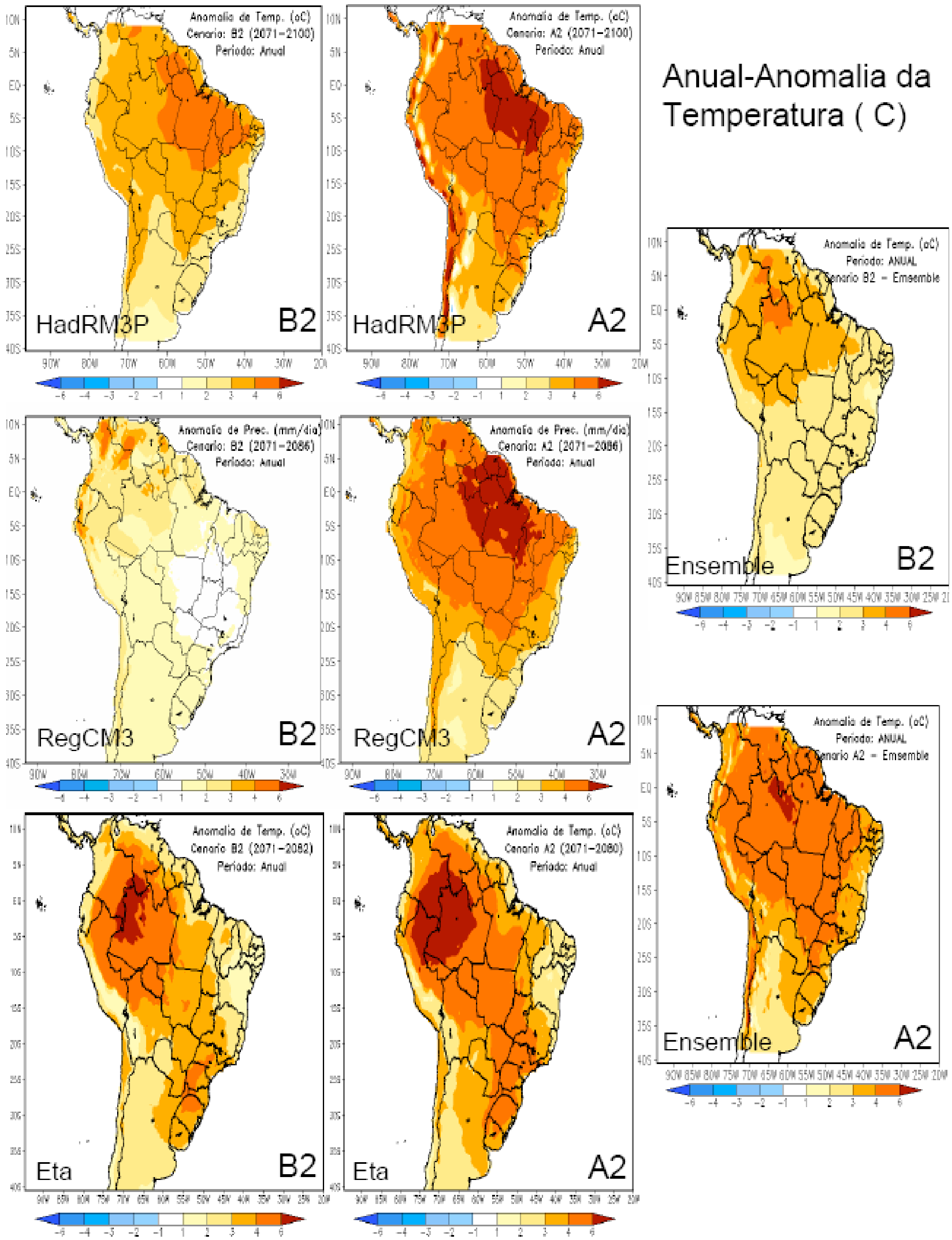

Figure 3. Precipitation anomalies of three regional models: Eta, RegCM3 and HadRM3P for A2 and B2 emission scenarios, for the period between 2071-2100 (Ambrizzi et al., 2007).

1.2.2. PRECIPITATION

For South America, the multi-model mean precipitation response (Figure 4) indicates marked regional variations. The annual mean precipitation is projected to decrease over northern South America near the Caribbean coasts, as well as over large parts of northern Brazil, Chile and Patagonia, while it is projected to increase in Colombia, Ecuador and Peru, around the equator and in south-eastern South America. The seasonal cycle modulates this mean change, especially over the Amazon Basin where monsoon precipitation increases in DJF and decreases in JJA. In other regions (e.g., Pacific coasts of northern South America, a region centered over Uruguay, Patagonia) the sign of the response is preserved throughout the seasonal cycle (IPCC, 2007). Most models project a wetter climate near the Rio de la Plata and drier conditions along much of the southern Andes, especially in DJF. However when estimating the likelihood of this response, the qualitative consensus within this set of model should be weighed against the fact that most models show considerable biases in regional precipitation patterns in their Control simulation. In the Amazon, different climate models show rather distinct patterns, even with almost opposite projections (Figure 4).

The increase in rainfall in south-eastern South America is related to a corresponding poleward shift in the Atlantic storm track [Yin, 2005]. Some projected changes in precipitation (such as the drying over east-central Amazon and northeast Brazil and the wetter conditions over south-eastern South America) could be a partial consequence of the El-Niño like response projected by the models. The accompanying shift and alterations in the Walker Circulation would directly affect tropical South America [Cazes Boezio et al., 2003] and affect southern South America through extratropical teleconnections [Mo and Nogués-Paegle, 2001].

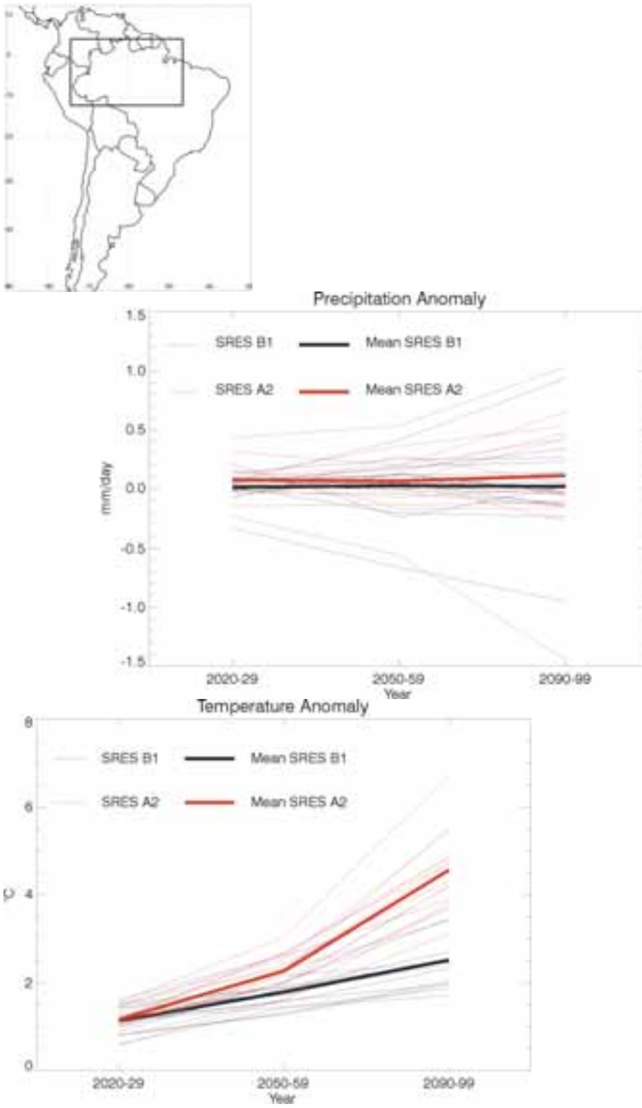

Figure 4. Precipitation and Temperature anomalies for Amazonia region from 15 AOGCMS for the SRES A2 and B1 emissions scenarios.

Figure 5 show the precipitation anomalies for 3 regional models: Eta, RegCM3, HadRM3p. This models have a resolution of 50 km and are forced with the global model HadCM3. The ensemble of the models shows decrease of the precipitation in the North and Northeast South America.

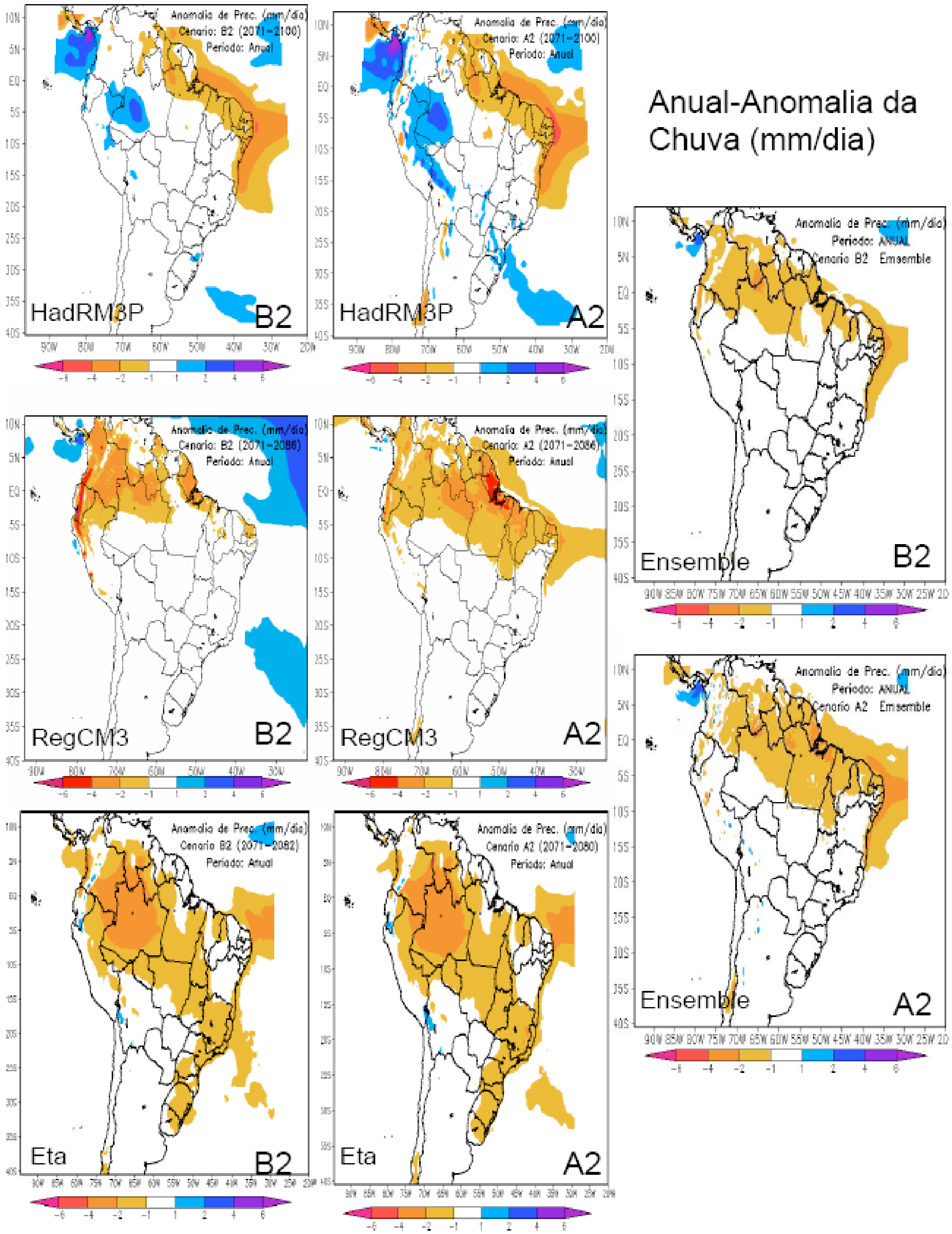

Figure 5 .Temperature anomalies of three regional models: Eta, RegCM3 and HadRM3P for A2 and B2 emission scenarios, for the period between 2071-2100 (Source: Ambrizzi et al., 2007)

Current OGCMs do not reliably produce projections of changes in the hydrological cycle at regional scales with confidence. That is a great limiting factor to the practical use of such projections for active adaptation or mitigation policies.

2. IMPACTS
2.1 Natural systems
2.1.1 Natural Hazards
- **Fires**

Another disturbance factor arises as a consequence of the increasing forest fire frequency. The dense primary forest of Amazonia has been by and large impenetrable to fire due to the high level of soil and litter layer humidity. However, forest fragmentation mostly due to selective logging and the widespread use of fire in agricultural practices in that region account for a substantial increase of the frequency of forest fires in the last two decades. For instance, the large forest fire that took place in northern Amazonia from January through March 1998 is an illustration of what may be in store fore the future. Caused by a intense and persistent drought associated to the strong 1997-98 El Niño and the indiscriminate use of fire in agriculture, over 13,000 km^2 of forests burned in which is likely to have been the largest forest fire of modern times in the Amazon [Nobre et al., 2005].

The synergistic combination of regional climate impacts due to deforestation and climate impacts resulting from global warming, resulting in warmer and possibly drier climates, and the increasing forest fire frequency, adds tremendously to the vulnerability of tropical forest ecosystems. The more adapted species to withstand the new conditions are typically those of the tropical and subtropical savannas, which are naturally more adapted to hotter climates with marked seasonality in rainfall and long dry seasons and where fire plays an important ecological role.

- **Floods**

Higher temperatures and higher precipitation increases flood magnitudes in parts of the region where floods tended to be generated from heavy rainfall in autumn but decrease flood magnitudes where floods are generated by spring snowmelt. In some cases, the peak flood season shifts from spring to autumn. This conclusion also is likely to apply in other environments where snow and rain floods both occur (IPCC, 2001).

2.1.2 Water Resources
- **Rivers and Reservoirs**

It is expected that regionally water scarcity may play an important role in affected areas of South America; it is projected that by 2025 the region will have suffered a 70% water loss per person since the resource availability of the 1950's. [UN 2006 human development report].

A probable scenario for the region is that the mean warming trend is likely to be similar to the rest of the world in southern south America but larger than the global mean in the rest of the subcontinent, however it is uncertain how annual and seasonal mean rainfall will change over northern South America, including the Amazon forest. However, there is a qualitative consistency among the simulations in some areas (rainfall increase in Ecuador and northern Peru, and decrease at the northern tip of the continent and in southern Northeastern Brazil-IPCC, 2007). These possible scenarios for precipitation change have negative consequences for the Northern countries (Caribbean dry belt) who depend mostly on rain water for agriculture production and of snow melt water for water consumption in the Northern Andes. In Southern Brazil a change in rain water will increase the use of the rivers on the region for irrigation purposes.

- **Glaciers:**

In South America Tropical glaciers are particularly exposed to global warming. Kaser et al. [1996] show that the equilibrium line altitude (ELA)—the line separating the accumulation zone from the ablation zone—of a tropical glacier is relatively more sensitive to changes in air temperature than that of a mid-latitude glacier. This is because of the lack of seasonality in tropical temperatures and the fact that ablation is significant year-round. Glaciers in Latin America have receded dramatically in the past decades, and many of them have disappeared completely.

Among the main impacts of global climate change in water resources of mountain areas are:

- Tropical glacier reduction or total disappearance (Cotacachi, Chacaltaya, Nevado del Cisne.
- Streamflow seasonality alteration.
- Increased risk of natural disaster. Ex: The melting of glaciers in Peru has caused sudden and violent flashfloods [Portocarrero, 1995] and avalanches like the one in Cuzco in 1998.
- Decreased water resources for human consumption, energy generation, agriculture and industry in general.

In terms of economical activities, agriculture in central Chile and the Argentinean central western plains are maintained through irrigation. Therefore, it may be said with high confidence that fluctuations in winter precipitation have a strong socioeconomic impact in the region (IPCC report 2001). Increasing glacier melting in this region may produce an increase in extreme events, threatening millions of people that depend on water from glaciers for human consumption. Food production in mountain areas in countries like Bolivia, are particularly vulnerable to climate change due mainly to its low technological development and poor economical diversification.

The IPCC report (2007), shows that in the absence of a change in precipitation, a rise in temperature of 0.4°C per decade would virtually eliminate all of the tropical South American glaciers by 2100.

Lakes:

Lakes are particularly vulnerable to changes in climate parameters. Variations in air temperature, precipitation, and other meteorological components directly cause changes in evaporation, water balance, lake level, ice events, hydrochemical and hydrobiological regimes, and the entire lake ecosystem. Under some climatic conditions, lakes may disappear entirely. There are many different types of lakes, classified according to lake formation and origin, the amount of water exchange, hydrochemistry, and so forth (IPCC, 2007).

Climate change will principally affect regions on South America with endorheic lakes (terminal or closed basins) this water bodies are located in the Altiplano high Andes. The best example of this type of lake is Titicaca (The highest commercial navigable lake in the world). More than 25 rivers empty into Titicaca, and the lake has 41 islands, some of which are densely populated (4). Titicaca is fed by rainfall and meltwater from glaciers on the sierras that abut the Altiplano. It is drained by the Desaguadero River, which flows south through Bolivia to Lake Poopó. This accounts for less than five percent of the lake's water loss, however, the rest is caused by evaporation as a result of the strong winds and sunlight at this altitude. A reduction in freshwater inflows, however, would change the lake regime and possibly lead to salinization of the freshwater part; this would effectively destroy the major source of water for a large area.

2.1.3 Sea level rise –coastal erosion

Observed sea-level rise at the local or regional level in South America could be greater than the global average value, and increase in sea level will displace a significant number of people who live or depend of coastal regions for shelter or economical activities [Field, 1995; Codignotto, 1997; Kjerve and Macintosh, 1997].

Saizar (1997) assessed the potential impacts of a 0.5-m sea-level rise on the coast of Montevideo (Uruguay). Given no adaptive response, the cost of such a rise in sea level was estimated to be US$23 million, with a shoreline recession of 56 m and land loss of 6.8 ha. In Venezuela, Olivo (1997) studied the potential economic impacts of a 0.5-m sea-level rise on the coast. At six study sites, she identified land and infrastructure at risk—such as oil infrastructure, urban areas, and tourist infrastructure. Evaluating four scenarios, Olivo (1997) suggests that Venezuela cannot afford the costs of sea-level rise, either in terms of land and infrastructure lost under a no-protection policy or in terms of the costs involved in any of three protection policies. In Argentina, the heavily populated Paraná Delta could be seriously affected by even small changes in sea level (Kovats *et al.,* 1998). The effects of sea-level rise may be counteracted by growing deltas as a result of the large amount of sediment coming down the Paraná and Uruguay Rivers from intense deforestation and consequential water erosion on the land of the upper basins.

Sea-level rise can also increase the damage caused by storms because mean water level (the base level for storm effects) is higher, waves can attack higher on the shore profile, and coastal erosion often is accelerated, bringing structures nearer the shoreline and potentially removing protection offered by dunes and other protective features. South American coastal zones with economies that are based in fishing and tourism are particularly vulnerable to physical changes associated with sea-level rise.

Shoreline migration will create new areas of economic opportunity as new beaches are built, but protection, replenishment, and stabilization of existing beaches represents a principal socioeconomic impact. It is difficult to separate the impact of climate-induced sea-level rise from erosion associated with the persistent interaction of the sea on the coast. Indirect socioeconomic effects on tourism from increasing pollution, coral reef mortality, and storm damage also are involved (UNEP, 1993).

2.1.4. Biodiversity loss

- **Forest loss and Savannization**

The future of the rainforest is not only of vital ecological importance, but also central to the future evolution of the global carbon cycle, and as a driver of regional climate change. The monsoon system is strongly influenced by ENSO (e.g., Lau and Zhou, 2003), and thus future changes in ENSO will induce complementary changes in the region. Displacements of the South Atlantic Convergence Zone have important regional impacts such as the large positive precipitation trend over the recent decades centered over southern Brazil [Liebmann et al., 2004]. There are well-defined teleconnection patterns [Mo and Nogués-Paegle, 2001] whose preferential excitation could help shape regional changes. The Mediterranean climate of much of Chile makes it sensitive to drying as a consequence of poleward expansion of the South Pacific subtropical high, in close analogy to other regions downstream of oceanic subtropical highs in the Southern Hemisphere (SH). Southeastern South America would experience an increase in precipitation from the same poleward storm track displacement.

Although feedbacks from carbon cycle and dynamic vegetation are not included in the IPCC/AR4 models, a number of coupled carbon cycle-climate projections have been performed since the TAR. The initial carbon-climate simulations suggest that drying of the Amazon potentially contributes to acceleration of the rate of anthropogenic global warming by increasing atmospheric CO_2 [Cox et al., 2000; Friedlingstein et al., 2001; Dufresne et al., 2002; Jones et al., 2003]. These models display large uncertainty in climate projections and differ in the timing and sharpness of the changes [Friedlingstein et al., 2003]. Changes in CO_2 are related to precipitation changes in regions such as the northern Amazon [Zeng et al., 2004]. In a version of the HadCM3 model with dynamic vegetation and an interactive global carbon cycle [Betts et al., 2004], a tendency to a more El Niño-like state contributes to reduced rainfall and vegetation dieback in the Amazon [Cox et al., 2004]. In Salazar et al [2007] the models shows consensus areas where a replacement of forest by Savanna will occur. This area is concentrated in Southeastern Amazon.

Biodiversity loss is a major concern related to the conversion of forest and savannas to agricultural purposes and climate change impacts are likely to exacerbate this trend in both ecosystems. Both plant and animal species are threatened. In a modeling study, Miles et al. (2004) estimates more severe plant species losses in the eastern than in the western part of the Amazon forest. 43% of the modeled species became non-viable by 2095.Savannization of the Amazon would imply the loss of habitats for the regions main mammals and bird species.

Ocean

Coral Reefs health is partly determined by water temperature, limiting this system to tropical areas where warm currents are found, like the Brazilian and Colombian coasts. These are organisms very sensitive to temperature, salinity, toxins and light and any stress in any of these variables can result in coral bleaching (Projeto Coral vivo).

The progressive acidification of oceans due to increasing atmospheric carbon dioxide is expected to have negative impacts on coral reefs and their dependent species. Increases in sea surface temperature of abut 1 to 3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatization by corals. Increases in sea surface temperature, increases in intense tropical cyclone activity and deterioration in coastal conditions (beach erosion) due to climate change are projected to have adverse effects on coral reefs, and cause shifts in fish stocks local resources and tourism.

2.2. Social and economical impacts

The prediction of climate change impacts in social and economic systems involve very large degrees of uncertainty as these systems are also affected by political events and economic trends that are independent from climate. The costs of climate change obviously depend on how humans adapt to it, which is particularly true for the widespread agricultural systems in forest and savanna ecosystems. The direction of impact is therefore not always straightforward. For example, drier conditions in the Amazon may pose risks for timber production from natural forests and plantations as well as agro-forestry production. However, extensive livestock production systems in moist forest areas might actually benefit from drier conditions due to reduced encroachment and higher carrying capacities per ha of pasture.

The types of social and economic climate change impacts that are expected in forest and savanna ecosystems can be broadly classified as follows:

Table 1. Characterization of impacts and impacts directions

Ecosystem	**Impact**	**Effect**	**Direction of effect**
Forest	Agricultural yields	Agricultural profits	+/-
	Vector borne human diseases	Health costs	+
	Plant diseases and pests	Agricultural profits	-
	Accidental forest fires	Asset wealth Health costs	- +
	Biodiversity loss	Income opportunities Value of natural forest	- -
	Temperature increase	Energy costs	+
	Reduced precipitation	Irrigation costs	+
	Soil loss (on slopes)	Agricultural profits	-
Savanna	Agricultural yields	Agricultural profits	-
	Plant diseases and pests	Agricultural profits	-
	Vector borne human diseases	Health costs	+
	Biodiversity loss	Income opportunities Value of natural	- -

		savannas	
	Temperature increase	Energy costs	+
	Reduced precipitation	Irrigation costs	+
	Soil loss (on slopes)	Agricultural profits	-

With regard to agricultural yields one of the major uncertainties relates to the effect of CO_2 fertilization. Future projections, mainly based on combining climate change scenarios with crop simulation models suggest that cereal yields in South American Forest and Savanna ecosystems may change between -30 and 5% depending on the effect of CO_2 fertilization [Parry et al. 2004]. Without CO_2 fertilization most models, however, predict large yield losses in tropical zones and to a lesser extent also in the temperate zones in South America due to drought stress and plant diseases and pests (Stern Review 2007).

Whether these yield losses can be directly translated in income and GDP losses is questionable, because some farmers might be able to quickly adapt to changing climate condition, by modifying crop mix and technology even without related changes in the policy environment.

With respect to human health the discussion currently focus on health related consequences of changes in atmospheric composition, hydrological cycle, food and fiber production, ecosystems, urbanization, as well as biodiversity changes.

In the South American region the principal causes of mortality associated with Global warming are: 1) Temperature increase, 2) extreme events related with climatic events (floods, hurricanes, etc..), 3) Diseases related to water quality and 4) vector borne diseases (Mosquitoes, rodents) [Diaz et.al. 2003]

An increase of El Niño events in the region will increase the epidemiologic risk of certain diseases transmitted by mosquitoes. Malaria incidence is expected to increase by 30% in Colombia and Venezuela. Southeastern South America it is expected to see greater occurrence in Dengue and Encephalitis as well as leishmaniosis events in the state of Bahia in Brazil, related to a predicted greater frequency in ENSO events [Diaz et.al. 2003, Franke et al. 2002].

Kattenberg *et al.* (1996) made generalized tentative assessments concerning extreme weather and climate events. Studies in temperate and subtropical countries have shown increases in daily death rates associated with extreme outdoor temperatures (Climate change scenarios constructed from three models have been used to estimate human mortality with changes in baseline climate conditions for Buenos Aires, Caracas, San José, and Santiago. In Caracas and San José, where present temperatures are close to the comfort temperature for all months, mortality rates (total, cardiovascular, and respiratory) increase for most of the climate change scenarios employed. However, decreases in winter mortality may offset excess summer mortality in cities with relatively colder climates, such as Santiago. People who are more than 65 years old are more temperature sensitive than younger people (Martens, 1998, IPCC 2001).

South American countries already struggle with large and growing populations, and malnutrition rates would be particularly vulnerable to changes in food production [Patz, 1998]. Changes in the distribution of plant pests have implications for food safety. Ocean warming could increase the number of temperature-sensitive toxins produced by phytoplankton, causing contamination of seafood more often and an increased frequency of poisoning. The rapid spread of cholera along the Peruvian coasts and the fact that the *V. cholerae* isolates involved constitute a separate genetic variant that could be a result of environmental change [Wachsmuth *et al.* 1993]—as well as the ability of *V. cholerae* to survive in seawater and freshwater—make cholera a persistent health hazard (IPCC, 2001). Thus, climate-induced changes in the production of aquatic pathogens and biotoxins may jeopardize seafood safety (IPCC, 1996). Increased ambient temperature has been associated with food poisoning; multiplication of pathogenic microorganisms in food is strongly dependent on temperature. This indicates the importance of ambient conditions in the food production process, including animal husbandry and slaughtering, to avoid the adverse effects of a warmer climate (IPCC, 2001).

Indirect effects of disasters can damage the health care sector. Environmental refugees could present the most serious health consequences of climate change. Risks that stem from overcrowding include virtually absent sanitation; scarcity of shelter, food, and safe water; and heightened tensions—potentially leading to social conflicts (IPCC, 2007).

3. Mitigation

3.1. Policy implementation

Policies to price greenhouse gases, and support technology development, are fundamental to tackling climate change. However, even if these measures are taken, barriers and market imperfections may still inhibit action, particularly on energy efficiency (Stern Review, 2007). General approaches for policy design can involve:

Tradable permits: establishes a carbon price. The volume of allowed emissions determines their environmental effectiveness, while the allocation of permits has distributional consequences. Fluctuation in the price of carbon makes it difficult to estimate the total cost of complying with emission permits.

Financial incentives (subsidies and tax credits) are frequently used by governments to stimulate the development and diffusion of new technologies. While economic costs are generally higher than for the instruments listed above, they are often critical to overcome barriers.

Voluntary agreements between industry and governments are politically attractive, raise awareness among stakeholders, and have played a role in the evolution of many national policies.

Information*:* Policies to promote: performance labels, certificates and endorsements; more informative energy bills; wider adoption of energy use displays and meters; the dissemination of best practice; or wider carbon disclosure help consumers and firms make sounder decisions and stimulate more competitive markets for more energy efficient goods and services.

RD&T can stimulate technological advances, reduce costs, and enable progress toward stabilization

Fostering a shared understanding of the nature and consequences of climate change and its solutions is critical both in shaping behavior and preferences, particularly in relation to their housing, transport and food consumption decisions, and in underpinning national and international political action and commitment. Governments cannot force this understanding, but can be a catalyst for dialogue through evidence, education, persuasion and discussion. And governments, businesses and individuals can all help to promote action through demonstrating leadership.

3.2. Education and capacity building

Environmental education is one of the principal alternatives to create an environmental conscience in the general public. Simple actions such as reducing energetic costs, water savings and a significant reduction of greenhouse gases may be accomplished by educating the general public.

These are some of the actions that the South American population may undertake to reduce the ecological footprint of the region, independently of culture or nationality:

- Switch off lights, appliances and equipment when they're not needed.
- Install energy-efficient compact fluorescent lamps.
- Divert garden and food wastes from landfill to composting (either at home or through a Council scheme).
- Manage home heating and cooling by insulating, draught-sealing and shading, while setting thermostats appropriately.
- Cut hot water usage by installing a water-efficient showerhead, taking shorter showers and using cold water clothes washing.
- Switch off your second fridge except when it's really needed.
- Switch to low greenhouse impact transport options like bicycle or public transport - or use phone or email.
- Minimize waste of packaging and materials - refuse, reduce, re-use, recycle

In the South American region it is imperative to increase the quality of education creating incentives for professionals willing to participate in environmental education. A few possible alternatives are the involvement of national and private enterprises to increase the awareness of the general public, through marketing campaigns, increasing the resources for education and support rural communities to develop environmental programs.

3.3. Forest conservation or reforestation

Forest conservation or reforestation

Tropical forests ecosystems function as both a sink and a source of atmospheric CO_2. Forests uptake carbon through photosynthesis, but also emits carbon through respiration, decomposition of organic material and fires due to anthropogenic or natural causes. Managing forests in order to retain and increase their stored carbon will help to reduce the rate of increase in atmospheric CO_2 and stabilize atmospheric concentrations.

Forest management practices that can restrain the rate of increase in atmospheric CO_2 can be grouped into three categories: (i) management for carbon conservation; (ii) management for carbon sequestration and storage; and (iii) management for carbon substitution. Conservation practices include options such as controlling deforestation, protecting forests in reserves, changing harvesting regimes, and controlling other anthropogenic disturbances, such as fire and pest outbreaks. Sequestration and storage practices include expanding forest ecosystems by increasing the area and/or biomass and soil carbon density of natural and plantation forests, and increasing storage in durable wood products. *Substitution* practices aim at increasing the transfer of forest biomass carbon into products rather than using fossil fuel-based energy and products, cement-based products and other non-wood building materials (IPCC, 2007).

The causes of deforestation range from clearing of forest land for agriculture, mineral extraction and hydro-reservoirs to degradation of forests for fuel wood. Land cleared for agriculture may eventually lose its fertility and become suitable only as rangeland. Socio-economic and political pressures, often brought about by the needs of growing populations living in marginal areas at subsistence levels, are principal factors causing deforestation in much of the tropics. In Brazil, on the other hand, private companies and private entrepreneurs are major agents of deforestation, clearing land for cattle ranches that often derive part of their financial attractiveness from land speculation.

Figure 6 shows the ten countries with the largest forest area. Two countries in the South America are included: Brazil and Peru. However, in these regions has been observed a great reduction in the forest area (Fig.7).

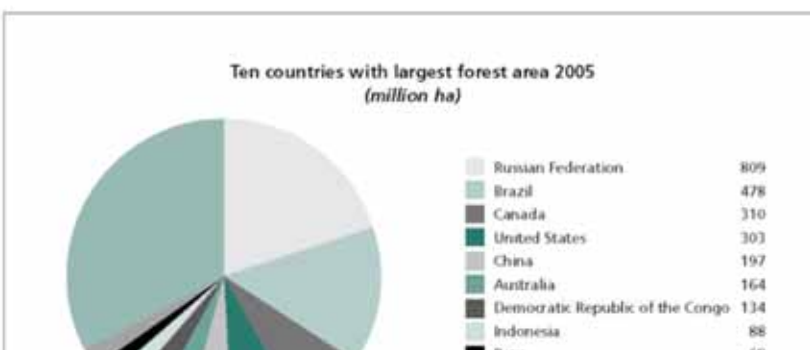

Figure 6. Ten countries with largest forest are in 2005. Source: FAO.

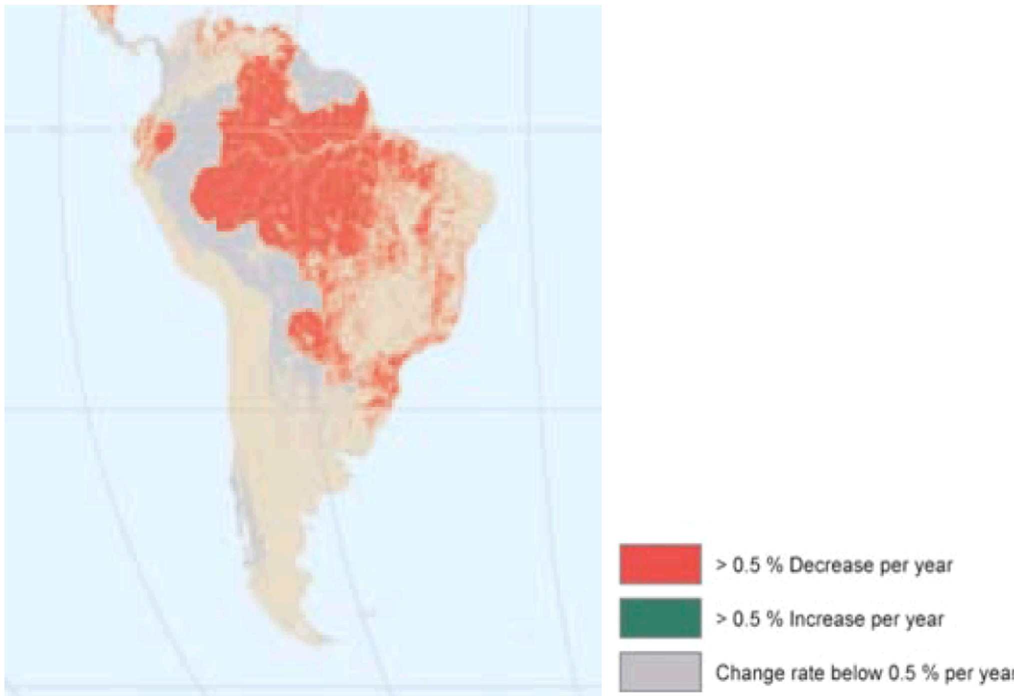

Figure 7. Net change in forest area between 2000 and 2005- Source: FAO.

In the whole region, Brazil has the biggest potential for CO_2 mitigation by reducing the speed of forest loss due to deforestation as opposite to reducing the consumption of fossil fuels or other activities. The deforestation in the Brazilian Amazon emits approximately 250 – 350 x 10^5 annual tons of carbon, this number dwarfs the annual emissions of carbon due to fossil fuels (60 x 10^5 tons) (Graça and Ketoff, 1992).

The Brazilian government has adopted explicit measures and policies to halt further deforestation. For instance, in June 1991, the Brazilian government issued a decree (No. 151) suspending the granting of fiscal incentives to new ranching projects in Amazonian forest areas in order to further decrease the annual rate of deforestation (which, as a consequence of economic recession, had reduced to 1.1 Mha for 1990–91 from 2 Mha/yr during 1978–88). The long-term impact of this decree is not yet known, but additional measures could be applied if necessary (IPCC, 2007).

The goal to reduce the fast deforestation process of the Amazon forest by the Brazilian government has influenced the creation of units for integral protection (Eg: national parks, ecological stations and natural preserves) and units of sustainable development. All of them controlled by the Sistema Nacional de Conservação da Natureza (SINUC).

3.4 Energy, transport, Industry and research

In the 2007 IPCC report the working group III propose several strategies on the mitigation issue. It also divides the problem in short and medium term (until 2030) and long term (after 2030). For this IPCC identifies key technological mitigation solutions as described in table 1.

Table 2: Key mitigation technologies and practices by sector

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Table SPM 3: *Key mitigation technologies and practices by sector. Sectors and technologies are listed in no particular order. Non-technological practices, such as lifestyle changes, which are cross-cutting, are not included in this table (but are addressed in paragraph 7 in this SPM).*

Sector	**Key mitigation technologies and practices currently commercially available.**	**Key mitigation technologies and practices projected to be commercialized before 2030.**
Energy Supply [4.3, 4.4]	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of CCS (e.g. storage of removed CO_2 from natural gas)	Carbon Capture and Storage (CCS) for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy, including tidal and waves energy, concentrating solar, and solar PV.
Transport [5.4]	More fuel efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorised transport (cycling, walking); land-use and transport planning	Second generation biofuels; higher efficiency aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries
Buildings [6.5]	Efficient lighting and daylighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulation ; passive and active solar design for heating and cooling; alternative refrigeration fluids, recovery and recycle of fluorinated gases	Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; solar PV integrated in buildings
Industry [7.5]	More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non-CO_2 gas emissions; and a wide array of process-specific technologies	Advanced energy efficiency; CCS for cement, ammonia, and iron manufacture; inert electrodes for aluminium manufacture
Agriculture [8.4]	Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions; improved nitrogen fertilizer application techniques to reduce N_2O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency	Improvements of crops yields
Forestry/forests [9.4]	Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use	Tree species improvement to increase biomass productivity and carbon sequestration. Improved remote sensing technologies for analysis of vegetation/ soil carbon sequestration potential and mapping land use change
Waste [10.4]	Landfill methane recovery; waste incineration with energy recovery; composting of organic waste; controlled waste water treatment; recycling and waste minimization	Biocovers and biofilters to optimize CH_4 oxidation

Although all this technologies can be potentially applied to South America, CO_2 emissions account only for 6% of the total world emissions. Since this is closely related to energy consumption, further consideration should be taken into account when applying IPCC recipes to these southern countries.

This is an analysis of the current situation and short and medium term mitigation technologies for each sector of South America:

- Energy: as stated by UNEP and the World Bank, in the year 1997 the region produced about 80% of the electric power from hydroelectric sources, the rest being some kind of hydrocarbon-fired generation and nuclear power.
  Advances in generation like micro-hydroelectric power and in electricity transport as direct current power lines are rapidly changing the efficiency of the electric power, hoping for an even cleaner scenario.
  Although clean, electricity is not widely available in poor areas of South America, so governments should implement modern power generation and transportation for this portion of the population.
- Transport: public transportation is based primarily in networks of roads, buses and trucks. More railroads with electric engines should be built to assure a solid growth with a minimized carbon emission impact.
  Eco-friendly biofuel has been in use in Brazil for several years now. Less practical natural-gas powered vehicles are very popular in Argentina. But the rest of the region relies on gasoline and diesel powered vehicles. In this aspect IPCC recommendations would be an important alternative for the region.
- Buildings: in such a heterogeneous climate region, buildings have very different characteristics throughout South America. It is also true that there is a deficit of residential buildings, so when designing new constructions IPPC advice should be taken into account.
- Industry: industrial activity is an important source of pollutants in South America. Lack of enough government control can be found in most of the countries of the region. Increased government direction and more environmental sensitive legilation is needed.
- Agriculture / Forestry: international market of agricultural commodities drive the South American land use. Forests are being devastated every day to make space for increased production of these goods principally associated with the increase of the agricultural fields.
- Waste: serious threats for human health produced by methane emissions of landfills are being neglected in countries such as Argentina.

4. Adaptation

4.1 Economy and adaptation potential:

Adaptation has the potential to reduce adverse impacts of climate change and to enhance beneficial impacts, but will incur costs and will not prevent all damages. Extremes, variability, and rates of change are all key features in addressing vulnerability and adaptation to climate change, not simply changes in average climate conditions. Human and natural systems will to some degree adapt autonomously to climate change. Planned adaptation can supplement autonomous adaptation, though options and incentives are greater for adaptation of human systems than for adaptation to protect natural systems. Adaptation is a necessary strategy at all scales to complement climate change mitigation efforts (IPCC, 2001).

The ability of human systems to adapt to and cope with climate change depends on such factors as wealth, technology, education, information, skills, infrastructure, access to resources, and management capabilities. There is potential for developed and developing countries to enhance and/or acquire adaptive capabilities. Populations and communities are highly variable in their endowments with these attributes, and the developing countries, particularly the least developed countries, are generally poorest in this regard. As a result, they have lesser capacity to adapt and are more vulnerable to climate change damages, just as they are more vulnerable to other stresses. This condition is most extreme among the poorest people (IPCC, 2001)

The table below shows the distribution of population and wealth in the South American countries.

Table 3. Population and GDP by country.

Country	**Population**	**GDP (millions USD)**	**GDP per capita**
Argentina	32615000	300000	8000
Uruguay	3308500	21060	6591
Venezuela	23242000	115900	4690
Chile	15300000	70000	4660
Brazil	160000000	591367	2872
Surinam	431000	1480	2454
Perú	25700000	54250	2170
Colombia	43000000	89400	2080
Paraguay	5434000	8608	1629
Ecuador	12640000	13921	1100
Bolivia	7800000	8617	1058
Guyana	705000	721	846

The capacity to access technologies for this region is highly limited by the distribution of wealth; the only two industrialized countries in the Americas (USA and Canada) have a PIB per capita of 43,500 and 35,200 USD respectively.

Table 4. External debt and expenditure shares for R&D and education by country.

Country	**DOD (external debt in millions)**	**Research and development (%) GDP**	**Per Capita Social Public Expenditure, Education (Constant 2000 USD)**

Argentina	169,247	0.41	384
Bolivia	6,096	0.28	53
Brazil	222,025	0.98	129
Colombia	37,732	0.17	191
Chile	44,058	0.61	85
Ecuador	168,676	0.07	22
Paraguay	34,326	0.1	62
Peru	31,296	0.1	51
Uruguay	123,757	0.26	196
Venezuela	35,569	0.28	241

Further, when aggregated to a global scale, world gross domestic product (GDP) would change by ± a few percent for global mean temperature increases of up to a few °C (low confidence), and increasing net losses would result for larger increases in temperature (medium confidence) More people are projected to be harmed than benefited by climate change, even for global mean temperature increases of less than a few °C (low confidence). These results are sensitive to assumptions about changes in regional climate, level of development, adaptive capacity, rate of change, the valuation of impacts, and the methods used for aggregating monetary losses and gains, including the choice of discount rate.

The effects of climate change are expected to be greatest in developing countries in terms of loss of life and relative effects on investment and the economy. For example, the relative percentage damages to GDP from climate extremes have been substantially greater in developing countries than in developed countries (IPCC, 2001).

4.2. Risk management

Although climate change is mostly expressed in gradually changing average temperatures and mean precipitation, it is well known that it may express itself in more extreme weather events and increased variability of weather, e.g. less rain in dry season and stronger single rainfall events during rainy seasons (Stern Review 2007). Extreme events, such as flooding and storms, are also expected to occur on a more frequent basis.

For agriculture and forestry, but also for other providers of goods and services, e.g. Tourism, energy, and other industries, this means that production risk that arises from ecosystem service provision will increase.

4.2.1. Agriculture and Forestry

Production risks in agriculture and forestry are expressed in increased yield variability, which in turn reflected in private firm profits or farm-household income.
Depending on local environmental and institutional conditions, farmers have therefore developed a variety of risk coping strategies that are summarized in table 5 based on Fafchamps (2003).

Table 5: Risk coping strategies

Strategy	Forms of the Strategy
Reducing exposure to shocks	1. Selecting and modifying environments 2. Specialization 3. Diversification 4. Self-sufficiency 5. Flexibility
Saving and liquidating assets	1. Seeking wage income 2. Liquidating productive assets 3. Reducing consumption to keep productive assets 4. Labor bonding and debt peonage 5. Precautionary saving 6. Borrowing
Risk sharing	1. Households, groups, associations 2. Gifts, transfers (e.g. Remittances) 3. Insurance 4. Interlinking and patronage 5. Contracts (e.g. With merchants)

Source: Fafchamps (2003)

That some of these strategies appear contradicting owes to the diversity of ecological, institutional and socio-economic conditions in which farm-households operate. Drought-plagued northeastern Brazilian farmers might rather specialize in drought resistant crop production, while farmers in the western Amazon would tend to diversify production to buffer against unexpected inundations after heavy rainfalls.

The same holds for plantation forestry, where genetic, species diversification and fire control rank highest among risk coping strategies.

R&D in drought resistant crop species has until today mainly focused on crops that are typically grown in semi-arid and arid regions, but may soon become an important source of new and adapted germplasm for tropical regions.

Another already existing means to buffer the risks involved in agricultural and forestry activities are yield and natural asset insurances. The Brazilian PROAGRO Program, for example, insures Brazilian farmers against yield losses, especially if plantations are credit financed.

In general it appears necessary that new technologies for climate change adaptation will have to be adopted at ever increasing rates in order to avoid that some, primarily poor, farmers become even more marginalized through climate change.

Studies on technology adoption all over the world have shown that one of the main factors that contribute to technology adoption is rural extension (e.g. Pattanyak et al.

2003). Mainstreaming climate change in rural extension programs, therefore, seems to be a meaningful risk coping strategy.

4.2.2. Risk management in other sectors

A recent review by a global wealth managing firm reveals that the private sector expects both risks and opportunities from climate change.

Table 6. Risks and opportunities

Risks related to climate change			
Regulatory risk from high direct emissions	Aluminum	Cement	Chemicals
	Oil and gas	Power utilities	Steel
Regulatory risk from high indirect emissions	Automotive	Aviation	Buildings
	Electronic equipment	Oil and gas	
Physical and operational exposure	Agriculture & fisheries	Forestry	Insurance
	Real estate	Tourism	Water utilities

Source: UBS

Opportunities related to climate change			
Renewable energy sources	Biofuels	Geothermal	Hydro
	Photovoltaic	Solar thermal	Wind
Energy efficiency processes and products	Combined heat and power	Automotive drive trains (hybrid, fuel cell)	Energy efficient appliances
	Heating, ventilation and cooling	Lighting	Lightweighting
	Traffic infra-structure technology	Thermal insulation	White biotechnology

Source: UBS

Many of these risks are not directly related to the impacts and consequences of climate change in natural systems, but rather related to the likely policy action that arises from it. In the private sectors of developed countries, severe risks are traditionally covered by insurances. Mills (2003) shows that in developing countries insurance penetration averages merely U$ 25 per capita as compared to U$ 2750 per capita in developed countries. Nevertheless, already today, the insurance payouts for weather-related disasters are three times higher than transfers through international aid.

As shown in Figure # (E), the increasing incidence of weather related damages has already led to a gradual increase in insurance premiums. This trend, which is likely to continue in the future, will make it ever more difficult for developing country enterprises to remain competitive on international markets.

Especially the increasing incidence of extreme weather events, which is hard to predict, is likely to result in overprices insurance premiums or complete withdrawal of insurance from certain markets. The insurance of climate change related risks is therefore likely to become an issue for increased cooperation of governments, private sector, and insurance companies as well as R&D.

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PART IV. SYNTHESIS OF RECOMMENDATIONS

The following recommendations are compiled from a review of the Southern American, Mesoamerican, and Northern American sections:

1. Reductions of greenhouse gas emission

It is absolutely vital that greenhouse gas emissions from all countries in North and South American be reduced. Several options include:

Continental carbon trading programs. Market based approaches may be one of the best methods to reduce emissions, and all North and South American countries should be encourage to participate in a program. The N.A. Recommendations section future discusses trading programs.

Estimation of the capacity of different species and ecosystems to store and capture carbon. Particularly due to the vast biodiversity of Latin American and Southern American countries, further research is needed into understanding the ability of ecosystems to capture and store carbon. This research effort would be vital to a comprehensive carbon trading program, but would also be important to guide other policy efforts to sequester carbon.

Incentives for carbon sequestration. Comprehensive emission reduction policies must include incentives for carbon sequestration. For example:

- *Specific incentives to preserve carbon sink areas.* For example, incentives to preserver mangrove forests.
- *Incentives to manage land use.* For example, riparian corridors
- *Technical means of carbon sequestration.* For example, carbon injection

Significant changes in energy use. The vast majority of energy in North and South America is produced by fossil fuel emissions. As part of a concerted effort to reduce emissions, this must be addressed through both more efficient use of fossil fuels and increased usage of alternative energy. See the North American Recommendation section for additional details.

Transportation. Transportation plays a critical role in global economies, yet is responsible for over a third of global greenhouse gas emissions. These emissions must be reduced as part of a comprehensive greenhouse reduction strategy. See the North American Recommendation section for additional details. Specific discussion in the N.A. section includes:

- *Energy efficient vehicles incentives.*
- *Incentives for the use of alternative fuels.*
- *Legislations of fuel economy standards.*
- *Policies to encourage public transportation.*

2. Population Management

Planning for Growth and Development. Population growth is occurring rapidly in all pan-American countries, and this growth must be managed to minimize carbon production as much as possible. See the North American Recommendation section for additional details on population management.

Incentives for population management. While often a difficult subject for both political and religious reasons, stabilization and reduction of population must be considered.

- Family planning and sexual education.
- Removal of tax incentives for families having more than two children.

3. Water Planning

Planning for water security. Different climate models indicate a range of possible changes in precipitation regimes across Pan America in response to climate change. Therefore, these countries need to consider plans for ensuring the security and equitable distribution of fresh water resources to all ecosystem components, including humans (see NA and MA sections for more specific information). We also recommend improving waste-water infrastructure and health plans to deal with human health concerns arising from changes in precipitation intensity.

International Law with Regards to Water. Furthermore, as an international group, we recognize that water is shared among countries but its' quality and availability is currently determined by provincial, state, and federal laws that do not necessarily (particularly the USA) follow the recommendations for water use issued by the World Bank. Therefore, it is necessary to re-evaluate water use and current implication of water laws (Western Water Law, for example). Following these guidelines will help to prevent water conflicts and evenly distribute water resources.

4. Planning for Resettlement

Individual countries must begin planning now both to cope with extreme events and for the need to consider resettlement options. Rising sea level, melting permafrost, and decreasing water resources will make resettlement a requirement for many people throughout North and South America.

5. Need for Additional Research

- *Increased research at the regional level to understand local climate change effects.* While North American countries have a plethora of climate data readily available, South American and Latin American countries do not enjoy the same amount of climate information. Because climate change is a global problem, we must have global information on the problem.
- *Estimation of capacity of different species to capture carbon*
- *Additional research on technical means of carbon sequestration*

6. Continued International Collaboration by Developing Interdisciplinary and Collaborative Projects

Effective and applied research projects of mitigation and adaptation to climate change requires an understanding of the complex relationships between the natural and social systems. To achieve this understanding requires dialogue and collaboration between the natural and social sciences disciplines. Moreover, applied research that can make significant contribution to policies to guide behavioral changes requires meaningful dialogue and engagement with stakeholders—including governments and industry—and civil society.

One avenue for achieving the goals of the Pan American Advanced Science Institute on Global Climate Change in the Americas of understanding climate change issues from an interdisciplinary perspective, and to foster and support collaboration between the various disciplines as well as between researches from the various Pan American countries, is through the development of interdisciplinary and collaborative projects.

Given the distinct perspectives of each natural and social sciences discipline, intellectual history, theoretical context and analytical approaches, effective dialogue and collaboration between the disciplines can pose significant challenges. Therefore, it is necessary to strive for finding commonalities and convergence among the disciplines collaborating in a research project.

One example of a climate change research project that has developed a common conceptual and methodological framework in integrating natural and social sciences disciplines is the Institutional Adaptation to Climate Change Project (IACC) (http://www.parc.ca/mcri/) that brings together researches from natural and social scientists from Canada and Chile. The IACC project developed a framework based on a vulnerability assessment model, which utilizes the concepts of exposure, adaptive capacity, and vulnerability, all of which can be applicable to natural and social systems. Both natural and social systems can be exposed to climatic stimuli, both have adaptive capacity, or lack of, to cope with the climatic stimuli, and both are vulnerable to climatic impacts as a function of their exposure and adaptive capacity.

Another potential conceptual and methodological approach is the use of a sustainability framework, which can be applicable to both natural and social systems, i.e. the continuous functioning of social and natural systems requires that the components of the systems be maintained and managed in a manner that does not jeopardize the function of the system.

Specific recommendations include:

- *Potential collaborative projects among the PASI participants should adopt or develop conceptual and methodological frameworks applicable to social and natural systems.*
- *Projects should whenever possible engage industries, governments, NGOs and civil society as partners in the project.*

- *Whenever possible, the projects should implement participatory action research methods which can help in the engagement of stakeholders and the adaptive capacity of those involved.*
- *Projects should have an outreach and educational components.*

Next steps include:

- *Develop a list of PASI participants committed to exploring collaborative research projects*
- *Maintain communication among interested participants*
- *Identify research projects and funding opportunities*