Understanding the potential impact of Climate Change and Variability in Latin America and the Caribbean

EXECUTIVE SUMMARY

Countries in Latin American and the Caribbean (LAC) are significantly affected by adverse consequences from climate variability and extremes, particularly the ENSO events. The Region's economy is strongly dependent on natural resources linked to climate, and patterns of income distribution and environmental degradation are a constraint for adaptation and exacerbate the impacts for specific sub-regions, countries and populations. However, only 19% of the climate-related damage costs have been quantified for the period 2000-2005 accounting for 0.15% of GDP. Thus, actual average yearly costs could reach up to ?0.7% of GDP. Estimated damages due to warming by the 2050s vary from ?1.3% to 7% of GDP, suggesting that the impacts of projected climate changes are important enough to be taken into account in planning initiatives. Based on vulnerability and consumption indicators related to past and future global warming, the LAC region can be placed close to the world's average indicating lower vulnerability within non-Annex 1 countries' average. Vulnerability indices place Haiti, Bolivia, Honduras, Nicaragua, Ecuador, El Salvador, Belize, Paraguay, Guyana and the small Caribbean states as the most vulnerable countries.

Focused primarily on LAC region and sub-regional scales, Section I describe summarily the potential direct impacts of climate change and variability on:

- Income, in terms of GDP generation, damages on infrastructure, and specifically on agriculture sector issues;
- human development, particularly related to human health; and,
- the environment, specifically biodiversity, water resources and coastal zones.

Country-level relevant examples (i.e. climate-related disasters, past and current variability) and, particularly, the current situation in relation to economic, human and natural system indicators are given as to illustrate on the type of climate risks and the scope for and constraints to adaptation that the Region faces.
This is mainly the approach in Section II.

The considered sub-regions are named as follows: Brazil-Bz; Andean countries-AC; Rio de la Plata-RP; Mexico and Central America-MA; and the Caribbean-Cb (fig. 1). Peer-reviewed literature; National Communications to the UNFCC; data-bases and reports were the sources for the present work.

Section I - Future climate change. This section deals with the quantification of impacts linked to Increases in global average temperatures, 1°C - 6°C, and the associated sea level rise (SLR), changes in precipitation, and increase in extreme weather events. Socio-economic scenarios without climate change and expected climate changes are summarised in tables 1 and 2 respectively.

Table 1. Current and Future Socio-Economic Scenarios (2025-2050; SRES A2-B2)

Current and Future Socio-Economic Scenarios			SRES A2		SRES B2	
Indicator	Unit	2004	2025	2050	2025	2050
Population	*M of people*	541,3	714,4	926,7	804,1	1,136.8
Population growth	*annual variation*	1.4%	1.3%	1.2%	1.9%	1.6%
GDP	*Current $ M*	2,000.000	4,203.246	9,372.519	4,553.856	10,908.918
GDP per capita	*Current $ /inhab*	3,789	5,884	10,114	5,663	9,597
GDP growth	*annual variation*	6.0%	3.6%	3.4%	4.0%	3.8%
VA in agriculture	*% of GDP*	6.7%	3.1%	3.4%	4.4%	2.9%
VA in industry	*% of GDP*	22.8%	20.3%	20.7%	28.9%	27.7%
VA in services	*% of GDP*	70,5%	76,7%	75,9%	66,8%	69,3%

Table 2. Expected climate changes. SS America includes RP, Southern Bz and Chile.

<table>
<tr><th>Time-slice</th><th>Region</th><th>Temperature (Δ in °C)</th><th>Precipitation (Δ in %)</th><th>runoff</th><th>extreme events</th><th>SLR (cm)</th></tr>
<tr><td rowspan="4">2015 - 2025</td><td>Cb</td><td>+0.5 – +1.1</td><td>-7 – +14</td><td rowspan="12">The glacier that supplies water resources to the city of La Paz (Bolivia) is predicted to melt in the next few years.

It is likely to expect 10-40% increases in SSA (RP basin) and less in Peru, Ecuador and southern Colombia.

Shortages are expected in Central Chile, Patagonia, MA, most of the Cb, Venezuela, the Guyanas, Amazonian and NE-Bz.</td><td rowspan="12">It is likely to expect that warming / cooling might have an increasing / decreasing effect on the intensity of the most severe storms, both in tropical and extra-tropical regions.</td><td rowspan="4">7-9</td></tr>
<tr><td>MA</td><td>+0.4 – +1.7</td><td>-10 – +7</td></tr>
<tr><td>Amazonian</td><td>+0.5 – +1.8</td><td>-10 – +6</td></tr>
<tr><td>SSA : Southern South America</td><td>+0.6 – +1.2</td><td>-5 – +5</td></tr>
<tr><td rowspan="4">2040 - 2260</td><td>Cb</td><td>+0.8 – +2.3</td><td>-40 – +30</td><td rowspan="4">12-15</td></tr>
<tr><td>MA</td><td>+1.0 – +4.0</td><td>-15 – +3</td></tr>
<tr><td>Amazonian</td><td>+1.0 – +4.0</td><td>-20 – +10</td></tr>
<tr><td>SSA</td><td>+1.0 -- +3.0</td><td>-12 – +10</td></tr>
<tr><td rowspan="4">2070 -2090</td><td>Cb</td><td>+1.0 – +4.0</td><td>-60 – +20</td><td rowspan="4">22-37</td></tr>
<tr><td>MA</td><td>+1.0 – +6.6</td><td>-30 – +8</td></tr>
<tr><td>Amazonian</td><td>+1.6 –+7.5</td><td>-40 – +10</td></tr>
<tr><td>SSA</td><td>+1.8 – +4.5</td><td>-12 – +12</td></tr>
</table>

I.1 Income effects. Agriculture will be the most affected income sector by temperature increase and rainfall changes, followed by energy. Infrastructure will be affected by extremes in wind, rainfall and runoff and beyond the 2080s by SLR in coastal zones.

I.1.1. Agriculture. The aggregated impact in productivity is estimated to vary from –9% (HADCM-3 / A2 without fertilisation by $C0_2$) to -2% (A2 + $C0_2$) by the 2050s. Most economically impacted countries are those of MA. In Southern SA crops would be benefited (especially soybean) if CO_2 effects were considered. Inversely without considering CO_2 effects, yields could be reduced but with a lower impact. It is likely that duplicating the variance of temperatures maize yields could suffer stronger reductions.

By 2055 subsistence farmers' maize production -the main source for food security- in the AC and Central American could decrease on an average by 14%.

I.1.2. Energy. Projections based on a decrease in the inequity in the distribution of income result in energy scenarios that multiply by more than 2 the Total Primary Energy Supply-TPES by 2055. It is very likely that climate change will impact hydro-power, depending on sub-regional runoff changes and the very likely severe growth in the electricity demand due to increases in temperature (+2ºC) and population (+75%).

I.1.3. Infrastructure. Assuming current conditions and without adaptation measures, it is likely to expect a minimum accumulated cost of floods of $ 30 bn for the period (2006-2025) or ~1.5% of GDP (2004). Under climate change estimations are still partial and diverse.

I.1.4. GDP. Beyond 2ºC, by 2050-2060, without adaptation, expected losses totalise between 1.3 and 7.3% in terms of GDP. The latter includes expansion of losses in agriculture and the quantification of all climate disasters.

I.2. Human development effects. It is expected that climate change will exacerbate the vulnerability of people and pose new threats such as availability of fresh water supplies and efficiency of local sewerage systems; availability of food; distribution and seasonal transmission of vector-borne infectious diseases.

I.2.1.Health. Dengue transmission will likely increase by 2 to 5 folds by the 2050s in most areas of SA and it is also likely that new transmission areas will appear in the south half of the continent and at higher elevations. The projected number of water-stressed watersheds under climate change scenarios in 2025 would imply that 106 M people would live with severe problems to have access to safe water instead of 36M without climate change (+68%). Mitigation investments will amount $16,500 M. Tropical Andean glaciers are predicted to melt between 2010 and 2050 affecting the supply of water to a large fraction of the population living west of the Tropical Andes. People living at risk zones are estimated to reach up to about 37 M in 2020 and 50 M in 2050. Particularly affected will be the cities of Quito, Lima and La Paz (i.e. the glaciers El Tuni condoriri and Chacaltaya close to El Alto and La Paz will completely melt by 2009 and 2015 respectively).

I.3. Environmental effects. Several scenarios show the impacts for runoff, wildfires and biome change. The reduction of tropical forests will likely imply the loss of biodiversity, i.e. 24% of tree species of the Central Brazil savannas by 2050 for a projected increase (HADCM-3/A2 and B2) of 2º C in surface temperature. Warming could also sharply increase species extinction in Mexico and in dry areas of Bolivia, Chile and Argentina. The most vulnerable biodiversity hotspots under a 2 x $C0_2$ warming scenario are the Caribbean, the Tropical Andes and the Atlantic forest. A 'savannization' of central-eastern Amazonian is also projected.
Projected scenarios of water-stress (in Million people) at watershed level without and with climate change are shown in table 3.

Table 3. Water-stressed people at watershed level projected by HADCM-3-A2.

Year / Million people	Without Climate Change			With Climate Change		
	MA	Cb	SA	MA	Cb	SA
2025	36		20	32-35	0-22	14-33
2055	105	36	45	74-108		70
2080	175	48	88			

Along the Atlantic coast of MA and the CC, less in SA, storm surges, SLR and warming could severely impact infrastructure, coastal cities, populations, natural habitats and tourism by the 2060s. There is a lack of assessments of their combined effects. Recent partial estimations predict that displaced people will reach about 0.4 to 0.7 M at the 2080s and the 2100s, with land losses of about 30 – 58 x 10^3 km^2, most of which of rich in biodiversity and eco-services wetlands. Damage costs would attain about 0.3 – 1.0% and 0.5 – 2.0% in terms of aggregated GDP at the 2050s and the 2080s respectively, in addition to very expensive protection costs (if adopted). These figures seem greater than those estimated for a full quantification of climate-disasters under current conditions (up to ?0.7% of GDP).

Section II - Recent past and current climate variability

Climate and climate impacts. ENSO signal is strong in most LAC. During *El Niño* high rainfall often occurs in the AC and in the RP basin, followed by floods, whereas drought occurs in the NE-Bz and wide regions over Amazonia. *La Niña* usually has a shift in signal. In Brazil, Uruguay and NE Argentina there is also a signal from tropical Atlantic sea surface temperature anomalies, affecting seasonal climate, especially the actual precipitation patterns. Sub-regions have different records in terms of disaster occurrence and impacts. About 50% of the disasters occur in SA as well as 65% of the fatalities, 75% of the population affected and 53% of total damages. Nevertheless, SA's exposure to risk is less than in MA or the Cb. MA has a greater proportion of population killed than SA does and the Cb has a greater proportion of affected population than SA. In terms of damages, cumulative losses for 1970-99 represent only 3.9% of the combined GDP of SA countries, whereas they amount to 43% for the Cb. The number of climate-related disasters per year between the periods 1970-99 and 2000-2005 increased by 2.4 times, continuing the trend observed during the 1990s. Likewise, during the latter period the quantification of damages only attained 19% of all disasters. The occurrence of wind-storms, river floods and droughts during the period 1970-2005 was around 9, 14 and 2 per year (Table 4), increased since the 1990' and totalised 82% of natural disasters. Their estimated damages on agriculture were $ 40, 36 and 11 bn respectively due to decreases in both crops and livestock production. The three of them affected land conservation and livelihood quality. The affected rural population was 30, 50 and 66% respectively. Droughts in particular affected planted surface, grasslands, eco-services, employment, BoP and widened social inequity. Floods increased hydro-power generation by 20-30 % and droughts decreased generation by 30-60%.

Table 4. Average occurrence (events per year) of climate-related disasters in the LAC region.

Period / Occurrence	Climate disasters	Wind-storms	Floods	Droughts
1970-1999	25	7	12	5
2000-2005	61	19	28	2
1970-2005	31	9	14	2

Losses in fluvial transportation in the Magdalena river (Colombia) during low-waters associated with El Niño 1997 attained $ 3.9 M. The impact of floods on infrastructure totalised around $ 40 bn for the period 1970-2005, 20% of which on roads and bridges.

As for human development, the impact of floods on life exposure (in Nº of people), physical exposure (in % of population) and killed people (per M exposed) was around 2,000, 20 and 34 per year respectively.
Since 2003 economic losses related to climate disasters have dramatically increased, i.e. a 2-3% decrease in GDP in MA and the Cb due to wind-storms (i.e. Hurricane Emily), and $ 0.9 bn loss in crops in Argentina due to a persistent drought affecting SSA since 2004/2005. Most environmental effects have not been estimated yet.

Scope for and constraints to adaptation

Income. Investment is still increasing too low to fuel the economies as to solve employment and population's general well-being problems. Skewed income distribution and poverty will continue to be the sources of constraints to adaptation.
Agriculture contributes 8% to the region's GDP, employs 30-40% of people and is the main source of exports in many countries. During the last few years extreme events disturbed the sector and food security risks increased in several countries as a consequence of successive economic crisis and extreme events, raising the vulnerability especially among the poor.
Fossil fuels account for 54% of primary energy and hydro-power generation 22%. The dependency of the electrical systems on hydro-power is 57%, thus they are highly dependent on water resources. However, it is likely that the region will be able to satisfy increasing demands by means of new dams' construction and interconnected transmission networks. Also, alternative sources of energy such as biomass, solar and nuclear should likely expand under high demand scenarios from < 5% in 2004 to about 10% in 2050 and 20% in 2080.

Human Development*.* LAC population is changing to a more urbanised, elderly, and with a lower rate of growth society. Population's yearly growth rate decreased from 2.7% in 1950 to 1.5% in 2000 and will decrease to 1.0 – 1.3% by 2050. Growth is greater in central age-classes and will turn to an increase of the class > 60 years by 2050, a situation that will require both developing production and employment policies and new responses for elderly protection.
As for the access to drinking water, the AC sub-region shows the highest vulnerability and this situation may be exacerbated under the expected changes in water availability. There is higher vulnerability in rural areas where drinking water coverage is 69%, against 95% in urban areas. Nevertheless, the latter are affected by insufficient access to water and sanitation services involving particularly poor population in large cities. Glacier melting impacts are greater during the dry season. Local adaptation measures should target reservoirs storage to manage a shift in the seasonal cycle of runoff.
The increase in vector-borne, infectious and ENSO-related diseases, the re-emergence and increase of malaria, dengue and schistosomiasis are related to climate variability and disasters. There is a linear relationship between per capita income and mortality. Incidence of malaria is already important in Bz, AC and MA, and particularly high in Guyana and Suriname. Health status indicators such as the living expectancy index, the likelihood of not surviving the age of 40, malaria cases, access to drinking water, total and per capita low public expenditures (in terms of GDP) illustrate on the prevalence of high vulnerability among LAC countries, i.e. Bolivia, El Salvador, Nicaragua, Haiti, Honduras, Guyana, Suriname, Brazil.

Environment

Land-use (i.e. deforestation, over-grazing, intensive cultivation) and its interaction with climate drive changes in ecosystems making patterns of vulnerability highly diverse. Of great concern are the desertification processes brought about by these interactions. About 25% of LAC area corresponds to arid, semi-arid or sub-humid land presenting serious degradation problems.
The most water-stressed countries are the Cb small states, whereas the lesser ones are Bolivia, Peru, Paraguay and Chile. However, the retreat of glaciers in the AC and the west arid zone of Argentina due to global warming will very likely affect water resources.
Adaptation costs in the water sector would include monitoring of resources, technological adaptations, social and environmental assessments and hydro-plants planning. All these should be done in coordination with stakeholders, in order to mitigate the impact of large storage reservoirs on the health and well being of the community and ecosystems.

Expert judgment of eighteen proxies was utilized to rank our concerns for the period 1980-2080. For the 2080s they are ranked as follows: 1st Income: 1-agriculture, fisheries and livestock, 2- Infrastructure, 3- Energy, 4- Tourism. 2nd Environment: 1-biodiversity loss, 2-natural habitats, 3-eco-services degradation and loss. 3rd Human Development: 1-diseases, 2-loss of livelihoods, 3-food availability, 4- life losses. These proxies were rearranged according to the five capital concepts (natural, physical, financial, human and social): the natural capital is which possesses the greatest value.

Concluding messages from the study and key insights and observations.

- Beyond 2ºC, by 2060, without adaptation, expected loss in agriculture and in energy will account for 1.3% of GDP. This estimation should increase by 2 to 6-folds if expansion of losses in agriculture and the quantification of all climate disasters are included.
- The sector the most affected by climate change and variability is agriculture. The aggregated impact in productivity is estimated to vary from –9% (HADCM-3 / A2 without fertilisation by $C0_2$) to -2% (A2 + $C0_2$) by 2050.
- On broad sub-regional basis carbon fertilisation will likely benefit soybean (+31 to +40%) and, in a less degree, maize and wheat cultures in temperate SSA by the 2050s. On the other hand maize production in the AC and MA countries could decrease affecting food security in countries such as Belize, Guyana and Venezuela.
- The energy sector will likely be affected by warming and hydro-climatic changes as well as by demand growth at a cost up to 4-5 $ bn by the 2050s. However, the sector will very likely adapt to gradual changes by means of new dams' construction, interconnected transmission networks, and the use of alternative sources of energy.
- Coastal sectors (i.e. biodiversity, fisheries, tourism, and infrastructure) that are highly vulnerable to floods, sea level rise (SLR) and windstorms will very likely be damaged. For instance infrastructure damages due to climate extremes could increase from ?0.15% of GDP /year over the period 1970-99 to ?0.7% / year over the next few decades. Beyond 2° C, and without adaptation measures, damages due to SLR are roughly estimated to reach ?0.3% of GDP per year by the 2050s to ?2.0% by the 2100s.
- A large fraction of the population living west of the Tropical Andes will be affected by melting of glaciers between 2010 and 2050. People at risk of water supply for human consumption, hydro-power and agriculture are estimated to reach about 37 M in 2020 and 50 M in 2050. Particularly affected will be the cities of La Paz, Lima and Quito.
- Vector borne diseases i.e. malaria and dengue fever could potentially increase and spread southward. People living at risk zones could increase from 1.5 Million currently up to 50 M by the 2050s. The adaptation costs to face increase in malaria will likely be two times greater (from $1.4 bn currently to 2.8 bn by 2050).
- Under climate change scenarios mitigation investments in safe drinking water are estimated to amount $16,500 M (2000) during the period 2000-2015.
- The reduction of tropical forests will lead to the loss of biodiversity, i.e. 24% of tree species of the Central Brazil savannas by 2050 for a projected increase (HADCM-3 / A2 and B2) of 2º C in surface temperature.
- It is likely that warming will increase species extinction in the Amazonian, Mexico and in dry areas of Bolivia, Chile and Argentina. The most vulnerable biodiversity hotspots are the Caribbean, the Tropical Andes and the Atlantic forest.
- There is very likely an underestimation of pressures disasters can exert on social and human capitals. Small-scale disasters are likely to have been played down through lack of data. Likewise reported data on the cost of disasters relate predominantly to direct costs. For instance, only 19% of the damages have been quantified for the period 2000-05[This study]
- The number of climate-related disasters per year between the periods 1970-99 and 2000-2005 increased by 2.4 times, continuing the trend observed during the 1990s.

1. Introduction

1.1 Latin America and the Caribbean (LAC) countries are highly heterogeneous in terms of climate, ecosystems, human population distribution, economy and cultural traditions. Most countries in the region are significantly affected with adverse socio-economic consequences by seasonal to inter-annual climate variability and extremes, particularly the ENSO phenomenon. The LAC economy is strongly dependent on the region's extensive natural ecosystems and on natural resources linked to climate such as agriculture and hydro-power generation. Current impacts from climate variability and extremes suggest that impacts from projected climate changes could be important enough to be taken into account in national and regional planning initiatives. Natural systems are driven by two major forcings: climate change on the medium- to long-term and land-use changes on the short- to medium-term. The latter makes the task of identifying common patterns of vulnerability to climate change very difficult[1]. We are particularly concerned about the projected increase in frequency and in intensity of extreme events and implied risks from that change in climate variability[1]. LAC countries have extraordinary biodiversity threatened by deforestation, global warming, rainfall changes and associated biome changes and wild-fires**.** The warm and humid Amazonian low-lands, the high and cold Andean mountains, the tropical Andes; the Brazilian Atlantic forest, the continental wetlands, the dry forests of Meso-America and the coasts and waters of the Caribbean and Meso-America are home to some of the world's richest ecosystems[2]. Arid and semi-arid vegetation occurs in the Andean mountainous plateaux North-eastern Brazil, Patagonia and the Atacama Desert. Forest reserves are being depleted and soil degradation is accelerating. Poor air quality and inadequate access to clean water, sewage, and solid waste collection directly impact livelihood quality and health of the 75 % of the urban population[3]. Recent progress in development is at risk from increases in climate variability: Better policies are required now to reduce the impact on the poor[4].

1.2 Approach and Scale of Analysis*.* At present most costing studies have focused on modelling the impacts of climate change and extremes over large regions, so the differential impacts on countries are often lost[5, 6]. In this study changes and impacts are aggregated for Latin America and the Caribbean (LAC) and divided into five sub-regions named as follows. Andean countries (AC: Chile, Peru, Ecuador, Colombia and Venezuela), Brazil (BZ), Rio de la Plata (RP: Argentina, Paraguay and Uruguay), Mexico and Meso-America (MA) and the Caribbean (Cb: State Islands + Suriname and Guyana). The first three will often be mentioned as South America (SA). Some sectors and countries cannot be aggregated for LAC because of lack of data. We put the emphasis on the regional aggregation, averages, extremes and selected countries. However, adaptation decisions are made at lower levels of aggregation[3,5].

Peer-reviewed literature; National Communications to the UNFCC; data-bases and reports (i.e. WB, UNEP, ECLAC, Geo-Outlook, and Country Studies) were the sources for the present work.

While data on injuries is relatively robust, economic loss and livelihood impacts are generally not considered to be complete at this stage[7]. Although the reinsurance companies give more emphasis to economic assessments of disaster loss, this is unlikely to provide a clear picture of livelihood losses[3,8]. At the same time, there is likely an underestimation of pressures disasters can exert on social and human capitals. In particular, the contribution to livelihood failure, household collapse and poverty of slow-onset and small-scale disasters is likely to have been played down through lack of data. Likewise reported data on the cost of

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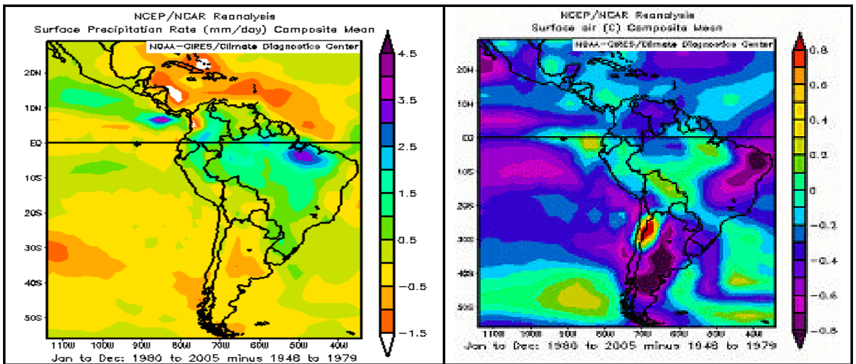
[1] Modified from IPCC, Climate Change 2001: Impacts, adaptation and vulnerability. TAR WG II, Cambridge Press Univ.
[2] GEO-outlook report (2000)
[3] Armstrong A (2002). Environment Matters 2002. Latin America and Caribbean Regional Office Environment Family Annual Review July 2001–June 2002.
[4] DFID (2004) Climate Change in Latin America
[5] Yohe, G. and Schlesinger, M. (2002): The economic geography of the impacts of climate change; Journal of Economic Geography, v. 2, no. 3, p. 311–41.
[6] Abler, D., Shortle, J., Rose, A. and Oladosu, G. (2000): Characterizing regional economic impacts and responses to climate change; Global and Planetary Change, v. 25, no. 1–2, p. 67–81.
[7] modified from ECLAC (2004) Statistical Year Book for Latin America and the Caribbean, 2004, G2264-P,
[8] World Bank Report (2001)

disasters relate predominantly to direct costs. Ongoing research suggests that the secondary effects of disasters can have significant impacts on long-term human and economic development[3, 4]. Our team believe that drought impacts have been underestimated.

1.3 Climate Setting. LAC countries have several types of climates showing strong inter-annual variability of precipitations and disaster occurrence often related to ENSO events and hurricane intensity and path. Mexico high plateaux have mid-latitude-like climates supporting temperate and even cold forests around the ever-snowy mountain peaks. Remaining MA and the CC have tropical climate with summer rainy season driven by the Inter Tropical Convergence Zone (ITCZ) trail. Exception made of Mexican western coast-side, these sub-regions receive eastern trade winds form the Atlantic and from warmer Gulf of Mexico and the Caribbean Sea. Extending from 10ºN to 60ºS, South America (SA) has features of tropical, subtropical and extra-tropical climate, with great influence of the surrounding oceans[9]. A distinct geographical feature is the steep and narrow Andes range extending all the way along the western coast. Another important feature is the Amazon jungle, occupying about 35% of the total continental area and 65% of the tropical area. SA also contains deserts (northern Chile) and arid regions, such as North-eastern Brazil and Patagonia, located deep-south. Maximum rainfall is observed in the west-coast of Colombia, southern Chile, Brazilian Southern High Plateau, the Amazonian depletion and the eastern side of the Andes. South of 23°S there is a belt of subtropical and mid-latitude climates driven by westerly winds. There are winter rain climate in Central Chile, evenly distributed rain in SSA prairies (Pampas) and summer rain in North-eastern Argentina and South-Eastern Brazil. Prairies are also present in the high plateaux of the Andes, in the Orinoco region in Colombia and Venezuela where distinct dry season occur in winter like in all the rest of tropical LAC. Long trend in precipitation[10] and surface air temperature[11] are shown in Fig. 1.



a)	b)

Figure 1. Trends in a) precipitation (mm/day) and b) surface air temperature (ºC). Difference of annual average fields 1980-1999 minus 1948-1979[12] from NCEP/NOAA Reanalysis. Drying region in the Argentine Pampas contradicts both observations and crop production indicating reverse trends[13,14]

1.4 Socio-economic setting and Vulnerability. LAC economy benefits since 2003 of a favourable international scenario, i.e. growth of world's GDP and trade; increase in the price of raw materials and decrease in the interest rates, which translates into a per capita GDP growth rate of ~3%[15]. This figure is higher than the average for the last two decades (Table 1) but slower than in the rest of the developing world. The SA economies (i.e. Argentina,

[9] Satyamurty, Nobre and Silva Dias. South America. Chapter 3C. In "Meteorology of the Southern Hemisphere", Karoly and Vincent (eds.) Meteorological Monographs Vol. 27 Number 49. 1998. Mass, USA.
[10] http://www.gewex.org/gpcpdata.htm
[11] *NCEP Reanalysis data* provided by the NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado, USA, from their Web site at http://www.cdc.noaa.gov/
[12] NOAA-CIRES CDC NCEP/NCAR Reanalysis
[13] Barros, V., E. Castañeda and M. Doyle 2000: Recent precipitation trends in Southern South América to the east of the Andes: an indication of a mode of climatic variability". *Southern Hemisphere Paleo and Neoclimates Key – S2tes, Methods, Data and Models.* P. Smolka and W. Wolkheimer, Eds., Springer- Verlag. P. 187 – 207.
[14] Quintela R. M., J. A. Forte Lay y O. E. Scarpati, 1989. "*Modification of the water resource characteristics of the Argentine's Pampean SubHumid-Dry Region."* 9th Conference on Biometeorology and Aerobiology (9thAgMet), USA, and 6th Conference on Applied Climatology, American Meteorological Society, pp J30-35.
[15] ECLAC (2005). Preliminary Overview of the economies of Latin America and the Caribbean

Venezuela and Uruguay) and, to a lesser extent, those of the Cb have witnessed a faster increase in activity than MA. Exports, boosted by the favourable international situation, continue to be one of the most rapidly growing components of demand, with the region's export volumes expanding at about 8% on average and 6.2% per annum in US$. This increase, together with that of remittances has been contributing with a mounting surplus on the balance-of-payments (BoP) current account of 1.3% of GDP for 2005[16]. Gross fixed capital formation rates have also increased (10% as a whole), less in MA than is SA. Nonetheless, investment, measured as a percentage of GDP, is still low to fuel the economies as to make it possible to solve employment and the population's general well-being deficit. However, the improvement in economic conditions in combination with a diminishing labour supply has pushed the unemployment rate down from 10.3% to 9.3%. Although many of countries' external debt coefficients are still very high, the reduction in their public debt-to-GDP ratios is helping to make the region less vulnerable to external economic shocks. The increase in fiscal revenues generated by brisker economic activity and the high prices of some of the region's commodity exports is not being accompanied by a matching trend in expenditure, but together with and improved BoP, a better management of public resources and, the adoption of more flexible exchange rates have led to both a reduction of inflation rates (7.4% in 2004 and 5.1% in 2005) and an appreciation of almost all countries currencies. Total population increased from 161 million (M) to 512 M between 1950 and 2000, the yearly growth rate decreased from 2.7% to 1.5%. Life expectancy has increased from 50 years to 72 years. Almost 10% of the population has an income less than $ 1 per day and about 23% with less than $ 2 per day. About 40% of total income is shared by the 10% richest (Table 2). Inequity is also represented by urban and rural household income: Rural population is almost 25% of total population and accounts for about a half of poor and the reduction of this unequal distribution has been slower in rural areas where the growth rate decreased from 1.3% in 1950 to 0.10% in 2000. Urban population growth decreased from 4.4% in 1950 to 1.9 in 2000%[16, 17]. Thus, LAC population is changing to a more urbanised, elderly, and with a lower rate of growth society. Population's yearly growth rate decreased from 2.7% in 1950 to 1.5% in 2000 and will decrease to 1.0-1.3% by 2050. Even poverty incidence has been diminishing in the last years due to economic recovery, social vulnerability is still of high concern: Under-nourishment represented 10% of the population in 2000-2002. Most countries show financial and management deficit for covering their population health needs. Inequity in health care depends not only on socio-cultural aspects and the physical environment but also on uneven income distribution which determines insufficient human living conditions[18]. Climate is a source of main health problems, like malaria and dengue. Shortage of safe drinking water and infection from contaminated water often leads to an increase in cases of hepatitis-A, cholera and diarrhoea. Moreover, disruption of croplands results in general under-nourishment of population, particularly in rural areas, increasing susceptibility to infections[19]. By 2002 only 89% of the population had access to safe drinking water[20] and 75% had sanitation services (89% and 53% in urban and rural areas, respectively). Overall vulnerability is estimated with several indices - vulnerability (which is a multi-indicator complex one), education, health and poverty[21,22]. A few countries have a good overall vulnerability index (Argentina, Chile, Costa Rica, Cuba and Uruguay) whereas others are highly vulnerable (Ecuador, El Salvador, Honduras, Nicaragua, Paraguay and Haiti).

1.5 **Agriculture and Development possibilities**. Although the contribution of agriculture to GDP varies widely across the region and has declined to ~7% over the last 30 years (Figs. 2 and 3) it still plays an important role and for some countries its contribution is above 20%. For the largest economies however it represents between 6 and 9% of their GDP[3]. Vertical

[16] ECLAC, 2004 and 2005
[17] Dirven M. (2004) Alcanzando las metas del milenio: una mirada hacia la pobreza rural y agrícola, CEPAL.
[18] CEPAL (2005) Panorama Social de America Latina
[19] Gross J (2002) The Severe Impact of Climate Change on Developing Countries, *M&GS 2002;7:96-100.*
[20] "Health Situation in the Americas, Basic Indicators 2005" , PAHO, Pan American Health Organization,
[21] http://www.disaster-info.net/LIDERES/spanish/panama2005
[22] UNDP (2001)

integration of agriculture multiplies its contribution to the GDP by 4 to 7 times[17] having great incidence in population's income and employment (30-40% of economically active population). Likewise, the sector is an important element for the BoP, as well as for the alleviation of poverty and environmental sustainability. Average agricultural exports were ~15% by 2003 with extremes for the Rio de la Plata (30%) and Trinidad and Tobago (6%).

Table 1. Socio-economic and Human Development status in Latin America and the Caribbean

Indicator	***Unit***	**Source**	**LAC**	**Minimum**	**Maximum**
Population	*M of people*	WB, ECLAC 2005	541,3	0.02 British Virgin Islands	187,6 Brazil 106,1 Mexico
Population growth (*2000-2005)*	*annual variation*	WB, ECLAC 2005	1.5%	-0.3% Grenada -0.3% Saint Kitts	2,5% Honduras 2,5% Paraguay
Gross National Income (GNI)	*current M U$*	WB	1,900.000		
Gross Domestic Product (GDP	*current M U$*	WB	2,000.000	430 Dominica 521 Saint Kitts	676,500 Mexico 604,900 Brazil
GDP growth	*annual variation*	WB, ECLAC 2005	6.0%	-3.8% Haiti -2.8% Granada	17,9% Venezuela 12,3% Uruguay
GDP per capita	*Cur. U$ /inhabit.*	WB HDR 2005	3,789	1,742 Haiti 2,587 Bolivia	17.1 Bahamas 15.7 Barbados
Value Added in agriculture	*% of GDP*	WB	6.7%		
Value Added in industry	*% of GDP*	WB	22.8%		
Value Added in services	*% of GDP*	WB	70.5%		
Exports	*% of GDP*	WB	26.7%		
Imports	*% of GDP*	WB	23.2%		
Current account balance	*% of GDP*	ECLAC 2005	1.3%	-16.1% Nicaragua -8.4% Panama	12,6% Venezuela 5,9% Dominicana
Public sector primary balance	*% of GDP*	ECLAC 2005	2.2%	-3.1% Bolivia -1.8% Honduras	3,3% Argentina 3,1% Chile
Public sector balance	*% of GDP*	ECLAC 2005	-0,7%	-5.7% Bolivia -5.6% Panama	2,2% Chile 2,0% Argentina
Gross Capital Formation	*% of GDP*	WB – ECLAC 2005	19,7%	10.0% Uruguay 10.3% Cuba	26,6% Nicaragua 26,4% Haiti
Foreign Direct Investment	*current MU$*	WB	42,400	6 Haiti 64 Paraguay	14.420 Mexico 8,695 Brazil
Gross External Debt – *% of GDP*	*current M U$*	ECLAC 2005	760,376 37.3%	221 San Vicente 245 Dominica	201,373 Brazil 171,115 Argentina
Inflation rate	*annual var. %*	WB – ECLAC 2005	7.4%	1.0% Bahamas 1.5% Panama	28,7%Dominicana 20,2% Haiti
Unemployment	*annual rate*	ECLAC 2005	10.3%	1.9% Cuba 3.1% Guatemala	18,4% Dominicana 15,4% Colombia
Human Development Index	*between 0-1*	HDR 2005	0.80	0.47 Haiti 0.66 Guatemala	0.88 Barbados 0.86 Argentina
Education index	*between 0-1*	HDR 2005	0.87	0.50 Haiti 0.66 Guatemala	0.96 Barbados 0.96 Argentina
Life Expectancy index	*between 0-1*	HDR 2005	0.78	0.44 Haiti 0.63 Guyana	0.89 Costa Rica 0.88 Chile
GDP per capita index	*between 0-1*	HDR 2005	0.74	0.48 Haiti 0.54 Bolivia	0.86 Bahamas 0.840 Barbados
Poverty of urban population (1990-2002)	*% pop. below poverty line*	ECLAC 2002	38%	18% Costa Rica 20% Uruguay	65% Haiti 64% Colombia
Income distribution /Gini Index	*between 0-1*	HDR 2005 WB 2005	0.55	0.38 Jamaica, 0.40 T & T, 0.44 Ecuador, Uruguay	0.60 Guatemala 0.59 Brazil
Pop. With access to safe water	*between 0-1*	HDR 2005	0.71	Haiti 0.34	Barbados 1
Pop. with access to sewage	*between 0-1*	HDR 2005	0.75	Bolivia 0.23	Trinidad-Tobago1

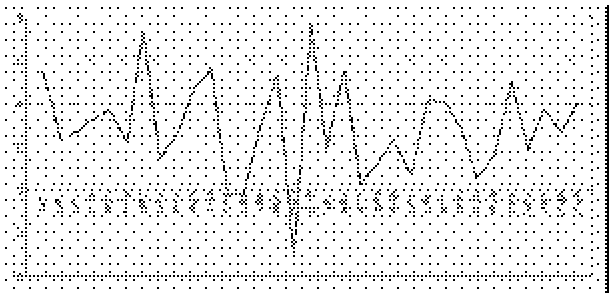



Figure 2. Contribution (%) of agriculture to the GDP. Figure 3. Agriculture GDP Growth Rate, LAC (1971-2003)[21].

Table 2. Household income distribution (%) in Latin America (average and extremes) [23]

	1990	1990	2002	2002
Country	40% poorest	10 % richest	40% poorest	10 % richest
LA Average	14,0	35,6	13.5	36.4
Brazil	9.5	43.9	10.2	46.8
Honduras	10.1	43.1	11.3	39.4
Costa Rica	16.7	25.6	14.5	30.2
Uruguay	20.1	31.2	21.6	27.3

2. Stream I: Future Impacts of Climate Change

This chapter deals with future impacts of climate change and adaptation constraints based upon current and future vulnerability, and projections of GCM models.

2.1. Climate Models and Scenarios. The four climate scenarios shown here[24,25] are related to different future greenhouse gas emissions pathways defined in the IPCC Special Report on Emissions Scenarios (SRES) called B1 (low change), B2, A1 and A2 (high change).

2.1.1. Future Temperature and Precipitation Change in MA and the Cb: The region warms slightly less rapidly than the global average except northern Mexico. Warming is greatest over the highland areas of Mexico and least in the Cb and Central America. Much of Mexico will be 5ºC or warmer than today by the 2080s under the A2 scenario, whereas Cuba and Jamaica will be ~3.5ºC warmer (table 3). There is a dominance of drying across the region, most notably in southern Mexico and Guatemala. This decrease in annual rainfall is noticeable even under the B1-low scenario. By the 2080s under the A2-high scenario, rainfall would decrease by 20 % or more. Most of the Cb also experience decreases in rainfall, although not as large as over the mainland. The northern edge of Mexico becomes slightly wetter, especially during the September-November season.

2.1.2. Future Temperature and Precipitation *Change over tropical Andes and Amazonian:* The northern Andes warm slightly less rapidly than the global average. Annual warming by the 2050s ranges from ~1ºC in the B1 scenario to over 3ºC in the A2 scenario. Warming rates are fairly constant throughout the year, but is rather more rapid over the Andean Plateau and the interior of the region than along the coast. It is likely that in the future Amazonian will warm more rapidly than the global average. Warming also varies by season, with the wetter December to February period warming by between 0.1º and 0.4ºC/decade, but the drier June to August season warming by between 0.2º and 0.6ºC/decade. Warming is greatest over the Amazonian rainforest and least rapid in subtropical South-eastern region. Peru, Ecuador and southern Colombia become wetter but northern Colombia and Venezuela become drier. For the B1 scenario these changes are modest and amount to only a few per cent. For the A2 scenario by the 2080s, however, the decrease in annual precipitation towards the Equator reaches 20 %. Much of Amazonian becomes drier. This is particularly evident in the March to May season which accounts for nearly 35 % of Brazil's rainfall. The dry Northeast region of Brazil experiences differing trends between the December to May half-year (becoming wetter)

[23] ECLAC (2004)) Tendencias y Desafíos de la agricultura, los montes y la pesca en América Latina y el Caribe Ch. 2 and 3.
[24] Ruosteenoja et al. (2003) Future climate in the world regions: an intercomparison of model-based projections for the new IPCC emissions scenarios. The Finnish Environment, 644.
[25] Hulme, M. and Sheard, N. (1999). Climate Change Scenarios for Australia. Clim Res. Unit, Univ. East Anglia, Norwich, UK,6 pp

and the June to November half-year (becoming drier). For the A2 scenario by the 2080s, the area of maximum annual drying is the Amazon delta region (~20 %).

2.1.3. Future Temperature and Precipitation Change over Southern SA. It is likely that Argentina will warm slightly less rapidly than the global average temperature. Within Argentina, however, the north of the country will warm considerably more rapidly than the south. For example, in the A2 scenario the southern peninsula warms at a rate of ~0.25º /decade, whereas the north of Argentina warms at the rate of ~0.4ºC/decade. For the B1-low scenario these rates are reduced by a factor of about three. All of the GCMs underestimate the precipitation over eastern Argentina, Uruguay and southern Brazil. The best precipitation field is simulated by the HADCM3, which simulates an annual rainfall 75% of the observed. Precipitation is overestimated in north-western Argentina and southern Bolivia[26]. The southern states of Brazil, north-eastern Argentina and Uruguay become wetter, and the area of maximum wetting is the southernmost part of Brazil (~20 %). Annual precipitation declines over the western sector (Andes and Chile) reaching ~15 % in some places by the 2080s under the A2 scenario. The east of the region (lower RP Basin) experiences increases in annual precipitation. Under the B1 scenario, and even by the 2080s, all of the precipitation changes are small – less than 5 %.

2.1.4. Climate variability and disasters. Changes in climate variability and in extreme event frequencies are important for determining both the likely impacts of climate change and the adaptation options. Although current knowledge does not permit reliable predictions to be made about future changes in hurricane frequency and intensity, it is possible to identify other changes in climatic variability. Droughts have large impacts on many of the forests of MA, Amazonian, and also in the Pampas. Their timing and severity is often the strongest climatic influence on the ecology of tropical moist forests and temperate grasslands. Rainfall scenarios suggest an increase in drought frequency across MA. Rainfall in the western part of MA and North-East of Brazil are related to the Southern Oscillation with a tendency for drought conditions to occur during El Niño. In the other hand in SSA during El Niño events wetter conditions tend to occur in north-eastern Argentina, southern Brazil and Paraguay. Scenarios suggest a reduction in rainfall and an increase in drought frequency across MA and the NE-Brazil, meanwhile an increase in rainfall and reduction of drought frequency is expected in the eastern part of SSA. An important component in the assessment of the probability of occurrence of future natural disasters is whether global warming can be expected to have an impact on their occurrence[29]. Given the relationship between tropical SST and storms[27], it is likely to expect that warming might have an effect on the intensity of extreme storms.

Table 3. Projected temperature and precipitation changes for sub-regions of Latin America and the Caribbean[15]. Ranges of values encompass estimates from seven GCMs and the four SRES scenarios.

Changes in temperature (C)		**2020**	**2050**	**2080**
Caribbean	Dry season	+0.5 -- +1.1	+0.8 -- +2.3	+1.0 -- +4.0
	Wet season	+0.5 -- +1.0	+0.8 -- +2.3	+1.0 -- +4.0
Central America and Mexico	Dry season	+0.4 -- +1.1	+1.0 -- +3.0	+1.0 -- +5.0
	Wet season	+0.5 -- +1.7	+1.0 -- +4.0	+1.3 -- +6.6
Amazonia	Dry season	+0.7 -- +1.8	+1.0 -- +4.0	+1.8 -- +7.5
	Wet season	+0.5 -- +1.5	+1.0 -- +4.0	+1.6 -- +6.0
Southern South America	Winter (JJA)	+0.6 -- +1.1	+1.0 -- +2.9	+1.8 -- +4.5
	Summer(DJF)	+0.8 -- +1.2	+1.0 -- +3.0	+1.8 -- +4.5
Changes in precipitation (%)		**2020**	**2050**	**2080**
Caribbean	Dry season	- 7 -- +14	-10 -- +30	-15 -- +20
	Wet season	-15 -- +10	-40 -- +10	-60 -- +10
Central America and Mexico	Dry season	- 7 -- +7	-12 -- +5	-20 -- + 8
	Wet season	-10 -- +4	-15 -- +3	-30 -- + 5
Amazonia	Dry season	-10 -- +4	-20 -- +10	-40 -- +10
	Wet season	-3 -- +6	-5 -- +10	-10 -- +10
Southern South America	Winter (JJA)	-5 -- +3	-12 -- +10	-12 -- +12
	Summer(DJF)	-3 -- +5	-5 -- +10	-10 -- +10

[26] Camilloni and Bidegain 2005, In Climate Change in the Rio de la Plata, Barros V, A Menéndez, GJ Nagy Eds.
[27] Trenberth K. (2005). *"Uncertainity in Hurricanes and Global Warming"* Science **308**, 1763-1754.

2.2 Economic Scenarios. Economic growth will likely stabilize at a lower level than present due to the decrease in the demand for some commodities and the high use of production capacity. The food-export countries should likely not have a fluid demand what should reduce production to a lower level than the likely expected increase in world's income. Export products other than petroleum, such as minerals, will very likely have a fluid demand because of the low stocks and the likely expected rate of increase of world's economy. Some other factors should play an important role in the deceleration of economic activity in the LAC region such as the likely expected level of international rates of interest that would affect countries with high external debt. Nonetheless, this impact could be reduced due to the reorganisation of debts since 2000[28]. It is very likely to expect better macroeconomic management, less fiscal disequilibria, greater liberalisation of economies, controlled inflation and it is also likely to expect the application of policies appropriated to the region. Under this scenario it is likely to expect the continuation of a satisfactory economic growth at lower levels than over the last few years allowing not to loss relative positions in the world's economy. Also it is likely to expect that long-term sustainability of these policies will allow to slowly decreasing poverty. An increase in the regional GDP is likely expected at an annual rate of 3.6-4.0% increasing the GDP per capita by ~2% for the period 2005-2025. Likewise, population growth will decrease to around 1.3% or less over the next few decades (Table 1). Growth will be greater in central age-classes and will turn to an increase of the class > 60 years by 2050, a situation that will imply new threats and challenges. The former will require developing production and employment policies to efficiently absorb the increasing labour supply; the latter, will need new responses for elderly protection.[29]. It is likely to expect a decrease in the agriculture and an increase in the industry what would be associated with technological change. Both the greater external opening and moderate economic growth will allow a substantial increase in export[28, 29]. Economic SRES-A2/B2 scenarios by 2025 and 2050 are shown in Table 4 [30,31,32]. Economic SRES-A2/B2 scenarios by 2025 and 2050 are shown in Table 4.

Table 4. Synthetic LAC region Economic Scenarios for 2025 / 2050 (based on SRES A2 and B2)[33]

Current & Future Economic Scenarios			SRES A2		SRES B2	
Indicator	**Unit**	**2004**	**2025**	**2050**	**2025**	**2050**
Population	*M of people*	541,3	714,4	926,7	804,1	1,136.8
Population growth	*annual variation*	1.4%	1.3%	1.2%	1.9%	1.6%
GDP	*Current M US$*	2,000.000	4,203.246	9,372.519	4,553.856	10,908.918
GDP per capita	*Curr US$/inhab*	3,789	5,884	10,114	5,663	9,597
GDP growth	*annual variation*	6.0%	3.6%	3.4%	4.0%	3.8%
VA in agriculture	*% of GDP*	6.7%	3.1%	3.4%	4.4%	2.9%
VA in industry	*% of GDP*	22.8%	20.3%	20.7%	28.9%	27.7%
VA in services	*% of GDP*	70,5%	76,7%	75,9%	66,8%	69,3%
Exports	*% of GDP*	26.7%	35.5%	34.6%	32.2%	33.9%
Imports	*% of GDP*	23.2%	33.0%	32.9%	29.2%	29.5%
Exports	*current MUS$*	534,000	1,490.741	3,243.955	1,465.233	3,703.561
Imports	*current M US$*	464,000	1,389.007	3,079.166	1,328.466	3,218.075

[28] World Bank, IMF, FAO, PNUD-GEF, IPCC, OECD, ECLAC, Centro de Estudios Latinoamericanos.
[29] *Situación actual y perspectivas CEPAL (2005). Dinámica demográfica y desarrollo en América Latina y el Caribe. CELADE – UNFPA, S E R I E población y desarrollo 58 Santiago de Chile. 67p.*
[30] Mexican Secretaries/Institutes of: Economy, Environment and Natural Resources, Agriculture, Livestock, Rural Development, Fisheries, Food, Ecology, Statistics, Geography and Informatics, Population.
[31] Brazilian Ministries/Secretaries of Economy, Planning, Budget and Management, Treasury, Development, Industry, Foreign Trade, Science and Technology, Institute of Geography and Statitstics, Getulio Vargas Foundation.
[32] Argentinean Ministries/Secretaries/Institutes of Economy and Public Works, Agriculture , Fisheries and Food, Agricultural Technology, Statistics and Census, Macroeconomic studies, Social Development and Environment.
[33] Scenario developed for this study based upon references 28 to 32.

2.3 Impacts on Income

2.3.1. Agriculture

Expected impacts on crop production. Considering main crops (maize, wheat, soybean and rice) Latin America production during 2004 attained 229 M tons[34]; Brazil, Argentina and Mexico totalised 87% of production (Fig. 4). A global study[35] that estimated main crops yields changes at the country-level considered HadCM3 projections under different SRES scenarios for 2020, 2050 and 2080.

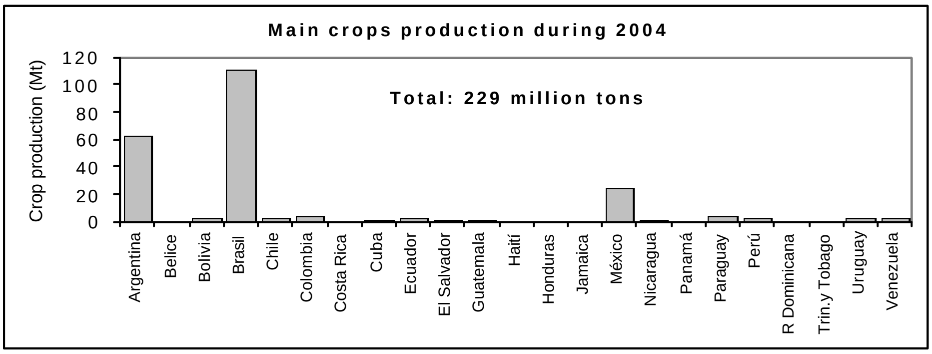


Figure 4: Crops production in Latin America countries in 2004[34].

Differences between baseline and future production aggregated for LA are presented in Table 5. If positive CO_2 effects on crop yields are considered, production could be slightly affected (between -1.6% and +2.5%) by temperature or rainfall changes and could range between 234 and 224 Mt depending on the time-slice and the SRES scenario considered. Without taking into account the CO_2 effects, an overall decrease in crops production could occur (-5% to -30%), being much stronger for 2080. Under this conditions crop production could be seriously affected dropping to 217 or 160 Mt under the worst scenario. Changes in crop yields obtained in the region for each crop are quite contrasting. In SSA maize, wheat and specially soybean crops would be benefited if CO_2 effects were considered. Inversely without considering CO_2 effects, yields could be reduced but with a lower impact as compared with those shown in Table 6. Another important issue is related to the likely impacts of climatic variability; duplicating the variance of temperatures maize yields could suffer stronger reductions[36]. For example in central Argentina increases of 1.5ºC and 3.5 ºC led to reductions of 13% and 19% respectively, while by duplicating the variance these figures were -17% and -34.5%.

2.3.2 Expected impacts and adaptation on crop production. It has been scientifically argued that crop adaptations to future climate changes are feasible at global scales. New input technologies and agricultural practices could be developed to overcome slow changes in temperature or precipitation patterns, as it was the case from a historical perspective. Easy adaptation options (i.e. new seed varieties, new crops; adjusting planting dates, supplementary irrigation schemes; shades and agrochemicals), have proved to be possible to adjust agriculture production to different climates. However, at a lower scale of analysis (from regional to livelihood strategies) availability of adaptations options is not always sufficient to guarantee adaptations. Problems of access to resources and multiple stressors determine the adaptive capacity that any of those might have. Moreover, subsistence-type and lower scale familiar agriculture, small scale fisheries and small countries are particularly vulnerable to climate variability and extremes, whose impacts are usually more difficult to cope with, and adaptation assessments cannot be aggregated on a regional basis[37, 38].

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[34] FAOSTAT (2005). www.fao.org/FAOSTAT

[35] Parry M.L, C. Rosenzweig, A. Iglesias, M. Livermore, and G. Fischer (2004). Effects of climate change on global food production under SRES emissions and socio-economic scenarios. Global Env. Change 14: 53-67

[36] Vinocur, M.G., R. A. Seiler, and L.O. Mearns (2000). Predicting maize yield responses to climate variability in Córdoba, Argentina. Abstracts Int. Scient. Meeting on Detection and Modelling of Recent Climate Change and its Effects on a Regional Scale, Tarragona, Spain. 29 – 31, May, 2000.

[37] Wehbe M, H Eakin, R Seiler, M Vinocur, C Avila and C Marutto. Accepted. Local Perspectives on Adaptation to Climate Change: Lessons form Mexico and Argentina. AIACC Synthesis Book on Adaptation to Climate Change in the Developing World.

Table 5. Aggregated Latin America differences (%) in crop production (maize, wheat, rice, and soybean) between baseline (2004) and HadCM3 SRES A2 and B2 in 2020, 2050 and 2080, with and without considering the CO_2 effects [based upon35]

LA	With CO2 effects			Without CO2 effects		
	2020	2050	2080	2020	2050	2080
SRES A2	2	-2	3	-5	-9	-30
SRES B2	-1	-1	-1	-5	-8	-25

Table 6. Changes in crop yield under GISS and HadCM3 scenarios with and without CO_2 effects

Site	Crop	Scenario	With CO_2 effects			Without CO_2 effects		
			2020	2050	2080	2020	2050	2080
Brazil[39]	Maize	GISS		-15				
	Wheat			-30				
	Soybean			+21				
South Brazil, Uruguay and Argentina's Pampas region[40].	Maize	HadCM3 A2	+8.3	+9.1	+13	-1.2	-1.7	-4.3
	Wheat		+1.1	+6.8	+16.6	-7.0	-8.2	-8.8
	Soybean		+21.5	+40.1	+45.6	-2.7	-4.6	-10.5
	Maize	HadCM3 B2	+4.1	+6.4	+11.7	-4.9	-3.7	-4.2
	Wheat		+0.8	+0.7	+9.9	-5.2	-10.3	-7.4
	Soybean		+15.8	+31.1	+36	-6.5	-6.2	-12.3

2.3.3 Vulnerability of Agriculture, Land and Food Security. Since there is no single indicator for measuring impacts from agriculture changes, different sources of countries´ vulnerability reflect their situation with regard to agriculture participation and possibilities for economic growth, foreign exchange earnings and domestic production of food (the latter in turn may affect dependency on food aid)[15,17,21]. Tables 7 to 9 summarises key aspects of vulnerability based on the fact that climate alone is unlikely to determine winners and losers, as vulnerability differences and adaptation measures can significantly shift the outcome of any climate change[41]. Thus, high vulnerability to expected outcomes from climate change prevails where: 1) the contribution of agriculture to the GDP is very high (Haiti, Guatemala, Bolivia). 2) The agriculture sector as percentage of exports is very important (Nicaragua and RP countries). The AC and Mexico are the less vulnerable. 3) Productivity is relatively low in relation to the population living from agriculture (Mexico, Bolivia, Peru, Ecuador, Paraguay) and 4) The combination of low-income (less than US$ 1,395/capita), food deficit and/or negative food BoP[21] (Haiti, Nicaragua, Bolivia, Honduras, Guatemala, Ecuador and Cuba).

Food Insecurity was assessed by using two models (HADCM3 and CSIRO) under SRES-A/B scenarios[42]. These models are two of the three that give better results in the region together with ECHAM-4[43]. Overall impact is similar from the results of both models. However, the distribution of additional undernourished differs, HADCM-3 giving increased hunger. Results given by A2 scenarios are the worst whereas under the three others -which assume a better balance between economic and population growths- poverty and hunger, though negatively impacted, would become much less prevalent than today.

Table 7. Land with severe environmental constraints for rain-fed crops (HADCM-A1F1) by 2080[42]

Region	Total Extents 10^6 ha	D of total extent with constraints % 10^6 ha		Too dry %	Too wet %	Too steep %	Poor soils %
World's average	13,400	-1	(65,4)	9.0	0.2	8.2	25.9
MA & the Cb	271	+7	(58.8)	37.9	0.0	14.1	6.9
South-America	1,0778	-1	(63.4)	18.3	1.2	3.1	40.7

38 Nagy GJ, M Bidegain, RM Caffera, JJ Lagomarsino, W Norbis, A Ponce and G Sención. Accepted. Assessing Climate Variability and Change Adaptive Capacity of Estuarine Fisheries of the Rio de la Plata. AIACC Synthesis Book on Adaptation to Climate Change in the Developing World.

39 Siqueira, O.J. W.; Salles, L.A.B.; Fernandes, J.M (2001). Efeitos potenciais das Mudanças Climáticas na Agricultura Brasileira e Estratégias Adaptativas para Algumas Culturas. In: Mudanças Climáticas Globais e a Agropecuária Brasileira, ed. by Lima, M.A, Cabral, O.M.R. ; Miguez, J.D.G., p. 33-63.

41 O´Brien, K. and R. Leichenko, 2000. Double exposure: assessing the impacts of climate change within the context of economic globalization. *Global Environmental Change* 10; 221-232

42 IIASA, 2002. *Climate Change and Agricultural Vulnerability.* G Fischer, Ma Shah and H van Velthuizen

43 Bidegain M & I Camilloni (2006). Performance of GCMs and climate future scenarios for South-Eastern South America

Table 8. Share of agricultural sector GDP in national GDP (%) [21]

	1980	1990	2000	2003
LAC	7.1	7.9	7.4	8.1
Argentina	4.5	5.8	5.1	5.8
Brazil	7.2	8.0	8.2	9.4
Jamaica	8.8	7.4	7.3	7.3
Mexico	5.4	5.1	4.2	4.5
Nicaragua	28.5	31.6	34.8	35.0
Uruguay	8.6	8.2	7.6	9.8

Table 9. Food sector balance of payments (BoP) and investments in selected countries [17,44]

Country	Food Export %	Food Import %	Food BoP	Sector Investment
Argentina	10.4.	1.6	8.8	2.8
Brazil	4.9	3.3	1.6	2.4
Chile	14.0	3.7	10.3	5.1
Colombia	19.8	6.0	13.8	1.6
Mexico	7.5	9.7	-2.2	1.4
Uruguay	11.8	4.7	7.1	0.8
Venezuela	2.3	10.3	-8.0	3.3

Projections of HadCM2 for 2055 suggest that small farmers' maize production in the AC and MA countries could decrease on average by 14% (Fig. 5), affecting mainly those countries where subsistence agriculture represents the main source of food security (i.e., Belize, Guyana and Venezuela)[44].

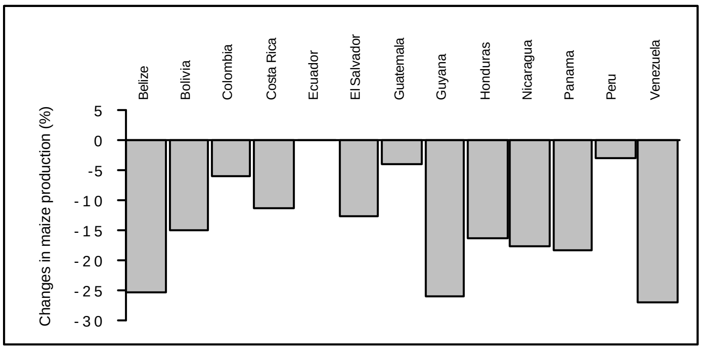

Figure 5: Changes in maize production for 2055 in the AC and MA countries according to HadCM2 projections[44].

LAC accounts for ~20% of world's fish landings. The sector is a significant contribution to the BoP, employment and food security of many countries (i.e. Peru). Exports are expected to expand from 7.3 Mt in 1990 to 10.6 by 2010 and then will likely stabilize due to increase in local demand. These figures are market-based and do not include climate factors which can severely impact fisheries income (– 40 to –80% in Peru during strong El Niño years[45],[46]).

2.3.4 Impacts and Adaptation on/of Physical and Financial Capitals.

Energy: Hydro-Power and Total Primary Energy Supply (TPES). The vulnerability of many electrical systems is very constrained by their dependence on water resources. Economic scenarios based on a better distribution of income result in energy scenarios that multiply by more than 2 the TPES from 2002 to 2055. According to projections based on a high economic growth with an average annual percent change in consumption of 2.7% from 2002 to 2025, 0.87% from 2025 to 2055 and 0.68% from 2055 to 2080[47],[48] the use of coal and hydro-energy will likely increase, especially beyond 2050. Also, biomass, solar and nuclear energies which only totalised < 5% in 2004 will very likely expand to about 10% in 2050 and 20% in 2080.

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[45] Geo-Outlook (2004), chapter 4.
[46] FAO (2005) Chapter 3, http://rlc.fao.org
[47] International Energy Outlook (2005)
[48] Battelle Institute (2002). Global Energy Technology Strategy -Addressing Climate Change

It is very likely that future changes in precipitation and temperature will impact hydro-power. Whether these changes would be beneficial will depend in each sub-region on the relationship between seasonal patterns of precipitation and the likely severe growth of electricity demand due to increases in temperature, added to the population growth. It is likely that the region will be able to satisfy increasing demands even if climate change results in some reductions in power generation. Many countries assume the operation of new dams and hydro-plants, particularly in SA, complemented with the installation of interconnected transmission networks among countries in the region[49, 50, 51]. Adaptation costs would include sensitivity studies and monitoring of water resources to prevent serious adverse climate impacts in hydro-generation. Refurbishment of hydro-plants, improvements in the efficiency by means of optimization of operation of installed capacities and the construction of medium-size hydro-plants that compensate carbon emissions, are likely to improve the response of the electrical systems to the impacts of climate change[52]. Adaptation measures will also have to include social and environmental impacts, which are important constraints and sources of uncertainty affecting hydro-power development. Improvement of water resources and hydro-plants planning, in coordination with stakeholders, is an important adaptation measure in order to mitigate the impact of large storage reservoirs on the health and well-being of the community and local ecosystems, particularly in tropical regions[1, 89].

Fluvial transportation. The development of the fluvial transportation is still incipient in the region exception made of Brazil, Argentina, Colombia and Venezuela. A South American North-South Fluvial Navigation Axis of 35.000 km of navigable rivers (Orinoco, Amazon and La Plata basins) and ~10,000 km length is planned in the mid-term[53]. Future periods of low flows and depths will very likely obstruct navigation in some of those navigable basins. Low flows associated with El Niño 1997-98 event caused serious economic damage to navigation in the Magdalena river estimated as $ 3,9 M. Future impacts are very likely to happen in some reaches of this river, the Lower Parana in Argentina and some reaches of the Lower Uruguay river between Uruguay and Argentina.

Although the energy, industry and transportation sectors are sensitive to climate change, as long as it takes place gradually and the lifetimes of most assets are relatively short compared with projected time-scales for climate change adaptation will be possible.

Infrastructure vulnerability and adaptation. Climate-related disasters produce important damages to infrastructure such as roads and bridges and the effects of floods, that are predicted to increase, represent the most likely impact (Table 10). Economic losses due to floods between 1970 and 2005 amounted ~$ 40 bn [31, 54]. Thus, even not considering an increase in the annual cost, nor increases in population neither intensification of storms, if no adaptation measures are adopted, it is likely to expect a minimum accumulated cost of floods of $ 30 bn for the period 2006-2025, 20 % of which correspond to roads and bridges. In order to reduce these damages infrastructure public organisations must seek opportunities to allow more floodwater access to floodplains.

Tourism vulnerability and impacts. As for tourism especially vulnerable countries are those where the sector contribution to the GDP, BoP and employment is relatively high and depend mostly on coastal areas threatened by projected increases in sea level and storms (see 2.5.1), such as those of the Cb and MA, and, in a less degree, Uruguay. Tourism accounts for 12% of GDP and 10 M employments in the Cb[4] and 3.8% in Uruguay[55].

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[50] ANEEL (2006) (Agencia Nacional de Energia Eléctrica). Technical Report. Brazil.
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[53] CAF- *Los ríos nos unen*
[54] CRED International Disaster Database, Université catholique de Louvain, Brussels, Belgium
[55] Second National Communication to the UNFCC, Uruguay (2004), UCC-MVOTMA, Uruguay 323 pp.

Table 10. Examples of climate damages to infrastructure (bridges and roads) produced by floods

Basin	Country	Year	Damages in U$S million		
			Total Direct	Roads and Bridges	
Parana, Paraguay, Uruguay[56]	Argentina	1983	965	203	21%
Parana, Paraguay, Uruguay[57]	Argentina	1992	1,790	340	19%
Andean Region[58]	Andean countries	1997-98	7,544	1,752	23%
Central Am (Hurricane Mitch)[59]	Guatemala	1998	307	89.8	29%
Yuna and Yaque[60]	Dominican Rep.	2003	32,6	5,5	17%

2.4 Impacts and Adaptation on/of Human Development, Health and Sanitation

2.4.1. Diseases. Expected climate changes may intensify impacts from chronic malnutrition and diseases. Facing increased temperature and precipitation, vector-borne (malaria, dengue) and infectious diseases (cholera) will expand to the south and to higher elevations. Air pollution and surface ozone concentration, triggered by warming would negatively affect population health, especially in urban areas[61]. Estimates of mortality due to vector-borne diseases as the result of a 1ºC global warming are 1,101 for malaria; -114 for Schistosomiasis; and, 0 for dengue fever[62], resulting from overlaying model-studies[63] with mortality figures of the WHO[64]. Recent estimations based on HadCM3 predicted that the augmented number of persons under infection risks due to malaria in SA would increase from 25 M in 2020 to 50 M in 2080 (Fig. 6). Changes in temperate ecosystems in Southern SA would permit *Anopheles darlingi* to expand its habitat to the south. Climate variability may affect the dynamic of dengue fever transmitted by *Aedes aegypti*, a species predominately urban. With an increase of 2º C intensity in dengue transmission would increase from 2 to 5 folds in most areas of SA and it is also likely that new transmission areas will appear in the south half of the continent (Table 11).

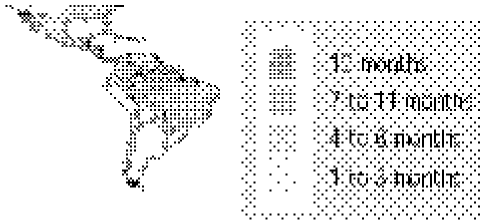

Figure 6. The impact of climate change on the potential distribution of malaria (HADCM-2080)[65]

It is expected that climate change will exacerbate the vulnerability of people and will pose new threats for human health such as: availability of fresh water supplies and efficiency of local sewerage systems; availability of food; distribution and seasonal transmission of vector-borne infectious diseases. A few indicators were selected as to draw the panorama on health vulnerability (table 12). Following the living expectancy index and the likelihood of not surviving the age of 40, it results that Bolivia, Guatemala and Honduras are the most vulnerable countries. As for percentage of population without sustainable access to improved water resources, the AC sub-region shows the highest vulnerability and this situation may be exacerbated under the expected changes in water availability. Incidence of malaria is already important in Brazil, most of AC and MA, although particularly high in Guyana and Suriname. Especially vulnerable are those countries where public expenditure on health is low or where the per capita health expenditure is low. In this category are most of AC and MA countries; however the highest levels of vulnerability are in those countries where public expenditure is

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[61] www.grida.no/climate/ipcc/spmpdf/region-s.pdf
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already a high proportion of their GDP but the resulting per capita health expenditure is nevertheless still very low. Bolivia, El Salvador, Nicaragua and Cuba are the most vulnerable.

Table 11. Tropical vector-borne diseases and the likelihood of change with climate change.

Disease	Likelihood of change with Climate Change	Vector	Present Distribution
Malaria	Highly likely	Mosquito	Tropics/subtropics
Schistosomiasis	Very likely	Water snail	Tropics/subtropics
Dengue	Very likely	Mosquito	Tropics
Leishmaniasis	Very likely	Phtebotomine sandfly	Americas
Chagas disease	Likely	Triatomine bug	Meso/SA
Lymphatic filariasis	Likely	Mosquito	Tropics/subtropics
River blindness	Likely	Blackfly	Latin America
Yellow fever	Likely	Mosquito	Tropical SA

Table 12. Social indicators on health vulnerability[66, 67, 68,69]

Region/ Country	Life Expectancy years 2003	Probability at birth of not arriving to age of 40 % cohort 2000-2005	Population without sustainable access to safe water 2002, %	Public Health Expenditure Per Capita % GDP	PPP US	Malaria cases per 100,000 people 2000
LAC	71.0	10.2	10.0	3.6	483	204
Brazil	70.5	10.3	11	3.6	611	344
Mexico	75.1	6.0	9	2.7	550	8
Centr. Am	71.5	10.4	10.7	4.3	375	236
CARICOM	70.0	10.4	6.6	3.5	483	166
AC	71.9	9.2	13.0	3.3	342	342
RP	74.0	5.8	--	3.5	701	3

2.4.2 Malaria Adaptation Cost. Of all climate change sensitive illnesses malaria occupies the first place. An important proportion of the population inhabits medium to high malaria risk zones in tropical and subtropical areas. Climate change and variability is also producing sporadic malaria cases in mountain ecosystems. Adaptation costs for malaria produced by *Plasmodium vivax and falciparum* can be observed in Table 13 [70, 71, 72, 73].

2.4.3. Sanitation Services. To attain the Millennium Development Goals-MDG target by 2015 without climate change, the percentage without a reliable source of drinking water in the region must be reduced to 10% or less. This implies increasing the number of people with access to an improved drinking source in LAC from 475 million (M) in 2002 to 603 M in 2015[74]. Without climate change and attaining the MDG goals of coverage, 66 M would remain without access to safe water in 2015. The rate of growth necessary to meet the target in 2015 implies an average of 9.8 M people gaining access to safe water each year at an annual cost of $ 1,096.5 M totalising $ 16,448 M during the period 2000-2015[74]. In terms of GDP these investments varies from less than 1% for Brazil and Mexico and more than 10% for Haiti and Nicaragua. At an average of 10 M people gaining access to safe water each year from 2015 to 2025 there would be 703 M with access to safe water by 2025.

Without climate change and notwithstanding the 100 M people gaining access to safe water, 36 M would still remain without access to safe water by 2025. Considering that climate change is likely to produce an increase in water stress by 2025 on an average of 70 M in Scenario A2, HadCM3 and CGCM2[75] (Table 14) the joint impact of increases in population and

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in the number of water stressed watersheds would imply that more than 100 M would live with severe problems to have access to safe water.

Table 13. Estimates Total Cost for climate change malaria (*vivax and falciparum*) adaptation.

Sub-region	Population in Mod/high risk areas 2000 10^3	API (2000) Cases/1000 Annual parasite index	Population in Mod / high risk of malaria cases 2000 10^3	otal Co 2000 10^6	Total Cost with climate change projected impact (US$) Total Cost 2010 10^6		Total Cost 2030 10^6	Total Cost 2050 10^6
Southern SA	12	23,30	475	820	853		1,114	1,665
AC	17	21,22	254	438	455		595	889
Cent. America	14	6,9	78	135	140		183	274
Mexico	43	0,17	727	10	10		14	20

Total cost include drugs, diagnostics, public facility 80% occupancy rate (by falciparum treatment of three types standard, with drugs resistance and complication), health staff and community health workers malaria training, fumigation, and impregnate mosquito net for Vivax Population coverage - the percent of population with physical access to primary health facilities, defined as living within 5 km or 1 hour away from the facility.

An estimation of the cost of mitigation of this impact, based on a cost per capita of $ 157 for investment in water supply systems[74] amounts a total investment of $16.500 M. To attain the MDG target by 2015 the percentage with sanitation would increase to 84.5%. This requires new sanitation being provided to 9.2 M people a year from now to 2015. Anyway, without climate change, in 2015 there would be still 103 M without sanitation services.

Table 14. Number of people without access to safe drinking water in 2002, 2015 and 2025 with and without climate change under the HadCM3 and CGCM2A2 scenarios [75].

Regions	People without access to safe drinking water					
	2002		2015		2025 (millions)	
	%	millions	%	millions	Without Climate Change	With Climate Change
Caribbean	13%	4,6	5%	2,6	0,6	10,5
Central America	10%	12,8	9,7%	16,3	8,4	43,0
South America	13%	46,7	10,5%	47,1	27,1	52,0
Total LAC	11%	64,1	9,9%	66,0	36,2	105,5

2.5 Future impacts on Natural Systems and the Environment

2.5.1 Coastal Systems. Human activities (i.e. erosion, eutrophication, over-population and -exploitation) and wind-storms are the main current impacts on the coastal systems and resources. Potential impacts of storm surges under SLR scenarios include multiple sectors. Most vulnerable countries are those of the Cb, MA, Argentina, Ecuador, Peru, Uruguay and Venezuela[76]. Between 2050 and 2080 low-lying coasts, mangroves, coral reefs, and estuaries will be severely impacted: reefs of the Cb constitute ~12% of the world total and 29% of them are at high risk due to increased run-off and sedimentation caused by deforestation, nutrient inputs, coastal construction and mining. Along the Atlantic coast of MA and the Cb SLR could become the main impact at the 2080s[77]. The combination of SLR and warming should severely impact natural systems; however there is a lack of assessments of their combined effects. Table 15 shows damage costs of one metre SLR. Even if projections for the 21st century vary between 30 and 50 cm (i.e. + 42 cm for the Uruguayan coast of the Rio de la Plata under HADCM-3 scenarios)[78], the magnitude of these figures is impressive. Assuming impacts 3 to 7 times less for 50 and 30 cm respectively, losses in terms of GDP and human and environmental impacts would very likely be greater than those experienced due to extreme events up to present. Wetland losses (and their associated biodiversity and eco-services) will very likely be severe in the Atlantic coast of MA between the 2050s and the 2080s due to SLR. However, human direct impact and storm surges are affecting now and will affect them between the 2020s and the 2050s. Thus, adaptation should target on protection measures under A-storylines[77] focused on the current environmental degradation.

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Table 15. Damage Costs of Climate Change Impact and adaptation for a one metre sea level rise [62]

Level protection (%)	Dryland loss (10^3 km^2)	Dryland value (10^6 \$/km^2)	Wetland loss (10^3 km^2)	Wetland value (10^6 \$/km^2)	Protection costs (10^9 \$)	Emigrants (10^6)
0.86	**7,8**	**0,3**	**50,2**	**0,9**	**147**	**0,71**

2.5.2 Water Resources

Regional patterns of warming-induced changes in surface hydro-climate are complex and less certain than those in temperature. However both regional increases and decreases are expected in precipitation and runoff. Annual changes in precipitation and temperature gathered from four GCMs (GFDL-R30, GISS, GISSA, and CCCM) conclude that climate change scenarios consistently show increases in runoff over the northwest and south-eastern regions of SA, while the central and northeast regions show a mixture of increases and decreases depending on the GCM scenario[79]. An ensemble of 12 climate models project increases in runoff in the La Plata, Ecuador and Southern Colombia basins, and decreases in Amazonian, NE-Bz, MA, the Cb and South-western SA (Fig.7)[80]. There is a new UKMO HadGEM1 model that includes direct effect of CO_2 under SRES A1b and A2[81]. It shows that the runoff in NE-Bz will decrease by 5-20 %. In the Amazonian decreases will be 25-50%. In the Parana-Plata increases varies between 50% in low and middle basins, and 25% in the upper Parana and in the Pantanal. Main conclusions for the region are: 1) Climate change increases water resources stresses in some basins but decreases them in others. 2) The estimated impact on water resources depends least on the rate of future emissions and most on the climate model and the assumed future population. 3) Areas with an increase in water resources stress include MA and SA[31]. Glaciers have a critical importance for the water resources in the region, and are of great significance to agriculture, drinking water, mining and tourism. Recent studies indicate that most of the South American glaciers are drastically reducing their volume at an accelerated rate and could even disappear between in the next few decades if the current warming trend continues into the future[82]. Tropical Andean glaciers are predicted to melt between 2010 and 2050 affecting the supply of water for human consumption, agriculture, hydro-power, ecosystem integrity and tourism to a large fraction of the population living west of the Tropical Andes. People living at risk zones are estimated to reach up to about 37 M in 2020 and 50 M in 2050. Particularly affected will be the cities of Quito, Lima and La Paz (i.e. the glaciers El Tuni condoriri and Chacaltaya close to El Alto and La Paz will completely melt by 2009 and 2015 respectively). Because melting impacts are greater during the dry season, local adaptation measures should target reservoirs storage to manage a shift in the seasonal water cycle [83,84,85]. Projected scenarios of people living in water-stressed watersheds without and with climate change are shown in table 16. Most affected countries and sub-regions will be Mexico, Guatemala, Dominicana, Haiti, Cb small states, Peru, Northern Chile, Bolivia and NE-Bz.

Table 16. Water-stressed people (in Million people) at watershed level projected by HADCM-3-A2[75]

Year / Million people	Without Climate Change			With Climate Change		
	MA	Cb	SA	MA	Cb	SA
2025	36		20	32-35	0-22	14-33
2055	105	36	45	74-108		70
2080	175	48	88			

2.5.3 Environment and biodiversity

A simple potential vegetation model (PVM), coupled to an Advanced GCM reproduces the tropical forests in Amazonian and Atlantic coastal region, the savannas in Central Brazil, the *caatinga* and *"cerrados"* in NE-Bz and Chaco region, the grasslands in the SSA Pampas and

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the semi-desert in Patagonia[86]. This model shows two stable equilibriums. One corresponds to the current biome distribution. The second is a new possible equilibrium state with eastern-Amazonian forests replaced by savannas and a semi-desert area appears in the driest portion of NE- Bz. If conservation policies were not able to halt the increasing environmental degradation, then land-use changes could, per se, tip the climate-vegetation system towards this new alternative with drier stable equilibrium state that include savannisation of parts of Amazonia and desertification of the driest area of NE-Bz, and with potential adverse impacts on its current biodiversity and on water resources.

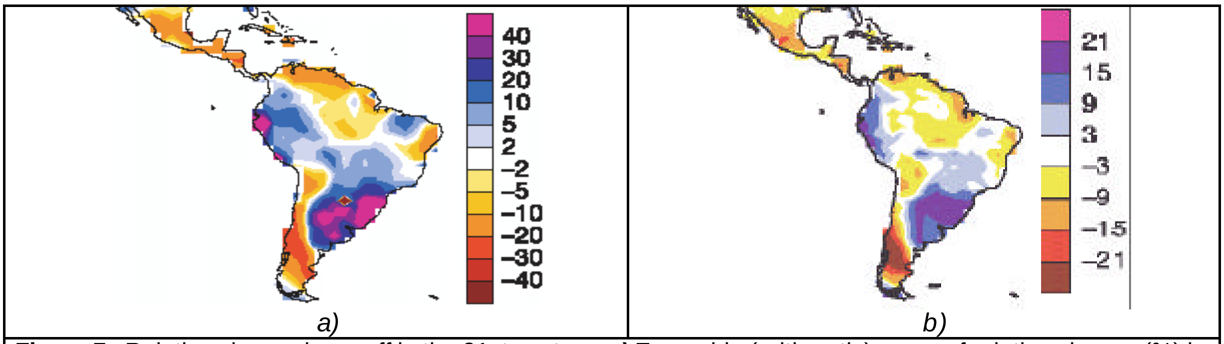

Figure 7. Relative change in runoff in the 21st century. ***a)*** Ensemble (arithmetic) mean of relative change (%) in runoff for the period 2041–60, computed as 100 times the difference between 2041–60 runoff in the SRESA1B experiments and 1900-70 runoff in the 20C3Mexperiments, divided by 1900–70 runoff. ***b)*** Number of pairs of runs (out of an available total of 24 pairs) showing a positive change minus the number showing a negative change[78]

A recent study[87] quantified the impacts of several scenarios of climate change on freshwater runoff, biome change from forest to non-forest (and vice-versa) and fire frequency. The study concludes, "The reduction of tropical forests area, especially in the tropical rain forests, will probably imply the loss of many species". Based on HADCM A2 and B2 scenarios, there is a potential of extinction of 24% of 138 tree species of the Central Brazil savannas (*cerrados*) by 2050 for a projected increase of 2º C [88, 89, 90]. The effect would be larger over eastern Amazonian than over western Amazonian, a conclusion supported by a projection of 'savannisation' of central-eastern Amazonian[91]. This study also indicates that for most climate change projections, the semi-arid region of NE-Bz could become even drier. Global warming projected for the year 2050 could sharply increase species extinction in Mexico[90] and in dry areas of Bolivia, Chile and Argentina (Fig.8)[92]. A very recent study[93] suggests that species lost under doubled-C0$_2$ warming scenarios should exceed those of deforestation. Especially vulnerable LAC hotspots are the Caribbean, the Tropical Andes and the Atlantic forest.

Assuming the very likely decrease in rainfall, the Amazonian is predicted to be a source of carbon estimated as being within the range 5-14 kg Cm^{-2}.[94]

2.6. Impact model

Market impacts of climate change projected by GCMs[95] for +2°C predict economic impacts for LA of -1.3% in terms of GDP. Although the overall effects of warming and carbon fertilisation are near zero, the marginal effect of higher temperature is expected to be harmful: changes beyond 2ºC are expected to reduce benefits and increase damages. Table 17 presents the

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[94] Levy PE et al. (2004) Modelling the impact of future changes in climate, C0$_2$ concentration and land use on natural ecosystems and the terrestrial carbon sink. Global Environmental Change 14:21-30
[95] Mendelsohn R., M. Schlesinger and L. Williams (2000a). Comparing impacts across climate models. Integrated Assessment 1, 37–48 37

market results using the reduced-form response functions. Most of these damages come from agriculture, which suffers a $78 bn loss. Energy contributes losses of $5 bn.

Table 17. Latin America market impacts (10^9 of 1990 U$/year) from the reduced form model for a 2°C global-mean warming (approximately by 2060).

Region	Sector						
	Agric	Forest	Coast	Energy	Water	Total	%GDP
Latin America	-78	7	0	-5	0	-76	-1.3

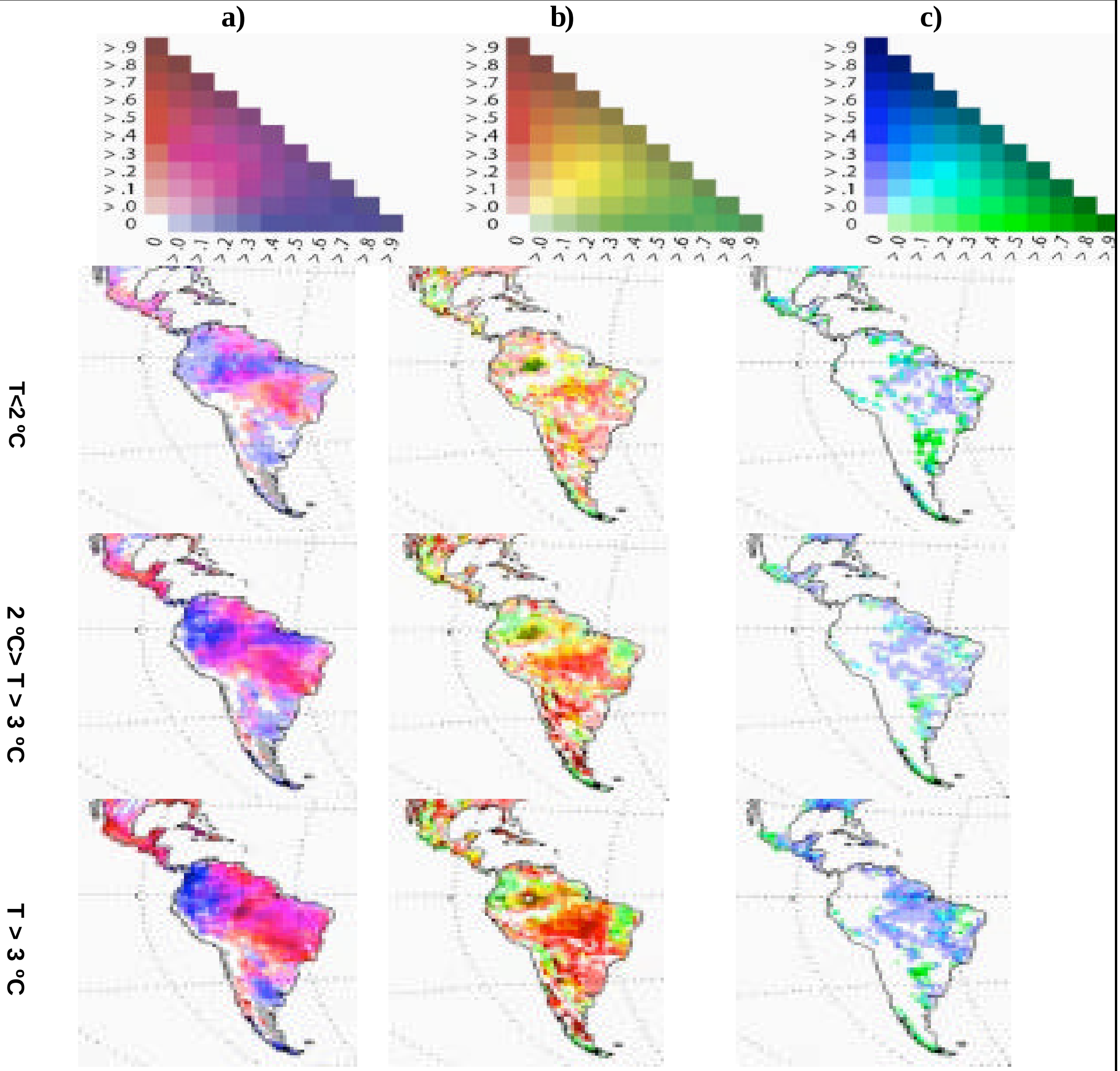

Figure 8. Probability of exceeding critical levels of change between 1961-1990 and 2071-2100 for three levels of global warming. For quantitative variables, critical change is defined where the change in the mean exceeds ±1 s of the observed (1961-1990) inter-annual variability. (a) Freshwater runoff (blue for increase, red for decrease; mixed colours show cases where different runs produce changes in opposite directions). Grey areas denote grid cells with =10 mm yr^{-1} mean runoff for 1961-1990. (b) Wildfire frequency (red for increase, green for decrease). (c) Biome changes from forest to non-forest (blue) or vice versa (green). For wildfire frequency and biome change colours are shown only for grid cells with less than 75% cultivated and managed areas. Adapted from[85].

Summary of Future Climate Change Summary of Future Climate Change Impact Matrix – LAC

Climate Models	Time-slice	INCOME Agriculture, Land constraints, Fisheries & Food Security	Energy	Tourism	Infrastructure & Coastal Cities	GDP $ bn (2004)
Global Warming		▪ LAC aggregated Crop Production (Mht of maize, wheat, soybean and rice) [34] ▪ with CO_2 fertilisation in green text and without CO_2 fertilisation in red text [35] ▪ LAC aggregated Fish production and exports (Million tones) ▪ Bz: Tropical and sub-tropical and Pampas: Central and NE-Argentina, Uruguay and Southern Brazil.	Biomass / Hydropower / Oil %		1-total 2- roads & bridges 3-coastal cities costs in $ bn 2004	
Baseline	~2002-04	▪ LAC - Crop production: Maize, wheat, soybean, and rice): 229 M ton (87% in Bz, Mx and Argentina[34] ▪ LAC - Fish production and exports: 21.0 and 7.3 M tones respectively [46]			1- 30 2- 6	2.6% increase in real GDP [96]
+0.5-1.0	2015-2030	▪ Slight increases in temperature, rainfall and CO_2 will benefit overall subtropical rain-fed cultures [83] ▪ Crop production changes from –1 to 2% and from –4 to –5%. ▪ Wheat varies +1% and from –7 to –5% in the Pampas ▪ Maize varies from +4 to +8% and from –5 to –1% in the Pampas. ▪ Soybean varies from +16 to +21% and from –3 to –6% in the Pampas [35,39,40] ▪ Fish exports are expected to expand to 10.6 by 2010 and decrease to 10.3 Mt by 2015 due to increase in local demand [45,46]	1/ 13/ 15 [47,48]	Will likely be affected by increase in storm surges ?		
+1.0-2.0	2040-2060	▪ Crop production changes from –1 to -2% and from –8 to –9 ▪ Central Argentina: crop production decreases from -13 to -17% ▪ Central Argentina: crop production decreases -13 % under a scenario of temperature variance x 2[36] ▪ Wheat varies - 30% in Bz, + 1% and from –10 to –8% in the Pampas ▪ Maize varies –15% in Bz , from +6 to +9% and from –4 to –1% in the Pampas ▪ Soybean varies +21% in Bz, from 31 to 40% and from –6 to –4% in the Pampas [35,39,40] ▪ Food security risk decreases in AC and MA due to decrease in Subsistence Maize production:-14%[44]	Losses: from $-4 to –5 bn of 2004 dollars this report	Will likely be affected by SLR in the Atlantic coast of MA, the Cb and Uruguay.		Optimistic = 2.58% increase in real GDP. Pessimistic = 2.47% increase in real GDP. Losses impacts (-93 to –425 $ bn), or –1.6% to –7.3% of GDP) by 2060 [96].
+2.0-3.0	2060-2080	▪ Central Argentina: crop production decreases -17% [36] ▪ Central Argentina: crop production decreases -34 % under a scenario of temperature variance x 2[36] ▪ LAC Losses: -78 $ bn / yr (1990) [96] ▪ LAC aggregated Food Security (and rural poverty) will likely increase in spite of the negative impacts of warming for all scenarios excepted under A2 storyline [42]	13/13/20		3-Buenos Aires: 0.3 /yr (2070-80)[97]	
3.0-4.0	2070-2090	▪ Crop production changes from –1 to +3 and from –25 to –30%. ▪ Total extent of land with constraints will likely vary: -1 % in SA and +7% in MA + the Cb ▪ Wheat varies from 10 to 17% and from –8 to –7% in the Pampas ▪ Maize varies from +11 to +13% and –4% in the Pampas. Soybean varies from +36 to +46% and from –12 to –10% in the Pampas [35,39,40]	15/20/18 -7 $ bn /yr (1990) this report		3-Montevideo: 0.03 to 0.12 /yr[98] LAC Damage: 0.3 -1.0% of GDP based on 62	-349 $ bn of impacts in 2100 included climate disasters impacts (15 $ bn [96]
4.0-5.0	2080-2100				3- 0.05 –to 0.3 /yr	
>+5.0	2090-2110				0.5 - 2.0% of GDP	
Model		HadCM2 and3 for crops and HadCM3 and CSIRO for Food Security·				
Adaptation assumptions		Easy Adaptations (new technologies, new seed varieties, adjusting planting dates, agricultural intensification) mostly at intensive and large-scale cultures; less if any at subsistence levels [37]			Unaffordable at current situation	
Socio-economic assumptions		Prevailing views of the future world between A2 and B2 storylines. Fish exports will increase 40% by 2010-2015. These figures are market-based and do not include climate change and El Niño which can decrease fish landings by. – 40 to –80% in Peru [45,46]		A2 / Table 4	LAC - protection cost: 147 bn (7% of GDP-2004) [62]	

97. Barros V et al. (2006) Vulnerability to floods in the metropolitan area of Buenos Aires. AIACC Work. Ser. Paper N 26.
98. Hareau A et al. (1999) Vulnerability to climate change in Uruguay: potential impacts on the agricultural and coastal resource sectors. Clim. Res. 12:185-193.

Global Warming since 1990	Time-slice	Human Development			Environment		
		People at risk of water stress at water shed level & water supply (SW) in Million people	People displaced by coastal flooding (due to storm surges and SLR)	People at risk of vector-borne diseases	Change in size of natural habitat	Species lost % N^b /per hotspot	Natural system services (water; glaciers; carbon sequestration)
Baseline		22 M (1995) 156 M (2002)		▪ Malaria Adaptation cost: $1.4bn ▪ Population at high risk of Malaria: 1.5 M [This study]	Threatened by land use changes, climate disasters, water pollution and wild-fires.		
+0.5-1.0	2015-2030	▪ Without climate change: 60 M ▪ With climate Change: 60-90 M. ▪ Access to SW without climate change: 66 M at a cost of ~$16 bn [74,75]		▪ Population at high risk of Malaria: 2 M ▪ Population at risk of Malaria: 20 M [65] ▪ Estimates of mortality due to malaria, schistosomiasis and dengue:1,101 /114 /0 thousand people [62,63,64]	Wetland and coral reefs losses will very likely be important due to the progressive and accumulated effects of human direct intervention and impact, storm surges, and warming under slightly increasing SLR in the Atlantic coast of MA and the Cb respectively [77]		The glacier that provide water resources to the city of La Paz is predicted to melt within the next 3-15 years [82,83,84,85]
+1.0-2.0	2040-2060	▪ Without climate change: 186 M ▪ With climate Change: 180-220 M [74,75]		▪ Population at high risk of Malaria: 3 M ▪ Population at risk of Malaria: 50 M ▪ Aedes darlingi will likely expand to the South ▪ Malaria will highly likely increase ▪ Dengue transmission will very likely increase 2 to 5 folds ▪ Schistosomiasis will very likely increase ▪ Leishmaniasis will very likely increase [62,63,64,65]			
+2.0-3.0	2060-2080						
3.0-4.0	2070-2090	▪ Without climate change: 311 M ▪ With climate Change: Not estimated yet	0.4 to 0.6 M in the Atlantic and Pacific coasts of SA and the Cb under A1/2 storylines [77]		Savannisation of Eastern Amazonian and desertification in NE-Bz [87,88,89,90,91]	24% of trees in central Bz; high risk in E-Amazonian and dry areas in Mx, Chile, Bolivia, Argentina. [89,90,91]	Negative trend in biodiversity and water resources in Eastern Amazonian. [86,87,88,89,91] Assuming the very likely decrease in rainfall the Amazonian will likely be a source of C: 5-14 kg C m^{-2} [95]
4.0-5.0	2080-2100				Wetland and coral reefs losses will very likely be severe under moderate SLR in the Atlantic coast of MA and the Cb respectively[77]		
>+5.0	2090-2110		0.7 M under 1 m SLR [62]				
Model		HADCM3 Sc. A-2	HADCM3/ECHAM, CSIRO A-2	HadCM3 / Econ. A2 - Composite / Table 4	HADCM A2/B2		
Adaptation assumptions		Attaining the MDG goals is the target		Malaria Adaptation cost is estimated to increase to $1.9 and 2.8 bn dollars by the 2030s and the 2050s respectively			

3. Stream II: Past and Current Climate Variability.

This section deals with recent-past (1970-1999) and current (2000-2005) situation in relation to human, economic and environmental vulnerability and impacts related to weather and climate-related disasters focused on wind-storms, floods and droughts). Aggregated and country-level relevant examples are given as to illustrate on non-climate sector status and the type of climate risks and the scope for and constraints to adaptation that the region faces. Also, an expert judgment to assess our perception was developed.

3.1 *Climate Variability*. ENSO signal is strong all along the Tropical and Subtropical belts. During El Niño high rainfall often occurs in semi arid high plateau and deserts along the Andes and in the Rio de la Plata basin (followed by floods), whereas drought occurs in NE-Bz and wide regions over Amazonian. La Niña usually has a shift in signal. In Brazil, Uruguay and NE-Argentina there is also a signal from tropical Atlantic sea surface temperature anomalies[96,97].

3.2 Climate Disasters. LAC Sub-regions have different records in terms of disaster occurrence, fatalities, affected populations and damages[98]. About 50% of the disasters occur in SA as well as 65% of the fatalities, 75% of the population affected and 53% of total damages. Nevertheless, SA's effective exposure to risk might not be as high as in MA or the Cb. Occurrence per thousand km^2 is only 0.3, compared with 10 for the Cb; MA has a greater proportion of population killed than SA does and the Cb has a greater proportion of affected population than SA. In terms of damages, cumulative losses for 1970-99 represent only 3.9% of the combined GDP of SA countries, whereas they amount to 43% for the Cb.

Flooding has caused nearly half the disasters in SA. The two other important events have been landslides and earthquakes, while windstorms only caused 7% of disasters. In the case of the Cb, more than half of disasters were due to windstorms, while flooding was the second major natural event. MA is the region that faces the biggest variety of disasters, with 31% caused by floods and 26% by windstorms. Nicaragua has the highest ratio of fatalities as a share of population, as well as a very high ratio of cumulative losses/GDP (338%). In SA, Bz has the highest occurrence of disasters, with 3.4 disasters per year on average. By contrast, Uruguay experienced a disaster every four years. Peru and Venezuela have a high ratio of fatalities per population and the rest of the region has a rather low ratio of fatalities/population. In terms of the ratio of damages to GDP, Ecuador, Bolivia, Colombia and Peru have a ratio greater than 10%, while the rest of the countries have a fairly low ratio, between 0.1 and 6%. These country indicators corroborate the positive correlation between poverty incidence and vulnerability to disasters and the negative correlation between country size and economic vulnerability to disasters. For MA and the Cb wind-storms are the main source of human and economic impact, whereas in the AC and RP floods have the greatest economic impact. In Bz both flood and droughts impacts are similar. Average event cost (1970-1999) are 180, 126, 86 and $ 15 M for droughts, windstorms, floods and others respectively [3.] On aggregated basis climate disaster account for ~74% and ~81% of damage costs and occurrence respectively. Regarding the share of climatic economic damages, floods account for 44%, wind-storms for 38%, and droughts for 15% and others for 3% of accumulated costs respectively. Others include famines, infestations and storm surges. As for human, social and natural capitals, long-lasting droughts are probably the worst climate disasters and, because of spatial coverage, more people are affected than in other disasters. Most floods and droughts have been ENSO-related and partly explain fluctuations in GDP (see Fig. 3). During 1970-83 and 1998 Peru's fish catch fell ~80% and 45 % respectively accounting for 10% and 5% of world's total due to El Niño events [99.100]. Current natural disasters (2000-2005, post *Charveriat's*

[96] Doyle M. and V. Barros (2002) Midsummer low-level circulation and precipitation in subtropical South America and related sea surface temperature anomalies in the South Atlantic, 2002. J. Climate, **15**, 3394-3410. Doyle, M. and V. Barros

[97] Doyle M. and V. Barros (2002) Barros V et al. 2002. *Climate variability over subtropical South America and the South American Monsoon: a Review.* Meteorológica, **27**, 33-57.

[98] Charvériat C. Natural disasters in Latin America and the Caribbean: an overview of risk (Working papers series 434). http://www.iadb.org/regions/re2/sida-idb-partnership/docs/ENVNatDisastLACeline.pdf

[99] IDB Report (1995)

[100] Prado J (1999) Research and Development in Fishery Technology in Latin America. http//www.esig.ucar.edu/un/ecuador.html.

work[98]) were compiled (table 18)[53]. Wind-storms produced the main economic impact followed by floods. However, the number of climate-related disasters economically quantified varied from only 16 to 30% (19% on an average). Droughts are now (2005-06) the prevailing disaster concentrated in large portions of SA.

Table 18. Climate-related Disasters in LAC (2000-05) [54]. Climate accounted for 86% of total disasters.

VARIABLE	EVENT TYPE	REGIONS OF LATIN AMERICA AND THE CARIBBEAN					
		BZ	RP	AC	MA	CB	LAC
Events (in number)	**Drought**	4	4	4	13	5	**30**
	Flood	18	18	60	47	23	**166**
	Wind-Storm	3	11	7	40	52	**113**
Events Quantified (in % of total)	**Drought**	25%	25%	0%	38%	40%	**30%**
	Flood	17%	17%	15%	15%	17%	**16%**
	Wind-Storm	33%	18%	0%	18%	19%	**18%**
Damages (in million US$)	**Drought**	220	250	-	351	9	**830**
	Flood	348	1,353	489	146	1,305	**3,641**
	Wind-Storm	350	40	-	2,198	10,490	**13,078**

3.3. Health. The increase in vector-borne, infectious and ENSO related diseases (i.e. malaria, dengue, cholera, Leishmaniasis, yellow fever, Hantavirus) and the re-emergence and increase of malaria and dengue since 1990 coincide with multi-factor causes such as climate variability, extremes and natural disasters. Tropical, subtropical and forest countries with disease low control, political instability and high inequity in both income distribution and access to health services are highly vulnerable, and the risk should increase due to climate change[1,101,102]. Vulnerability and impacts range from countries where none or very few of these diseases are present (i.e. Costa Rica, Cuba and Uruguay) to others seriously affected such as Bolivia, Ecuador and, particularly, increased spread in the subtropical regions of Brazil, Paraguay, Bolivia and Argentina of Leishmaniasis (Table 19). However, ENSO events are the cause of many flooded, drought and landslides areas that are prone to the transmission of many diseases (i.e. Hantavirus) affecting countries with good health index such as Argentina, Chile and Uruguay. Economic development (i.e. agricultural intensification, dam construction, overcrowded urban areas) have triggered the suitable environmental conditions for the appearance of potential diseases[14] i.e. cyanobacterial blooms in the lower RP basin[103].

Table 19. Diseases which are sensitive to current climate change and variability in the LAC region.

Disease	Prior to 1990	Current / near-future (1990-2010)
Vector-borne	**Hemorrhagic dengue** **Yellow Fever** in tropical regions	**Dengue and Hemorrhagic dengue** increased by 60 times from 1989 to 1993 Frequent epidemics occurred in tropical regions during the 90s where it had low prevalence for 50 years. **Yellow fever** reappeared in Peru in 1995 with a morbidity of ~50%. **Malaria** increased and expanded over the last decade (1 M cases) and 37.9% of population's is at risk (i.e. Bolivia, Ecuador). **Cholera** reappeared as epidemics in 1991, remaining as endemics in many countries.
Infectious		Diphtheria and Poliomyelitis
New, emerging & re-emerging		**AIDS** (1.5 M people) and co-infection with **tuberculosis**. **New viruses**: hemorrhagic fevers in Argentina, Bolivia, Venezuela.
ENSO-related		**ENSO-related outbreaks** i.e. V. Cholerae, E. Coli, Salmonella, Shigella, Hepatitis A, Malaria, Dengue, Leptospirosis, Leishmaniasis. **Hantavirus** outbreaks since 1996 (Argentina: 10 deaths in first few months, Brazil, Bolivia, Chile, Ecuador Paraguay and Uruguay) related to ENSO driven flood-droughts. **Leptospirosis** in MA and Colombia (1995).

3.4 Agriculture. The greatest climate threats to agriculture are drought, flooding and climate change[104]. Climate variability has been severely disturbing the agriculture sector during the last few years. Intense droughts, flooding and windstorms were the most common episodes (Table 20). Only during 2005 and the first quarter of 2006 generalized droughts and flooding

[101] UNEP-WHO-Wealth Canada (2003). Health and Global Environmental Change Series 1, Conpenhaguen.
[102] OPS/OMS report (2000).
[103] Nagy et al. (2006) Vulnerability of the Rio de la Plata to Climate Variability and Change, AIACC Working Series Paper Nº 22.
[104] FAO (2000)

affected several countries. During the winter and spring of 2005 precipitations were almost 50% of normal values in the Bz Amazonian, between 25% and 50% lower than normal in most of Brazil and Uruguay, while an intense drought focus was observed in south Bolivia, most of Paraguay, the centre-north of Argentina and the west of the Pampas[105]. Precipitation values were the lowest in the last 100 years in southwest Buenos Aires and centre-east of Cordoba in Argentina, and in the last 40 years in Amazonian[106]. These climatic disasters are not ENSO-related as most of the recent-past.

Recent projections estimated that losses in crop production in Argentina would rise to $ 900 M[107]. After a record harvest of 84 million t of grain in 2004-05, the grain harvest of Argentina would decrease by 10 Mt (12%). Most of this decrease is due to the lower planted area of wheat and corn, and the effects of the severe drought of December 2005 in most of the grain producing regions[108]. In Paraguay 55% of soybean lands were affected due to deficit in precipitation between November and January, and losses could attain $ 170 M[109]. At the beginning of 2006 floods threatened crop production and food security of the poorest communities of Bolivia, Brazil, Peru, Ecuador and Guyana. Unprecedented heavy rains have been lashing Bolivia since January 2006. It is estimated that 96,300 hectares of cultivated lands were lost with losses of $15 M[110]. In the highlands rainfall has been nearly three times the annual average. Consequently the highlands and the Amazonian have suffered severe flooding, causing serious damage to crops[111].

Table 20: Extreme events affecting the agriculture sector of LAC since 2003

Event	Year	Country	Site	Sector	Losses	
					Production	M US
Droughts	2004	Ecuador		Crops	70%	
	2004	Guatemala		Crops	80%	4
	2004/05	Brazil	RG do Sul	oybean and other	8 Mt	2200
	2004/05	Argentina	NOA NEA	Soybean	2 Mt	340
	2005	Argentina	centre-north-western Pampas	Main Crops	10 Mt	*900*
	2005	Paraguay		Soybean	55%	*170*
	2005	Bolivia	Santa Cruz: hail and floodin			1
	2005	Peru	Piura frost			11
Flooding	2003	Argentina	Santa Fe	Soybean, Maize Sorghum	0.4 Mt 0.2 Mt	68 16
	2004	Argentina	Chaco		0.3 Mha	200
	2006	Bolivia	Potosí, Oruro, La Paz	Crops	70%	15
	2006	Guyana	Mahaica, Mahaicony	Cash crops Rice export	100%	4
Hurricane Catarina	2004	Brazil		Banana Rice	85% 40%	
Hurricane Stan	2005	Guatemala		Basic grains Horticulture Coffee Cattle		160 16 30 134
		Mexico	Chiapas	Coffee	0.23 Mha	120
		El Salvador		Productive lands	9.1%	
Hail storm	2006	Argentina	Santa Fe	Soybean & Maize	0.016Mh	*5*

Most poor communities living in the highland rural areas have lost nearly 70% of their crops. In Guyana some farmers lost all their cash crops; losses to rice exports are valued at $ 4 M. In Ecuador 250 subsistence farmers lost their crops[112]. Coupled with successive economic crisis,

[105] http://www.aapresid.org
[106] http://www.conexionagraria.com. http://www.ipsnews.net
[107] http://www.laopinion-rafaela.com.ar
[108] http://www.ppi-ppic.org
[109] http://www.lanacion.com.py
[110] http://www.ens-newswire.com
[111] http://www.reliefweb.int
[112] www.reliefweb.int

crop failures have increased food security risks in several countries increasing malnutrition among the poor[113].

The case of Uruguay illustrates on the late and partial assessment of the impacts of droughts and how they are a main constraint for future adaptation in the Pampas grasslands "*There is an intimate connection between the country's natural environment and its economic performance. Inadequate natural resource management could jeopardize the otherwise promising performance of the livestock and agricultural sectors during the last decade. Poor water resource management is still widespread, leading to inefficient water use and increased pressure on water resources. Livestock production, which has been dominated by extensive, low profit production systems, represented until recently little or no threat to natural resources management. However, exposure to prolonged periods of economic hardship and frequent weather-related difficulties are resulting in an over-exploitation, and consequent deterioration, of the natural resource base. The attention for these concerns may have been triggered the droughts in 1996 and 1999/2000, which severely affected Uruguay*[114] ". The cost of the 1999/2000 drought was recently estimated as being $ 191 M, about 1.2% of the national GDP (2000), shared as directs costs in agriculture and indirect costs in agro-industry and commerce[115]. This figure does not include the use of thermo-electrical power plants.

3.5. The environment and biodiversity. The LAC Region is one of the richest sources of biodiversity in the world and has potential for carbon sequestering[116,117]. One third of its surface area is covered with grassland where productivity depends on rainfall. Significant tracts of grassland are subjected to overgrazing, rendering them vulnerable to the periodic droughts. Land-use and cover changes and its interaction with climate is nowadays one of the most important causes of changes in eco- and agro-systems, making patterns of vulnerability highly diverse[118]. Of great concern are the desertification processes brought about by these interactions. LAC has an area of 20 x 10^6 km^2, 25% of them correspond to arid, semi-arid or sub-humid land presenting serious degradation problems. SA is the first world's source of $C0_2$ emissions associated with land-use changes[119]. Some examples are the deforestation of tropical forests in the Amazonian and MA; intensification of agriculture in the humid pampas of SSA which is exacerbating soil erosion due to climatic factors; and the miss-management of water resources in arid and semiarid habitats depending on irrigation.

3.6 Water Resources. In 1995 22,3 M people were living in water stressed regions, with less than 1000 m^3/capita/year; 19,3 M people in MA and 2,9 M people in the Andean watersheds of Peru and Northern Chile. Brazil has the largest Total Water Resources followed by Colombia, Peru, Venezuela and Chile, whereas the lesser volume belongs to the Cb small states (CbSS). In terms of m^3/capita/year the most water-stressed (vulnerable) countries are CbSS and the lesser ones are Bolivia, Peru, Paraguay and Chile (Table 21). Main water internal resources belong to Brazil, Colombia, Peru, Chile and Venezuela and the minor ones to the CbSS. The Internal Renewable Resources class first Peru followed by Chile, Panama, Colombia and Nicaragua, whereas in the bottom of the list are CbSS. There is strong evidence of the retreat of glaciers and ice-fields in the AC[120] due to the rise in temperature in the 20th century[121]. Their melt-water supplies nine % of the total water in the world.

3.7 Energy consumption and $C0_2$ emissions. Total Primary Energy consumption increased from 21 exajoules (EJ) in 1990 to 29 EJ in 2002. Fossil fuels accounts for ~54% of primary energy, natural gas 18%, hydro-power 22%, nuclear ~1% and other sources ~5%[122]. The

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113 http://www.hewsweb.org/drought/298
114 3242988ocdeUruguay.pdf page 20, 2004
115 Barrenechea P. (2004). "Emergencias Ambientales de Origen Climático. Inventario de Información Económica Existente". Unidad de cambio Climático, Dinama, MVOTMA. Mimeo. Montevideo, agosto 2004.
116 WRI Report 1990-91.
117 LAC CDE (1992)
118 (www.grida.no/climate/ipcc/spmpdf/region-s.pdf).
119 COP 10 (2005)
120 Rignot E., Rivera A., Casassa G. (2003). Contribution of the Patagonia Ice fields of South America to Sea Level Rise. Science, 302, 434-437.
121 WWF (2003). Going, going, gone! Climate Change and Global Glacial Decline. Berlin, World Wide Fund for Nature Climate Change Program. http://www.panda.org/downloads/climate_change/glacierspaper.pdf
122 International Energy Outlook (2005)

dependency of the electrical systems (ES) of the hydro-power plants is 57% of the total generation of LAC[123].

Table 21. Water Resources and stress in the LAC region.

Country	Population (FAOSTAT, 2000)	Total Renewal Water Resources (Km^3)	Water-stressed (m^3/capita/year)	Internal resources total (km3/year)	IRWR (m^3/yr inhab)
LAC	521,234	18,380		13,420	
Argentina	37,032	814.00	22,129	276.00	7,453
Brazil	170,406	8,233.00	47,121	5,418.00	31,795
Costa Rica	4,024	112.40	28,637	112.40	27,932
México	98,872	457.22	4,624	409.00	4,137
Peru	25,662	1,913.00	73,750	1,616.00	62,972
Barbados	267	0.08	301	0.08	301

Regional analysis of the use of energy and Total Dependency on Energy Systems in the LAC region is summarised as follows: The Cb: Fuels are 79% and renewable energies account for 17%. The AC: Fuels are 80% and main renewable source is hydro-power. The Southern Cone**:** Fuels are 66% and renewable sources account for 30%, from which hydro-power accounts for 13%. Energy consumption and $C0_2$ emissions are shown in Table 22.

Table 22. Energy consumption and $C0_2$ emissions for the LAC region and selected countries (2004)[124]

Country	Per capita final consumption (Boe* x 1000)	Energy Intensity FCE/GDP (Boe/1000)*	Per capita Final Electr. Consump. (KWh)	Per capita Petroleum Consump. (Boe)	CO_2 Emissions 1000 x ton.			
					EG-Electrical Generation	EG per cap.	ES-Energy Sector	ES per cap.
LAC total					239,00		1330,05	
LAC mean	6.3	1.6	1558	4.0	9,19	44	51,15	2248
Argentina	8.9	1.1	2217	5.1	22,66	1,69	124,06	9251
Brazil	6.7	1.6	1874	3.3	24,02	13	351,01	1900
Chile	9.7	1.5	2723	5.9	16,35	1,14	60,58	4223
Honduras	3.4	4.6	573	2.1	2,08	29	6,86	957
Mexico	7.2	1.5	1509	6.2	100,10	96	414,34	3974
Trinidad-T	52.6	7.9	4557	10.0	4,33	3,31	26,57	20299
Venezuela	10.3	3.6	2607	7.0	23,18	89	129,89	4986

Boe: Barrel of oil equivalent

3.8. Expert judgment of the trend of climate change impacts, vulnerability and adaptation.

Mitchell and Hulme[125] estimated world's region vulnerability as a function of consumption based upon an analysis of past and future global warming. Indicators of vulnerability and consumption are the ratios GDP/capita/ºC and carbon emissions in tonnes/capita respectively. Fig. 9 is a modification of their graphic showing significant differences within LAC. The RP is some less vulnerable (especially Argentina and Uruguay) than the region.

We developed an expert judgment of the vulnerability and impacts to/of climate change to specific environmental, infrastructure, financial, human and social variables. The data collection design was based on Likert Scales utilized to attribute value to otherwise qualitative perception[126]. They allow turning abstract concepts into empirically observable statements that could be utilized as indicators of the level of impacts on Human Development, Income and Environment. We selected 18 proxies directly related to climate change impacts and adaptation issues (Table 23). For each statement, a scale of values (from 1: irrelevant to 5: crucial, and then also weighting each factor from 1 to 3) was used by consultants to determine our perception of reality. Then, these proxies were rearranged according to the five capital concepts (natural, physical, financial, human and social) in order to analyze the data obtained in the survey quiz through Principal Component Analysis (PCA). The box plot (Fig. 10) allows seeing the dispersion of the data. The highest value is 15 (product of the maximum perception

[123] OLADE Report (2005)
[124] Organización Latinoamericana de Energía, Versión n°17, Sistema Información Económica Energética (2005)
[125] modified from Mitchell T and M Hulme (2000). A country-by-country analysis of past and future warming rates. Tyndall Centre for Climate Change Research.
[126] Pittaluga F. et al. (2004). Livelihood systems profiling: mixed methods for the analysis of poverty and Vulnerability. LSP working papers series. FAO. Rome

value for the impact of climate change on each capital and the greatest weighting). Notoriously the natural capital is which possesses the greatest; also it can be seen that all capitals but human show negative asymmetry (most values are located above the median).

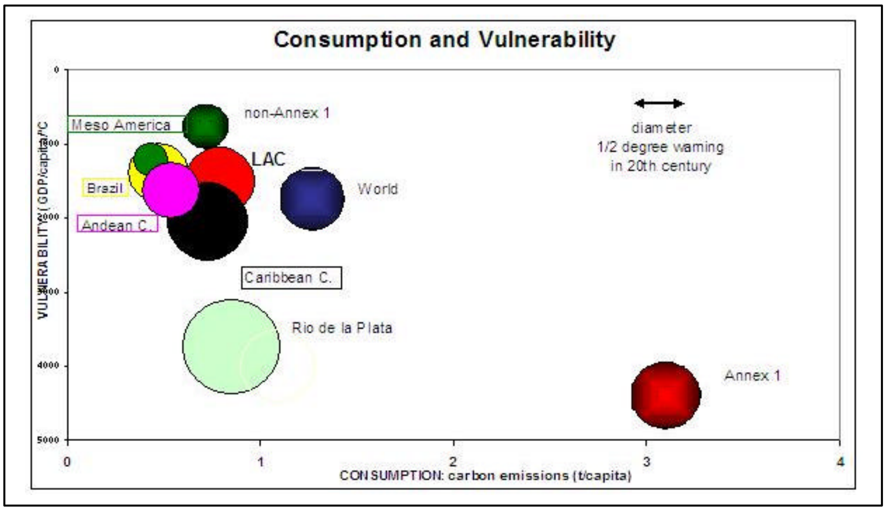

Figure 9. Consumption and Vulnerability in the world, Latin America and the Caribbean; modified[48]

The analysis shows a clear association between human and social capitals on one side, and physical and financial on the other side, while natural capital remains apart. This can explain the strong links between these two pair of capitals, which are affected in similar ways by CC, and thus can give an opportunity to target adaptation options.

Table 23. Expert judgment proxies utilized to assess the perception on Climate Change and Variability Impacts. Average for each of the 18 proxies. Average for each key factor (Environment, Human Development and Income). Value range = 1-15.

	Past	Present	Future
ENVIRONMENT: effects/impacts on	**5**	**7.5**	**8**
Average weighting factor (1-3)	***2.5***	***2.5***	***1.75***
Biodiversity loss	6.1	8.6	8.8
Natural habitats (forest and coastal zones) destruction	6.8	8.6	8.5
Ecosystem services decrease	5.4	7.9	8.2
Natural resources availability	5	6.8	7.9
Sea level rise	3.2	5.4	6.4
Fresh water resources degradation/scarcity	5	7.5	8.2
HUMAN DEVELOPMENT: effects/impacts on	**5**	**6**	**7**
Average weighting factor	***2***	***2***	***1.6***
Direct life losses	4.6	6.3	6.8
Food availability/hunger	4.6	5.7	7.1
Loss of livelihoods	4.9	6	7.1
Migration/displacements/rapid coastal urbanisation	5.4	6.6	6.2
Potential for conflicts	3.7	4.9	6
Vector-borne disease increase	5.1	6.6	7.3
INCOME: effects/impacts on	**3**	**4**	**11**
Average weighting factor	***1.4***	***1.3***	***2.5***
Crop production	3.9	4.5	12
Livestock productivity	3.4	3.7	10
Fisheries	3.4	4.3	12
Tourism	2.8	3.9	11
Infraestructure/properties	3.9	4.5	12
Energy production and supply	3.2	3.9	11

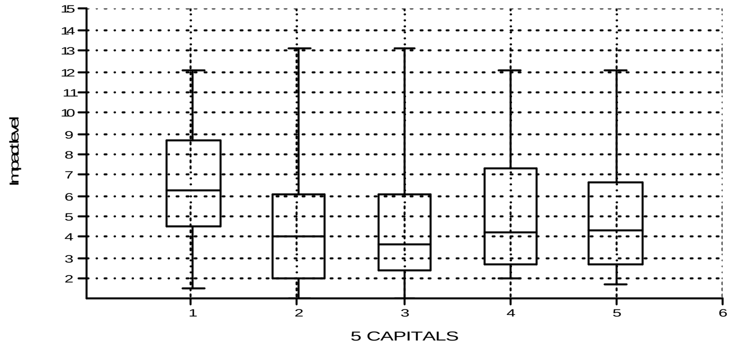

Figure 10. 1-Natural Capital, 2-Human Capital, 3-Social Capital, 4-Economic Capital, 5-Physical C.

Summary of Past and Current Impact Matrix I. Income, Human Development and the Environment Aggregated for the LAC region.

Sectors, Systems & Groups	**INCOME**	**Agriculture**				**Energy**	**Tourism**	**Infra-structure**	**Coastal Cities**	**Fluvial Transport.**
Climatic Event	a. Return Period b. Intensity & CC effects in LAC c. % exposed basins	**Crops** 1. Productivity 2. Livelihood Losses 3. losses in $ Millions	**Fisheries** (El Niño)	**Food Security**	I. %GDP II. BoP III. Af. Peo IV. $ M V. ENSO% losses					
Wind Storms	a. 9 y^{-1} b. more than 50% of Cb disasters	1. decrease in crops & livestock, increase in soil erosion [83] 2. decline livelihood 3. only 2005 occurrences: $4.6*10^2$ compiled for this study from 54	*El Niño events 82/83 and 97/98 in Peru:* catch fell ~80% and ~45% respectively affecting employment of 70,000 people, BoP and decreases of ~3 and ~2% of national GDP [45,46]		I. -1.1% GDP II. ↓BoP III. 30% IV. $4.0*10^{10}$ compiled for this study from 54, 83		high Impact [76]	High Impact [76]	High Impact [76]	
River Floods	a. 14 y^{-1} a. $5*10^2$ days b. $3*10^3$ - $1*10^1$ b. rainfall>50 mm/d c. Increase 12%	1. decrease in crops & livestock, increase in soil erosion & grassland productivity [83] 3. $3*10^2$ compiled for this study from 54		Increase pests disease [83] Decrease FS in 2006 for the poorest	I. 1.3% II. BoP III. 50% IV. $3.6*10^{10}$ V. -3-6% compiled for this study from 54, 83	increase 20-30% hydro-power generation compiled for this study from 47 to 61	Moderate [76]	High Impact Roads, bridges, houses compiled for this study from 54		
Droughts	a. 2 y^{-1}	1. decrease in crops, grassland productivity & livestock 2. decrease in livelihood decrease employment 3. $3.6*10^3$ compiled for this study from 54 decrease Mht planted		Extreme impact: 33% of area are vulnerable grass-lands	I. 0.5% II. decrease BoP III. 65% IV. $1.1*10^{10}$ V. -3-8% compiled for this study from 54, 83	decrease 30-60% hydro-power generation	Moderate [76]		Saline Intrusion [76]	Loss: $3,9 M Magdalena river low-water, El Niño 97 [53]
Sub-total	1970-1999: 3.9% & 43% of GDP in SA & Cb respectively	2003-06 $4.4*10^3$			IV. $9*10^{10}$					

	Human Development						**Environment**			
Event / Sector, System.	Life Losses	Number of displaced People	**Potential Migration conflict**	**Health**		*Safe Water*	**Water Stress**	**Environ. changes**	Loss of species	Ecosystem services
Wind storms		Very High	Very High	• Increase of killed & injured people.	Increase Killed & injured people	decrease				
Floods	Average physical exposure per year: $2*10^3$ Physical exposure in % of pop: 20 Killed per M exposed: 34.	$10-10^4$	High in the short-term: 10^2-10^4	• Dengue increased by 60 times from 1989 to 1993. • Malaria increased Nb of cases and expanded its area and elevation. • AIDS co-infection with tuberculosis	Increases: • Malaria • Dengue • HantaVirus • Leishmamiasis • Leptospirosis • Cyanobacteriae	• Increase reservoir • Increase risk of inundation & water pollution				Changes $C0_2$ sequestration rates
Droughts		Very high on the mid-term	Extremely high in the long term. Increase inequity & conflicts between users*	• New hemorrhagic virusial fevers in Argentina, Bolivia & Venezuela • Re-appearence of cholera as epidemics (1991). • Reappearance of yellow fever in Peru (1995). • Hantavirus, leptospirosis, leishmaniasis in SSA, Colombia & MA since 1995.	Increases Famine & Water-borne diseases.	Decrease	• Increase by ~30 M People living in Water-stressed areas • decrease reservoirs	Increase Impact on grasslands & water quality		•increase Impact •decrease $C0_2$ sequestration
Sub-total										

Summary of Impact Matrix II: Country-level Examples of Current (2004-2006) Climatic Events

Type of Climatic Event	**Hurricane** Emily, fifth major. Breaking 2005 Atlantic tropical season[127]. Category 4 (Saffir-Simpson scale)	**Drought** in the Chaco region of Bolivia and Paraguay 2004.	Mexico above-normal rainfall during August 2005 contributed to **flooding and landslides** in Southern Mexico
Intensity	Hurricane Emily : Winds of 215 km/h reached the Gulf of Mexico in Southern Mexico States. Max. precipitation >350 mm / 24 h Storm surge between 1 - 4m.	A decline in summer precipitation has been blamed for contributing to the developing drought. There is also concern that forecast low water levels on the Paraguay River will lead to a large decline in barge traffic along the river by the end of 2005[128]	
Return period	hurricane Charlie, category 4 (1951)		A series of tropical depressions and Tropical Storm Jose[129] contributed to the heavy rainfall in the region[130].

INCOME	Total losses estimated 837MUS$ (plus oil industry damages $ 400 M); 38,6% direct damage, 61,4% indirect damage)	$ 2 M required to attend this national disaster
Agriculture	Losses estimated at $ 1,1 M	Most of the rural population relies upon rain-fed subsistence agriculture. In 7 Mexican States 93% of the crops (mainly corn), on average, were lost.
Productivity	Taxes not collected in some; 18,722 small farmers and fishermen affected; 55,484 beehives lost (2,500 farmers and 600,000US$ in aids); losses in power supply, transport and communications sectors; losses in fisheries $ 2,3 M ($ 1,7M direct damages and $ 0,6 M indirect damages).	
Food Security		42,200 people in southeastern Bolivia's Chaco region required emergency food. 85% percent of affected families living mainly on rain-fed subsistence agriculture
Vulnerability & Livelihoods	Quintana Roo St.: Losses estimated at $79 M; 15,534 homes affected (70,4% total lost); Yucatan St.: losses at $ 63,000 in hydraulic infrastructure.	
Energy	Yucatan: Losses estimated at 6MUS$ 200,000 people without electricity	
Tourism	Quintana Roo St.: Losses estimated at $27,9 M direct + $58 M indirect; 12,510 tourist rooms affected; 17,11% reduction in hotel occupation during 10 days after the event.	
Damage to infrastructure & vulnerability of coastal cities	Losses at $49M (52,9% of total losses. Quantified only in Yucatan Sate of Mexico)	

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[127] CENAPRED-CEPAL, 2005. Características e impactos socio-económicos del huracán "Emily" en la República Mexicana. LC/MEX/L.693
IRI. International Research Institute for climate and society. http://iri.columbia.edu/climate/cid/Sep2005/impacts.html (consulted March 30th, 2006)
[128] http://www.riosvivos.org.br/canal.php?canal=13&mat_id=7718
[129] http://weather.unisys.com/hurricane/atlantic/2005/JOSE/track.gif
[130] http://www.dartmouth.edu/~floods/Archives/2005sum.htm