IPCC WGII Fourth Assessment Report – Draft for Government and Expert Review

Chapter 13 - Latin America

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Executive summary

Climatic variability and extreme events, primarily those related to precipitation variability, have been severely affecting the Latin America (LA) region over recent years (high confidence). Severe droughts and flood episodes occurred in most of countries. Unexpected extreme weather events were reported, as the Venezuelan intense precipitations of 1999 and 2005; the unprecedented and destructive hail storm in Bolivia of 2002, the unprecedented hurricane Catarina in the South Atlantic in 2004 and the record hurricane season of 2005 in the North Atlantic. [13.2.2]

During the last hundred years were evidenced important changes in precipitation, and increases in temperature and in the rate of SLR (high confidence). Increases in rainfall in southeast Brazil, Uruguay, the Argentina's Pampas region and some parts of Bolivia have had impacts on land use, crop yields and flooding. Inversely a declining trend in precipitation was observed in Ecuador, central Chile and western Central America. A warming close to 1^{o}C in Meso-America and South- America and close to 0.5C in Brazil was evidenced. Increases in the rate of sea level rise attained 2-3 mm/year during the last 10-20 years in south-eastern South America.

The glaciers retreat trend reported in the TAR is being exacerbated (high confidence). This issue is critical in Bolivia, Peru, Colombia and Ecuador. Recent research in the Andes shows that in the next 15 years inter-tropical glaciers could disappear, affecting water availability and hydropower generation. [13.2.4.1]

Land use changes have intensified the use of natural resources and exacerbated many of the processes of land degradation. Almost three quarters of the dry lands are moderately or severely affected by degradation processes and droughts. Natural land cover in general continued to decline at very high rates (high confidence). In particular, rates of deforestation of tropical forests have increased during the last five years. There is evidence that biomass burning aerosols may change regional temperature and precipitation south of Amazonia (medium confidence). [13.2.3.2] [13.2.4.2]

The realization of current vulnerability to extreme events and the costs of reactive policies have led to the strengthening of institutions and creation of new ones. New legal frameworks, capacity building and new institutions capable of dealing with current threats from a preventive perspective represent a new strategy to confront climatic challenges. The development of early warning systems and risk analysis in several sectors such as agriculture, human health, water resources, fisheries and coastal resources, has increased their capacity for planning and management (high confidence). Those systems are being implemented in most countries as a means of reducing vulnerability to current climate variability and represent the first steps in coping with climate change. However low economic growth and institutional weaknesses in some parts of LA decrease the resilience of the social systems to cope with climate variability and change by hindering adaptation measures (medium confidence). [13.2.5]

Adaptation strategies based on the concept of ecological corridors have been adopted for the maintenance of biodiversity in natural ecosystems in the face of species extinctions. The main threats come from land use change. To counteract these based on conservation policies a significant number of such corridors have been implemented covering several biomes [13.2.5.1].

The projected mean warming for LA to the end of the Century according to different climate models ranges from 1 to 4 C for emissions scenario B2 and from 2 to 6^{o}C for scenario A2. Most GCM projections indicate rather larger (positive and negative) rainfall anomalies for the Tropical portions of LA and smaller for extra-tropical South America. In addition, the frequency of occurrence of weather and climate extremes will likely to increase in the future; for instance, the frequency of strong hurricanes in the North Atlantic. [13.3.1.1.] [13.3.1.2]

Under future conditions, there is the likelihood of significant species extinctions in many areas of tropical LA (high confidence). Replacement of tropical forest by savannas is expected in eastern Amazonia, along with replacement of semi-arid by arid vegetation in parts of Northeast Brazil due to synergistic effects of both land use and climate changes (high confidence). [13.4.1]. With important consequences for the well being of the population by the year 2050, 50% of agricultural lands will be subjected to desertification and salinization processes in many areas (high confidence). [13.4.2]

There are generalized reductions of rice yields after the year 2010, as well as increases in soybean yields when CO2 effects are considered (medium confidence). For other crops (wheat, maize) the behaviour is more erratic depending on the scenario imposed. On the other hand, cattle productivity is expected to decline in response to increasing temperatures. [13.4.2]

In 2025 between 30 and 90 million people will suffer from the lack of adequate water supplies (medium confidence). The figures for 2055 are much worse and vary between 100 and 180 millions, depending on the climate scenario considered [13.4.3]

Changes in geographical distribution and transmission of diseases have been observed. Decreases in the transmission of malaria would occur in Amazonia and Central America where reductions in precipitation are projected. Inversely, the population at risk would increase at its southern limit of distribution in South America. Changes in the geographical distribution of dengue are also projected, with increasing areas in the west coast of Mexico, southern Brazil and the west of Peru and Ecuador. [13.4.5]

The expected increase in SLR and weather and climatic variability and extremes will likely affect coastal areas (high confidence). Sea level rise will lead to loss of low-lying areas; will threaten built environment and tourism; will produce alterations of coastal morphology, loss of mangroves in low lying coastlines, scarcity of drinking water and threaten Mesoamerican coral reefs. It will also perturb the location of fish stocks in the south-east Pacific. Many of these impacts are already observed in many countries of the region [13.4.4].

Future adaptation strategies should contemplate the integration of climate change policies in national / regional sustainable development plans making them more robust. In the agricultural sector changing planting dates, improvements in crop cultivars, irrigation and drainage technology, and water management are common adaptation strategies. Measures for coastal systems and low-lying areas include coastal zone management, coastal defence infrastructure, rehabilitation and conservation of endangered ecosystems. For both sectors policies should promote early warning systems, observation systems and capacity building. [13.5].

13.1 Summary of knowledge assessed in the TAR

There is a positive trend in the observed temperature in LA. In northwestern South America and Amazonia this trend is clearer and amounts to 0.63 C over the last 100 years. However, the warming trend is not uniform and there are a few areas presenting a cooling one, such as Chile between 35 S to 45 S. Consistent precipitation trends are seen in the region. Over the last 40 years, there is increasing winter precipitation in Mexico, as opposed to decreasing precipitation in northern parts of Nicaragua. In Amazonia, interdecadal variability in the hydrological record (in both rainfall and streamflow) is more significant than any observed trend. Records suggest a positive trend for the past 200 years at higher elevations in northwestern Argentina.

Observational evidence of climate change by proxy in the region, although sparse, gives further evidence of positive temperature trends. Cloud forests are migrating to higher elevations and glacier and ice covers have been decreasing and may soon disappear. The latter may pose a danger for local water supply that have to be shared among human consumption, regional agriculture and hydroelectricity. Tourism, river navigation, hydropower generation, biodiversity, and remaining forests mainly the Amazon are threatened by a combination of population increase, land use change and global warming. An increasing number of forest fires in the tropics are expected due to human disturbances, higher temperatures, a decrease of precipitation caused by a reduction in evapotranspiration and to the presence of El Niño as they are affected by climate change. Tree mortality increases under dry conditions that prevail near newly formed edges in Amazonian forests.

ENSO is the dominant mode of climate variability in LA and the natural phenomena with the largest socio-economic impacts. During the warm phase (El Niño), winter precipitation increases and summer precipitation decreases over most of Mexico and in the Pacific coast of Central America. Peru experiences increases in precipitation in its western coast while western Colombia, northern and eastern Amazonia and Northeast Brazil suffer from decreased precipitation during their rainy season. Southeastern South America experiences precipitation increases as well as northern Chile. In general, La Niña effects on precipitation are approximately the opposite of those caused by El Niño.

In LA many diseases are weather and climate related through the outbreaks of vectors that develop in warm and humid environments like malaria and dengue that are very important because the number of affected people. Cholera and diarrhoea are caused by poor sanitary conditions and the occurrence of drought or flood sometimes related to El Niño. Climate change could influence the frequency of outbreaks of these diseases by altering the variability associated with the main controlling phenomena i.e. El Niño (likely). Climate change could also affect human health indirectly through the decrease of food production.

Agriculture in LA is a very important economic activity representing about the 10% of the GDP of the region. While, subsistence agriculture is of vital importance representing the only source of food and income for many families. Studies in Argentina, Brazil, Chile, Mexico, and Uruguay based on GCMs and crop models project decreased yields for numerous crops (e.g., maize, wheat, barley, grapes) even when the direct effects of CO_2 fertilization and implementation of moderate adaptation measures at the farm level are considered.

Studies carried out to assess the potential impacts of climate change on natural ecosystems indicate that neotropical seasonally dry forest should be considered severely threatened in Mesoamerica. In Mexico, nearly 50% of the deciduous tropical forest would be affected. Global warming could expand southward the area suitable for tropical forests in South America, but current land use make it unlikely that tropical forests will be permitted to occupy these new areas. On the other hand, large portions of the Amazonian forests could be replaced by tropical savannas due to land use change and climate change.

Sea-level rise will affect mangrove ecosystems damaging the region's fisheries. Coastal inundation and erosion resulting from sea-level rise in combination with riverine and flatland flooding would affect water quality and availability, exacerbating socioeconomic and health problems in these areas.

Another environmental stress of great importance in LA is due to land use and land cover changes. The Amazon region exhibits the highest rates of deforestation all over the world. Most of the deforested area is being converted to pasture and agricultural uses. Deforestation contributes directly to global warming increasing emissions of GHG. For large scale deforestation in Tropical South America, there is relatively high confidence that reduced evapotranspiration and increasing temperatures will lead to less rainfall during the dry season. Greater severity of droughts reinforced by deforestation effects could lead to erosion of the remainder of the forest once a substantial portion of the region had been converted to pasture.

From the TAR it is apparent that very few studies have considered options for adaptation to climate change. Adaptive capacity of human systems in LA is low, particularly to extreme climate events, and vulnerability is high as inferred from the studies. Adaptation measures have the potential to reduce climate-related losses in agriculture and forestry but less so for biological diversity.

13.2. Current sensitivity/vulnerability

13.2.1 What is distinctive about the Latin America region?

LA is highly heterogeneous in terms of climate, ecosystems, human population distribution and cultural traditions. A large portion of the region is located in the Tropics showing a climate dominated by convergence zones such as the Intertropical Convergence Zone (ITCZ), and the South Atlantic Convergence Zone (SACZ). The summer circulation in tropical and subtropical America is dominated by the North America Moonson System which affects Mexico and parts of Central America and the South America Monsoon System. These monsoon climates are closely interconnected with ocean-atmosphere interactions of the tropical and subtropical oceans. Low Level Jets in South America east of the Andes, and in North America east of the Rockies, Baja California and over the Intra-Americas Seas transport moisture from warm oceans to participate in continental rainfall. Most of the rainfall is organized in the convergence zones or by topography, leading to strong spatial and temporal rainfall contrasts, such as the expected subtropical arid regions of Northern Mexico and Patagonia, but also the driest desert in the world in northern Chile, a tropical semi-arid region of Northeast Brazil next to humid Amazonia and one of the wettest areas in the world over western Colombia.

LA possesses a large variety of ecosystems, ranging from the Amazonian tropical rain forest, cloud forest, savannas, Andean Paramos, rangelands, shrublands, deserts, grasslands, and wetlands (Gitay *et al.*, 2002); and includes about 95% of world’s tropical glaciers. LA holds one of the most important forest regions of the world, including 834 Mha of tropical forest and 130 Mha of other forests, which cover 48% of the total land area , and represent almost a quarter of the world’s forest cover (FAO, 2001). The hotspots analysis of Myers *et al.* (2000) found that in LA are located seven out of the 25 most critical places with highest endemic species concentrations and these areas are suffering their habitat loss.

Over the past three decades LA was subjected to climate-related impacts of increased El Niño occurrences (Trenberth *et al.*, 2004). Two extremely intense episodes of El Niño phenomenon (1982-83 and 1997-98) and other increased climate extremes (EPA, 2001; Haylock *et al.* 2005; Vincent *et al.* 2005; Alexander *et al.* 2005) happened during this period and contributed greatly to augment the vulnerability of human systems to natural disasters (floods, droughts, landslides, etc.). The main drivers of this increased vulnerability, in addition to climate, are demographic pressure, poverty and rural migration, being the poorest communities among the most vulnerable group to hydro-meteorological extremes (Geo 2003). Some of these vulnerabilities are caused by their location in the path of hurricanes (about 8.4 million people are exposed to hurricane risk in Central America (FAO, 2004a)), unstable lands (erosion and landslides), precarious settlements, low-lying areas settlements, and flooding from rivers (BID, 2000; Geo 2003).

13.2.2 Weather and Climate stresses

Climatic variability and extreme events have been affecting the LA region over recent years, where severe droughts and flood episodes occurred in most countries. Unexpected extreme weather events were reported, as the Venezuelan intense precipitations of 1999 and 2005; the unprecedented and destructive hail storm in Bolivia of 2002, the unprecedented hurricane Catarina in the South Atlantic in 2004 and the record hurricane season of 2005 in the North Atlantic. Since the TAR (2001) more than 24 extreme events of catastrophic proportions have desolated the region; 2005 was particularly intense with 9 of these events (Table 13.1 shows the most important recent events).

Table 13.1: *Extreme events and their impacts (period 2004-2005)*

Event/date	**Country/Impacts**
H. Beta Nov.2005	Nicaragua: Four deaths; 9,940 injuries; 506 homes, 250 ha of crops, 240 Km^2 of forest and 2,000 artisan fishermen affected. (SINAPRED, 2006)
H.Wilma Oct. 2005	Mexico: Several landfalls, mainly in the Yucatán Peninsula. Losses of 1,881 M U$S. 95% of the tourist infrastructure was seriously damaged (www.wilmareport.com).
H.Stan Oct. 2005	Guatemala, Mexico, El Salvador, Nicaragua, Costa Rica: Losses of 3.000 M U$D, more than 1,500 deaths. Guatemala was the most affected country accounting for 80% of casualties and more than 60% of infrastructure damages (Fundación Desc, 2005)
Wind and Rain storm Aug. 2005	Southern Uruguay: Wind and rain storm (up to 187 km/h) and storm surge, 100,000 people affected, more than 100 people injured and 10 people death, 20,000 houses without electricity, phones and/or water supply. (NOAA, 2006)
H. Emily Jul. 2005	Mexico-Cozumel & Q. Roo: Losses of 837 M U$D. Tourism losses: 100 M U$D; dunes and coral reefs affected and losses of 1506 turtle nests. (CENAPRED, 2005)
Heavy rains Feb. 2005	Venezuela: Heavy precipitations (mainly in central coast and Andean mountain), severe floods and heavy slides. Losses of 52 M U$D; 63 deaths and 175,000 injuries. (UCV, 2005; DNPC, 2005/06)
Drought 2005	Argentina-Chaco: Losses estimated in 360 MUS$ (SRA, 2005)
Drought 2005	Brazil-Amazonia: Severe drought affected central and southwestern Amazonia and it was likely associated to warm sea surface temperatures in the Tropical North Atlantic. (www.cptec.inpe.br).
Drought 2004/05	Brazil-RG do Sul: Reductions of 65% and 56% in soybean and maize production (www.ibge.gov.br)
Drought 2004	Argentina-Chaco: Damage in agriculture and livestock. Losses of 300 M U$D, 120,000 cattle losses, 10,000 evacuees. (La Nación, 2004)
H. Catarina Mar. 2004	Brazil: Was the first observed hurricane in the South Atlantic ever (Pezza & Simmonds, 2005) and demolished over 3000 houses in Southern Brazil (Cunha 2004); severe flooding hit eastern Amazonia affecting tens of thousands of people (www.cptec.inpe.br).

The dominating mode of intraseasonal, seasonal and interannual climate variability in LA is associated to ocean-atmosphere interactions in the tropical Pacific (ENSO, tropical cyclones and hurricanes), tropical and subtropical Atlantic (ITCZ and South Atlantic Convergence Zone variability), and in the Intra-Americas Seas (tropical cyclones and hurricanes), but also tropical-extratropical interactions and remotely forced atmospheric perturbations such as intraseasonal oscillations and teleconnection patterns: Pacific-North America (PNA), Pacific-South America (PSA), Antarctica Angular Mode (AAM)). At intra-seasonal and seasonal timescales the role of land surface-atmosphere interactions and feedback play an important role over tropical South America

Tropical forests of LA, particularly those of Amazonia, are increasingly susceptible to fire occurrences due to increased ENSO-related droughts and to land use change (deforestation, selective logging and forest fragmentation) (Fearnside, 2001; Nepstad *et al.*, 2002; Cochrane, 2003). During 2001 ENSO period, approximately one-third of Amazon forests became susceptible to fire (Nepstad *et al*, 2004). This climatic phenomenon has the potential to generate large scale forest fires due to the extended period without rain in the Amazon, exposing even undisturbed dense forest to the risk of understory fire (Nepstad *et al.*, 2002, 2004; Jipp *et al.*, 1998). Mangroves forests located in low-lying coastal are particulary vulnerable to sea level rise, increased mean temperatures, and hurricane frequency and intensity (Roth, 1997; Schaeffer-Novelli *et al.*, 2002; Cahoon and Hensel, 2002), especially those of Mexico, Central America and Caribbean continental regions (Kovacs *et al.*, 2001; Meagan *et al.*, 2004). Moreover, floods accelerate the changes in mangrove areas and in the mangrove-up and interface (Conde, 2001; Medina *et al.*, 2001; Villamizar, 2004). In relation to biodiversity populations of toads and frogs are disappearing from cloud forests after years of low precipitation (Pounds *et al.*, 1999; Ron *et al.*, 2003; Burrowes *et al.*, 2004). In addition, at least four species of Brazilian anurans have declined as a result of habitat alteration (Eterovick, *et al.*2005), and two species of *Atelopus* have disappeared following deforestation (La Marca *et al.*, 2005). Furthermore, habitat loss might be contributing into elevations of range in Mexican (Parra-Olea *et al.,* 2005) and Ecuadorian species (Bustamante *et al.*, 2005).

The impact of ENSO related climate variability on the agricultural sector has been well documented in the TAR (IPCC, 2001). Most recent findings include: high/low wheat yields during El Niño/La Niña in Sonora-Mexico (Salinas-Zavala and LLuch-Cota, 2003); shortening of cotton and mango growing cycles (time to flowering and fructification) in the northern coast of Peru during El Niño because of increases in temperature (Torres, 2001). Increases in plant diseases like "*Cancrosis*" in citrus in Argentina (Canteros *et al.*, 2004), "*Fusarium*" in wheat in Brazil and Argentina (Moschini *et al.*, 1999; Del Ponte *et al.*, 2005); and several fungal diseases in maize, potato, wheat, and bean in Peru (Torres, 2001) during El Niño due to high rainfall and environmental humidity. In relation to other sources of climatic variability, anomalies in South Atlantic SST were significantly related to crop yields anomalies in the pampas region of Argentina (Travasso *et al.*, 2003 a,b). Moreover, heat waves in central Argentina lead to reductions in milk production in "Holando argentino" dairy cattle and the animals are not able to completely recover after these events (Valtorta *et al.*, 2004).

In global terms, LA is recognized as a region with large freshwater resources. However, the irregular temporal and spatial distribution of these resources affects its availability, as well as water quality. By 2000s, almost 13.9% of the population (71.5 million people) have no access to safe water supply; 63% of them (45 million people) live in rural areas (IDB, 2004). Many rural communities rely on limited freshwater and many others on rainwater from catchments being very vulnerable to droughts (IDB, 2004). People living in water-stressed watersheds (less than 1000m3/capita/year) in the absence of climate change is estimated in 21.2 million people (1995) (Arnell, 2004). Stress on water availability and quality has been documented where lower precipitations and/or higher temperatures occur. For example, droughts related to La Niña years create severe restrictions for the water supply and irrigation demands in the Central Western Argentina provinces and in Central Chile regions between

25ºS and 40ºS (Maza *et al.*, 2001), (CONAMA,2003). In addition, droughts related to El Niño impacts on the flows of the Colombia Andean region basins, particularly in the Cauca river basin, causing a 30% reduction in the mean flow, with a maximum of 80% loss in some tributaries (Carvajal *et al.*, 1999), whereas extreme floods are enhanced during La Niña (Waylen & Poveda, 2002). Further the Magdalena river basin also shows a high vulnerability (55% losses) (IDEAM, 2004). The vulnerability to flooding events is high in almost 70% of LA countries (GEO YEAR BOOK, 2003). Hydropower is the main electrical energy source for most countries in LA and it is vulnerable to large-scale and persistent rainfall anomalies due to El Niño and La Niña, e.g. in Colombia (Poveda *et al.* , 2003), Venezuela (IDEAM, 2004), Peru (UNMSM,2005), Chile (CONAMA,2003), Brazil, Uruguay, Argentina (Kane,2002). A combination of increased energy demand and droughts caused a virtual breakdown of hydroelectricity in Brazil in 2001 that caused a GDP reduction of 1.5% (Kane, 2002).

Low-lying coasts, in several LA countries (i.e. part of Argentina, Belize, Colombia, Costa Rica, Ecuador, Guyana, Mexico, Panama, El Salvador, Uruguay, Venezuela) and large cities (Buenos Aires, Rio de Janeiro, Recife, etc.) would be among the most vulnerable to extreme hydro-meteorological events enhanced by sea level-rise (SLR). With most of their population, economic activities and vital infrastructure located at or near sea-level, they are especially vulnerable to SLR, coastal inundation and erosion (Grasses *et al.*, 2000; OECD, 2004, Kokot 2004c).

Climate fluctuations alter transmission of infectious diseases that are sensitive to climate, such as malaria, dengue, cholera, leishmaniasis (tegumentary and visceral leishmaniasis) leptospirosis, and hantavirus. Outbreaks of hantavirus pulmonary syndrome were reported for Argentina, Bolivia, Chile, Paraguay, Panama and Brazil under prolonged droughts (Pini *et al.*, 1998, Espinoza *et al.*, 1998; William *et al.*, 1997); a suggested cause was the increase in peri-domestic rodents following increased rainfall and flooding in surrounding. Temperature has been directly associated with episodes of diarrhoea in adults and children in Peru (Lama *et al.*, 2004).

Malaria continues to pose a serious health risk in LA, where 262 million people (31% of population) live in tropical and subtropical regions with some potential risk of transmission, ranging from 9% in Argentina, to 100% in El Salvador (PAHO, 2003). People in risk face crowding, poverty and lack of services. Increase in malaria transmission during El Niño (high temperature) was reported for Colombia (Rúa *et al.*, 2005). There is a risk of epidemic malaria after the onset of an El Niño event in Costa Rica, Panama, Colombia, Venezuela and northern part of Brazil (Kovats *et al.*, 2003). In northeastern Venezuela the number of hospitalizations due to malaria has been higher/lower during La Niña (rain-cold)/ El Niño (dry-warm) (Delgado *et al.*, 2004). Flooding engenders malaria epidemics in the dry northern coastal region of Peru (Gagnon, 2002), and outbreaks of leptospirosis in Nicaragua and Brazil (Ko *et al.*, 1999).

In Honduras and Nicaragua climate-driven fluctuations in the vector densities appear to be related to annual variations in dengue/dengue haemorrhagic fever. In larger countries, such as Brazil and Mexico, the association for dengue was not significant because the disease data were at country level (Patz *et al.*, 2005).

In the cities of the semi arid north-eastern Brazil, prolonged droughts during early 1980s and 1990s, provoked rural-urban migration of subsistence farmers, and a re-emergence of visceral leishmanisis (Confalonieri, 2003). A significant increase in visceral leishmaniasis in Bahia State (Brazil) after El Niño years of 1989 and 1995 has also been reported (Franke *et al.*, 2002).

In Venezuela, an increase of 66,7% in cutaneous leishmaniasis was associated with the presence of a weak La Niña (not too cold and rainy), inversely with high SOI values the incidence was reduced (Cabaniel *et al.*, 2005).

Many recent studies call for the attention about the possible reemergence of Chagas disease in different zones of Venezuela, particularly at the Llanos and Andean regions (Ramírez *et al.*, 2004).

In Buenos Aires roughly 10% of summer deaths may be associated with thermal stress caused by the heat island effect (de Garín and Bejarán, 2003). Gouveia *et al.* (2003) have reported for São Paulo, Brazil an increase of 2.6% in all-cause morbidity in the elderly, per degree increase in temperature above 20°C, and a 5.5% increase per degree drop in temperature below 20°C. During heat waves women have been particularly affected (Díaz *et al.*, 2002). The associations reported in northern and cooler countries of the effect of high and low temperature on mortality is also present in a sub-tropical city with moderate climate conditions (Gouveia *et al.*, 2003). A national assessment of Brazilian regions demonstrated that the northeastern is the most vulnerable due to its poor social indicators, the high level of endemic infectious diseases as well as the periodic droughts that affect this semi-arid region (Confalonieri *et al.*, 2005).

13.2.3. Non climatic stresses

Demographic pressures effects: Migration to urban areas in the Region exceeds absorption capacity, resulting in broad unemployment, overcrowding, and the spread of infectious diseases, including HIV/AIDS, due to lack of adequate infrastructure and urban planning (UNEP, 2003). LA is the most urbanized region in the developing world (75% of its population). Most urbanized countries are Argentina, Chile, Uruguay and Venezuela whereas the less urbanized are Guatemala and Honduras (UNCHS, 2001). As a consequence, the Region population faces traditional risks (infectious and transmissible diseases) and modern risks (chronic and degenerative diseases) in addition to those related to urban landslides and floodings. Modern risks result from urbanization and industrialization; while poor and rural areas still suffer from "traditional risks" resulting from malnutrition, lack of drinking water, services and education. For example, the emerging cases of cities like Buenos Aires and Santa Fe, in Argentina, with poverty rates in the order of 50% of the urban and peri-urban population and unemployment rates exceeding 15%, are new sources for disease and infection dissemination (Canziani, 2005).

Over exploitation of natural resources: Urbanization (without a land planning legal framework in most of the countries), the large aquaculture developments, ecotourism and oil industries expansion, the accidental capture of ecologically important species, the introduction of exotic species, land-based sources of coastal and marine pollution, depleting coral reefs, and the wrong management of water resources impose increasing environmental pressures (UNEP, 2000; IRDB, 2000; Hoggarth *et al.*, 2001; CIDAS, 2003; Geo 2003). It is well established that overexploitation is a threat to 34 out of 51 local production systems of particular importance to artisanal fishing along the coastal waters in LA (CIDEIBER, 1999) and has caused destruction of habitats such as mangroves, estuaries and salt marshes in Central America and Mexico (Suman, 1994; Yañez-Arancibia, *et al.*., 1998; Sullivan and Bustamante, 1999). Aquifer overexploitation and mismanagement of the irrigation systems (water/phreatic layer/soil, drainage and sanitary pits) are originating severe environmental problems; e.g. salinization of soils and waters in Argentina, (where more than 500.000 ha of the phreatic aquifer presents high levels of salinity and nitrates (IRDB, 2000), or sanitation problems to a great number of cities like Mexico City, San José de Costa Rica; Trelew, Río Cuarto and Buenos Aires in Argentina.

Land use changes: Agricultural expansion has intensified the use of natural resources and the processes of land degradation (FAOSTAT, 2001). The soybean cropping boom has exacerbated deforestation in Argentina, Bolivia, Brazil and Paraguay (Maarten Dros, 2004; Canziani, 2005). This critical land use change will enhance aridity/desertification in many of the already water-stressed regions in South America. The blindness of the important economic interests involved not only affects the landscape but also modifies the water cycle and the climate of the region in which almost three quarters of the dry lands are moderately or severely affected by degradation processes and droughts (Malheiros, 2004). The region contains 16% of the world total of 1 900 Mha of degraded land (UNEP, 2000). In Brazil 100 Mha are facing desertification processes, including the semi arid and dry sub-humid regions (Malheiros, 2004). Deforestation and forest degradation trough forest fire, selective logging, hunting, edge effects and forest fragmentation, are the dominant transformation that threatens the biodiversity in South America (Fearnside, 2001; Peres and Lake, 2003; Asner *et al.*, 2005).

Pollution: Severe problems of pollution of natural resources like natural arsenic contamination of freshwater affect almost 2 million people in Argentina, 450.000 in Chile, 400.000 in Mexico, 250.000 in Peru and 20.000 in Bolivia (Pearce, 2003; Canziani, 2003; Clark &King, 2004). Another insidious contamination by heavy metals (F) is widespread in the region; the so-called Bel-Ville syndrome in Argentina puts about 2 million people at risk of death+K19 (Canziani, 2003). In the Puyango river basin (Ecuador) suspended sediments and metal contamination increase significantly during ENSO events (Tarras-Waldberg & Lane, 2003). In the Pilcomayo basin (SE Bolivia, Southwest Paraguay and Northwest Argentina) ENSO phenomena influence strongly annual discharges creating siltation of river bed. Pollution by heavy metals from mining districts in Potosí affect migration and catching of Sabalo (Prochilodus lineatus), which is a very important source of income in the region (Smolders *et al.*, 2002). As a result of the Salado del Norte (Argentina) river flood of 2003, 60.000 tons of solid wastes were disseminated all over the city of Santa Fé; 135 cases of hepatitis, 116 of leptospirosis and 5000 lung affections were officially recognized (La Nación, 2003).

Air pollution due to the burning of fossil fuels is a problem-that affects many urban areas of the region. Transport is the main contributor (eg. Mexico City, Santiago de Chile, São Paulo and Buenos Aires) followed by the production of electricity in thermoelectric plants. Climate and geography play a significant role in this situation (PAHO, 2005), e.g. the occurrence of thermal inversions, such as the case of Mexico City and Santiago de Chile. In Mexico City, ozone has been linked to increased hospital admissions for lower respiratory infections and asthma in children (Romieu *et al.*, 1996. Regarding exposure effects due to biomass particles, Cardoso *et al.* (2004) have estimated the economic costs of fire in the Amazon regarding human health finding an increase from US$3.4 millions in 1996 to US$10.7 millions in 1999.

13.2.4 Past and current trends

13.2.4.1 Climate trends

During the 20th century important increases in precipitation were evidenced in the Argentina's Pampas region, Uruguay, southeast Brazil and some parts of Bolivia. Inversely a declining trend in precipitation was observed in Ecuador, central Chile and western Central America. In addition, increases in the rate of sea level rise attained 2-3 mm/year during the last 10-20 years in south-eastern South America (Table 13.2a).

The largest positive trend in precipitation south of 20ºS during 1976–99, occurs during January–March, and is centred over southern Brazil. This is more than twice as large as the trend from 1948–75, and is due to an increase in the number of wet days and from larger amounts of precipitation per event (Liebman *et al.,* 2004). Also, in Central America and northern South America, rainfall events are intensifying and the contribution of wet days is increasing, while temperature is also increasing (Aguilar *et al.*, 2005). These changes might affect the transmission of infectious diseases, as for example diarrhoea in crowded and poor regions. Other consequences arising during or soon after the flooding are injuries, exposure to toxic substances, while malnutrition and mental health disorders appear latter (McMichael *et al.*, 2006).

Other negative impacts associated to increases in precipitation are 10% increases in flood due to rises in annual discharges in the Amazon River at Obidos (Callède *et al.,* 2004); floods in the Mamore basin in the Bolivian Amazonia (Ronchail *et al.,* 2004); and increases in morbidity and mortality due to flooding, landslides and storms in Bolivia (Ministry of Sustainable Development and Environment, 2000). Inversely, positive impacts were reported for the Argentina Pampas region where increases in precipitation led to increases in crop yields close to 38% in soybean, 18% in maize, 13% in wheat and 12% in sunflower (Magrin *et al.,* 2005). In the same way, pasture production increased by 7% in Argentina and Uruguay (AIACC-LA27).

Increases in the rate of SLR are leading flooding, inland penetration of salt water and estuaries' salinity, and shoreline retreat in Guyana (Douglas, 1995; Smith *et al.*, 1999).

The glacier retreat trend reported in the TAR is being exacerbated reaching critical conditions in Bolivia, Peru, Colombia and Ecuador (Table 13.2b). Recent studies indicate that most of the South American glaciers from Colombia to Chile and Argentina (up to 25ºS) are drastically reducing their volume at an accelerated rate (Mark & Seltzer, 2003; Leiva *et al.,* 2003). In the next 15 years intertropical glaciers could disappear affecting water availability and hydropower generation (Geology news, 2001, Mendoza and Francou, 2004).

Table13.2a: *Current Climatic trends.*

Precipitation	**Period**	**Change**
Amazonia, Northern/ Southern*[1]	1949-1999	-11% to -17% /-23% to +18%
Amazonia, Entire		-17% to +5%
Amazonia, Entire*[2]	1957-1999	+5 %
Bolivian Amazonia *[3]	Since 1970	+15%
Argentina, Central and northeast*[4]	1900-2000	+1 STD to +2 STD
Argentina, Córdoba*[5]	1931-1990	+6.5% (yr); +15% (DJF)
Uruguay*[6]	1961-2002	+ 20%
Ecuador*[7]	1930-1990	Greater trend to decline
Chile, Central*[8]	Last 50 years	-50%
Annual discharge		
River Amazon at Obidos*[9]	1903-1999	+9%
River Tocantins*[10]	1960-1995	+25%
Streamflow		
River Uruguay at Salto/Concordia *[6]	1921-2003	+ 40%
Paraguay River (Pto.Bermejo) *[11]	Since 1970	+50%
Uruguay River (Pso de los Libres) *[11]	Since 1970	+40%
Paraná River (Corrientes)*[11]	Since 1970	+40%
Mean Temperature		**ºC/10years**
Amazonia*[12]	1901-2001	+0.08
Uruguay, Montevideo*[6]	1900-2000	+0.08
Ecuador*[7]	1930-1990	+0.08 to +0.27
Maximum Temperature		
Brazil, R.G.do Sul, Parana, S.Catarina*[13]	1960-2000	+0.39 to +0.62
Brazil, R.G.do Sul, Parana, S.Catarina *[14]	1930-2000	+0.26 to -0.33 (DJF)
Argentina, Centre*[15]	1959-1998	-0.2 to -0.8 (DJF)
Argentina, Córdoba*[5]	1931-1990	-0.18 to -0.33 (DJF)
Argentina, Patagonia*[15]	1959-1998	+0.2 to +0.4 (DJF) 0 to +0.8 (JJA)

Precipitation	**Period**	**Change**
Uruguay*[14]	1930-2000	-0.23 (DJF)
Minimum Temperature		
Brazil, R.G.do Sul, Parana, S.Catarina*[13]	1960-2000	+0.51 to +0.82 (yr); +0.3 to +0.4 (JJA); +0.4 to +0.9(DJF)
Brazil, R.G.do Sul, Parana, S.Catarina*[14]	1930-2000	+0.18 to +0.52 (DJF)
Brazil, Campinas and Sete Lagoas*[16]	1890-2000	+0.2
Brazil, Pelotas*[16]	1890-2000	+0.08
Argentina*[15]	1959-1998	+0.2 to +0.8 (DJF, JJA)
Argentina, Córdoba*[5]	1931-1990	+0.07 to +0.2 (MAM)
Uruguay*[14]	1930-2000	+0.19 to +0.48 (DJF)
Sea Level Rise		**mm/year**
Guyana*[17] *[18]	Last century	+1.0 to +2.4
Uruguay, Montevideo*[19]	Last 100/ 30/ 15 yr	+1.0 / +2.5 / +4.0
Argentina, Buenos Aires*[20]	Last ~100 yrs	+1.7
Brazil, Several ports*[21]	1960-2000	+4.0
Southwestern Atlantic at 33-37°S*[22]	1992-2004	> +10.0
Panamá, Caribbean coast*[23]	1909-1984	+1.3

pp= precipitation, STD= standard deviation, yr= years

*[1]Marengo, 2004; *[2] Chen *et al.*, 2003; *[3]Ronchail *et al.*, 2004: *[4]Penalba &Vargas, 2004; *[5]Vinocur& Seiler, 2005; *[6]Bidegain *et al.*, 2005; *[7]Ecuador, 2000; *[8]Camilloni, 2005a, *[9] Callède *et al.*, 2004; *[10]Costa *et al.*, 2003; *[11]Camilloni,2005b; *[12] Marengo, 2003; *[13]Marengo & Camargo, 2005; *[14]AIACC-LA27; *[15]Rusticucci & Barrucand, 2004; *[16]Pinto *et al.*, 2002; *[17]Douglas, 1995; *[20]Smith *et al.*, 1999; *[19]Nagy *et al.*, 2005; *[20]Barros *et al.*, 2003; *[21]Mesquita, 2000; *[22]Miller *et al.*, 2005; *[23] Panamá, 2000.

Table 13.2b: *Glaciers retreat trends.*

Glaciers/ Period	**Change/ Impacts**
Perú *[1] *[2] Last 35 years	22% reduction in glacier total area./ Reduction of 12% in fresh water in the coastal zone (60% of country population). Estimated water loss near to 7,000 Mm^3
Peru*[3] Last 30 years	Reduction up to 80% of glacier surface from small rangers./ Loss of 188 Mm^3 in water reserves during last 50 years.
Colombia*[3] 1990-2000	82% reduction in glaciers, showing a linear withdrawal of the ice of 10-15 m yearly./ Under the current climate trends, glaciers of the country will disappear completely within the next 100 years.
Ecuador*[4] 1956-1998	There has been a gradual decline in the length of the glacier./ Reduction on water supply for irrigation, clean water supply for the city of Quito, and hydropower generation for the cities of La Paz and Lima.
Bolivia *[6] Since midst of 90'	Chacaltaya glacier lost half of its surface and two thirds of its volume. It could disappear by 2010./ Total loss of the tourism and the skiing sport.
Bolivia*[6] *[7] Since 1991	Zongo glacier lost 9.4% of the surface. It could disappear by 2045-50./ Important troubles in agriculture, soustainability of «bofedales» and impacts in terms of socio-economics for the rural populations.
Bolivia: *[6] *[7] Since 1940	Charquini glacier lost 47.39% of the surface.

*[1] García Vargas, 2003; *[2]Mark & Seltzer, 2003; *[3]Peru, 2000; *[3]Colombia, 2001; *[4]Ecuador, 2000; *[6] Francou *et al.*, 2003; *[7]Ramirez, 2001;

13.2.4.2. Environmental trends

Deforestation

Natural land cover in general continued to decline at very high rates. In particular, rates of deforestation of tropical forests have increased during the last five years. In 1990, the total forest area in LA was 1,011 Mha and it was reduced by 46.7 Mha in ten years (Fig. 13.1) (GEO3, 2003). Increases in arable lands at the expenses of forest between 1972 and 1999 reached 30.2 Mha (35.1%) in South America and 6.3 Mha (21.3%) in Meso America (FAOSTAT, 2001). In Ecuador agricultural lands increased 5.7 per cent per year between 1990 and 2000 (Ecuador, 2000).

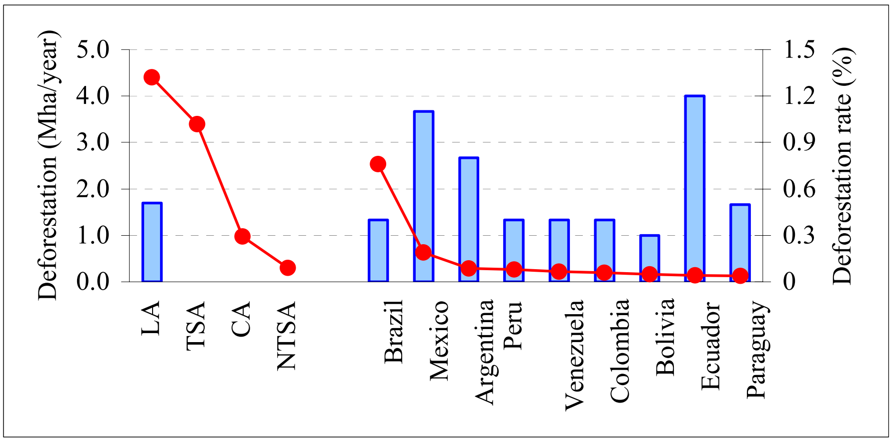

***Fig. 13.1**: Deforestation rate (bars) and total deforestation between 1990 and 2000 in Latin America (LA), Tropical South America (TSA), non tropical South America (NTSA), Central America (CA) and individual countries.*

The expansion of the agricultural frontier, mechanized agriculture, livestock expansion, selective logging, financing of big scale projects like construction of dams for energy generation, construction of roads and increased links to commercial markets have been the main causes of deforestation (FAO, 2001; Laurance *et al.*, 2001; Geist and Lambin, 2002; FAO, 2005; Asner *et al.*, 2005). In Amazonia the total area of forest lost rose from 41.5 Mha in 1990 to 58.7 Mha in 2000 (Kaimowits, 2004). Annual deforestation rates in Brazilian Amazonia increased 32% (from 1.68 Mha in 1996-2000 to 2.23 Mha in 2001-2005) though the annual rate decreased from 2.61 Mha in 2004 to 1.89 Mha in 2005 (INPE-MMA, 2005 & 2006). Up to date over 60 Mha have been deforested in Brazilian Amazonia owed to roads construction and afterwards new urban settlements, (Alves, 2002; Laurence *et al.*, 2005). There is evidence that biomass-burning aerosols may change regional temperature and precipitation south of Amazonia.

Biodiversity

Changes in land use led to biodiversity fragmentation and habitat loss. Climate Change will increase the actual extinction rate, which is documented in the Red List of Endangered Species (IUCN, 2000), e.g. amphibian populations and changes on reproductive characteristics of some birds (IUCN, 2001). The majority of the endangered ecoregions are located in the northern and middle Andes valleys and plateaus, Tropical Andes, in Central America and other cloudy forests, in South American steppes, in the Cerrado and other dry forests located in the South of the Amazon Basin (GEO 3; Dinerstein *et al.*, 1995).

Coral Reefs

Panama and Belize Caribbean case's studies illustrate in terms of inter-ocean contrasts both the consistencies and the variations in coral reef responses to complex environmental changes (Gardner *et al.*, 2003, Buddemeier *et al.*, 2004). Cores taken from the Belizean barrier reef show that *A. cervicornis* dominated this coral reef community continuously for at least 3,000 years, but was killed by white band disease (WBD) and replaced by another species after 1986 (Aronson *et al.*, 2002). Dust transported from Africa to America (Shinn *et al.*, 2000), and land-derived flood plumes from major storms transport materials from the Central American mainland to reefs that are normally considered remote from such influences are potential bsources of pathogens, nutrients, and contaminants. Also, human involvement has been a factor in the spread of the pathogen that killed Caribbean *Diadema;* the disease began in Panama, suggesting a possible link to shipping through the Panama Canal (Andréfouët *et al.*, 2002).

13.2.4.3 Trends in socioeconomics factors

From 1950 to the end of the 1970's LA benefited from a GDP growth of an average of 5% annual (ECLAC, 2003). This remarkable growth rate permitted the development of national industries, urbanization, and the creation or extension of national education and public health services. The strategy for economic development was based on the import substitution model which consisted on imposing barriers to imports and developing the national industry to produce what was needed. Nevertheless, this model produced a weak industry not able to compete in international markets and had terrible consequences for other sectors (agriculture in particular) which funded the industrial development.

In the 1980's the region faced the great debt crisis which forced the region's countries to make efforts to implement rigorous macroeconomic measures regarding public finances and to liberate the economy. Control of inflation and public deficit became the main targets of most governments. Deterioration of economic and social conditions, unemployment, the extension of the informal economy and poverty characterized this decade. In most of LA, the results of economic liberalization can be characterized by substantial heterogeneity and volatility in the long run growth, and modest (or even negative) economic growth (ECLAC, 2005).

The shift of economic paradigm produced contradicting results. On the one hand, more liberalized economies attained greater economic growth than less liberalized economies and achieved higher levels of democracy. On the other hand, there has been an increase in volatility which has led to recurrent crises, poverty and inequality levels have increased and the governments have failed to create strong social safety nets to ameliorate social conditions (Huber and Solt, 2004).

In LA the wealthier 10% of the population obtains between the 40% and 47% of national income while the poorest 20% only between the 2% and 4%. This type of income distribution is only comparable to some African and ex-USSR countries (World Bank, 2004). The lack of equity in education, health services, justice and access to credit can restrain economic development, reduce investment and extend poverty. A recent study conducted by CEPAL concludes that the possibilities for the poorest LA countries to reach the 7% GDP growth they need are almost null in the medium term. Even for wealthier countries in the region it will be hard to reach a 4.1% GDP growth target. Predictions for GDP growth in the region range from 2.1% to 3.8%, which are very far from the 5.7% average estimated to reduce poverty.

The combination of low economic growth and high levels of inequality can make large parts of the region's population very vulnerable to economic and natural stressors which would not necessarily have to be very big to cause great social damage (UNDP, 2003).

13.2.5 Current adaptation

Weather and Climate Forecast

The mega 1982-83 El Niño set in motion an international effort (the Tropical Ocean-Global Atmosphere (TOGA) Program) to understand and predict this ocean-atmosphere phenomenon. The result was the emergence of increasingly reliable seasonal climate forecasts for many parts of the world, especially for LA. These climate forecasts became even more reliable with the use of TOGA observations of the upper Tropical Pacific from the mid-90's, although they still lack the ability to correct predict onset of some El Niño and La Niña (Kerr, R.A., 2003). Such climate forecasts gave rise to a number of applications. Starting in the late 1980's for fisheries and crops in Peru (Lagos, ???) to subsistence agriculture in Northeast Brasil (Funceme, ???) to prevention of vegetation fires in Tropical South America (Nepstad *et al.* 2004; http://www.cptec.inpe.br) and streamflow prediction for hydropower in the Uruguay river (Tucci *et al.*, 2004), fisheries in the Eastern Pacific (Suáres-Sánchez *et al.*, 2004) and in the Southwestern Atlantic (Severov et. al., 2004) and dengue epidemics in Brazil (IRI, 200?).

Agriculture is a key sector for the potential use of ENSO-based climate forecasts for planning productions strategies as adaptive measures. Changes in crop management practices (planting date, fertilization, irrigation, crop varieties, among others) could lead to optimize crop yields and net returns during extreme ENSO phases. Increases in net return attributable to the use of ENSO-based forecast could attain up to 10% in potato and winter cereals in Chile (Meza *et al.*, 2003); 6% in maize and 5% in soybean in Argentina (Magrin & Travasso 2001); and more than 20% in maize in Santa Julia Mexico (Collado & Villalobos, 2001). Adjusting crop mix to ENSO phases in Argentina could produce benefits averaging 9%, depending on site, farmers' risk aversion, prices, and the preceding crop and ENSO phase (Messina, 1999). ENSO forecast was used in Tlaxcala (Mexico) to change crops (form maize to oats) during the El Niño event (Conde & Eakin, 2003), this successful experience was based on strong stakeholder involvement (Conde & Lonsdale, 2005). Benefits of an ENSO early warning system for commercial agricultural areas of Mexico are approximately US$ 10 million annually when a forecast skill of 70% is assumed, representing an internal rate of return of 30% (Adams *et al.*, 2003). Applications of climate forecasts in the health sector are increasing. Institutional support for early warning systems may help to facilitate early, environmentally sound public health interventions. For instance, the Colombian Ministry of Health developed a contingency plan to control epidemics associated with the 1997-98 El Niño event (Poveda *et al.*, 1999).

In LA whether forecasts increased dramatically in the last 10 years and their use is enabling the emergence of Early Warning and Risk Prevention Systems for extreme weather and climate-related hazards. It is also recognized that full implementation of such systems in the region will take long time. Those systems are being implemented in many countries to reduce vulnerability to current climate variability (Ministério de Medio Ambiente Colombia, 2002; Aparicio, 2000; Maganã and Vásquez, 2005; Comunidade Andina, 2004). For instance, prototype early warning systems proved to be very practical too for adapting the response of riverine communities to floods in Rio de La Plata Basin in Argentina (IRDP, 2000), in Mexico (Maganã, 2004), and in other important basins of LA.

As a result networks to predict climate extremes (e.g., the Climate Outlook Fora (COF)) and networks to mitigate and prevent impacts from natural hazards, and even to influence behavioural changes to diminish social vulnerability have emerged in LA. Examples of the former are the Regional Disaster Information Centre-Latin America and Caribbean (CRID, 2005), the International Centre for Research on El Niño Phenomenon (Ecuador), the Permanent Commission of South Pacific (CIFEN, 2005; CPPS, 2005), and the Andean Committee for Disaster Prevention and Response CAPRADE); more recently the Social Studies Network for Disaster Prevention in LA (ITDG, 2005) which includes women more effectively in risk prevention activities (Anderson, cited in Briseño, 2002).

In the Mesoamerican Region eight countries (Mexico, Cuba, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama) are participating in one project assessing current and future vulnerability of different sectors or activities and designing future adaptation strategies and measures with local populations fully involved (INE, 2006). The Mesoamerican Visualization and Monitoring System (SERVIR) has been established as a tool to support multiple georeferenced decision making in the area of climate change, disaster management, land planning, terrestrial carbon stocks, forest fires monitoring, water resources and coastal zone management in LA (Sempris *et al.*, n/d).

13.2.5.1 Natural ecosystems

Adaptation strategies for the protection of biodiversity in natural ecosystems against species extinctions due to land use change have been expanded to include the concept of ecological corridors between protected areas, particularly in forests. A significant number of such corridors have been implemented covering several biomes in LA. For example, the Mesoamerican Biological Corridor; natural corridors project in Amazon and Atlantic forests (De Lima & Gascon, 1999; CBD, 2003); and Villcabamba – Amboró biological corridor in Peru and Bolívia (Cruz Choque, 2003).

Other positive practices in the region are: maintaining and restoring native ecosystems; protecting and enhancing ecosystem services like carbon emission reduction in Noel Kempff Mercado Climate Action Project in Bolivia (Brown *et al.*, 2000; Santilli *et al.* 2005). Conservation of biodiversity and maintenance of ecosystem structure and function are important for climate change adaptation strategies due to the protection of genetically-diverse populations and species-rich ecosystems (CBD, 2003; World Bank, 2002).

A new option to promote mountainous forest conservation in LA consists in compensating forest owners for environmental services which those forests brings to the society (GEO 3, 2003). The compensation is often financed by charging a small overprice to water users, for the water originated in forests. Such schemes are being implemented in various countries of LA and were tested in Costa Rica (Campos and Calvo, 2000). In Brazil the "ProAmbiente" is an environmental credit program of the Brazilian government paying for environmental services provided by small holders that preserve their forest (MMA, 2004).

13.2.5.2 Agriculture and forestry

Some adaptive measures like changes in land use, diversification, sustainable management, insurance mechanisms, irrigation, adapted genotypes and changes in agronomic crop management, are used in the agricultural sector to cope with climatic variability. For example, farmers located in the US- Mexico border by changes in irrigation technology, crop diversification and market orientation were able to continue farming in the valley despite the crisis with the local aquifers derived of droughts and over-exploitation (Vasquez Leon *et al.*, 2003). Sustainable land management based on familiar practices (contour barriers, green manures, crop rotation and stubble incorporation) allowed smallholders in Nicaragua to better cope with the impacts of Hurricane Mitch (Holt-Gimenez, 2002). In Mexico, some small farmers are testing adaptations measures for current and future climate implementing dripping irrigation systems, greenhouses and the use of compost. (Conde et al, 2005). The adjustments in planting dates and crop choice, the construction of earthen dams to capture rainwater for auxiliary irrigation and the conversion of agriculture to livestock are increasingly popular adaptation measures in Gonzalez (Mexico). In southern Cordoba (Argentina) climate risk insurance, irrigation, adjusting planting dates, spatial distribution of risk through geographically separated plots, changing crops; accumulating commodities as an economic reserve and maintaining a livestock herd were identified as common measures to cope with climatic hazards (Wehbe *et al.*, 2006)

As a response to deforestation, degradation and forest fires, Argentina, Brazil, Costa Rica and Peru have adopted new forestry laws and policies that include better regulatory measures, sustainability principles, expanding protected areas, certifying forestry products and expanding forest plantations in non-forest areas (BOLFOR, *et al.*, 1998; Tomaselli, 2001).

Most countries provide incentives for managing their native forests: exemption from land taxes (Chile, Ecuador, Uruguay), technical assistance (Ecuador), and subsidies (Argentina, Mexico, Colombia)(GEO 3, 2003). Chile and Guyana demand prior studies on environmental impact before approving forestry projects of any importance; Mexico, Belize, Costa Rica and Brazil are already applying forestry certification. Argentina, Chile, Paraguay, Costa Rica and Mexico have established model forests designed to demonstrate the application of sustainable management, taking into account productive and environmental aspects, and with the wide participation of the civil society, including community and indigenous groups.

13.2.5.3 Water resources

Current adaptation of socioeconomic systems in LA to floods and droughts is limited by low GNPs, the increasing population in vulnerable (flood prone) areas and poor-developed political, institutional and technological support systems. Nevertheless, several communities and cities have organized themselves, becoming active in disaster prevention (Fay *et al.*, 2003). Many poor inhabitants were organized to resettle from their location in flood prone areas, to safer ones building themselves their new houses with the aid of IRDB and IDB loans, e.g. resettlements in Argentina, Parana basin, after the 1992 flood (IRDB, 2000). In some cases, the adaptation potential of LA natural systems to the impact of floods, in rural areas is proving to be possible; for example, in rural areas affected by floods during the 90´s in the Salado basin of the Buenos Aires province of Argentina, some livestock producers reconverted their activities during years of great inundation to commercial fishing of Pejerrey (odontesthes bonareriensis) (La Nación, 2002). Another example, but in this case related to the adapting capacity of people to water stresses, is given by programs of in self organization for water supply systems in very poor communities. The organization Business Partners for Development Water and Sanitation Clusters has been working in four “focus” plans in LA: Cartagena (Colombia), La Paz and El Alto (Bolivia) and some underprivileged districts of Gran Buenos Aires (Argentina) (Water 21, 2002; The Water Page, 2001). Rainwater catchment and storage systems are seen as important factors of sustainable development in the semi-arid tropics. Particularly, a joint project elaborated in Brazil by the NGO Network ASA Project called P1MC- Project for 1 million cisterns to be executed by the civilian society in a decentralized manner (at the community, municipal, micro region, state and regional levels) The plan is to supply drought proof drinking water to one million rural households in the Brazilian Semi-Arid Tropics (BSATs). At first stage, 12,400 cisterns were built by ASA and the Ministry of Environment of Brazil and further 21,000 were planned until the end of 2004 (Gnadlinger, 2003). In Argentina, national safe water programs for local communities in arid regions of Santiago del Estero province installed 10 rainwater catchments and storage systems between 2000 and 2002. (Bazán Nickisch, 2002).

13.2.5.4 Coasts

A planned adaptation is the common approach by some LA countries in response to current climate variability (Hoggarth, *et al.*, 2001; GEO-LAC, 2003, Natenzon *et al.*, 2005). Among these**,** the Caribbean Planning for Adaptation to Global Climate Change project is promoting actions to assess vulnerability (especially regarding the rise in sea level), and plans for adaptation and development of appropriate capacities. Since 2000, some countries have been improving the legal framework on matters related to establishing restrictions on air pollution and integrated marine and coastal regulation (e.g. Venezuela’s integrated coastal zone plan since 2002). Due to the strong pressure of human settlement and economic activity, a comprehensive policy design is now within the "integrated coastal management" modelling in some countries like Venezuela (MARN, 2005).

13.2.5.5 Human Health

Preventive actions for malaria and dengue can be identified as adaptation measures to climate change. In the case of dengue, chemical vector control, surveillance, public education and environmental management are the main identified actions (PAHO, 2002).

Adaptation measures for Bolivia include: biological and chemical control; reservoirs control; community participation; climatological surveillance; health education and avoidance of contact with vectors; establishment of an epidemiological surveillance system; the development of governmental programmes focused on high risk areas for malaria and leishmaniasis transmission taking into account climate change; promotion of entomological studies focused on transmission; strengthening sanitary services and strengthening research centres dealing with tropical diseases (including vulnerability studies) (Ministry of Sustainable Development and Environment, 2000).

Adaptation measures in Colombia include the development of an Integrated National Pilot Adaptation Plan for high mountain ecosystems, Caribbean islands, and human health (INAP) to formulate mitigation measures for climate change. INAP will constitute the first adaptation project to tackle the problems brought about by climate change worldwide (IDEAM, 2005).The activities include strengthening prevention and control of malaria through activities related to application of chemical pesticides and treatment of ill people, measures for environmental management in urban and rural areas, improved early diagnosis, better access to health services and treatment, health education, and community protection (Colombian Ministry of the Environment, 2001).

In Peru, a multi-stakeholder decision making system has been developed. This consists of groups (voluntary or statutory) of different stakeholders who perceive the same resource management problem. The groups could play a significant role in risk management for disaster prevention and vulnerability reduction on behalf of the weaker section of society (Warner, 2006). In Mexico, risk communication programs for indigenous populations have been developed. The experience has been very successful and has been identified as an important tool to strengthen the community response to weather hazard (Alcántara *et al.*, 2004).

13.3 Assumptions about future trends

13.3.1 Climate

13.3.1.1. Climate change scenarios

Even though climate change scenarios can be generated by several methods (IPCC, TAR, 2001), the use of GCMs outputs based on SRES scenarios is currently the more relevant methodology. Projections of average temperature and rainfall anomalies throughout the current Century derived from a number of Global Climate Models (GCM) are available at the IPCC Data Distribution Center (IPCC DDC, 2003; http://ipcc-ddc.cru.uea.ac.uk /asres/scatter_plots/ scatterplots_region.html) at typical model resolution of 300 km, and for two different GHG emissions scenarios (IPCC, 2000). Additionally, Chapter 11 of WGI presents regional projections for many parts of the world. The Table 13.3 indicates ranges of temperature and precipitation changes for sub-regions of LA for several time-slices (2020, 2040, 2080), obtained from seven global climate models and the four main emission (SRES) scenarios.

Table13-3: *Projected temperature (C) and precipitation (%) changes for broad sub-regions of Central and South America based on Ruosteenoja et al. (2003). Ranges of values encompass estimates from seven global climate models and the four main SRES scenarios.*

		2020	2050	2080
Changes in temperature (C)				
Central America	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
Change in precipitation (%)				
Central America	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

For 2020, temperature changes range from a warming of 0.4 C to 1.8 C, and for 2080, 1.0 C to 7.5 C. The highest values of warming are projected to occur over Tropical South America (referred to as Amazonia on the Table 13.3). The case for precipitation changes is more complex since regional climate projections show a much higher degree of uncertainty. For Central and Tropical South America, they range from a reduction of 20% to 40% to an increase of 5% to 10% for 2080. Uncertainly is even larger for Southern South America both in winter and summer seasons, although the percent change of precipitation is somewhat smaller in comparison to tropical Latin America. Analyses of these scenarios reveal larger differences in temperature and rainfall changes among models than among emission scenarios for the same model. As expected, the main source of uncertainty for regional climate change scenarios is that one associated to different projections from different GCMs. The analysis is much more complicated for rainfall changes. Different climate models show rather distinct patterns, even with almost opposite projections. In sum, current GCMs do not produce projections of changes in the hydrological cycle at regional scales with confidence. That is a great limiting factor to the practical use of such projections for active adaptation or mitigation policies.

Global Climate Models-derived scenarios are commonly downscaled using Statistical Downscaling Models (SDSM) to generate region- or site-specific scenarios. There have been a number of such exercises for South America using an array of GCMs (HADCM3, ECHAM4, GFDL, CSIRO, CCC, etc.) usually for SRES emissions scenarios A2 and B2: for Southern South America (Bidegain and Camilloni, 2004; Solman et al, 2005a; Solman *et al.* 2005b; Nuñez *et al.* 2005), for Brazil (Marengo, 2004), for Colombia (Eslava and Pabón, 2001), and for Mexico (Conde, 2003; Morales, 2002). Downscaled scenarios may reveal smaller scale phenomenon associated with topographic features or mesoscale meteorological systems, but in general the uncertainty associated with using different GCMs as input to SDSM is still present in the downscaled scenarios.

13.3.1.2 Changes in the occurrence of extremes

Many of the current climate change studies indicate that the frequency in the occurrence of extremes will increase in the future. Many impacts of climate change will be realized as the result of a change in the frequency of occurrence of extreme weather events such as windstorms, heavy precipitation or extreme temperatures over a few hours to a few days. A number of regional studies have been completed for southern South America (Vincent *et al.*, 2005, Marengo and Camargo 2006, Haylock *et al.*, 2006; Alexander *et al.*, 2006), Central America and northern South America (Aguilar *et al.*, 2005, Alexander *et al.*, 2006). They all show patterns of changes in extremes consistent with a general warming, especially positive trends in warm nights and decreasing trends in the occurrence of cold nights. There is also a positive tendency for intense rainfall events and consecutive dry days. A study by Groissman *et al.*(2005) identified positive linear trends in the frequency of very heavy rains over Northeast Brazil and over Central Mexico. However, the lack of long term records of daily temperature and rainfall in most of tropical South America does not allow for any conclusive evidence of trends in extremes in regions such as Amazonia. Section 3.8 of the Chapter 3-WGI IPCC AR4 has discussed observational aspects of variability of extremes and tropical cyclones. Section 11.3 of Chapter 11- WGI IPCC AR4 acknowledges that little research is available on extremes of temperature and precipitation for this region. Some limited studies on extremes from global models from IPCC AR4 (Tebaldi *et al.*2006) provide estimates on how frequently the seasonal temperature and precipitation extremes as simulated in the present and by the end of Century XXI under the A1B scenario. Essentially all seasons and regions are extremely warm by this criterion by the end of the century. In Central America, the projected time mean precipitation decrease is accompanied by more frequent dry extremes in all seasons. In South America, some models anticipate extremely wet seasons in the Amazon region and in Southern South America while other shows opposite tendency. All models show in some or less degree warming in the entire LA region.

13.3.2 Land use changes

Deforestation in LA tropical areas is now and will be one of the most serious environmental problems that the regions faces, with long term impacts and consequences over biodiversity, loss of economic opportunities, social problems and its contribution to Climate Change . The region is responsible for 48.3% of the world's total carbon dioxide emissions from land-use changes (GEO, 2000). By 2010 the forest area in South and Central America will be reduced by 18 Mha and 1.2 Mha respectively (FAO, 2005). These deforested areas will be used for pasture and expanding livestock production in ranges of 69% in South America and 62% in Central America (FAO, 2005).

If the deforestation rate in 2002-2003 (2.3 Mha per year) in Brazilian Amazonia continues indefinitely, then 100 Mha of forest will have disappeared by the year 2020. This is about 25% of the original forest (*Laurance et al.*, 2005). Other analysis estimates that by 2050 for a Business as Usual Scenario 269.8 Mha will be deforested in Brazilian Amazon (Santilli *et al.*, 2004). By means of simulation models, Soares-Filho *et al.* (2005) estimated for the Brazilian Amazonia that in the worst-case scenario, by 2050, the projected deforestation trend will eliminate 40% of the current 540 Mha of Amazon forests, releasing approximately 32 Pg (10^9 tons) of carbon to the atmosphere. Moreover, under the current trend the agricultural expansion will eliminate two thirds of the forest cover of five major watersheds, ten ecoregions, besides 164 mammalian species in Amazon will lose more than 40% of their habitats.

Projected to be one of the main drivers of future land use change, soybean planted area in South America is expected to increase from 38 Mha in 2003/04 to 59 Mha in 2019/20 (Maarten Dros, 2004). Total production of Argentina, Brazil, Bolivia and Paraguay will rise 85% to 172 million tons or 57% of the world production. Direct and indirect conversion of natural habitats to accommodate this expansion amounts to 21.6 Mha. Habitats with greatest predicted area losses are the Cerrado (9.6 M ha), dry and humid Chaco (6.3 M ha), Amazon transition and rainforests (3.6 M ha), Atlantic forest (1.3 M ha), Chiquitano Forest (0.5 M ha), and Yungas Forest (0.2 M ha). Soybean cultivation in LA will continue to expand, especially in Brazil, followed by Bolivia and Paraguay (Fearnside, 2000).

13.3.3 Development

13.3.3.1 Demographics and societies

The population of the LA region has continued to grow and is expected be 50% larger than in 2000 by year 2050. Its annual population growth rate has decreased and is expected to reach a value of 0.89 by 2015 which is smaller than 1.9, the average rate for the 1975-2002 period. The population has continued to migrate from the country side to the cities and will amount to 80% by year 2015 almost a 30% more than in the1960 decade. The population under 15 years will decline and at the same time the population over 65 years of age will increase. Total fertility rate (births per woman) has decreased from 5.1 to 2.5 from periods 1970-75 to 2000-05 respectively and is expected to decrease to 2.2 by year 2015 (ECLAC, 1998)

According to ECLAC (1998) the number of people in a range of age that would make them dependant (between 0 to 14 and more than 65 years) will increase from 54.8% in present date to almost 60% in year 2050. This will increase pressures on the social security systems in the region and enlarge the size of contributions population in working age will have to make to maintain the availability of health and educational services. Life expectancy at birth has increased from 61.2 years in the 1970’s to 72.1 years in the 2000-2005 quinquennia and is expected to increase to 74.4 years by year 2015. Crude mortality rate is expected to remain 7.8 (per thousand) and increase to almost 12 by year 2050.

Human migration has become an important issue in the region. Recent studies (ECLAC, 2002a) have estimated that 20 million LA and Caribbean nationals reside outside their countries, the vast majority in North America. This phenomenon has important effects in national economies and creates important social dependencies: 5% of households in the region benefit from remittances which in 2003 amounted for 38 billion US dollars (17.6% more than in 2002) (IMO, 2005).

According to the Human Development Index all countries in the region are classified within high and medium development ranks. In particular LA Countries are ranked within the upper half of the Human poverty index and have shown a positive trend since 1975 to 2002. It is difficult to ignore that, although there are not Latin American countries classified in the low development rank, there are large contrasts among and within countries in terms of levels of technological development, sophisticated financial sectors, export capacities and income distribution (ECLAC, 2002b).

13.3.3.2 Economic scenarios

Projections of economic evolution for the region strongly depend on the interpretation of the results of liberalization process that the region experienced during the last 20 years and therefore can be contradictory. On the one hand, economist that favours liberalization of LA’s economies argue that countries that have implemented these type policies have improved in terms of rate of growth, stability, democracy and even inequality and poverty (for example Walton, 2004, World Bank, 2006). On the other hand, another group of experts in economics, sociology and politics are concerned with the results that neoliberalization has had for the region specially in terms of increases in inequality and poverty but also in terms of lack of economic growth (Huber and Solt, 2004). This is still an unsolved debate that imprints great uncertainty to economic scenarios for LA.

The first group’s view provides the following insights for economic prospects. Analysts from the World Bank argue that while the real per capita GDP of LA has had a very low growth, about 1.3 percent average during the 1990 to 2000 period in the long term, (from 2006 to 2015) regional GDP is projected to increase by 3.6 percent a year, and per capita income is expected to rise by 2.3 percent on average (World Bank, 2006). Current estimations forecast a growth of 4% for the region in 2006 and

3.6% in 2007 and a real per capita GDP growth of 2.6 and 2.3% respectively (World Bank, 2006, Inter-American Dialog, 2006)).

These positive prospects are attributed to the implementation of economic policies such as substantial reduction of the fiscal imbalances and inflation control that have restrained growth in the past. According to this source, the area is on track to meet its Millennium Development poverty goals, although is important to notice that the region's performance is not as good as other developing regions like Europe, Central Asia and notably Asia. Improvement of this rate of growth could be achieved from consolidating current economic policies (Walton, 2004; World Bank, 2006).

The second group of experts argue that the results of the liberalization, far from establishing the basis for a sound economic growth, have weakened the strength of the regional economy reducing its rate of growth and making it more volatile, exacerbating social inequality and poverty and limiting the regional capacity for future growth (ECLAC, 2005; Huber and Solt, 2004). Lack of economic growth, inequality, deficient legal framework and demographic pressures have shown to be important factors for increasing environmental depletion and vulnerability to climate variability and extreme events (ECLAC, 2002b).

13.4 Summary of expected key future impacts and vulnerabilities.

13.4.1 Natural ecosystems

Tropical plant species are especially sensitive to even small variations of climate since biological systems' respond slowly to relatively rapid changes of climate. This fact might lead to a decrease of species diversity. Based on Hadley Centre AOGCM projections for A2 emissions 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 in surface temperature (Thomas *et al.*, 2004; Siqueira & Peterson, 2003). By the end of the Century, of 69 tree plant species studied 43% could become extinct in Amazonia (Miles *et al.*, 2004). In terms of species and biome redistributions larger impacts would occur over northeast Amazonia than over western Amazonia. Several AOGCM scenarios indicate a tendency of 'savannization' of eastern Amazonia and in the Northeast Brazil the semi -arid vegetation would be replaced by vegetation of arid regions (Nobre *et al.*, 2004).

Forty percent of the Amazonian forests could react drastically even to a slight reduction of precipitation; this means that the tropical vegetation, hydrology and climate system in South America, could change very rapidly to another steady state not necessarily producing gradual changes between the actual and the future situation (Rowell and Moore, 2000). It is more probable that forests will be replaced by ecosystems that have more resistance to multiple stresses caused by temperature increase, droughts and fires.

By forcing a dynamic global vegetation model with multiple scenarios from 16 climate models and mapping the proportions of model runs showing forest/non-forest shifts, or exceedance of natural variability in wildfire frequency and freshwater supply the risks of climate induced changes in key ecosystems processes during the 21st century are estimated (Scholze *et al.*, 2005). This study considers the distribution of outcomes within three sets of model runs grouped according to the amount of global warming they simulate: <2°C, 2-3°C, and >3°C. High risk of forest loss is shown for Central America, and Amazonia, more frequent wildfire in Amazonia, more runoff in northwestern South America, and less runoff in Central America. More frequent wildfires are likely (>60% for >3ºC) in much of South America. Extant forests are destroyed with lower probability in Central America and Amazonia. The risks of forest losses in some parts of Amazonia exceed 40% for increases of temperature >3ºC

(Scholze *et al.*, 2005). (See hotspots in Latin America Fig. 12.3)

The mountain tropical cloudy forests will be threatened if the temperature increases by 1 to 2°C during the next 50 years due to changes in the altitude of the clouds level during the dry season which will be increasing by 2m per year. In the places where mountains are isolated some plants will become locally extinct because they will not have enough altitude to adapt to the temperature increase, (FAO, 2002). The change in temperature and cloud base in these forests could have substantial effects on the diversity and composition of species. For example, in the cloudy forest of Monteverde Costa Rica, these changes are already happening. Declines in the frequency of mist days have been strongly associated with a decrease in population of birds, reptiles and amphibians (Pounds *et al.*, 1999).

Modelling studies show that the ranges occupied by many species will become unsuitable for them as the climate changes (IUCN, 2004). Using modelling projections of species distributions for future climate scenarios, Thomas *et al.,* (2004) show for the year 2050, for a mid-range climate change scenario, that species extinction in Mexico could sharply increase: mammals.,8 % (with dispersal) and 26% (without dispersal), birds 5% or 8% (with or without dispersal) and butterflies 7% or 19% (with or without dispersal). For a minimum expected climate change scenario 13% (with dispersal) of frogs and 9% (with dispersal) of reptiles are projected to become extinct in Mexico.

13.4.2 Agriculture

Several studies using crop simulation models and future climate scenarios were carried out in the region for commercial annual crops (Table 13.4). According to a global assessment, in LA grain yield reductions (wheat, rice, maize and soybean) could reach up to 30% by 2080 under the warmer scenario (HadCM3 SRES A1F1). However when CO2 effects are considered, yield changes could range between a 30% of reduction in Mexico and a 5% of increase in Argentina (Parry *et al.*, 2004). More specifics studies considering individual crops and countries are also presented in Table 13.4. The great uncertainty in yield projections could be attributed to the GCM or incremental scenario used, the time slice and SRES scenario considered, the inclusion or not of CO2 effects, and the site considered. Despite great variability in yield projections some behaviour seem to be consistent all over the region like the projected reduction of rice yields after the year 2010, and the increase in soybean yields when CO2 effects are considered. The increase of crop yield reductions is also remarkable if the variance of temperature were doubled in the future (Table 13.4). For non commercial farmers (Table 13.4) a mean reduction of 10% in maize yields could be expected by 2055, although in Colombia yields are essentially unchanging, while in the Venezuelan piedmont yields are predicted to decline almost to zero (Jones & Thornton, 2003). Other important issues are the expected reduction in suitable lands for coffee in Brazil, and in production in Mexico.

Pastures production could increase between 1% and 9% in selected sites of Argentina and Uruguay according to HadCM3 projections under SRES A2 for 2020 (AIACC-LA27). Concerning beef cattle production in Bolivia, future climatic scenarios would have slight impacts on animal weight if CO2 effects are not considered, while doubling CO2 leads to decreases in weight that could reach up to 20% depending on animal genotype and region (Bolivia, 2000).

Furthermore, the combined effects of climate change and land use change on food production and food security are related to a larger degradation of lands and a change on erosion patterns (FAO, 2001). By the year 2050 desertification and salinization will affect 50% of agricultural lands in LA and the Caribbean zone (FAO, 2004a). According to the World Bank Report (2002), some developing countries are loosing 4-8% of their Gross Domestic Product, caused by productive and capital loss related to environmental degradation.

The demand of water for irrigation is projected to rise in a warmer climate, bringing increased competition between agriculture and drinking as well as industrial users. Falling water tables and the resulting increase in the energy used for pumping will make the practice of agriculture more expensive (Maza *et al.*, 2001). In the state of Ceará (Brazil) large scale reductions in the availability of stored surface water would lead to an increasing imbalance between water demand and water supply after 2025 (ECHAM scenario) (Krol & van Oel, 2004).

An increase of heat stress, and more dry soils, may reduce yields to a third in tropic and subtropics areas where harvests are near the maximum heat tolerance. Both prairies/meadows productivity and pastures will be affected, with loss of carbon stock in organic soils and also organic matter as well as shifts on interactions and balance between species, including plagues and diseases incidence on cultivated plants (FAO, 2001).

13.4.3 Water resources

The current vulnerabilities observed in many regions of LA countries will be increased by the joint negative effect of growing demands due to an increasing population rate for water supply and irrigation, and the expected drier conditions in many basins. The impact of climate change in safe water supply in LA has been estimated in the numbers of people with an increase in water stress. By the 2025s, 30 million people would have increase in water stress (36 million people would be in stress in absence of climate change) in scenarios A1 and B1, 70 million people in scenario A2 (56 million people in absence of climate change) and 75 million people in scenario B2 (47 million people in absence of climate change). By the 2055s, people living in water stressed watersheds may be estimated in 134 million in scenarios A1 and B1 (54 million people would be in stress in absence of climate change), 202-320 million in scenario A2 (150 million people in absence of climate change) and 95-145 million in scenario B2 (60 million people in absence of climate change) (Arnell, 2004). In zones where severe water stresses could be expected (east Central America, in the plains, Motagua valley and Pacific slopes of Guatemala, east and western regions of El Salvador, the Central Valley and Pacific region of Costa Rica, in the northern, central and western Intermountain regions of Honduras and in the Peninsula of Azuero in Panama) water supply and hydroelectric generation would be seriously affected (Ramirez, 2003).

Vulnerability studies foresee the ongoing reduction of glaciers. A much stressed condition is projected between 2015 and 2025 in the water availability of at least ten States of Colombia (IDEAM, 2004) and impact on the availability of water supply for the 60% of the population of Peru. (García Vargas, 2003). The potential reductions in the glaciers would impact the hydroelectricity generation in some regions such as Colombia (IDEAM, 2004) and Peru where one of the more affected rivers would be the Mantaro, where an hydroelectric plant represents the 40% of the Peruvian electrical generation and the energy supply for the 70% of the industries, concentrated in Lima (UNMSM,2005). (See case study 2).

In Ecuador, recent studies signal that 7 of the 11 principal basins would be affected by a decrease in annual runoffs, with monthly decreases varying up to 421% of unsatisfied demand (related to mean monthly runoff) in year 2010 with the scenario of +2ºC and P-15% (Cáceres, 2004). In Chile, recent studies confirm the potential damages in water supply and sanitation services in coastal cities, as well as groundwater contamination by saline intrusion. In the Central region river basins, changes in the streamflows would oblige to retrofit many water regulation works (CONAMA, 2004).

Table 13.4: *Future Impacts in the agricultural sector.*

Study	**Climate Scenario**	**Yield Impacts (%)**				
		Wheat	**Maize**	**Soybean**	**Rice**	**Others**
Guyana	CGCM1 2020-2040 (2CO2)				-3	Sugar: -30
(Guyana, 2002)	CGCM1 2080-2100 (3CO2)				-16	Sugar: -38
Panamá	HadCM2-UKHI (IS92c-IS92f)					
(Panama, 2000)	2010/2050/2100 (1CO_2)		+9/-33.5/-21			
Costa Rica	+2ºC -15% pp (1CO_2)				-31	Potato:
(Costa Rica, 2000)						reductions
Guatemala	+1.5ºC +5% pp		+8 to -11		-16	
(Guatemala, 2001)	+2ºC +6% pp		+15 to -11		-20	
	+3.5ºC -30% pp		+13 to -34		-27	
Bolivia	GISS and UK89 (2CO_2). I		-25		-2	
(Bolivia, 2000)	Incremental (2CO_2)		+50			
	+3ºC -20% pp				-15	Potato:
	optimistic-pessimistic (1CO_2)					+4.6 to+1.7*^{2}
	optimistic-pessimistic (2CO_2)					+6.6 to+4.6*^{2}
	IS92a (1CO_2) *^{1}			-3.3 to -19.6		
	IS92a (2CO_2) *^{1}			+59 to +12		
Brazil	GISS (550 CO_2)	-30	-15	+21		
(Siqueira *et al.*, 2001)						
SESA ^{*3}	Hadley CM3-A2 (500ppm)	+9 to +13	-5 to +8	+31 to +45		
(AIACC-LA27)	Hadley CM3-A2 (500ppm). I	+10 to +14	0 to+2	+24 to +30		
Argentina, Pampas	+1/+2/+3ºC (550 CO_2). I	+11/+3/-4	0/-5/-9	+40/+42/+39		
(Magrin & Travasso, 2002)	UKMO (+5.6ºC) (550 CO_2). I	-16	-17	+14		
Honduras	Hadley CM2 (1CO_2) 2070		-21			
(Díaz-Ambrona *et al.*, 2004)	Hadley CM2 (2CO_2) 2070		no changes			
Central Argentina	Hadley CM3-B2 (477ppm)		+21			
(Vinocur, 2005; Vinocur *et al.*, 2000)	ECHAM98-A2 (550ppm)		+27			
	+1.5/+3.5ºC (1CO2) I		-11/-13.5			
	+1.5/+3.5ºC (1CO2) I (2Tσ) ^{*4}		-15/-27			

Study	**Climate Scenario**	**Yield Impacts (%)**				
		Wheat	**Maize**	**Soybean**	**Rice**	**Others**
	+1.5/+3.5ºC (1CO2)		-13/-17			
	+1.5/+3.5ºC (1CO2) (2Tσ) ^{*4}		-19/-34.5			
Latin America (Jones & Thornton, 2003)	Hadley CM2 (smallholders)		-10			
Latin America (Parry *et al.*, 2004)	HadCM3 A1F1 (1CO_2)	**Cereal** -5 to -2.5 (2020)	-30 to -5 (2050)	-30	(2080)	
	HadCM3 B1 (1CO_2)	**yields** -10 to -2.5 (2020)	-10 to -2.5 (2050)	-30 to -10	(2080)	
	HadCM3 A1F1 (2CO_2)	-5 to +2.5 (2020)	-10 to +10 (2050)	-30 to +5	(2080)	
	HadCM3 B1 (2CO_2)	-5 to -2.5 (2020)	-5 to +2.5 (2050)	-10 to +2.5	(2080)	
México, Veracruz (Gay *et al.*, 2004)	HadCM2 ECHAM4 (2050)	**Coffee:** 73% to 78% reduction in production				
Brasil, Sao Pablo (Pinto *et al.*, 2002)	+1ºC + 15% pp +5.8ºC + 15%pp	**Coffee:** 10% reduction in suitable lands for coffee 97% reduction in suitable lands for coffee				
Costa Rica (Costa Rica, 2000)	Sensitivity analysis	**Coffee:** Increases (up to 2ºC) in temperature would benefit crop yields				

I= Irrigated crops; pp= precipitation; $*^1$ = Values correspond to soybean sowing in winter and summer for 2010 and 2020; $*^2$ = Increases every 10 years. ^{*3} SESA= South East South America ^{*4} 2Tσ: duplicated variance of temperature

Table 13.5: *Future impacts and vulnerability to climate change and variability in Latin America coastal systems:*

Country Region	**Climate Scenario**	**Impacts/costs (infrastructure, ecosystems, sectors)**
Low-lying coasts in Brazil, Ecuador, Colombia, Guyana, El Salvador, Venezuela	SRES A2: 38-104 cm	Mangrove areas could disappear from more exposed and marginal environments and the same time, the greatest development would occur in the more optimal high sedimentation, high tide, and drowned river-valley environments. Shrimp production will be affected with the consequent drop in production and GDP share. (Medina *et al.*, 2001; Hensel and Proffit, 2002)
El Salvador	SLR: 13 cm- 110 cm	Land loss ranging from 10%-27,6% of the total area (141 km^2 - 400,7 km^2). (El Salvador, 2000)
Guyana	SLR 100 cm projected by GCMs	Over 90 % of the population and the most important economic activities are located in the coastal areas where is expected that to retreat as much as 2.5 km. (Guyana,2002)
Mesoamerican coral reef and mangroves from Gulf of Mexico	Warmer SST:1º-3ºC by the 2080s under IPCC SRES scenarios	Coral reef and mangroves are expected to be threaten, with consequences over a number of endangered species: e.g. the green, hawksbill and loggerhead turtles, the West Indian manatee and the American and Motelet's species of crocodile. (CLR-UEA, 1999; Cahoon and Hensel, 2002)

Country Region	Climate Scenario	Impacts/costs (infrastructure, ecosystems, sectors)
Costa Rica, Puntarenas coast.	SLR 0.3m and 1.0 m	Seawater should penetrate 150 m to 500m affecting 60%-90% of urban areas. Costa Rica, 2000)
Ecuador, Guayas river system, associated coastal zone, and Guayaquil city	no-change: LANM0, moderate: LANM1, and severe changes: LANM2, without and with development respectively	Losses of US$ 1,305 that include shrimp cultures, mangroves, urban and recreation areas, supply of drinking water, as well banana, rice and sugar cane cultures. US$ 1,040 should be under risk. Evacuated and under risk population should rise 327,000 and 200,000 people, respectively. Of the current 1,214 km^2 mangroves, it is estimated that 44% will be affected by LANM2 scenario. (Ecuador, 2000)
Perú	Intensification of ENSO events and increases in SST. Potential SLR	Increased wind stress, hypoxia and deepening of thermocline impact the marine ecosystem and Fisheries, i.e. reduction of spawning areas and fish catch of anchovy. Flooding of infrastructure, houses and fisheries will raise US$ 168 250 000. Global losses on 8 coastal regions from Peru will raise US$ 1 000 000 000.
Colombia	SLR 1.0 m	Permanent flooding of 4.900 km^2 of low lying coast. About 1,4 million people would be affected. 29% of homes would be highly vulnerable; agriculture sector would be exposed to flooding (e.g. 7,208,299 ha of crops and pasture will be lost). 44.8% of the coastal roads network would be highly vulnerable. (Colombia, 2001).
Argentina (Buenos Aires City)	SLR 2070/2080	Very low-lying areas which will be likely permanently flooded are now scarcely populated. Vulnerability is mostly conditioned by future exposure to extreme surges. Quick erosion with its consequent coastline backward, depending on geologic characteristics of the area. As a result of this adaptation to present storm surge conditions, the social impact of future permanent flooding will be small. (Kokot, 2004; Menéndez- Ré, Kind, 2005).
Argentina and Uruguay (Western Montevideo) coastal areas. Buenos Aires and Rio Negro Provinces	SLR Climate Variability, storm surges and SLR SLR > 0.30 m- Uruguay	Increase in yearly rates and non eustatic factors (i.e. increase in southeastern winds and freshwater flow) would accelerate SLR in the Rio de la Plata having diverse environmental and societal impacts on both the Argentinean and Uruguayan coasts over the next few decades, i.e. Coastal erosion and inundation Low lying-areas (estuarine wetlands and sandy beaches very rich in biodiversity) will be highly vulnerable to SLR, and storm surge. Loss of land would have a major impact on tourism industry which accounts for 3.8% of Uruguay's GDP. (Barros *et al.*, 2003; Nagy *et al.*, 2005 a,b; Natenzon *et al.*, 2005 ; Ramos Mañé *et al.*, 1998 ; Kokot, 2004c ; Uruguay, 2004)

Agriculture malpractices (soil erosion, herbicides, pesticides, fertilisers) will probably impact on the deterioration of surface and groundwater availabilities; under more severe dry conditions. That would be the case of areas currently degraded as Leon, Sebaco valley, Matagalpa and Jinoteca in Nicaragua, metropolitan and rural areas of Costa Rica, Central Valley rivers in Centro America, Magdalena river in Colombia, Rapel river basin in Chile, Uruguay river in Brazil, Uruguay and Argentina (GEO-LAC, 2003).

Landslides in LA are generated by intense precipitations (heavy rains), associated with deforestation and lack of land planning; since many cities of the Region are vulnerable to landslides, the exacerbation of extreme events would bring increasing risks/hazards to local populations (Fay *et al.*, 2003).

Accelerated urban growth, increasing poverty and low investment in water supply will contribute with: water shortages in many cities, high percentages of urban population without access to sanitation services, absence of treatment plants, high groundwater pollution, lack of urban drainage systems, storm sewers used for domestic waste disposal, occupation of flood valley without control during drought seasons and high impacts during flood seasons (Tucci, 2001) (IRDB, 2003).

13.4.4 Coasts

Significant impacts of climate change on the LA densely populated coastal areas; on people and resources are projected. Results from several studies using SLR incremental and future climate change scenarios are summarized in Table 13.5. Projected impacts include floods, salinization of low-land areas affecting sources of drinking water (Ubitaran Moreira *et al.*1999), coastal storm regime modification, increased erosion and altered coastal morphology (Conde *et al.*, 2001; Schaeffer-Novelli *et al.*, 2002; Villamizar, 2004; Codignotto, 2004), and seawater acidification on sea and coastal environments (Revkin, 2004) which would entail serious socio-economic consequences (Ubitaran Moreira *et al.*, 1999). Other factors such as the artificial opening of littoral bars, pressures from tourism, excessive afforestation with foreign species and coastal setback starting from the decrease of the fluvial discharge in the patagonian rivers will add impacts to coastal environments (CIDAS, 2003; Grasses *et al.*, 2000; Rodríguez Acevedo, 2001; Kokot 2004c).

13.4.5 Human health

The regional assessments of health impacts due to climate change in the Americas have indicated that the main concerns are heat stress, malaria, dengue, cholera and other water-borne diseases (Githeko and Woodward, 2003). Climate change could modify the geographical distribution of vectors (such as malaria and dengue vectors) in parts of LA (Haines and Patz, 2004; Martens and McMichael, 2001), and it is expected to affect health via various indirect pathways, including the patterns of infectious diseases (McMichael, 2003).

Colombia has recognized the potential increase of vulnerable areas where malaria and dengue vectors may live due to climate change, increasing the probability of transmission and the number of cases (Ministerio de Medio Ambiente, 2002). As a result, the authorities are aware of the importance to strengthen the epidemiological surveillance system in order to identify new outbreaks.

Kovats *et al.* (2005) have estimated relative risks in the year 2030 in different outcomes in Central America based on current and future prevalence. For example, there is a 4.64 relative risk for coastal floods deaths (drowning) in unmitigated scenario, 3.76 relative risk for stabilization at 750 ppm CO_2, and 3.58 relative risk for stabilization at 550 ppm CO_2. For malaria deaths, relative risk is lower, 1.08

in unmitigated scenario, 1.05 relative risk for stabilization at 750 ppm CO_2, and 1.04 relative risk for stabilization at 550 ppm CO_2.

Based on SRES emission scenarios (A1F1, A2, B1 and B2) and socio-economic scenarios, some projections indicate decreases in the transmission season of malaria in many areas where reductions in precipitation are projected by the HadCM3, such as the Amazon and Central America. The results report additional population at risk in areas around the southern limit of the distribution in South America (Lieshout *et al.*, 2004).

In Bolivia, a change in climate could increase the incidence of malaria in 27% (11.3% for *P. vivax* and 43.6% for *P. falciparum*). Based on the IS92a scenario, malaria (*P. vivax*) could present seasonal variation (with peaks in April-May) in 2010. The malaria due to *P. falciparum* could increase the seasonal variation, showing three peaks (January, April-May, and August-September) (Bolivian Ministry of Sustainable Development and Environment, 2000).

Climate change scenarios have predicted a possible increase in malaria cases from 2-6% to 3-9% of the Nicaraguan population in 2030, to 3-10% in 2050, and 5-15% for 2100. The increase in malaria could impact costs in health services, including treatment and social security payments. Depending on scenario and region, increase in temperature would mean a 38-150% increase in malaria cases (MARENA, 2001).

For LA (based on a dynamic integrated assessment model (FUND)) assuming population and income as is today, 1,101 (mean) additional deaths due to malaria and -114 (mean) deaths due to schistosomiasis for a 1°C global warming is reported. However there is a predicted 0.22% change in cumulative climate change induced vector borne mortality due to a 1% emission reduction in 2000-2009 (Tol and Dowlatabadi, 2001).

A substantial increase in the number of LA people at risk of dengue fever has been reported based on the IS92 due to changes in the geographical limits of dengue fever transmission (Hales *et al.*, 2002). The east and west cost of Mexico; the east and southern regions of Brazil, and the west region of Peru and Ecuador would be affected by these changes (Hales *et al.*, 2002). The potential for an increase of dengue epidemics is provided by Climate Change (Gagnon *et al.*, 2001; Hoop and Foley 2001).

Based on GARP models, *Lutzomyia intermedia* (cutaneous leishmaniasis vector) is predicted to occur throughout eastern and southern-eastern Brazil, extending south into Paraguay, Uruguay and Argentina. A large area is predicted extending from northern Argentina into Bolivia, and connecting to the rest of the known distributional areas through the Mato Grosso. *Lutzomyia migonei* will have a distribution quite similar to that of *L. intermedia*, except in that it extends sparsely along the northern coast of Brazil and north along the east slope of the Andes to central Peru and western Brazil. *L. whitmani* will be distributed form the northern and north-eastern coasts of South America south to northern Argentina (Peterson and Shaw, 2003).

Based on projections for 2010, in Bolivia, an increase in leishmaniasis is expected, between July-September. Morbidity due to leishmaniasis could be increased due to temporal migration patterns (labour migration) in high risk areas (Bolivian Ministry of Sustainable Development and Environment, 2000).

Future analysis based on ecological niche modelling will approach the challenges of predicting dispersal potential for chagas´ vectors species into new areas, (Costa *et al.*, 2002) as well as monthly distribution of dengue vector (spatial dynamics) (Peterson *et al.*, 2005).

Forest fires have significant sanitary, economic and environmental effects (Haines and Patz, 2004). Climate change is likely to affect the risk of forest fires, which in some countries, such as Brazil, have been associated with the increase risk of outpatient visits for respiratory disease and increased risk of respiratory disease (WHO, 2000).

The production of various air pollutants and of allergenic spores and pollens would be affected by warmer and wetter conditions (Haines and Patz, 2004; Martens and McMichael, 2001). It has been reported under the high-emission “A2” IPCC scenarios, that the daily average ozone level increases 3.7 ppb across eastern American cities, with the most polluted cities today experiencing the greatest increase in ozone pollution (Patz *et al.*, 2005). Therefore, cities, such as Mexico city, São Paulo and Santiago, might expect worsened conditions.

Small changes in temperature variability, along with a shift in mean temperature, can greatly increase the frequency of extreme heat. Therefore a greater proportion of people (particularly the elder) in all countries will be at risk (McMichael *et al.*, 2006). Also population living in cities with poor quality housing that currently experience an urban heat island effect, and cities that have topography that gives rise to stagnant air masses and summer pollution will be at risk (for example, Santiago and Mexico City) (PAHO, 2005).

- ● Coral reef and mangroves seriously threatened with warmer sea surface temperature
- ● Under the worst SLR scenario, mangroves could disappear in low-lying coastlines
- ● *Amazonia*: Losses of 43% of 69 tree species (end of the 21 century). Savannization of eastern part.
- ● *Cerrados*: Losses of 24% of 138 tree species (+2ºC)
- ● Important reduction of suitable lands for coffee
- ● Increasing aridity and scarcity of water resources.
- ● Sharply increase in mammals, birds, butterflies, frogs, and reptile’s extinction (2050).
- ● Water availability and hydroelectrical generation seriously reduced because of glacier’s reduction
- ● Increased probability of dengue transmission

Fig 13.2: *Key hotspots for Latin America.*

13.5 Adaptation

13.5.1 Practices and options

13.5.1.1 Natural ecosystems

Some options to reduce the ecosystem degradation in LA are the improvement of policy, planning and management. According to Millennium Ecosystem Assessment (2005), FAO (2004b), Laurance *et al.* (2001), Brown *et al.* (2000), and Nepstad *et al.* (2002), these options basically are:

- Integrate decision-making between different departments and sectors, as well as international institutions, to ensure that policies are focused on protection of ecosystems.
- Empowerment of marginalized groups to influence on the decisions, which affect the ecosystem services, and recognize in law local communities ownership of natural resources.
- This option is the key to reduce forests fires incidence.
- Include sound management of ecosystem services in all regional planning decisions and in the poverty reduction strategies being prepared by many developing countries, e.g., Noel Kempff Mercado Climate Action Project in Bolivia and Rio Bravo carbon sequestration pilot project in Belize.
- Establish additional protected areas, particularly the biologic or ecological corridors for preserving the connections between protected areas, with the aim to prevent the fragmentation of natural habitats, as for example had been happening in the Meso-American Biological Corridor, natural corridor projects under way in Brazil's Amazon and Atlantic forests, the Andean Corridors of Ecuador, Bolivia and Peru, and some initiatives in Argentina (i.e., Iniciativa Corredor de Humedales del Litoral Fluvial de la Argentina, Corredor Verde de Misiones, and Proyecto de Biodiversidad Costera), Colombia (i.e., Corredor Biológico Guácharos – Puracé and Corredor de Bosques Altoandinos de Roble) Venezuela (i.e., Corredor Biológico de la Sierra de Portuguesa), Chile (i.e., Corredor entre la cordillera de los Andes y la Cordillera de la Costa and Proyecto Gondwana), Binational Corridors (i.e., Tariquía-Baritú between Argentina and Bolivia, Vilcabamba-Amboro between Peru and Bolivia), Cóndor Kutukú between Peru and Ecuador), and Chocó–Manabí between Ecuador and Colombia).
- Tropical countries in the region can reduce deforestation through adequate funding of programs designed to enforce environmental legislation, support for economic alternatives to extensive forest clearing (including carbon crediting), and building capacity in remote forest regions, as recently suggested in part of the Brasilian Amazon ((Nepstad *et al.*, 2002; Fearnside, 2003). Moreover substantial forest can be saved in protected areas if adequate funding is available ((Bruner *et al.*, 2001; Pimm *et al.*, 2001).

13.5.1.2 Agriculture and forestry

In the region, there was only limited assessment of adaptation in the agricultural sector. For example in Ecuador several options such as: agro-ecological zoning and appropriate sowing and harvesting seasons, introduction of higher-yield varieties, installation of irrigation systems, adequate use of fertilizers, and implementation of a system for controlling pests and disease, were proposed (Ecuador, 2000). In Guyana several adjustments related to: crop variety (thermal and moisture requirements and shorter-maturing varieties), soil management, land allocation to increase cultivable area, using new sources of water (recycling of wastewater), harvesting efficiency, and purchases to supplement production (fertilizers and machinery) were identified (Guyana, 2002).

In other countries, adaptation measures were assessed by mean of crop simulation models. For example in the Pampas region of Argentina anticipating planting dates and the use of wheat and maize genotypes with longer growth cycle would allow taking advantage of projected longer growing seasons as a result of the shortening in frost's period (Magrin & Travasso, 2002). More recently Travasso *et al.*, (2006) reported that in South Brazil, Uruguay and Argentina, negative impacts of future climate on maize and soybean production could be offset by changing planting dates and adding supplementary irrigation.

A global study (which includes Northern Argentina and Southeastern Brazil) concludes that in Northern Argentina occasional problems in water supply for agriculture under the current climate may be exacerbated by climate change, and may require timely improvements in crop cultivars, irrigation and drainage technology, and water management. Inversely, in Southeastern Brazil, future water supply for agriculture appears to be plentiful (Rosenzweig *et al.*, 2004).

Carbon-sequestration opportunities in the agriculture, livestock, and forestry sectors, which are responsible for more than 80% of GHG emissions in Uruguay, should be taken advantage of. For example Uruguay has enacted a number of sector policies that were driven by conservation or economic development objectives, which have already had significant climate change benefits: the Soil Management Law passed in 1982 has resulted in the sequestration of 1.8 million ton C/year over the last 20 years; the application of Forestry Promotion Policy of 1987, increased from about 200km^2 in 1987 to over 6,500 km^2 in 2000 and the cumulative net carbon sequestration during 1988 to 2000 was estimated at 27.4 Mt CO2 (Agrawala *et al.*, 2004).

13.5.1.3 Water resources

Water management policies in LA are the central point of the adaptation criteria to be established in order to strengthen the countries capacities to manage water resources under climate changing conditions. Principal actions for adaptation must include: improve and further develop legislation relating land use on floodplains, ensuring compliance with existing regulations of risk zones, floodplain use and building codes; re-evaluate the design and safety criteria of structural measures for water management; develop ground water protection and restoration plans to maintain water storage for dry seasons; public awareness campaigns to highlight the value of the rivers and wetlands as buffers against increased climate variability and improve participation of vulnerable groups in flood adaptation and mitigation programs, (Bergkamp *et al.,* 2003; IRDB, 2000).

Adaptation to drier conditions in 60% of the territory of LA would produce a great increase in the amounts of the investments in water supply systems, additionally to the 17.7 billion dollars necessary to accomplish the incorporation of 121 million persons to safe water systems, attaining the Millennium Declaration for Safe Water goals by 2015 (even leaving 10% of the population of LA without access to safe water) (IDB**,** 2004).

Transbasin diversions have been the solutions for water development in some regions of the world, particularly in California. In LA, transbasin transfers in Yacambú Basin (Venezuela), Catamayo-Chira basins (Ecuador, Peru), Alto Piura and Mantaro Basins (Peru), Sao Francisco River (Brazil) would be an option to mitigate the likely stress of water supply for the population, taking into account properly the environmental consequences and the hydrological restrictions (García Vargas, 2003; Marengo & Raigoza, 2006).

The use of urban and rural groundwater needs to be controlled and rationalised, taking into account the quality of distributions and trends identified in each region. To develop a sustainable groundwater and aquifer management the rules to comply would be: limit or reduce the consequences of excessive abstractions, slow down growth of abstractions, explore possibilities for artificial aquifer recharge and evaluate options for planned mining of groundwater storage (World Bank, 2002; IRDB, 2000).

13.5.1.4 Coasts

Assessments of coastal systems are very different. Most countries based their assessments on incremental scenarios (SLR 0.3 - 1.0 m), in some cases combined with coastal river flooding. Some of them included a cost-benefit analysis without and with measures (i.e., Ecuador, El Salvador, Costa Rica). Long-term and recent trends of SLR, flooding and storm surges are not always analyzed or available. Some other countries (i.e. Chile and Peru) prioritized their assessment on the impacts of ENSO events and increase in SST on fisheries. Most countries focus their adaptation on integrated coastal management (i.e., Colombia, Costa Rica, Venezuela, Uruguay and Argentina). Central

America and Mexico are implementing the project "Fomento de las capacidades para la 2da etapa de adaptación al cambio climático" (CATHALAC, 2003). Table 13.6 shows some examples of practices and options related with adaptations to climate change.

The current coastal environmental framework from LA countries should be an important support to implementing adaptation options to climate change. Most fishing countries have regulations governing access to their fishing grounds (i.e., Chile and Ecuador) and others have been including new legislation in order to control the uses of the coastal and fishing resources and to propose adaptation measures (i.e. Costa Rica, Guyana, Panama, Peru, Venezuela). A number of regional agreements have also been signed on the protection of the marine environment, the prevention of pollution from marine or terrestrial sources, and the management of commercial fisheries (CAPP, 2000; CIDEIBER, 1999; Sullivan and Bustamante, 1999; CIDAS, 2003). Brazil and Costa Rica ratified the UN Convention on the Law of the Sea (UNCLOS, 2005), relating to the conservation and management of straddling fish stocks and highly migratory fish stocks).

Coastal biodiversity could be maintained and even improved through sustainable use by promoting community management to make conservation part of sustainable development of coastal resources like mangroves and its artisanal fisheries. In this regard, Mexico, Ecuador, Guatemala, Brazil and Nicaragua promoted initiatives to develop the critical local community participation in the managed forest (Windevoxhel and Sención, 2002; Ubiratan-Moreira, 1999; Kovacs, 2000).

Table 13.6: *Adaptation Practices and Options in Latin American coasts: selected countries.*

Country/Study	Climate Scenario	Adaptation (practices and options)/costs
Ecuador (Ecuador, 2000)	LANM2 (+1.0 m)	Full protection against severe scenarios conditions: coastal defence of Guayas river basin at a cost less than 2 billion US$ and benefits two to three times greater; reforestation of mangroves and preservation of flooded areas to protect 1,204 km^2 and shrimp farms (the shrimp industry is the country’s third largest export item) against flooding.
Guyana (Guyana, 2002)	LANM2	Accretion development on low-lying coastal strip 77 km wide in the east and 26 km wide in the western Essequibo region
Colombia (Colombia, 2001)	SLR	Recovery and strength resiliency of natural systems in order to facilitate natural adaptation to SLR as well as a program of coastal zone management which emphasize on wetland preservation, areas prone to be flooded and those of high value.
Panamá (Panamá, 2000)	SRL	Autonomous and planned adaptation measures to protect the loss of beaches based mainly on soft engineering practices.
Peru (Peru, 2000)	ENSO, SST	Modern satellite observation systems of sea and continent similar to international programs TOGA and CLIVAR, and capacity building for at least 50 scientists in: Oceanic, atmospheric and hydrologic modelling and GIS´s systems.
Uruguay (Uruguay, 2004; Agrawala, 2004; Ramos *et a.l,* 2002).	SLR	Monitoring system in order to: track impacts on the coasts; restore degraded areas: develop an institutional framework for integrated coastal management (ICM); define setback regulations; improve local knowledge on beach nourishment; develop contingency plans against flooding; assess socioeconomic and environmental; stakeholders’ participation.
Argentina (Kokot, 2004; Menéndez, Ré & Kind, 2005).	SRL 2070	Flood risk maps for Buenos Aires based on SLR trends, storm surges records and a two-dimensional hydrodynamic model. These maps will be useful for early warning to extreme events.

13.5.1.5 Human health

The ideal defensive strategy would have multiple components. One would include improved surveillance systems that would promptly spot the emergency or resurgence of infectious diseases or the vectors that carry them. A second component would focus on predicting when climatological and other environmental conditions could become conducive to disease outbreaks so that the risks could be minimized (Epstein, 2001).

Colombia has reported that the epidemiological surveillance system will be strengthened in order to identify cases of malaria and dengue in susceptible areas (Poveda *et al.*, 1999). In Guyana a similar approach based on surveillance and data bases is being developed (National Task Force, 2001). Panama is improving its statistical information to be able to apply a pro-active system to forecast outbreaks (ANAM, 2000). Other recommended adaptation measures are chemical control to eliminate adult mosquitoes, environmental measures to prevent them from breeding; and clean-up campaigns organized with the aid of community organizations and health workers (Colombian Ministry of the Environment).

In Brazil, different institutions are planning to conduct a retrospective study of social-environmental vulnerability of the population when subject to extreme climatic events and to endemic diseases sensitive to climatic oscillations (Brazilian Ministry of Science and Technology, 2004).

Future analysis based on ecological niche modelling for disease vectors (e.g. chagas and dengue vectors) will be very useful to provide new potential for optimizing use of resources for disease prevention and remediation via automated forecasting of disease transmission rate (Costa *et al.*, 2002; Peterson *et al.*, 2005).

Regarding community involvement there is an experience in Buenos Aires, Argentina where public participation is strengthened so that security may start to be part of the daily life of the potentially affected people due to climate change (Murgida and Gasparotto, 2004; Murgida and González, 2005).

There is a need for more research to reduce the potential impacts of climate change on human health, including the development of improved methods for quantitative risk assessment, as there is no “safe limit” of climate change with respect to health impacts (Kovats *et al.*, 2005). Researchers must engage with the formulation, evaluation and economic costing of adaptive strategies using computer modelling and satellite technologies (McMichael *et al.*, 2006). It is therefore important that the health community further develops the ability to provide reasoned, responsible and policy-relevant advice on the health implications of long-term, wide-ranging global environmental trends, as well as clear and immediate priorities (Campbell-Lendrum, 2005).

LA should take advantage of international initiatives like the *Global Health Watch 2005*-2006. This is a collaboration of public health experts, non-governmental organizations, community groups, health workers and academics; the. Humanitarian Early Warning System (HEWS) that gives information for countries affected by food insecurity due to natural hazards, such as droughts or rainfalls for regions of the world. Evidence and anticipation of adverse health effects will strengthen the case for pre-emptive policies, and will also guide priorities for planned adaptive strategies (McMichael *et al.*, 2006).

13.5.2. Constraints

The impact of climate change in LA's productive sectors is estimated to be of a 1.3% reduction of the region's GDP for a change of 2C in global temperature (Mendelsohn *et al.*, 2000). If no structural changes in economic policy are made to promote investment, employment and productivity, economic and social future scenarios for the region do not hold the economic growth needed for its development, unless a uncommon combination of external positive shocks occur (ECLAC, 2003).

Lack of awareness, technical knowledge or appropriate monitoring, and difficulties in the dissemination of data and information are the main constrains in several sectors to adapt to current climate trends in Argentina (Barros, 2005) and in many other places (Ecuador, 2000).

Socio-economic and political factors (e.g. lack of credit and public investment in social and economic infrastructure in rural areas, and access to resources and information) could seriously reduce the capability to implement adaptive options in the agricultural sector, in particular for small farmers. For example, in dry zones of Mexico for small-holders who have rainfed crops or non efficient irrigation system, adaptation measures only involve incremental, low-input and short term investments that help "to get by" during periods of drought. Inversely, commercial farms can implement efficient irrigation systems and combine livestock with agriculture (Vasquez Leon *et al.*, 2003). Also, if small farmers believe that one crop is necessary for household food security, adaptation measures that emphasize the benefits of alternative crops are not likely to be widely adopted (Eakin, 2000).

The lack of public investment in infrastructure to face flooding or droughts in poor rural areas and the privatization of education and public health due to economic public policies in the Region would be a major barrier to decrease climate change impacts. In the majority of cases, current limitations which impede the deployment of early warning systems for landslides and El Niño are related to the poor understanding of the phenomena, which does not allow for precise forecasts, and the lack of resources to implement and operate them (Villagrán *et al.*, 2003).

Several LA countries have not identified clearly the different health effects due to climate change due to lack of awareness and information. In general, public health policies are focused on curative approaches rather than on preventive massive programmes and are not integrated to other socio-economic policies in order to be more effective in addressing climate change impacts. There is a lack of tools to address cross-cutting issues, ecologically complex, and long-term public health challenges (Patz *et al.*, 2000). For many countries, there is a lack of intersectorial work between the health sector and other sectors such as, the environment, water resources, agriculture, climatological/meteorological services.

The limited number of specialists working on climate change in coastal environments and the lack of sufficient research and cartographic information in many countries poses an important limitation to the adoption of adaptation measures (National communications). Institutional factors which inhibit co-ordination across multiple stakeholder groups -, particularly those related to the restoration of coastal areas vulnerable to sea level rise constitute another constraint (Agrawala *et al.*, 2004). Tourism and the overexploitation of fisheries are significant barriers for the successful implementation of adaptation options to climate change impacts. The lack of significant investment for coastal adaptations options in many degraded urban developments for residential and industrial purposes (60 of the 77 largest urban settlements from LA are on the coast, and 60 per cent of the regional population live within 100 km of the coast) GEO 3 (UNEP, 2002a) Environmental policies, laws and regulations in coastal areas have been conflictive in the implementation of adaptation options to climate change related-impacts UNEP (2002b), GEO-LAC (2003).

13.6 Case studies

Amazonia

The Amazon Basin contains the largest, contiguous extent of tropical forest on Earth, almost 5.8 million km^2. It harbours perhaps 20% of the planet's plant and animal species. There is abundance of water resources and the Amazon river accounts for 18% of the freshwater input to the global oceans. Over the past 30 years almost 600,000 km^2 have been deforested in Brazil alone (INPE, 2005) due to the rapid development of Amazonia, making the region one of 'hot-spots' of global environmental change in the planet. Field studies carried out over the last 20 years clearly showed local changes in the water, energy, carbon, and nutrient cycling, and in the atmospheric composition caused by deforestation, logging, forest fragmentation and biomass burning. The continuation of current trends show that over 30% of the forest may be gone by 2030 (Alencar *et al.*, 2004 and Soares-Filho *et al.*, 2006). In the last decade, research of the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) is uncovering novel features of the complex interaction of vegetated land surface and the atmosphere in many spatial and temporal scales. The LBA Experiment is producing new knowledge on the physical, chemical and biological functioning of Amazonia, its role for our planet and the impacts in that functioning due to changes in climate and land use (www.cptec.inpe.br/lba).

There are observational evidences of sub-regional changes in surface energy budget and boundary layer cloudiness and regional changes in the lower troposphere radiative transfer due to biomass burning aerosol loadings. Large number of cloud condensation nuclei (CCN) due to biomass burning has led to the speculation of their possible direct and indirect role in cloud formation and rainfall, possibly reducing dry season rainfall (e.g., Andreae *et al.*, 2004). During the rainy season, in contrast, there are very few amounts of CCN of biogenic origin and the Amazonian clouds show characteristics of oceanic clouds. Carbon cycle studies of the LBA Experiment indicate that the Amazonian undisturbed forest may be a sink of carbon of about 100 to 400 Mton C/year, roughly balancing CO_2 emissions due to deforestation, biomass burning, and forest fragmentation of about 300 Mton C/year (e.g., Ometto *et al.*, 2005). On the other hand, the effect of deforestation and forest fragmentation is increasing the susceptibility of the forest to fires (Nepstad *et al.* 2004).
Observational evidence of changes in the hydrological cycle due to land use change is inconclusive at present, though observations have shown reductions of streamflow and no change of rainfall for a large sub-basin, the Tocantins river basin (Costa *et al.*, 2003). Modelling studies of large-scale deforestation indicate a likely drier and warmer post-deforestation climate. Reductions of regional rainfall might lead to atmospheric teleconnections affecting the climate of remote regions (Werth and Avissar, 2002). In sum, deforestation may lead to regional climate changes that would lead to a 'savannization' of Amazonia (Oyama and Nobre, 2003; Hutyra *et al.*, 2005). That factor is likely to be greatly amplified by global warming. The synergistic combination of both regional and global changes may severely affect the functioning of Amazonian ecosystems, resulting in large biome changes with catastrophic species disappearance (Nobre *et al.*, 2004).

Adaptation of Altiplano's indigenous communities to climate change

Established in different regions of the American continent, the subsistence of indigenous groups was, as it is nowadays, based in the resources cropped under compatible climate conditions, as predominant in the surroundings of their settlements. In the highlands of South America, where the pre-Colombian civilizations developed, one of the critical limitations stemmed out from the irregular distribution of the water resources. This situation still persist on the Andean mountain slopes, the extensive Altiplano, and in many of its valleys and is the result of the variability of the atmospheric processes, already influenced by the greenhouse effect; the rapid runoff, and the variable soil coverage and edaphic conditions. The snowmelt from the many glaciers in the tropical Andes was, as still is today, a sure source of freshwater; however, the glacier ´s streams, running down within deep valleys, do no favor all regions, as shown by the paramo like high Andes ´ landscape.

Under such limitations, these civilizations developed the necessary capacity to adapt to those environmental conditions (Wright & Zegarra, 2000). Ancestral habits include a historical continuity of the local knowledge on a number of species which, being less vulnerable than other, develop under the existing climate conditions. A number of animal and plant species, on which they crop their foodstuff, medicines and even products for leisure is known (Gadgil *et al.*, 2002; Canziani & Mata, 2004). Nowadays, the GEF/STAP group, responsible for collecting information on the nutritional values, and pharmaceutical and medical applications of the different species used by ancient civilizations, is searching for such valuable information, either for direct use or biotechnology development.

To proceed with development in a sustainable manner, they wisely managed the environmental conditions and resources. This was particularly noticeable when dealing with the water issue. In this regard, a number of engineering activities were developed. They range from the basic and badly needed water supply for irrigation to the use of water to cut the stones for their buildings as well as for its utilization for religious and leisure purposes, either to simulate the roaring of the "jaguar", in the Chavin Culture, for worshiping purposes and, particularly, to frighten the incredulous peasants, or to produce water music or to cultivate flowers for their deities. All these activities, involving important adaptation measures have awaken the interest of engineers and other professionals, as depicted in papers and publications

The description of important actions, as the interconnection of river basins, the rainwater and snowmelt filtration and collection in large reservoirs, the irrigation procedures, exceeding the material work involve in their development. They also acquired the ability to foreseeing climate variations, as those from El Niño (Orlove *et al.*, 2000), enabling the appropriate organization of their agricultural activities. Summing up, they undertook important pioneering efforts to adapt to local conditions and define sustainable development paths.

To day, facing the vagaries of weather and climate, exacerbated by the greenhouse effect rising the Earth's surface temperature and changing the precipitation patterns and intensities, added to the rapid glaciers' retreat, it would be quite useful to redeem such adaptation and sustainability practices to teach the actual indigenous communities to defend their subsistence. The case study's lesson shall be complemented with the necessary governmental and private action to assist the new adaptation efforts with the required observation and monitoring of these changes.

Moreover, due to the observed rapid glaciers melting and the associated GLOFs, it is necessary to introduce the required watching and early alert services, to protect people and property and to adapt to the new climate system.

As a colophon to the case study, the ancestral indigenous knowledge (Gadgil *et al.*, 1993) should be complemented with appropriate use of the land regulations, under the new environmental conditions, so to ensure the subsistence of these groups. Also, action to protect the genetic local species ´s wealth and provide the grounds for biotechnological research should complement this action (Southgain & Clark, 1993). Examples, like the development of the long duration tomatoes, with genes provide by the International Potato Institute, in Lima, could bring new research on the valuable local species and, through the UNCBD, ensure royalties to support the communities and provide means for further research on the genotypes from these lands local biodiversity (Orlove *et al.*, 2000).

13.7 Implications for sustainable development

The concept of sustainable Development has evolved and now is linked to ideas of equality that have been reinforced by the potential impacts of climate change either when mitigating (reducing emissions) or when confronting increased costs for adaptation. One approach to deal with these issues is discussed by Gay and Estrada, (2001) that propose to use the Kyoto mechanisms to reduce the costs of confronting climate change in an equitable manner. Most of the countries of the LA region have adopted programs and projects on sustainable development, some of them to ministerial level. All the countries have signed the Climate Convention, the Biodiversity Convention and the Kyoto Protocol (GEO America Latina y el Caribe 2003).

In terms of sustainable development, after the Stockholm Conference in 1972 on the Human Environment, the first governmental agencies on the environment were established. The content of these laws is similar: national environmental policy, legal instruments to apply it and protection of certain natural resources (Brañes, 2001). The Earth Summit 1992 impulsed the creation of more ministries of the environment in the region which have been ratifying or approving international treaties, conventions or agreements dedicated to the environment (Morán, 1996).

Ministers of the Environment of LA and the Caribbean held within the framework of the Johannesburg Summit, the LA and Caribbean Initiative for Sustainable Development (ILAC) that was approved and included in the Summit's implementation plan. Its main objectives are to increase the use of renewable energy sources, increase natural protected areas and forest lands, improve management of watersheds and marine and coastal zones, adopt regulatory frameworks for access to genetic resources, implement plans and policies to reduce urban environmental vulnerability in the face of anthropogenic disasters and those caused by natural phenomena, including the formulation of a regional early warning system, advance in areas such as health, the eradication of poverty and equality and sustainability of production and consumption patterns.

The region's vulnerability to climate variability and extremes has been illustrated here and in the recent past. According to Swiss Re estimations, if no action is taken to slow down climate change, in the next decades climate related disasters could cost 300 billion dollars a year (CEPAL, 2002; Swiss Re, 2002).

The macroeconomic costs of the impacts of climate change are highly uncertain, but very likely have the potential to threaten development in several countries of the region. In this sense, adaptation to climate change is a priority for ensuring the long-term effectiveness of the investment in Sustainable Development.

Achieving widely agreed environmental and social goals, such as the UN's Millennium Development Goals or the goals contained in the Latin American and Caribbean Initiative for Sustainable

Development, requires urgent and coordinated actions.. If the countries in LA and the Caribbean continue to follow the business as usual scenario, the wealth of natural resources that have supported economic and socio-cultural development in the region will be further degraded, reducing the regional potential for growth. Urgent measures must also be taken to help bring environmental and social considerations from the margins to the decision-making and development (UNEP, 2002c).

13.8 Key uncertainties and investigation priorities

To look into the future climate we rely on models, but there is a lot of uncertainty in their results. The sources of uncertainty come from: i) the models themselves (i.e. parameterization of physical processes) and inherent chaos that compels to produce probability distribution functions; ii) the differences among models that produce different results even starting with the same boundary conditions; iii) differences about emission scenarios that translate in projections of future temperatures differing by many degrees (difference between the smallest value and the largest may amount to 300% by the year 2100).

Uncertainties in emission scenarios are generated by the many possible pathways for future development. These scenarios are highly aggregated and therefore ignorant of regional differences mainly in geographical and social aspects. This makes the process of downscaling to the region or country level almost an impossible proposition. Therefore there is the question of how compatible are the regional scenarios with their particular socio-economic and environmental aspirations with the global emission scenarios.

The spatial resolution of the climate models is still too large; they are unable to accommodate for processes smaller than the resolution and they do not reproduce with credibility phenomena that would be very important for the LA region like the ENSO. Therefore the uncertainty associated with the process of downscaling has to be added to the previous ones. Also, uncertainties related to changes in climatic variability and occurrence of extreme events are especially important in LA where unprecedented and continuous extreme events occurred during the last few years.

Uncertainties in climate predictions are translated to impacts studies in all sectors. For example, for the Amazonia region, percentage change in average annual runoff “2050´s” compared with 1961-1990 A2 scenarios shows values that vary from -30% up to +20%, depending on climate model (Arnell, 2004; Marengo et al, 2006).

In addition, there are other uncertainties inherent to each sector. For example the assessment of impacts of climate change on crop yields and food security is constrained by uncertainties related to: i) the direct effect of rising CO2 concentration on crop yields, mainly in soybean which is projected to continue expanding; ii) the lack of integrated assessments concerning crops, weeds, pest and diseases; iii) the likely impact of ozone on crop yields.

Recent discussions about the possibility of an abrupt climate change due to a perturbation (slowdown or even a complete stop) of the thermohaline circulation open a new theme for concern in the LA region where there are not studies about its possible effects. Another related problem is about possible surprises (even in a monotonously changing climate) that may arise for certain activities or sectors or ecologic systems when certain thresholds are surpassed and a negative feedback mechanism is triggered that can destroy the sector or the resource. Tropical forests and tropical glaciers are special candidates for surprises.

A recognized way to approach the problem of adaptation to climate change is to observe and document current adaptation and vulnerability to current climate variability, under the premise that climate change will impact ecosystems and society's sectors and activities through future variability. Important lessons can be learned from analyzing the current adaptation capacities to remediate deficiencies and propose future adaptation. In order to implement plans for future adaptation it is necessary to cover the gaps produced by the fact that there are: 1) very few integrated assessments; 2) few studies on the economic impacts of current and future climate variability and climate change; 3) few studies reviewed on the impacts of climate change on societies; 4) there is not a clear prioritization (order of importance under certain assumption) in the treatment of topics for the region as a whole.

Priorities

Priority should be given to the task of reducing uncertainties in the projections of the future. Priority should be given to the study of the impacts that different policy options in different sectors and activities would have in the future in terms of reducing vulnerability increasing adaptive capacity and mitigating the intensity of climatic impacts. The development of scenarios under policy measures and options would be very important to help in the decision process. These studies should include the estimated costs of climate with and without policies to help in the decisions to invest in the implementation of such measures.

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