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Latin America

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Executive summary

Climatic variability and extreme events have been severely affecting the Latin America region over recent years (high confidence).

Highly unusual extreme weather events were reported, such as intense Venezuelan rainfall (1999, 2005), flooding in the Argentinean Pampas (2000-2002), Amazon drought (2005), hail storms in Bolivia (2002) and the Great Buenos Aires area (2006), the unprecedented Hurricane Catarina in the South Atlantic (2004) and the record hurricane season of 2005 in the Caribbean Basin [13.2.2]. Historically, climate variability and extremes have had negative impacts on population; increasing mortality and morbidity in affected areas. Recent developments in meteorological forecasting techniques could improve the quality of information necessary for people's welfare and security. However, the lack of modern observation equipment, the urgent need for upper-air information, the low density of weather stations, the unreliability of their reports and the lack of monitoring of climate variables work together to undermine the quality of forecasts, with adverse effects on the public, lowering their appreciation of applied meteorological services as well as their trust in climate records. These shortcomings also affect hydrometeorological observing services, with a negative impact on the quality of early warnings and alert advisories (medium confidence). [13.2.5]

During the last decades important changes in precipitation and increases in temperature have been observed (high confidence).

Increases in rainfall in south-east Brazil, Paraguay, Uruguay, the Argentinean Pampas and some parts of Bolivia have had impacts on land use and crop yields, and have increased flood frequency and intensity. On the other hand, a declining trend in precipitation has been observed in southern Chile, south-west Argentina, southern Peru and western Central America. Increases in temperature of approximately 1°C in Mesoamerica and South America, and of 0.5°C in Brazil, were observed. As a consequence of temperature increases, the trend in glacier retreat reported in the Third Assessment Report is accelerating (very high confidence). This issue is critical in Bolivia, Peru, Colombia and Ecuador, where water availability has already been compromised either for consumption or for hydropower generation [13.2.4.1]. These problems with supply are expected to increase in the future, becoming chronic if no appropriate adaptation measures are planned and implemented. Over the next decades Andean inter-tropical glaciers are very likely to disappear, affecting water availability and hydropower generation (high confidence). [13.2.4.1]

Land-use changes have intensified the use of natural resources and exacerbated many of the processes of land degradation (high confidence).

Almost three-quarters of the drylands are moderately or severely affected by degradation processes. The combined effects of human action and climate change have brought about a continuous decline in natural land cover at very high rates (high confidence). In particular, rates of deforestation of tropical forests have increased during the last 5 years. There is evidence that biomass-burning aerosols may change regional temperature and precipitation in the southern part of Amazonia (medium confidence). Biomass burning also affects regional air quality, with implications for human health. Land-use and climate changes acting synergistically will increase vegetation fire risk substantially (high confidence). [13.2.3, 13.2.4.2]

The projected mean warming for Latin America to the end of the century, according to different climate models, ranges from 1 to 4°C for the SRES emissions scenario B2 and from 2 to 6°C for scenario A2 (medium confidence).

Most general circulation model (GCM) projections indicate rather larger (positive and negative) rainfall anomalies for the tropical portions of Latin America and smaller ones for extra-tropical South America. In addition, the frequency of occurrence of weather and climate extremes is likely to increase in the future; as is the frequency and intensity of hurricanes in the Caribbean Basin. [13.3.1.1, 13.3.1.2]

Under future climate change, there is a risk of significant species extinctions in many areas of tropical Latin America (high confidence).

Replacement of tropical forest by savannas is expected in eastern Amazonia and the tropical forests of central and southern Mexico, along with replacement of semi-arid vegetation by arid vegetation in parts of north-east Brazil and most of central and northern Mexico due to synergistic effects of both land-use and climate changes (medium confidence) [13.4.1]. By the 2050s, 50% of agricultural lands are very likely to be subjected to desertification and salinisation in some areas (high confidence) [13.4.2]. Seven out of the 25 most critical places with high endemic species concentrations are in Latin America and these areas are undergoing habitat loss. Biological reserves and ecological corridors have been either implemented or planned for the maintenance of biodiversity in natural ecosystems, and these can serve as adaptation measures to help protect ecosystems in the face of climate change. [13.2.5.1]

By the 2020s, the net increase in the number of people experiencing water stress due to climate change is likely to be between 7 and 77 million (medium confidence).

While, for the second half of the century, the potential water availability reduction and the increasing demand from an increasing regional population would increase these figures to between 60 and 150 million. [13.4.3]

Generalised reductions in rice yields by the 2020s, as well as increases in soybean yields, are possible when CO_2 effects are considered (medium confidence).

For other crops (wheat, maize), the projected response to climate change is more erratic, depending on the chosen scenario. If CO_2 effects are not considered, the number of additional people at risk of hunger under the A2 scenario is likely to reach 5, 26 and 85 million in 2020, 2050 and 2080, respectively (medium confidence). On the other hand, cattle and dairy productivity is expected to decline in response to increasing temperatures. [13.4.2]

The expected increases in sea-level rise (SLR), weather and climatic variability and extremes are very likely to affect coastal areas (high confidence).

During the last 10-20 years the rate of SLR has increased from 1 to 2-3 mm/yr in south-eastern South America [13.2.4.1]. In the future, adverse impacts would be observed on: (i) low-lying areas (e.g., in El Salvador, Guyana and the coast of Buenos Aires Province in Argentina), (ii) buildings and tourism (e.g., in Mexico and Uruguay); (iii) coastal morphology (e.g., in Peru); (iv) mangroves (e.g., in Brazil, Ecuador, Colombia and Venezuela); (v) availability of drinking water on the Pacific coast of Costa Rica, Ecuador and the Rio de la Plata estuary. In particular, sea-level rise is very likely to affect both Mesoamerican coral reefs (e.g., in Mexico, Belize and Panama) and the location of fish stocks in the south-east Pacific (e.g., in Peru and Chile). [13.4.4]

Future sustainable development plans should include adaptation strategies to enhance the integration of climate change into development policies (high confidence).

Some countries have made efforts to adapt, particularly through conservation of key ecosystems, early warning systems, risk management in agriculture, strategies for flood, drought and coastal management, and disease surveillance systems. However, the effectiveness of these efforts is outweighed by: a lack of basic information, observation and monitoring systems; lack of capacity-building and appropriate political, institutional and technological frameworks; low income; and settlements in vulnerable areas; among others [13.2]. Without improvements in these areas, the Latin America countries' sustainable development goals will be seriously compromised, adversely affecting, among other things, their ability to reach the Millennium Development Goals [13.5].

13.1 Summary of knowledge assessed in the Third Assessment Report

The principal findings in the Third Assessment Report (TAR) (IPCC, 2001) were as follows.

- In most of Latin America, there are no clear long-term tendencies in mean surface temperature. Nevertheless, for some areas in the region, there are some clear warming (Amazonia, north-western South America) and, in a few cases, cooling (Chile) trends.
- Precipitation trends suggest an increase in precipitation for some regions of the mid-latitude Americas, a decrease for some central regions in Latin America, and no clear trends for others. For instance, the positive trends seen in north-eastern Argentina, southern Brazil and north-western Mexico contrast with the negative trends observed in some parts of Central America (e.g., Nicaragua). Records suggest a positive trend for the past 200 years at higher elevations in north-western Argentina. In Amazonia, inter-decadal variability in the hydrological record (in both rainfall and streamflow) is more significant than any observed trend.
- El Niño-Southern Oscillation (ENSO) is the dominant mode of climate variability in Latin America and is the natural phenomenon with the largest socio-economic impacts.
- Glaciers in Latin America have receded dramatically in the past decades, and many of them have disappeared completely. The most affected sub-regions are the Peruvian Andes, southern Chile and Argentina up to latitude 25°S. Deglaciation may have contributed to observed negative trends in streamflows in that region.
- In Latin America many diseases are weather and climate-related through the outbreaks of vectors that develop in warm and humid environments, including malaria and dengue. Climate change could influence the frequency of outbreaks of these diseases by altering the variability associated with the main controlling phenomenon, i.e., El Niño (likely).
- Agriculture in Latin America is a very important economic activity representing about 10% of the gross domestic product (GDP) of the region. Studies in Argentina, Brazil, Chile, Mexico and Uruguay based on General Circulation Models (GCMs) and crop models project decreased yields for numerous crops (e.g., maize, wheat, barley, grapes) even when the direct effects of CO_2-fertilisation and implementation of moderate adaptation measures at the farm level are considered.
- Assessments of the potential impacts of climate change on natural ecosystems indicate that neotropical seasonally dry forest should be considered severely threatened in Mesoamerica. Global warming could expand the area suitable for tropical forests in South America southwards, but current land use makes 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. Sea-water intrusion would exacerbate socio-economic and health problems in these areas.
- The adaptive capacity of human systems in Latin America is low, particularly to extreme climate events, and vulnerability is high. Adaptation measures have the potential to reduce climate-related losses in agriculture and forestry but less ability to do so for biological diversity.

13.2 Current sensitivity/vulnerability

13.2.1 What is distinctive about the Latin America region?

Latin America 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 Inter-tropical Convergence Zone (ITCZ), and the South Atlantic Convergence Zone (SACZ) (Satyamurty et al., 1998).

The summer circulation in tropical and sub-tropical Latin America is dominated by the North America Monsoon System, which affects Mexico and parts of Central America, and the South America Monsoon System, which affects tropical and sub-tropical South America east of the Andes. These monsoon climates are closely interconnected with ocean-atmosphere interactions over the tropical and sub-tropical oceans. Low Level Jets in South America east (Marengo et al., 2004) and west (Poveda and Mesa, 2000) 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 concentrated in the convergence zones or by topography, leading to strong spatial and temporal rainfall contrasts, such as the expected sub-tropical arid regions of northern Mexico and Patagonia, the driest desert in the world in northern Chile, and a tropical semi-arid region of north-east Brazil located next to humid Amazonia and one of the wettest areas in the world in western Colombia. A remarkable ecogeographical zone is that of the South America's highlands (see case study in Box 13.2), located in the tropics and presenting paramo-like (neotropical Andean ecosystem, about 3,500 m above sea level) landscapes with deep valleys (yungas) holding important biodiversity, with a wealth of vegetal and animal species.

13.2.2 Weather and climate stresses

Over the past three decades, Latin America has been subjected to climate-related impacts of increased El Niño occurrences (Trenberth and Stepaniak, 2001). Two extremely intense episodes of the El Niño phenomenon (1982/83 and 1997/98) and other severe climate extremes (EPA, 2001; Vincent et al., 2005; Haylock et al., 2006) have happened during this period, contributing greatly to the heightened vulnerability of human systems to natural disasters (floods, droughts, landslides, etc.).

Since the TAR, several highly unusual extreme weather events have been reported, such as the Venezuelan intense precipitations of 1999 and 2005; the flooding in the Argentinean Pampas in 2000 and 2002; the Amazon drought of 2005; the unprecedented and destructive hail storms in Bolivia in 2002 and Buenos Aires in 2006; the unprecedented Hurricane Catarina in the South Atlantic in 2004; and the record hurricane season of 2005 in the Caribbean Basin. The occurrence of climate-related disasters increased by 2.4 times between the periods 1970-1999 and 2000-2005 continuing the trend observed during the 1990s. Only 19% of the events between 2000 and 2005 have been economically quantified, representing losses of nearly US$20 billion (Nagy et al., 2006a). Table 13.1 shows some of the most important recent events.

In addition to weather and climate, the main drivers of increased vulnerability are demographic pressure, unregulated urban growth, poverty and rural migration, low investment in infrastructure and services, and problems with inter-sectoral co-ordination. The poorest communities are among the most vulnerable to extreme events (UNEP, 2003a), and some of these vulnerabilities are caused by their location in the path of hurricanes (about 8.4 million people in Central America; FAO, 2004a), on unstable lands, in precarious settlements, on low-lying areas, and in places prone to flooding from rivers (BID, 2000; UNEP, 2003a).

Table 13.1. *Selected extreme events and their impacts (period 2004-2006).*

Event/Date	Country/Impacts
Hurricane (H.) Beta Nov. 2005	Nicaragua: 4 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 US$1,881 million. 95% of the tourist infrastructure seriously damaged.
H. Stan Oct. 2005	Guatemala, Mexico, El Salvador, Nicaragua, Costa Rica: losses of US$3,000 million, more than 1,500 deaths. Guatemala was the most affected country, accounting for 80% of the casualties and more than 60% of the infrastructure damage (Fundación DESC, 2005).
Extra-tropical cyclone Aug. 2005	Southern Uruguay: extra-tropical cyclone (winds up to 187 km/h, and storm surge), 100,000 people affected, more than 100 people injured and 10 people dead, 20,000 houses without electricity, telephone and/or water supply (NOAA, 2005; Bidegain et al., 2006).
H. Emily Jul. 2005	Mexico – Cozumel and Quintana Roo: losses of US$837 million. Tourism losses: US$100 million; dunes and coral reefs affected; loss of 1,506 turtle nests; 1-4 m storm surges (CENAPRED-CEPAL, 2005).
Heavy rains Sep. 2005	Colombia: 70 deaths, 86 injured, 6 disappeared and 140,000 flood victims (NOAA, 2005).
Heavy rains Feb. 2005	Venezuela: heavy precipitation (mainly on central coast and in Andean mountains), severe floods and heavy landslides. Losses of US$52 million; 63 deaths and 175,000 injuries (UCV, 2005; DNPC, 2005/06).
H. Catarina Mar. 2004	Brazil: the first hurricane ever observed in the South Atlantic (Pezza and Simmonds, 2005); demolished over 3,000 houses in southern Brazil (Cunha et al., 2004); severe flooding hit eastern Amazonia, affecting tens of thousands of people (http://www.cptec.inpe.br/).
Droughts 2004-2006	Argentina – Chaco: losses estimated at US$360 million; 120,000 cattle lost, 10,000 evacuees in 2004 (SRA, 2005). Also in Bolivia and Paraguay: 2004/05. Brazil-Amazonia: severe drought affected central and south-western Amazonia, probably associated with warm sea surface temperatures in the tropical North Atlantic (http://www.cptec.inpe.br/). Brazil – Rio Grande do Sul: reductions of 65% and 56% in soybean and maize production (http://www.ibge.gov.br/home/).

Natural ecosystems

Tropical forests of Latin America, particularly those of Amazonia, are increasingly susceptible to fire occurrences due to increased El Niño-related droughts and to land-use change (deforestation, selective logging and forest fragmentation) (see Box 13.1; Fearnside, 2001; Nepstad et al., 2002; Cochrane, 2003). During the 2001 ENSO period, approximately one-third of the 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 understorey fire (Jipp et al., 1998; Nepstad et al., 2002, 2004). Mangrove forests located in low-lying coastal areas are particularly vulnerable to sea-level rise, increased mean temperatures, and hurricane frequency and intensity (Cahoon and Hensel, 2002; Schaeffer-Novelli et al., 2002), especially those of Mexico, Central America and Caribbean continental regions (Kovacs, 2000; Meagan et al., 2003). Moreover, floods accelerate changes in mangrove areas and at their landward interface (Conde, 2001; Medina et al., 2001; Villamizar, 2004). In relation to biodiversity, populations of toads and frogs are affected in cloud forests after years of low precipitation (Pounds et al., 1999; Ron et al., 2003; Burrowes et al., 2004). In Central and South America, links between higher temperatures and frog extinctions caused by a skin disease (*Batrachochytrium dendrobatidis*) were found (Dey, 2006).

Agriculture

The impact of ENSO-related climate variability on the agricultural sector was well documented in the TAR (IPCC, 2001). More 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 on the northern coast of Peru during El Niño because of increases in temperature (Torres et al., 2001); increases in the incidence of plant diseases such as '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 beans in Peru (Torres et al., 2001) during El Niño events, due to high rainfall and humidity. In relation to other sources of climatic variability, anomalies in South Atlantic sea-surface temperatures (SST) were significantly related to crop-yield variations in the Pampas region of Argentina (Travasso et al., 2003a, b). Moreover, heatwaves in central Argentina have led to reductions in milk production in Holando argentino (Argentine Holstein) dairy cattle, and the animals were not able to completely recover after these events (Valtorta et al., 2004).

Water resources

In global terms, Latin America is recognised as a region with large freshwater resources. However, the irregular temporal and spatial distribution of these resources affects their availability and quality in different regions. Stress on water availability and quality has been documented where lower precipitation and/or higher temperatures occur. For example, droughts related to La Niña create severe restrictions for water supply and irrigation demands in central western Argentina and central Chile between 25°S and 40°S (NC-Chile, 1999; Maza et al., 2001). 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., 1998), whereas extreme floods are enhanced during La Niña (Waylen and Poveda, 2002). In addition, the Magdalena river basin also shows high vulnerability (55% losses in mean flow; IDEAM, 2004). Consequently, soil moisture and vegetation activity are strongly reduced/augmented by El Niño/La Niña in Colombia (Poveda et al., 2001a). The vulnerability to flooding events is high in almost 70% of the area represented by Latin American countries (UNEP, 2003c). Hydropower is the main electrical energy source for most countries in Latin America, and 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, 2004), Chile (NC-Chile, 1999), Brazil, Uruguay and Argentina (Kane, 2002). A combination of increased energy demand and drought caused a virtual breakdown in hydroelectricity generation in most of Brazil in 2001, which contributed to a GDP reduction of 1.5% (Kane, 2002).

Coasts

Low-lying coasts in several Latin American countries (e.g., parts of Argentina, Belize, Colombia, Costa Rica, Ecuador, Guyana, Mexico, Panama, El Salvador, Uruguay and Venezuela) and large cities (e.g., Buenos Aires, Rio de Janeiro and Recife) are among the most vulnerable to climate variability and extreme hydrometeorological events such as rain and windstorms, and sub-tropical and tropical cyclones (i.e., hurricanes) and their associated storm surges (Tables 13.1 and 13.2). Sea-level rise (within the range 10-20 cm/century) is not yet a major problem, but evidence of an acceleration of sea-level rise (SLR) rates (up to 2-3 mm/yr) over the past decade suggests an increase in the vulnerability of low-lying coasts, which are already subjected to increasing storm surges (Grasses et al., 2000; Kokot, 2004; Kokot et al., 2004; Miller, 2004; Barros, 2005; Nagy et al., 2005; UCC, 2005). Moreover, some coastal areas are affected by the combined effects of heavy precipitation, landward winds and SLR (for example, 'sudestadas' in the La Plata river estuary), as already observed in the city of Buenos Aires (EPA, 2001; Bischoff, 2005).

Human health

After the onset of El Niño (dry/hot) there is a risk of epidemic malaria in coastal regions of Colombia and Venezuela (Poveda et al., 2001b; Kovats et al., 2003). Droughts favour the development of epidemics in Colombia and Guyana, while flooding engenders epidemics in the dry northern coastal region of Peru (Gagnon et al., 2002). Annual variations in dengue/dengue haemorrhagic fever in Honduras and Nicaragua appear to be related to climate-driven fluctuations in the vector densities (temperature, humidity, solar radiation and rainfall) (Patz et al., 2005). In some coastal areas of the Gulf of Mexico, an increase in SST, minimum temperature and precipitation was associated with an increase in dengue transmission cycles (Hurtado-Díaz et al., 2006). Outbreaks of hantavirus pulmonary syndrome have been reported for Argentina, Bolivia, Chile, Paraguay, Panama and Brazil after prolonged droughts (Williams et al., 1997; Espinoza et al., 1998; Pini et al., 1998; CDC, 2000), probably due to the intense rainfall and flooding following the droughts, which increases food availability for peri-domestic (living both indoors and outdoors) rodents (see Chapter 8, Section 8.2.8). Prolonged droughts in semi-arid north-eastern Brazil have provoked rural-urban migration of subsistence farmers, and a re-emergence of visceral leishmaniasis (Confalonieri, 2003). A significant increase in visceral leishmaniasis in Bahia State (Brazil) after the El Niño years of 1989 and 1995 has also been reported (Franke et al., 2002). In Venezuela, an increase in cutaneous leishmaniasis was associated with a weak La Niña (Cabaniel et al., 2005). Flooding produces outbreaks of leptospirosis in Brazil, particularly in densely populated areas without adequate drainage (Ko et al., 1999; Kupek et al., 2000; Chapter 8, Section 8.2.8). In Peru, El Niño has been associated with some dermatological diseases, related to an increase in summer temperature (Bravo and Bravo, 2001); hyperthermia with no infectious cause has also been related to heatwaves (Miranda et al., 2003), and SST has been associated with the incidence of Carrion's disease (*Bartonella bacilliformis*) (Huarcaya 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). In São Paulo, Brazil, Gouveia et al. (2003) reported an increase of 2.6% in all-cause morbidity in the elderly per °C increase in temperature above 20°C, and a 5.5% increase per ºC drop in temperature below 20°C (see Chapter 8).

13.2.3 Non-climatic stresses

Effects of demographic pressure

Migration to urban areas in the region exceeds absorption capacity, resulting in widespread unemployment, overcrowding, and the spread of infectious diseases including HIV/AIDS, due to lack of adequate infrastructure and urban planning (UNEP, 2003b). Latin America is the most urbanised region in the developing world (75% of its population). The most urbanised countries are Argentina, Brazil, Chile, Uruguay and Venezuela, while the least urbanised are Guatemala and Honduras (UNCHS, 2001). As a consequence, the regional population faces both traditional (infectious and transmissible diseases) and modern risks (chronic and degenerative diseases) in addition to those related to urban landslides and floods. Modern risks result from urbanisation and industrialisation, while poor and rural populations still suffer from 'traditional risks'. There is a significant problem of urban poverty in areas where malnutrition, poor water quality and a lack of sewage/sanitary services and education prevail. However, the line between urban and rural in many parts of the region is becoming increasingly blurred, particularly around large urban areas.

A strong reduction in employment rates, with the associated downgrading of the social situation, observed in Latin America in the 1990s (poverty affecting 48.3% and extreme poverty 22.5% of the population), has generated large-scale migration to urban areas. Although this migration trend continues, the Economic Commission for Latin America and the Caribbean (ECLAC) reports that, in spite of the fact that the region is on track to meet the Millenium Development Goals' (MDGs) extreme poverty goal (to halve the number of people living on less than $1/day by 2015), the year 2006 would show a reduction to 38.5% and 14.7% of the above poverty indices (La Nación, 2006).

Over-exploitation of natural resources

It is well established that over-exploitation is a threat to 34 out of 51 local production systems of particular importance to artisanal fishing along the coastal waters in Latin America (UNEP, 2003b; FAO, 2006) and has caused the destruction of habitats such as mangroves, estuaries and salt marshes in Central America and Mexico (Cocos in Costa Rica, Tortuguero-Miskitos Islands in Nicaragua and the Gulf of Mexico in Mexico) (Mahon, 2002; NOAA/OAR, 2004).

Urbanisation (without a land planning or legal framework in most of the countries), large aquaculture developments, the expansion of ecotourism and the oil industry, the accidental capture of ecologically important species, the introduction of exotic species, land-based sources of coastal and marine pollution, the depletion of coral reefs and the mismanagement of water resources impose increasing environmental pressures on natural resources (Young, 2001; Viddi and Ribeiro, 2004).

The rapidly expanding tourism industry is driving much of the transformation of natural coastal areas, paving the way for resorts, marinas and golf courses (WWF, 2004). Aquifer over-exploitation and mismanagement of irrigation systems are causing severe environmental problems; e.g., salinisation of soil and water in Argentina (where more than 500,000 ha of the phreatic (i.e., permanently-saturated) aquifer shows high levels of salinity and nitrates) (IRDB, 2000) and sanitation problems in a great number of cities such as Mexico City, San José de Costa Rica, and Trelew, Río Cuarto and La Plata in Argentina. In Belize City, a system of mangrove-lined ponds and mangrove-wetland drainage areas has served as a natural sewage treatment facility for much of the city's waste water. Recently, dredging for a massive port expansion has resulted in the destruction of more mangroves and the free ecosystem services they provided (WWF, 2004).

Pollution

Pollution of natural resources, such as natural arsenic contamination of freshwater, affects almost 2 million people in Argentina, 450,000 in Chile, 400,000 in Mexico, 250,000 in Peru and 20,000 in Bolivia (Canziani, 2003; Pearce, 2003; Clark and King, 2004). Another insidious contamination widespread in the region is produced by fluorine. In the Puyango river basin (Ecuador), suspended sediments and metal contamination increase significantly during ENSO events (Tarras-Wahlberg and Lane, 2003). In the upper Pilcomayo basin, south-east Bolivia, pollution by heavy metals from mining operations in Potosí affects the migration and fishing of sábalo (*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 (which covered more than one-third of the urban district), 60,000 tonnes of solid waste were disseminated all over the city of Santa Fe; 135 cases of hepatitis, 116 of leptospirosis and 5,000 of lung disease were officially reported as a result (Bordón, 2003).

Air pollution due to the burning of fossil fuels is a problem that affects many cities of Latin America. Transport is the main contributor (e.g., in Mexico City, Santiago de Chile and São Paulo). Thermoelectric energy generation is the second primary source of air pollution in Lima, Quito and La Paz (PAHO, 2005). Climate and geography play a significant role in this situation; e.g., the occurrence of thermal inversions, such as in Mexico City, Lima and Santiago de Chile. In Mexico City, surface ozone has been linked to increased hospital admissions for lower respiratory infections and asthma in children (Romieu et al., 1996). Regarding exposure effects to biomass particles, Cardoso de Mendonça et al. (2004) have estimated that the economic costs of fire in the Amazon affecting human health increased from US$3.4 million in 1996 to US$10.7 million in 1999.

13.2.4 Past and current trends

13.2.4.1 Climate trends

During the 20th century, significant increases in precipitation were observed in southern Brazil, Paraguay, Uruguay, north-east Argentina and north-west Peru and Ecuador. Conversely, a declining trend in precipitation was observed in southern Chile, south-west Argentina and southern Peru (Figure 13.1, Table 13.2). In addition, increases in the rate of sea-level rise have reached 2-3 mm/yr during the last 10-20 years in south-eastern South America (Table 13.2).

A number of regional studies have been completed for southern South America (Vincent et al., 2005; Alexander et al., 2006; Haylock et al., 2006; Marengo and Camargo, 2007), Central America and northern South America (Poveda et al., 2001a; Aguilar et al., 2005; Alexander et al., 2006). They all show patterns of changes in extremes consistent with a general warming, especially positive trends for warm nights and negative trends for the occurrence of cold nights. There is also a positive tendency for intense rainfall events and consecutive dry days. A study by Groisman et al. (2005) identified positive linear trends in the frequency of very heavy rains over north-east Brazil and 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 extreme events in regions such as Amazonia. Chapter 3, Section 3.8 of the Working Group I Fourth Assessment Report (Trenberth et al., 2007) discusses observational aspects of variability of extreme events and tropical cyclones. Chapter 11, Section 11.6 of the Working Group I Fourth Assessment Report (Christensen et al., 2007) acknowledges that little research is available on extremes of temperature and precipitation for this region.

These changes in climate are already affecting several sectors. Some reported impacts associated with heavy precipitation are: 10% increase in flood frequency due to increased annual discharge in the Amazon River at Obidos (Callède et al., 2004); increases of up to 50% in streamflow in the rivers Uruguay, Paraná and Paraguay (Bidegain et al., 2005; Camilloni, 2005b); floods in the Mamore basin in Bolivian Amazonia (Ronchail et al., 2005); and increases in morbidity and mortality due to flooding, landslides and storms in Bolivia (NC-Bolivia, 2000). In addition, positive impacts were reported for the Argentinean 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 productivity increased by 7% in Argentina and Uruguay (Gimenez, 2006).

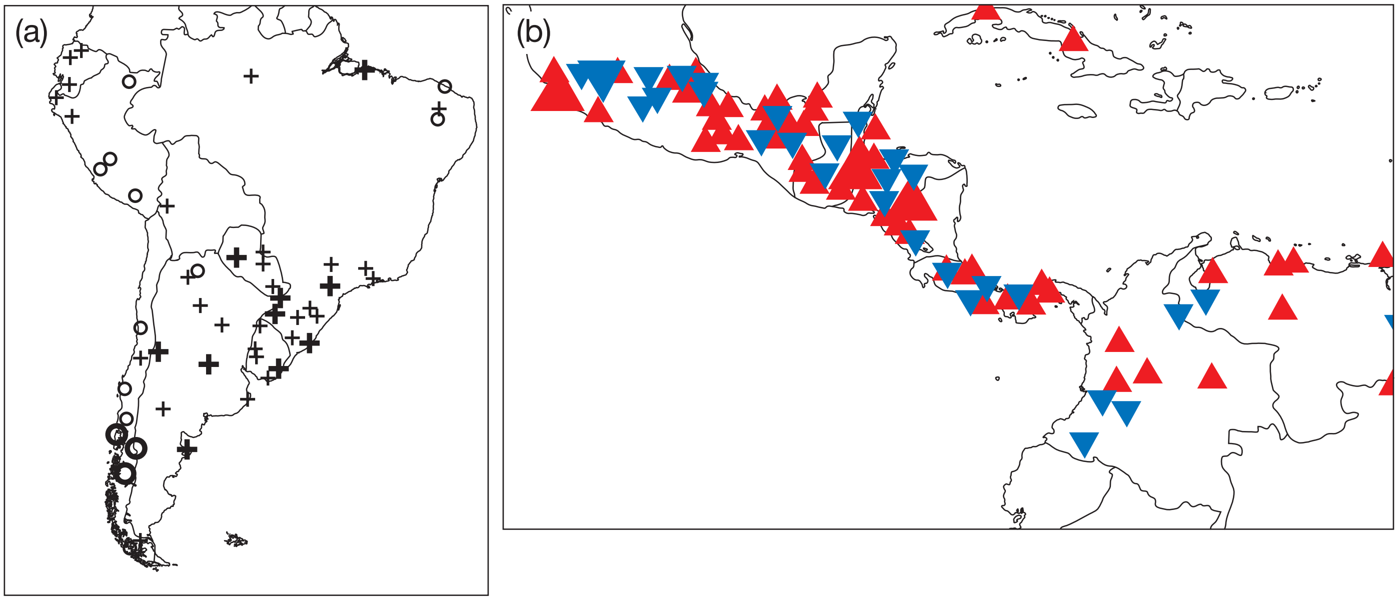

Figure 13.1. *Trends in rainfall in (a) South America (1960-2000). An increase is shown by a plus sign, a decrease by a circle. Bold values indicate significance at P ≤ 0.05. Haylock et al. (2006); reprinted with permission from the American Meteorological Society. (b) Central America and northern South America (1961-2003). Large red triangles indicate positive significant trends, small red triangles indicate positive non-significant trends, large blue triangles indicate negative significant trends, and small blue triangles indicate negative non-significant trends. Aguilar et al. (2005); reprinted with permission from the American Geophysical Union.*

Table 13.2. *Current climatic trends.*

Precipitation (change shown in % unless otherwise indicated)	Period	Change
Amazonia – northern/southern (Marengo, 2004)	1949-1999	–11 to –17/–23 to +18
Bolivian Amazonia (Ronchail et al., 2005)	since 1970	+15
Argentina – central and north-east (Penalba and Vargas, 2004)	1900-2000	+1 STD to +2 STD
Uruguay (Bidegain et al., 2005)	1961-2002	+ 20
Chile – central (Camilloni, 2005a)	last 50 years	–50
Colombia (Pabón, 2003a)	1961-1990	–4 to +6
Mean temperature (°C/10 years)		
Amazonia (Marengo, 2003)	1901-2001	+0.08
Uruguay, Montevideo (Bidegain et al., 2005)	1900-2000	+0.08
Ecuador (NC-Ecuador, 2000)	1930-1990	+0.08 to +0.27
Colombia (Pabón, 2003a)	1961-1990	+0.1 to +0.2
Maximum temperature (°C/10 years)		
Brazil – south (Marengo and Camargo, 2007)	1960-2000	+0.39 to +0.62
Argentina – central (Rusticucci and Barrucand, 2004)	1959-1998	–0.2 to –0.8 (DJF)
Argentina – Patagonia (Rusticucci and Barrucand, 2004)	1959-1998	+0.2 to +0.4 (DJF)
Minimum temperature (ºC/10 years)		
Brazil – south (Marengo and Camargo, 2007)	1960-2000	+0.51 to +0.82
Brazil – Campinas and Sete Lagoas (Pinto et al., 2002)	1890-2000	+0.2
Brazil – Pelotas (Pinto et al., 2002)	1890-2000	+0.08
Argentina (Rusticucci and Barrucand, 2004)	1959-1998	+0.2 to +0.8 (DJF/JJA)
Sea-level rise (mm/yr)		
Guyana (NC-Guyana, 2002)	last century	+1.0 to +2.4
Uruguay, Montevideo (Nagy et al., 2005)	last 100/30/15 years	+1.0 / +2.5 / +4.0
Argentina, Buenos Aires (Barros, 2003)	last ~100 years	+1.7
Brazil – several ports (Mesquita, 2000)	1960-2000	+4.0
Panama – Caribbean coast (NC-Panama, 2000)	1909-1984	+1.3
Colombia (Pabón, 2003b)	1961-1990	+1 to +3

STD= standard deviation, DJF= December/January/February, JJA= June/July/August.

The glacier-retreat trend reported in the TAR has intensified, reaching critical conditions in Bolivia, Peru, Colombia and Ecuador (Table 13.3). Recent studies indicate that most of the South American glaciers from Colombia to Chile and Argentina (up to 25°S) are drastically reducing their volume at an accelerated rate (Mark and Seltzer, 2003; Leiva, 2006). Changes in temperature and humidity are the primary cause of the observed glacier retreat during the second half of the 20th century in the tropical Andes (Vuille et al., 2003). During the next 15 years, inter-tropical glaciers are very likely to disappear, affecting water availability and hydropower generation (Ramírez et al., 2001).

Table 13.3. *Glacier retreat trends.*

Glaciers/Period	Changes/Impacts
Peru[a, b] Last 35 years	22% reduction in glacier total area; reduction of 12% in freshwater in the coastal zone (where 60% of the country's population live). Estimated water loss almost 7,000 Mm^3
Peru[c] Last 30 years	Reduction up to 80% of glacier surface from small ranges; loss of 188 Mm^3 in water reserves during the last 50 years.
Colombia[d] 1990-2000	82% reduction in glaciers, showing a linear withdrawal of the ice of 10-15 m/yr; under the current climate trends, Colombia's glaciers will disappear completely within the next 100 years.
Ecuador[e] 1956-1998	There has been a gradual decline glacier length; reduction of water supply for irrigation, clean water supply for the city of Quito, and hydropower generation for the cities of La Paz and Lima.
Bolivia[f] Since mid-1990s	Chacaltaya glacier has lost half of its surface and two-thirds of its volume and could disappear by 2010. Total loss of tourism and skiing.
Bolivia[f] Since 1991	Zongo glacier has lost 9.4% of its surface area and could disappear by 2045-2050; serious problems in agriculture, sustainability of 'bofedales'[1] and impacts in terms of socio-economics for the rural populations.
Bolivia[f] Since 1940	Charquini glacier has lost 47.4% of its surface area.

[a] Vásquez, 2004; [b] Mark and Seltzer, 2003; [c] NC-Perú, 2001; [d] NC-Colombia, 2001; [e] NC-Ecuador, 2000; [f] Francou et al., 2003.

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[1] Bofedales: wetlands and humid areas of the Andean high plateaux.

13.2.4.2 Environmental trends

Deforestation and changes in land use

In 1990, the total forest area in Latin America was 1,011 Mha, which has reduced by 46.7 Mha in the 10 years from 1990 to 2000 (UNEP, 2003a) (Figure 13.2). In Amazonia, the total area of forest lost rose by 17.2 Mha from 41.5 Mha in 1990 to 58.7 Mha in 2000 (Kaimowitz et al., 2004). The expansion of the agricultural frontier and livestock, selective logging, financing of large-scale projects such as the construction of dams for energy generation, illegal crops, the construction of roads and increased links to commercial markets have been the main causes of deforestation (FAO, 2001a; Laurance et al., 2001; Geist and Lambin, 2002; Asner et al., 2005; FAO, 2005; Colombia Trade News, 2006).

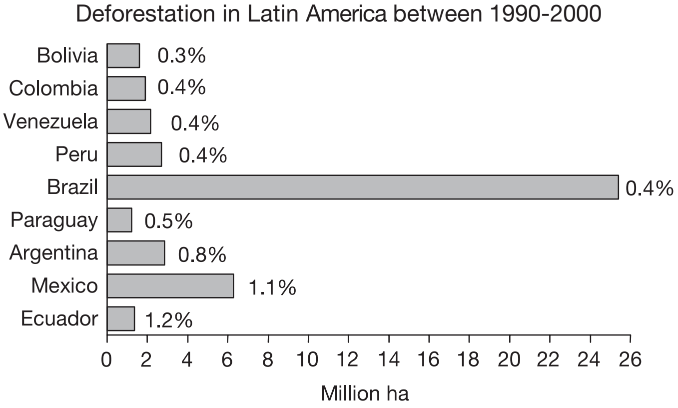

Figure 13.2. *Total deforestation in Latin America (Mha) between 1990 and 2000. Number indicates deforestation rate (%/yr) for each country. Based on FAO (2001a).*

Natural land cover has continued to decline at very high rates. In particular, rates of deforestation of tropical forests have increased during the last five years. Annual deforestation in Brazilian Amazonia increased by 32% between 1996 and 2000 (1.68 Mha) and 2001 and 2005 (2.23 Mha). However, the annual rate of deforestation decreased from 2.61 Mha in 2004 to 1.89 Mha in 2005 (INPE-MMA, 2005a, b, c). An area of over 60 Mha has been deforested in Brazilian Amazonia due to road construction and subsequent new urban settlements (Alves, 2002; Laurance et al., 2005). There is evidence that aerosols from biomass burning may change regional temperature and precipitation south of Amazonia (Andreae et al., 2004) and in neighbouring countries, including the Pampas as far south as Bahía Blanca (Trosnikov and Nobre, 1998; Mielnicki et al., 2005), with related health implications (increases in mortality risk, restricted activity days and acute respiratory symptoms) (WHO/UNEP/WMO, 2000; Betkowski, 2006).

The soybean cropping boom has exacerbated deforestation in Argentina, Bolivia, Brazil and Paraguay (Fearnside, 2001; Maarten Dros, 2004). This critical land-use change will enhance aridity/desertification in many of the already water-stressed regions in South America. Major economic interests not only affect the landscape but also modify the water cycle and the climate of the region, in which almost three-quarters of the drylands 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).

Biodiversity

Changes in land use have led to habitat fragmentation and biodiversity loss. Climate change will increase the actual extinction rate, which is documented in the Red List of Endangered Species (IUCN, 2001). The majority of the endangered eco-regions are located in the northern and mid-Andes valleys and plateaux, the tropical Andes, in areas of cloud forest (e.g., in Central America), in the South American steppes, and in the Cerrado and other dry forests located in the south of the Amazon Basin (Dinerstein et al., 1995; UNEP, 2003a) (see Figure 13.5). Among the species to disappear are Costa Rica's golden toad (*Bufo periglenes*) and harlequin frog (*Atelopus* spp.) (Shatwell, 2006). In addition, at least four species of Brazilian anurans (frogs and toads) have declined as a result of habitat alteration (Eterovick et al., 2005), and two species of *Atelopus* have disappeared following deforestation (La Marca and Reinthaler, 2005). Deforestation and forest degradation through forest fires, selective logging, hunting, edge effects and forest fragmentation are the dominant transformations that threaten biodiversity in South America (Fearnside, 2001; Peres and Lake, 2003; Asner et al., 2005).

Coral reefs and mangroves

Panama and Belize Caribbean case studies illustrate, in terms of inter-ocean contrasts, both the similarities and differences 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 and Precht, 2002). Dust transported from Africa to America (Shinn et al., 2000), and land-derived flood plumes from major storms, can transport materials from the Central American mainland to reefs, which are normally considered remote from such influences, as potential sources of pathogens, nutrients and contaminants. Human involvement has also been a factor in the spread of the pathogen that killed the Caribbean *Diadema*; the disease began in Panama, suggesting a possible link to shipping through the Panama Canal (Andréfouët et al., 2002). Since 1980 about 20% of the world's mangrove forests have disappeared (FAO, 2006), affecting fishing. In the Mesoamerican reef there are up to 25 times more fish of some species on reefs close to mangrove areas than in areas where mangroves have been destroyed (WWF, 2004).

13.2.4.3 Trends in socio-economic factors

From 1950 to the end of the 1970s Latin America benefited from an average annual GDP growth of 5% (Escaith, 2003). This remarkable growth rate permitted the development of national industries, urbanisation, 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 of imposing barriers to imports and developing national industry to produce what was needed. Nevertheless, this model produced a weak industry that was not able to compete in international markets and this had terrible consequences for the other sectors (agriculture in particular) which funded the industrial development.

In the 1980s the region faced a great debt crisis which forced countries to make efforts to implement rigorous macroeconomic measures regarding public finances in order to liberate the economy. Control of inflation and public deficit became the main targets of most governments. Deterioration of economic and social conditions, unemployment, extension of the informal economy and poverty characterised this decade. In most of Latin America, the results of economic liberalisation can be characterised by substantial heterogeneity and volatility in long-term growth, and modest (or even negative) economic growth (Solimano and Soto, 2005).

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

In Latin America the wealthiest 10% of the population own between 40% and 47% of the national income while the poorest 20% have only 2-4%. This type of income distribution is comparable only to some African and ex-USSR countries (Ferroni, 2005). The lack of equity in education, health services, justice and access to credit can restrain economic development, reduce investment and allow poverty to persist. A study conducted by CEPAL (2002) concludes that the likelihood of the poorest Latin American countries reaching the 7% GDP growth they need is almost zero in the medium term. Even the wealthier countries in the region will find it hard to reach a 4.1% GDP growth target. Predictions for GDP growth in the region for 2015 range from 2.1% to 3.8%, which is very far from the 5.7% average estimated as necessary 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 large in order to cause great social damage (UNDP-GEF, 2003). The effects of climate change on national economies and official development assistance have not been considered in most vulnerability assessments. The impact of climate change in Latin America's productive sectors is estimated to be a 1.3% reduction in the region's GDP for an increase of 2°C in global temperature (Mendelsohn et al., 2000). However, this impact is likely to be even greater because this estimation does not include non-market sectors and extreme events (Stern, 2007). 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 an uncommon combination of external positive shocks occurs (Escaith, 2003).

13.2.5 Current adaptation

Weather and climate variability forecast

The mega 1982/83 El Niño set in motion an international effort (the Tropical Ocean-Global Atmosphere (TOGA) programme) 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 Latin America. These climate forecasts became even more reliable with the use of TOGA observations of the Upper Tropical Pacific from the mid-1990s, although they still lack the ability to correctly predict the onset of some El Niño and La Niña events (Kerr, 2003). Nowadays such forecasting systems are based on the use of coupled atmospheric-ocean models and have lead times of 3 months to more than 1 year. Such climate forecasts have given rise to a number of applications and have been in use in a number of sectors: starting in the late 1980s for fisheries in the Eastern Pacific and crops in Peru (Lagos, 2001), subsistence agriculture in north-east Brazil (Orlove et al., 1999), prevention of vegetation fires in tropical South America (Nepstad et al., 2004; http://www.cptec.inpe.br/), streamflow prediction for hydropower in the Uruguay river (Tucci et al., 2003; Collischonn et al., 2005), fisheries in the south-western Atlantic (Severov et al., 2004), dengue epidemics in Brazil (IRI, 2002), malaria control (Ruiz et al., 2006) and hydropower generation in Colombia (Poveda et al., 2003).

Agriculture is a key sector for the potential use of ENSO-based climate forecasts for planning production strategies as adaptive measures. Climate forecasts have been used in the north-east region of Brazil since the early 1990s. During 1992, based on the forecast of dry conditions in Ceara, it was recommended that crops better suited to drought conditions should be planted, and this led to reduced grain production losses (67% of the losses recorded for 1987, a year with similar rainfall but without climate forecasting). However, this tool has not yet been fully adopted because of some missed forecasts which eroded the credibility of the system (Orlove et al., 1999). Recently, in Tlaxcala (Mexico), ENSO forecasting was used to switch crops (from maize to oats) during the El Niño event (Conde and Eakin, 2003). This successful experience was based on strong stakeholder involvement (Conde and Lonsdale, 2005). Recent studies have quantified the potential economic value of ENSO-based climate forecasts, and concluded that increases in net return could reach 10% in potato and winter cereals in Chile (Meza et al., 2003); 6% in maize and 5% in soybean in Argentina (Magrin and Travasso, 2001); more than 20% in maize in Santa Julia, Mexico (Jones, 2001); and 30% in commercial agricultural areas of Mexico (Adams et al., 2003), when crop management practices are optimised (e.g., planting date, fertilisation, irrigation, crop varieties). Adjusting crop mix could produce potential benefits close to 9% in Argentina, depending on site, farmers' risk aversion, prices and the preceding crop (Messina, 1999). In the health sector, the application of climate forecasts is relatively new (see Section 13.2.5.5). 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 some countries of Latin America, improvements in weather-forecasting techniques will provide better information for hydrometeorological watching and warning services. The installation of modern weather radar stations (with Doppler capacity) would improve the reliability of these warnings, but the network is still very sparse (WMO, 2007). Furthermore, the deficiencies in the surface and upper air networks adversely affect the reliability of weather outlooks and forecasts. Nevertheless, the exacerbation of weather and climate conditions and the problems arising from extreme events have led to planning and implementation actions to improve the observation, telecommunications and data processing systems of the World Weather Watch (WWW). Moreover,the participation of Latin American countries in the UN-IDSR would lead to the implementation of new (and further development of existing) monitoring and warning services in the region. Examples of networks that predict seasonal climate and climate extremes are the Regional Disaster Information Centre-Latin America and Caribbean (CRID), the International Centre for Research on El Niño Phenomenon (Ecuador), the Permanent Commission of South Pacific (CIIFEN; CPPS) and the Andean Committee for Disaster Prevention and Response (CAPRADE). Some networks set up to respond to and prevent impacts are, for example, the multi-stakeholder decision-making system developed in Peru (Warner, 2006), the National Development Plan and the National Risk Atlas implemented in Mexico (Quaas and Guevara, 2006) and the communication programme for indigenous populations, based on messages in the local language (Alcántara-Ayala, 2004).

13.2.5.1 Natural ecosystems

Ecological corridors between protected areas have been planned for the maintenance of biodiversity in natural ecosystems. Some of these, such as the Mesoamerican Biological Corridor, have been implemented, and these serve also as adaptation measures. Important projects are those for natural corridors in the Amazon and Atlantic forests (de Lima and Gascon, 1999; CBD, 2003) and the Villcabamba–Amboró biological corridor in Peru and Bolivia (Cruz Choque, 2003). Conservation efforts would be also devoted to implementing protection corridors containing mangroves, sea grass beds and coral reefs to boost fish abundance on reefs, benefit local fishing communities, and contribute to sustainable livelihoods (WWF, 2004). Other positive practices in the region are oriented towards maintaining and restoring native ecosystems and protecting and enhancing ecosystem services such as carbon sequestration in the Noel Kempff Mercado Climate Action Project in Bolivia (Brown et al., 2000). 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 (World Bank, 2002a; CBD, 2003); an example is the initiative to implement adaptation measures in high mountain regions which has been developed in Colombia and other Andean countries (Vergara, 2005). A new option to promote mountainous forest conservation consists of compensating forest owners for the environmental services that those forests bring to society (UNEP, 2003a). The compensation is often financed by charging a small price supplement to water users for the water originating in forests. Such schemes are being implemented in various countries of Latin America and were tested in Costa Rica (Campos and Calvo, 2000). In Brazil, 'ProAmbiente' is an environmental credit programme of the government, paying for environmental services provided by smallholders that preserve the forest (MMA, 2004). Another initiative in Brazil is the ecological value-added tax, a fiscal instrument that remunerates municipalities that protect nature and generate environmental services, which was adopted initially by the states of Paraná and Minas Gerais, and more recently implemented in parts of the Amazon as well (May et al., 2004).

13.2.5.2 Agriculture

Some adaptive measures, such as changes in land use, sustainable management, insurance mechanisms, irrigation, adapted genotypes and changes in agronomic crop management, are used in the agricultural sector to cope with climatic variability. In addition, economic diversification has long been a strategy for managing risk (both climatic and market) and this has increased in recent years. While not a direct adaptation to climatic change, this diversification is lessening the dependence of farmers on agricultural income and enabling greater flexibility in managing environmental change (Eakin, 2005). Farmers located on the U.S.–Mexico border have been able to continue farming in the valley through changes in irrigation technology, crop diversification and market orientation, despite the crisis with the local aquifers caused by drought and over-exploitation (Vásquez-León 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-Giménez, 2002). In Mexico, some small farmers are testing adaptation measures for current and future climate, implementing drip-irrigation systems, greenhouses and the use of compost (Conde et al., 2006). According to Wehbe et al. (2006), adjustments in planting dates and crop choice, construction of earth dams and the conversion of agriculture to livestock are increasingly popular adaptation measures in González (Mexico), while in southern Cordoba (Argentina), climate risk insurance, irrigation, adjusting planting dates, spatial distribution of risk through geographically separated plots, changing crops and maintaining a livestock herd were identified as common measures to cope with climatic hazards.

13.2.5.3 Water resources

The lack of adequate adaptation strategies in Latin American countries to cope with the hazards and risks of floods and droughts is due to low gross national product (GNP), the increasing population settling in vulnerable areas (prone to flooding, landslides or drought) and the absence of the appropriate political, institutional and technological framework (Solanes and Jouravlev, 2006). Nevertheless, some communities and cities have organised themselves, becoming active in disaster prevention (Fay et al., 2003). Many poor inhabitants were encouraged to relocate from flood-prone areas to safer places. With the assistance of IRDB and IDFB loans, they built new homes, e.g., resettlements in the Paraná river basin of Argentina, after the 1992 flood (IRDB, 2000). In some cases, a change in environmental conditions affecting the typical economy of the Pampas has led to the introduction of new production activities through aquaculture, using natural regional fish species such as pejerrey (*Odontesthes bonariensis*) (La Nación, 2002). Another example, in this case related to the adaptive capacity of people to water stresses, is given by 'self organisation' programmes for improving water supply systems in very poor communities. The organisation Business Partners for Development Water and Sanitation Clusters has been working on four 'focus' plans in LA: Cartagena (Colombia), La Paz and El Alto (Bolivia), and some underprivileged districts of Gran Buenos Aires (Argentina) (The Water Page, 2001; Water 21, 2002). Rainwater cropping and storage systems are important features of sustainable development in the semi-arid tropics. In particular, there is a joint project developed in Brazil by the NGO Network ASA Project, called the P1MC- Project, for 1 million cisterns to be installed by civilian society in a decentralised manner. The plan is to supply drinking water to 1 million rural households in the perennial drought areas of the Brazilian semi-arid tropics (BSATs). During the first stage, 12,400 cisterns were built by ASA and the Ministry of Environment of Brazil and a further 21,000 were planned by the end of 2004 (Gnadlinger, 2003). In Argentina, national safe water programmes for local communities in arid regions of Santiago del Estero province installed ten rainwater catchments and storage systems between 2000 and 2002 (Basán Nickisch, 2002).

13.2.5.4 Coasts

Several Latin American countries have developed planned and autonomous adaptation measures in response to current climate variability impacts on their coasts. Most of them (e.g., Argentina, Colombia, Costa Rica, Uruguay and Venezuela) focus their adaptation on integrated coastal management (Hoggarth, et al., 2001; UNEP, 2003b, Natenzon et al., 2005a, b; Nagy et al., 2006b). The Caribbean Planning for Adaptation to Global Climate Change project is promoting actions to assess vulnerability (especially regarding rise in sea level), and plans for adaptation and development of appropriate capacities (CATHALAC, 2003). Since 2000, some countries have been improving their 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 included within the 'integrated coastal management' modelling in some countries, such as Venezuela (MARN, 2005) and Colombia (INVEMAR, 2005). In Belize and Guyana, the implementation of land-use planning and zoning strengthens the norms for infrastructure, the coastal-zone management plan, the adjustment of building codes and better disaster-mitigation strategies (including floodplain and other hazard mapping), which, along with climate-change considerations, are used in the day-to-day management of all sectors (CDERA, 2003; UNDP-GEF, 2003).

13.2.5.5 Human health

In Latin America, adaptation measures in the health sector should basically be considered as isolated initiatives. A project on adaptation to climate variability and change undertaken in Colombia is oriented towards formulating measures to reduce human health vulnerability and cope with impacts. The project includes the development of an integrated national pilot adaptation plan (INAP), for high mountain ecosystems, islands, and human health concerns related to the expansion of areas for vectors linked to malaria and dengue (Arjona, 2005). The project includes the development of a comprehensive and integrated dengue and malaria surveillance control system, aiming to reduce the infection rate from both diseases by 30% (Mantilla, 2005). Other isolated measures have been identified for several countries. For example, in Bolivia, adaptation measures regarding the health impacts of climate change include activities on vector control and medical surveillance. The aim is also to have community participation and health education, entomological research, strengthened sanitary services and the development of research centres dealing with tropical diseases. Government programmes would also focus on high-risk areas for malaria and leishmaniasis under climate change (Aparicio, 2000).

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, 2001), the use of GCM outputs based on the Special Report on Emissions Scenarios (SRES: Nakićenović and Swart, 2000) is the adopted method for the Fourth Assessment Report (AR4). Projections of average temperature and rainfall anomalies throughout the current century derived from a number of GCMs are available at the IPCC Data Distribution Centre (IPCC DDC, 2003; http://www.ipcc-data.org//) at a typical model resolution of 300 km, and for two different greenhouse-gas (GHG) emissions scenarios (A2 and B2). Additionally, Chapter 11 of the Working Group I Fourth Assessment Report (Christensen et al., 2007) presents regional projections for many parts of the world. Table 13.4 indicates ranges of temperature and precipitation changes for sub-regions of Latin America for several time-slices (2020, 2040, 2080), obtained from seven GCMs and the four main SRES emissions scenarios.

For 2020, temperature changes range from a warming of 0.4°C to 1.8°C, and for 2080, of 1.0°C to 7.5°C. The highest values of warming are projected to occur over tropical South America (referred to as Amazonia in Table 13.4). 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. Uncertainty is even larger for southern South America in both winter and summer seasons, although the percentage change in precipitation is somewhat smaller than that for tropical Latin America. Analyses of these scenarios reveal larger differences in temperature and rainfall changes among models than among emissions scenarios

Table 13.4. *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 GCMs and the four main SRES scenarios.*

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

DJF= December/January/February, JJA= June/July/August.

for the same model. As expected, the main source of uncertainty for regional climate change scenarios is that associated with 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 summary, the current GCMs do not produce projections of changes in the hydrological cycle at regional scales with confidence. In particular the uncertainty of projections of precipitation remain high (e.g., Boulanger et al., 2006a, b, for climate-change scenarios for South America using ten GCMs). That is a great limiting factor to the practical use of such projections for guiding active adaptation or mitigation policies.

GCM-derived scenarios are commonly downscaled using statistical or dynamical approaches to generate region- or site-specific scenarios. These approaches are described in detail in Chapter 11 of the Working Group I Fourth Assessment Report (Christensen et al., 2007). There have been a number of such exercises for South America using an array of GCM scenarios (HADCM3, ECHAM4, GFDL, CSIRO, CCC, etc.), usually for SRES emissions scenarios A2 and B2: for southern South America (Bidegain and Camilloni, 2004; Nuñez et al., 2005; Solman et al., 2005a, b), Brazil (Marengo, 2004), Colombia (Eslava and Pabón, 2001; Pabón et al., 2001) and Mexico (Conde and Eakin, 2003). Downscaled scenarios may reveal smaller-scale phenomena associated with topographical features or mesoscale meteorological systems and land-use changes, but in general the uncertainty associated with using different GCMs as input is a dominant presence in the downscaled scenarios (Marengo and Ambrizzi, 2006).

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 extreme events will increase in the future. Many impacts of climate change will be realised as the result of a change in the frequency of occurrence of extreme weather events such as windstorms, tornados, hail, heatwaves, gales, heavy precipitation or extreme temperatures over a few hours to several days. A limited number of studies on extremes from global models assessed during the AR4 (e.g., Tebaldi et al., 2007) provide estimates of frequency of seasonal temperature and precipitation extreme events as simulated in the present and by the end of 21st century under the A1B emissions scenario. In Central America, the projected time-averaged 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 others show the opposite tendency.

13.3.2 Land-use changes

Deforestation in Latin America's tropical areas will be one of the most serious environmental disasters faced in the region. Currently, Latin America is responsible for 4.3% of global GHG emissions. Of these, 48.3% result from deforestation and land-use changes (UNEP, 2000). By 2010 the forest areas in South and Central America will be reduced by 18 Mha and 1.2 Mha, respectively. These areas (see Figure 13.3) will be used for pasture and expanding livestock production (FAO, 2005).

If the 2002-2003 deforestation rate (2.3 Mha/yr) in Brazilian Amazonia continues indefinitely, then 100 Mha of forest (about 25% of the original forest) will have disappeared by the year 2020 (Laurance et al., 2005), while by 2050 (for a business-as-usual scenario) 269.8 Mha will be deforested (Moutinho and Schwartzman, 2005). By means of simulation models, Soares-Filho et al. (2005) estimated for 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 (109 tonnes/ha) of carbon to the atmosphere. Moreover, under the current trend, agricultural expansion will eliminate two-thirds of the forest cover of five major watersheds and ten eco-regions, besides the loss of more than 40% of 164 mammalian species habitats.

Projected to be one of the main drivers of future land-use change, the area planted to soybeans in South America is

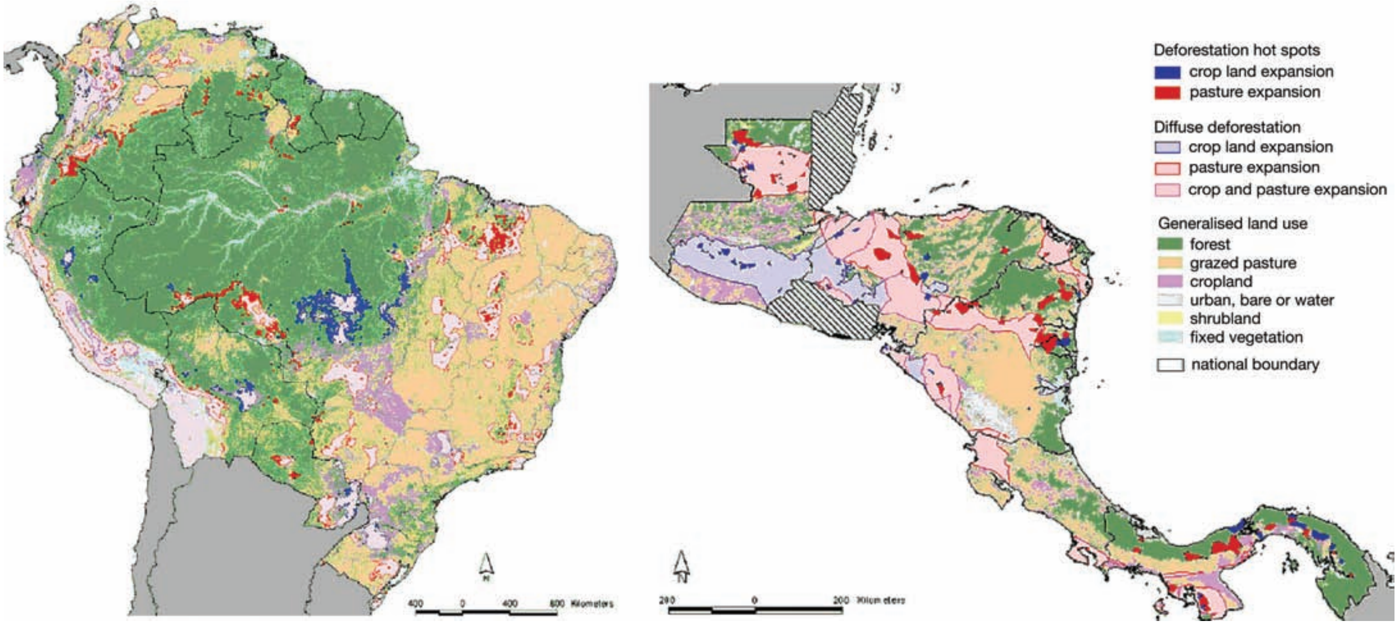

Figure 13.3. *Predicted 2000-2010 South American and Central American deforestation hotspots and diffuse deforestation areas (available at: http://www.virtualcentre.org/en/dec/neotropics/south_america.htm and http://www.virtualcentre.org/en/dec/neotropics/central_america.htm).*

expected to increase from 38 Mha in 2003/04 to 59 Mha in 2019/20 (Maarten Dros, 2004). The total production of Argentina, Brazil, Bolivia and Paraguay will rise by 85% to 172 million tonnes or 57% of world production. Direct and indirect conversion of natural habitats to accommodate this expansion amounts to 21.6 Mha. Habitats with the greatest predicted area losses are the Cerrado (9.6 Mha), dry and humid Chaco (the largest dry forest in South America, which covers parts of Argentina, Paraguay, Bolivia and Brazil; 6.3 Mha), Amazon transition and rain forests (3.6 Mha), Atlantic forest (1.3 Mha), Chiquitano forest (transition between Amazonian forest and Chaco forest; 0.5 Mha) and Yungas forest (0.2 Mha). This massive deforestation will have negative impacts on the biological diversity and ecosystem composition of South America as well as having important implications for regional and local climate conditions.

13.3.3 Development

13.3.3.1 Demographics and societies

The population of the Latin American region has continued to grow and is expected to be 50% larger than in 2000 by the year 2050. Its annual population growth rate has decreased and is expected to reach a value of 0.89% by 2015, which is considerably less than 1.9%, the average rate for the 1975-2002 period. The population has continued to migrate from the countryside to the cities, and by 2015 about 80% of the population will be urban, almost 30% more than in the 1960s. The population aged under 15 years will decline and at the same time the population aged over 65 years will increase. Total fertility rate (births per woman) decreased from 5.1 to 2.5 between 1970-1975 and 2000-2005 and is expected to decrease to 2.2 by 2015 (ECLAC, 1998).

According to ECLAC (1998) the number of people in an age-range making them dependent (between 0 and 14 and over 65 years) will increase from 54.8% at present to almost 60% in 2050. This will increase pressure on the social security systems in the region and increase the contributions that the population of working age will have to make in order to maintain the availability of health and educational services. Life expectancy at birth increased from 61.2 years in the 1970s to 72.1 years in the 2000-2005 five-year period, and is expected to increase to 74.4 years by 2015. Crude mortality rate is expected to increase from the current value of 7.8 (per thousand) to almost 12 by 2050.

Human migration has become an important issue in the region. Recent studies (ECLAC, 2002b) have estimated that 20 million Latin American and Caribbean nationals reside outside their countries, with the vast majority in North America. This phenomenon has important effects on national economies and creates important social dependencies: 5% of households in the region benefit from remittances which in 2003 amounted to US$38 billion (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 addition, Latin American countries are ranked within the upper half of the Human Poverty Index and have shown a systematic improvement between 1975 and 2002. It is difficult to ignore the fact that, although there are no Latin American countries classified in the low development rank, there are huge contrasts among and within countries in terms of levels of technological development, sophistication of financial sectors, export capacities and income distribution (CEPAL, 2002).

13.3.3.2 Economic scenarios

Projections of economic evolution for the region strongly depend on the interpretation of the results of the liberalisation process that the region has experienced during the last 20 years, and therefore can be contradictory. On the one hand, economists who favour liberalisation of Latin American economies argue that countries that have implemented these types of policies have improved in terms of growth rate, stability, democracy and even with regard to inequality and poverty (for example: Walton, 2004; World Bank, 2006). On the other hand, another group of experts in economics, sociology and politics is concerned with the effects that neoliberalisation has had for the region, especially 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 unresolved debate that imparts great uncertainty to economic scenarios for Latin America.

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 Latin America has had a very low growth – about 1.3%/yr average during the 1990 to 2000 period – in the long term (from 2006 to 2015), regional GDP is projected to increase by 3.6%/yr, and per capita income is expected to rise by 2.3%/yr on average (World Bank, 2006). Current estimates forecast a growth of 4%/yr for the region in 2006 and 3.6%/yr in 2007 and real per capita GDP growth of 2.6%/yr and 2.3%/yr, respectively (Loser, 2006; World Bank, 2006). These positive prospects are attributed to the implementation of economic policies such as a 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 Goals on poverty; however, it is important to note that the region's performance is not as good as other developing regions such as central Asia and, notably, China. An improvement on this rate of growth could be achieved by consolidating current economic policies (Walton, 2004; World Bank, 2006).

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

13.4 Summary of expected key future impacts and vulnerabilities

13.4.1 Natural ecosystems

Tropical plant species may be sensitive to 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 Atmosphere-Ocean General Circulation Model (AOGCM) projections for A2 emissions scenarios, there is the potential for extinction of 24% of 138 tree species of the central Brazil savannas (Cerrados) by 2050 for a projected increase of 2°C in surface temperature (Siqueira and Peterson, 2003; Thomas et al., 2004). By the end of the century, 43% of 69 tree plant species studied could become extinct in Amazonia (Miles et al., 2004). In terms of species and biome redistributions, larger impacts would occur over north-east Amazonia than over western Amazonia. Several AOGCM scenarios indicate a tendency towards 'savannisation' of eastern Amazonia (Nobre et al., 2005) and the tropical forests of central and south Mexico (Peterson et al., 2002; Arriaga and Gómez, 2004). In north-east Brazil the semi-arid vegetation would be replaced by the vegetation of arid regions (Nobre et al., 2005), as in most of central and northern Mexico (Villers and Trejo, 2004).

Up to 40% of the Amazonian forests could react drastically to even a slight reduction in 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 current 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, such as tropical savannas.

The study of climate-induced changes in key ecosystem processes (Scholze et al., 2005) 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. A high risk of forest loss is shown for Central America and Amazonia, more frequent wildfire in Amazonia, more runoff in north-western South America, and less runoff in Central America. More frequent wildfires are likely (an increase in frequency of 60% for a temperature increase of 3°C) 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 temperature increases of more than 3°C (see Figure 13.3).

The tropical cloud forests in mountainous regions will be threatened if temperatures increase by 1°C to 2°C during the next 50 years due to changes in the altitude of the cloud-base during the dry season, which would be rising by 2 m/yr. In places with low elevation and isolated mountains, some plants will become locally extinct because the elevation range would not permit natural adaptation to 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 cloud 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 amphibians (20 of 50 species) and probably also bird and reptile populations (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 and for a mid-range climate change scenario, that species extinction in Mexico could sharply increase: mammals 8% or 26% loss of species (with or without dispersal), birds 5% or 8% loss of species (with or without dispersal), and butterflies 7% or 19% loss of species (with or without dispersal).

13.4.2 Agriculture

Several studies using crop-simulation models and future climate scenarios were carried out in Latin America for commercial annual crops (see Table 13.5). According to a global assessment (Parry et al., 2004), if CO_2 effects are not considered, grain yield reductions could reach up to 30% by 2080 under the warmer scenario (HadCM3 SRES A1FI), and the number of additional people at risk of hunger under the A2 scenario is likely to reach 5, 26 and 85 million in 2020, 2050 and 2080, respectively (Warren et al., 2006). However, if direct CO_2 effects are considered, yield changes could range between reductions of 30% in Mexico and increases of 5% in Argentina (Parry et al., 2004), and the additional number of people at risk of hunger under SRES A2 would increase by 1 million in 2020, remain unchanged in 2050 and decrease by 4 million in 2080.

More specific studies considering individual crops and countries are also presented in Table 13.5. The great uncertainty in yield projections could be attributed to differences in the GCM or incremental scenario used, the time-slice and SRES scenario considered, the inclusion or not of CO_2 effects, and the site considered. Other uncertainties in yield impacts are derived from model inaccuracies and unmodelled processes. Despite great variability in yield projections, some behaviour seems to be consistent all over the region, such as the projected reduction in rice yields after the year 2010 and the increase in soybean yields when CO_2 effects are considered. Larger crop yield reductions could be expected in the future if the variance of temperatures were doubled (see Table 13.5). For smallholders a mean reduction of 10% in maize yields could be expected by 2055, although in Colombia yields remain essentially unchanged, while in the Venezuelan Piedmont yields are predicted to decline to almost zero (Jones and Thornton, 2003). Furthermore, an increase in heat stress and more dry soils may reduce yields to one-third in tropical and sub-tropical areas where crops are already near their maximum heat tolerance. The productivity of both prairies/meadows and pastures will be affected, with loss of carbon stock in organic soils and also a loss of organic matter (FAO, 2001b). Other important issues are the expected reductions in land suitable for growing coffee in Brazil, and in coffee production in Mexico (see Table 13.5).

In temperate areas, such as the Argentinean and Uruguayan Pampas, pasture productivity could increase by between 1% and 9% according to HadCM3 projections under SRES A2 for 2020 (Gimenez, 2006). As far as beef cattle production is concerned, in Bolivia future climatic scenarios would have a slight impact on animal weight if CO_2 effects are not considered, while doubling CO_2 and increases of 4°C in temperature are very likely to result in decreases in weight that could be as much as 20%, depending on animal genotype and region (NC-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 in erosion patterns (FAO, 2001b). According to the World Bank (2002a, c), some developing countries are losing 4-8% of their GDP due to productive and capital losses related to environmental degradation. In drier areas of Latin America, such as central and northern Chile, the Peruvian coast, north-east Brazil, dry Gran Chaco and Cuyo, central, western and north-west Argentina and significant parts of Mesoamerica (Oropeza, 2004), climate change is likely to lead to salinisation and desertification of agricultural lands. By 2050, desertification and salinisation will affect 50% of agricultural lands in Latin America and the Caribbean zone (FAO, 2004a).

In relation to pests and diseases, the incidence of the coffee leafminer (*Perileucoptera coffeella*) and the nematode *Meloidogyne incognita* are likely to increase in future in Brazil's production area. The number of coffee leafminer cycles could increase by 4%, 32% and 61% in 2020, 2050 and 2080, respectively, under SRES A2 scenarios (Ghini et al., 2007). According to Fernandes et al. (2004), the risk of *Fusarium* head blight incidence in wheat crops is very likely to increase under climate change in south Brazil and Uruguay. The demand for water for irrigation is projected to rise in a warmer climate, bringing increased competition between agricultural and domestic use in addition to industrial uses. Falling watertables 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 could lead to an increasing imbalance between water demand and water supply after 2025 (ECHAM scenario; Krol and van Oel, 2004).

13.4.3 Water resources

Almost 13.9% of the Latin American population (71.5 million people) have no access to a safe water supply; 63% of these (45 million people) live in rural areas (IDB, 2004). Many rural communities rely on limited freshwater resources (surface or underground) and many others on rainwater, using water-cropping methods which are very vulnerable to drought (IDB, 2004). People living in water-stressed watersheds (less than 1,000 m^3/capita per year) in the absence of climate change were estimated to number 22.2 million in 1995 (Arnell, 2004). The number of people experiencing increased water stress under the SRES scenarios is estimated to range from 12 to 81 million in the 2020s, and from 79 to 178 million in the 2050s (Arnell, 2004). These estimates do not take into account the number of people moving out of water-stressed areas (unlike Table 13.6). The current vulnerabilities observed in many regions of Latin American countries will be increased by the joint negative effects of growing demands for water supplies for domestic use and irrigation due to an increasing population, and the expected drier conditions in many basins. Therefore, taking into account the number of people experiencing decreased water stress, there will still be a net increase in the number of people becoming water-stressed (see Table 13.6).

In some zones of Latin America where severe water stresses could be expected (eastern Central America, in the plains, Motagua valley and Pacific slopes of Guatemala, eastern and western regions of El Salvador, the central valley and Pacific region of Costa Rica, in the northern, central and western inter-montane regions of Honduras and in the peninsula of Azuero in Panama), water supply and hydroelectric generation would be seriously affected (Ramírez and Brenes, 2001; ECLAC, 2002a).

Table 13.5. *Future impacts on the agricultural sector.*

		Yield impacts (%)				
Study	**Climate scenario**	**Wheat**	**Maize**	**Soybean**	**Rice**	**Others**
Guyana (NC-Guyana, 2002)	CGCM1 2020-2040 (2xCO_2)				–3	Sg: –30
	CGCM1 2080-2100 (3xCO_2)				–16	Sg: –38
Panama (NC-Panama, 2000)	HadCM2-UKHI (IS92c-IS92f) 2010/2050/2100 (1xCO_2)		+9/–34/–21			
Costa Rica (NC-Costa Rica, 2000)	+2°C –15% precip. (1xCO_2)				–31	Pt: ↓
Guatemala (NC-Guatemala, 2001)	+1.5°C –5% precip.		+8 to –11		–16	Bn: +3 to –28
	+2°C +6% precip.		+15 to –11		–20	Bn: +3 to –42
	+3.5°C –30% precip.		+13 to –34		–27	Bn: 0 to –66
Bolivia (NC-Bolivia, 2000)	GISS and UK89 (2xCO_2).I		–25		–2	
	Incremental (2xCO_2)		+50			
	+3°C –20% precip.				–15	
	optimistic-pessimistic (1xCO_2)					Pt: +5 to+2^{*2}
	optimistic-pessimistic (2xCO_2)					Pt: +7 to+5^{*2}
	IS92a (1xCO_2)^{*1}			–3 to –20		
	IS92a (2xCO_2)^{*1}			+12 to +59		
Brazil (Siqueira et al., 2001)	GISS (550 ppm CO_2)	–30	–15	+21		
SESA^{*3} (Gimenez, 2006)	Hadley CM3-A2 (500 ppm)	+9 to +13	–5 to +8	+31 to +45		
	Hadley CM3-A2 (500 ppm).I	+10 to +14	0 to +2	+24 to +30		
Argentina, Pampas (Magrin and Travasso, 2002)	+1/+2/+3°C (550 ppm CO_2).I	+11/+3/–4	0/–5/–9	+40/+42/+39		
	UKMO (+5.6°C) (550 ppm CO_2).I	–16	–17	+14		
Honduras (Díaz-Ambrona et al., 2004)	Hadley CM2 (1xCO_2) 2070		–21			
	Hadley CM2 (2xCO_2) 2070		0			
Central Argentina (Vinocur et al., 2000; Vinocur, 2005)	Hadley CM3-B2 (477ppm)		+21			
	ECHAM98-A2 (550ppm)		+27			
	+1.5/+3.5°C (1xCO_2)		–13/–17			
	+1.5/+3.5°C (1xCO_2) (2T)^{*4}		–19/–35			
Latin America (Jones and Thornton, 2003)	HadCM2 (smallholders)		–10			
Latin America (Parry et al., 2004)	HadCM3 A1FI (1xCO_2)	Cereal yields: –5 to –2.5 (2020)		–30 to –5 (2050)		–30 (2080)
	HadCM3 B1 (1xCO_2)	–10 to –2.5 (2020)		–10 to –2.5 (2050)		–30 to –10 (2080)
	HadCM3 A1FI (2xCO_2)	–5 to +2.5 (2020)		–10 to +10 (2050)		–30 to +5 (2080)
	HadCM3 B1 (2xCO_2)	–5 to –2.5 (2020)		–5 to +2.5 (2050)		–10 to +2.5 (2080)
Mexico, Veracruz (Gay et al., 2004)	HadCM2 ECHAM4 (2050)	Coffee: 73% to 78% reduction in production				
Brazil, São Paulo (Pinto et al., 2002)	+1°C + 15% precip.	Coffee: 10% reduction in suitable lands for coffee				
	+5.8°C + 15%precip.	97% reduction in suitable lands for coffee				
Costa Rica (NC-Costa Rica, 2000)	Sensitivity analysis	Coffee: Increases (up to 2°C) in temperature would benefit crop yields				

I = Irrigated crops; precip. = 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: doubled variance of temperature. Bn: bean, Sg: sugar cane, Pt: potato.

Table 13.6. *Net increases in the number of people living in water-stressed watersheds in Latin America (millions) by 2025 and 2055 (Arnell, 2004).*

	1995	2025		2055	
Scenario/ GCM		**Without climate change (1)**	**With climate change (2)**	**Without climate change (1)**	**With climate change (2)**
A1 HadCM3	22.2	35.7	21.0	54.0	60.0
A2 HadCM3	22.2	55.9	37.0-66.0	149.3	60.0-150.0
B1 HadCM3	22.2	35.7	22.0	54.0	74.0
B2 HadCM3	22.2	47.3	7.0-77.0	59.4	62.0

(1) according to Arnell (2004, Table 7); (2) according to Arnell (2004, Tables 11 and 12).

Vulnerability studies foresee the ongoing reductions in glaciers. A highly stressed condition is projected between 2015 and 2025 in the water availability in Colombia, affecting water supply and ecosytem functioning in the páramos (IDEAM, 2004), and very probably impacting on the availability of water supply for 60% of the population of Peru (Vásquez, 2004). The projected glacier retreat would also affect hydroelectricity generation in some countries, such as Colombia (IDEAM, 2004) and Peru; one of the more affected rivers would be the Mantaro, where an hydroelectric plant generates 40% of Peru's electricity and provides the energy supply for 70% of the country's industries, concentrated in Lima (UNMSM, 2004) .

In Ecuador, recent studies indicate that seven of the eleven principal basins would be affected by a a decrease in their annual runoff, with monthly decreases varying up to 421% of unsatisfied demand (related to mean monthly runoff) in year 2010 with the scenario of +2°C and −15% precipitation (Cáceres, 2004). In Chile, recent studies confirm the potential damage to water supply and sanitation services in coastal cities, as well as groundwater contamination by saline intrusion. In the Central region river basins, changes in streamflows would require many water regulation works to be redesigned (NC-Chile, 1999).

Under severe dry conditions, inappropriate agricultural practices (deforestation, soil erosion and the excessive use of agrochemicals) will deteriorate surface and groundwater quantity and quality. That would be the case in areas that are currently degraded, such as Leon, Sebaco Valley, Matagalpa and Jinoteca in Nicaragua, metropolitan and rural areas of Costa Rica, Central Valley rivers in Central America, the Magdalena river in Colombia, the Rapel river basin in Chile, and the Uruguay river in Brazil, Uruguay and Argentina (UNEP, 2003b).

Landslides are generated by intense/persistent precipitation events and rainstorms. Furthermore, in Latin America they are associated with deforestation and a lack of land planning and disaster-warning systems. Many cities of Latin America, which are already vulnerable to landslides and mudflows, are very likely to suffer the exacerbation of extreme events, with increasing risks/hazards for local populations (Fay et al., 2003). Accelerated urban growth, increasing poverty and low investment in water supply will contribute to: water shortages in many cities, high percentages of the urban population without access to sanitation services, an absence of treatment plants, high groundwater pollution, lack of urban drainage systems, storm sewers used for domestic waste disposal, the occupation of flood valleys during drought seasons, and high impacts during flood seasons (Tucci, 2001).

13.4.4 Coasts

The majority of vulnerability and impacts assessments in Latin America have been made under the framework of National Communications (NC) to the UNFCCC (United Nations Framework Convention on Climate Change). Unfortunately the methodological approaches adopted are very diverse. Many are based on incremental scenarios (SLR 0.3-1.0 m), in some cases combined with coastal river flooding. Some include a cost-benefit analysis with and without measures (e.g., Ecuador, El Salvador and Costa Rica). Long-term and recent trends of SLR, flooding and storm surges are not always available or analysed. Some other countries (e.g., Chile and Peru) prioritise the impacts of ENSO events and the increase in SST on fisheries.

Significant impacts of projected climate change and sea-level rise are expected for 2050-2080 on the Latin American coastal areas. With most of their population, economic activities and infrastructure located at or near sea-level, coastal areas will be very likely to suffer floods and erosion, with high impacts on people, resources and economic activities (Grasses et al., 2000; Kokot, 2004; Barros, 2005; UCC, 2005). Results from several studies using SLR incremental and future climate change scenarios are summarised in Table 13.7. Projected impacts which would entail serious socio-economic consequences include floods; population displacement; salinisation of lowland areas affecting sources of drinking water (Ubitarán Moreira et al., 1999); coastal storm regime modification; increased erosion and altered coastal morphology (Conde, 2001; Schaeffer-Novelli et al., 2002; Codignotto, 2004; Villamizar, 2004); diversion of farm land; disruption of access to fishing grounds; negative impacts on biodiversity, including mangroves; salinisation and over-exploitation of water resources, including groundwater (FAO, 2006); and pollution and sea-water acidification in marine and coastal environments (Orr et al., 2005). 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 to the impacts on coastal environments (Grasses et al., 2000; Rodríguez-Acevedo, 2001; OAS-CIDI, 2003; Kokot, 2004).

As for coastal tourism, the most impacted countries will be those where the sectoral contribution to the GDP, balance of payments and employment is relatively high, and which are threatened by windstorms and projected sea-level rise: such as those of Central America, the Caribbean coast of South America and Uruguay (Nagy et al., 2006a, c). Thus, climate change is very likely to be a major challenge for all coastal nations.

13.4.5 Human health

The regional assessments of health impacts due to climate change in the Americas show that the main concerns are heat stress, malaria, dengue, cholera and other water-borne diseases (Githeko and Woodward, 2003). Malaria continues to pose a serious health risk in Latin America, where 262 million people (31% of the population) live in tropical and sub-tropical regions with some potential risk of transmission, ranging from 9% in Argentina to 100% in El Salvador (PAHO, 2003). Based on SRES emissions scenarios and socio-economic scenarios, some projections indicate decreases in the length of the transmission season of malaria in many areas where reductions in precipitation are projected, such as the Amazon and Central America. The results report additional numbers of people at risk in areas around the southern limit of the disease distribution in South America (van Lieshout et al., 2004). Nicaragua and Bolivia have predicted a possible increase in the incidence of malaria in 2010, reporting seasonal variations (Aparicio, 2000; NC-Nicaragua, 2001). The increase in malaria and population at risk could impact the costs of health services, including treatment and social security payments.

Kovats et al. (2005) have estimated relative risks (the ratio of risk of disease/outcome or death among the exposed to the risk among the unexposed) of different health outcomes in the year 2030 in Central America and South America, with the highest relative risks being for coastal flood deaths (drowning), followed by diarrhoea, malaria and dengue. Other models project a substantial increase in the number of people at risk of dengue due to changes in the geographical limits of transmission in Mexico, Brazil, Peru and Ecuador (Hales et al., 2002). Some models project changes in the spatial distribution (dispersion) of the cutaneous leishmaniasis vector in Peru, Brazil, Paraguay, Uruguay, Argentina and Bolivia (Aparicio, 2000; Peterson and Shaw, 2003), as well as the monthly distribution of dengue vector (Peterson et al., 2005).

Table 13.7. *Future impacts and vulnerability to climate change and variability in Latin America: people and coastal systems.*

Country/Region	Climate scenario	Impacts/costs (people, infrastructure, ecosystems, sectors)
Latin America	HADCM3: SRES B2, B1, A2, A1FI. SLR (Nicholls, 2004)	Assuming uniform population growth, no increase in storm intensity and no adaptation response (constant protection) the average annual number of coastal flood victims by the 2080s will probably range between 3 million and 1 million under scenarios A and B, respectively. If coastal defences are upgraded in line with rising wealth (evolving adaptation), the number of victims would be 1 million people under the worst-case scenario (A1FI). Finally, if coastal defences are upgraded against sea-level rise (enhanced adaptation); no people should be affected (Warren et al., 2006). People at risk[1] on coastal flood plains are likely to increase from 9 million in 1990 to 16 million (B1) and 36 million (A2) by the 2080s.
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, at 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 a consequent drop in production and GDP share (Medina et al., 2001).
El Salvador	SLR: 13-110 cm	Land loss ranging from 10% to 27.6% of the total area (141-400.7 km^2) (NC-El Salvador, 2000).
Guyana	SLR 100 cm projected by GCMs	Over 90% of the population and the most important economic activities are located in coastal areas which are expected to retreat by as much as 2.5 km (NC-Guyana, 2002).
Mesoamerican coral reef and mangroves from Gulf of Mexico	Warmer SST: 1-3°C by the 2080s under IPCC SRES scenarios	Coral reef and mangroves are expected to be threatened, with consequences for 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 (Cahoon and Hensel, 2002).
Costa Rica, Punta Arenas coast	SLR 0.3-1.0 m	Sea water could penetrate 150 to 500 m inland, affecting 60-90% of urban areas (NC-Costa Rica, 2000).
Ecuador, Guayas river system, associated coastal zone and Guayaquil City	No-change: LANM0, moderate: LANM1, and severe changes: LANM2, with and without economic development	Losses of US$1,305 billion, which include shrimp cultures, mangroves, urban and recreation areas, supply of drinking water, as well as banana, rice and sugarcane cultivation. US$1,040 billion would be under risk. Evacuated and at-risk population should rise to 327,000 and 200,000 people, respectively. Of the current 1,214 km^2 of mangroves, it is estimated that 44% will be affected by the LANM2 scenario (NC-Ecuador, 2000).
Peru	Intensification of ENSO events and increases in SST. Potential SLR	Increased wind stress, hypoxia and deepening of the thermocline will impact on the marine ecosystem and fisheries, i.e., reduction of spawning areas and fish catches of anchovy. Flooding of infrastructure, houses and fisheries will cause damage valued at US$168.3 million. Global losses on eight coastal regions in Peru are estimated at US$1,000 million (NC-Perú, 2001).
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; the agricultural sector would be exposed to flooding (e.g., 7.2 Mha of crops and pasture would be lost); 44.8% of the coastal road network would be highly vulnerable (NC-Colombia, 2001).
Argentina (Buenos Aires City)	Storm surges and SLR 2070/2080	Very low-lying areas which are likely to be permanently flooded are now only thinly populated. Vulnerability is mostly conditioned by future exposure to extreme surges. Rapid erosion with its consequent coastline retreat will occur at a rate depending on geological characteristics of the area. As a result of adaptation to present storm-surge conditions, the social impact of future permanent flooding will be relatively small (Kokot, 2004; Kokot et al., 2004; Menéndez and Ré, 2005).
Argentina and Uruguay (western Montevideo) coastal areas. Buenos Aires and Rio Negro Provinces	SLR, climate variability, ENSO, storm surges ('sudestadas')	Increases in non-eustatic factors (i.e., an increase in 'sudestadas' (a strong south-eastern wind along the Rio de la Plata coast) and freshwater flow, the latter often associated with El Niño, would accelerate SLR in the Río de la Plata, having diverse environmental and societal impacts on both the Argentine and Uruguay 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 surges (southern winds). Loss of land would have a major impact on the tourism industry, which accounts for 3.8% of Uruguay's GDP (Barros, 2003; Codignotto, 2004; Kokot, 2004, Kokot et al., 2004; NC-Uruguay, 2004; Nagy et al., 2005, 2006c; Natenzon et al., 2005b).

[1] This is defined as living below the 1 in 1,000 year flood level.

Climate change is likely to increase the risk of forest fires. In some countries, wildfires and intentional forest fires have been associated with an increased risk of out-patient visits to hospital for respiratory diseases and an increased risk of breathing problems (WHO, 2000; Mielnicki et al., 2005). In urban areas exposed to the 'heat island' effect and located in the vicinity of topographical features which encourage stagnant air mass conditions and the ensuing air pollution, health problems would be exacerbated, particularly those resulting from surface ozone concentrations (PAHO, 2005). Furthermore, urban settlements located on hilly ground, where soil texture is loose, would be affected by landslides and mudflows; thus people living in poor-quality housing would be highly vulnerable.

Highly unusual stratospheric ozone loss and UV-B increases have occurred in the Punta Arenas (Chile) area over the past two decades, resulting in the non-photoadapted population being repeatedly exposed to an altered solar UV spectrum causing a greater risk of erythema and photocarcinogenesis. According to Abarca and Cassiccia (2002), the rate of non-melanoma skin cancer, 81% of the total, has increased from 5.43 to 7.94 per 100,000 (46%).

Human migration resulting from drought, environmental degradation and economic reasons may spread disease in unexpected ways, and new breeding sites for vectors may arise due to increasing poverty in urban areas and deforestation and environmental degradation in rural areas (Sims and Reid, 2006).

Recent studies warn of the possible re-emergence of Chagas' disease in Venezuela (Feliciangeli et al., 2003; Ramírez et al., 2005) and Argentina (PNC, 2005), and a wider vector distribution in Peru (Cáceres et al., 2002). Some models project a dispersal potential for Chagas' vector species into new areas (Costa et al., 2002).

A national assessment of Brazilian regions demonstrated that the north-east is the most vulnerable to the health effects of changing climate due to its poor social indicators, the high level of endemic infectious diseases, and the periodic droughts that affect this semi-arid region (Confalonieri et al., 2005).

13.5 Adaptation: practices, options and constraints

13.5.1 Practices and options

13.5.1.1 Natural ecosystems

Some options to increase the capacity to adapt to climate change include the reduction of ecosystem degradation in Latin America through the improvement and reinforcement of policy, planning and management. According to the Millennium Ecosystem Assessment (2005), Biringer et al. (2005), FAO (2004b), Laurance et al. (2001), Brown et al. (2000) and Nepstad et al. (2002), these options are basically as follows.

- In the government context: integrate decision-making between different departments and sectors and participate in international institutions in order to ensure that policies are focused on the protection of ecosystems.
- Identify and exploit synergies: taking advantage of synergies between proposed and existing adaptation policies and actions can provide significant benefits to both endeavours (Biringer et al., 2005).
- Procure the empowerment of marginalised groups so as to influence the decisions that affect them and their ecosystem services, and campaign for legal recognition of local communities' ownership of natural resources. This option is the key to reducing the incidence of forest fires.
- Include sound valuation and management of ecosystem services in all regional planning decisions and in poverty reduction strategies, e.g., Noel Kempff Mercado Climate Action Project in Bolivia and Río Bravo Carbon Sequestration Pilot Project in Belize.
- Establish additional protected areas, particularly the biological or ecological corridors, for preserving the connections between protected areas, with the aim of preventing the fragmentation of natural habitats. Some programmes and projects involving actions with different degrees of implementation are: the Meso-American Biological Corridor; Binational Corridors (e.g., Tariquía-Baritú between Argentina and Bolivia, Vilcabamba-Amboro between Peru and Bolivia, Cóndor Kutukú between Peru and Ecuador, Chocó–Manabí between Ecuador and Colombia), the natural corridor projects under way in Brazil's Amazon region and the Atlantic forests of Colombia (e.g., Corredor Biológico Guácharos–Puracé and Corredor de Bosques Altoandinos de Roble); those in Venezuela (e.g., Corredor Biológico de la Sierra de Portuguesa), Chile (e.g., Corredor entre la Cordillera de los Andes y la Cordillera de la Costa and Proyecto Gondwana), and some initiatives in Argentina (e.g., Iniciativa Corredor de Humedales del Litoral Fluvial de la Argentina, Corredor Verde de Misiones, and Proyecto de Biodiversidad Costera).
- Tropical countries in the region can reduce deforestation through adequate funding of programmes 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 Brazilian Amazon (Nepstad et al., 2002; Fearnside, 2003). Moreover, substantial amounts of forest can be saved in protected areas if adequate funding is available (Bruner et al., 2001; Pimm et al., 2001).
- Monitoring and evaluating (M&E) adaptation strategy impacts on biodiversity. The process of monitoring change in biological systems can be complex and resource-intensive, requiring involved observation and data collection, painstaking analysis, etc. Care should be taken to ensure that an M&E plan is developed which ensures a robust yet streamlined M&E process (Biringer et al., 2005).
- Agroforestry using agroecological methods offers strong possibilities for maintaining biological diversity in Latin America, given the overlap between protected areas and agricultural zones (Morales et al., 2007).

13.5.1.2 Agriculture and forestry

Some adaptation measures aiming to reduce climate change impacts have been proposed in the agricultural sector. For example, in Ecuador, options such as agro-ecological zoning and appropriate sowing and harvesting seasons, the introduction of higher-yielding varieties, installation of irrigation systems, adequate use of fertilisers, and implementation of a system for controlling pests and disease were proposed (NC-Ecuador, 2000). In Guyana several adjustments relating 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 (fertilisers and machinery) were identified (NC-Guyana, 2002).

In other countries, adaptation measures have been assessed by means 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 cycles would take advantage of projected longer growing seasons as a result of the shortening of the period when frosts may occur (Magrin and Travasso, 2002). More recently, Travasso et al. (2006) reported that, in South Brazil, Uruguay and Argentina, the negative impacts of future climate on maize and soybean production could be offset by changing planting dates and adding supplementary irrigation.

In terms of food security, a significant number of smallholders and subsistence farmers may be particularly vulnerable to climate change in the short term, and their adaptation options may be more limited. Of particular concern are farmers in Central America, where drying trends have been reported, and in the poorer regions of the Andes. Adaptations in these communities may involve policies for market development of new and existing crop and livestock products, breeding drought-tolerant crops, modified farm-management practices, and improved infrastructure for off-farm employment generation. Increasingly, cross-sectoral perspectives are needed when considering adaptation options in these communities (Jones and Thornton, 2003; Eakin, 2005). In dry areas of north-eastern Brazil, where small farmers are among the social groups most vulnerable to climate change, the production of vegetable oils from native plants (e.g., castor bean) to supply the bio-diesel industry has been proposed as an adaptation measure (La Rovere et al., 2006).

A global study (which includes case studies of northern Argentina and south-eastern Brazil) concluded 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. Conversely, in south-eastern Brazil, future water supply for agriculture is likely to be plentiful (Rosenzweig et al., 2004).

As a way of avoiding the consequences of deforestation as a likely impact on the regional climate, several measures are currently being initiated in the region and are likely to be intensified in the future. Argentina, Brazil, Costa Rica and Peru have adopted new forestry laws and policies that include better regulatory measures, sustainability principles, expansion of protected areas, certification of forestry products and expansion of forest plantations into non-forested areas (Tomaselli, 2001). In the Brazilian Amazon state of Mato Grosso, where 18,000 km^2 of forest and savannas were converted to pasture and soybean fields in 2003, requirements for licensing of deforestation and environmental certification of soybean have been introduced as a way to preserve the environment. A similar proposal is under development for the Mato Grosso cattle industry (Nepstad, 2004). Most countries provide incentives for managing their native forests: exemption from land taxes (Chile, Ecuador), technical assistance (Ecuador), and subsidies (Argentina, Mexico and Colombia) (UNEP, 2003a). Chile and Guyana demand prior studies on environmental impact before approving forestry projects, depending upon their 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 civilian society, including community and indigenous groups.

13.5.1.3 Water resources

Water management policies in Latin America should be the central point of the adaptation criteria to be established in order to strengthen the countries' capacities to manage water resources availability and demand, and ensure the safety of people and protection of their belongings under changing climatic conditions. In this regard, the principal actions for adaptation must include: improvement and further development of legislation related to land use on floodplains, ensuring compliance with existing regulations of risk zones, floodplain use and building codes; re-evaluating the design and safety criteria of structural measures for water management; developing groundwater protection and restoration plans to maintain water storage for dry seasons; developing public awareness campaigns to highlight the value of rivers and wetlands as buffers against increased climate variability and to improve participation of vulnerable groups in flood adaptation and mitigation programmes (IRDB, 2000; Bergkamp et al., 2003; Solanes and Jouravlev, 2006).

Adaptation to drier conditions in 60% of the territory of Latin America would require a great increase in the amount of investment in water supply systems, in addition to the US$17.7 billion needed to accomplish the provision of safe water systems to 121 million people, necessary to achieve the Millennium Declaration for Safe Water goals by 2015 (even though this would leave 10% of the population of Latin America without access to safe water) (IDB, 2004).

Managing transbasin diversions has been the solution for water development in some regions of the world, particularly in California. In Latin America, transbasin transfers in Yacambú basin (Venezuela), Catamayo-Chira basins (Ecuador and Peru), Alto Piura and Mantaro basins (Peru), and the São Francisco River (Brazil) would be an option to mitigate the likely stresses on water supply for the population. Transbasin diversions should be practiced responsibly, taking into account environmental consequences and the hydrological regime (Vásquez, 2004; Marengo and Raigoza, 2006).

The use of urban and rural groundwater needs to be controlled and rationalised, taking into account the quality, distribution and trends over time identified in each region. To develop sustainable groundwater and aquifer management, the rules to apply 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 (IRDB, 2000; World Bank, 2002b; Solanes and Jouravlev, 2006). Water conservation practices, re-use of water, water recycling by modification of industrial processes and optimisation of water consumption bring opportunities for adaptation to water-stressed periods (COHIFE, 2003).

13.5.1.4 Coasts

Future adaptation of coastal systems in Latin America is mostly based on coastal zone management, monitoring and protection plans (see Sections 13.2.5.4 and 13.4.4) which are not specific for climate variability and change and are not yet fully implemented. However, the current coastal environmental framework should be an important support for implementing adaptation options to climate change. Table 13.8 shows some examples of practices and options related to adaptations to climate change.

Most fishing countries have regulations governing access to their fishing grounds (e.g., Argentina, Chile and Ecuador) and others have been drafting new legislation in order to control the use of coastal and fishing resources and to introduce adaptation measures (e.g., 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 (Young, 2001; UNEP, 2002; Bidone and Lacerda, 2003; OAS-CIDI, 2003). Brazil and Costa Rica ratified the UN Convention on the Law of the Sea (UNCLOS, 2005), related to the conservation and management of straddling fish stocks[2] and highly migratory fish stocks.

Coastal biodiversity could be maintained, and even improved, through sustainable use by promoting community management to make conservation a part of sustainable development of coastal resources such as mangroves and their artisanal fisheries. In this regard, Mexico, Ecuador, Guatemala, Brazil and Nicaragua have promoted initiatives to develop the necessary local community participation in the managed forest of coastal zones (Kovacs, 2000; Windevoxhel and Sención, 2000; Yáñez-Arancibia and Day, 2004; FAO, 2006).

13.5.1.5 Human health

There are many initiatives that should be implemented in order to deal with different health impacts due to climate change in Latin American countries. Awareness regarding impacts should be enhanced in the region, including community involvement (see Chapter 8, Section 8.6.1). One main shortcoming is that a lack of information adversely affects decision-making, so research and human-resource training are fundamental. Therefore, one of the main tasks to support research and decision-making is to build up statistical information relating health conditions and events to the corresponding climate and related environmental issues (e.g., floods, tornados, landslides, etc.), based on a strengthened surveillance system for climate-sensitive diseases (see Chapter 8, Section 8.6) (Anderson, 2006). It is essential to establish a regular channel of communication -with the Pan American Health Organization (PAHO/WHO) to report and classify such information, to integrate the data into a regionalisation of sanitary/health conditions, and thus improve early warnings of epidemics. The advantages of international initiatives such as the Global Health Watch 2005-2006 – not simply as a recipient of information but also as a provider of information – should also be considered. The assessments should take into account human health vulnerability and public health adaptation to climate change.

As human health is a result of the interplay between many different sectors, it is important to consider the impacts in the water sector in order to identify the measures focusing on the surveillance of water-borne diseases and vulnerable populations, as well as impacts from the agricultural sector, biodiversity, natural resources, air pollution and drought. An important concern relating to health is the implications of increased human migration and changes in disease patterns; this implies greater intergovernmental co-ordination and cross-boundary actions. Future analysis based on ecological niche modelling for disease vectors will be very useful

Table 13.8. *Adaptation practices and options for Latin American coasts: selected countries.*

Country/Study	Climate scenario	Adaptation (practices and options)/costs
Ecuador (NC-Ecuador, 2000)	LANM2 (+1.0 m)	Protection against severe scenario conditions: coastal defence of Guayas river basin at a cost of less than US$2 billion with 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 (NC-Guyana, 2002)	LANM2	Accretion development on a low-lying coastal strip 77 km wide in the east and 26 km wide in the western Essequibo region.
Colombia (NC-Colombia, 2001)	SLR	Recovery and strengthening resiliency of natural systems in order to facilitate natural adaptation to SLR as well as a programme of coastal zone management which emphasizes preservation of wetlands, areas prone to flooding and those of high value.
Panama (NC-Panama, 2000)	SLR	Autonomous and planned adaptation measures to protect the loss of beaches, based mainly on soft engineering practices.
Peru (NC-Perú, 2001)	ENSO, SST	Modern satellite observation systems of sea and continent similar to the international programmes TOGA and CLIVAR, and capacity-building for at least 50 scientists in oceanic, atmospheric and hydrological modelling and GIS systems.
Uruguay (NC-Uruguay, 2004)	Flooding and SLR	Monitoring systems 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 socio-economic and environmental needs; encourage stakeholders' participation.
Argentina (Kokot, 2004; Menéndez and Ré, 2005)	SLR 2070	Flood risk maps for Buenos Aires based on SLR trends, records of storm surges ('sudestadas') and a two-dimensional hydrodynamic model. These maps will be useful for early warning of extreme events.

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[2] Straddling fish stocks: found in both the coastal zone and high seas.

to provide new potentials for optimising the use of resources for disease prevention and remediation via automated forecasting of disease transmission rates (Costa et al., 2002; Peterson et al., 2005).

13.5.2 Constraints on adaptation

At the present time, constraints of a different nature are observed in the region that are very likely to damp stakeholders' capacities, and decision-makers' capabilities, to achieve policy efficacy and economic efficiency for adapting to climate change. Socio-economic and political factors such as limited availability of credit and technical assistance, and low public investment in infrastructure in rural areas, have been shown to seriously reduce the capability to implement adaptive options in the agricultural sector, particularly for small producers (Eakin, 2000; Vásquez-León et al., 2003). In addition, inadequate education and public health services are key barriers to decreasing climate change and variability impacts, and developing coping mechanisms for extreme weather events such as flooding and droughts, mainly in poor rural areas (Villagrán de León et al., 2003).

A poor appreciation of risk, lack of technical knowledge, inappropriate monitoring, and scarce or incomplete databases and information are important constraints to adaptation to current climate trends. The usefulness of weather forecasts and early warning systems in the region is typically limited by these factors as well as by the lack of resources to implement and operate them (NC-Ecuador, 2000; Barros, 2005).

Public health policies are focused on curative approaches rather than on large-scale preventative programmes and are not integrated with other socio-economic policies that could enhance their effectiveness in addressing climate change impacts. There is a lack of tools to address cross-cutting issues and long-term public health challenges. In most countries, the inter-sectoral work between the health sector and other sectors such as environment, water resources, agriculture and climatological/meteorological services is very limited (Patz et al., 2000). In coastal areas, environmental policies, laws and regulations, have been conflicting in the implementation of adaptation options to climate-change-related impacts (UNEP, 2003b).

13.6 Case studies

Box 13.1. Amazonia: a 'hotspot' of the Earth system

The Amazon Basin contains the largest contiguous extent of tropical forest on Earth, almost 5.8 million km^2 (see Figure 13.3). 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-MMA, 2005a) due to the rapid development of Amazonia, making the region one of the 'hotspots' of global environmental change on the planet. Field studies carried out over the last 20 years clearly show local changes in water, energy, carbon and nutrient cycling, and in atmospheric composition, caused by deforestation, logging, forest fragmentation and biomass burning. The continuation of current trends shows that over 30% of the forest may be gone by 2050 (Alencar et al., 2004; Soares-Filho et al., 2006). In the last decade, research by the Large Scale Biosphere-Atmosphere (LBA) Experiment in Amazonia is uncovering novel features of the complex interaction between vegetated land surfaces and the atmosphere on 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 on that functioning due to changes in climate and land use (http://lba.cptec.inpe.br/lba/site/).

There is observational evidence of sub-regional changes in surface energy budget, boundary layer cloudiness and regional changes in the lower troposphere radiative transfer due to biomass-burning aerosol loadings. The discovery of large numbers of cloud condensation nuclei (CCN) due to biomass burning has led to speculation about their possible direct and indirect roles 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 low amounts of CCN of biogenic origin and the Amazonian clouds show the characteristics of oceanic clouds. Carbon cycle studies of the LBA Experiment indicate that the Amazonian undisturbed forest may be a sink of carbon for about 100 to 400 Mt C/yr, roughly balancing CO_2 emissions due to deforestation, biomass burning, and forest fragmentation of about 300 Mt C/yr (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, although observations have shown reductions in streamflow and no change in rainfall for a large sub-basin, the Tocantins river basin (Costa et al., 2003). Modelling studies of large-scale deforestation indicate a probably drier and warmer post-deforestation climate (e.g., Nobre et al., 1991, among others). Reductions in 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 in turn to a 'savannisation' of Amazonia (Oyama and Nobre, 2003; Hutyra et al., 2005). That factor might 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., 2005).

Box 13.2. Adaptation capacity of the South American highlands' pre-Colombian communities

The subsistence of indigenous civilisations in the Americas relied on the resources cropped under the prevailing climate conditions around their settlements. In the highlands of today's Latin America, one of the most critical limitations affecting development was, as currently is, the irregular distribution of water. This situation is the result of the particularities of the atmospheric processes and extremes, the rapid runoff in the deep valleys, and the changing soil conditions. The tropical Andes' snowmelt was, as it still is, a reliable source of water. However, the streams run into the valleys within bounded water courses, bringing water only to certain locations. Moreover, valleys and foothills outside of the Cordillera Blanca glaciers and extent of the snow cover, as well as the Altiplano, receive little or no melt-water at all. Therefore, in large areas, human activities depended on seasonal rainfall. Consequently, the pre-Colombian communities developed different adaptive actions to satisfy their requirements. Today, the problem of achieving the necessary balance between water availability and demand is practically the same, although the scale might be different.

Under such limitations, from today's Mexico to northern Chile and Argentina, the pre-Colombian civilisations developed the necessary capacity to adapt to the local environmental conditions. Such capacity involved their ability to solve some hydraulic problems and foresee climate variations and seasonal rain periods. On the engineering side, their developments included rainwater cropping, filtration and storage; the construction of surface and underground irrigation channels, including devices to measure the quantity of water stored (Figure 13.4) (Treacy, 1994; Wright and Valencia Zegarra, 2000; Caran and Nelly, 2006). They also were able to interconnect river basins from the Pacific and Atlantic watersheds, in the Cumbe valley and in Cajamarca (Burger, 1992).

Figure 13.4. *Nasca (southern coast of Peru) system of water cropping for underground aqueducts and feeding the phreatic layers.*

Other capacities were developed to foresee climate variations and seasonal rain periods, to organise their sowing schedules and to programme their yields (Orlove et al., 2000). These efforts enabled the subsistence of communities which, at the peak of the Inca civilisation, included some 10 million people in what is today Peru and Ecuador.

Their engineering capacities also enabled the rectification of river courses, as in the case of the Urubamba River, and the building of bridges, either hanging ones or with pillars cast in the river bed. They also used running water for leisure and worship purposes, as seen today in the 'Baño del Inca' (the spa of the Incas), fed from geothermal sources, and the ruins of a musical garden at Tampumacchay in the vicinity of Cusco (Cortazar, 1968). The priests of the Chavin culture used running water flowing within tubes bored into the structure of the temples in order to produce a sound like the roar of a jaguar; the jaguar being one of their deities (Burger, 1992). Water was also used to cut stone blocks for construction. As seen in Ollantaytambo, on the way to Machu Picchu, these stones were cut in regular geometric shapes by leaking water into cleverly made interstices and freezing it during the Altiplano night, reaching below zero temperatures. They also acquired the capacity to forecast climate variations, such as those from El Niño (Canziani and Mata, 2004), enabling the most convenient and opportune organisation of their foodstuff production. In short, they developed pioneering efforts to adapt to adverse local conditions and define sustainable development paths.

Today, under the vagaries of weather and climate, exacerbated by the increasing greenhouse effect and the rapid retreat of the glaciers (Carey, 2005; Bradley et al., 2006), it would be extremely useful to revisit and update such adaptation measures. Education and training of present community members on the knowledge and technical abilities of their ancestors would be the way forward. ECLAC's procedures for the management of sustainable development (Dourojeanni, 2000), when considering the need to manage the extreme climate conditions in the highlands, refer back to the pre-Colombian irrigation strategies.

13.7 Conclusions and implications for sustainable development

In Latin America there is ample evidence of increases in extreme climatic events and climate change. Since the TAR, unusual extreme weather events have occurred in most countries, such as continuous drought/flood episodes, the Hurricane Catarina in the South Atlantic, and the record hurricane season of 2005 in the Caribbean Basin. In addition, during the 20th century, temperature increases, rainfall increases and decreases, and changes in extreme events, were reported for several areas. Changes in extreme episodes included positive trends in warm nights, and a positive tendency for intense rainfall events and consecutive dry days. Some negative impacts of these changes were glacier retreat, increases in flood frequency, increases in morbidity and mortality, increases in forest fires, loss of biodiversity, increases in plant diseases, reduction in dairy cattle production and problems with hydropower generation. However, beneficial impacts were reported for the agricultural sector in temperate zones. According to Swiss Re estimations, if no action is taken in Latin America to slow down climate change, in the next decades climate-related disasters could cost US$300 billion per year (CEPAL, 2002; Swiss Re, 2002).

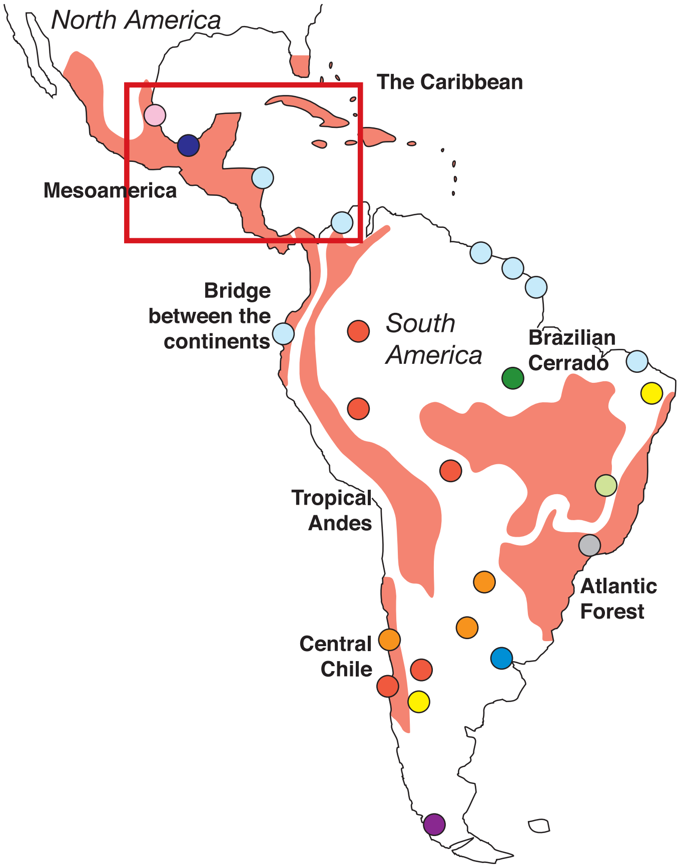
On the other hand, rates of deforestation have increased since the TAR (e.g., in Brazilian Amazonia). In Argentina, Bolivia, Brazil and Paraguay, agricultural expansion, mainly the soybean cropping boom, has exacerbated deforestation and has intensified the process of land degradation. This critical land-use change will enhance aridity and desertification in many of the already water-stressed regions in South America, affecting not only the landscape but also modifying the water cycle and the climate of the region.

As well as climatic stress and changes in land use, other stresses are compromising the sustainable development of Latin America. Demographic pressures, as a result of migration to urban areas, result in widespread unemployment, overcrowding and the spread of infectious diseases. Furthermore, over-exploitation is a threat to most local production systems, and aquifer over-exploitation and mismanagement of irrigation systems are causing salinisation of soils and water and sanitation problems.

By the end of the 21st century, the projected mean warming for Latin America ranges from 1 to 4°C or from 2 to 6°C, according to the scenario, and the frequency of weather and climate extremes is very likely to increase. By the year 2020, 100 Mha of Brazil Amazonia forest will have disappeared if deforestation rates continue as in 2002/03, and the soybean-planted area in South America could reach 59 Mha, representing 57% of the world's soybean production. By 2050, the population of LA is likely to be 50% higher than in 2000, and migration from the countryside to the cities will continue.

Predicted changes are very likely to severely affect a number of ecosystems and sectors (see Figure 13.5) by:

- decreasing plant and animal species diversity, and causing changes in ecosystem composition and biome distribution,
- melting most tropical glaciers in the near future (2020-2030),



● Coral reefs and mangroves seriously threatened with warmer SST

● Under the worst sea-level rise scenario, mangroves are very likely to disappear from low-lying coastlines

● Amazonia: loss of 43% of 69 tree species by the end of 21st century; savannisation of the eastern part

● Cerrados: Losses of 24% of 138 tree species for a temperature increase of 2°C

● Reduction of suitable lands for coffee

● Increases in aridity and scarcity of water resources

● Sharp increase in extinction of: mammals, birds, butterflies, frogs and reptiles by 2050

● Water availability and hydro-electric generation seriously reduced due to reduction in glaciers

● Ozone depletion and skin cancer

● Severe land degradation and desertification

● Rio de la Plata coasts threatened by increasing storm surges and sea-level rise

☐ Increased vulnerability to extreme events

Areas in red correspond to sites where biodiversity is currently severely threatened and this trend is very likely to continue in the future

Figure 13.5. *Key hotspots for Latin America.*

- reducing water availability and hydropower generation,
- increasing desertification and aridity,
- severely affecting people, resources and economic activities in coastal areas,
- increasing crop pests and diseases,
- changing the distribution of some human diseases and introducing new ones.

One beneficial impact of climate change is likely to be the projected increase in soybean yields in the south of South America. However, the future conversion of natural habitats to accommodate soybean expansion are very likely to severely affect some ecosystems such as the Cerrados, dry and humid Chaco, Amazon transition and rainforest, and the Atlantic, Chiquitano and Yungas forests.

If the Latin American countries 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 be taken to help bring environmental and social considerations from the margins to the fore of decision-making and development strategies (UNEP, 2002).

Climate change would bring new environmental conditions resulting from modifications in space and time, and in the frequency and intensity, of weather and climate processes. These atmospheric processes are closely interlinked with environmental, social and economic pillars on which development should be based, and all together may influence the selection of sustainable development paths. Facing a new climate system and, in particular, the exacerbation of extreme events, will call for new ways to manage human and natural systems for achieving sustainability. Future development in regional, sub-regional and local areas must be based on reliable and sufficiently-dense basic data. Consequently, any action towards sustainable development already commits governments and stakeholders to take the lead in the development of the information necessary to facilitate the actions needed to cope with the adversities of climate events, from the transitional period until a new climate system is established, and to take advantage of the new climate system's potential advantages.

13.8 Key uncertainties and investigation priorities

The projections mentioned in this chapter rely on the quality of the available mathematical models. As it can be seen in its different sections, there are contradictory statements. Such contradictions, also observed in other sectoral and regional chapters, make evident some of the weaknesses of models, especially when the necessary observational background is missing. In addition to the models' shortcomings, the use of socio-economic scenarios which are not sufficiently representative of the socio-economic conditions in the region, plus the problems still being faced with downscaling techniques, puts more emphasis on the lack of information as a critical uncertainty. Additionally, the communication of risk to stakeholders and decision-makers under uncertainty has been shown to be a significant weakness that needs to be addressed in the short term.

In order to promote economic efficiency and policy efficacy for future adaptation, important multidisciplinary research efforts are required in order to reduce the information gaps. In preparing for the challenges that climate change is posing to the region in the future, the research priorities should be to resolve the constraints already identified in terms of facing current climate variability and trends, such as:

- lack of awareness,
- lack of well-distributed and reliable observation systems,
- lack of adequate monitoring systems,
- poor technical capabilities,
- lack of investment and credits for the development of infrastructure in rural areas,
- scarce integrated assessments, mainly between sectors,
- limited studies on the economic impacts of current and future climate variability and change,
- restricted studies on the impacts of climate change on societies,
- lack of clear prioritisation in the treatment of topics for the region as a whole.

In addition, other priorities considering climate change are:

- to reduce uncertainties in future projections,
- to assess the impacts of different policy options on reducing vulnerability and/or increasing adaptive capacity.

It is also worth stating that we must change the attitude from planning to effective operation of observation and alerting systems. Currently, the typical response to a severe climatic event consists of intervening after the fact, usually with insufficient funds to restore the conditions prior to the event. A necessary change would be to migrate from a culture of response to a culture of prevention.

In addition, the possibility of abrupt climate change due to a perturbation of the thermohaline circulation opens up a new theme for concern in the Latin American region, where there have been no studies about its possible effects. Another related problem is the occurrence of possible climatic 'surprises' (even in a gradually changing climate) when certain thresholds are surpassed and a negative feedback mechanism is triggered, affecting different sectors and resources. Tropical forests and tropical glaciers are likely candidates for surprises.

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